Greater Farallones National Marine Sanctuary
Condition Report:
Status and Trends 2010–2022

Authors

Greater Farallones National Marine Sanctuary
Lead author: Jan Roletto
Contributing authors, in alphabetical order:
Max Delaney
Lilli Ferguson
Danielle Lipski
Carol Preston
Karen Reyna
Monisha Sugla

Office of National Marine Sanctuaries
Lead author: Kathy Broughton
Contributing authors, in alphabetical order:
Jack Eynon
Stephen R. Gittings, Ph.D.

National Centers for Coastal Ocean Science
Contributing authors, in alphabetical order:
Dan Dorfman
Sarah Hile
Ayman Mabrouk, Ph.D.

Cover photo caption and credit:

Suggested citation: Office of National Marine Sanctuaries. (2024). *Greater Farallones National Marine Sanctuary condition report: 2010–2022*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service.

Office of National Marine Sanctuaries

The Office of National Marine Sanctuaries (ONMS), part of the National Oceanic and Atmospheric Administration (NOAA), serves as the trustee for a system of underwater parks encompassing more than 620,000 square miles of ocean and Great Lakes waters. The 15 national marine sanctuaries and two marine national monuments within the National Marine Sanctuary System represent areas of America's ocean and Great Lakes environment that are of special national significance. Within their waters, giant humpback whales breed and calve their young, coral colonies flourish, and shipwrecks tell stories of our maritime history. Habitats include beautiful coral reefs, lush kelp forests, whale migration corridors, spectacular deep-sea canyons, and underwater archaeological sites. These special places also provide homes to

thousands of unique or endangered species and are important to America's cultural heritage. Sanctuaries range in size from less than one square mile to more than 582,000 square miles and serve as natural classrooms, are cherished recreational spots, and are home to valuable commercial industries.

Greater Farallones National Marine Sanctuary

Just beyond San Francisco's Golden Gate lies a globally significant ecosystem. Few ocean regions in the world host the diversity and abundance of marine life found in Greater Farallones National Marine Sanctuary. The unique combination of seafloor contours, ocean currents and wind patterns, along with energy from the sun, triggers an explosion of life in these waters. Huge blooms of microscopic phytoplankton are consumed by zooplankton, which in turn provide a feast for fishes, seabirds, seals, whales, sharks, and humans. Greater Farallones National Marine Sanctuary protects this rich marine ecosystem through research, education, conservation, and stewardship programs.

Framework for Condition Reports

Condition reports are used by NOAA to assess the condition and trends of national marine sanctuary resources and ecosystem services. These reports provide a standardized summary of resources in NOAA's sanctuaries, driving forces and pressures on those resources, and current conditions and trends for resources and ecosystem services. These reports also describe existing management responses to pressures that threaten the integrity of the marine environment. Condition reports include information on the status and trends of water quality, habitat, living resources, maritime heritage resources, and the human activities that affect them. They present responses to a set of questions posed to all sanctuaries (Appendix A). The reports also rate the status and trends of ecosystem services (Appendix B). Resource and ecosystem service status are assigned ratings ranging from good to poor, and the timelines used for comparison vary from topic to topic. Trends in the status of resources and ecosystem services are also reported, and unless otherwise specified, are generally based on observed changes in status since the prior condition report.

Sanctuary condition reports are structured around two frameworks: 1) a series of questions posed to all national marine sanctuaries; and 2) a management-logic model called the Driving forces (Drivers)-Pressure-State-Ecosystem Services-Response (DPSER) framework (detailed below). The questions are derived from a conceptual, generic model of a marine ecosystem. The DPSER framework defines the structure of condition reports.

Although the National Marine Sanctuary System's 15 national marine sanctuaries and two marine national monuments are diverse in many ways, including size, location, and resources, condition reports allow ONMS to consistently analyze the status and trends of resources and ecosystem services in each site's ecosystem to inform place-based management. To that end, each unit in the sanctuary system is asked to answer the same set of questions, located in Appendix A and Appendix B. Additional details on the evolution of the condition report process are below.

DPSER Framework

In 2019, ONMS began restructuring sanctuary condition reports based on a model that describes the interactions between driving societal forces (Driving forces), resulting threats (Pressures), their influence on resource conditions (State), the impact to derived societal benefits (Ecosystem services), and management responses (Response) to control or improve them. The DPSER framework recognizes that human activities, the primary target of

Commented [1]: might be good to talk about why the DPSER was chosen as a framework. I wonder why DPSIR was changed to DPSER. this explanation might be in a chapter coming up

management actions, are linked to demographic, economic, social, and/or institutional values and conditions (collectively called drivers). Changes in these drivers affect the nature and level of pressures placed on both natural and heritage resources, which determines their condition (e.g., the quality of natural resources or aesthetic value). This, in turn, affects the availability of benefits that humans receive from the resources (ecosystem services[1]), which prompts targeted management responses intended to prevent, reduce, or mitigate undesirable changes (see Figure FCR.1).

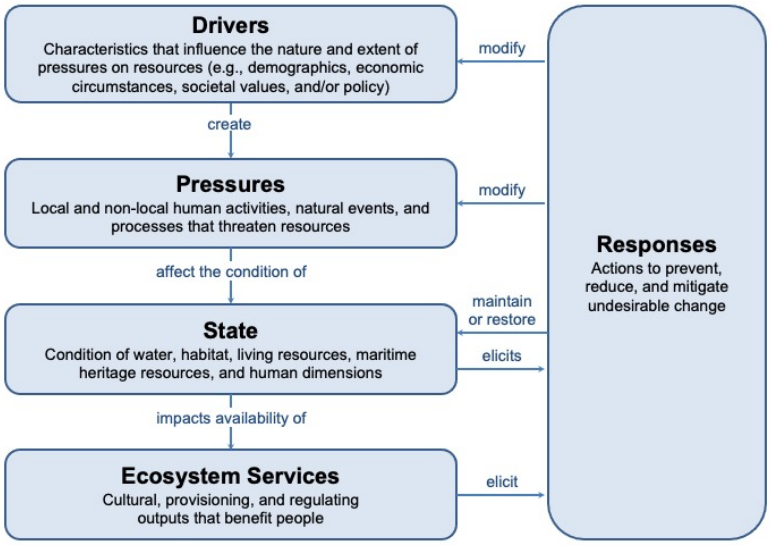

Figure FCR.1. This diagram of the DPSER framework illustrates the functional connections between components and the targets of management responses designed to modify driving forces, pressures, and resource conditions. Image: NOAA

About This Report

The purpose of a condition report is to use the best available science and most recent data to assess the status and trends of various parts of the sanctuary's ecosystem. The first condition report for GFNMS was released in 2010 (Office of National Marine Sanctuaries [ONMS], 2010); ratings from that report are provided in Appendix F. Two notable management changes have occurred since the last condition report. In 2015, the sanctuary expanded and changed its name

[1] For the purposes of this report, ecosystem services are defined as benefits that humans desire from the environment (e.g., recreation, food). They are what link humans to ecosystems, can be goods (e.g., food) or services (e.g., coastal protection), are valued to varying degrees by various types of users, and can be regulated directly by the environment or managed by controlling human activities or ecosystem components (e.g., restoring habitats). Whether or not specific services are rendered can be evaluated directly or indirectly based on attributes of the natural ecosystem that people care about. For example, recreational scuba divers care about water clarity and visibility in coral reef ecosystems. These are attributes that can be measured and factored into status and trend ratings to assess ecosystem services.

from Gulf of the Farallones National Marine Sanctuary to Greater Farallones National Marine Sanctuary. In 2021, the staff merged with Cordell Bank National Marine Sanctuary to form one joint management unit to administer the two sanctuaries. This updated condition report marks a second comprehensive description of the status and trends of sanctuary resources and ecosystem services. Because of the considerable differences between the sanctuary's coastal and offshore region and the estuarine and lagoon region, these two environment types have been assessed separately. Specifically, the findings in this condition report document status and trends in water quality, habitat, living resources, maritime heritage resources, and ecosystem services from 2010–2022, unless otherwise noted. The report helps identify gaps in current monitoring efforts, as well as causal factors that may require monitoring and potential remediation through management actions in coming years. The data presented will not only enable sanctuary resource managers and stakeholders to acknowledge and have a shared perspective on prior changes in resource status, but will also inform management efforts to address challenges stemming from pressures, such as increasing coastal populations and climate change.

Commented [2]: good to note this, but does that mean/imply for the reader that this CR addresses both GFNMS and CBNMS? (might want to address that)

Commented [3]: Similar note- many of the drivers, particularly climate and regional population trends, and many of the drivers or indicators reported in the CCIEA, will presumably be very similar (if not identical) among these and the other large marine sanctuary (Monterey Bay), it might be helpful to provide some context about whether and how this condition report was coordinated with Monterey and/or other CA sanctuaries..?

The findings in this condition report will provide critical support for identifying high-priority sanctuary management actions and will specifically help to shape updates to the GFNMS management plan. The management plan helps guide future work and resource allocation decisions at GFNMS by describing strategies and activities designed to address priority issues and advance core sanctuary programs. The next update to the sanctuary management plan will begin in 2024, building on the 2014 management plan, which contains a number of actions to address issues and concerns (ONMS, 2014a). The process will involve significant public input, agency consultation, and environmental compliance work, and, depending on the complexity of actions proposed, may take one to three years to complete.

The State of Resources section of this document reports the status and trends of water quality, habitat, living resources, and maritime heritage resources from 2010–2022, unless otherwise noted. The State of Ecosystem Services section includes an assessment of human benefits derived from science, education, heritage, sense of place, consumptive recreation, non-consumptive recreation, commercial harvest, and coastal protection within the sanctuary.

In order to rate the status and trends of resources, human activities, and ecosystem services, sanctuary staff consulted with a group of non-ONMS experts familiar with resources, activities, and services in the sanctuary (Appendix C). These experts also had knowledge of previous and current scientific efforts in the sanctuary. Evaluations of status and trends were based on the interpretation of quantitative and, when necessary, qualitative assessments, as well as observations of scientists, managers, and users.

Two other important changes to the condition report process since 2010 should be noted. First, in response to feedback provided to ONMS, the process used to generate the current condition report is more quantitatively robust and repeatable. This was achieved by using the NOAA Integrated Ecosystem Assessment framework (National Oceanic and Atmospheric Administration [NOAA], 2020a), which takes a data-driven approach to developing indicators for key components of the ecosystem. Status and trend assessments can then be made for the selected indicators over time. This approach ensures that, whenever possible, the expert community has quantitative data representative of core ecosystem components available to them as they contribute to assessment ratings. These indicators continue to be tracked over time, and updated time series data can be used in subsequent assessments.

The second improvement pertains to communication of confidence, which was not done in a consistent way in earlier reports. Determination of confidence is now based on an evaluation of the quality and quantity of data used to determine the rating (e.g., peer-reviewed literature, expert opinion) and the level of agreement among experts (Appendix C). The new approach allows for a consistent and standardized characterization of confidence. The symbols used for status and trend ratings have been modified to depict levels of confidence as judged by the expert panel.

This condition report meets the aforementioned standardized format and framework prescribed for all ONMS condition reports. To the extent possible, authors have attempted to make each section's narrative consistent and comparable in terms of content, detail, and length; however, it is important to understand that each section contains different types and amounts of information given the realities and confines of data sets and expert opinions that were available during this process. Finally, ratings reflect the collective interpretation of sanctuary staff and outside experts based on their knowledge and perception of local conditions. When the group could not agree on a rating, sanctuary staff determined the final rating with an acknowledgement of the differences in opinion noted in the report. The interpretation, ratings, and text in this condition report are final and the responsibility of ONMS. To emphasize this important point, authorship of the report is attributed to ONMS; subject matter experts are not authors, though their efforts and affiliations are acknowledged in the report. This report has been peer reviewed and complies with the White House Office of Management and Budget's peer review standards, as outlined in the Final Information Quality Bulletin for Peer Review (White House Office of Management and Budget, 2004).

Literature Cited

National Oceanic and Atmospheric Administration. (2020a). *The Integrated Ecosystem Assessment approach*. https://www.integratedecosystemassessment.noaa.gov/about-iea/iea-approach

Office of National Marine Sanctuaries. (2010). *Gulf of the Farallones National Marine Sanctuary condition report 2010*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service. https://nmssanctuaries.blob.core.windows.net/sanctuaries-prod/media/archive/science/condition/pdfs/gfnms_conditionreport10.pdf

Office of National Marine Sanctuaries. (2014a). *Gulf of the Farallones National Marine Sanctuary: Final management plan; Updated in response to the sanctuary expansion*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service. https://nmsfarallones.blob.core.windows.net/farallones-prod/media/archive/manage/pdf/expansion/GFNMS_FMP_12_04_14.pdf

White House Office of Management and Budget. (2004). *Final information quality bulletin for peer review*. https://georgewbush-whitehouse.archives.gov/omb/memoranda/fy2005/m05-03.pdf

Sanctuary Setting

Overview

Greater Farallones National Marine Sanctuary (GFNMS) is part of the National Marine Sanctuary System—a network of underwater parks encompassing more than 620,000 square miles of marine and Great Lakes waters. GFNMS is located off the California coast, extending west of southern Mendocino county, Sonoma, Marin, San Francisco, and San Mateo counties (Figure SS.1). From east to west, the sanctuary extends from the mean high tide line, with exceptions, to the continental margin at or about the 10,000-foot depth contour. The sanctuary is adjacent to Cordell Bank National Marine Sanctuary (CBNMS), sharing CBNMS's northern and eastern boundaries and Monterey Bay National Marine Sanctuary (MBNMS), sharing MBNMS's northern boundary. GFNMS includes Estero Americano, Estero de San Antonio, Tomales Bay, and Bolinas Lagoon. The sanctuary also includes the waters surrounding the Farallon Islands.

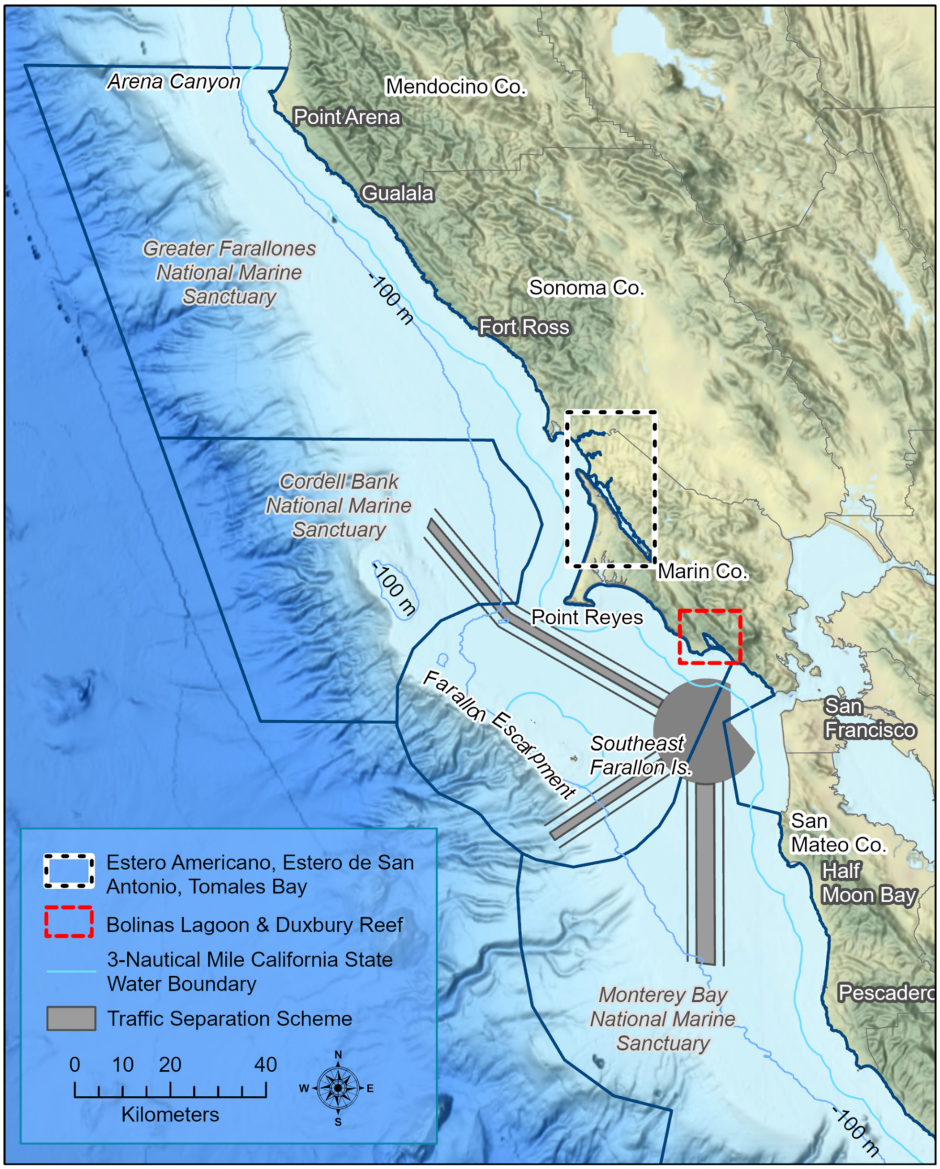

Figure SS.1. Map of GFNMS, and the adjacent CBNMS and MBNMS. Image: NOAA; Source: Esri, 2020

Alt text: Map of Greater Farallones National Marine Sanctuary.

GFNMS was established in 1981 to protect the largest assemblage of breeding seabirds in the contiguous United States, as well as large concentra-tions of marine mammals that use these productive waters. Recognizing GFNMS as one of the most biologically important ecosystems in the world, the federal gov-ernment expanded the sanctuary in 2015 to encom-pass the nutrient-rich upwelling zone off of Point Arena. Originally named Point Reyes-Farallon Islands National Marine Sanctuary and renamed Gulf of the Farallones National Marine Sanctuary in 1987, the sanctuary was renamed Greater Farallones National Marine Sanctuary in 2015 and now encompasses 3,295 square miles. GFNMS has been vested with the authority, in accordance with the National Marine Sanctuaries Act (1972), to pro-vide comprehensive and coordinated conservation and management of the nearshore and offshore wa-ters within its boundaries. In addition, the Office of National Marine Sanctuaries has designated GFNMS staff to manage the portion of MBNMS north of the Santa Cruz/San Mateo county line, which encompasses 1,374 square miles. The sanctuary is administered by the National Oceanic and Atmospheric Administration (NOAA).

Commented [1]: LIke the comment in chapter one p4 (re CBNMS), does this comment imply that the northern MBNMS portion is covered in this GFNMS CR?

GFNMS protects a complex array of habitats, from exposed rocky head-lands to protected sandy beaches; open bays to calm estuaries; rocky intertidal habitats to mudflats; offshore islands to submerged seamounts and kelp forests; and the continental slope, dissected by numerous submarine canyons, to the deep sea.

Figure SS.2. The Farallon Islands, a national wildlife refuge, provide habitat for nesting seabirds, as well as resting and breeding pinnipeds. Photo: J. Roletto/NOAA
Alt text: Aerial photograph of the Farallon Islands in the sanctuary.

Commented [2]: perhaps be clear that the islands themselves as refuges are governed by USFWS

Some of the largest and most diverse eastern Pacific populations of seabirds and pinnipeds (seals and sea lions) south of Alaska occur in GFNMS. Large flocks of Cassin's auklets, common murres, western gulls, and brown pelicans feed on the small fish and crustaceans that are abundant in the surface waters of the sanctuary. This food source also supports California's largest breeding population of harbor seals, as well as a growing population of northern elephant seals. Large numbers of whales and dolphins, including California gray whales, humpback whales, and blue whales are found in the area. Around the Farallon Islands is one of the world's largest seasonal congregations of adult white sharks. Twenty-seven endangered or threatened species breed and/or feed in the sanctuary. Few ocean regions in the world host the diversity and abundance of marine life that is found in GFNMS.

Commented [3]: I suppose when I think of "diverse" I think of assemblages a bit more than populations, it may be that greater clarity would help here?

Commented [4]: Not that it is a big deal, but the elephant seals are not really foraging on surface prey, nor really foraging a whole lot in Sanctuary waters, but rather migrating long distances to the Gulf of Alaska (and other places), where they are foraging much more on mesopelagic fishes and squids...

Regional Cultural History

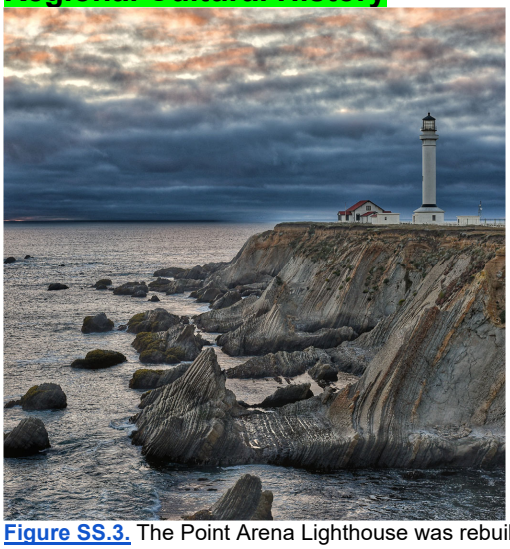

Figure SS.3. The Point Arena Lighthouse was rebuilt in 1908 after the first one perished in the 1906 Earthquake. Photo: M.I. Beattie
Alt text: The rebuilt Point Arena Lighthouse along the coast with gray skies on the horizon over the ocean.

The history of California's North Central Coast is predominantly a maritime one. From the arrival of the early Indigenous peoples 11,000 or more years ago, through the exploration and settlement of California from the mid-16th century onwards by the English, Spanish, Mexicans, Russians, Chinese, Italians and others, coastal waterways have been a main route of travel and source of subsistence, trade and supply. Ocean-based commerce and industries, such as fisheries, hunting for blubber and fur, logging, shipping, military, recreation, tourism, extractive industries, exploration, and research, are all parts of the maritime history, modern economy, and social character of this region. Groups that continue to make their homes in the region include descendants of the original inhabitants. Locations of Pleistocene/Early Holocene habitation or archaeological sites may possibly be parts of the ancient paleo shoreline, submerged now by the modern ocean stand (ICF International et al, 2013). Ever-changing human uses of the region's ocean and coasts are defining features of its maritime heritage.

Commented [5]: simply a suggestion to mention this, but it has not been investigated deeply

Commented [6]: citation: ICF International, Davis Geoarchaeological Research, and Southeastern Archaeological
Research. 2013. Inventory and Analysis of Coastal and Submerged Archaeological Site
Occurrence on the Pacific Outer Continental Shelf. U.S. Department of the Interior, Bureau
of Ocean Energy Management, Pacific OCS Region, Camarillo, CA. OCS Study BOEM
2013-0115. 280 pages, plus appendices.

Indigenous peoples on the west coast of North America had and continue to have many connections to coastal and ocean resources. Today, there are three federally recognized tribes along the coastline of GFNMS: the Kashia Band of Pomo Indians, the Manchester Band of Pomo Indians, and the Federated Indians of Graton Rancheria (GFNMS, n.d.).

San Francisco Bay ports, including at San Francisco and Oakland, were developed through fishing, shipping, and economic exchange and are now major urban areas. Regional economies and populations notably increased as a result of the California Gold Rush which started in 1848, turning remote and sparsely populated Yerba Buena into the multi-cultured, cosmopolitan San Francisco. Coastal harbor communities like Bodega Bay, Point Arena, and other small "dog hole" ports formed at locations along the coastline where goods were loaded and unloaded on ships and passengers embarked or disembarked. Cities inland from the GFNMS coastline, such as Santa Rosa, also became urbanized, bringing millions of residents and visitors in proximity to GFNMS. In addition to maritime commerce, recreational activities connect people to GFNMS, including surfing, boating, diving, and fishing.

Commented [7]: one of the largest and busiest commercials ports in the country

Commented [8]: there have been many gold rushes in many parts of the world

Commented [9]: explain the term

Commented [10]: a small landing/port on the Northern CA coast, dog hole became the ubiquitous term for dozens of them...

Commented [11]: citation: NOAA Office of National Marine Sanctuaries and California State Parks. 2021. MARITIME CULTURAL LANDSCAPE OF SONOMA'S DOGHOLE PORTS. Sacramento CA: California Department of Parks and Recreation

Physical Setting

Oceanography

The unique combination of oceanographic conditions and undersea topography create conditions that support a rich and diverse assemblage of marine species. GFNMS is located in one of the world's four major coastal upwelling systems. There are three oceanographic seasons in this region: upwelling season in the spring and early summer (April–June), relaxation in the late summer and fall (July–September), and storm season in winter (December–February; García-Reyes & Largier, 2012).

During the upwelling season (spring–summer), strong northwest winds and the southward flowing California Current system combine with the earth's rotation to drive surface waters away from the shore. These surface waters are replaced by an upwelling of nutrient-rich deeper water from offshore, which spurs phytoplankton growth, and in turn supports zooplankton and fuels higher levels of the food web. While upwelled waters are rich in nutrients, they are also lower in oxygen and are more acidic than surface waters, which also influences the ecological community of the sanctuary. Upwelling is a major oceanographic and ecological process in the sanctuary and is responsible for the incredible productivity of the ocean in this region. The upwelling-driven productivity influences many aspects of the sanctuary's ecosystem, from the timing and success of seabird nesting (Piatt et al., 2020; Jahncke et al., 2008) to the presence of migratory species. Species such as blue and humpback whales travel from Mexico and Central America to feed in the sanctuary, while seabirds arrive from as far as New Zealand (Shaffer et al., 2006) and South America (Felis et al., 2019) to take advantage of upwelling-driven blooms of prey. Species diversity is directly related to the diversity of habitats and oceanic conditions, and its location within a broad biogeographic transition zone (Point Arena to Año Nuevo). This transition zone provides a complex gradient of changing environments in which the relative proportions of species changes from north to south.

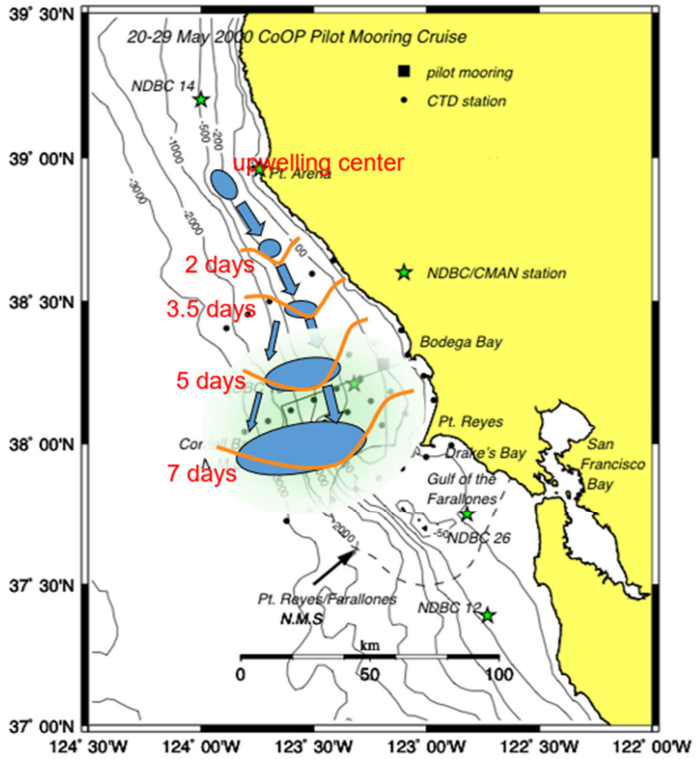

Figure SS.4. Point Arena upwelling center with a plankton bloom growing and moving within the California Current to GFNMS. Image: J. Largier/University of California, Davis
Alt text: Map and diagram of upwelling within the California current.

The portion of GFNMS that is offshore of San Francisco is characterized by the widest continental shelf on the west coast of the contiguous United States. The Gulf of the Farallones region lies mostly within GFNMS, extending westward from the opening of San Francisco Bay and Drakes Bay to the Farallon Islands, with the northward extent offshore of Point Reyes and the southern extent offshore of Point Año Nuevo. The continental shelf reaches a width of about 36 miles (58 km) in the Gulf of the Farallones region and narrows to a width of about 17 miles (27 km) in the Point Arena region. Shoreward of the shelf break and Farallon Islands, the continental shelf is sandy and contains large underwater sand dunes. The shelf slopes gently to the west and north from the mainland shoreline and provides an especially large and relatively shallow (about 394 feet [120 meters]) foraging and habitat area for coastal and oceanic seabirds, marine mammals, and fish.

Biological Settings

Rocky Shore

The intertidal habitat between the low and high tides is biologically rich, supporting diverse assemblages of algae, plants, and animals. There is approximately 79 miles of rocky shoreline in GFNMS, which hosts foundation species, such as mussels, and endangered species, such as black abalone. Rocky shores are characterized by extreme conditions caused by wind, waves, and the fluctuation of tides. Organisms living in the intertidal face many challenges that are unique to living at the edge of the ocean, including threat of desiccation, physical wave action, and competition for limited space. Rocky shores are found throughout GFNMS, but particularly at Duxbury Reef, Farallon Islands, Bodega Head, Sea Ranch, Salt Point, and Point Arena.

Figure SS.5. Duxbury Reef is one of the largest shale reefs in North America. It is home to a large diversity of marine invertebrates, such as sea snails, sea stars, anemones, crabs, and octopuses. Photo: T. Mears/NOAA

Alt text: Duxbury Reef within the sanctuary.

Sandy Shore

North Central California beaches exhibit classic structures like cliffs or dunes that demarcate the upper boundary of the beach; berms at mean high tide lines; and beach flats, troughs, or sandbars that form the seaward side of beaches.The total length of sandy beach habitat within GFNMS boundaries is approximately 110.4 miles including fine- to medium-grained sand beaches, coarse-grained sand beaches, and mixed sand and gravel beaches (NOAA, 2006; NOAA, 2008; Vos et al., 2019). Exposed sand beaches are harsh environments subjected to high wave action, wide temperature ranges, and periodic tidal exposure. Beaches of estuaries and bays are calmer environments subjected to less wave action.

Figure SS.6. Bowling Ball beach south of Point Arena features unique concretions where the surrounding rock has eroded away but has left “bowling balls”. Photo: NOAA
Alt text: Large round boulders alongside cliffs

Species distributions on exposed sand beaches are strongly influenced by physical factors, whereas species distributions on protected beaches of estuaries and bays are more influenced by biological factors (e.g., competition and predation). Exposed beaches of northern California show distinct patterns of biological zonation defined by the amount of tidal inundation to each region. The biological zones of the sandy beach habitat are: upper intertidal beach zone, mid-littoral beach zone, swash zone, low intertidal beach zone, and surf zone.

Commented [12]: probably not needed...unless you setting the reader up for future use of these terms

Estuaries

Estuaries, including bays, mudflats, and marshes, are productive natural systems. Their physical, chemical, and biological characteristics are critically important to sustaining living resources (Mann, 1982; Weinstein, 1979). Bays and estuaries are important nursery areas that provide food, refuge from predation, and a variety of habitats. The four main estuaries within GFNMS are Estero Americano, Estero de San Antonio, Tomales Bay, and Bolinas Lagoon. The two esteros are typically closed to the ocean during summer and fall by seasonally formed sand bars, while both Tomales Bay and Bolinas Lagoon remain open to the ocean year-round. The open bays are sheltered from prevailing southerly currents by headlands and points projecting westward and are important nutrient and plankton retention areas.

Figure SS.7. Bolinas Lagoon is a 1,100-acre tidal estuary that was designated as a Ramsar Site (a wetland of international importance) by UNESCO in 1998. Photo: B. Wilson and LightHawk
Alt text: Photograph overlooking Bolinas Lagoon.

Eelgrass beds occur along the subtidal margin of Tomales Bay and within the esteros. Eelgrass supports a unique and diverse assemblage of invertebrates and fishes, including snails, shrimp, nudibranchs, and sea hares. The structure of eelgrass beds provides protection from predation, especially for juvenile invertebrates and fishes.

Commented [13]: I'm surprised that Brant were not mentioned as eelgrass habitat specialists..?

Commented [14]: This seems a bit out of place and all by itself. You might include it in the paragraph above after the 3rd sentence. Somthing like "Eelgrass habitat is also found in the bays and estuaries and provides...

Or you could put it down below in the Tomales Bay section

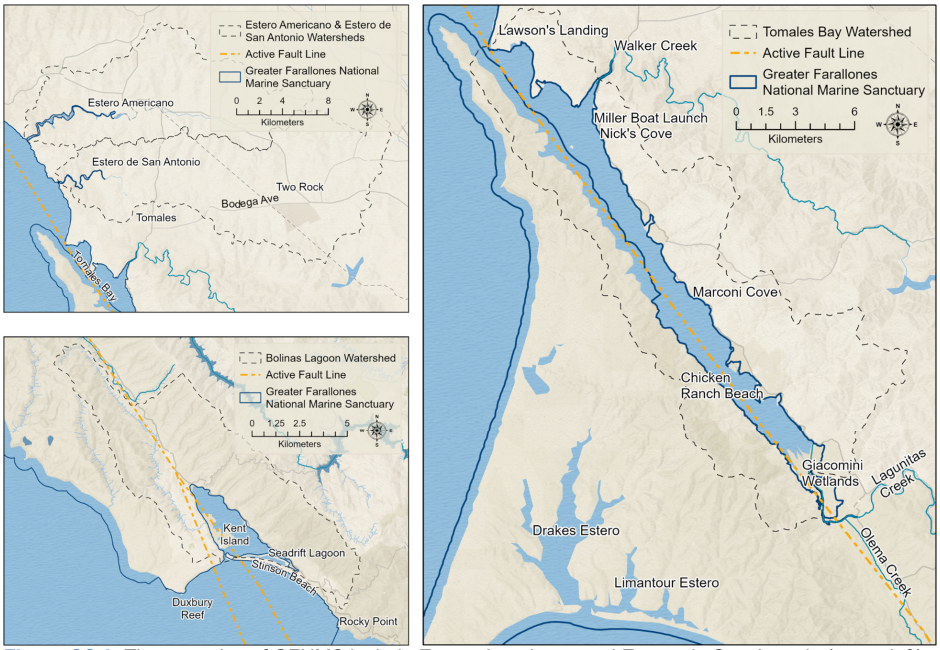

Figure SS.8. The estuaries of GFNMS include Estero Americano and Estero de San Antonio (upper left); Bolinas Lagoon (lower left); and Tomales Bay (right). Subwatersheds of Tomales Bay, Lagunitas Creek and Walker Creek are not delineated on the map due to scale, as they lie mainly outside of the map boundaries. Also shown on each map are active fault lines. Image: NOAA; Source: Esri, 2016.
Alt text: Map displaying Estero Americano, Estero de San Antonio, Tomales Bay, and Bolinas Lagoon.

Tomales Bay

Tomales Bay is one of the top five coastal estuaries for eelgrass abundance along the U.S. west coast (Sherman & DeBruyckere, 2018), and eelgrass meadows occur primarily in shallow areas of the bay (Merkel & Associates, 2022). Tomales Bay is a fault-controlled valley along the San Andreas Fault. Lagunitas Creek, one of two major sub watersheds that drain into Tomales Bay, supports a run of approximately 10% of California's coho salmon population. Pacific herring use the eelgrass beds for spawning. Tomales Bay also supports seasonal populations of salmon, steelhead, sardines, and lingcod. The shallow bay's sandy bottom attracts a variety of bottom-dwelling fish, including sole, halibut, skates, and rays in addition to red rock crab and Dungeness crab. Leopard sharks are common in Tomales Bay, and blue sharks are sighted occasionally. White sharks, although not usually found in enclosed bays or estuaries, do hunt for seals and sea lions that frequent the bays to haul out on the sandy beaches and rocks near the mouth of Tomales Bay. Over 20,000 shorebirds and seabirds, including loons, grebes, geese, cormorants, and ducks, spend the winter in Tomales Bay. Tomales Bay was designated in 2002 as a wetland of international importance under the Ramsar Convention by UNESCO. Tomales Bay and its main tributaries Lagunitas, Walker, and Olema creeks, are impaired by human and animal waste pathogens (CSWRCB, 2016, 2020, 2023).

Commented [15]: and Bolinas Lagoon...might be more general and just state at the mouths of the estuaries

Estero Americano and Estero de San Antonio

The Estero Americano and Estero de San Antonio are coastal, river-like estuaries located on Bodega Bay. Estero Americano drains into Bodega Bay at the Sonoma-Marin county line. South of Estero Americano, the Estero springs converge with Stemple Creek and become the Estero de San Antonio, draining into Bodega Bay. Many different habitat types are found in the esteros, including mudflats, marshes, and rocky shore. With their variety of habitats, the esteros support many species of plants, invertebrates, fishes, birds, and mammals. They provide essential feeding and resting areas for shorebirds and seabirds. Some common fish species found in the esteros include Pacific herring, staghorn sculpins, and starry flounder. The endangered tidewater goby breeds in the shallow waters of Estero de San Antonio (ONMS, 2014b).

Bolinas Lagoon

Bolinas Lagoon is a 1,100-acre tidal estuary that supports a rich diversity of shorebirds and waterfowl, fish, invertebrates, and marine mammals, including threatened and special status species. Located on the Pacific Flyway, Bolinas Lagoon's diverse open water, mudflat, and marsh habitats provide a major stopover and wintering area for 50,000 migratory birds and over 245 bird species year-round. The lagoon's tidal flats and protected sandbars also provide year-round haul-out sites for harbor seals, as well as seasonal pupping grounds. The lagoon was designated as a Ramsar Site (a wetland of international importance) by UNESCO and an Important Bird Area by Audubon.

Kelp Forest

Kelp forests are recognized as highly dynamic ecosystems that support dense populations of fishes, invertebrates, and other algal species. Bull kelp (*Nereocystis luetkeana*) is the dominant canopy-forming species in GFNMS and is most abundant in the nearshore sanctuary waters along Sonoma and Mendocino counties, where it grows at depths from 6 feet to just over 60 feet and attaches to bedrock reefs and boulder fields.

Figure SS.9. Bull kelp growing offshore in GFNMS. Photo: S. Lonhart/NOAA
Alt text: Bull Kelp growing in the ocean.

Kelp provides habitat and food for threatened, and endangered species like abalone, and increases local biodiversity. Kelp beds form habitats for juvenile fishes, which hide among kelp stalks, canopies and floating kelp. When kelp detaches and washes ashore, it becomes a food source for kelp flies, beach hoppers, and various insects. Birds such as snowy plovers, whimbrels, and black-bellied plovers feast on the organisms that live in the beach wrack. Similar to terrestrial rainforests, bull kelp contributes to climate resilience by capturing carbon from the atmosphere and exporting it to deep-sea environments for long-term storage.

Commented [16]: citation?

Open Ocean

The pelagic (open ocean) habitat covers the largest area within GFNMS. This habitat includes the euphotic zone where sunlight penetrates and photosynthesis occurs, forming the base of the productive food web. Zooplankton, including larval fish, krill, copepods, crab larvae, and other species, are an important component of the food web in this habitat. Distribution and abundance of zooplankton are related to the physical dynamics of the California Current system (Reid et al., 1958; Parrish et al., 1981; Huntley et al.,1995) and ~~copepod abundance and~~ species composition responds to seasonal shifts and climate variability (Peterson and Keister, 2003; Hooff and Peterson, 2006; Lilly and Ohman, 2021). The euphotic zone supplies food for deep sea organisms like deep sea corals and sponges as food sources rain down in marine snow.

Commented [17]: seemed strange to call out copepods and not other zooplankton...Lilly and Ohman 2021 is a krill reference to round things out. "Euphausiid spatial displacements and habitat shifts in the southern California Current System in response to El Niño variability". Progress in Oceanography

Commented [18]: In this general intro paragraph to the open ocean, seems odd to mention the euphotic zone, but not other photic categories of the Dysphotic (Mesopelagic) zone or Aphotic (Bathypelagic) zone, also big parts of GFNMS

Figure SS.10. Krill form the foundation of the food web in GFNMS; they are critical prey for many species of seabirds, whales, and fish. Photo: S. Haddock
Alt text: An individual krill with black background.

Continental Shelf Communities (0–200 meters)

The continental shelf off central and northern California is generally gradual to the shelf break, and the bottom substrate is a combination of varying amounts of sand, silt, and clay. Much of the mud and sand on the continental shelf was deposited by rivers that formed during the melting of the glaciers approximately 18,000 years ago (Eittreim et al., 2000). **Figure SS.11.** Strawberry anemones, corals, sponges, and other invertebrates cover Rittenburg Bank in GFNMS. Photo: MARE and NOAA
Alt text: Fish, corals, sponges, and anemones on Rittenburg Bank in the sanctuary.

Submarine banks and shoals are found near the shelf break along a submarine ridge that extends for approximately 30 nautical miles between the Farallon Islands and Cordell Bank. A few of these vertical structures include Fanny Shoal, Rittenburg Bank and Cochrane Bank and the submerged rocky outcrops surrounding the Farallon Islands, all provide rich habitat for diverse rocky reef communities. There are other known rocky banks and rock outcrops in GFNMS on the continental shelf including, “The Football” (an elevated feature on the continental shelf north of Bodega Canyon) and within an offshore area 65 km northwest of Point Reyes.

Continental Slope Communities (200–2,000 meters)

At a depth of about 200 meters, the continental slope drops steeply to the seafloor at an area referred to as the shelf break. The deep waters of the continental slope are characterized by extremely low light conditions, nearly freezing temperatures, and very high pressures (Laidig, 2002). Species that live here, such as deep-sea corals and sponges, are adapted to dark, cold, conditions with sparse food resources, and tend to be slow growing, long-lived, and can take many years to reach sexual maturity and reproduce.

Commented [19]: A good, more recent publication highlighting California cold water/deep sea corals might be Watters, D.L., Laidig, T.E. and Yoklavich, M.M., 2022. A biogeographical assessment of deep-sea coral assemblages from coastwide visual surveys off California. Deep Sea Research Part I: Oceanographic Research Papers, 185, p.103773. https://doi.org/10.1016/j.dsr.2022.103773

Submarine Canyons and Seamounts

Submarine canyons traverse the continental slope and beyond to depths of over 6,000 feet. Submarine canyons, gullies, and rocky ridges indent the steep continental slope and include the Farallon Escarpment, Arena Canyon, and an unnamed canyon west of the South Arena Biogenic Area. Deep-sea corals and sponges, as well as rockfish, can be found in these submarine canyons and seamounts.

Living Resources

Marine and Coastal Birds

One of the most spectacular components of the sanctuary's abundant and diverse marine life is its nesting and migratory seabirds and shorebirds. Over 420,000 seabirds and shorebirds breed on islands, rocks, cliffs adjacent to the sanctuary, plus millions of seabirds migrate to the sanctuary to forage on the abundant prey species (McChesney et al., 2013).

Over 400,000 birds breed in the Farallon Islands National Wildlife Refuge (McChesney et al., 2013), including 12 species of seabirds, plus one shorebird and one landbird species. Eleven of the 16 species of seabirds known to breed along the U.S. Pacific coast have breeding colonies on the Farallon Islands. Breeding colonies include ashy and Leach's storm-petrels; Brandt's, pelagic, and double-crested cormorants; California and western gulls; common murres; pigeon guillemots; tufted puffins; and Cassin's and rhinoceros auklets. The black oystercatcher, a moderate-sized shorebird, also nests on the Farallon Islands.

Figure SS.12. Nearly half the world's ashy storm-petrels feed and nest in island burrows adjacent to the sanctuary on the Farallon Islands. These petrels feed on krill, larval fish, and squid. Photo: National Park Service
Alt text: An ashy storm-petrel standing on a rock.

The sanctuary also protects foraging habitat for aquatic birds such as waterfowl, shorebirds, pelicans, loons, and grebes, plus millions of migrating and wintering birds. More than 170 species of birds use the sanctuary for shelter, food, or as a migration corridor. Of these, over 55 species of birds are known to use the sanctuary during their breeding season. Four marine and coastal bird species that are federally listed as threatened or endangered can be observed in the sanctuary on rare occasions(U.S. Fish and Wildlife Service, 2022). These include the marbled murrelet, western snowy plover, short-tailed albatross, and dark-rumped petrel.

Commented [20]: Might be worth mentioning that submarine canyons are also hotspots for krill and other epipelagic forage species, and consequently also frequently hotspots for seabirds, marine mammals and other predators- a good recent summary in Santora, J.A., Zeno, R., Dorman, J.G. and Sydeman, W.J., 2018. Submarine canyons represent an essential habitat network for krill hotspots in a Large Marine Ecosystem. Scientific reports, 8(1), p.7579.

Commented [21]: Seems to me that a quick nod to what the most abundant species numerically might be could be helpful (e.g., common murre, Brandt's cormorant), as well as perhaps fact that many of these populations are or have been increasing following decades (or more for some) of human impacts that kept populations at low levels..

Marine Mammals

At least 37 species of marine mammals have been observed in GFNMS, including blue, gray, and humpback whales; harbor and elephant seals; Pacific white-sided dolphins; and one of the southernmost U.S. breeding colonies of the once-threatened Steller sea lion. Specifically, there are six species of pinnipeds (seals and sea lions), 29 species of cetaceans (whales, dolphins, and porpoises), and two species of otters (southern sea otter and river otter). Pinnipeds and cetaceans occur in large concentrations and are dependent on the productive and secluded habitats for breeding, pupping, hauling out, feeding, and/or resting during migration. The Farallon Islands provide habitat for breeding populations of five species of pinnipeds. The sanctuary and adjacent haul-outs support at least 20% of the harbor seal population within California.

Commented [22]: citation needed here? or, simply common enough knowledge?

Figure SS.13. Humpback whale breaching. Photo: R. Schwemmer/NOAA
Alt text: A humpback whale propelling its body out of the ocean.

Turtles

Figure SS.14. Leatherback turtles transit through GFNMS in late summer and fall. Photo: A. Eilers, NOAA Permit #1596
Alt text: A leatherback turtle poking its head out of the water.

All sea turtles in the sanctuary are federally listed as endangered or threatened. The largest of these, weighing up to 1,500 pounds, are leatherback sea turtles (*Dermochelys coriacea*). This species is observed annually in GFNMS, which is part of their critical feeding habitat. Threats to leatherback sea turtles include habitat loss at their nesting areas in Indonesia, where egg harvesting and entanglement in nets and trawls from commercial and artisanal fisheries also greatly impact their survival. In addition to leatherbacks, three other sea turtle species have been ~~are rarely~~ observed in the sanctuary: green sea turtle (*Chelonia mydas*), olive Ridley sea turtle (*Lepidochelys olivacea*), and loggerhead sea turtle (*Caretta caretta*).

Commented [23]: latin names here, nowhere else in the narrative

Fish

More than 400 species of fish use sanctuary habitats for shelter, food, reproduction, and/or as a migration corridor. Because of the comparatively wide continental shelf and the configuration of the coastline, the sanctuary is vital to the health and existence of salmon (Chinook and coho), northern anchovy, rockfish, sardines, and flatfish. Sanctuary waters offshore of the Farallon Islands act as a location for shallow and intertidal fishes, which further enhance finfish stocks.

Commented [24]: confused by this sentence...waters offshore of SEFI act as habitat for shallow and intertidal fishes? I would change "as a location" to "as habitat"

Figure SS.15. Rockfish (*Sebastes*) spp. are among the most diverse fish species in nearshore and deep habitats within GFNMS. Photo: C. King/NOAA
Alt text: A rockfish nestled into invertebrate encrusted habitat.

Bays and estuaries are especially important as feeding, spawning, and nursery areas for a wide variety of finfish. Common fish species of the major bays and estuaries include Pacific herring, smelts, starry flounder, surfperch, sharks and rays, and coho salmon. The rocky intertidal zone supports a specialized group of fish adapted for life in tidepools, including monkeyface prickleback, rock eels, dwarf surfperch, juvenile cabezon, sculpins, and blennies. Subtidal habitats, such as kelp forests and eelgrass beds, support large populations of juvenile finfish (e.g., flatfish, rockfish). Nearshore pelagic environments are habitat for large predatory finfish, such as sharks and tuna. Northern anchovies, Pacific mackerel, sardines, and market squid are abundant coastal pelagic forage species that are also ~~and can be~~ commercially importantvaluable. At the mid-depth or mesopelagic range over sand and mud bottoms, bocaccio, chilipepper rockfish, widow rockfish, and Pacific hake are abundant.

Commented [25]: I'd echo comment on consistency for including latin names throughout, or not, but I would also point out that Northern anchovy and Pacific mackerel are the proper common name, so you should also use "Pacific sardine" rather than "sardines" for consistency.

Commented [26]: interesting that you are listing rockfish as over sand and mud bottoms - it is true that these species are more frequently found over soft bottom and/or semi-pelagic (I"m not sure I would call them "mesopelagic") than others but they are also found in rocky or hard benthic habitats..

Benthic Fauna

Benthic fauna communities refer to invertebrates living directly on or in the seafloor. Benthic fauna communities differ according to habitat type and exist in all habitats of the sanctuary (bays and estuaries, intertidal zones, nearshore, and offshore). Generally, each habitat area supports differing benthic assemblages of most classes (e.g., corals, sponges, worms, clams, crabs). The most conspicuous species nearshore include abalone, crabs, and sea urchins. Hundreds of other species (including sea stars, clams, amphipods, and shrimp) are part of~~critical links in~~ the food web~~chains~~ of fish, birds, and mammals.

Over 4,963 square kilometers of the sanctuary's deep seafloor regions have~~s~~ been mapped on the continental shelf and slope, and some of this area includes rocky and mixed substrate that supports deep-sea corals and sponges. Cochrane Bank, Rittenburg Bank, The Football, and Point Arena Biogenic Area South are documented to support biologically rich rocky seafloor habitats.

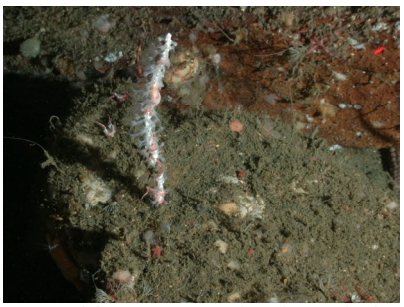

Figure SS.16. Named after GFNMS, *Swiftia farallonesica* is a coral species that was discovered in 2014 at The Football. Photo: NOAA

Alt text: A new species of coral, Swiftia farallonescia, discovered in 2014 in the sanctuary.

Marine Flora

Algal and plant communities within the sanctuary include kelp forests, salt marshes, and eelgrass beds. Plants, algae, and microscopic phytoplankton provide food, nurseries, and protected habitat for many coastal species. In addition to providing habitat and food for wildlife, salt marshes and eelgrass beds improve water quality along the coast by trapping sediments and reducing excess nutrients and pollutants in the water column. In some cases, eelgrass beds and salt marshes also help prevent coastal erosion by buffering the impacts of wave energy and storms, and can ameliorate impacts from excess carbon, thus reducing impacts from ocean acidification and release of carbon dioxide in the air. There are 3.17 square miles of eelgrass and 1.37 square miles of marsh habitat within the GFNMS boundary.

Commented [27]: classes has a taxonomic context...how about "many groups of organisms"

Commented [28]: as well as a diversity of fishes?

Commented [29]: map that shows these?

Commented [30]: I know I know it's more work but...would be nice to have a map showing the location of these banks

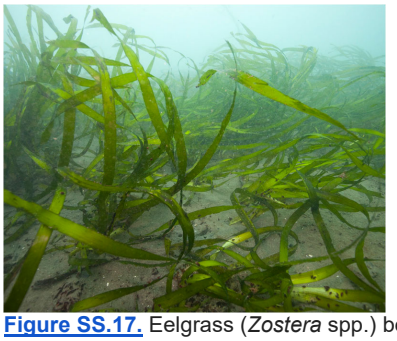

Figure SS.17. Eelgrass (*Zostera* spp.) beds trap sediments and reduce excess nutrients and pollutants in the water column. They also serve as buffer zones, protecting the coast from erosion. Photo: C. King/NOAA
Alt text: Eelgrass beds on the seafloor.

Maritime Heritage Resources

The National Marine Sanctuary Act of 1972 authorized the Secretary of Commerce to "designate and protect areas of the marine environment with special national significance due to their conservation, recreational, ecological, historical, scientific, cultural, archeological, educational or esthetic qualities as national marine sanctuaries" (emphasis added)..The term "maritime heritage" encompasses historical, cultural and archaeological resources, and these~~Maritime heritage resources~~ can take a wide variety of forms.[1] Archaeological and historical resources are material evidence of past human activities and may include vessels, aircraft, structures, habitation sites, and objects created or modified by humans. Cultural resources and locations or other forms of intangible cultural heritage often contribute to community identity in terms of traditional religion, beliefs, customs, and practices. Cultural resources may include certain culturally significant resources, locations, and viewsheds (Appendix A).

[1] Historical resource means any resource possessing historical, cultural, archaeological, or paleontological significance, including sites, contextual information, structures, districts, and objects significantly associated with or representative of earlier people, cultures, maritime heritage, and human activities and events. Historical resources include "submerged cultural resources," and also include "historical properties," as defined in the National Historic Preservation Act, as amended, and its implementing regulations, as amended (15 CFR 922.3).

GFNMS is rich in historical resources and sites. Thirty-four wrecks of ships used for trade, transportation, and military purposes are documented at locations throughout the sanctuary. Based on historical loss records, remnants of many more ships and sunken aircraft, beyond those documented to exist now~~, some military aircraft~~, and other historic or prehistoric maritime heritage resources may also be~~are also~~ present within GFNMS. These are covered by water, sand, or mud, particularly in precontact~~historic~~ or historic areas of human activity. There are also 24 documented doghole port sites in GFNMS. Doghole port sites were so named because they were so small and exposed that mariners joked they were barely large enough for a dog to turn around (GFNMS, 2022). Learning~~Determining~~ more about the sanctuary's maritime heritage resources and tribal and other aspects of the sanctuary's cultural landscape[2] are areas for future investigation.

Commented [31]: doghole ports used for....and where primarily?

Figure SS.18. The USS *Conestoga* was lost at sea in 1921 and now lies within GFNMS. Image: Naval Heritage and History Command
Alt text: A ship, the USS Conestoga, sailing on the water.

Citations (Sanctuary Setting)

California State Water Resources Control Board (CSWRCB). (2016). Water quality report card: Pathogens in Tomales Bay tributaries. San Francisco Bay, Region 2. https://www.waterboards.ca.gov/about_us/performance_report_1920/plan_assess/tmdl_outcomes/r2_tomales_bay_pathogens.pdf

California State Water Resources Control Board (CSWRCB). (2019). Water quality report card: Mercury in Tomales Bay. San Francisco Bay, Region 2. https://www.waterboards.ca.gov/about_us/performance_report_1920/plan_assess/docs/fy1819/r2_tomalesbayhg.pdf

California State Water Resources Control Board (CSWRCB). (2020). Tomales Bay Pathogen TMDL. San Francisco Bay, Region 2. https://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/TMDLs/tomalesbaypathogenstmdl.html

[2] The National Park Service (2022) defines a cultural landscape as "a geographic area, including both cultural and natural resources and the wildlife or domestic animals therein, associated with a historic event, activity, or person, or exhibiting other cultural or aesthetic values."

California State Water Resources Control Board (CSWRCB). (2023). Tomales Bay Pathogen TMDL. San Francisco Bay, Region 2. https://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/TMDLs/TomalesBayHgTMDL.html
https://spo.nmfs.noaa.gov/sites/default/files/pdf-content/1977/752/colebrook.pdf
Eittreim, S. L., Field, M. E., & Noble, M. (2000). *Where does the mud go?* U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Monterey Bay National Marine Sanctuary.
Felis, J. J., Adams, J., Hodum, P. J., Carle, R. D., & Colodro, V. (2019). Eastern Pacific migration strategies of pink-footed shearwaters *Ardenna creatopus*: Implications for fisheries interactions and international conservation. *Endangered Species Research*, *39*, 269–282. https://doi.org/10.3354/esr00969
García-Reyes, M., & Largier, J. L. (2012). Seasonality of coastal upwelling off central and northern California: New insights, including temporal and spatial variability. *Journal of Geophysical Research: Oceans*, *117*(C3), C03028. https://doi.org/10.1029/2011JC007629
Greater Farallones National Marine Sanctuary. (n.d.) *First peoples*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of National Marine Sanctuaries. https://farallones.noaa.gov/heritage/firstpeoples.html
Greater Farallones National Marine Sanctuary. (2022b). *Doghole ports*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of National Marine Sanctuaries. https://farallones.noaa.gov/heritage/doghole.html
Hooff RC, Peterson WT. 2006. Copepod diversity as an indicator of changes in ocean and climate conditions of the northern California current ecosystem. Limnology and Oceanography 51(6): 2607-2620.
Huntley, M. E., Zhou, M., & Nordhausen, W. (1995). Mesoscale distribution of zooplankton in the California Current in late spring, observed by Optical Plankton Counter. Journal of Marine Research, 53, 647–674.
Jahncke, J., Saenz, B. L., Abraham, C. L., Rintoul, C., Bradley, R. W., & Sydeman, W. J. (2008). Ecosystem responses to short-term climate variability in the Gulf of the Farallones, California. *Progress in Oceanography*, *77*(2–3), 182–193. https://doi.org/10.1016/j.pocean.2008.03.010
Laidig, T. (2002). Continental slope communities. In H. A. Karl, J. L. Chin, E. Ueber, P. H. Stauffer, & J. W. Hendley II (Eds.), *Beyond the Golden Gate: Oceanography, geology, biology, and environmental issues in the Gulf of the Farallones* (pp. 185–191). U. S. Department of the Interior and U. S. Geological Survey. https://pubs.usgs.gov/circ/c1198/
Loeb, V. J., Smith, P. E., & Moser, H. G. (1983a). Ichthyoplankton and zooplankton abundance patterns in the California Current area, 1975. *California Cooperative Oceanic Fisheries Investigations Reports*, *24*, 109–131.
Mann, K. H. (1982). *Ecology of coastal waters*. University of California Press.
McChesney, G. J., Carter, H. R., Bechaver, C. A., Rhoades, S. J., Bradley, R. W., Warzybok, P. M., Golightly, R. T., & Capitolo, P. J. (2013). Seabird breeding population sizes within the North Central Coast Study Region of the California Marine Life Protection Act Initiative, 2010–2012. In G. J. McChesney & D. Robinette (Eds.), *Baseline characterization of newly established marine protected areas within the North Central California Study Region—seabird colony and foraging studies* (pp. 78–110) [Unpublished report]. U.S. Fish and Wildlife Service, San Francisco Bay National Wildlife Refuge Complex, and Point Blue Conservation Science.

Merkel & Associates, Inc. (2022). *2022 eelgrass surveys to support national marine sanctuary management: Tomales Bay, Marin County, CA* [Unpublished report]. Report to Greater Farallones and Cordell Bank National Marine Sanctuaries.

National Park Service. (2022). *Understand cultural landscapes*. U.S. Department of the Interior. https://www.nps.gov/subjects/culturallandscapes/understand-cl.htm

NOAA, Office of Response and Restoration, ESI Atlas for Central California. (2006).

NOAA, Office of Response and Restoration, ESI Atlas for Northern California. (2008).

Office of National Marine Sanctuaries. (2014b). *Cordell Bank and Gulf of the Farallones national marine sanctuaries expansion: Final environmental impact statement*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service. https://nmssanctuaries.blob.core.windows.net/sanctuaries-prod/media/archive/library/pdfs/feis-cb-gf2014.pdf

Parrish, R. H., Nelson, C. S., & Bakun, A. (1981). *Transport mechanisms and reproductive success of fishes in the California Current*. *Biological Oceanography*, *1*(2), 175–203.

Peterson W.T., and J. E. Keister. 2003. Interannual variability in copepod community composition at a coastal station in the northern California Current: A multivariate approach. Deep Sea Res.II50:2499–2517.

Piatt, J. F., Parrish, J. K., Renner, H. M., Schoen, S. K., Jones, T. T., Arimitsu, M. L., Kuletz, K. J., Bodenstein, B., García-Reyes, M., Duerr, R. S., Corcoran, R. M., Kaler, R. S. A., McChesney, G. J., Golightly, R. T., Coletti, H. A., Suryan, R. M., Burgess, H. K., Lindsey, J., Lindquist, K…& Sydeman, W. J. (2020). Extreme mortality and reproductive failure of common murres resulting from the northeast Pacific marine heatwave of 2014–2016. *PloS ONE*, *15*(1), e0226087. https://doi.org/10.1371/journal.pone.0226087

Reid, J. L., Roden, G. L., & Wyllie, J. G. (1958). Studies in the California Current system. *California Cooperative Oceanic Fisheries Investigations Reports*, *6*, 27–57.

Shaffer, S. A., Tremblay, Y., Weimerskirch, H., Scott, D., Thompson, D. R., Sagar, P. M., Moller, H., Taylor, G. A., Foley, D. G., Block, B. A., & Costa, D. P. (2006). Migratory shearwaters integrate oceanic resources across the Pacific Ocean in an endless summer. *Proceedings of the National Academy of Sciences of the United States of America*, *103*(34), 12799–12802. https://doi.org/10.1073/pnas.0603715103

Sherman, K., & DeBruyckere, L. A. (2018). *Eelgrass habitats on the U.S. west coast: State of the knowledge of eelgrass ecosystem services and eelgrass extent*. A publication prepared by the Pacific Marine and Estuarine Fish Habitat Partnership for The Nature Conservancy. https://www.pacificfishhabitat.org/wp-content/uploads/2017/09/EelGrass_Report_Final_ForPrint_web.pdf

U.S. Fish and Wildlife Service. (2022). *Environmental Conservation Online System* [Data set]. U.S. Department of the Interior. https://ecos.fws.gov/ecp/

Vos, K., M.D.Harley, K.D.Splinter, J.A. Simmons, I.L.Turner. Water Research Laboratory, School of Civil and Environmental Engineering, UNSW Sydney, 110 King Street, Manly Vale, NSW, 2093, Australia. (2019). CoastSat Accessed March 2022.

Weinstein, M. P. (1979). Shallow marsh habitats as primary nurseries for fishes and shellfish, Cape Fear River, North Carolina. *Fisheries Bulletin*, *77*(2), 339–357.

Reviewers:

1. Please make suggested edits in ***suggesting mode***.
2. Highlighting is used to denote headings etc. for copy editing and formatting, please disregard.
3. The draft condition report will be available to review through **November 1, 2023**.
4. Please contact kathryn.lohr@noaa.gov with any questions or concerns.

Drivers and Pressures on the Sanctuary

For the purpose of condition reports, drivers, or driving forces, are defined as societal values, policies, and socioeconomic factors that influence human pressures on the ecosystem. By shaping the ways that humans interact with the marine environment, driving forces can result in either positive impacts or negative impacts (pressures) to the condition of resources like water, habitat, living resources, and maritime heritage resources. In turn, the condition, or state, of resources determines the flow of benefits that humans are able to derive from that ecosystem. Accordingly, understanding driving forces can be useful in anticipating, evaluating, and reacting to changes in the condition of resources and ecosystem services.

Commented [1]: drivers can also be more direct, like direct threats or actions. in a traditional DPSIR framework, Drivers are often described as 'causes' . This is just further information. http://dx.doi.org/10.1016/j.envsci.2015.11.001 http://dx.doi.org/10.1016/j.ocecoaman.2016.09.005

Drivers on the Sanctuary

Whereas pressures on sanctuary resources occur locally, drivers emerge at many different scales, from local to global. A pressure may be affected by one or more drivers, and a driver may also affect multiple pressures. For example, human population growth at all scales can increase demand for seafood and, as a result, fishing pressure. Fishing pressure is also influenced by drivers like fuel prices and ocean policy, and population drivers simultaneously influence other pressures like marine debris and vessel traffic. Drivers and pressures may vary from sanctuary to sanctuary. Relevant drivers and associated pressures were identified in consultation with GFNMS staff and based on past experience identifying drivers and pressures at other sanctuary sites. Table D.1 summarizes the drivers that influence pressures at GFNMS and the scale at which they occur.

Table D.1. Drivers and their relationship to pressures that affect GFNMS resources. Each row begins with a pressure that is known to act at GFNMS, and bullets across the row indicate each driver that affects that pressure. Each column begins with a driver, and the bullets indicate the range of pressures upon which that driver acts. The letter(s) following each driver indicate the geographic scale(s) at which that driver originates to affect pressure (G=global, N=national, R=regional, L=local). The following narrative describes each driver and pressure in detail.

Drivers (→) Pressures (↓)	**Population** (G, N, R, L)	**Per-capita Income** (G, N, R, L)	**GDP** (G, N, R, L)	**Fuel Prices** (G, N, R, L)	**Demand for Seafood** (G, N, R, L)	**Regulatory Exemptions** (N, L)	**Societal Values and Conservation Ethic** (N, R, L)	**Trade Policy** (N, R, L)	**Ocean Policy** (N, R, L)	**Environmental Activism** (R, L)	**Technological Advancement** (G, N, R, L)	**Demand for Energy** (G, N, R, L)	**U.S. National Security** (N)
Climate change: Changing ocean conditions	●	●	●	●	●		●		●	●		●	
Land use: Coastal development and nearshore construction	●	●	●			●	●		●	●	●	●	●
Land use: Nonpoint source pollution	●	●			●		●		●	●	●		
Land use: Point source pollution	●	●	●		●		●		●	●	●		
Marine harvest activities: Aquaculture	●	●	●		●		●		●	●	●		
Marine harvest activities: Fishing	●	●	●	●	●		●	●	●	●	●		
Vessel activity: Ship strikes	●	●	●		●			●	●	●	●	●	●
Vessel activity: Anchoring	●	●	●	●	●			●	●	●	●	●	

Commented [2]: this is a great table!

Vessel activity: Petroleum and other chemical spills	●	●	●						●	●	●	●	
Vessel activity: Vessel discharges	●	●	●	●	●	●		●	●	●			●
Vessel activity: Exhaust gas cleaning discharges	●	●	●						●	●	●		
Vessel activity: Dredging	●	●	●				●		●	●			●
Vessel activity: Vessel groundings	●	●	●	●	●			●			●		
Vessel activity: Noise	●	●	●	●	●	●		●	●	●	●	●	●
Marine debris	●	●	●	●	●		●		●	●	●		
Wildlife disturbance: Visitation	●	●	●	●	●		●	●	●	●			●
Wildlife disturbance: Vessel and aircraft disturbance	●	●	●	●		●	●	●	●	●	●		●
Non-indigenous species	●	●	●		●		●		●	●	●		

Drivers affect pressures by influencing demand for marine-based goods and services like food, energy, recreational opportunities, and transportation. Drivers that influence demand in GFNMS include population, per capita income, trade policy, and societal values and conservation ethic. Other factors that influence demand may include consumer tastes and preferences. As demand for marine resources increases, higher prices and/or quantity demanded create incentives for higher levels of extraction or use, which can impact the state of resources.

Other drivers influence the supply of or access to marine resources. Examples of these drivers include fuel prices, technological advancement, ocean policy, tribal government relationships, and regulatory exemptions. Fuel prices and technology determine the cost and feasibility of exploiting marine resources and, subsequently, levels of activity and use. The other three drivers relevant to GFNMS relate to the governance of marine resources. Ocean policy (e.g., permitting for offshore energy, vessel speed reduction zones, fishing regulations), along with exemptions, may increase or decrease pressures on resources. Additionally, environmental activism, shaped by preferences, societal values, and conservation ethic, can influence levels of ocean use by applying political pressure to ocean policymakers and stakeholders.

Population and Per Capita Income

International and domestic demand for goods and services, at all scales ranging from local to global, is directly tied to changes in population and real per capita income. Demand is a ubiquitous, primary driver of pressures on sanctuary resources. The data provided in this section are from the U.S. Census Bureau (2022) and U.S. Bureau of Economic Analysis (2022). The GFNMS study area for assessing population and per capita income was identified following the methods of Leeworthy (2015). First, the counties directly bordering GFNMS were selected; these include Mendocino, Sonoma, and Marin counties. Next, employment in neighboring counties was assessed using data from the American Community Survey (U.S. Census Bureau, 2020). Non-adjacent counties were included in the study area if >1% of workers in that county were employed in one of the counties that directly border the sanctuary; non-adjacent counties that met these criteria were San Francisco, Contra Costa, and Solano counties. Although only these six counties met the criteria for inclusion in the economic study area for the sanctuary, other neighboring counties, such as Alameda and San Mateo, are also considered to be sanctuary stakeholders, and GFNMS works closely with these counties on various conservation and management initiatives.

Table D.2. Population and mean per capita income in a six-county study area associated with GFNMS. The counties included in the study area were Contra Costa, Solano, Marin, Mendocino, San Francisco, and Sonoma. Monetary values are inflation-adjusted to 2021 dollars. Source: U.S. Bureau of Economic Analysis, 2022; Federal Reserve Bank of Minneapolis, 2022

Year	Mean Per Capita income	Population	Per Capita Income (% Change)	Population (% Change)
2010	$71,497	3,098,058	--	--
2011	$73,327	3,130,790	2.56%	1.06%
2012	$76,895	3,165,515	4.87%	1.11%
2013	$76,470	3,205,170	-0.55%	1.25%
2014	$80,335	3,246,707	5.05%	1.30%
2015	$86,267	3,284,673	7.38%	1.17%
2016	$89,501	3,316,226	3.75%	0.96%
2017	$92,111	3,337,924	2.92%	0.65%

2018	$95,605	3,345,816	3.79%	0.24%
2019	$97,493	3,344,982	1.97%	-0.02%
2020	$104,547	3,330,325	7.23%	-0.44%
2021	$111,194	3,265,728	6.36%	-1.94%

From 2010 to 2021, the population in the GFNMS study area (including six counties: Contra Costa, Marin, Mendocino, San Francisco, Solano, and Sonoma) grew by roughly 5.4%, which is less than the rate of population increase for the United States (7.3%) and slightly greater than that of California (5.1%). As of 2021, roughly 8.3% of California residents lived in the study area. In addition to being a determinant of demand for marine resources, population can influence land-based pressures on the marine environment, like changes in land use and waste management requirements. Given the decline in study area population in 2019, 2020, and 2021, population-driven pressures do not seem to be of immediate concern to GFNMS on a regional level, although localized population pressures may persist.

From 2010 to 2021, real per capita income in the GFNMS study area increased by around 56%, outpacing income growth in the state of California and the United States (roughly 43% and 27%, respectively). With higher real incomes, consumers have greater purchasing power, enabling them to buy more of the products they already purchase and/or substitute preferred, more expensive products for cheaper ones. The expected result of increases in both per capita income and population over the past decade is an increase in pressures on resources in GFNMS, created by higher demand for products and services. Activities required to meet the demand could include fishing, transportation, construction and land development, and visitation, among others.

Gross Domestic Product

Another high-level driver is the gross domestic product (GDP) of trade partners. The top importers of U.S. seafood and other fishery products from 2013 to 2022 were the European Union, Canada, China, Japan, and South Korea (Foreign Agricultural Service, 2023). Changes in GDP in these countries directly affect demand for all goods. Furthermore, seafood is bought and sold in a global market such that changes to demand directly affect prices of species caught in GFNMS and, thus, affect fishing behavior in and around the sanctuary itself. From 2010 to 2022, most countries experienced positive GDP growth, with a lower rate of growth during the later half of the study period and several countries experiencing negative growth rates in 2020 (International Monetary Fund, 2023). The slow growth rates and disruption to economic growth caused by the COVID-19 pandemic likely reduced pressure for seafood imports during 2020.

Fuel Prices

Fuel prices are an important and often immediate driver of many ocean activities. Ocean users consider fuel prices in their decisions about whether and how to conduct activities like commercial fishing, recreational boating, and shipping (e.g., Sumaila et al., 2008; Maloni et al., 2013). In turn, those decisions determine the intensity of pressures, such as vessel traffic, discharges, noise, and resource extraction. Importantly, changes in fuel prices do not impact all fisheries equally. Globally, fisheries targeting crustaceans or flatfish and those employing pots/traps or trawl gear have the highest intensity of fuel use in terms of volume of fuel per live weight landed (Parker & Tyedmers, 2014). The price of retail gasoline in California varied without trend from 2010 to 2022 (Energy Information Administration, 2022; Figure D.1).

Commented [3]: Most commercial fishing operations use diesel (at least, larger vessels), are the trends comparable (many small scale and rec use gasoline, so both helpful).

Would it make sense to use inflation-adjusted values?

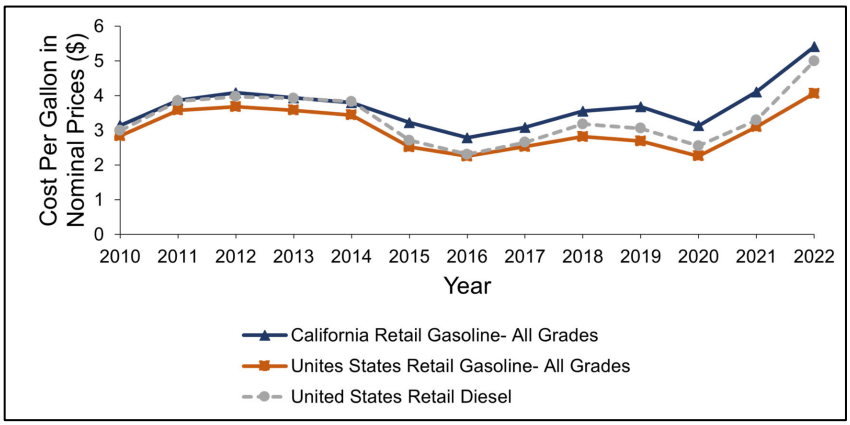

Figure D.1. Nominal prices for California retail gasoline (all grades), U.S. retail gasoline (all grades), and U.S. retail diesel from 2010–2022. Source: Energy Information Administration, 2022

Demand for Seafood

Seafood is one of the top traded food commodities globally, and the United States is both a top importer and top five exporter of seafood (Froehlich et al., 2021). Global seafood catch has increased by an estimated average annual rate of 3.1% from 1961 to 2017 (FAO, 2020). Although aquaculture already accounts for over half of seafood produced for human consumption globally, farmed seafood makes up only 8% of domestic production in the U.S. (FAO, 2020; Froehlich et al., 2021). Offshore farming has been identified as a strategy (e.g., Executive Order No. 13921) to increase U.S. seafood production and reduce reliance on imports, which currently comprise roughly two-thirds of domestic seafood consumption (Gephart et al., 2019).

From 2015 to 2019, the average volume of seafood products exported from the San Francisco U.S. Customs District, which covers all counties adjacent to GFNMS except Mendocino, totaled roughly 55.5 million pounds (Office of Science and Technology [OST], 2022). Over the same period, an average of over 132 million pounds of seafood products were imported through the district (OST, 2022). Of the top species harvested in GFNMS, market squid has the highest volume of exports from San Francisco, with an average of 26.7 million pounds exported from 2015–2019 (OST, 2022). For other commercially important species, the five-year (2015–2019) average exports from San Francisco were approximately 601,000 pounds of sablefish, 364,000 pounds of Dungeness crab, 193,000 of unspecified groundfish, and 170,000 pounds of salmon.

The U.S. seafood industry was heavily impacted by the COVID-19 pandemic and response. Restaurants and other “away from home” venues accounted for roughly 65% of consumer seafood expenditures in the U.S., and restaurant orders declined by upwards of 70% beginning in March of 2020 (Love et al., 2020; Froehlich et al., 2021). These events resulted in processor closures, shortened fishing seasons, decreased catch, and revenue losses (White et al., 2021). Disruptions in the restaurant market were not felt equally across fisheries, as consumers were more likely to purchase some species in retail stores (e.g., canned tuna, salmon) and others in

Commented [4]: Might be good to include some information on ex-vessel value- as well as recreational catches- to scale these impacts more broadly and better represent the relative importance of the different fisheries more robustly. Also for squid, I suspect that 26.7 million pounds were not landed in San Francisco per say but from San Francisco port groups- as I suspect most squid landings are in Half-moon bay not SF -or are these actually just exports, regardless of area caught, such that they could include Monterey Bay?

restaurants (e.g., crab, shrimp, cod; Love et al., 2020). Frozen and canned seafood products (e.g., sablefish, tuna) were less impacted than fresh seafood products (e.g., halibut; White et al., 2021).

Consumer tastes and preferences are an important determinant of demand for seafood and, consequently, resource impacts. As a potent example of this, the growing popularity of sushi and sashimi in the late twentieth century led to the industrialization of bluefin tuna fisheries and overfishing of stocks (Longo, 2011). Increasingly, demand for seafood is being driven by perceptions of health risks and benefits and a desire for sustainable products (Lem et al., 2014). These shifts in attitudes toward and perceptions of food will place pressures on marine resources worldwide, including those in GFNMS.

Regulatory Exemptions

Federal agencies implement regulatory requirements under their respective statutes and mandates. However, in some cases, individuals, entities, or certain activities are exempt from statutory or regulatory requirements. For example, the Clean Water Act provides a permit exemption for some point source pollution. These regulatory exemptions could affect the sanctuary through water quality degradation, injury to sanctuary resources or habitats, or other impacts. As outlined in the sanctuary regulations, all activities carried out by the Department of Defense at the time of designation that are necessary for national defense are exempt from prohibition (15 C.F.R. § 922.72). This exemption does not extend to Department of Defense activities like routine exercises and vessel operations. Other activities exempt from prohibitions include the discharge of materials, like fish or chumming materials, as part of lawful fishing activity and activities necessary for emergency response (15 C.F.R. § 922.72).

Commented [5]: so, just to confirm...naval routine exercises and vessel operations can be prohibited by the NMS?

Societal Values and Conservation Ethic

Information on societal values related to conservation can be obtained from various national or local opinion polls. A statewide study conducted in 2021 provides point estimates of Californians' attitudes and perceptions toward the environment (Baldassare et al., 2021). Almost half of adults reported that ocean and beach pollution along the coast is an issue, with 61% saying that plastics and marine debris are a big problem in the section of coast closest to them (Baldassare et al., 2021). An overwhelming majority of Californians (95%) stated that the conditions of oceans and beaches are either very important or somewhat important to the economy and quality of life in the state (Baldassare et al., 2021). Finally, about three in four respondents are either very or somewhat concerned about the impact of sea level rise on flooding and beach erosion (Baldassare et al., 2021).

A separate 2009 survey of Monterey Bay area residents provides some indication of Californians' attitudes toward marine protected areas (ACSF, 2009). In 2009, an overwhelming percentage (93%) of respondents expressed support for "the designation of certain areas of U.S. ocean waters as sanctuaries for special management to conserve the marine habitats and cultural features" (ACSF, 2009). A majority (64%) also agreed that "sanctuary managers should have the power to make rules to prohibit human use of the designated sanctuaries," with 30% disagreeing (ACSF, 2009). Over half of residents (58%) support funding the creation and management of marine protected areas through the general revenue fund from state taxes, but less than half support a tax increase to fund that same goal (ACSF, 2009).

Trade Policy

As with many industries, U.S. seafood harvesters and producers are impacted by foreign trade policies, like import bans and tariffs on U.S. goods by foreign countries, that reduce demand for

U.S. exports, and import bans on foreign goods to the U.S., which could increase demand for domestic goods. Since import competition can alter the incentives for resource use, harvesters are also affected by domestic trade policies that affect the competitiveness of U.S. seafood at home (Asche et al., 2022). In 2019, the seafood industry faced a major disruption due to the trade war with China, (Froehlich et al., 2021). In addition, as of spring 2023, the industry continues to be impacted by a Russian ban on all food imports from the U.S. that began in 2014. On March 11, 2022, President Biden issued Executive Order 14068, which prohibits the importation of seafood originating in Russia.

Trade policy might also affect pressure on sanctuary resources by influencing the volume of trade flows and shipping activity between ports. Resource impacts related to vessel use are described below.

Ocean Policy

The U.S. is party to numerous agreements that establish international entities composed of member governments that focus on various topics, ranging from managing shipping (International Maritime Organization), global whale stocks (International Whaling Commission), fisheries (International Pacific Halibut Commission, Pacific Salmon Commission, etc.), and oil spill response (CANUSPAC). These international agreements affect local processes.

The West Coast states have collaborated on ocean policy initiatives since the Tri-State Agreement on Ocean Health was signed in 2006. Since that time, this regional ocean partnership has evolved to better include tribal governments, broaden federal agency representation, and identify a variety of regional priorities. The West Coast Ocean Alliance is focused on: (1) compatible and sustainable ocean uses; (2) effective and transparent decision making; (3) comprehensive ocean and coastal data; and (4) increased understanding of and respect for tribal rights, traditional knowledge, resources, and practices.

The Pacific Fishery Management Council is another partnership of West Coast states that manages federal fisheries for around 119 species in the U.S. Exclusive Economic Zone. The council collaborates with states, tribes, and international forums to develop management measures for recommendation to NOAA Fisheries (Pacific Fishery Management Council, 2020a). The California Department of Fish and Wildlife manages fisheries in state waters (1–3 miles offshore) and certain fisheries that occur in federal waters, like Dungeness crab, California halibut, and pink shrimp (California Department of Fish and Wildlife [CDFW], 2020d).

Commented [6]: I am generally surprised at how little fisheries management is attributed to altering fishing pressure- fuel prices, markets, many factors are important- but to me at least- the activities of the managers to ensure that overexploitation is not happening, Magnuson act objectives are being met, etc (on PFMC level, similarly for state managed) are key drivers of fishing pressure- both commercial and recreational. I think a bit more on this could be said. This section does not even specify which fisheries are managed by the PFMC (does list a few of the state managed).

Environmental Activism

Environmental activism refers to activity by community members to address or raise awareness of environmental issues. As stewardship ethics change, levels of environmental activism are likely to change as well. This can affect the implementation of many types of activities and management actions, which can dramatically alter and redistribute pressures. The GFNMS community has engaged in activism to support ocean protection in the region. For example, members of the public initially proposed expansion of the sanctuary in 2001, which led NOAA to initiate a public process to evaluate and assess a proposed expansion beginning in 2012. Leading up to the 2015 expansion of the sanctuary, members of the public expressed support through providing public comment and attending public meetings.

Technological Advancement

Technology can influence pressures on marine resources in several ways. As mentioned before, technological advancements can lower costs for existing marine-based industries. For example, technologies like electronic navigational aids, acoustic fish-finding equipment, and stronger polymers for line and netting have increased fishing efficiency (Marchal et al., 2006). For a given level of human activity or ocean use, technological advancements can also result in lower levels of impact or pressure. Examples of these types of technologies include low-emissions propulsion systems and carbon-capture in shipping, waste management technologies (e.g., marine sanitation devices, bioremediation of wastewater, new materials to replace plastics), and bycatch reduction devices (e.g., turtle excluder devices), among many others. In response to large whale and turtle entanglements in Dungeness crab gear on the West Coast and subsequent fishery closures, manufacturers and fishers have tested ropeless crab gear to mitigate entanglement risk. The development of new technologies can also contribute to the growth or emergence of new sectors in the blue economy (e.g., offshore aquaculture, offshore wind), which may even substitute for traditional industries (e.g., wild-capture fisheries, offshore oil). Finally, some technologies may contribute directly to improved resource management outcomes or ecosystem restoration (e.g., “green gravel” for kelp reforestation, drones for monitoring, wave attenuation devices).

Commented [7]: Perhaps worth acknowledging that this technology is promising but generally considered to be some time away from potentially being broadly adopted by the fishing community (many cost and practical constraints), but promising in longer term.

Demand for Energy

The demand for energy, whether from non-renewable or renewable resources, is also a driver. Pressure to increase supplies of energy or energy products (e.g., raw or refined) may place pressures on sanctuary resources through increased development and/or shipping near or through the sanctuary. Development of oil and gas resources is prohibited in GFNMS. However, large volumes of energy products, including crude oil, refined petroleum products, and coal, are shipped in and out of the Bay Area, which includes the ports of Oakland and San Francisco and several refineries (SFBCDC, 2020). Expected to be finished in the first quarter of 2023, the Transmountain Pipeline expansion in Canada would increase the volume of tar sands being shipped to refineries in the bay (CBD, 2020). Along with infrastructure changes affecting supply, changes in the U.S. and global demand for energy products can impact levels of vessel traffic and associated impacts on sanctuary resources.

U.S. National Security

The ocean plays a critical role in the mobility and readiness of U.S. armed forces and the preservation of national security. Uncertainty regarding the dynamics of future conflicts requires the U.S. military to train and prepare for a variety of scenarios, especially given emergent technologies. The State Department, Department of Defense, Department of Homeland Security, National Security Administration, Department of Transportation, and others all play key roles in national security. Climate change is also viewed as a national security issue, not only because of its direct effects on military infrastructure via sea level rise, but also because of its potential to exacerbate geopolitical tensions. The increasing intensity and frequency of natural disasters also increases demand for disaster relief, further threatening national security.

The Eleventh Coast Guard District, headquartered in San Francisco Bay, conducts training, search and rescue, and emergency response activities in the sanctuary. The Coast Guard is responsible for enforcing federal laws in U.S. waters, including sanctuary regulations. It is also responsible for vessel traffic management and managing the control and removal of oil and hazardous substances resulting from offshore spills (ONMS, 2014). Although the U.S. Navy no longer has active bases in the San Francisco Bay area, it does conduct operations within or near the sanctuary (ONMS, 2014). The Navy maintains two special-use airspaces in and around

the boundaries of GFNMS and CBNMS, and naval submarines and surface ships routinely transit the area (ONMS, 2014).

Literature Cited (Drivers)

Alliance of Communities for Sustainable Fisheries. (2009). Monterey Bay Area Residents' Opinions on the Management of the Monterey Bay National Marine Sanctuary.

Asche, F., Oglend, A., and Smith, M. (2022). Global markets and the commons: The role of imports in the US wild-caught shrimp market. *Environmental Research Letters*, 17, 045023. https://doi.org/10.1088/1748-9326/ac5b3e

Baldassare, M., Bonner, D., Lawler, R., & Thomas, D. (2021). *Californians and the environment*. Public Policy Institute of California. https://www.ppic.org/wp-content/uploads/ppic-statewide-survey-californians-and-the-environment-july-2021.pdf

California Department of Fish and Wildlife. (2020d). California commercial landing receipt data, 1994-2020 [Data set]

Center for Biological Diversity. (2020). Press Release: Trump Administration to Dredge San Francisco Bay to Make Room for More Oil. https://biologicaldiversity.org/w/news/press-releases/trump-administration-dredge-sanfrancisco-bay-make-room-more-oil-2019-06-25/email_view/

Energy Information Administration. (2022). *Petroleum and other liquids* [Data set]. U.S. Department of Energy. https://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_nus_w.htm

Federal Reserve Bank of Minneapolis. (2022). *Consumer price index, 1913-*. https://www.minneapolisfed.org/about-us/monetary-policy/inflation-calculator/consumer-price-index-1913-

Foreign Agricultural Service. (2023). *Fish and seafood: U.S. fish and seafood exports in 2022* [Data set]. U.S. Department of Agriculture. https://www.fas.usda.gov/data/commodities/fish-and-seafood#:~:text=The%20United%20States%20is%20the,herring%2C%20crab%2C%20and%20lobster

Froehlich, H. E., Gentry, R. R., Lester, S. E., Cottrell, R. S., Fay, G., Branch, T. A., Gephart, J. A., White, E.R., & Baum, J. K. (2021). Securing a sustainable future for US seafood in the wake of a global crisis. *Marine Policy*, *124*, 104328. https://doi.org/10.1016/j.marpol.2020.104328

Gephart, J.A., Froehlich, H.E., and Branch, T.A. (2019). Opinion: To create sustainable seafood industries, the United States needs a better accounting of imports and exports. Proceedings of the National Academy of Sciences, 116(19), 9142-9146.

International Monetary Fund. (2023). *Real GDP growth*. https://www.imf.org/external/datamapper/NGDP_RPCH@WEO/OEMDC/ADVEC/WEOWORLD/CHN/JPN/CAN/KOR

Leeworthy, V., & Schwarzmann, D. 2015. Economic Impact of the Recreational Fisheries on Local County Economies in the Greater Farallones National Marine Sanctuary 2010,

2011 and 2012. Marine Sanctuaries Conservation Series ONMS-2015-04. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD. 29 pp.

Lem, A., Bjorndal, T. & Lappo, A. (2014). *Economic analysis of supply and demand for food up to 2030—Special focus on fish and fishery products*. Fisheries and Aquaculture Circular No. 1089. Food and Agriculture Organization of the United Nations. https://www.fao.org/3/i3822e/i3822e.pdf

Longo, S. B. (2011). Global sushi: The political economy of the Mediterranean bluefin tuna fishery in the modern era. *Journal of World-Systems Research*, *17*(2), 403–427. https://doi.org/10.5195/jwsr.2011.422

Love, D. C., Asche, F., Conrad, Z., Young, R., Harding, J., Nussbaumer, E. M., Thorne-Lyman, A. L., & Neff, R. (2020). Food sources and expenditures for seafood in the United States. *Nutrients*, *12*(6), 1810. https://doi.org/10.3390/nu12061810

Maloni, M., Paul, J. A., & Gligor, D. M. (2013). Slow steaming impacts on ocean carriers and shippers. *Maritime Economics and Logistics*, *15*, 151–171. https://doi.org/10.1057/mel.2013.2

Marchal, P., Andersen, B., Bromley, D., Iriondo, A., Mahévas, S., Quirijns, F., Rackham, B., Santurtún, M., Tien, N., & Ulrich, C. (2006). Improving the definition of fishing effort for important European fleets by accounting for the skipper effect. *Canadian Journal of Fisheries and Aquatic Sciences*, *63*(3), 510–533. https://doi.org/10.1139/f05-238

National Marine Fisheries Service Office of Science and Technology. (2022). Foreign Trade, https://www.fisheries.noaa.gov/inport/item/3480.

NOAA, Office of National Marine Sanctuaries. 2014. Cordell Bank and Gulf of the Farallones National Marine Sanctuaries Expansion Final Environmental Impact Statement. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries. Silver Spring, MD.

Pacific Fishery Management Council (PFMC). 2020a. Pacific Fishery Management Council. https://www.pcouncil.org. Accessed July 1, 2020.

Parker, R. W., & Tyedmers, P. H. (2014). Fuel consumption of global fishing fleets: Current understanding and knowledge gaps. *Fish and Fisheries*, *16*(4), 684–696. https://doi.org/10.1111/faf.12087

San Francisco Bay Conservation and Development Commission (2020). 2019-2050 Bay Area Seaport Forecast. https://www.bcdc.ca.gov/seaport/2019-2050-Bay-Area-SeaportForecast.pdf

Sumaila, U. R., Teh, L., Watson, R., Tyedmers, P., & Pauly, D. (2008). Fuel price increase, subsidies, overcapacity, and resource sustainability. *ICES Journal of Marine Science*, *65*(6), 832–840. https://doi.org/10.1093/icesjms/fsn070

U.S. Bureau of Economic Analysis. (2022). *CAINC1 personal income summary: Personal income, population, per capita personal income* [Data set]. U.S. Department of Commerce. https://www.bea.gov/itable/

U.S. Census Bureau. (2022). *Population and housing units estimates tables* [Data set]. U.S. Department of Commerce. https://www.census.gov/programs-surveys/popest/data/tables.html

U.S. Census Bureau. (2020). *2016–2020 5-year ACS commuting flows* [Data set]. U.S. Department of Commerce. https://www.census.gov/data/tables/2020/demo/metro-micro/commuting-flows-2020.html

White, E. R., Froehlich, H. E., Gephart, J. A., Cottrell, R. S., Branch, T. A., Agrawal Bejarano, R., & Baum, J. K. (2021). Early effects of COVID-19 on US fisheries and seafood consumption. *Fish and Fisheries*, *22*(1), 232–239. https://doi.org/10.1111/faf.12525

Pressures on the Sanctuary

Human activities and natural processes affect the condition of natural, cultural, and maritime heritage resources in national marine sanctuaries. This section describes the general nature and extent of known human-caused pressures with documented effects on GFNMS resources, including climate change, land use, marine harvest activity, vessel activities, marine debris, wildlife disturbance, and non-indigenous species. The list of pressures in this section is not exhaustive and does not discuss the potential full range of additional pressures that can cause impacts to sanctuary resources. Other pressures considered included radioactive waste and military activity, but these are not discussed as they did not rise to the level of a documented, existing threat with known impacts.

Climate Change

Climate change resulting from human activities has profoundly impacted coastal and marine ecosystems on a global scale, with projected worsening effects on sea level rise, ocean temperatures, ocean chemistry, storm intensity, and ocean current patterns. The impacts of climate change are intensifying both globally and locally, threatening America's physical, social, economic, and environmental wellbeing (U.S. Global Change Research Program, 2018).

Anthropogenic climate change is accelerated primarily by greenhouse gas emissions (e.g., carbon dioxide, methane), which trap heat in the atmosphere and lead to higher air and water temperatures. Since pre-industrial times, global air temperature has increased on average by 1°C, and in the last 50 years, this increase was driven nearly entirely by anthropogenic greenhouse gas emissions (Intergovernmental Panel on Climate Change [IPCC], 2019). GFNMS is affected by global greenhouse gassesgases and local emissions from vessel and aircraft engines, shipboard incinerators (ONMS, 2014), and other motorized equipment that produces exhaust. As global temperatures rise, the ocean has absorbed over 90% of the excess heat, causing the average ocean temperature to increase worldwide (IPCC, 2019).

Rising Ocean Temperatures, El Niño-Southern Oscillation, and Marine Heat Waves

From 1980 to 2019, annual sea surface temperatures were consistently above average globally, and increased over time (NCEI, 2023). Water temperatures in the GFNMS region have risen slightly over the past century (Johnstone & Mantua, 2014; ONMS, 2020a).

Rising ocean temperatures are also linked to oceanographic phenomena: the El Niño-Southern Oscillation (ENSO) and marine heat waves. El Niño is the warm phase of the ENSO cycle and is characterized by above-average sea surface temperature (SST) in the central and eastern tropical Pacific Ocean (L'Heureux, 2014). Although conditions may vary, El Niño can result in warmer SSTs in GFNMS that last for months to years. During the past 30 years, the California Current Ecosystem has experienced an intensification of El Niño events (McGowan et al., 1998; Fiedler, 2002). In contrast, marine heatwaves (MHWs) occur when ocean temperatures are extremely warm for an extended period of time, generally from weeks to months and occasionally longer (e.g., the 2014–2016 MHW). MHWs are defined as sea surface temperatures that exceed the 90th percentile of the baseline climatology (i.e., the previous three decades of temperatures) for at least five consecutive days (Hobday et al., 2016).

The timing and magnitude of upwelling has become much more variable over the last six centuries (Sydeman et al., 2014), and upwelling intensity is expected to increase (Xiu et al., 2018). However, warm water events like El Niño and MHWs can alter the timing, intensity, and location of upwelling events, often by creating stratification or forcing nutrient-rich water closer to shore, away from the majority of the sanctuary (Jacox et al., 2016; Santora et al., 2020;). When this occurs, coastal waters receive fewer nutrients, leading to lower biological productivity (Cavole et al., 2016; McGowan et al., 1998). Such changes can lead to cascading effects throughout the food web, potentially affecting plankton, krill, fish, seabirds, and marine mammals (Piatt et al., 2020; Cavole et al., 2016; McGowan et al., 1998; Sanford et al., 2019; DiLorenzo & Mantua, 2016). During past El Niño events and MHWs in the California Current Ecosystem, zooplankton communities shifted to smaller, less nutritious copepod species from the south (Fisher et al., 2015; Leising et al., 2015, Elliott et al., 2022a), plankton biomass declined, and functional groups shifted (McGowan et al., 1998).

Commented [8]: also see Garcia-Reyes et al 2023 https://doi.org/10.3389/fmars.2023.1158472

Higher water temperatures and reduced food availability may affect species abundance and distribution by encouraging species to move to northern or deeper, cooler waters (Poloczanska et al., 2013) and by altering migration patterns (Gulland et al., 2022). Some species that are unable to acclimate or adapt over time could decline in abundance (Hobday et al., 2016). Warmer water holds less oxygen and could fall below the range of natural variability by 2030 (Long et al., 2016), reducing habitat for species like rockfish (Koslow et al., 2011; Hamilton et al., 2017). Higher temperatures can also increase the occurrence of disease outbreaks such as sea star wasting syndrome (Bates et al., 2009; Eisenlord et al., 2016), and lead to more frequent and more intense harmful algal blooms (HABs) (Cavole et al., 2016; Gobler 2020). HABs can produce toxins that can harm wildlife, causing mass mortalities of sea lions, whales, seabirds, and other animals (McCabe et al., 2016; Griffith & Gobler, 2019; Sanford et al., 2019; Gulland et al., 2022).

Warmer water temperatures, especially MHWs, can be a catalyst for habitat compression in the offshore environment. The recent 2014–2016 MHW, for example, caused by a persistent high pressure system in the eastern North Pacific (Bond et al., 2015), raised water temperatures in the sanctuary by 7.2°F (3.6°C) above normal (Gentemann et al., 2017; Sanford et al., 2019), causing many southern species to move northward (Hobday et al., 2016). During this period, offshore upwelling was reduced and the cooler upwelling habitat for forage species such as anchovy and krill in the central California Current Ecosystem, was also compressed eastward towards the mainland which resulted in habitat compression for some predator species, such as whales and seabirds (Santora et al., 2020). For whales, foraging closer to shore as a result of habitat compression can increase the risk of ship strikes and entanglement in crab pots. MHWs are expected to increase in frequency and intensity (Frölicher et al., 2018) and these

phenomena may be a predictor of future ecological conditions in the offshore environment (Cavole et al., 2016).

Ocean Acidification (Aragonite Saturation)

Ocean acidification occurs when increased levels of carbon dioxide (CO_2) in the atmosphere dissolve in seawater, reducing the pH value and making the ocean more acidic (ONMS, 2020b). The ocean absorbs around 30% of CO_2 emissions (NCEI, 2023),and global average surface ocean pH has decreased by 0.1 units since pre-industrial times (Doney et al., 2009) which is a 30% increase in acidity. Aragonite is considered a key indicator of ocean acidification, as it is a form of calcium carbonate that is more sensitive to increasing CO_2 than calcite. The saturation state of aragonite is projected to drop rapidly in the California Current Ecosystem within the next 30 years, with much of the nearshore region developing summertime undersaturation in the top 60 meters (Gruber et al., 2012).

Commented [9]: more recent: Anderson et al 2022 https://doi.org/10.1016/j.rsma.2022.102286

Ocean acidification slows the growth of calcium carbonate structures and can dissolve these structures faster than they form, impacting shelled organisms in the California Current Ecosystem (Hales et al., 2005). Corrosive conditions can occur for many species, like oysters, crabs, and pteropods, when aragonite saturation is <1.0 (Barton et al., 2012; Bednaršek et al., 2014; Marshall et al., 2017; Hodgson et al., 2018). Ocean acidification can also impact larval and juvenile fish through changes in behavior, physiology, and patterns of gene expression (Munday et al., 2009; Hamilton et al., 2013) Acidification in the sanctuary is accelerated by upwelling because cool upwelled waters are more acidic than surface waters (Garcia-Reyes and Largier 2010). As a result, California waters have increased in acidity by up to 60% since 1895 and could increase 40% above 1995 levels by 2050 (Gruber et al., 2012; Osborne et al., 2020). Portions of the sanctuary's nearshore region are already acidic enough to impair the growth of shell-forming animals (Davis et al., 2017; Chan et al., 2017), including species with commercial or recreational value such as Dungeness Crab (Bednaršek et al., 2020), oysters, clams and mussels. Increasingly acidic waters make it difficult for organisms like coral to make and maintain their shells and stony skeletons. Deep-sea corals are particularly susceptible as the deep waters where they live are naturally more acidic than the surface (Gomez et al., 2018). Pteropods, important prey for fish, are particularly susceptible to increasingly acidic waters (Bednaršek et al., 2017) and krill, prey for salmon, seabirds and whales, may experience reduced larval survival as acidity increases (McLaskey et al., 2016). The effects of ocean acidification could have consequences for the entire food web (Bednaršek et al., 2017; Hodgson et al., 2018; Gentemann et al., 2017; ONMS 2020a).

Ocean acidification, in combination with other local conditions, may also affect historic resources. Historic wrecks could be threatened by an increasingly acidic ocean as it has the potential to change the corrosion rate of metal ship parts and artifacts (Rockman et al., 2016).

Sea Level Rise, Increased Storms and Wave Activity, and Precipitation Variability

Sea level rise (SLR) impacts beaches and dunes, marshes, and rocky intertidal habitats through increased coastal erosion and damage from increased storm surges, which can lead to drowning and/or eroding coastal habitats. Numerous factors contribute to global SLR including melting glaciers and thermal expansion of seawater. Factors such as currents and changing land height cause SLR to rise at different rates in different locations (Slagen et al., 2014). In the sanctuary, sea level has risen approximately 9 inches since 1854 (NOAA, 2022), and the most recent NOAA SLR projections predict another 9-11 inches by 2050 and up to 78 inches (high scenario) of SLR by 2100 (Sweet et al., 2022). In GFNMS, SLR is impacting critical pupping and haul-out habitat for marine mammals such as harbor seals and Steller sea lions as well as

nesting areas for birds like the threatened western snowy plover (Largier et al. 2010, Funayama et al. 2011).

In the region of the sanctuary, winter storms have increased in frequency and intensity since 1950 as a result of climate change (Largier et al., 2010; Graham and Diaz, 2001) and strong waves driven by these storms are exacerbating SLR impacts, like erosion (Largier et al., 2010; Dettinger, 2011; Erikson et al., 2015). Overall, increased erosion and run-off are likely to occur in association with winter storms that bring large waves and heavy precipitation to the region (Largier et al. 2010). Projected increases in the intensity of storms and waves (Dettinger, 2011; Erickson et al., 2015) could also reduce the ability of encrusting organisms to stay attached to substrate in the intertidal zone.

As with ocean acidification, SLR and increased wave activity and erosion can (and if fact is) having a negative impact on near shore maritime heritage properties and coastal cultural sites in many locations (Roth, 2022). The Society for California Archaeology (SCA) launched a Climate Change and California Archaeology study in 2011, and current research includes coastal regions adjacent to GFNMS (Newland, 2014).

Commented [10]: https://docs.google.com/document/d/1pliRgl7zF2jWDgsfdMXApJr2nkNvnJwE/edit

Commented [11]: Newland, Michael. 2014. SOCIETY FOR CALIFORNIA ARCHAEOLOGY CLIMATE CHANGE AND CALIFORNIA ARCHAEOLOGY SERIES TECHNICAL REPORT 1. OVERVIEW AND WORKPLAN. Chico, CA: California Society for Archaeology.

https://scahome.org/resources/Documents/Website%20Materials/SCA-Climate-Change-Report-Volume-1.pdf

Climate change is also altering precipitation. Snowpack in the Sierras has declined in recent decades (Sun et al., 2019; Pederson et al., 2011). The shift from snowpack to rain-dominated runoff, along with increases in extreme wet and dry events, could alter the timing and intensity of runoff and sediment into the sanctuary, impacting organisms that depend on streamflow, such as salmon.

Shoreline Change and Sediment Transport

SLR, increased frequency and intensity of storms, and changes in precipitation can alter sedimentation patterns along the sanctuary's coast through increased flooding of low-lying areas and increased erosion of cliffs, bluffs, and dunes (Limber et al.,2018), which can lead to disappearing beaches and coastal wetlands with significant ecological implications.

Tidal marshes depend on a steady sediment supply and factors such as altered precipitation patterns and land use may prevent marshes from keeping pace with the expected rate of SLR (Thorne et al., 2008; Weston et al., 2014). In some cases, over-accumulation of sediment can occur which damages habitats, interferes with the food chain, obstructs channels, and increases turbidity.

Warmer water events can exacerbate shoreline change as well. California shorelines retreated beyond previously measured landward extremes during the 2015–2016 El Niño, one of the strongest of the last 145 years (Barnard et al., 2017).

Land Use

Land use activities adjacent to marine and estuarine waters, such as agriculture, forestry, transportation, urbanization, and construction, can create pollutants including sediments, plastics, and chemicals, that can impact water quality, marine species and habitats.

High pollution loads can lead to eutrophication—an overload of nutrients such as nitrogen and phosphorus. The excess nutrients can cause algal blooms which can lead to depleted oxygen levels and subsequent harmful effects on marine life. These pollutants often come from runoff from land activities such as agriculture and can enter the sanctuary through rivers, estuaries, and other pathways, adversely impacting water quality.

Artificial structures that stabilize shorelines (such as seawalls, rip rap, roadways, etc.) can result in narrower coastal habitats and reduced space for habitat migration as sea level rises and storm surge intensity increases (See the Changing Ocean Conditions section for more discussion on this topic).

Marine Harvest Activities

Fishing offers many benefits to society, including the economic, nutrition, and employment benefits of commercial fisheries (Kelleher et al., 2012) and the economic, social, physiological, educational, and economic benefits of recreational fishing (Leeworthy & Schwarzmann, 2015; Arlinghaus et al., 2019) but it can also negatively impact sanctuary resources, including habitat, living resources, and maritime heritage resources. The extraction of certain fish species can alter ecosystem function, especially when one part of the food web or a predator and prey population is reduced or removed from the food chain (Hammerschlag, 2019). The removal of targeted fish species, along with mortality through bycatch, can also result in changes in biodiversity. Catch-and-release recreational fishing (and the release of incidentally caught species) can also result in mortality through barotrauma, increased depredation, hook wounds, and other pathways, as well as sublethal effects like behavioral impairment and decreased feeding success (Davis et al., 2002; Campbell et al., 2010). The mortality rate of catch and release has a large range (0-95%, median 11%, mean 18%) depending on factors such as hooking location, type of hook used, type of bait used, depth of capture, temperature, and hooking and handling times (Bartholomew & Bohnsack 2005).

The use of mobile commercial fishing gear, such as bottom trawls, is of particular concern. Bottom trawling disturbs the structure of the seafloor, affects the three dimensional character and availability of fish habitat, changes the composition of biologic communities in the area, disrupts the food web, and results in additional adverse effects (National Research Council, 2002; Kaiser et al., 2006).

Impacts to deep sea communities from these activities may be long lasting. Corals and sponges on hard substrate are vulnerable to damage and removal from bottom trawling (Althaus et al., 2009), as well as the biota of soft-sediment habitats, such as sea pens (Hall-Spencer et al., 2002; Heifitz et al., 2009). Deep sea corals and sponges are slow growing and may have long recovery times from disturbance (Prouty et al., 2016). Slow-growing large-biomass biota such as sponges and soft corals take much longer to recover (up to 8 yr) than biota with shorter life-spans such as polychaetes (<1 yr) (Kaiser et al., 2006).

Additional impacts can occur from other commercial fishing gear such as bottom longlines and vertical hook and line, which can cause damage to sensitive habitats and species, such as deep sea corals (Stone, 2006; Stone et al., 2014). Derelict (lost or discarded) fishing gear is also a concern as these items can continue to trap and kill marine life for many years (NOAA Marine Debris Program, 2015), although some gear, such as Dungeness crab traps, are required to have a disabling mechanism via a biodegradable release, which can have varying degrees of success based on design and crab health (Antonelis et al., 2023). Lost or discarded lines and hooks can lead to marine mammal and seabird strandings (Moore et al., 2009, Donnelly-Greenan et al., 2016). Commercial fishing can also cause mechanical damage to and entanglement on maritime heritage resources particularly from bottom trawling (Meyer-Kaiser et al., 2022; Brennan et al., 2016).

Commented [12]: effect on marine mammals more specifically here? bycatch, entanglement, ghost gear?

Commented [13]: i see ghost gear is later

Aquaculture operations can impact ecosystems by altering the deposition of organic material; altering sedimentation processes due to the anchoring, harvesting, and maintenance of moored oyster bags and floats, which can affect biogeochemical and biological processes in sediments (McKindsey et al., 2006; Dumbauld et al., 2009); removing benthic species; and causing changes to resource or habitat availability (Dumbauld et al., 2009); and influence the number and intensity of phytoplankton blooms directly through grazing and indirectly by modifying nutrient fluxes. Shellfish aquaculture operations occur in Tomales Bay, which has the greatest number of state bottom water leases in California (CDFW, 2020b).There is some evidence aquaculture activities may affect birds in Tomales Bay; some species avoided artificial oyster racks and oyster culture bags while others may be attracted to these structures (Kelly et al., 1998).

A variety of fishing gear types are used in the offshore region, including pots/traps, troll gear, trawls, seines, longlines, and hook and line (CDFW, 2020a). The most commonly-used types of commercial bottom fishing gear (in terms of harvest revenue and pounds landed) throughout GFNMS that can alter seafloor habitat are traps and trawls (CDFW, 2020a, ONMS, 2023). Commercial and recreational fishing of invertebrates also occurs in some intertidal areas through direct collection (harvesting). Fishing activities in GFNMS estuaries include the harvest of crab, herring, halibut, surf perch, striped bass, salmon, leopard shark, and bat rays primarily through fishing by traps and hook and line. Most fishing activity is by recreational anglers, however, commercial fishing is allowed in GFNMS estuaries and may occur for certain species

GFNMS does not have the authority to manage fisheries. Instead, commercial and recreational fisheries in GFNMS including species managed through the Groundfish Fishery Management Plan, Highly Migratory Species Management Plan, Coastal Pelagic Species Management Plan and Salmon Management Plan are managed by NOAA's National Marine Fisheries Service and the Pacific Fisheries Management Council. State fisheries (e.g., Dungeness crab, Market squid, Herring and nearshore finfish) are managed by the California Department of Fish and Wildlife.

Commented [14]: I'm not a biologist, but are Market squid, Herring (and Dungeness for that matter) always capitalized?

Vessel Activity

Private, commercial, and military vessels may impact the sanctuary and sanctuary users in several ways, including:

- Ship strikes on whales and other species;
- Anchor damage to seafloor habitats and/or maritime heritage resources;
- Discharge of oil, sewage, chemicals, and non-biodegradable materials;
- Seafloor damage from vessel groundings and sinkings;
- Elevated noise levels

Pressures from vessel traffic vary with the size, frequency, routes, and type of vessels transiting the sanctuary. Numerous types of domestic and foreign-flagged commercial vessels (some with hazardous materials), including large vessels (greater than 300 gross tons) such as container ships, tankers, car carriers, bulk cargo carriers, and cruise ships transit through GFNMS. Since 2010, the size of commercial ships has increased, but the number of ships using the three lanes of the San Francisco Traffic Separation Scheme (TSS, Figure SS.1) has remained constant at about 8,000 transits a year, including inbound and outbound transits (Jensen et al., 2015; OCM, 2022). Smaller commercial and recreational vessels are also present in the sanctuary including Tomales Bay and Bolinas Lagoon. Thousands of commercial, recreational, fishing, military, and research vessels berth in harbors near the sanctuary.

Pressures are likely to continue in the region from small boat and large vessel traffic, given forecasted trends and the increase in size of commercial ships over the last several decades.

Ship Strikes

Vessels can injure or kill animals. Slow-moving whales rely on the highly productive waters of the sanctuary as a destination feeding ground or part of their migratory routes and are particularly vulnerable to ship strikes. Ship strike risk for whales is highest in the shipping lanes and at the western ends of the lanes over the shelf break (Rockwood et al., 2020a), a whale foraging area (Rockwood et al., 2020b).

Levels and location of shipping traffic, vessel speeds, whale abundance, and whale behavior are factors affecting ship strike risk to whales (Laist et al., 2001; Dransfield et al., 2014; McKenna et al., 2015; Rockwood et al., 2017). Ship strikes, along with entanglements, are the primary sources of anthropogenic mortality to threatened and endangered whales listed under the Endangered Species Act along the west coast (Carretta et al., 2021), with a model-estimate of approximately 80 threatened and endangered whales hit and killed each year along the west coast (Rockwood et al., 2017). Scientists estimate that the rate of detection and reporting of ship strikes is a small percentage of the actual number of animals struck; about 2% for blue whales and 10% for humpbacks (Carretta et al., 2021). The impact of ship strikes on endangered blue whales is of concern, given their low population estimate (1,050 in CA, OR, and WA; Carretta et al., 2021). In addition, humpback and fin whales are also at risk; humpback whales traveling to GFNMS are listed as threatened for the Mexico Distinct Population Segment (DPS) and endangered for the Central America DPS (Carretta et al., 2021) and fin whales are listed as threatened.

Anchoring

Anchoring by vessels of all sizes can damage sensitive benthic habitats and protected maritime heritage resources, in particular shipwrecks found in anchor-depth waters. Further, improper anchoring can lead to the anchor dragging and potential grounding of the vessel leading to the vessel breaking apart, discharging debris and pollution.Anchoring in eelgrass can scour the seafloor and uproot eelgrass, causing fragmentation of the beds, and reductions in habitat integrity and eelgrass community structure (Kelly et al., 2019).

Petroleum and Other Chemical Spills

Oil pollution can come from vessel collisions, sinkings, groundings, discharges, and historic sunken wrecks. Cargo ships and oil tankers transit the sanctuary and are of particular concern for spills and discharges. Large cargo ships can carry up to 4 million gallons of fuel oil (NOAA, 2016). Oil tanker size varies and these ships can carry 9–150 million gallons of oil (Kummerlowe et al., 1996). Supertankers can carry over 80 million gallons of oil. Vessels can introduce pollution into the marine environment from spills, blowing or drifting trash (e.g., oil containers and portable gas tanks), faulty equipment, and other mishaps or poor waste control practices.

Oil pollution in any form has adverse impacts on sanctuary water quality, plants, animals, and habitats. Oil contamination of marine mammals and seabirds can cause eye irritation, impairment of thermal regulation, loss of buoyancy, toxicity, reproductive abnormalities, and ultimately death. Oil spills can deplete food sources and destroy habitat characteristics essential for survival of vertebrate species. Past spills, such as the 2007 M/V *Cosco Busan* spill which killed an estimated 6.849 birds both inside and outside the sanctuary (Cosco Busan Oil Spill Trustees, 2012), have impacted seabird populations and future spills could, in a worst-case scenario, impact multiple species on a local or regional scale. Oil spills can have lethal as well

as long-term, sub-lethal effects on fish (e.g., behavioral changes, reproductive abnormalities) and can also contaminate fish targeted for human consumption. Some sectors of fishing industries could be shut down for years by an oil spill.

Due to its proximity to San Francisco and surrounding metropolitan area, shipping ports, and petroleum refineries, GFNMS has a history of large spills and has been impacted by six major vessel-based oil spills since designation in 1982: S/S *Jacob Luckenbach* (which sank in 1953 and had ongoing releases until oil was lightered in 2002), T/V *Puerto Rican* (1984), T/B *Apex Houston* (1986), S/S *Cape Mohican (*1996), T/V *Command* (1998), and S/S *Cosco Busan* (2007). Vessels that sink with product on-board can continue to release oil due to currents and large swell events moving the vessel. For example, S/S *Jacob Luckenbach*, which sank in 1953, released an estimated 300,000 gallons of bunker fuel oil over more than 48 years, killing at least eight sea otters and over 51,000 birds (Luckenbach Trustee Council, 2006). Small oil releases caused by small to medium sized boat groundings and sinkings (i.e., recreational and commercial fishing vessels) also occur every year in estuarine, coastal, and offshore sanctuary waters.

Due to proximity to San Francisco Bay and its tributaries, land-based spills and discharges also pose threats to the sanctuary. Naturally occurring oil seeps cause periodic tarball pollution events along the GFNMS coastline.

Offshore Discharges

While GFNMS regulations prohibit most discharges in the sanctuary, illegal discharges have occurred, including the dumping of sewage and other hazardous liquid substances, and solid materials such as shipping containers and other marine debris (See Marine Debris subsection), that can result in impacts to water quality, seafloor habitat, and wildlife.

Cruise ships carry over 3,000 people, generate and incinerate large amounts of waste, and have the potential to severely impact water quality in localized areas if they are not responsibly operated. Cruise ships regularly transit the sanctuary and embark passengers at the cruise ship terminal in San Francisco Bay. Cruise ship discharges are prohibited within the sanctuary except clean vessel engine cooling water, clean vessel generator cooling water, vessel engine or generator exhaust, clean bilge water, or anchor wash. Volumes of sewage generated by a typical cruise ship have been estimated at 8.4 gallons per person per day, or 147,000 gallons per week (MBNMS, 2023). Known pollutants generated by cruise ships include food waste, processed permeate, treated and untreated greywater (wastewater from sinks and showers) and blackwater (sewage), membrane bioreactor sludge, advanced waste water treatment permeate, exhaust gas cleaning system (EGCS or scrubbers[1]) wash water, oily bilge water, hazardous wastes, and trash. Scrubber wash water is of particular concern, because it may emit wash water with concentrations of metals that could result in increased acidification, eutrophication, and accumulation of polycyclic hydrocarbons in the marine environment (USEPA, 2011). Illegal cruise ship discharges of a number of these substances have been documented over the last decade in GFNMS. Nutrients and compounds can remain in the waste streams after treatment (USEPA, 2008; USEPA, 2012). These discharges are known to have effects on water quality and sea life through the potential introduction of harmful components such as bacteria, heavy metals, pharmaceuticals, pathogens, and viruses (USEPA, 2011).

[1] Scrubbers are devices used on large vessels to remove sulfur dioxide from the exhaust of marine engines to reduce air emissions. The extracted sulfur is removed using either seawater or freshwater wash and may not be discharged in the sanctuary.

Feeding in polluted waters has been known to negatively affect the health of marine mammals including dolphins, sea otters, seals and sea lions (Stoskopf, 2018).

The discharge of dredged material (either accidental loss or intentional) can affect water clarity by blocking sunlight, restricting the growth of plankton and disrupting the foraging of fish, birds and marine mammals. It can also change the character of the seafloor habitat and smother bottom dwelling organisms, such as corals and sponges, and potentially bury or damage submerged maritime heritage resources. Material dredged from marinas and navigation channels in nearby harbors and ports (mainly from Bodega Harbor and San Francisco Bay) is periodically towed via barge and scow through the sanctuary for legal disposal at the SF-DODS Deep Ocean Disposal Site, located approximately 56 miles offshore due west of the Golden Gate Bridge and 11 miles west of the sanctuary. While material is tested for suitability for ocean disposal and is relatively clean, accidental releases have been known to occur in the last 10 years in the sanctuary.

Grounded and Sunken Vessels

Grounded and sunken vessels cause physical adverse effects to seafloor habitat and maritime heritage resources, release fuel and other chemicals, and cause marine debris. Groundings and sinkings are a regular but unpredictable occurrence in the sanctuary and cause a range of impacts, including short- and long-term habitat loss from recovery of the vessel or complete habitat loss with ongoing debris and pollutant risk. (Vessels grounded or sunk less than 50 years ago are not considered potential heritage or historic properties for management purposes.)

Noise

Many marine organisms, including marine mammals, turtles, fish, and invertebrates, rely on sound for their survival and the degree to which biota are impacted depends on the interaction of noise intensity, duration, timing, and frequency, among other factors. Exposure to high decibel noise, especially in close proximity, can cause acute impacts like tissue damage, rupturing or hemorrhaging of body parts, and hearing loss (either temporary or permanent)(Gedamke et al., 2016, Southall et al., 2019). Elevated underwater noise levels can mask biologically important acoustic signals (e.g., those used for echolocation, interspecies communication, mother/calf contact, predator-prey cues, and navigation) as well as cause behavioral alterations (such as changes in migration patterns or abandonment of important habitats) (Southall et al., 2019). Many marine mammals respond to noise by altering their breathing rates, increasing or reducing their time underwater, changing the depths or speeds of their dives, shielding their young, changing their song durations, and swimming away from the affected area. Higher stress loads have been documented in whale populations exposed to chronically louder conditions (Gedamke et al., 2016). These alterations can have adverse effects on animals' energy and physiology, which in turn can reduce their abilities to survive and reproduce (reviewed in Francis & Barber, 2013).

The level of noise pollution in the oceans has increased dramatically during the last 50 years, mainly from commercial shipping in coastal environments (National Research Council, 2003; Frisk, 2012; Southall et al., 2018). Large, ocean-going commercial traffic produces low-frequency noise through cavitation (the bursting of bubbles from propellers), the flow of water over the hull, as well as other onboard sources such as machinery (McKenna et al., 2013; Richardson et al., 1995). Studies have also shown that slower ships, and smaller ships, produce less noise (McKenna et al., 2013). Since 2010, the number of vessels using the TSS has not substantially increased, however, the size of the vessels has increased.

Noise was not selected for this condition report as an indicator in this report due to limited data available. Analysis of acoustic data, vessel traffic patterns, and related noise inputs to GFNMS is needed to assign a status and trend.

Marine Debris

Marine debris is any persistent, manufactured or processed solid material that is directly or indirectly, intentionally or unintentionally, disposed of or abandoned in the marine environment (NOAA, 2021). Marine debris enters the sanctuary from both water and land-based activities, and it has been found accumulating in the water column and benthic habitats. Land-based sources include stormwater runoff, landfills, and recreational and commercial activities. Marine-based sources include commercial and recreational fishing and aquaculture, research operations, military activities, and cargo containers falling off ships in high seas (Keller et al., 2010). Marine debris can include a wide variety of objects including lost fishing gear, overboard disposal of passenger and commercial shipboard waste, lost vessel cargo, metal military debris, abandoned or lost moorings and buoys, abandoned, grounded and/or sunken vessels, and a variety of household goods. Of these types, plastic is the most prevalent type of marine debris found in all oceans, including the sanctuary.

Marine mammals and seabirds are known to be affected by marine debris (FSCOP, 2019). Marine mammals can become entangled in fishing gear; on the U.S. West Coast, including GFNMS, this is particularly a problem for large whales.. Derelict (lost or discarded) fishing gear can trap, injure or kill marine life, sometimes impacting wildlife for years. The timing of the arrival of humpback whales in the Gulf of the Farallones region has shifted since the mid-1990s to an earlier arrival, which has increased co-occurrence of whales with the historic timing of commercial fishing activities, thus increasing the risk of entanglement, particularly in the lines and surface buoys of Dungeness crab traps (Figure S.P.4.4).

Other sanctuary wildlife, such as pinnipeds and seabirds can also become entangled in fishing gear and debris. Marine debris can be ingested, which may result in drowning, starvation, physical trauma, systemic infections, or increased susceptibility to other threats, such as ship strikes (Marine Debris Program, 2014). Plastics in the marine environment never fully degrade, and organisms consume plastic at all levels of the marine food web (Turri and Leterme, 2023). In general, given the quantities of plastic debris floating in the ocean, the potential for wildlife to ingest plastic is high. The ability for plastics to attract and transport contaminants into the marine food web has been documented (Arthur et al., 2009) and research suggests microplastics (i.e. plastic pieces less than five millimeters in length) can accumulate in seafood (Avio et al., 2017). Surface feeding seabirds that are common in GFNMS, which include albatross, shearwaters, fulmars, and storm-petrels, are highly susceptible to plastic ingestion (Nevins et al., 2005).

Sunken vessels, shipping containers, and other large debris that sink are also a source of marine debris. Corals, sponges, and other benthic invertebrates may be crushed, smothered, or displaced in offshore and/or nearshore environments by these objects. Heavier objects can cause the permanent loss and/or scarring and damage to rocky reef habitat which reduces the value of substrate to support coral/sponge colonies, algal assemblages, and other encrusting and habitat-forming organisms. (Vessels grounded or sunk less than 50 years ago are not considered potential heritage or historic properties for management purposes.)

Wildlife Disturbance

Wildlife in GFNMS is diverse and includes iconic species such as whales, pinnipeds, white sharks, and seabirds, in addition to fish and invertebrates. There are documented cases of human disturbance to wildlife at seabird colonies and pinniped haul-outs at the Farallon Islands; pinniped colonies at Bolinas Lagoon and Tomales Bay; and at Duxbury Reef (Bewley, 2017; Codde, 2020; McChesney, 2021).

Disturbances that have been studied include (Reyna et al., 2021):

- Close-approaching water-based activities (e.g., kayaking, stand up paddleboarding, jet ski), and boating tourism/recreation (e.g. wildlife watching, diving);
- Low-flying planes, helicopters, uncrewed aerial systems (UAS or drones);
- Increased visitation impacts, including rocky intertidal trampling and harvesting of flora and fauna; and
- Close approach land-based activities like human foot traffic and dog interactions with birds and marine mammals on beaches.

For seabirds, frequent disturbance or a single severe event can disrupt nest site prospecting, courtship, resting, and feeding of young. It can lead to increased predation, increased stress levels, and higher energy costs —the net effect of which reduces breeding success, results in fewer young, and can cause colony abandonment over time (Rojeck et al., 2007). Marine mammal disturbance can cause stress, displacement, and trampling of pups (Rhodes, 2017).

Visitors at rocky reefs have been documented trampling and collecting intertidal invertebrate species (Lindquist and Roletto, 2022b; WMEAC 2022). These activities can cause long-term negative impacts to habitats and species through altered abundances and community interactions.

Non-indigenous Species

Non-indigenous species are organisms living outside their native distributional range, having arrived there by human activity, either deliberate or accidental, and are also called alien, exotic, non-native, or introduced species. Non-indigenous species that have damaging effects on ecosystems are called “invasive” species. Invasive species are one of the greatest threats to rare, threatened, or endangered species in this country, thought to be second only to habitat destruction (Dueñas et al., 2018). In general, non-indigenous species in the marine and estuarine environment can alter species composition, threaten the abundance and diversity of native marine species, interfere with ecosystem function and disrupt fisheries (Bax et al., 2003; (Grosholz 2002). Invasive marine species can result in declines, extirpations, or extinctions of native plants and marine life, reduce biodiversity by competing with native organisms for limited resources, limit resiliency of wildlife and habitats to recover from anthropogenic impacts, limit effectiveness of restoration actions, alter habitats, and compound the impacts from climate change.

Marine non-indigenous species may be introduced to the sanctuary by traveling on the hulls of ocean-going ships and on the hulls, propellers, or trailers of small private and commercial boats, including from San Francisco Bay, which is considered the most invaded aquatic ecosystem in the world, with over 230 non-indigenous species (Cohen & Carlton, 1998). In addition, they may be released in or near the sanctuary in ballast water. Other potential vectors for the spreading of non-indigenous species in the sanctuary include recreational and research equipment, debris

and buoys. Organisms used for live bait and aquaculture, also have the potential for accidental or intentional release into the marine/estuarine environment.

European green crabs are highly adaptable predators originating from Western Europe and Africa that first appeared along the Western U.S. in 1989, likely transited in the ballast water of cargo ships and boats and becoming established in shallow intertidal and subtidal habitats. The highest density of green crabs along the entire west coast is in Seadrift Lagoon, a man made lagoon adjacent to Bolinas Lagoon and connected by a managed intake near the northwestern end and an outfall on the southeastern end. They are also established in Bolinas Lagoon and Tomales Bay with interannual variability in the numbers ranging from low to high.

Literature Cited (Pressures)

Althaus F., Williams A., Schlacher T.A., Kloser R.J. et al., (2009) Impacts of bottom trawling on deep-coral ecosystems of seamounts are long-lasting. Mar Ecol Prog Ser 397:279-294. https://doi.org/10.3354/meps08248

Antonelis, K., Drinkwin, J., Rudell, P., Morgan, J., Selleck, J., Velasquez, D., & Rothaus, D. P. (2023). Determining effectiveness of dungeness crab escapement in derelict traps. *Marine Policy*, *149*, 105499. https://doi.org/https://doi.org/10.1016/j.marpol.2023.105499

Arlinghaus, R., Abbott, J. K., Fenichel, E. P., Carpenter, S. R., Hunt, L. M., Alós, J., Klefoth, T., Cooke, S. J., Hilborn, R., Jensen, O. P., Wilberg, M. J., Post, J. R., & Manfredo, M. J. (2019). Governing the recreational dimension of global fisheries. *Proceedings of the National Academy of Sciences, 116*(12), 5209–5213. https://doi.org/10.1073/pnas.1902796116

Baer, A., Donaldson, A., and Carolsfeld, J. (2010). Impacts of Longline and Gillnet Fisheries on Aquatic Biodiversity and Vulnerable Marine Ecosystems. Department of Fisheries and Oceans Canada, Canadian Science Advisory Secretariat, Research Document 2010/012 vii + 78. https://waves-vagues.dfo-mpo.gc.ca/library-bibliotheque/340472.pdf

Barbier, E. B., Hacker, S. D., Kennedy, C., Koch, E. W., Stier, A. C., & Silliman, B. R. (2011). The value of estuarine and coastal ecosystem services. *Ecological monographs*, 81(2), 169-193. https://doi.org/10.1890/10-1510.1

Barnard, P.L., Hoover, D., Hubbard, D.M., Snyder, A., Ludka, B.C., Allan, J., Kaminsky, G.M., Ruggiero, P., Gallien, T.W., Gabel, L. and McCandless, D. (2017). Extreme oceanographic forcing and coastal response due to the 2015–2016 El Niño. *Nature communications*, *8*(1), 14365. https://doi.org/10.1038/ncomms14365

Bartholomew, A., & Bohnsack, J. A. (2005). A Review of Catch-and-Release Angling Mortality with Implications for No-take Reserves. *Reviews in Fish Biology and Fisheries*, *15*(1), 129–154. https://doi.org/10.1007/s11160-005-2175-1

Barton, A., Hales, B., Waldbusser, G. G., Langdon, C., & Feely, R. A. (2012). The Pacific oyster, *Crassostrea gigas*, shows negative correlation to naturally elevated carbon dioxide levels: Implications for near-term ocean acidification effects. *Limnology and oceanography*, *57*(3), 698-710. https://doi.org/10.4319/lo.2012.57.3.0698

Bates, A.E., Hilton, B.J., & Harley, C.D.G. (2009). Effects of temperature, season and locality on wasting disease in the keystone predatory sea star Pisaster ochraceus. Diseases of Aquatic Organisms 86(3):245-51. DOI:10.3354/dao02125.

Bax, N., Williamson, A., Aguero, M., Gonzalez, E., & Geeves, W. (2003). Marine invasive alien species: a threat to global biodiversity. *Marine Policy*, *27*(4), 313–323. https://doi.org/https://doi.org/10.1016/S0308-597X(03)00041-1

Bednaršek, N., R. A. Feely, J. C. P. Reum, B. Peterson, J. Menkel, S. R. Alin, and B. Hales. (2014). *Limacina helicina* shell dissolution as an indicator of declining habitat suitability owing to ocean acidification in the California Current Ecosystem. Proceedings of the Royal Society B–Biological Sciences 281:20140123. https://doi.org/10.1098/rspb.2014.0123
Bednaršek, N., Feely, R.A., Tolimieri, N., Hermann, A.J., Siedlecki, S.A., Waldbusser, G.G., McElhany, P., Alin, S.R., Klinger, T., Moore-Maley, B. & Pörtner, H.O. (2017). Exposure history determines pteropod vulnerability to ocean acidification along the US West Coast article. Scientific Reports, 7(1): 1–12. 7, 4526. https://doi.org/10.1038/s41598-017-03934-z.
Bednaršek, N., Feely, R., Beck, M.W., & Alin, S. (2020). Exoskeleton dissolution with mechanoreceptor damage in larval Dungeness crab related to severity of present-day ocean acidification vertical gradients. Science of The Total Environment 716(8):136610 DOI:10.1016/j.scitotenv.2020.136610
Bond, N.A., Cronin, M.F., Freeland, H., & Mantua, N. (2015). Causes and impacts of the 2014 warm anomaly in the NE Pacific. *Geophysical Research Letters*, *42*(9), 3414–3420. https://doi.org/10.1002/2015GL063306
Brennan, M. L., Davis, D., Ballard, R. D., Trembanis, A. C., Vaughn, J. I., Krumholz, J. S., Delgado, J.P., Roman, C.N., Smart, C., Bell, K.L. and Duman, M. & DuVal, C. (2016). Quantification of bottom trawl fishing damage to ancient shipwreck sites. Marine Geology, 371, 82-88. https://doi.org/10.1016/j.margeo.2015.11.001
Bureau of Ocean Energy Management & National Oceanic and Atmospheric Administration. (2022). Marine cadastre. https://marinecadastre.gov
California Department of Fish and Wildlife. (2020a). California commercial landing receipt data, 1994-2020 [Unpublished data set].
California Department of Fish and Wildlife (CDFW) (2020b). The status of commercial marine aquaculture in California. Retrieved from https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=187229&inline
California Department of Fish and Wildlife (2023). Duxbury Reef State Marine Conservation Area. Retrieved from https://wildlife.ca.gov/Conservation/Marine/MPAs/Duxbury-Reef
Campbell, M. D., Patino, R., Tolan, J., Strauss, R., & Diamond, S. L. (2010). Sublethal effects of catch-and-release fishing: Measuring capture stress, fish impairment, and predation risk using a condition index. *ICES Journal of Marine Science,* 67(3), 513–521. https://doi.org/10.1093/icesjms/fsp255
Carretta, J. V., Oleson, E. M., Forney, K. A, Muto, M. M., Weller, D. W., Lang, A. R., Baker, J., Hanson, B., Orr, A. J., Barlow, J., Moore, J. E., & Brownell, R. L. (2021). U.S. Pacific marine mammal stock assessments: 2020. Technical Memorandum NMFS-SWFSC-646. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. https://doi.org/10.25923/r00a-m485
Cavole, L. M., Demko, A. M., Diner, R. E., Giddings, A., Koester, I., Pagniello, C. M. L. S., Paulsen, M.-L., Ramirez-Valdez, A., Schwenck, S. M., Yen, N. K., Zill, M. E., & Franks, P. J. S. (2016). Biological Impacts of the 2013–2015 Warm-Water Anomaly in the Northeast Pacific: Winners, Losers, and the Future. *Oceanography*, *29*(2), 273–285. http://www.jstor.org/stable/24862690
Chan, F., Barth, J.A., Blanchette, C.A. et al. (2017). Persistent spatial structuring of coastal ocean acidification in the California Current System. *Scientific Reports*, *7*(1), 2526. https://doi.org/10.1038/s41598-017-02777-y
Codde, S. (2020). Pacific harbor seal (Phoca vitulina richardii) monitoring at Point Reyes National Seashore and Golden Gate National Recreation Area: 2019 monitoring season.

Natural Resource Report NPS/SFAN/NRR—2020/2129. National Park Service, Fort Collins, Colorado. https://irma.nps.gov/DataStore/DownloadFile/640169.
Cohen, A. N., & Carlton, J. T. (1998). Accelerating invasion rate in a highly invaded estuary. *Science*, *279*(5350), 555-558. https://doi.org/10.1126/science.279.5350.555
Cosco Busan Oil Spill Trustees. (2012). Cosco Busan Oil Spill Final Damage Assessment and Restoration Plan/Environmental Assessment. Prepared by California Department of Fish and Game, California State Lands Commission, National Oceanic and Atmospheric Administration, United States Fish and Wildlife Service, National Park Service, Bureau of Land Management.
Davis, C. V., Rivest, E. B., Hill, T. M., Gaylord, B., Russell, A. D., & Sanford, E. (2017). Ocean acidification compromises a planktic calcifier with implications for global carbon cycling. *Scientific reports*, 7(1), 2225. https://doi.org/10.1038/s41598-017-01530-9
Davis, M. W. (2002). Key principles for understanding fish bycatch discard mortality. *Canadian Journal of Fisheries and Aquatic Sciences*, *59*(11), 1834–1843. https://doi.org/10.1139/f02-139
Dettinger, M. (2011). Climate change, atmospheric rivers, and floods in California–a multimodel analysis of storm frequency and magnitude changes 1. JAWRA Journal of the American Water Resources Association, 47(3), 514-523. https://doi.org/10.1111/j.1752-1688.2011.00546.x
Di Lorenzo, E., & Mantua, N. (2016). Multi-year persistence of the 2014/15 North Pacific marine heatwave. *Nature Climate Change*, *6*(11), 1042-1047. https://doi.org/10.1038/nclimate3082
Doney, S. C., Fabry, V. J., Feely, R. A., & Kleypas, J. A. (2009). Ocean acidification: the other CO2 problem. *Annual review of marine science*, *1*, 169-192. https://doi.org/10.1146/annurev.marine.010908.163834
Donnelly-Greenan, E. L., Nevins, H. M., & Harvey, J. T. (2019). Entangled seabird and marine mammal reports from citizen science surveys from coastal California (1997–2017). *Marine Pollution Bulletin*, *149*, 110557. https://doi.org/https://doi.org/10.1016/j.marpolbul.2019.110557
Dransfield, A., Hines, E., McGowan, J., Holzman, B., Nur, N., Elliott, M., Howar, J., & Jahncke, J. (2014). Where the whales are: using habitat modeling to support changes in shipping regulations within National Marine Sanctuaries in Central California. Endangered Species Research, 26(1), 39-57. https://doi.org/10.3354/esr00627
Dueñas, MA., Ruffhead, H.J., Wakefield, N.H., Roberts, P.D., Hemming, D.J, & Diaz-Soltero, H. The role played by invasive species in interactions with endangered and threatened species in the United States: a systematic review. Biodiversity and Conservation 27, 3171–3183 (2018). https://doi.org/10.1007/s10531-018-1595-x.
Duarte, C. M., Middelburg, J. J., & Caraco, N. (2005). Major role of marine vegetation on the oceanic carbon cycle. Biogeosciences, 2(1), 1-8. https://doi.org/10.5194/bg-2-1-2005
Dugan, J. E., & Hubbard, D. M. (2010). Ecological effects of coastal armoring: a summary of recent results for exposed sandy beaches in southern California. In *Puget Sound Shorelines and the Impacts of Armoring. Proceedings of a State of the Science Workshop (Richland, Washington)* (pp. 187-194). https://www.researchgate.net/publication/228499136_Ecological_effects_of_coastal_armoring-
A_summary_of_recent_results_for_exposed_sandy_beaches_in_Southern_California
Dumbauld, B. R., Ruesink, J. L., & Rumrill, S. S. (2009). The ecological role of bivalve shellfish aquaculture in the estuarine environment: a review with application to oyster and clam culture in West Coast (USA) estuaries. *Aquaculture*, *290*(3-4), 196-223. https://doi.org/10.1016/j.aquaculture.2009.02.033

Elliott, M., Lipski, D., Roletto, J., Warzybok, P., & Jahncke, J. (2022a). *Ocean climate indicators status report: 2021*. Contribution No. 2422. Point Blue Conservation Science. http://www.accessoceans.org/wp-content/uploads/2022/09/Ocean_Climate_Indicators_Report_2021.pdf
Eisenlord, M.E., Groner, M.L., Yoshioka, R.M., Elliott, J., Maynard, J., Fradkin, S., Turner, M., Pyne, K., Rivlin, N., van Hooidonk, R., & Harvell, C.D. (2016). Ochre star mortality during the 2014 wasting disease epizootic: role of population size structure and temperature. Philosophical Transactions of the Royal Society B: Biological Sciences Volume 371, Issue 1689: 1-11. https://doi.org/10.1098/rstb.2015.0212
Erikson, L. H., Hegermiller, C. A., Barnard, P. L., Ruggiero, P., & van Ormondt, M. (2015). Projected wave conditions in the Eastern North Pacific under the influence of two CMIP5 climate scenarios. *Ocean Modelling*, 96, 171-185. https://doi.org/10.1016/j.ocemod.2015.07.004
Fiedler, P. C. (2002). Environmental change in the eastern tropical Pacific Ocean: review of ENSO and decadal variability. *Marine Ecology Progress Series*, *244*, 265-283. doi:10.3354/meps244265
Fisher, J. L., Peterson, W. T., & Rykaczewski, R. R. (2015). The impact of El Niño events on the pelagic food chain in the northern California Current. *Global Change Biology*, *21*(12), 4401-4414. https://doi.org/10.1111/gcb.13054
Frölicher, T. L., Fischer, E. M., & Gruber, N. (2018). Marine heatwaves under global warming. Nature, 560(7718), 360-364. https://doi.org/10.1038/s41586-018-0383-9
Funayama, K., Hines, E., Davis, J., & Allen, S. (2013). Effects of sea-level rise on northern elephant seal breeding habitat at Point Reyes Peninsula, California. Aquatic Conservation: Marine and Freshwater Ecosystems, 23(2), 233-245. https://doi.org/10.1002/aqc.2318
Fyfe, J.C., Derksen, C., Mudryk, L., Flato, G.M., Santer, B.D., Swart, N.C., Molotch, N.P., Zhang, X., Wan, H., Arora, V.K., Scinocca, J. and Jiao, Y. (2017). Large near-term projected snowpack loss over the western United States. *Nature communications*, *8*(1), 14996. https://doi.org/10.1038/ncomms14996
García-Reyes, M., & Largier, J. (2010). Observations of increased wind-driven coastal upwelling off central California. Journal of Geophysical Research: Oceans, 115(C4), C04011. https://doi.org/10.1029/2009JC005576
Gentemann, C. L., Fewings, M. R., and García-Reyes, M. (2017). Satellite sea surface temperatures along the West Coast of the United States during the 2014–2016 northeast Pacific marine heat wave. Geophys. Res. Lett. 44, 312–319. doi: 10.1002/2016gl071039
Gobler, C.J. (2020). Climate Change and Harmful Algal Blooms: Insights and perspective. Harmful Algae Volume 91, 101731, ISSN 1568-9883. https://doi.org/10.1016/j.hal.2019.101731.
Gómez, C. E., Wickes, L., Deegan, D., Etnoyer, P. J., & Cordes, E. E. (2018). Growth and feeding of deep-sea coral Lophelia pertusa from the California margin under simulated ocean acidification conditions. PeerJ, 6, e5671. https://doi.org/10.7717/peerj.5671
Graham, N. E., & Diaz, H. F. (2001). Evidence for intensification of North Pacific winter cyclones since 1948. Bulletin of the American Meteorological Society, 82(9), 1869-1894. https://doi.org/10.1175/1520-0477(2001)082%3C1869:EFIONP%3E2.3.CO;2
Griffith, A.W. & Gobler, C.J. (2019). Harmful algal blooms: A climate change co-stressor in marine and freshwater ecosystems. Harmful Algae, Volume 91, 2020, 101590, ISSN 1568-9883, https://doi.org/10.1016/j.hal.2019.03.008.
Griggs, G.B., (2010). The effects of armoring shorelines—The California experience, in Shipman, H., Dethier, M.N., Gelfenbaum, G., Fresh, K.L., and Dinicola, R.S., eds., 2010, Puget Sound Shorelines and the Impacts of Armoring— Proceedings of a State of the

Science Workshop, May 2009: U.S. Geological Survey Scientific Investigations Report 2010-5254, p. 77-84. https://pubs.usgs.gov/sir/2010/5254/pdf/sir20105254.pdf
Grosholz, E. (2002). Ecological and evolutionary consequences of coastal invasions. *Trends in Ecology & Evolution*, *17*(1), 22–27. https://doi.org/https://doi.org/10.1016/S0169-5347(01)02358-8
Grosholz E., Ashton G., Bradley M., Brown C., Ceballos-Osuna L., Chang A., de Rivera, C., Gonzalez, J., Heineke, M., Marraffini, M., McCann, L., Pollard, E., Pritchard, I., Ruiz, G., Turner, B., and Tepolt, C. Stage-specific overcompensation, the hydra effect, and the failure to eradicate an invasive predator. *Proceedings of the National Academy of Sciences*, *118*(12), e2003955118.
Gruber et al. (2012). Rapid progression of ocean acidification in the California Current System. Science. https://doi.org/10.1073/pnas.2003955118
Gulland, Frances M.D., Jason D. Baker, Marian Howe, Erin LaBrecque, Lauri Leach, Sue E. Moore, Randall R. Reeves, Peter O. Thomas. A review of climate change effects on marine mammals in United States waters: Past predictions, observed impacts, current research and conservation imperatives. Climate Change Ecology, Volume 3, (2022), 100054, ISSN 2666-9005. https://doi.org/10.1016/j.ecochg.2022.100054.
Hales, B., T. Takahashi, and L. Bandstra. (2005). Atmospheric CO2 uptake by a coastal upwelling system. Global Biogeochemical Cycles, 19: 1-11. https://doi.org/10.1029/2004GB002295
Hall–Spencer J., A. Valerie and F. Jan Helge. (2002). Trawling damage to Northeast Atlantic ancient coral reefs. Proc. R. Soc. Lond. B. 269507–511. https://doi.org/10.1098/rspb.2001.1910
Hamilton, S.L., Logan, C.A., Fennie, H.W., Sogard, S.M., Barry, J.P., Makukhov, A.D., Tobosa, L.R., Boyer, K., Lovera, C.F. and Bernardi, G. (2017). Species-specific responses of juvenile rockfish to elevated p CO2: from behavior to genomics. *PLoS One*, *12*(1), e0169670. https://doi.org/10.1371/journal.pone.0169670
Hammerschlag, N, Schmitz, O.J., Flecker, A.S., Lafferty, K.D., Sih, A., Atwood, T.B., Gallagher, A.J., Irschick, D.J., Skubel, R., and Cooke, S.J. (2019). Ecosystem function and services of aquatic predators in the Anthropocene. *Trends in ecology & evolution*, *34*(4), 369-383. https://doi.org/10.1016/j.tree.2019.01.005
Heifetz J., Stone R.P., Shotwell S.K. (2009). Damage and disturbance to coral and sponge habitat of the Aleutian Archipelago. Mar Ecol Prog Ser 397:295-303. https://doi.org/10.3354/meps08304
Hobday, A.J., Alexander, L.V., Perkins, S.E., Smale, D.A., Straub, S.C., Oliver, E.C.J., Benthuysen, J.A., Burrows, M.T., Donat, M.G., Feng, M., Holbrook, N.J., Moore, P.J., Scannell, H.A., Sen Gupta, A., Wernberg, T. (2016). A hierarchical approach to defining marine heatwaves. Progress in Oceanography, 141: 227-238. ISSN 0079-6611. https://doi.org/10.1016/j.pocean.2015.12.014.
Hodgson, E.E., Kaplan, I.C., Marshall, K.N., Leonard, J., Essington, T.E., Busch, D.S., Fulton, E.A., Harvey, C.J., Hermann, A.J., and McElhany, P. (2018). Consequences of spatially variable ocean acidification in the California Current: Lower pH drives strongest declines in benthic species in southern regions while greatest economic impacts occur in northern regions. *Ecological modelling*, *383*, 106-117. https://doi.org/10.1016/j.ecolmodel.2018.05.018
Hutto, S.V., K.D. Higgason, J.M. Kershner, W.A. Reynier, D.S. Gregg. (2015). Climate Change Vulnerability Assessment for the North-central California Coast and Ocean. Marine Sanctuaries Conservation Series ONMS-15-02. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD. 473 pp. https://repository.library.noaa.gov/view/noaa/13953

Intergovernmental Panel on Climate Change (2019). Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley (Eds.). https://www.ipcc.ch/site/assets/uploads/2019/11/SRCCL-Full-Report-Compiled-191128.pdf

Jacox, M. G., Hazen, E. L., Zaba, K. D., Rudnick, D. L., Edwards, C. A., Moore, A. M., & Bograd, S. J. (2016). Impacts of the 2015–2016 El Niño on the California Current System: Early assessment and comparison to past events. Geophysical Research Letters, 43(13), 7072–7080. https://doi.org/10.1002/2016GL069716

Jennings, S., & Kaiser, M. J. (1998). The effects of fishing on marine ecosystems. In Advances in marine biology (Vol. 34, pp. 201-352). Academic Press. https://doi.org/10.1016/S0065-2881(08)60212-6

Johnstone, J. A., & Mantua, N. J. (2014). Atmospheric controls on northeast Pacific temperature variability and change, 1900–2012. Proceedings of the National Academy of Sciences of the United States of America, 111(40), 14360–14365. https://doi.org/10.1073/pnas.1318371111

Kaiser, M. J., Clarke, K. R., Hinz, H., Austen, M. C., Somerfield, P. J., & Karakassis, I. (2006). Global analysis of response and recovery of benthic biota to fishing. Marine Ecology Progress Series 311: 1-14. doi:10.3354/meps311001

Kelly, J. J., Orr, D., & Takekawa, J. Y. (2019). Quantification of damage to eelgrass (Zostera marina) beds and evidence-based management strategies for boats anchoring in San Francisco Bay. Environmental management, 64(1), 20-26. https://doi.org/10.1007/s00267-019-01169-4

Kelly, J. P., Evens, J. G., Stallcup, R. W., & Wimpfheimer, D. A. V. I. D. (1996). Effects of aquaculture on habitat use by wintering shorebirds in Tomales Bay, California. *California Fish and Game*, *82*(4), 160-174.

Kingsley, S. (2016). Environmental Reviews and Case Studies: Impacts on Maritime Cultural Resources: Assessing the Invisible. Environmental Practice, 18(3), 184-191. doi:10.1017/S1466046616000284

Kummerlowe, D.; Jackson, D., Fox, J., & Moulton, M. (1996). Guidelines for Determining Oil Spill Volume in the Field: Terminology, Ranges, Estimates and Experts. CADRE, Inc. for Washington State Department of Ecology. Publication No. 96**–**250. 196 pps. https://apps.ecology.wa.gov/publications/documents/96250.pdf

L'Heureux, M. (2014). What is the El Niño–Southern Oscillation (ENSO) in a nutshell? NOAA Climate.gov. https://www.climate.gov/news-features/blogs/enso/what-el-ni%C3%B1o%E2%80%93southern-oscillation-enso-nutshell

Laist, D. W., Knowlton, A. R., Mead, J. G., Collet, A. S., & Podesta, M. (2001). Collisions between ships and whales. Marine Mammal Science, 17(1), 35-75. https://doi.org/10.1111/j.1748-7692.2001.tb00980.x

Largier, J. L., Cheng, B. S., & Higgason, K. D. (Eds.). (2010). Climate change impacts: Gulf of the Farallones and Cordell Bank National Marine Sanctuaries. Report of a Joint Working Group of the Gulf of the Farallones and Cordell Bank National Marine Sanctuaries Advisory Councils. Marine Sanctuaries Conservation Series ONMS-11-04. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries. https://nmssanctuaries.blob.core.windows.net/sanctuaries-prod/media/archive/science/conservation/pdfs/gf_cbnms_climate_report.pdf

Leeworthy, V., & Schwarzmann, D. 2015. Economic Impact of the Recreational Fisheries on Local County Economies in California's National Marine Sanctuary 2010, 2011 and 2012. Marine Sanctuaries Conservation Series ONMS-2015-07. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries.
https://sanctuaries.noaa.gov/science/socioeconomic/pdfs/california_rec_sanctuaries.pdf
Leising, A., Schroeder, I., Bograd, S., Abell, J., Durazo, R., Gaxiola-Castro, G., Bjorkstedt, E., Field, J., Sakuma, K., Robertson, R., Goericke, R., Peterson, W., Brodeur, R., Barceló, C., Auth, T., Daly, E., Suryan, R., Gladics, A., Porquez, J., McClatchie, S., Weber, E., Watson, W., Santora, J., Sydeman, W., Melin, S., Chavez, F., Golightly, R., Schneider, S., Fisher, J., Morgan, C., Bradley, R., & Warybok, P. (2015). State of the California Current 2014-15: Impacts of the Warm-Water" Blob". *California Cooperative Oceanic Fisheries Investigations Reports*, *56*.
https://ir.library.oregonstate.edu/concern/articles/h989r499g
Limber, P. W., & Barnard, P. L. (2018). Coastal knickpoints and the competition between fluvial and wave-driven erosion on rocky coastlines. *Geomorphology*, *306*, 1-12. https://doi.org/10.1016/j.geomorph.2017.12.035
Lindquist, K., & Roletto, J. (2022b). *Beach Watch database* [Data set]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of National Marine Sanctuaries, Greater Farallones National Marine Sanctuary & Greater Farallones Association.
https://bwonline.beachwat.ch/BeachWatchData.php
Long, M. C., Deutsch, C., & Ito, T. (2016). Finding forced trends in oceanic oxygen. *Global Biogeochemical Cycles*, *30*(2), 381-397. https://doi.org/10.1002/2015GB005310
Luckenbach Trustee Council. (2006). S.S. Jacob Luckenbach and Associated Mystery Oil
Spills Final Damage Assessment and Restoration Plan/Environmental Assessment. Prepared by California Department of Fish and Game, National Oceanic and Atmospheric Administration, United States Fish and Wildlife Service, National Park Service. https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=1c6a76e202bbe79bd3125a64b43d3ea89ffa6896
Klos, P. Z., Link, T. E., & Abatzoglou, J. T. (2014). Extent of the rain-snow transition zone in the western US under historic and projected climate. *Geophysical Research Letters*, 41(13), 4560-4568. https://doi.org/10.1002/2014GL060500
Koslow, J. A., Goericke, R., Lara-Lopez, A., & Watson, W. (2011). Impact of declining intermediate-water oxygen on deepwater fishes in the California Current. *Marine Ecology Progress Series*, *436*, 207-218. https://doi.org/10.3354/meps09270
Marshall, K.N., Kaplan, I.C., Hodgson, E.E., Hermann, A., Busch, D.S., McElhany, P., Essington, T.E., Harvey, C.J. and Fulton, E.A. (2017). Risks of ocean acidification in the California Current food web and fisheries: ecosystem model projections. *Global Change Biology*, *23*(4), 1525-1539. https://doi.org/10.1111/gcb.13594
McCabe, R.M., Hickey, B.M., Kudela, R.M., Lefebvre, K.A., Adams, N.G., Bill, B.D., Gulland, F.M., Thomson, R.E., Cochlan, W.P. and Trainer, V.L. (2016). An unprecedented coastwide toxic algal bloom linked to anomalous ocean conditions. *Geophysical Research Letters*, *43*(19), 10-366. https://doi.org/10.1002/2016GL070023
McGowan, J. A., Cayan, D. R., & Dorman, L. M. (1998). Climate-ocean variability and ecosystem response in the Northeast Pacific. *Science*, *281*(5374), 210-217. https://doi.org/10.1126/science.281.5374.210
McKenna, M. F., Calambokidis, J., Oleson, E. M., Laist, D. W., & Goldbogen, J. A. (2015). Simultaneous tracking of blue whales and large ships demonstrates limited

behavioral responses for avoiding collision. *Endangered Species Research, 27*(3), 219-232. https://doi.org/10.3354/esr00666

McKenna, M. F., Wiggins, S. M., & Hildebrand, J. A. (2013). Relationship between container ship underwater noise levels and ship design, operational and oceanographic conditions. *Scientific Reports*, *3*(1), 1760. https://doi.org/10.1038/srep01760

McLaskey, A. K., Keister, J. E., McElhany, P., Olson, M. B., Busch, D. S., Maher, M., & Winans, A. K. (2016). Development of Euphausia pacifica (krill) larvae is impaired under pCO2 levels currently observed in the Northeast Pacific. *Marine Ecology Progress Series*, *555*, 65-78. https://doi.org/10.3354/meps11839

McKibben, S. M., Peterson, W., Wood, A. M., Trainer, V. L., Hunter, M., & White, A. E. (2017). Climatic regulation of the neurotoxin domoic acid. Proceedings of the National Academy of Sciences, 114(2), 239-244. https://doi.org/10.1073/pnas.1606798114

McKindsey, C. W., Anderson, M. R., Barnes, P., Courtenay, S., Landry, T., & Skinner, M. (2006). *Effects of shellfish aquaculture on fish habitat*. Fisheries and Oceans. https://www.protectourshoreline.org/articles/16CanadaAquacultureFishHabitatNov2006.pdf

Melius, M. L., & Caldwell, M. R. (2015). California coastal armoring report: Managing coastal armoring and climate change adaptation in the 21st century. *Environment and Natural Resources Law & Policy Program Working Paper*. https://coastalcare.org/2015/05/california-coastal-armoring-report-managing-coastal-armoring-and-climate-change-adaptation-in-the-21st-century/

Meyer-Kaiser, K. S., Mires, C. H., Kovacs, M., Kovacs, E., & Haskell, B. (2022). Structural factors driving benthic invertebrate community structure on historical shipwrecks in a large North Atlantic marine sanctuary. *Marine Pollution Bulletin*, *178*, 113622. https://doi.org/https://doi.org/10.1016/j.marpolbul.2022.113622

Möller, I., Kudella, M., Rupprecht, F., Spencer, T., Paul, M., Van Wesenbeeck, B.K., Wolters, G., Jensen, K., Bouma, T.J., Miranda-Lange, M. and Schimmels, S. (2014). Wave attenuation over coastal salt marshes under storm surge conditions. *Nature Geoscience*, *7*(10), 727-731. https://doi.org/10.1038/ngeo2251

Moore, E., Lyday, S., Roletto, J., Litle, K., Parrish, J. K., Nevins, H., Harvey, J., Mortenson, J., Greig, D., Piazza, M., Hermance, A., Lee, D., Adams, D., Allen, & Kell, S. (2009). Entanglements of marine mammals and seabirds in central California and the north-west coast of the United States 2001–2005. Marine pollution bulletin, 58(7), 1045-1051. https://doi.org/10.1016/j.marpolbul.2009.02.006

Munday, P., Leis, J., Lough, J., Kingsford, M., Berumen, M., Lambrechts, J. (2009). Climate change and coral reef connectivity. Coral Reefs. 28. 379-395. https://doi.org/10.1007/s00338-008-0461-9

National Research Council. (2002). Effects of trawling and dredging on seafloor habitat. Washington, DC: National Academy Press. https://nap.nationalacademies.org/catalog/10323/effects-of-trawling-and-dredging-on-seafloor-habitat

NOAA. (2021) What is marine debris? National Ocean Service website, https://oceanservice.noaa.gov/facts/marinedebris.html, 1/04/21

NOAA. (2022). Mean sea level trend: 9414290 San Francisco, California. National Oceanic and Atmospheric Administration (NOAA), National Ocean Service. https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?id=9414290

NOAA. (2023). National Centers for Environmental Information. Accessed in March 2023. https://www.ncei.noaa.gov/news/ocean-heat-content-rises#:~:text=The%20ocean%20absorbs%20excess%20heat,attributed%20to%20greenhouse%20gas%20emissions

NOAA Fisheries. (2020). West Coast large whale entanglement response program. https://www.fisheries.noaa.gov/west-coast/marine-mammal-protection/west-coast-large-whaleentanglement-response-program
NOAA, Office of National Marine Sanctuaries. (2014). Cordell Bank and Gulf of the Farallones National Marine Sanctuaries Expansion Final Environmental Impact Statement. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries. Silver Spring, MD.
NOAA. (2016). How much oil is on that ship? NOAA Office of Restoration and Response. https://response.restoration.noaa.gov/about/media/how-much-oil-ship.html
NOAA, Office of National Marine Sanctuaries (ONMS). (2020a). Climate Change Impacts: Greater Farallones National Marine Sanctuary.
NOAA, Office of National Marine Sanctuaries (ONMS). (2020b). Climate Change and Ocean Acidification.
NOAA Fisheries. (2020). West Coast large whale entanglement response program. https://www.fisheries.noaa.gov/west-coast/marine-mammal-protection/west-coast-large-whaleentanglement-response-program
NOAA, Office of National Marine Sanctuaries. (2023). Fishing Impacts. https://sanctuaries.noaa.gov/science/sentinel-site-program/fishing-impacts.html.
NOAA Marine Debris Program. (2015). Report on the impacts of “ghost fishing” via derelict fishing gear. https://marinedebris.noaa.gov/sites/default/files/publications-files/Ghostfishing_DFG.pdf
Office for Coastal Management (OCM). (2022). Nationwide Automatic Identification System 2016-2020. https://marinecadastre.gov/ais/.
Osborne, E. B., Thunell, R. C., Gruber, N., Feely, R. A., & Benitez-Nelson, C. R. (2020). Decadal variability in twentieth-century ocean acidification in the California Current Ecosystem. *Nature Geoscience*, *13*(1), 43-49. https://doi.org/10.1038/s41561-019-0499-z
Pederson, G.T., Gray, S.T., Woodhouse, C.A., Betancourt, J.L., Fagre, D.B., Littell, J.S., Watson, E., Luckman, B.H. and Graumlich, L.J. (2011). The unusual nature of recent snowpack declines in the North American Cordillera. *science*, *333*(6040), 332-335. https://doi.org/10.1126/science.1201570
Piatt, J.F., Parrish, J.K., Renner, H.M., Schoen, S., Arimitsu, M., Bodenstein, B., Burgess, H., Coletti, H., Corcoran, R., Duerr, R., García-Reyes, M., Golightly, R., Jahncke, J., Jones, T., Kaler, R., Kuletz, K., Lindquist, K., McChesney, G., Lindsey, J., Roletto, J., Suryan, R., Sydeman, W., & Warzybok, P.(16) (2020). Extreme mortality and reproductive failure of common murres resulting from the northeast Pacific marine heatwave of 2014-2016.PLoS ONE 15(1): e0226087. https://doi.org/10.1371/journal.pone.0226087
Poloczanska, E.S., Brown, C.J., Sydeman, W.J., Kiessling, W., Schoeman, D.S., Moore, P.J., Brander, K., Bruno, J.F., Buckley, L.B., Burrows, M.T. and Duarte, C.M. (2013). Global imprint of climate change on marine life. *Nature Climate Change*, *3*(10), 919-925. https://doi.org/10.1038/nclimate1958
Pozo Buil, M., Jacox, M.G., Fiechter, J., Alexander, M.A., Bograd, S.J., Curchitser, E.N., Edwards, C.A., Rykaczewski, R.R. and Stock, C.A. (2021). A dynamically downscaled ensemble of future projections for the California current system. *Frontiers in Marine Science*, *8*, 612874. https://doi.org/10.3389/fmars.2021.612874
Prouty, N. G., Fisher, C. R., Demopoulos, A. W., & Druffel, E. R. (2016). Growth rates and ages of deep-sea corals impacted by the Deepwater Horizon oil spill. *Deep Sea Research Part II: Topical Studies in Oceanography*, *129*, 196-212. https://doi.org/10.1016/j.dsr2.2014.10.021

Reyna, K., Hobi, P, Kordesch, W. (2021). 2020-2030 Seabird Protection Network Action Plan. Greater Farallones National Marine Sanctuary. https://seabirdprotectionnetwork.org/wp-content/uploads/2023/02/Draft-Bodega-Head-to-Point-Sur-Action-Plan.pdf
Rockman, M., Morgan, M., Ziaja, S., Hambrecht, G. & Meadow, A. (2016). *Cultural Resources Climate Change Strategy*. Cultural Resources, Partnerships, and Science and Climate Change Response Program, National Park Service, US Department of the Interior. https://www.nps.gov/subjects/climatechange/upload/NPS-2016_Cultural-Resoures-Climate-Change-Strategy.pdf
Rockwood, R.C., Calambokidis, J., & Jahncke, J. (2017) High mortality of blue, humpback and fin whales from modeling of vessel collisions on the U.S. West Coast suggests population impacts and insufficient protection. PLoS ONE 12(8): e0183052. https://doi.org/10.1371/journal.pone.0183052
Rockwood, R.C., Elliott, M.L., Saenz, B., Nur, N., & Jahncke J (2020a). Modeling predator and prey hotspots: Management implications of baleen whale co-occurrence with krill in Central California. PLoS ONE 15(7): e0235603. https://doi.org/10.1371/journal.pone.0235603
Rockwood, R.C., Adams, J., Silber, G., Jahncke, J. (2020b). Estimating effectiveness of speed reduction measures for decreasing whale-strike mortality in a high-risk region. Endangered Species Research 43:145-166. https://doi.org/10.3354/esr01056
Roemmich, D., & McGowan, J. (1995). Climatic warming and the decline of zooplankton in the California Current. *Science*, *267*(5202), 1324-1326. https://doi.org/10.1126/science.267.5202.1324
Sanford, E., Sones, J. L., García-Reyes, M., Goddard, J. H., & Largier, J. L. (2019). Widespread shifts in the coastal biota of northern California during the 2014–2016 marine heatwaves. *Scientific reports*, *9*(1), 4216. https://doi.org/10.1038/s41598-019-40784-3
Santora, J.A., Mantua, N.J., Schroeder, I.D. et al. (2020). Habitat compression and ecosystem shifts as potential links between marine heatwave and record whale entanglements. Nat Commun 11, 536. https://doi.org/10.1038/s41467-019-14215-w
Scholz, A., Steinbeck, C., Klain, S., & Boone, A. (2004). Socioeconomic profile of fishing communities associated with the Gulf of the Farallones and Cordell Bank National Marine Sanctuaries. Administrative Report to NOAA, Office of National Marine Sanctuaries, San Francisco, CA. pp122. Electronic document available from: http://archive.ecotrust.org/jmpr/JMPRsocioeco_final.pdf
Shepard, C. C., Crain, C. M., & Beck, M. W. (2011). The protective role of coastal marshes: a systematic review and meta-analysis. *PloS one*, 6(11), e27374. https://doi.org/10.1371/journal.pone.0027374
Slangen, A. B. A., Carson, M., Katsman, C. A., Van de Wal, R. S. W., Köhl, A., Vermeersen, L. L. A., & Stammer, D. (2014). Projecting twenty-first century regional sea-level changes. Climatic Change, 124, 317-332. https://doi.org/10.1007/s10584-014-1080-9
Stone, R. P. (2006). Coral habitat in the Aleutian Islands of Alaska: depth distribution, fine-scale species associations, and fisheries interactions. *Coral Reefs*, *25*(2), 229–238. https://doi.org/10.1007/s00338-006-0091-z
Stone, R. P., Masuda, M. M., & Karinen, J. F. (2015). Assessing the ecological importance of red tree coral thickets in the eastern Gulf of Alaska. *ICES Journal of Marine Science*, *72*(3), 900–915. https://doi.org/10.1093/icesjms/fsu190
Swain, D. L., Langenbrunner, B., Neelin, J. D., & Hall, A. (2018). Increasing precipitation volatility in twenty-first-century California. Nature Climate Change, 8(5), 427-433. https://doi.org/10.1038/s41558-018-0140-y

Sweet, W.V., Hamlington, B.D., Kopp, R.E., Weaver, C.P., Barnard, P.L., Bekaert, D., Brooks, W., Craghan, M., Dusek, G., Frederikse, T. and Garner, G. (2022). *Global and regional sea level rise scenarios for the United States: Updated mean projections and extreme water level probabilities along US coastlines*. NOAA Technical Report NOS 01. National Oceanic and Atmospheric Administration, National Ocean Service, Silver Spring, MD, 111 pp. https://oceanservice.noaa.gov/hazards/sealevelrise/noaa-nostechrpt01-global-regional-SLR-scenarios-US.pdf

Sydeman, W. J., García-Reyes, M., Schoeman, D. S., Rykaczewski, R. R., Thompson, S. A., Black, B. A., & Bograd, S. J. (2014). Climate change and wind intensification in coastal upwelling ecosystems. *Science*, *345*(6192), 77-80. https://doi.org/10.1126/science.1251635

Stoskopf, M.K. (2018). Bacterial Diseases of Marine Mammals. In: Line S, Moses MA, editors. The Merck veterinary manual. Kenilworth, NJ. https://www.merckvetmanual.com/exotic-and-laboratoryanimals/marine-mammals/bacterial-diseases-of-marinemammals. https://www.msdvetmanual.com/exotic-and-laboratory-animals/marinemammals/ bacterial-diseases-of-marine-mammals

Sun, F., Berg, N., Hall, A., Schwartz, M., & Walton, D. (2019). Understanding end-of-century snowpack changes over California's Sierra Nevada. Geophysical Research Letters, 46(2), 933-943. https://doi.org/10.1029/2018GL080362

Thorne, K., MacDonald, G., Guntenspergen, G., Ambrose, R., Buffington, K., Dugger, B., Freeman, C., Janousek, C., Brown, L., Rosencranz, J. and Holmquist, J., Smol, J., Hargan, K., & Takekawa, J. (2018). US Pacific coastal wetland resilience and vulnerability to sea-level rise. *Science Advances*, *4*(2). DOI:10.1126/sciadv.aao3270

Tuuri, E. M., & Leterme, S. C. (2023). How plastic debris and associated chemicals impact the marine food web: A review. *Environmental Pollution*, 121156. https://doi.org/10.1016/j.envpol.2023.121156

U.S. Global Change Research Program (USGCRP). (2018) *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* ([Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 1515 pp. doi: 10.7930/NCA4.2018.

Wehner, M.F., Arnold, J.R., Knutson, T., Kunkel, K.E., and LeGrande, A.N. (2017). Droughts, floods, and wildfires. In: Climate Science Special Report: Fourth National Climate Assessment, Volume I [Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 231-256. doi: 10.7930/J0CJ8BNN. https://science2017.globalchange.gov/downloads/CSSR_Ch8_Drought_Floods_and_Wildfires.pdf

Weston, N. B. (2014). Declining sediments and rising seas: an unfortunate convergence for tidal wetlands. *Estuaries and Coasts*, *37*(1), 1-23. https://doi.org/10.1007/s12237-013-9654-8

Xiu, P., Chai, F., Curchitser, E. N., & Castruccio, F. S. (2018). Future changes in coastal upwelling ecosystems with global warming: The case of the California Current System. *Scientific reports*, *8*(1), 2866. https://doi.org/10.1038/s41598-018-21247-7

Status and Trends of Drivers and Pressures 1
Status and Trends of Drivers (Question 1) 2
Question 1: What are the states of influential human drivers & how are they changing? 2
Status and Trends of Pressures (Questions 2–5) 3
Question 2. What are the levels of human activities that may adversely influence water quality and how are they changing? 3
Coastal and Offshore Region (Q2) 3
Estuarine and Lagoon Region (Q2) 59
Question 3: What are the levels of human activities that may adversely influence habitats and how are they changing? 20
Coastal and Offshore Region (Q3) 20
Estuarine and Lagoon Region (Q3) 35
Question 4: What are the levels of human activities that may adversely influence living resources and how are they changing? 38
Coastal and Offshore Region (Q4) 38
Estuarine and Lagoon Region (Q4) 52
Question 5: What are the levels of human activities that may adversely affect maritime heritage resources and how are they changing? 59
Coastal and Offshore Region (Q5) 59
Estuarine and Lagoon Region (Q5) 65

Status and Trends of Drivers and Pressures

This section answers questions related specifically to the drivers and pressures discussed in the previous chapter~~above~~. Drivers, or driving forces, are the socio-economic and socio-cultural forces driving human activities, which increase or mitigate pressures on the environment. Pressures are the stresses that human activities place on the environment. The effect of pressures on the status and trends of sanctuary resources are addressed in the following section.

Two virtual expert workshops were convened on May 17 and July 11, 2022 to discuss and determine status and trend ratings in response to a series of standard condition report questions related to human activities occurring in the sanctuary (see Appendix A and Appendix C). It is important to note that, in general, the assessments of the status and trends of key indicators in GFNMS are for the period from 2010–2021. During the virtual workshops, indicators for each topic were presented, accompanied by datasets ONMS had collected prior to the meeting. Attendees were then asked to review the indicators and datasets, identify data gaps or misrepresentations, and suggest any additional datasets that may be relevant. Once all datasets were reviewed, experts were asked to provide status and trend recommendations and supporting arguments. After assigning status and trend ratings, experts were asked to assign a level of confidence for each value by: (1) characterizing the sources of information they used to

make judgments; and (2) their agreement with the selected status and trend ratings. The evidence and agreement ratings were then combined to determine the overall confidence ratings. Appendix C provides a detailed description of the methods used to develop this report.

The following responses for each question summarize the key indicators, supporting data sets, and rationale for each status and trend rating. Where published or additional information exists, the reader is provided with appropriate references. Workshop discussions and ratings were based on data available at the time (e.g., through May or July 2022). However, in some instances, sanctuary staff later reevaluated and/or incorporated newly available data in order to more accurately describe the current status and trends of resources. Situations where post-workshop rating decisions were made and/or data were used by sanctuary staff to support a rating, but were not presented or discussed during the workshop, are noted in the text.

Commented [1]: a precedent for this, though a different context: https://doi.org/10.1016/j.ocecoaman.2020.105431

Status and Trends of Drivers (Question 1)

Question 1: What are the states of influential human drivers and how are they changing?

Status Rating: Not Rated	Status Confidence:
Trend Rating: Not Rated	Trend Confidence:
Status Description:	
Rationale: ONMS and GFNMS staff decided not to rate the status and trend of influential human drivers at GFNMS. The primary purposes for rating the status and trends of resources are to use condition reports to assess program effectiveness and to influence management of human activities and certain natural resource actions. For the most part, drivers are not manageable, at least not under the authority of the National Marine Sanctuaries Act, nor do most of them originate at scales relevant to national marine sanctuary management. While understanding them is important, rating them is not necessary to achieve the goals of the condition report.	

Commented [2]: agreed...main drivers seem beyond ratings, more appropriate for the pressures. Do other sites rate drivers?

The primary drivers influencing pressures on GFNMS resources were previously described in the Drivers section of this report. Drivers are the societal values, policies, and socioeconomic factors that influence human pressures on marine ecosystems. Understanding drivers helps to explain the origins of pressures on resources and potentially anticipate future trends for those pressures but are not typically manageable by the sanctuary. Drivers include economic factors, such as income and spending; policies and legal frameworks; demographics, like population levels and urbanization; and societal values, such as levels of conservation/stewardship awareness, political leanings, or changing opinions about the acceptability of specific behaviors (e.g., littering). All influence pressures on resources by changing the ways that humans interact with the marine environment. Pressures are typically manageable by the sanctuary, thus status and trend ratings for pressures (i.e., human activities) and their potential effects on sanctuary resources have been determined and are described in Questions 2–5.

Status and Trends of Pressures (Questions 2–5)

Human activities that adversely impact water quality are the focus of Question 2. These include vessel transits and use of the sanctuary, including cruise ship transits, dredge material barge transits, and oil release incidents associated with vessels; coastal development; and agriculture and other types of land use.

Commented [3]: would include I assume water treatment, outfalls, street runoff...

Question 3 covers human activities that may adversely influence habitats. Some human activities may have structural and non-structural impacts to habitats. For example, commercial fishing activities that physically disrupt the seafloor (e.g., trawling, lost gear) may result in structural impacts to seafloor habitats. Non-structural impacts could include oil spills, anthropogenic sounds, and climate change. For this question, we focus on structural impacts to habitats.

Human activities that have the potential to negatively impact living resources are the focus of Question 4. These include activities that remove plants or animals, as well as activities that have the potential to injure or degrade the condition of living resources.

Activities that influence maritime heritage resource quality are the subject of Question 5. These include activities that diminish resource quality through intentional or inadvertent destruction of maritime heritage resources. Importantly, and unlike most natural resources, maritime archaeological resources are non-renewable. Once degraded or destroyed, their archaeological value is lost forever.

Human activities that influence climate change at a global scale (e.g., those that produce greenhouse gasses) are not discussed in this report. National marine sanctuaries are not charged with controlling this and other issues (e.g., plastic pollution) at such large scales, and therefore do not regulate or otherwise control the activities that cause them, at least not for the purpose of reducing their global impact. ONMS does recognize, however, that some activities in national marine sanctuaries contribute to climate change (e.g., vessel traffic).

Because of the considerable differences in environmental pressures and responses between the coastal and offshore region and the estuarine and lagoon region, each question is assessed twice in order to represent these two environment types separately.

Question 2. What are the levels of human activities that may adversely influence water quality and how are they changing?

Coastal and Offshore Region (Q2)

Status Rating: Fair	Status Confidence: Medium
Trend Rating: Mixed	Trend Confidence: High

Status Description: The status of human activities that may adversely influence water quality suggests measurable but not severe degradation in some attributes of ecological integrity.
Rationale: Consideration of both land and sea-based activities that pose threats to water quality indicate a mix of increasing and decreasing threats. While the number of transits by large commercial shipping vessels remained consistent throughout the study period, the distance transited through the sanctuary decreased. Cruise ships reported illegal discharges in the sanctuary during the study period. However, there was a decrease in the number of discharge incidents and volume discharged from barges transporting dredged materials, as well as a decrease in the number of large oil spills. Lastly, there was a minor increase in land use along the coast in recent years.

Findings From the 2010 Condition Report

A direct comparison of status and trends to the 2010 condition report is not possible because the sanctuary expanded in 2015, during the time period for this assessment. The expansion added new areas and habitats that were not assessed in the 2010 condition report. In the 2010 condition report, the status for this question in the coastal and offshore region was good/fair and the trend was not changing. Ratings were based on observations of few harmful algal blooms, continued nonpoint source discharges from San Francisco Bay and Russian River, new coastal Clean Water Action 303(d) listings for various pollutants, decreased oil pollution, and decreased sediment spills from barges.

New Information in the 2010–2022 Condition Report

Human activities used to evaluate this question included vessel traffic, known discharges from cruise ships and dredge barges, oil spills, and changes in land use. Because discharges from vessels impact water quality but are likely underreported and challenging to track, vessel traffic data since 2016 from the automatic identification system (AIS) were used as a proxy for the potential for discharges (Table S.P.2.1).

Table S.P.2.1. Summaries for the key indicators related to human activities that impact water quality in the coastal and offshore region that were discussed during the July 11, 2022 virtual status and trends workshop.

Indicator	Source	Data Summary	Figure
Vessel Traffic	BOEM et al., 2022	Status: Cargo vessels were the most documented vessels in terms of distance traveled, percent of traffic and number of transits. Trend: Globally cargo vessels have been getting larger over the study period. Distances traveled within the sanctuary decreased during this study period.	Figure S.P.2.1
Cruise Ship Discharges	Blank Rome LLP, 2017	Status: During this study period, annually 100 cruise ships entered the sanctuary each year, except during the pandemic. From 2015 through 2017, there were 190 incidents discharging 8,502,138 gallons of prohibited discharges, in the region, 95% of which was within GFNMS.	

		Trend: Since 2017, there have been no reports of cruise ship discharges.	
Dredge Material Discharges	Etrac, 2022	Status: A small number of dredged material leaks occurred from barges transiting through the sanctuary since 2010,From 2017–2021 there were 15 leaks with a total discharge of 21.5 cubic yards Trend: There was a significant decrease since 2010 in both the number of discharge incidents and total volume of discharge.	
Oil Release Events	GFNMS, 2022; USCG MISLE, 2022	Status: Oil spills from smaller vessels (20–100ft) were a chronic issue throughout the southern portion of GFNMS with an average of 6.8 incidents per year. Trend: Improving: no large ship (>300 gross tons) spills occurred since the 2010 condition report.	S.P.2.2
Agriculture and Developed Land Use	Dewitz & U.S. Geological Survey, 2021	Status: Land use in the areas surrounding GFNMS includes natural habitat, development, and agriculture. Trend: Since 2016 there has been a 1.2% increase of developed land and agricultural land within 10 miles of GFNMS.	
Data Gaps: Numbers of large vessels by type need to be better documented on an annual basis. The amounts of sulfur oxide emissions entering the sanctuary are not known. The runoff from developed land use into the sanctuary has not been quantified. More information on the quantified impacts from vessel sizes, distance traveled and speeds (e.g., sulfur oxide emissions), and the numerous small fuel spills would better inform this question. An improved understanding of why distances cargo vessels transit through the sanctuary have decreased during this study period.			

Commented [4]: sentence structure..."an improved understanding...have decreased" ? suggest rewriting

Vessel Traffic

Vessel traffic is a human activity of interest for water quality because of the risk of oil spills, illegal discharges of exhaust gases and ballast water, air pollution (which can affect water quality, for example, through ocean acidification), container losses, and biological invasions (Hassellöv et al., 2013; Jagerbrand et al., 2019; Ruiz et al., 2000). GFNMS has regulations that prohibit discharge of material within sanctuary boundaries, with few exceptions. Other discharge regulations within the boundary of GFNMS include multiple state regulations prohibiting the discharge of pollutants and waste, USCG regulations on trash disposal, and the International Maritime Organization Ballast Water Management Convention requirements, which limits releases of invasive species from discharged ballast water.

Because there are limited data on how most incidents have affected water quality in the sanctuary, vessel traffic data were used as a proxy for oil spills and other discharge risks. Given the large volume of commercial traffic that transits the sanctuary, there is a heightened risk for spills and discharges. Large commercial ships use the San Francisco Traffic Separation Scheme (SF TSS, Figure SS.1), merging three shipping lanes into one precautionary circle near the entrance to San Francisco Bay. During the study period, the size of commercial ships

Commented [5]: a reasonable proxy, given the difficulty of tracking this. One (I might assume) that is commonly used by other agencies or programs tracking water quality? If so, might consider mentioning...

increased, but the number of ships using the three lanes of the SF TSS remained constant at about 8,000 transits a year, including inbound and outbound transits, with the exception of cargo vessel. The distances cargo vessels transit through the sanctuary have decreased during this study period (Jensen et al., 2015; BOEM et al., 2022). We speculate that more vessels are using the western traffic separation lanes, which are shorter in distance across the sanctuary. Further analysis is warranted.

Commented [6]: a figure showing this? just an idea, but doesn't AIS data show which vessels are using which TSS lanes?

An estimated 1,383,729 miles (1,202,428 nm) of vessel transits through GFNMS occurred from 2016 to 2020 (BOEM et al., 2022), not including vessels that are not required to carry AIS (Figure S.P.2.1). AIS carriage requirements for commercial vessels expanded in 2015, with a 2016 deadline for installation of working transponders in all commercial vessels and passenger and fishing vessels 65 ft or greater in length. Previously, only vessels 300 gross tonnage and larger were required to carry and transmit AIS (33 C.F.R. § 164). A Vessel Monitoring System (VMS) is required by NOAA's National Marine Fisheries Service on any vessel registered to a limited entry groundfish permit (NMFS, 2022). VMS beacons do not reflect all fishing vessel activity in GFNMS (50 C.F.R. § 660.14). Therefore, VMS records only represent a subset of the fishing vessels in the sanctuary. Spatial data for vessels not equipped with VMS or AIS beacons were not available.

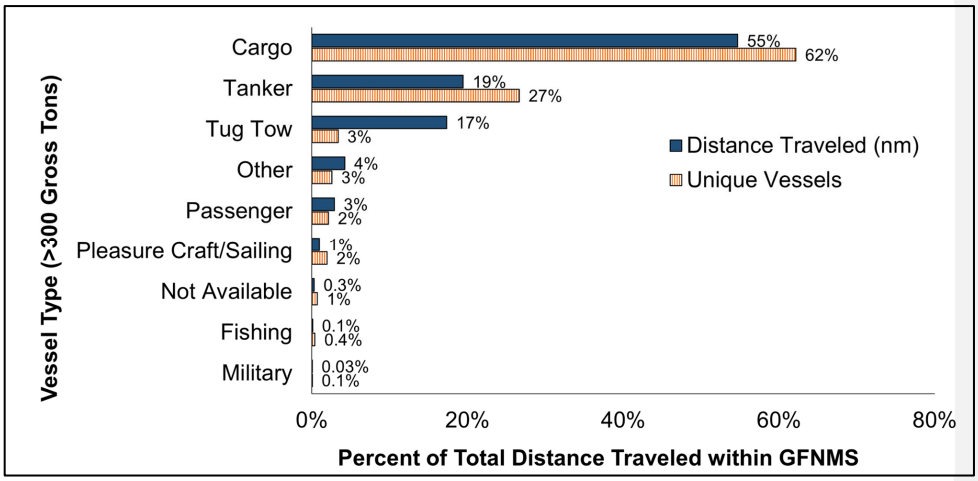

Figure S.P.2.1. Proportion of vessel type of all large ships in GFNMS and distance traveled in GFNMS from 2016–2020. Source: BOEM et al., 2022

Commented [7]: sorry, I'm just not clear on what "unique vessels" means in this context. Tankers traveled 19% of the total nm, but "unique tankers" (?) traveled 27%?

Transit of cargo ships and oil tankers through the sanctuary is of interest, because of their capacity to carry large volumes of fuel and other materials and the potential for spills and discharges. Large cargo ships can carry up to 4 million gallons of fuel oil (NOAA, 2016). Oil tanker size varies and these ships can carry 9–150 million gallons of oil (Washington State Department of Ecology, 1996). Supertankers can carry over 80 million gallons of oil.

The number of vessels and the speed of the vessels will influence the amount of sulfur and other pollutants released into air and ocean. High sulfur fuel used in commercial shipping for much of the 20th century emitted significant amounts of pollution. Now, to allow the use of the

lower cost, high-sulfur fuel, pollutants from fuels are redirected through exhaust gas cleaning systems (EGCS), or scrubbers, which reduce emissions, but generate effluents and residues that need to be disposed of. In 2009 the California Air Resources Board (CARB) used data from the Emission Control Areas (ECA) for ocean-going vessels that mandate the use of low sulfur fuels and restricted the use of EGCS to comply with these standards out to 24 nautical miles. In 2015 California ECAs were expanded to encompass the entire U.S. Exclusive Economic Zone. The net effect of these regulations was a reduction in emissions from ships over the study period; however, some cruise ships used EGCS illegally in GFNMS (Blank Rome LLP, 2017), which is prohibited, and there is uncertainty as to the scale of EGCS effluent that entered GFNMS. Emissions remain high and are affecting water chemistry (Smith et al., 2014; Faber et al., 2020). The impacts of emissions are considered in Question 9 (other stressors affecting water quality).

Commented [8]: still?

Cruise Ship Discharges

Cruise ships (noted as Passenger in Figure S.P.2.1) transiting the sanctuary are one vessel type of particular concern because of the amount of sewage and garbage that are generated from these types of vessels and the potential of illegal use of EGCS. During this study period, annually 100 cruise ships entered the sanctuary each year, except during the pandemic, 2020–2021. Since the opening of the new cruise ship terminal in 2014, the Port of San Francisco has hosted over 100 cruise ship calls and more than 400,000 passengers every year (Port of San Francisco, 2023). From 2015–2017, there were 190 illegal discharges in GFNMS and CBNMS from two cruise ship lines (Blank Rome LLP, 2017). A combined total 8,000,000 gallons of untreated black and gray, untreated black and gray water, membrane bio-reactor desludging, EGCS effluent, and food waste were illegally discharged in CBNMS and GFNMS (NOAA, 2021). Approximately 95% of the discharges were within GFNMS. Over half the discharges were from EGCS. Reporting vessel discharges is a self-reporting requirement, therefore it is likely that vessel discharges within and near the sanctuary are likely underreported.

Dredge Material Barge Transits

San Francisco Bay's 85 miles of navigable waterways require annual maintenance dredging (Chin & Ota, 2001). Barges transiting dredge materials accidentally discharging clean sediment into the sanctuary can affect water clarity by blocking sunlight, restricting the growth of plankton and disrupting foraging for fish, birds and marine mammals. It can also change the character of the seafloor habitat and smother bottom dwelling organisms. San Francisco Deep Ocean Disposal Site (SF-DODS) was designated to dispose of clean, dredged sediment that does not contain toxic levels of chemicals (LTMS, 1998) and is the farthest offshore and in the deepest water of any ocean disposal site in the United States, located 55 miles beyond the Golden Gate Bridge and outside the GFNMS western boundary (Chin & Ota, 2001).

Commented [9]: on a figure?

Through the Long-Term Management Strategy (LTMS) for ports maintenance in San Francisco Bay, barges transporting dredged material across sanctuary waters on the way to SF-DODS are required to have an on-board, computerized recording system that notes the location of accidental spillage or premature dumping (LTMS, 1998). This system notifies the sanctuary when the barge leaks or dumps sediment outside of the SF-DODS disposal site. From 1999–2003, there were 178 separate occasions where barges leaked significant amounts of dredge materials in GFNMS (U.S. Environmental Protection Agency & U.S. National Oceanic and Atmospheric Admin. v. Dutra Dredging Company, 2006). The amounts released varied, but the total volume was estimated to be 91,158 cubic yards[1]. Since an enforcement case in 2006 (U.S. Environmental Protection Agency, U.S. National Oceanic and Atmospheric Admin. v. Dutra

[1] One cubic yard is approximately the size of a standard home washing machine.

Dredging Company; JAMS Reference No. 1100047346; NOAA Case No. SW060015A), and real time reporting implemented in 2010, incidents decreased. Between 2011 and 2016 there were no incidents of leaks and spills within GFNMS. Between 2017 and 2021 there were 15 barge leaks reported within GFNMS that resulted in approximately 21.5 cubic yards of dredge materials leaked, which is a significant decrease both in terms of the number of incidents and the amount discharged (Etrac, 2022).

Oil Release Events

No major oil spills occurred during the current assessment period. Compared to the 2010 condition report, spill volumes declined substantially throughout GFNMS even after sanctuary expansion. Between 2010 and 2021, there were 35 incidents (average of 6.4 incidents per year) of vessel and object discharges (e.g., airplanes), groundings, and sinkings within the GFNMS coastal and offshore region (GFNMS, 2022; USCG MISLE, 2022). The majority were small fuel spills. There was no discernible trend, and rough weather was a significant factor in vessel groundings and sinkings.

The total reported amount of fuel spilled between 2010 and 2021 was less than 10,000 gallons. Reported estimates were provided by agency emergency response partners and responsible parties (USCG-MISLE, 2022), and are considered to be rough estimates due to the uncertainty of the exact quantities of fuel aboard a particular vessel at the time of an incident. Multiple reported spills did not have any estimated fuel quantities, and it is likely that small fuel spills are underreported because of the numbers of small recreational vessels operating throughout the sanctuary. Further, for a number of incidents, the fuel type may not be reported. However, most reported discharges from vessel incidents during this time period, when known, were diesel, which is lighter and evaporates quicker but is more acutely toxic than crude oil (Kummerlowe et al., 1996; USCG-MISLE, 2022). These types of incidents still can have localized effects on water quality and wildlife (see Question 9 for more discussion on the impacts of oil and other hazardous material from vessel discharges).

Commercial fishing vessels were responsible for the largest number of small incidents. Petroleum product released from one grounded vessel in 2021, F/V *American Challenger,* was responsible for the largest release of fuel, estimated to have been between 6,000 and 9,000 gallons of diesel (USCG-MISLE, 2022). As of April 2023, the vessel was still aground in the sanctuary and may still contain diesel fuel, hydraulic oil, and lube oil onboard as well as other materials that are known to be toxic.

Tarball deposition rates on beaches decreased over the past 11 years, and since the lightering of the S/S *Jacob Luckenbach* in 2002 (ONMS, 2010). There was a spike in reported tarballs in 2016, attributable to a high number of tarballs (>10,000) reported on Limantour Beach during one survey (Figure S.P.2.2). The source of the majority of the tarballs is unknown due to lack of testing, but no oiled wildlife were recorded during the 2016 event (Lindquist & Roletto, 2022b). Of the few representative tarballs that were analyzed (n=6) by the Office of Spill Prevention and Response, Petroleum Chemistry Lab (OSPR, 2021), all were determined to be from the Monterey Formation. These are likely to be from natural seeps although they could be from fuel derived from the Monterey Formation (Henkel et al., 2014). Seasonal peak tarball deposition is in the fall and winter months. It is suspected that tarballs from natural seeps along the southern-central California region are transported to northern California beaches via the Davidson Current, which prevails along our coast November through February (García-Reyes & Largier, 2012). Oil pollution in the sanctuary has decreased since 2010 and only a few oiled birds (less than 1%, n=30) were documented 2010–2021 (Lindquist & Roletto, 2022b).

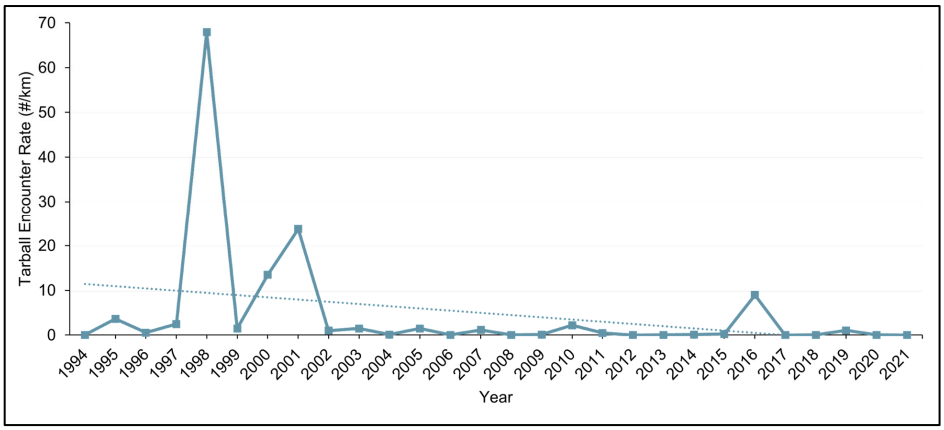

Figure S.P.2.2. Tarball encounter rates (#/km surveyed) on GFNMS beaches from 1994–2021. The peak in 2016 was due to a high number of tarballs (>10,000) on Limantour Beach during one survey, most likely attributed to a natural seep. Source: Lindquist & Roletto, 2022b

Agriculture and Developed Land Use

GFNMS regulations prohibit construction of any structure within the sanctuary, but land development in the watersheds of the sanctuary can impact water quality through increased sediment and runoff discharges. We reviewed the level of land use, agriculture, and construction within the watersheds of the sanctuary, as a proxy for water quality from runoff and sedimentation. The National Land Cover Database (NLCD), serves as the national database for the characteristics of the land surface, (e.g., percent of urban, agriculture, forest, impervious surface, tree canopy cover; Homer et al., 2012). We evaluated all land use within 10 miles of the GFNMS boundary in the NLCD 2008–2019. From 2008–2015 there was no change in development but from 2016–2019 there was approximately a 1.2% increase of high, medium and low intensity developed land (Dewitz & U.S. Geological Survey, 2021). The largest type of agriculture that increased is cultivated crops, which increased 3 sq miles since 2009. During this same time period there was a decrease of shrub/scrub and grassland (11 sq miles and 3.5 sq miles, respectively). These decreases may be due to converting these lands into agricultural lands (Dewitz & U.S. Geological Survey, 2021).

Commented [10]: I'm not a specialist, but did occur to me that this category (for non-estuarine lagoon) could include water treatment, outfalls etc. So, no outfalls from treatment plants in GFNMS? If yes, seems there would be quantitative data. Or, treated outfall no impact on water quality? Storm street runoff? I don't know if these things need to be mentioned.

Conclusion

This question was rated fair based primarily on the level of vessel traffic, a decrease in miles of transit by large commercial vessels, an increase in fishing vessels, and slightly decreasing distance traveled by cargo vessels, along with their associated risks to water quality (via legal and illegal discharges and accidents). Of note were prohibited discharges from cruise ships via EGCS, treated and untreated sewage, desludging material, and food waste, 2015-2017. Over half the discharges were from EGCS. Large (spills greater than 500,000 gallons or smaller spills with significant environmental damages) did not occur during this study period, but remain a significant risk due to the amount of vessels transiting the sanctuary.) but remain a significant risk due to the amount of vessels transiting the sanctuary. Oil spills and fuel releases from smaller vessels were persistent but quantification was difficult due to self reporting requirements and remoteness of the majority of the sanctuary. Dredged material accidental spills declined. Land use data indicated only slight increases in developed land within the sanctuary watershed. The mixed trend was based on some indicators such as oil pollution decreasing, while data on

illegal discharges increased. More information on the quantified impacts from vessel sizes, distance traveled and speeds (e.g., sulfur oxide emissions), the numerous small fuel spills, would better inform this question.

References (Q2/Coastal and Offshore)

Blank Rome LLP. (2017). Letter to NOAA Special Agent Don Tanner. RE: Response to request for Information from NOAA dated May 31, 2017 related to the self-reported discharge events in the Cordell Bank and Greater Farallones National Marine Sanctuaries by four Princess vessels and one Holland America Line vessel.

Bureau of Ocean Energy Management & National Oceanic and Atmospheric Administration. (2022). Marine cadastre. https://marinecadastre.gov

Chin, J.L. & Ota, A. (2001). Disposal of dredged materials and other wastes on the continental shelf and slope. *In*: Karl, H.A., Chin, J.L., Ueber, E., Stauffer, P.H., & Hendley, J.W. (Eds) *Beyond the golden gate—oceanography, geology, biology, and environmental issues in the Gulf of the Farallones. U.S. Geological Survey Circular 1198.* http://pubs.usgs.gov/circ/c1198/

Dewitz, J., and U.S. Geological Survey (USGS). (2021). National Land Cover Database (NLCD) 2019 Products (ver. 2.0, June 2021): U.S. Geological Survey data release, https://doi.org/10.5066/P9KZCM54

Etrac. (2022). *The eTrac barge monitoring system for EPA required barge tracking.* [Unpublished data set]

Faber, J., Hanayama, S., Zhang, S., Pereda, P., Comer, B., Hauerhof, E., Schim van der Loeff, W., Smith, T., Zhang, Y., Kosaka, H., Adachi, M., Bonello, J., Galbraith, C., Gong, Z., Hirata, K., Hummels, D., Kleijn, A., Lee, D. S., Liu, Y.,…& Xing, H. (2021). *Fourth IMO greenhouse gas study 2020*. London, UK: International Maritime Organization.

Greater Farallones National Marine Sanctuary (GFNMS). (2022). *Emergency response incidents, 2010–2021: Supplementary data* [Unpublished data set]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of National Marine Sanctuaries.

Homer, C.H., Fry, J.A., and Barnes C.A. (2012). The National Land Cover Database, U.S. Geological Survey Fact Sheet 2012–3020, 4 p.

Hassellöv, I. M., Turner, D. R., Lauer, A., & Corbett, J.J. (2013). Shipping contributes to ocean acidification. Geophysical Research Letters, 40, 2731–2736. https://doi.org/10.1002/grl.50521

Jägerbrand, A. K., Brutemark, A., Barthel Svedén, J., & Gren,I. M. (2019). A review on the environmental impacts of shipping on aquatic and nearshore ecosystems. Science of The Total Environment, 695, 133637, https://doi.org/10.1016/j.scitotenv.2019.133637

Jensen, C. M., Hines, E., Holzman, B. A., Moore, T. J., Jahncke, J., & Redfern, J. V. (2015). Spatial and temporal variability in shipping traffic off San Francisco, California. Coastal Management, 43(6), 575–588. https://doi.org/10.1080/08920753.2015.1086947

Kummerlowe, D.; Jackson, D., Fox, J., & Moulton, M. (1996). Guidelines for Determining Oil Spill Volume in the Field: Terminology, Ranges, Estimates and Experts. CADRE, Inc. for Washington State Department of Ecology. Publication No. 96–250. 196 pps. https://apps.ecology.wa.gov/publications/documents/96250.pdf

LTMS (Long-Term Management Strategy). (1998). Long-term management strategy for bay area dredged material final environmental impact statement/environmental impact report. Prepared by Ogden Beeman & Associates with Jones & Stokes Associates, Inc. and Moffatt & Nichol Engineers, Inc.

National Marine Fisheries Service. (2022). Regional Vessel Monitoring Information. NOAA Fisheries. https://www.fisheries.noaa.gov/national/enforcement/regional-vessel-monitoring-information

NOAA. (2016). How much oil is on that ship? NOAA Office of Restoration and Response. https://response.restoration.noaa.gov/about/media/how-much-oil-ship.html

NOAA. (2021). Office of General Counsel, Enforcement Section Civil Administrative Enforcement Actions. Princess Cruise Lines, Ltd., NOAA Case No. NW1703667A, and Holland America Line N.V., NOAA Case No. NW1703667B.

Port of San Francisco. (2023). *Cruising at the port*. https://sfport.com/maritime/cruise

Smith, T. W. P., Jalkanen, J. P., Anderson, B. A., Corbett, J. J., Faber, J., Hanayama, S., O'Keeffe, E., Parker, S., Johansson, L., Aldous, L., Raucci, C., Traut, M., Ettinger, S., Nelissen, D., Lee, D. S., Ng, S., Agrawal, A., Winebrake, J. J., Hoen, M…& Pandey, A. (2015). *Third IMO greenhouse gas study 2014*. London, UK: International Maritime Organization.

Ruiz, G. M., Rawlings, T. K., Dobbs, F. C., Drake, L. A., Mullady, T., Huq, A., & Colwell, R. R. (2000). Global spread of microorganisms by ships. Nature, 408, 49–50.

USCG Marine Information for Safety and Law Enforcement (USCG-MISLE). (2022). Marine Information for Safety and Law Enforcement, Casualty and Pollution Incidents. https://cgmix.uscg.mil/psix/.

U.S. Environmental Protection Agency, U.S. National Oceanic and Atmospheric Administration v. Dutra Dredging Company. (2006). NOAA Case No. SW060015A. JAMS Reference No. 1100047346.

Estuarine and Lagoon Region (Q2)

Status Rating: Fair	Status Confidence: Low

Trend Rating: Mixed	Trend Confidence: Low
Status Description: Selected activities have caused measurable resource impacts, but effects are localized and not widespread or persistent.	
Rationale: There is a limited amount of quantitative data on human activities for this rating, therefore surrogate indicators such as mercury levels and coliform counts were used. Some conditions are improving, such as mercury discharges from the Gambonini Mine but mercury continues to exist in the Walker Creek delta. There are fairly high levels of human activities that pose risks to water quality in the estuarine and lagoon regions and watersheds of the sanctuary estuaries, such as vessel activities. Some vessel activities have increased, while fecal coliform counts have decreased. There was a minor increase in developed high intensity land, but with unknown impacts to the estuaries' water quality. Oil releases from vessels and vehicles occurred but the volumes and impacts are unknown.	

Findings From the 2010 Condition Report

In the 2010 Condition Report the status rating for human activities that influence water quality was fair/poor, and the trend was improving. The rating was based on land use pressures having caused changes to sediment and freshwater regimes; loss of eelgrass beds in Bolinas Lagoon; increased restoration activities, increased regulations, and best management practices that may allow for improvements.

New Information in the 2010–2022 Condition Report

Information considered for the current assessment included: construction of new development and changes to land use adjacent to all estuaries; fecal coliform discharges as a source of water quality degradation in Tomales Bay; evidence of increased recreational human use of Tomales Bay; and implementation of the Tomales Bay Mooring Program, which includes new requirements for all privately-owned moorings that provide additional protections against impacts to water quality (Table S.P.2.2).

Table S.P.2.2. Summaries for the key indicators related to human activities that may impact water quality in the estuarine and lagoon regions of the sanctuary.

Indicator	Data Source/data visualization	Data Summary	Figures
Watershed Activities Impacting Water Quality—Mines and Ranching	CSWRCB, 2019; CSWRCB, 2023	Status: All estuaries in GFNMS are on the 303(d) list as impaired bodies of water, and impairments were sourced from mines, dairy, cattle and sheep ranching practices in the sanctuary's watersheds. Trend: Mercury in Walker Creek and delta decreased since mine remediation in 2000. However, TMDL load allocation has not been reached for some parameters and species.	

		The amount of ranching has been stable.	
Watershed Activities Impacting Water Quality—Developed Land Use	Dewitz and U.S. Geological Survey, 2021	Status: In 2019, there were low levels of Developed High Intensity land use within 2-3 miles of Estero Americano, Estero de San Antonio, Tomales Bay, and Lagoon Trend: Between 2008 and 2019, Developed High Intensity land use only slightly increased in the watersheds of Esteros Americano, de San Antonio, Tomales Bay, and Bolinas Lagoon. There was only a slight change in the amount of ranch and agriculture activities.	

Vessel Activities–Human Waste Discharge Sources in Tomales Bay	CSWRCB, 2016; CSWRCB, 2020; CDPH, 2019a; CDPH, 2019b; Lindquist & Roletto, 2022b	Status: There was limited data on the number of vessels using Tomales Bay and Bolinas Lagoon. What data there are, indicates that some vessel activities have increased, while fecal coliform counts have decreased. Most likely input of fecal coliform counts are not primarily sourced from vessels. Vessel activities that can be associated with human waste discharges were used as a proxy for a source of fecal coliform impacts throughout Tomales Bay. From 2010–2021, the annual rates of motorized vessels ranged from 0.13 vessels per km surveyed to 0.41 vessels/km; rates of non-motorized vessels ranged from less than 0.01 vessel/km to 0.64 vessels/km. Trend: Trends of motorized vessels on Tomales Bay appear to be stable and trends of non-motorized vessels appear to be increasing. Fecal coliform concentrations have decreased significantly since the TMDL was enacted in 2008.	
Moorings in Tomales Bay	GFNMS, 2022b	Status: Moored vessels are present in Tomales Bay but must be compliant with GFNMS regulations, which include a requirement for approved Marine Sanitation Devices for all moored vessels. In 2016, 130 unpermitted moorings were recorded in Tomales Bay. Between 2016 and 2022, 51 unpermitted moorings were recorded. As of May 2022, 3 unpermitted moorings were recorded. Trend: Unpermitted moored vessels decreased and availability of dump stations increased.	
Oil Release Events	GFNMS, 2022	Status: Minor incidents throughout Tomales Bay were uncommon but most cases are unknown petroleum products. No releases have been documented in the other estuaries.	Table S.P.2.3

Commented [11]: I guess I'm too sensitive to this issue. I live in Hawaii, where every time we get a big rain event our treatment plants are overwhelmed and the fecal loads shut the beaches down for day. Welcome to paradise. So, no treatment plant outfalls in estuaries/lagoons?

		Trend: There was no apparent trend due to the infrequency of incidents.	
Data Gaps: There is a lack of data on human activities that may impact water quality in Estero Americano, Estero de San Antonio, and Bolinas Lagoon. Surveys for vessels legally and illegally moored in Tomales Bay are infrequent. Data are limited on the number of boats moored or transiting throughout Tomales Bay. Vessel transit levels are only available at two beaches and within 0.5 km of the shoreline. There are no data on leaking septic systems or illegal discharges of human waste.			

There are four estuaries within GFNMS;, Estero Americano, Estero de San Antonio, Tomales Bay and Bolinas (Figure SS.8). Human activities affecting water quality in these estuaries, particularly Tomales Bay, can come from various sources, including, but not limited to:

- Runoff from historic mining activities in the watershed;
- Runoff from dairy, sheep and cattle ranches;
- Improperly functioning residential septic systems;
- Malfunctioning wastewater treatment facilities (there are eight facilities within the watershed);
- Illegal camping, RV camping, or improper disposal of human waste adjacent to Tomales Bay;
- Illegally moored or anchored vessels;
- Overboard discharges from vessels that are moored, anchored, or operated in the bay, including kayaks, motorboats, and sailboats; and
- Oil pollution from abandoned vessels and vehicles in the estuaries.

Commented [12]: Ah, OK. Now I'm happy. I guess if they did malfunction, there would be a record of that. And also, if there are none in the offshore category above for water quality, it should probably be noted.

To best assess the levels of human activities that may affect water quality we looked at activities not only within the sanctuary boundaries but also in the watersheds of the sanctuary. The areas around GFNMS estuaries are generally rural, residential, or agricultural. Because of a lack of direct measurements of human activities, several of the indicators are proxies for human activities, such as areas listed as impaired bodies of water under the Clean Water Act (303(d) list) and the state's Regional Water Quality Control Board, Region 2 (RWQCB) and developed land use (Dewitz and U.S. Geological Survey, 2021)

Watershed Activities Impacting Water Quality—Mines and Ranching

Mercury mining in the Walker Creek watershed occurred in the 1960s and ceased by 1972. The Gambonini Mine was the largest mercury mine in the watershed, operating from 1964–1970. Other mine sites that are no longer active in the Walker Creek watershed include the Franciscan, Cycle, and Chileno Valley mines. Prior to the establishment of the TMDL, the Water Board and U.S. EPA conducted an emergency superfund cleanup at the Gambonini Mine site, which was the greatest source of mercury in the watershed (CSWRCB, 2021). These efforts resulted in reductions of mercury pollution coming from the mine site. Conditions appear to be improving, although more information is needed (CSWRCB, 2021).

The Walker Creek and delta within Tomales Bay and its northern watershed is impaired due to high levels of mercury and mining debris (CSWRCB, 2019, 2023) originating from the inactive Gambonini mercury mine in the upper watershed. Other inactive mines (e.g., the Franciscan, Cycle, and Chileno Valley mines), as well as naturally occurring mercury found in water runoff, and atmospheric deposition (e.g., fossil fuel emissions) (MCSTOPPP, 2022) have been noted but the the majority of the mercury in the Walker Creek delta originated from mining activities at

the Gambonini Mine. The mines have been closed and clean up and remediation of the mercury has been underway since the early 2000s (CSWRCB, 2019, 2023), which improved water quality conditions although more information is needed.

The predominant land use in the Esteros Americano and de San Antonio watersheds is livestock agriculture (dairy, sheep, and cattle ranching), which has seen little change in the past three decades. Runoff from ranching contributing to the impairment of the esteros and Tomales Bay include high levels of nutrients, sediment, ammonia, copper, and bacteria, and low levels of dissolved oxygen (California Coastal Commission 2019b). It is suspected that these pollutants are from inadequate storage of animal wastes and manure ponds, and the lack of adequate fencing to keep livestock out of the watersheds or estuaries. Increased sediment in runoff can originate from grazing livestock, modified drainage pathways, removal of riparian vegetation, destabilized streambanks, and upland erosion (Gold Ridge Resource Conservation District, 2007). The amount of land used for cultivated crops increased by 0.0178 sq miles, for a total of 0.0577 sq miles of cultivated land use in 2019.

Watershed Activities Impacting Water Quality—Developed Land Use

The areas around GFNMS estuaries are generally rural, residential, or agricultural. Between 2008 and 2019, there was a slight increase of Developed High Intensity (i.e., the area contains significant land area covered by concrete, asphalt, and other constructed materials, with vegetation) land use within 2 miles of Estero Americano and Estero de San Antonio, 0.004 sq miles and 0.002 sq miles, respectively. See Dewitz and USGS, 2021 for definitions of land use intensities found in the National Land Use Cover Database (NLUCD). Between 2008 and 2019 Developed High Intensity land use in Tomales Bay increased by 0.004 sq miles, for a total of 0.057 sq miles of Developed High Intensity land use in 2019 (Dewitz and U.S. Geological Survey, 2021). Land cover for activities that could impact Bolinas Lagoon water quality changed slightly between 2008 and 2019, with an increase in High Density development of 0.003 sq miles, to a total of 0.030 sq miles, in the watershed to the lagoon (Dewitz and U.S. Geological Survey, 2021).

Vessel Activities—Human Waste Discharge Sources in Tomales Bay

Since 2006, Tomales Bay has been CWA 303(d) listed for pathogens (CSWRCB, 2020, 2023). Tomales Bay and its main tributaries Lagunitas, Walker, and Olema creeks, are impaired by human and animal waste pathogens. Human activities that contribute to the fecal coliform levels in Tomales Bay are most likely from motorized and non-motorized vessels, improperly disposal of human waste from illlegal tent, RV, and kayak camping, improperly functioning residential septic systems, and malfunctioning wastewater treatment facilities (there are eight facilities within the watershed) adjacent to Tomales Bay. Since most of these activities are not directly measured, we reviewed the number of advisories issued by the state's Department of Public Health for poor water quality, which are issued when fecal coliform, *Enterococcus* exceeds 104 MPN/100 ml) or *E. coli* exceeds 400 MPN/100 ml (Ghodrati, 2022; CDPH, 2021a and 2021b).

Commented [13]: So I assume that review confirmed no plant malfunctions during the time period? Findings of that review? Needs to be stated

Vessel Activities, Moorings, and Anchoring in Tomales Bay

Tomales Bay continues to be a popular boating location for recreational vessels that are permanently and temporarily (day use) moored or anchored on the bay, though data are limited on the number of motorized and non-motorized vessels transiting or moored throughout the bay. The more vessels transiting and moored on the bay the higher the risk of discharges, thus lowering water quality. Data from vessel activities within 0.5 km of two beaches along Tomales Bay showed that from 2014 through 2015, the annual rates of motorized vessels ranged from

0.13 vessels per km surveyed to 0.41 vessels/km, with a stable trend (Lindquist and Roletto, 2022b). The rates of non-motorized vessels ranged from less than 0.01 vessel/km to 0.64 vessels/km, with an increasing trend (Lindquist and Roletto, 2022b). The number of private vessels permanently moored year-round on the bay decreased since 2010 (GFNMS, 2022b). One hundred-thirty unpermitted vessel moorings were recorded in Tomales Bay in 2016 and consisted of unregulated and potentially toxic materials, such as tires and engine blocks. From 2016 to 2022 unpermitted moorings in Tomales Bay decreased by more than 50% reducing the potential of toxic material to enter the bay from moorings. Between 2016 and 2022 a total of 51 unpermitted moorings were found and removed. As of May 2022, there were 59 permitted and installed moorings on the bay and only 3 unpermitted moorings (GFNMS, 2022b). Additionally, prior to 2010 there were no waste dump stations in Tomales Bay. In 2014 the first waste disposal station for Tomales Bay was installed at Miller Park on the east shore allowing for proper disposal of untreated waste.

Oil Release Events within GFNMS Estuaries and Lagoon

Boats and cars have released fuel almost every year in Tomales Bay since GFNMS started to track incidents in 2014 (Table S.P.2.3; GFNMS, 2022a). No incidents were documented in the Esteros or Bolinas Lagoon within this timeframe. Since 2014, 14 known incidents involving release of petroleum products from vessels, automobiles, or other sources were reported within Tomales Bay. The volume of fuel released was undetermined for 11 of the incidents, with the remaining three releasing a combined estimated minimum of 170 gallons. Because of the unknown quantities, it was not possible to determine a trend for the volume of oil pollution.

Table S.P.2.3. Known petroleum release events in Tomales Bay since 2014. Source: GFNMS, 2022a[2]

Incident Year	Vessel, Automobile, Container, or Other?	Recreational or Commercial or Other?	Estimated Fuel Capacity (gallons)	Fuel Type (If Known)	Estimated Fuel Released into Sanctuary (gallons)
2014	Vessel	Recreational	100	Gasoline	Unknown
2014	Automobile	Private	Unknown	Gasoline	Unknown
2014	Automobile	Private	Unknown	Gasoline	Unknown
2015	Vessel	Recreational	Unknown	Unspecified Petroleum Product	Unknown
2015	Vessel	Recreational	Unknown	Unspecified Petroleum Product	Unknown
2015	Vessel	Recreational	Unknown	Unspecified Petroleum Product	Unknown
2015	Automobile	Commercial	Unknown	Gasoline	Unknown

[2] Information provided is from reporting by various sources to GFNMS that are subsequently tracked by GFNMS to determine the type of incident and type and amount of fuel spilled. Fuel quantities, if provided, are rough estimates as the exact amount of fuel onboard a vessel at any given time is typically not well documented.

Incident Year	Vessel, Automobile, Container, or Other?	Recreational or Commercial or Other?	Estimated Fuel Capacity (gallons)	Fuel Type (If Known)	Estimated Fuel Released into Sanctuary (gallons)
2016	Vessel	Recreational	15	Unspecified Petroleum Product	15
2016	Automobile	Unknown	Unknown	Gasoline	Unknown
2017	Discharge	Unknown	5	Diesel	5
2018	Vessel	Commercial	Unknown	Unspecified Petroleum Product	Unknown
2020	Vessel	Commercial Fishing	300	Diesel	Unknown
2021	Vessel	Other	Unknown	Diesel	150
2021	Vessel	Recreational	Unknown	Unknown	Unknown

Conclusion

Human activities within GFNMS and on the land surrounding the estuaries in GFNMS have the potential to adversely affect water quality. The fair rating for status is based on the level of boating activities which can increase discharges, which negatively impacts water quality but also the cleanup of mercury in Walker Creek delta. The mixed rating for trend reflects that some activities have ceased (e.g., mining), decreased (e.g., illegal mooring), and are ongoing (e.g., ranching), while others are increasing(e.g., recreation), resulting in a mixed trend. Mining in the Walker Creek watershed has ceased and significant remediation has occurred. Highly developed land use along the estuaries increased slightly. More information is needed on which human activities, such as the number of leaking septic systems and illegal dumping of human waste, is needed. There was limited data on the number of vessels using Tomales Bay and Bolinas Lagoon. What data there are, indicates that vessel activities have increased, while fecal coliform counts have decreased. There is a lack of data on human activities that may impact water quality in Estero Americano, Estero de San Antonio, and Bolinas Lagoon. Data are limited on the number of boats anchored or transiting throughout Tomales Bay. Vessel transit levels in Tomales Bay are only available at two beaches and within 0.5 km of the shoreline.

References (Q2/Estuarine and Lagoon)

California Department of Public Health (CDPH). (2021a). *Environmental Management Branch Preharvest Shellfish Program Annual Sanitary Survey Update Reports*, *2010-2021* [Unpublished data set]. California Department of Public Health.

California Department of Public Health (CDPH). (2021b). *Annual Sanitary Survey Update Report: 2020-2021* [Unpublished data set]. California Department of Public Health.

California Department of Public Health (CDPH). (2019a). *Norovirus Outbreak December 2018/January 2019 Summary Report* [Unpublished data set]. California Department of Public Health.

California Department of Public Health (CDPH). (2019b). *Norovirus Outbreak April 2019 Summary Report* [Unpublished data set]. California Department of Public Health.

California State Water Resources Control Board (CSWRCB). (2016). *Water quality report card: Pathogens in Tomales Bay tributaries*. San Francisco Bay, Region 2. https://www.waterboards.ca.gov/about_us/performance_report_1920/plan_assess/tmdl_outcomes/r2_tomales_bay_pathogens.pdf

California State Water Resources Control Board (CSWRCB). (2019). *Water quality report card: Mercury in Tomales Bay*. San Francisco Bay, Region 2. https://www.waterboards.ca.gov/about_us/performance_report_1920/plan_assess/docs/fy1819/r2_tomalesbayhg.pdf

California State Water Resources Control Board (CSWRCB). (2020). *Tomales Bay Pathogen TMDL*. San Francisco Bay, Region 2. https://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/TMDLs/tomalesbaypathogenstmdl.html

California State Water Resources Control Board (CSWRCB). (2023). *Tomales Bay Pathogen TMDL*. San Francisco Bay, Region 2. https://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/TMDLs/TomalesBayHgTMDL.html

Dewitz, J.& U.S. Geological Survey (USGS). (2021). National Land Cover Database (NLCD) 2019 Products (ver. 2.0, June 2021): U.S. Geological Survey data release, https://doi.org/10.5066/P9KZCM54

Gold Ridge Resource Conservation District. (2007). *The Estero Americano watershed management plan, Version 1*. http://goldridgercd.org/documents/esteroamericanowmp_final.pdf

Ghodrati, F. (2022). *Tomales Bay fecal coliform: 2004-2021* [Unpublished data set] Dataset Excel file titled *TB Data for GFNMS (2004-2021)*. Regional Water Quality Control Board, San Francisco Bay Region.

Greater Farallones National Marine Sanctuary (GFNMS). (2022a). *Emergency response incidents, 2010–2021: Supplementary data* [Unpublished data set]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of National Marine Sanctuaries.

Greater Farallones National Marine Sanctuary (GFNMS). (2022b). *GFNMS Tomales Bay Mooring Program Records and Database: Supplementary data* [Unpublished data set]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of National Marine Sanctuaries.

Lindquist, K., and Roletto, J. (2022b). *Beach Watch database: Supplementary data* [Unpublished data set]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of National Marine Sanctuaries, Greater Farallones National Marine Sanctuary & Greater Farallones Association.

Marin Countywide Stormwater Pollution Prevention Program (MCSTOPP). 2022. *Reducing Marin's priority pollutants to improve water quality*. https://mcstoppp.org/reducing-priority-pollutants/

United States Environmental Protection Agency (USEPA). (2023). *Impaired waters and TMDL website. https://www.epa.gov/tmdl/overview-identifying-and-restoring-impaired-waters-under-section-303d-cwa*

Question 3: What are the levels of human activities that may adversely influence habitats and how are they changing?

Coastal and Offshore Region (Q3)

Status Rating: Fair	Status Confidence: Low
Trend Rating: Undetermined	Trend Confidence: Medium
Status Description: Selected activities have caused measurable resource impacts, but effects are localized and not widespread or persistent.[3]	
Rationale: Marine debris was documented on beaches in the region and on the surface and the seafloor in the sanctuary. The most commonly found type of debris on the seafloor was commercial fishing gear. Trawling and crab fishing activities occur each year through large areas of the sanctuary. In 2020, more areas were opened to trawling in GFNMS. Easy access to some rocky reefs in the sanctuary, such as Duxbury Reef, resulted in comparatively high human visitation. The lack of baseline data for these indicators prevents the determination of a trend.	

Findings From the 2010 Condition Report

A direct comparison to the 2010 condition report for this question is not possible. The sanctuary expanded in 2015, during the time period for this assessment. The expansion added a new area that was not assessed in the 2010 condition report. That said, in 2010, the status was determined to be good/fair and the trend appeared stable. While increases in urbanization, visitation and shipping had been occurring prior to 2010, decreases in trawling and chronic oil pollution, cessation of discharging of radioactive waste, and increased regulations to prevent introduced species also occurred. The 2010 assessment thus concluded that some potentially harmful activities were occurring, but none appeared to have had a negative effect on habitat quality.

[3] At the 2022 status and trends workshop, experts assigned a status rating of fair/poor with a high confidence score. Following the workshop, GFNMS staff re-evaluated the indicators, datasets, and expert input that was received during the workshop, and determined that a status rating of fair with low confidence, as the data do not sufficiently show that impacts were severe during the study period. See Appendix C for more information regarding these changes.

New Information in the 2010–2022 Condition Report

Prior to 2012, GFNMS did not have baseline data for benthic seafloor habitat characterization, deep sea debris. Since 2012, GFNMS has acquired data on the types of debris found in benthic habitat as well as habitat characterization data at multiple offshore locations.

Table S.P.3.1. Summaries for the key indicators related to human activities that impact habitat in the coastal and offshore region that were discussed during the July 11, 2022 virtual status and trends workshop.

Indicator	Source	Data Summary	Figure
Beach Debris	NOAA 2020; Bimrose et al., 2020	Status: Land-sourced debris(bottle caps, food wrappers, and straws) and to a lesser extent ocean-sourced debris (fishing lures, line, rope and tubes) were both found on beaches adjacent to GFNMS where surveyed[4]. Trend: The trend is undetermined for the study period (2010–2022) due to insufficient data. Oyster farm debris decreased at two monitoring sites on the outer coast.	Figure S.P.3.1
Surface Debris	Elliott et al., 2022b	Status: Surface debris is generally sparse but has been observed throughout the sanctuary. Surface debris ranged from 0.1–0.4 traps/sq km. Trend: There was a spike of surface debris observed in 2010 but generally the trend appears to be stable or possibly slightly improving for the study period (2010–2022).	Figure S.P.3.3
Sunken Debris in the Benthic Environment	Etnoyer et al., 2014; Graiff et al., 2016; Graiff et al. 2021	Status: Debris was found on the seafloor during all 4 NOAA research cruises conducted since 2012. The most prevalent observed underwater debris was fishing gear, including longlines, gillnets, and crab gear. Trend: The trend was undetermined for the study period (2010–2022) due to insufficient data.	
Vessel Incidents	GFNMS, 2022; USCG, 2022	Status: A total of 33 vessel incidents occurred from 2012–2021 in GFNMS that resulted in impacts to habitat and water quality. Trend: The number of incidents every year is variable, with no discernible trend during the assessment period.	Figure S.P.3.4
Benthic Commercial Fishing Activities	CDFW, 2020; CDFW 2023	Status: An estimated 29,200-83,500 Dungeness crab pots were deployed on the seafloor in the sanctuary each year. An average of eight trawl vessels per year operated in the sanctuary between 2010–2020.	Figure S.P.3.5

[4] Marine debris monitoring data for beaches inside GFNMS were not available. However, beach debris monitoring has been conducted on 6 beaches adjacent to GFNMS that have been determined to be high deposition areas for marine debris and were determined to be suitable proxies for assessing beach debris at sanctuary beaches (Source: Bimrose et al., 2020).

		Trend: The trend for crab pots was undetermined for the study period (2010–2022) due to insufficient data. The trend for trawling was also undetermined for the study period due to insufficient data. As of 2020, new seafloor areas in the sanctuary have been opened to trawling, however, data is not yet available to assess whether trawling is occurring in these areas.	
Visitors at Reefs	Lindquist and Roletto, 2022b	Status: Visitor use at Duxbury Reef was high compared to other rocky intertidal sites in Marin County. Trend: Visitor activities at rocky reefs appeared to decrease slightly from 2015–2019.	
Data Gaps	For some indicators, there are data gaps about the level of human impacts that are occurring that adversely affect habitat, which is why proxies for human activities are used, for example visitor use at intertidal sites. More data is needed on marine debris through the sanctuary, including beach debris, especially at coastal sites in the expansion area of GFNMS, and sunken marine debris to better determine impacts and trends over time. Benthic habitat mapping is needed in areas where fishing occurs to help assess benthic habitat impacts. More data is needed on noise impacts to the soundscape in GFNMS.		

Types of Marine Debris

Marine debris is not a specific human activity but rather a category of material discharged into the marine environment that can result from a variety of activities in and adjacent to the sanctuary such as storm runoff that carries construction and household debris, littering, plastic manufacturing, hunting, and aquaculture. Marine debris is defined as “any persistent solid material that is manufactured or processed and directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine environment or Great Lakes” (33 U.S.C. § 1956). Marine debris may be found in any location throughout the sanctuary including water column, water surface, beaches, estuaries, and the seafloor. Some of the most common and harmful types of marine debris include plastic, such as cigarette butts, plastic bags, and food wrappers, aquaculture debris, and derelict fishing gear (NOAA, 2023). Marine debris can range greatly in size from microplastics, that can be too small to be seen with the human eye, to large abandoned and derelict vessels, construction debris, and household appliances that can damage sensitive habitats (NOAA, 2023). Although some of these items may eventually break down, others may never fully degrade and may persist in the marine environment (NOAA, 2023).

Beach Debris

Marine debris monitoring data for GFNMS beaches were not available for this assessment. However, data from beaches adjacent to but outside the sanctuary can provide information on debris trends in the region. Monitoring data was assessed from 6 sandy beaches just outside of the sanctuary which have all been historically determined to be deposition areas for marine-sourced debris (Bimrose et al., 2020). Land-sourced consumer, single-use products (e.g., bottle caps, food wrappers, plastic straws), are the most common type of debris observed on beaches in the region. Marine-sourced debris was found in lower amounts than land-sourced debris with

fishing gear being the most common type (e.g., fishing lures, line, rope and separator tubes) (NOAA, 2020, Bimrose et al. 2020) (SeeFigure S.P.3.1).

Photos documenting wood construction products and plastic debris on multiple beaches along the Sonoma Coast have been uploaded to MD-MAP. Without ongoing monitoring at these beaches, the extent and trends for beach debris in this area is unknown.

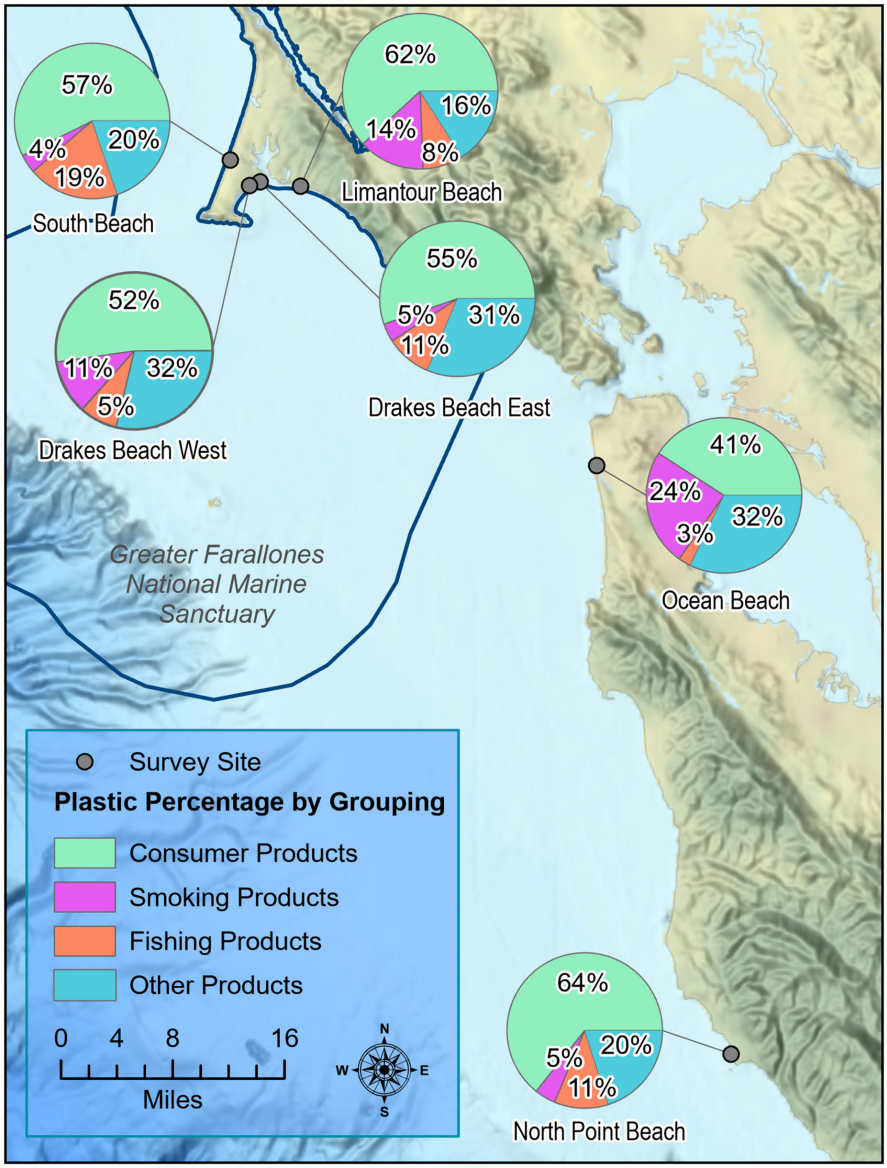

Figure S.P.3.1. Types and percentages of marine debris items found at six shoreline monitoring sites adjacent to GFNMS during 334 surveys conducted between July 2012 through June 2018. NOTE: Data were not readily available for marine debris on beaches within the boundary of the

sanctuary. The sites in this figure are located outside of the sanctuary but have been identified as beaches where marine-sourced debris is likely to accumulate and thus are used as a proxy for beaches in the sanctuary. Image: NOAA; Source: NOAA, 2020; Esri, 2020.

Surface Debris

Marine debris in the offshore environment is monitored through the Applied California Current Ecosystem Studies project (Elliott et al., 2022b), which has been conducting 3–4 ship-based surveys per year in GFNMS and CBNMS since 2004 (See Box 1, Figure S.P.3.2).

Box 1: Applied California Current Ecosystem Studies (ACCESS)

Applied California Current Ecosystem Studies (ACCESS) is a public-private partnership of GFNMS, CBNMS, and Point Blue Conservation Science to monitor ocean ecosystem health and inform management of the sanctuaries. Since 2004, ACCESS has conducted vessel-based surveys between Bodega Head and Half Moon Bay, spanning over 480 km, 16 transects, and 31 water column sample stations in nearshore and offshore regions of GFNMS, CBNMS, and the northern portion of MBNMS. Surveys are conducted approximately three times per year to capture the beginning, peak, and the end of the upwelling season. In some years, sampling efforts extend farther north and south, depending on weather and funding. Staff from these three agencies have numerous partners, including Greater Farallones Association, California Department of Fish and Wildlife, National Marine Fisheries Service, U.S. Fish and Wildlife Service, University of California Davis, San Francisco State University, and Monterey Bay Aquarium Research Institute. ACCESS samples for abundance and distribution of birds, mammals, marine debris, nutrients, water properties, ocean acidification, environmental DNA, and quantification of fish, krill, and other zooplankton. ACCESS also provides training and enrichment opportunities for science teachers, undergraduate and graduate students, and paid internships. Further, ACCESS provides a platform for partner research, like NOAA's "ADRIFT in the California Current" program that uses drift buoys to record soundscape metrics (including human noise inputs like vessels and marine mammal species presence offshore). ACCESS data on the status and trend of nearshore and offshore wildlife and human activities have been used for:

- Identification of wildlife hotspots and forage areas to inform management efforts to reduce ship strikes and entanglements (e.g., using data on krill, other zooplankton, birds, and mammals);
- Understanding how climate change is affecting this region of the California Current ecosystem, particularly water quality, forage species abundance and distribution, predator responses, ocean acidification, eutrophication, and habitat compression;
- Detection of emerging impacts and anthropogenic influences;
- Providing marine science learning opportunities for teachers, interns, undergraduate and graduate students; and
- Informing oil pollution response activities and natural resource damage assessment.

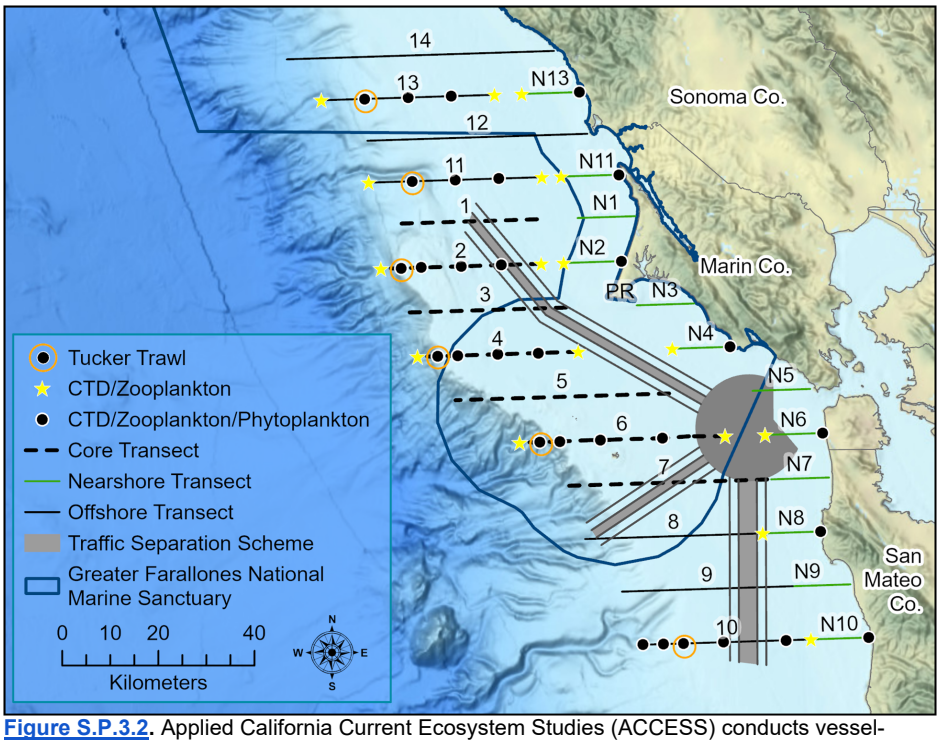

Figure S.P.3.2. Applied California Current Ecosystem Studies (ACCESS) conducts vessel-based surveys between Bodega Head and Half Moon Bay, with nearshore and offshore transects, and water column sample stations. Image: NOAA; Source: Elliott et al., 2022a; Esri, 2020

Surface debris observed included items such as out of season crab pot buoys, plastic bags, bottles, floats, balloons, and styrofoam. Floating debris is generally sparse but has been commonly recorded throughout the sanctuary, average density was 0.3 traps/sq km and ranged from 0.1-0.4 traps/sq km (Elliott et al., 2022b). An unexplained spike in conspicuous surface debris was observed in 2010 and has since decreased with an overall slight decrease over the last 10 years in the amount of observed surface debris (Figure S.P.3.3).

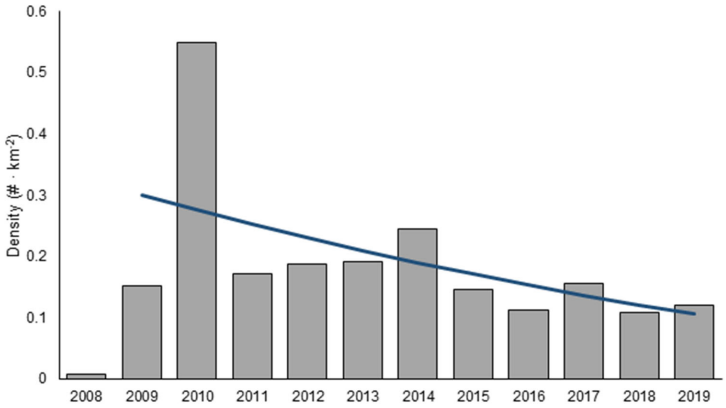

Figure S.P.3.3. Density of floating conspicuous, surface marine debris observed during ACCESS cruises in GFNMS and CBNMS from 2008–2019. Image: NOAA, Source: Elliott et al., 2022b

Sunken Debris in the Benthic Environment

Traps used for crab fishing are the most common gear type found in the sanctuary on the seafloor. These circular steel traps, commonly called pots, measure between 36" to 48" in diameter (9.5-12.5 feet circumference). The number of trips per vessel can vary each year depending on the length of the season. However, an average of 167 (standard deviation of 31.5) vessels set crab pots each season with each vessel setting between 175-500 pots per year in GFNMS (CDFW, 2020, 2023). This means a range of approximately 29,200-83,500 pots are set on the seafloor each year in GFNMS. Assuming an approximate 10% loss (PFMC, 2013) this could mean that an average minimum of lost pots impacting benthic habitat in perpetuity could be at a minimum of 2,923 lost pots a year in GFNMS (and as much as 8,350 a year) without interventions to remove lost pots. Impacts to seafloor from fishing gear is discussed in Question 10 of this report.

Vessel Incidents

Sunken and grounded vessels and lost containers impact GFNMS benthic habitat. Large objects that sink to the seafloor can crush or smother corals, sponges, and other benthic fauna, cause permanent loss and/or scarring and damage to rocky reef habitat, and reduce carbon storage (i.e., sequestered carbon in the seafloor) (Hutto et al., 2021). A total of 33 incidents occurred in GFNMS from 2010–2021 that resulted in impacts to habitat and/or water quality, and most of them were close to shore (GFNMS, 2022; USCG, 2022)(Figure S.P.3.3). An individual incident can result in extensive, significant, or multiple impacts. Debris from these incidents can include styrofoam, wood, metal, plastic, fishing gear, petroleum products, and other hazardous materials, such as heavy metals, polychlorinated biphenyls (PCBs), asbestos, and household cleaners. The number of incidents every year was variable, with no discernible trend (Figure S.P.3.4).

Commented [14]: "An assumption of a 10% loss has been established by..." would be nice to see a little more explanation here in the body of the text, as well as the ref cited.

Commented [15]: Many kinds of containers. I assume you mean marine shipping industry steel cargo containers (i.e., CONEX boxes), the large steel intermodal containers developed in the 1950s. General reader might need a it more clarity here.

Commented [16]: To confirm, "incident" here means "sunken/grounded vessel and/or cargo container", yes? Might need to be more specific.

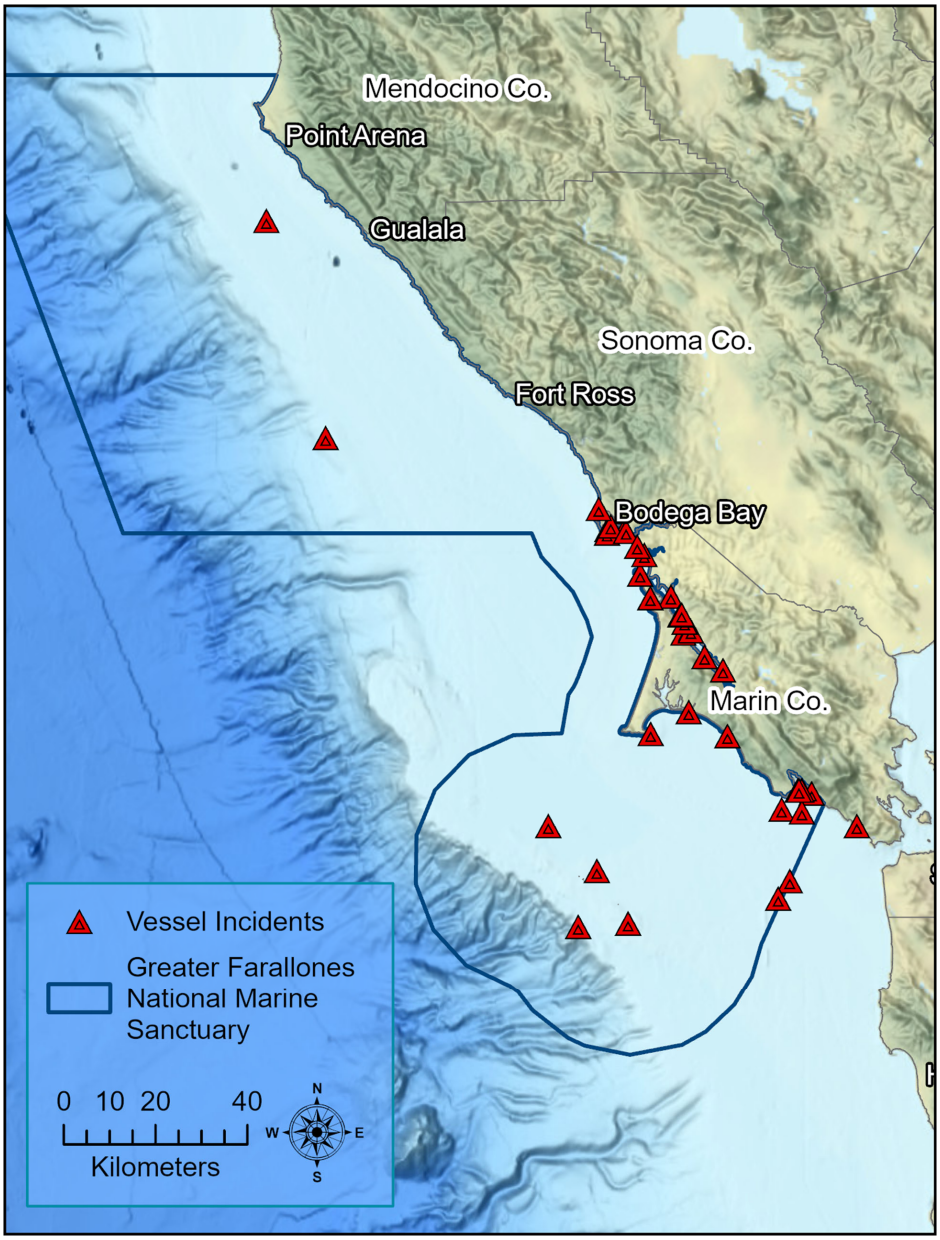
Mendocino Co.
Point Arena
Gualala
Sonoma Co.
Fort Ross
Bodega Bay
Marin Co.
Vessel Incidents
Greater Farallones National Marine Sanctuary
0 10 20 40
Kilometers
N
W
E
S

Figure S.P.3.4. The locations in red show where vessel incidents occurred between 2012 and 2021, each of which likely resulted in the release of marine debris. Image: NOAA; Source: GFNMS, 2022; USCG, 2022; Esri, 2020.

Benthic Commercial Fishing Activities

Fishermen use a variety of gear types in this region, including pots/traps, troll gear, trawls, seines, longlines, and hook and line (CDFW, 2020). The most common types of bottom commercial fishing gear in terms of harvest revenue and pounds landed are pots/traps and trawls (CDFW, 2020). The commercial Dungeness crab fishery is the largest fishery using trap gear in GFNMS (CDFW, 2020). The fishery occurs at depths from about 15 to 200 meters. It is generally conducted in areas of low relief and low complexity (MSC, 2010). Most commercial Dungeness crab fishing occurs in waters with silty sand to sandy bottoms, so contact from crab pots with the seafloor is less likely to impact sensitive benthic species, like corals, found in more structurally complex habitats (PFMC 1978; Kaiser et al., 2001). However, derelict crab gear may still have an impact on the benthos, especially by continuing to entrap marine life (i.e., “ghost fishing”).

Bottom trawl gear can cause direct impacts to benthic habitats through crushing, breaking, and removing rocks or animals, and disturbing the top layers of sediment that house infauna fish and invertebrates. The average number of trawl vessels operating in the sanctuary each year from 2010–2020 was eight (1.6 standard deviation) (CDFW, 2020), which is significantly less than the number of vessels commercially fishing with pots and hook and line. In 2020, new Essential Fish Habitat Conservation Areas were closed to bottom trawling in GFNMS, however, the Rockfish Conservation Area was opened, making more benthic habitat overall subject to bottom trawl impacts. As a result, benthic habitat protection decreased in 2020 because an additional 150.29 square miles of seafloor was opened to bottom trawling within GFNMS (NCCOS, 2020)(Figure S.P.3.5). This was primarily the result of opening the Rockfish Conservation Area and a redesign and modification that changed the size of Point Arena Biogenic Area South from 99.06 square miles to 36.09 square miles. For the majority of areas where bottom trawling is allowed, there is a lack of data on the types of habitat, including biogenic habitat (corals, sponges, sea pens and whips). Data is not yet available to indicate the extent of bottom trawling that has occurred thus far in the areas that were opened in 2020, so it cannot be assumed that there is trawling occuring in open areas.

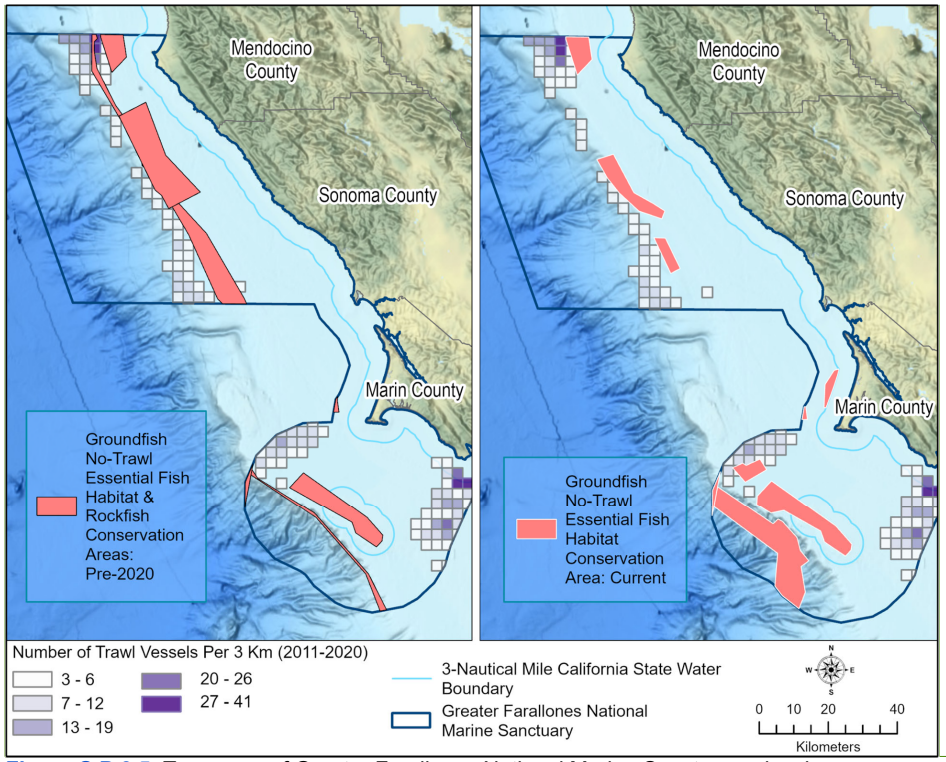

Figure S.P.3.5. Two maps of Greater Farallones National Marine Sanctuary, showing areas closed to bottom trawling prior to 2020 (left), and after 2020 (right). Also included in the maps are the number of trawl vessels per 3 kilometers from 2011 to 2020. Darker filled grid cells have higher numbers of trawl vessels. Image: NOAA; Source: NCCOS, 2020; Esri, 2020

Commented [17]: Note to reviewers: there is additional EFH area in the southwest portion of the sanctuary that is not currently shaded in this figure. This will be corrected prior to report finalization. Please note that the associated information stated in the text above is correct despite the error in this image.

Human Use at Coastal Reefs

Human use occurs at multiple intertidal reef locations throughout GFNMS, however, Duxbury Reef, which is designated by the state as a State Marine Conservation Area, remains the most easily accessible rocky intertidal reef within GFNMS. While it has a high level of use compared to other rocky intertidal sites in Marin County, it has a moderate to low level of visitor use in comparison to rocky reefs in southern California or San Mateo County. It is a sensitive intertidal habitat where trampling and collecting can cause long-term negative impacts to habitat and species. The Beach Watch project (see Box 2, Figure S.P.3.6) collects data on human activities along the shoreline of GFNMS, including Duxbury Reef.

Box 2: Beach Watch

Beach Watch is a public-private shoreline monitoring program that is run in partnership between GFNMS and Greater Farallones Association. Since 1993, the Beach Watch program has conducted bimonthly surveys along 40–65 beaches, spanning 210 miles (339 km) from Mendocino County to southern San Mateo County, including Bolinas Lagoon and Tomales Bay. Over the years, staff have partnered with over 10 institutions and agencies, including California

Department of Fish and Wildlife, National Marine Fisheries Service, California Academy of Sciences, and the National Park Service. Data are presented as encounter rates, number per kilometer surveyed and are best used to identify distribution, seasonality, and trends of organisms and activities along the shoreline, out to 300 m. The Beach Watch program has trained over 600 volunteers who collect data on coastal and estuarine wildlife and human activities including:

- Bird and mammal abundance and distribution along the coast,
- Species inventories in county, state, and national parks,
- Seasonal, relative abundance and distribution of beach wrack, an important shoreline biogenic (living structural) habitat,
- Marine debris entanglement,
- Early alerts of mortality events and changing conditions along the coast,
- Resources at risk from coastal human activities, such as disturbance and oil pollution,
- Predator-prey of breeding coastal birds and mammals, and
- Severity of impacts from oil pollution and boat groundings and length of time to restore lost ecosystem services.

Figure S.P.3.6. Beach Watch survey locations showing the central point of each beach survey segment. Image: NOAA; Source: Lindquist & Roletto, 2022a; Esri, 2020.

From 2015 through 2021, the average visitor rate to the rocky shore line of Duxbury Reef and Agate Beach was 2.5–7.7 people per km, with a peak average of 7.7 visitors/km in 2015 and an average low of 2.5 visitors/km in 2019, with a slightly decreasing trend during this study period (Lindquist & Roletto, 2022b). The numbers of people on the reef may be an indication of variable impacts such as trampling, collection, and disturbance impacts to the reef organisms.

Conclusion

This question was rated fair based primarily on the fact that marine debris has been found on sandy beaches in the region and floating and sunken throughout the sanctuary, trawling and crab fishing activities occur each year throughout large areas of sanctuary seafloor, and there is high human use at one rocky intertidal location in GFNMS. Floating debris on the surface, including out of season crab pots, plastic bags, bottles, floats, balloons, styrofoam, and wood debris, was sparse but present throughout the sanctuary. Sunken marine debris was documented in offshore habitats with the most common type of debris on the seafloor being fishing gear, especially crab pots, nets and lines. Approximately 150 square miles reopened to bottom trawling in GFNMS in 2020 thus decreasing the overall seafloor protections, but data is not yet available to determine if bottom trawling has occurred in those areas. High human use continued at Duxbury reef with a slight decline from 2015–2019. The trend for this question was undetermined based on a lack of information about the long term trends for a number of the indicators; some appear to be stable while others need more information to determine a trend. More data is needed on marine debris through the sanctuary, including beach debris, especially at coastal sites, and sunken marine debris across a larger area of seafloor to better determine trends over time.

References (Q3/Coastal and Offshore)

Bimrose, K., N. Van Leuvan, L. Highleyman, C. Tsai, K. Lindquist, S. Lippiatt, K. Reyna, and J. Roletto. (2020). A Behavior Change Campaign to Reduce Plastic Shotgun Wad Debris on the North-Central California Coast. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD. 77 pp.

California Department of Fish and Wildlife. (2020). California commercial landing receipt data, 1994-2020 [Data set]

California Department of Fish and Wildlife. (2023). Dungeness Crab Enhanced Status Report, https://marinespecies.wildlife.ca.gov/dungeness-crab/the-fishery/

Elliott, M., Lipski, D., Roletto, J., Warzybok, P., & Jahncke, J. (2022b). *Applied California Current Ecosystem Studies* [Unpublished data set]. Point Blue Conservation Science.

Etnoyer, P. J., G. Cochrane, E. Salgado, K. Graiff, J. Roletto, G. Williams, K. Reyna, and J. Hyland. 2014. Characterization of deep coral and sponge communities in the Gulf of the Farallones National Marine Sanctuary: Rittenburg Bank, Cochrane Bank and the Farallon Escarpment. NOAA Technical Memorandum NOS NCCOS 190. NOAA National Centers for Coastal Ocean Science, Charleston, SC. 32 pp.

Graiff, K., J. Roletto, S. Tezak, G. Williams, and G. Cochrane. 2021. Characterization of deep-sea coral and sponge communities in Greater Farallones National Marine Sanctuary: Point Arena South Essential Fish Habitat Conservation Area and New Amendment 28

Areas. National Marine Sanctuaries Conservation Science Series ONMS-21-03, San Francisco, CA. 42 pp.

Graiff, K., D. Lipski, P. Etnoyer, G. Cochrane, G. Williams, E. Salgado. 2016. Benthic Characterization of Deep-Water Habitat in the Newly Expanded Areas of Cordell Bank and Greater Farallones National Marine Sanctuaries. Marine Sanctuaries Conservation Series ONMS-16-01. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD. 38 pp.

Greater Farallones National Marine Sanctuary. (2022). *Emergency response incidents, 2010–2021: Supplementary data* [Unpublished data set]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of National Marine Sanctuaries.

Hutto, S. H., Hohman, R., & Tezak, S. (2021). Blue carbon in marine protected areas: Part 2; A blue carbon assessment of Greater Farallones National Marine Sanctuary. National Marine Sanctuaries Conservation Series ONMS-21-10. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries.

Kaiser, MJ, JS Collie, SJ Hall, S Jennings and IR Poiner. 2001. Impacts of fishing gear on marine benthic habitats. *In* Reykjavik Conference on Responsible Fisheries in the Marine Ecosystem. Reykjavik, Iceland: FAO.

Lindquist, K., and Roletto, J. (2022b). *Beach Watch database: Supplementary data* [Unpublished data set]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of National Marine Sanctuaries, Greater Farallones National Marine Sanctuary & Greater Farallones Association.

Marine Stewardship Council (MSC). 2010. MSC Public Certification Report Oregon Dungeness Crab Fishery. Scientific Certification Systems.

McKenna, M., Wiggins, S. & Hildebrand, J. Relationship between container ship underwater noise levels and ship design, operational and oceanographic conditions. Sci Rep 3, 1760 (2013). https://doi.org/10.1038/srep01760

National Centers for Coastal Ocean Science. (2020). Vessel monitoring system data [Unpublished data set]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service.

NOAA. (2020). MDMAP Database. Owner: Marine Debris Program, Office of Response and Restoration, National Ocean Service, National Oceanic and Atmospheric Administration. https://mdmap.orr.noaa.gov. Accessed January 19, 2023.

NOAA. (2023). Marine Debris Program website. Accessed January 20, 2023. https://marinedebris.noaa.gov/discover-marine-debris/what-marine-debris.

Pacific Fishery Management Council (PFMC). 2013. Pacific Coast Fishery Ecosystem Plan for the U.S. Portion of the California Current Large Marine Ecosystem. Public Review Draft.

Pacific Marine Fisheries Commission (PMFC). 1978. Dungeness crab project of the state federal fisheries management program. PMFC, Portland, Oregon. 335p.

U.S. Coast Guard Marine Information for Safety and Law Enforcement (USCG MISLE (2022). Marine Information for Safety and Law Enforcement, Casualty and Pollution Incidents. https://cgmix.uscg.mil/psix/

Estuarine and Lagoon Region (Q3)

Status Rating: Fair	Status Confidence: Medium
Trend Rating: Undetermined	Trend Confidence: Medium
Status Description: Selected activities have caused measurable resource impacts, but effects are localized and not widespread or persistent.	
Rationale: There is limited information on specific human activities that may adversely impact estuarine and lagoon habitat in GFNMS. Ratings were based on a limited number of relevant indicators for which information was available in Tomales Bay, including moorings, marine debris, and clamming. Removal of moorings from eelgrass beds since 2016 seems to be improving eelgrass habitat. Marine debris is present in Tomales Bay and has not changed despite some removal efforts. Clamming activities continue to occur, though data on the extent of most of these activities are limited; based on the cessation of chartered boat trips to the mudflats of Tomales Bay for clamming, this activity has likely decreased. The Esteros and Bolinas Lagoon are data poor for both status and trend for all key indicators.	

Findings From the 2010 Condition Report

In the 2010, the status was fair and the trend appeared stable for habitat integrity in estuaries. Measurable habitat impacts related to urbanization and poor land use practices were continuing to occur, but evidence suggested effects were localized, not widespread. However, impacts on eelgrass and the presence of marine debris in Tomales Bay were not considered in the 2010 condition report.

New Information in the 2010–2022 Condition Report

Since 2010, a substantial amount of data has been collected on eelgrass in Tomales Bay but no new eelgrass surveys have been done in Bolinas Lagoon or the esteros. The sanctuary has also been closely tracking data on moorings in Tomales Bay through the Tomales Bay Mooring Program (TBMP). Information that was considered for the current assessment includes moorings, marine debris, and impacts from recreational clamming in Tomales Bay (Table S.P.3).

Table S.P.3. Summaries for the key indicators related to human activities that impact habitat in the estuarine and lagoon region that were discussed during the May 17, 2022 virtual status and trends workshop.

Indicator	Data Source/data visualization	Habitat	Data Summary	Figure
Moorings	GFNMS, 2022b; Merkel and Associates, 2015; Merkel and Associates, 2017; R. Feris, Personal communication, 2023	Estuarine & Lagoon	Status: In Tomales Bay, in 2016, 71 moorings and 3 docks were removed from eelgrass beds and in 2022 there were no moorings in eelgrass beds. A small number of moorings exist in Bolinas Lagoon with no change since 2010. There are no known moorings in the Esteros. Trend: Conditions appear to be stable in Bolinas Lagoon and improving in Tomales Bay. The trend is undetermined in the Esteros due to a lack of data.	Figure S.P.3.7
Marine Debris	GFNMS, 2022; GFNMS, 2022b	Estuarine & Lagoon	Status: Marine debris has been documented in Tomales Bay. Bolinas has had some marine debris incidents; there is no data for the Esteros. Trend: The trend is stable in Tomales Bay and Bolinas Lagoon but undetermined in the Esteros due to a lack of data.	
Recreational Activities: Clamming in Tomales Bay		Estuarine & Lagoon	Status: There are no data about current use. Trend: Clamming activities have likely decreased. The trend is likely slightly improving for the study period (2010–2022).	
Data Gaps	More data is needed on human activities in all estuaries that can be correlated with changes in habitat integrity, such as clamming, marine debris, or boating activities. More data is needed on the impacts from other recreational fishing activities that may occur in the estuaries, especially Tomales Bay.			

Moorings

Since the 2010 condition report, Tomales Bay continues to be a popular boating location for vessels that are permanently moored or anchored on the bay or transported to the bay from other locations for day use. While overall boat use in the bay appeared to be increasing, the number of private vessels permanently moored in the bay decreased significantly since 2010 (GFNMS, 2022b). If not properly designed and sited, moorings can disrupt the marine ecosystem by altering or destroying seafloor habitat, such as eelgrass beds. Moorings can damage habitat if anchors or chains are abandoned on the seafloor as marine debris (GFNMS, 2013).

Up to 130 unpermitted vessel moorings of various materials and sizes existed in Tomales Bay as recently as June 2016, some of them in sensitive habitats throughout Tomales Bay (GFNMS, 2013). Since 2016, 71 abandoned mooring systems, 3 moored docks, and 3 abandoned vessels have been removed from the bay or relocated outside of eelgrass beds, preventing the potential

for additional habitat damage from anchor blocks and chain scour and/or the release of marine debris (GFNMS, 2022b).

A small number of moorings exist in Bolinas Lagoon (personal communication with Rudi Feris, September 26, 2023). Moorings are not known to exist in either of the Esteros.

Prior to the introduction of the Tomales Bay Mooring Program, in 2015, there were numerous incidents of vessels breaking loose from their moorings in the bay and causing damage to habitats, other vessels, and manmade structures. Since 2017, when mandatory inspections and maintenance of vessel moorings were enacted, vessels separating from their moorings and causing impacts to habitat or personal property have not been reported. However, there have been several incidents of vessels at anchor breaking loose and causing damage (GFNMS, 2022b). For example, in 2019 the F/V *Marian* broke free of its anchor and damaged approximately 82.66 m² of eelgrass habitat (USEPA, 2021).

Marine Debris

Known marine debris (both land-sourced and marine-sourced debris) of various weights, shapes, and sizes are found throughout Tomales Bay, and that has not changed since the 2010 condition report. Hundreds of large truck tires were submerged off Marconi Cove as breakwaters in the 1960s (F. Vilicich/mooring contractor, personal communication, September 26, 2022). The estimated length of the northern group of tires is at least 50–60 feet and the tires are clumped together, five tires wide (laid flat) and three tires on edge underneath (Merkel, 2015). The length of the southern group is less than 30 feet. Additional marine debris in the bay has been observed, but only documented in photos or sidescan sonar data (Merkel, 2015), and includes a large steel frame, several abandoned creosote pilings, and numerous other pieces of submerged waste left by abandoned aquaculture facilities throughout the bay.

Land-sourced marine debris that has been removed from Tomales Bay since 2010 includes cars, vessels, a fence, and a berm constructed to divert water for aquaculture purposes. A local citizen has also documented an extensive amount of debris in the bay, including plastic zip ties, mesh bags, and other land-sourced debris resulting from aquaculture operations, and has worked since 2014 (or possibly earlier) with aquaculture operators and independently to remove it (The Coastodian, 2023). Two cars crashed into Bolinas Lagoon in 2014 which were removed (GFNMS, 2022.)but habitat damage occurred as a result of the incidents. There is no information on the long-term impacts or recovery of the areas of impact from the incidents.

Recreational Activities: Clamming

Clamming in Tomales Bay occurs on the mudflats when the tide is 0.5 feet or lower (Lawson's Landing Website, 2022). Clam diggers harvest gaper clams, geoducks, littlenecks, basket cockles and Washington clams (ONMS, 2010). While clamming has been a popular activity in the bay for many decades, its extent has decreased since the conservation measures by Lawson's Landing and California Department of Fish and Wildlife were implemented prior to 2010 and the cessation of chartered boat trips from Lawson's Landing to the mudflats in 2000. These actions may have decreased harvesting of bivalve mollusks, such as clams. There are no data on the status and trend of this activity.

Conclusion

The status rating for this question is fair based on a decrease in unpermitted moorings and the continued presence of marine debris in Tomales Bay, which does not appear to have changed since the last condition report, although some debris has been removed. Most marine debris was not quantified and documentation was limited to photos. Recreational clamming activities

continue to occur. The trend was undetermined due to the need for more information on marine debris and fishing, although it appears that levels of recreational clamming in Tomales Bay are lower than historical levels.

References (Q3/Estuarine and Lagoon)

Greater Farallones National Marine Sanctuary (GFNMS). (2013). *Tomales Bay Vessel Management Plan*. https://nmsfarallones.blob.core.windows.net/farallones-prod/media/archive/eco/tomales/pdf/tbvmp_ea-is_final-8-27-2013-WM.pdf

Greater Farallones National Marine Sanctuary (GFNMS). (2021). *Tomales Bay Mooring Program Requirements (Policies and Criteria)*.

Greater Farallones National Marine Sanctuary. (2022). *Emergency response incidents, 2010–2021: Supplementary data* [Unpublished data set]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of National Marine Sanctuaries.

Greater Farallones National Marine Sanctuary (GFNMS). (2022b). GFNMS Tomales Bay Mooring Program Records and Database.

Lawson's Landing Website. (2022). Retrieved December 10, 2022, from https://www.lawsonslanding.com/

Merkel & Associates, Inc. (Merkel). (2015). *Tomales Bay Eelgrass Habitat Evaluation and Site Monitoring in Areas Affected by Vessel Moorings, Tomales, Bay, CA.*

Merkel & Associates, Inc. (Merkel). (2017). *2017 Tomales Bay Eelgrass Inventory, Tomales Bay, CA.*

Office of National Marine Sanctuaries (ONMS). (2010). *Gulf of the Farallones National Marine Sanctuary Condition Report 2010*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD. 97 pp.

The Coastodian. (2023). https://coastodian.org/. Website accessed, May 10, 2023. Multiple blog posts from 2014-2022 documented debris removal in Tomales Bay.

U.S. Environmental Protection Agency. (2021). *Roy Harper* ALJ Ruling No. NW1902615, *F/V Marian* (US EPA, November 30, 2021).

Question 4: What are the levels of human activities that may adversely influence living resources and how are they changing?

Coastal and Offshore Region (Q4)

Status Rating: Fair	Status Confidence: High

Trend Rating: Mixed	Trend Confidence: High
Status Description: Selected activities have caused measurable living resource impacts, but effects are localized and not widespread or persistent.	
Rationale: Some potentially harmful activities exist, such as vessel activities, trap and line fisheries, and municipal dumps. Vessel activities and trap fisheries in particular could potentially impact the recovery of listed species through vessel collisions and entanglement. These activities do not appear to have substantially changed but instead, there has been a change in distribution of whales, placing them at greater risk of ship strikes and entanglements. The commercial Dungeness trap fishery was stable in the first half of this study and experienced declined efforts in the later half of this study, while the recreational crab fishery slightly increased during this study period. Entanglements in trash and fishing gear of some species have increased over the past 10 years, while other impacts have declined. Illegal oil discharges from vessels occurred but it appears that the levels are so low that they have not significantly impacted wildlife. Tarball deposition rates are very low and are declining. Tarballs from human activities were not detected. Activities known to disturb wildlife, such as aircraft flights, humans on foot, dogs, and motorized vessels were low. In recent years shoreline activities appear to be slightly increasing; however, disturbance levels do not appear to be reducing wildlife abundance in the sanctuary.	

Commented [18]: This is a fairly "in the know" term...might want to say listed threatened and endangered species.

Findings From the 2010 Condition Report

In 2010, the status for this question was fair and conditions were not changing. The rating was based on impacts from increased urbanization and use of coastal areas. Vessel traffic impacts (discharges and noise) and wildlife disturbances were increasing, but this was offset by reductions in trawling, fishing pressure, and establishment of new marine zones.

New Information in the 2010–2022 Condition Report

A direct comparison of status and trends to the 2010 condition report is not possible because the sanctuary expanded in 2015, during the time period for this assessment. The expansion added new areas and habitats that were not assessed in the 2010 condition report. Indicators for this question included distance traveled by large vessels greater than 300 gross tons, confirmed ships strikes, commercial fishing gear and whale entanglements, entanglements of pinnipeds and seabirds in trash and fishing gear, wildlife disturbance, and oil pollution (Table S.P.4.1).

Table S.P.4.1. Summaries for the key indicators related to human activities that impact living resources in the coastal and offshore region that were discussed during the July 11, 2022 virtual status and trends workshop.

Indicator	Source	Data Summary	Figures & Tables
Vessel Traffic and Ship Strikes	BOEM & NOAA, 2022; NOAA Fisheries, 2022; NOAA Fisheries, 2020; Rockwood et al., 2017;	Status: High numbers of large vessels transited the sanctuary and confirmed ship strikes occurred annually in the region, which may be impacting recovery of endangered and threatened whale populations.	Figure S.P.4.1; Figure S.P.4.2

	Rockwood et al., 2020; Vanderlaan & Taggart, 2007; Santora et al., 2020; Elliott et al., 2022b	Trend: Numbers of large vessels slightly decreased, the distance traveled decreased, and speed decreased. Confirmed ship strikes increased in the region.	
Benthic Traps and Entanglement	Scholz et al., 2004; NOAA Fisheries, 2020; Rockwood et al., 2020; Elliott et al., 2022b; Santora et al., 2020; Ingman et al., 2021; CDFW, 2020a	Status: Dungeness crab gear is common in GFNMS and the surrounding region; entanglement of whales occurred annually and may be impacting recovery of endangered and threatened whales. Trend: The commercial Dungeness trap fishery was stable in the first half of this study and experienced declined efforts in the later half of this study and the recreational fishery slightly increased during this study period. The amount of spatial and temporal overlap of the commercial Dungeness crab fishery and foraging humpback whales has increased.	Figure S.P.4.3; Figure S.P.4.4
Trash and Entanglement	Lindquist & Roletto, 2022b; Warzybok, 2022; Shaffer et al., 2017	Status: Entanglements occur primarily to California and Steller sea lions from fishing gear, and western gulls from trash but are not impacting population levels in the sanctuary. Trend: It appears that wildlife entanglements are decreasing.	Figure S.P.4.5; Table S.P.4.3; Figure S.P.4.6
Wildlife Disturbance: Birds	GFNMS-SPN, 2022; Lindquist & Roletto, 2022a; Lindquist & Roletto, 2022b,	Status: Disturbance to birds occurred primarily from low flying aircraft, but does not appear to be impacting population levels or bird use of the sanctuary. Trend: Reports of disturbances to birds appear to be stable or declining.	Figure S.P.4.7
Wildlife Disturbance: Harbor Seals	Codde, 2020	Status: Disturbance to harbor seals from humans, dogs, and motorized vessels occurred, but does not appear to be impacting population levels or harbor seal use of the sanctuary. Trend: Harbor seal disturbance reports were stable with a recent increase at one location but lower than in the previous decade.	Figure S.P.4.8

Vessel Traffic: Oil Pollution	USCG MISLE, 2022; Lindquist & Roletto, 2022b; OSPR, 2021; Santora et al., 2020; Gulland et al., 2022	Status: Small amounts of oil pollution from vessels occurred. Tarballs occurred at very low rates on sanctuary beaches. Most are likely from natural sources. Rates of oiled wildlife were very low. Trend: Oiled wildlife and tarball deposition rates declined.	Figure S.P.4.1; Figure S.P.2.2
Data Gap: There is a lack of data pertaining to human activities that can be correlated with changes in biodiversity or densities of wildlife. More analyses of available data are needed for vessels transiting the sanctuary, data categorized by type, vessel speeds, and rates of vessel discharges. Data on vessel speeds and types near the entrance to San Francisco Bay are particularly needed due to the eastward/nearshore shift of whales and their prey species. Quantification of people of rocky reefs and the impacts of trampling tide pooling and extraction, are needed. There are limited data on the percent of human activities that elicit disturbance behaviors (e.g., tide pooling, extraction, low flying motorized aircraft, jet skis, boating activities), making it difficult to determine the severity of the activities. There is limited data on the amount of oil pollution released when vessels are grounded or sink. More data is also needed on noise impacts to living resources in GFNMS.			

Commented [19]: there is the radar/ais unit east of Pt Bonita, data on all ships is kept by Anthropocene and is available, its been there about 2-3 years now

Vessel Traffic and Ship Strikes

Vessel traffic impacts living marine resources through ship strikes to whales. The risk of fatal ship strikes to whales is influenced by the number, size, and speed of vessels, and how much vessel traffic overlaps with preferred whale habitat. Annually, from 2016–2020, 834–2,003 vessels transited through the sanctuary. The number of large vessels (>300 gross tons) transiting the sanctuary and within the traffic separation scheme varied each year, from 2016–2020, with the highest in 2016 (n = 1,243) and the lowest in 2020 (n = 942; Bureau of Ocean Energy Management [BOEM] & NOAA, 2022; see Figure SS.1 in the Sanctuary Setting chapter for a map of shipping lanes). In 2019 and 2020, the majority of large vessels were cargo carriers (1,988), tank vessels (852), and tug tow vessels (108) (BOEM & NOAA, 2022). The distance large vessels traveled through the sanctuary decreased slightly from 2016–2020 (BOEM & NOAA, 2022; Figure S.P.4.1).

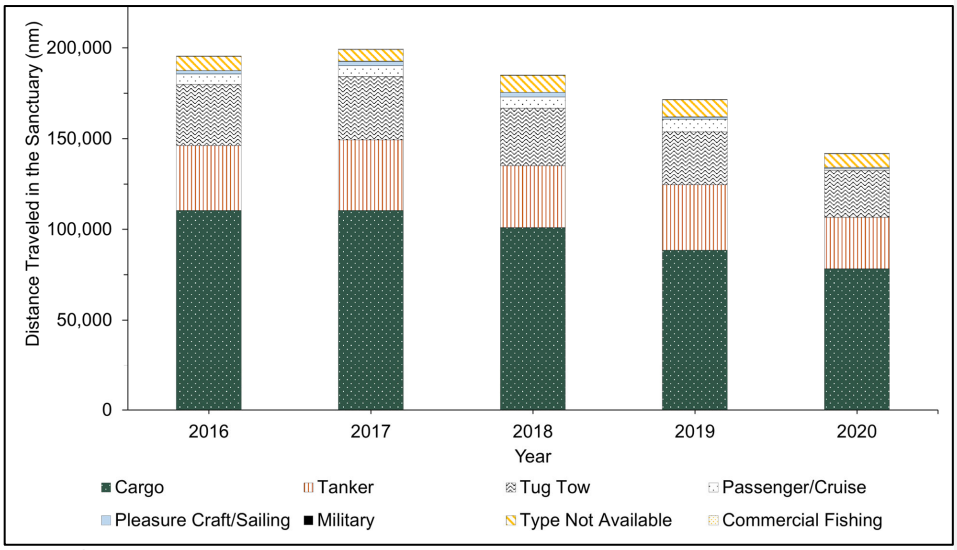

Figure S.P.4.1. Total distance traveled by vessels greater than 300 gross tons that transit through GFNMS from 2016–2020. Source: BOEM & NOAA, 2022

Vessel speed is used as a proxy for increased risk of lethal ship strikes on baleen whales. As vessel size and speed increases, lethality of a vessel striking a whale increases (Vanderlaan & Taggart, 2007; Rockwood et al., 2017). Overall, the mean speed for large vessels ≥300 GT declined between 2009–2016 (BOEM & NOAA, 2022).

Even though vessel speeds declined, there has been an increase in the number of whales confirmed by necropsy to have been killed by vessel collisions between 2010–2019 (Moore et al., 2018), possibly influenced by compressed forage habitat (i.e., habitat compression) and increased co-occurrence of ships and foraging areas of humpback whales (Rockwood et al., 2020) during and following the 2014–2016 marine heat wave (MHW). For more information regarding how habitat compression influences water quality, thus the redistribution whales and their forage species distribution whales, see this Condition Report questions #8 and #13 (Figure S.P.4.2, NOAA Fisheries, 2022). Ship strikes may be impacting recovery of endangered and threatened whales (Rockwood et al. 2017; NOAA Fisheries, 2020).

Commented [20]: should reference Santora here https://doi.org/10.1038/s41467-019-14215-w

Commented [21]: The increase in # of whales struck comes with an inherent assumption that the capacity for reporting/tracking/assessment of whale strikes has remained constant throughout the period...yes? If the ability to track/assess has increased in, say, 2015, that would need to be considered?

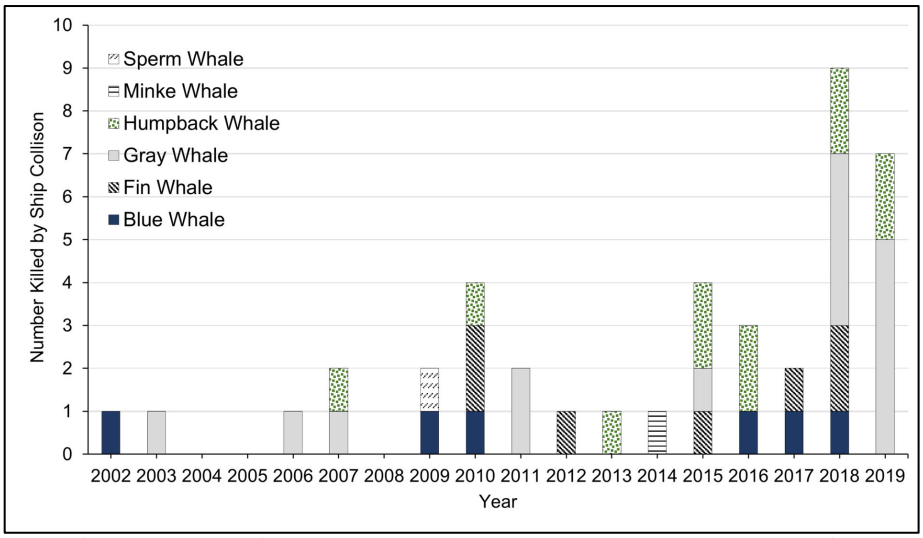

Figure S.P.4.2. Number of whales confirmed to have been killed by vessel collisions from 2002–2019 in or adjacent to GFNMS. Data from 2020 and 2021 were not included due to a reduction in necropsies performed during the pandemic. Source: NOAA Fisheries, 2022

Benthic Traps and Entanglement

Entanglement in fishing gear is a significant threat to marine wildlife. Approximately ~~approximately~~ 29,200-83,500 commercial Dungeness crab traps are set on the seafloor each year in GFNMS (CDFW, 2020a), with an average density of 0.3 traps/sq km, ranging from 0.1-0.4 traps/sq km (Elliott et al., 2022b). Entanglement of whales in Dungeness crab gear occurred annually in the region and may be impacting recovery of endangered and threatened whales. Baleen whales are particularly vulnerable to entanglement because of their habitat use and behavior; humpback whales continue to be the most common species entangled (NOAA Fisheries, 2020; Figure S.P.4.3). Note that during the COVID-19 pandemic, efforts to investigate entanglements were greatly reduced. Dungeness crab gear is the most common fishing gear found in whale entanglements. The area of the Dungeness crab commercial fishery in GFNMS was consistent from 2010–2020 (Figure S.P.4.4), while the effort was stable in the first half of this study and effort declined in recent years (CDFW, 2020a). However, in the past several years the main foraging area of humpback whales shifted from being primarily at the shelf break (100-200 m contour) to the east, across shallower waters and closer to the mainland (i.e., habitat compression). This redistribution of whales, meant there was increased co-occurrence of whales with the commercial Dungeness crab fishery across the shelf (Elliott et al., 2022b; Santora et al., 2020), increasing the risk of entanglements of humpback whales (Santora et al., 2020). There was a peak in fishing gear related whale entanglement during the 2014–2016 MHW, when habitat compression occurred.

Commented [22]: This does not seem like an accurate range...I'm not out on the water often but is the upper range really 0.4 traps per sq kilometer? I'm guessing that a line of 8-10 crab pots doesn't extend more than a km...

Commented [23]: reference Ingman et al

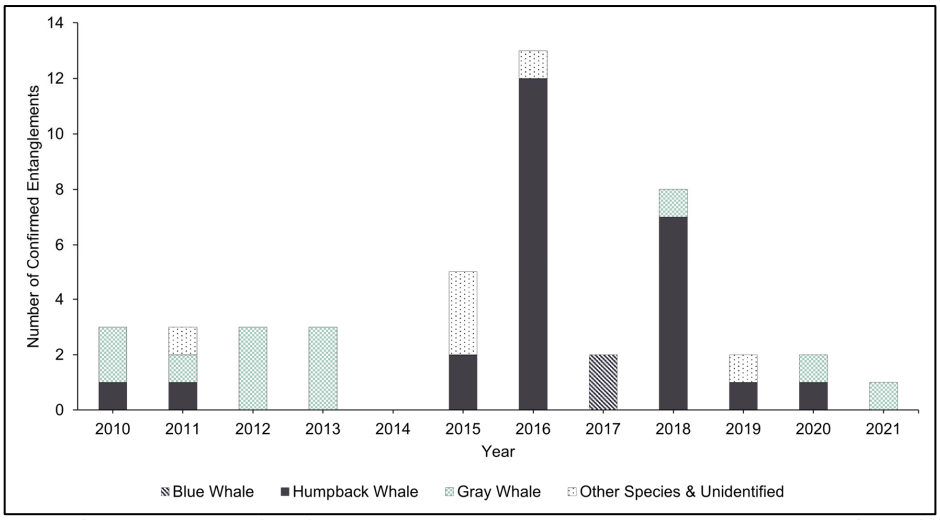

Figure S.P.4.3. Number of confirmed entanglements by species within and adjacent to GFNMS, from 2010–2021. Note that during the 2020-2021 pandemic, efforts to investigate entanglements were greatly reduced. Source: NOAA Fisheries, 2020

Commented [24]: Similar to comment above...otherwise (besides pandemic), capacity for investigate entanglements has remind steady throughout the period?

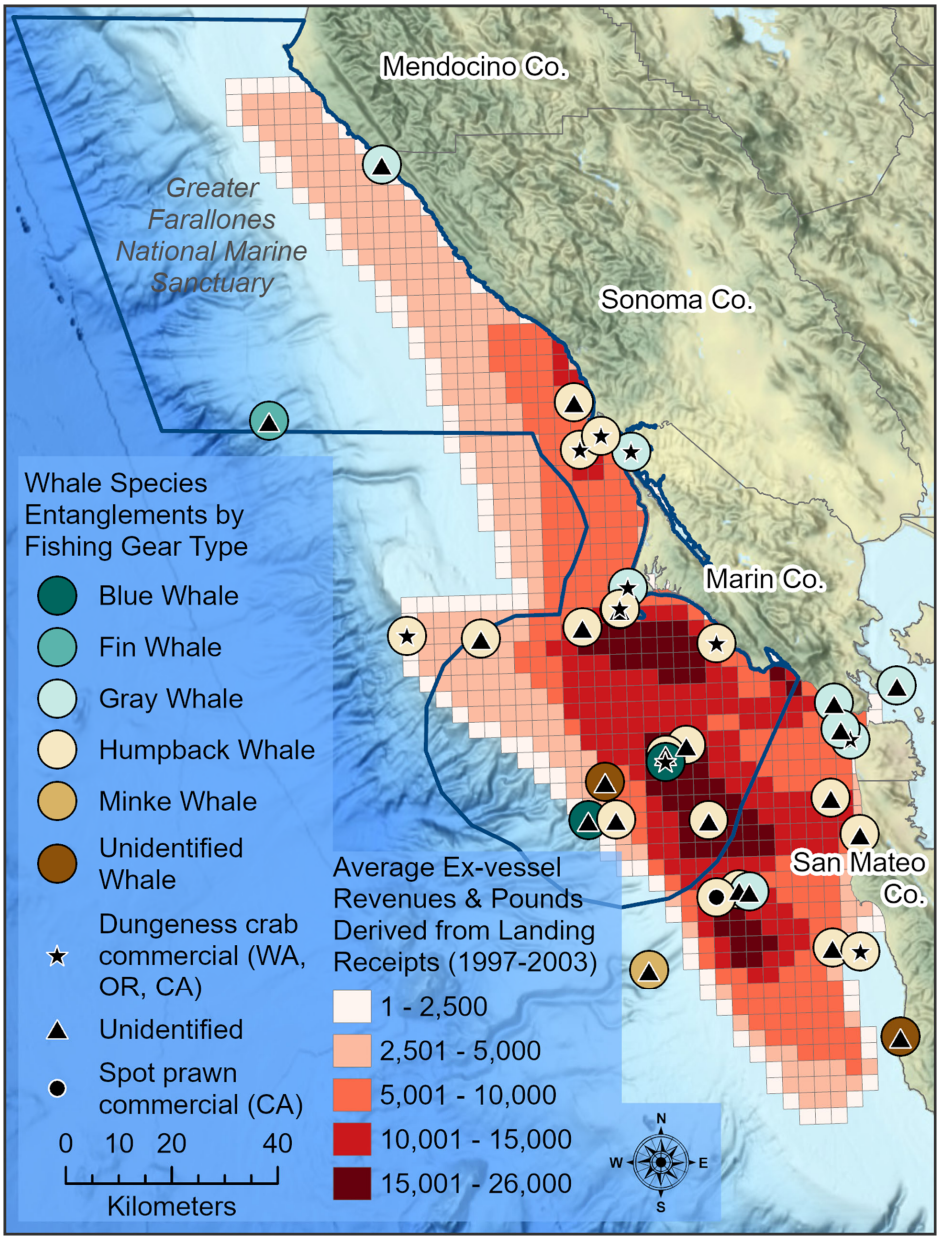
Mendocino Co.
Greater Farallones National Marine Sanctuary
Sonoma Co.
Marin Co.
San Mateo Co.
Whale Species Entanglements by Fishing Gear Type
Blue Whale
Fin Whale
Gray Whale
Humpback Whale
Minke Whale
Unidentified Whale
Dungeness crab commercial (WA, OR, CA)
Unidentified
Spot prawn commercial (CA)
0 10 20 40
Kilometers
Average Ex-vessel Revenues & Pounds Derived from Landing Receipts (1997-2003)
1 - 2,500
2,501 - 5,000
5,001 - 10,000
10,001 - 15,000
15,001 - 26,000
N
W
E
S

Figure S.P.4.4. Areas of commercial Dungeness crab catch and observations of entangled whales (2010–2021). Map adapted from: Scholz et al., 2004; entanglement data from NOAA Fisheries, 2020. Image: NOAA; Source: Scholz et al., 2004; NOAA Fisheries, 2020; Esri, 2020

In addition to a shift in spatial distribution of whales, there was a shift in the timing of arrival of whales to forage in GFNMS. ~~On average, i~~In comparison to 1993, humpback whales in 2017 arrived 120 days earlier, thus increasing the number of days whales were present in the sanctuary during the commercial Dungeness crab fishery, which generally takes place November 15–June 30 (Ingman et al., 2021). In some seasons (e.g., 2015–2016 season), the opening of the fishery was delayed as a result of the presence of domoic acid. The delay meant that the highest levels of fishing activity occurred later in the spring when more whales were present and subsequently there were high levels of entanglement (Table S.P.4.2; Figure S.P.4.4). Observations of dead whales reported to have been entangled in fishing gear occurred throughout the central California region but were concentrated within the Gulf of the Farallones region.

Commented [25]: Delays due to domoic adic push back the opening in the fall...sometimes to the winter, but I'm not sure it has ever pushed it back to the spring...Highest levels of fishing (I'm guessing here) is when the season opens...which again, I don't think is in the spring...

Entanglements may be impacting recovery of endangered and threatened whales (NOAA-SWFSC, 2022). Efforts to reduce the risk were underway during the time period of this report. There were efforts to disentangle humpback whales along the West Coast through the Large Whale Entanglement Response Network coordinated by NOAA (NOAA Fisheries, 2020). In addition, the Risk Assessment and Mitigation Program California Dungeness Crab Fishing Gear Working Group worked to reduce timing of the overlap of the Dungeness crab fishery with whales and modify fishing gear to reduce the risk of entanglement (CDFW, 2022). In recent years, the opening of the commercial Dungeness crab fishery was delayed twice and closed early three times due to the increased risk of entanglements (Table S.P.4.2).

Table S.P.4.2. Bolded dates denote years when the Dungeness crab fishery opening was delayed or there was an early closure due to the presence of humpback whales and increased risk of entanglement in the Gulf of the Farallones region. Source: Pacific States Marine Fisheries Commission, 2022; CDFW, 2022

Commented [26]: Note to graphic designer: Please retain bolding in table.

Commented [27]: great, i was just going to ask about this..

Season	Date Commercial Fishery Opened	Reason for Delay	Date Commercial Fishery Closed	Reason for Early Closure
2010–2011	15-Nov		30-Jun	
2011–2012	15-Nov		30-Jun	
2012–2013	15-Nov		30-Jun	
2013–2014	15-Nov		30-Jun	
2014–2015	15-Nov		30-Jun	
2015–2016	**30-Mar**	Domoic Acid	30-Jun	
2016–2017	15-Nov		30-Jun	
2017–2018	15-Nov		30-Jun	
2018–2019	15-Nov		**15-Apr**	Entanglement Risk

2019–2020	**15-Dec**	Regional Entanglement Risk & Regional Domoic Acid	**15-May**	Entanglement Risk
2021–2022	**18-Jan**	Entanglement Risk	**8-April**	Entanglement Risk

Trash and Entanglement

Entanglement is also a risk to other sanctuary wildlife, such as pinnipeds and seabirds, which can become entangled in fishing gear, debris, and trash (Figure S.P.4.5). Data from the primary breeding grounds on Southeast Farallon Island (SEFI), showed that a total of 1,020 entangled birds and mammals were observed between 2013 and 2021. A peak in entanglement occurred in 2014, and the lowest numbers were observed in 2018, but entanglements increased again from 2019–2021, indicating a variable trend (Warzybok, 2022 The vast majority were California sea lions (n=867), Steller sea lions (n=75), and Western Gulls (n=31). Mainland shoreline surveys of dead birds and mammals, 2010–2019, indicated a wide variety of types of entanglements (e.g., fishing line, hooks, monofilament nets, packing straps, plastic bags, toys, trash). Data from biweekly Beach Watch surveys (see Box 2, Figure S.P.3.6) indicated entanglement rates of 0.004 birds/km surveyed and 0.0002 mammals/km surveyed. On the mainland beaches, common murres, cormorants, western gulls, loons, grebes, and sea lions were documented with entanglements (Linquist & Roletto, 2022b).

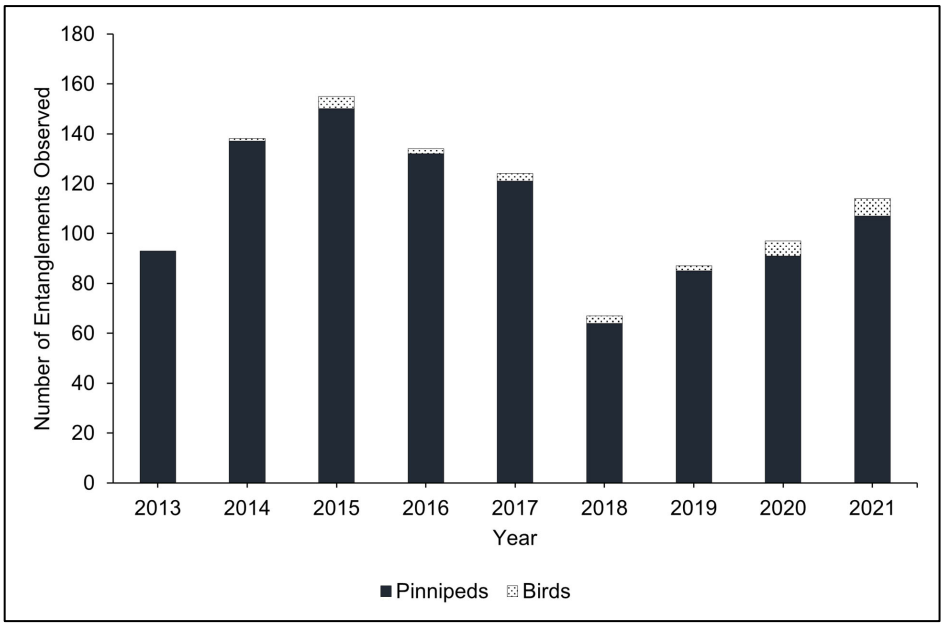

Figure S.P.4.5. Number of pinnipeds and birds observed with entanglement on SEFI from 2013–2021. Source: Warzybok, 2022

Wildlife are entangled in a wide variety of fisheries-related and non-fisheries related materials (Table S.P.4.3). At SEFI, pinnipeds were primarily entangled in materials associated with sport and commercial fishing (Warzybok, 2022). Gulls were primarily entangled in trash, likely from municipal dumps and recycling facilities that are within a one-day flight range. There are 36 municipal waste and recycling facilities in the vicinity of the typical flight distance of gulls to/from SEFI (Figure S.P.4.6). Tracking studies found that during the breeding season western gulls forage closer to SEFI than other times of the year, staying within 33 miles (53 km), and that 30% of western gulls' foraging trips were to landfills. Outside of the breeding season they may forage further. Favored landfills were the Recology facility in South San Francisco, Waste Management in Oakland, and City of Santa Cruz Resource Recovery Center (Warzybok, 2022; Shaffer et al., 2017; Figure S.P.4.6). It does not appear that entanglements are impacting population levels of seabirds or pinnipeds in the sanctuary.

Table S.P.4.3. Types of materials entangling birds and pinnipeds on the South Farallon Islands, 2010–2021. Unknown means the observer could not see or determine the type of material. Other fishing related materials included lures, hooks, lines and/or rope. All Other Materials included plastic and rubber straps, fabrics, 6-pack holders, balloons, plastic toys, trash, or wires. Source of materials is not documented. Source: Warzybok, 2022

Material	Count
Unknown	465
Monofilament	359
Other Fishing Related Materials	59
Plastic Strap	57
Rope	41
All Other Materials & Trash	68

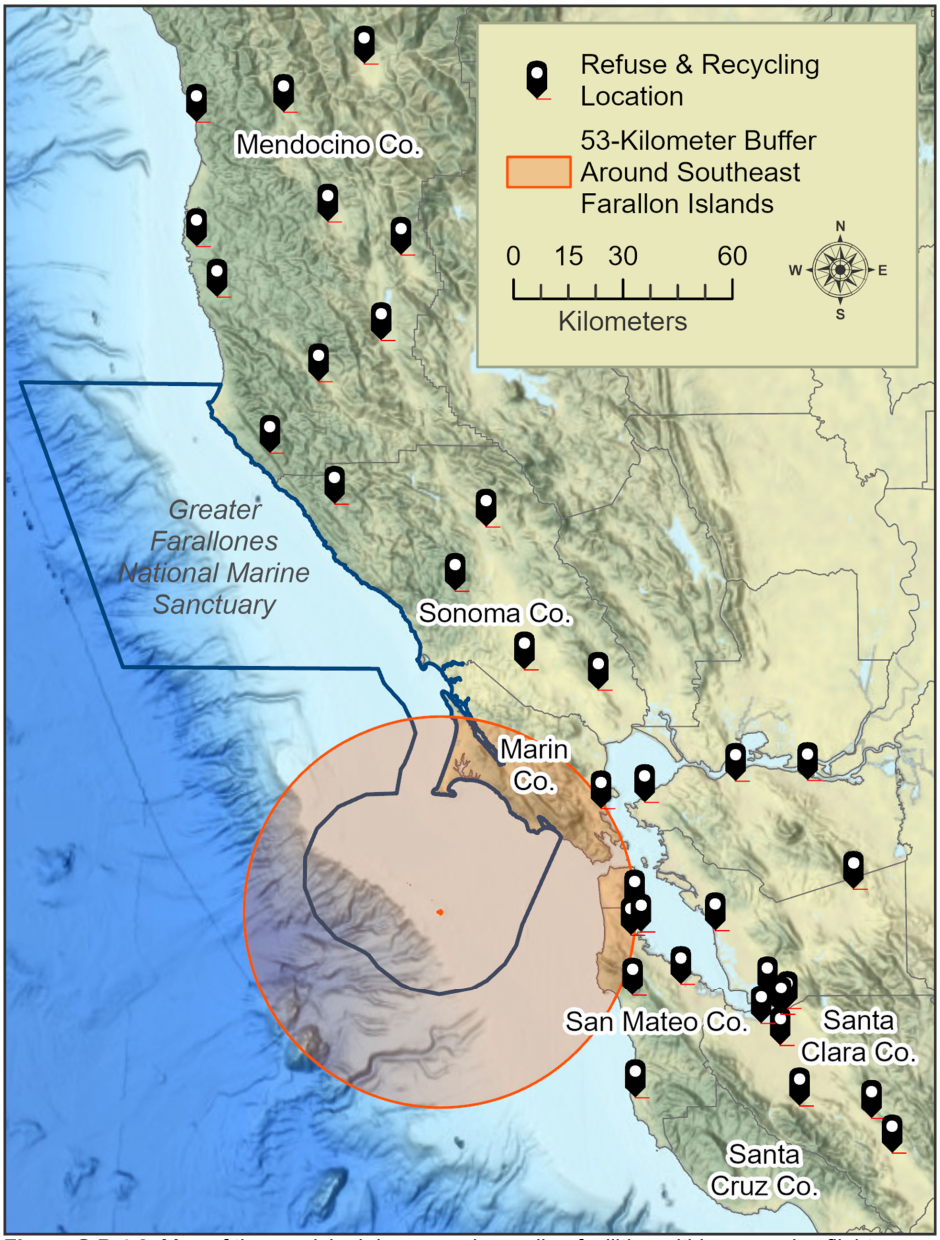

Figure S.P.4.6. Map of the municipal dumps and recycling facilities within a one-day flight range (30 miles, indicated by orange circle) of western gulls during their breeding period. Flight range

is extended in the non-breeding season. Image: NOAA; Source: Adapted from Shaffer, 2017; Esri 2020.

Wildlife Disturbance

The co-occurrence of human activities and wildlife can cause disturbance, which can disrupt feeding, resting, breeding, and nesting behavior, cause stress, and expose wildlife to predators (Lindquist, 2022). Disturbance events of seabird and harbor seals, both abundant in the sanctuary, were selected as indicators for this question. The seabird breeding colony at the South Farallon Islands is the densest population of breeding seabirds in the continental U.S. and at least 20% of California's harbor seals breed in the Gulf of the Farallones region (Codde, 2020; NOAA-SWFSC, 2022). Disturbance data for the coast and open ocean were collected by two projects in the sanctuary: 1) the Seabird Protection Network (GFNMS-SPN), which catalogs reports of wildlife disturbances from researchers on the Farallon Islands, Beach Watch surveyors, (see Beach Watch project description in Q3), and ad hoc reports from the public; and 2) the harbor seal monitoring program led by staff from PRNS (Codde, 2020). Of the 78 reports of wildlife disturbances the sanctuary received from 2012–2021, 53 were associated with low flying aircraft. Most of the wildlife disturbance events reported to GFNMS were medium or large incidents, impacting 10–1,000 individuals. Bird disturbance reports appeared to be stable or declining (GFNMS-SPN, 2022). Data from Beach Watch surveys indicated that human activities and the presence of dogs, which may affect the presence of shorebirds, has been stable or decreasing until recent years (2018-2019; Lindquist & Roletto, 2022a; Lindquist & Roletto, 2022b; Figure S.P.4.7). On average, harbor seals are disturbed from their haul-outs 0.21 times per hour (Codde, 2020). The majority of disturbances were associated with humans on the beach, unknown sources, and motor boats (Figure S.P.4.8). It appears that the disturbance rates were consistently lower than in the previous decade. The 2010-2019 trend of disturbances at outer coast beaches appeared to be stable, with an uptick in recent years at Double Point (Codde, 2020). Although disturbance to wildlife occurs on a regular basis, the level of disturbances does not appear to be impacting populations levels or wildlife use of the sanctuary (Codde, 2020; Lindquist & Roletto, 2022a).

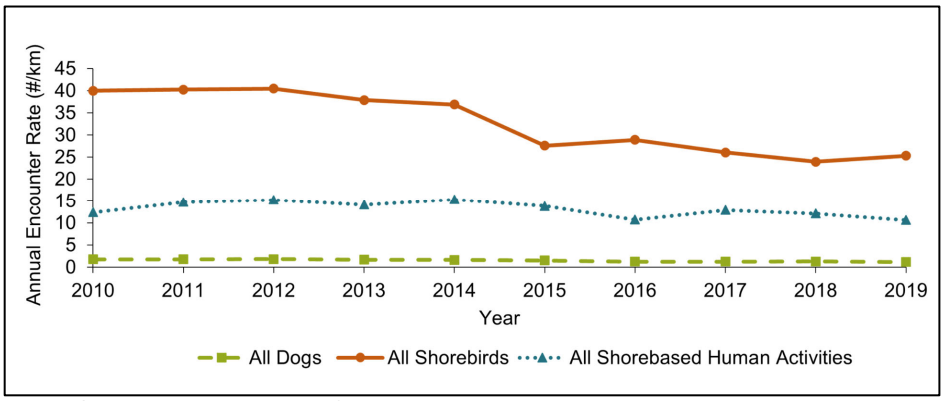

Figure S.P.4.7. Encounter rates of dogs, human activities, and all shorebird species along sanctuary beaches, 2010–2019. Source: Lindquist & Roletto, 2022a, 2022b

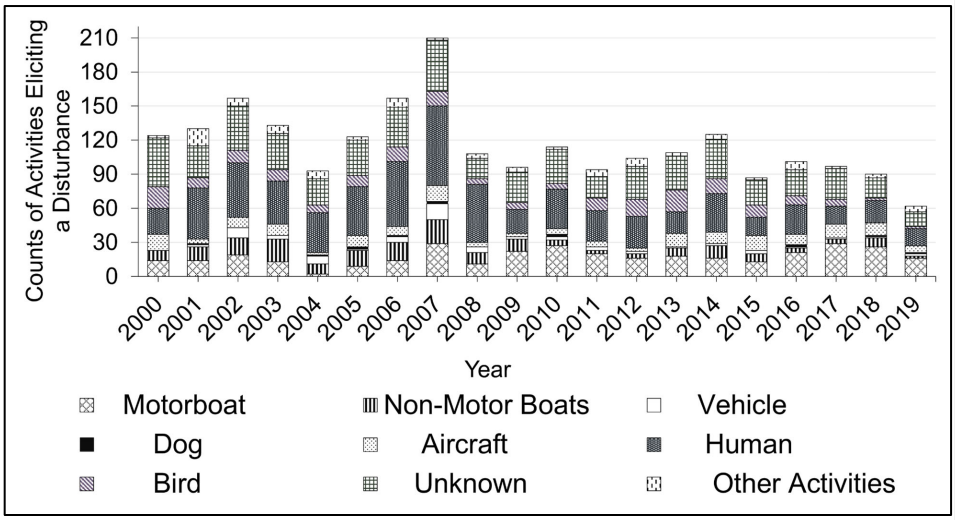

Figure S.P.4.8. Counts of activities eliciting a harbor seal disturbance by activity type and year. Source: Codde, 2020

Vessel Traffic and Oil Pollution

Vessel traffic is a human activity that is a concern for wildlife because of the risk of oil spills (Jagerbrand et al., 2019), which can cause fouling of feathers and fur, hyperthermia, and internal organ damages to wildlife. We have used distance ships traveled through the sanctuary as an indicator of risk for oil pollution from vessels (Figure S.P.4.1) versus oil pollution from natural seeps. See Question # 3 in this report for a review of vessel activities. There were no medium or large oil pollution events in the sanctuary during this study period, 2010–2021 and only infrequent deposition of tarballs (S.P.2.2). The last large oil spill that impacted the sanctuary was in 2007 (S/S *Cosco Busan*; ONMS, 2010). From 2010–2020, there were eight incidents that were reported to the U.S. Coast Guard that may have resulted in oil pollution, but the amount of discharged oil was not documented (USCG MISLE, 2022).

Conclusion

The rating of fair considered that some human activities are causing impacts such as vessel strikes to whales, and whale entanglement in commercial fishing gear. Shifts in distribution of baleen whales since the 2014–2016 MHW has increased risk of entanglements and ship strikes of baleen whales, rather than increases in these activities or shifts in the traditional fishing areas or shipping lanes (Santora et al., 2020; Gulland et al., 2022). Other human activities considered included entanglement of pinnipeds and seabirds in fishing gear and trash, disturbance of pinnipeds and seabirds on beaches and rocky shores, and oil pollution. Pinnipeds and seabirds were documented with entanglements in debris from municipal dumps and fisheries but incidents were at low levels that do not appear to significantly impact local populations. Disturbance of pinnipeds and seabirds and shorebirds were documented, mostly from aircraft, humans and dogs on beaches, and motorized vessels, but the level of disturbances does not appear to be impacting populations levels or wildlife use of the sanctuary. Some oil pollution

occurs through vessel incidents and natural seeps but oiling events to wildlife were not observed. The trend rating of mixed is due to some indicators worsening, such as ship strikes and entanglements, and some improving, such as oil pollution impacting wildlife and rates of disturbances to birds and mammals. There is a lack of data on the percent of human activities that elicit disturbance behaviors (e.g., tide pooling, extraction, low flying motorized aircraft, jet skis, boating activities), making it difficult to determine the severity of the activities. Data on vessel speeds within the vessel traffic separation scheme and entrance to San Francisco Bay are available but needs to be analyzed due to the eastward/nearshore shift of whales and their prey species. There is limited data on the amount of oil pollution released when vessels are grounded or sink. More data is also needed on noise impacts to living resources in GFNMS.

Estuarine and Lagoon Region (Q4)

Status Rating: Good/Fair	Status Confidence: Medium
Trend Rating: Not changing	Trend Confidence: Medium
Status Description: Some potentially harmful activities exist, but they have not been shown to degrade living resource quality.	
Rationale: Activities influencing this rating included increased recreational use. Disturbances to wildlife were low and did not appear to be hindering use of the sanctuary by wildlife. Rates of disturbance in the estuarine habitats were fairly consistent 2010–2019. Data indicates low disturbances until 2019, when disturbance rates increased. Human activities and disturbances increased in recent years, 2020–2021. Oil pollution from vessels and vehicles in Bolinas Lagoon and Tomales Bay were observed but not quantified. No tarballs and only one oiled seabird were reported during this study period.	

Commented [28]: but trend is "not changing"...just curious. Not significantly increasing? (possibly associated with pandemic?)

Findings From the 2010 Condition Report

In the 2010 condition report, the status for this question was fair/poor and conditions were declining. The basis for judgment was that the impacts resulting from urbanization and wildlife disturbances caused by visitor activities were increasing. Management activities were needed to increase monitoring of and outreach about disturbance.

New Information in the 2010–2022 Condition Report

Indicators used to rate this question were: human activities that disturb birds and harbor seals, or create oil pollution and trash (Table S.P.4.4). Data on human activities and their impacts to wildlife were available for two of the sanctuary's estuaries, Bolinas Lagoon and Tomales Bay (Figure SS.8). Humans participating in various activities, including walking their dogs on the beach are examples of shoreline activities that can disturb wildlife, particularly shorebirds (USFWS, 2007).

Table S.P.4.4. Summaries for key indicators related to human activities that impact living resources in the estuarine and lagoon region that were discussed during the May 17, 2022 virtual status and trends workshop.

Indicator	Source	Data Summary	Figures & Tables
Shoreline activities	Codde, 2020; Lindquist & Roletto, 2022b	Status: A variety of human activities disturbed coastal wildlife throughout the sanctuary, including motor boats, low flying aircraft and people on foot. Trend: Most activities are stable or slightly increasing in recent years, during the 2020-2021 pandemic.	
Wildlife Disturbance: Birds	GFNMS-SPN, 2022; Lindquist & Roletto, 2022a; Lindquist & Roletto, 2022b	Status: Reported disturbance incidents to birds were low and the few reports were people on foot or with their dogs. Disturbances tend to impact 10–1,000 birds but did not appear to change the number of birds using the shoreline. Trend: Disturbances to birds in GFNMS estuaries were very low and appear to be stable.	Table S.P.4.5
Wildlife Disturbance: Harbor Seals	Codde, 2020	Status: Disturbance to harbor seals was low and mostly from people on foot and in boats. Trend: Disturbance incidents appeared to be decreasing and the harbor seal population in the Bolinas Lagoon and Tomales Bay appeared to be stable or slightly increasing.	Figure S.P.4.10, Figure S.P.4.11
Oil Pollution	USCG MISLE, 2022; Lindquist & Roletto, 2022b	Status: Oil pollution from vessels and vehicles in Bolinas Lagoon and Tomales Bay were observed but not quantified. No tarballs and only one oiled seabird were reported during this study period. Trend: Oiled wildlife and tarball deposition rates declined.	Figure S.P.2.2
Data Gaps: There are no data on human activities or impacts to wildlife in Estero Americano or Estero de San Antonio. There are limited data on the levels of human activities (e.g., clamming, extraction, vessel activities, low flying motorized aircraft, jet skis) that are not associated with or known to elicit wildlife disturbance. There is limited data pertaining to human activities that can be correlated with changes in biodiversity or densities of wildlife, rates of vessel discharges, and particularly trampling from clamming, extraction or other activities that may negatively impact living resources in the intertidal habitat. There is limited data on the amount of oil pollution released when vessels are grounded or sink.			

Wildlife Disturbance

Data from the GFNMS-SPN indicated there were four disturbance events of birds in the sanctuary's estuaries from 2012 to 2021. The level of impacts of each disturbance were medium to large (i.e., 10–100 or 100–1,000 animals disturbed) (Table S.P.4.5, GFNMS-SPN, 2022). The co-occurrence of human activities and wildlife can cause disturbance, which can disrupt feeding, resting, breeding, and nesting behavior, cause stress, and expose wildlife to predators. The Beach Watch project collects data on both shorebird presence and over 20 types of human activities (Lindquist & Roletto, 2022a; Lindquist & Roletto, 2022b). Data from the bi-monthly

Beach Watch surveys showed that the rates of human activities along the shoreline were stable from 2010–2019, then increased slightly during the pandemic in 2020 and 2021, with a concurrent slight increase in shorebird abundance (Lindquist & Roletto, 2022a).

Table S.P.4.5. The number of disturbances to seabirds in Tomales Bay and Bolinas Lagoon, as reported by the public, from 2012–2021. Source: GFNMS-SPN, 2022

Size of Incident	**Number of Animals Disturbed**
Very Large Incidents (>1000 animals disturbed)	0
Large Incidents (100-1000 animals disturbed)	2
Medium Incidents (10-100 animals disturbed)	2
Small Incidents (1-10 animals disturbed)	0
Size of Incident Not Reported	2

Disturbances of harbor seals in Tomales Bay and Bolinas Lagoon are documented by the harbor seal monitoring project led by PRNS (Codde, 2020; Figure S.P.4.10; Figure S.P.4.11). Most disturbances were of harbor seals hauled out at Clam and Seal Islands in Tomales Bay and were associated with motorboats coming too close to the haul-outs. Humans on foot, usually digging for clams, ranked second. In Bolinas Lagoon, harbor seal disturbances were mostly associated with humans on foot. Non-motorized boats and vehicles on the nearby road (Highway 1) ranked second. Even though disturbances to harbor seals are common in Tomales Bay and Bolinas Lagoon, the harbor seal population and pupping rates appeared to be stable or slightly increasing (Codde, 2020).

Commented [29]: is a figure of population #'s over time relevant here?

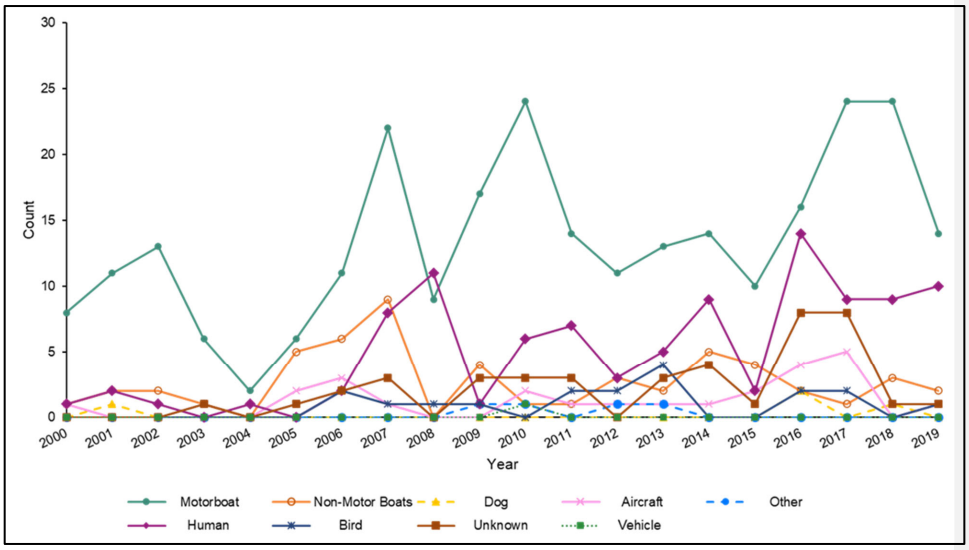

Figure S.P.4.10. Counts of disturbance events of harbor seals by activity from 2000–2019 at Clam and Seal Islands in Tomales Bay from standardized effort monitoring. Source: Codde, 2020

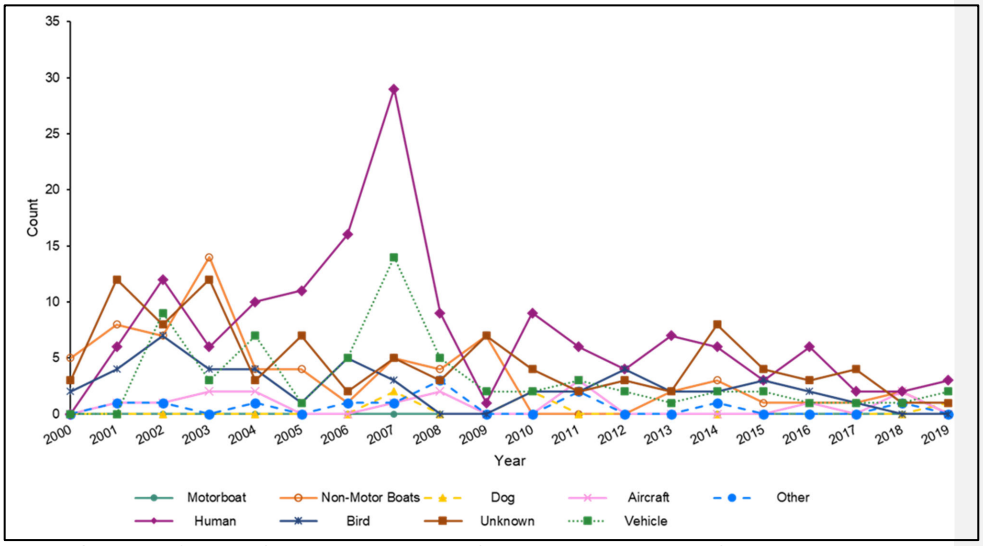

Figure S.P.4.11. Counts of disturbance events of harbor seals by activity from 2000-2019 in Bolinas Lagoon from standardized effort monitoring. Source: Codde, 2020

Oil Pollution & Entanglement

Oil pollution from boating, vessel groundings, sinkings, and vehicles have been observed but not quantified (USCG MISLE, 2022). There were no reports of oiled wildlife in Tomales Bay or Bolinas Lagoon, 2010–2022 (Lindquist & Roletto, 2022b). Marine debris may be a source of contamination, but there were no reported wildlife entanglements in the sanctuary estuaries (Lindquist & Roletto, 2022b).

Conclusion

Some potentially harmful activities exist in the estuarine and lagoon region of the sanctuary, but they have not been shown to degrade living resource quality. Therefore, the response for this question is rated good/fair, based on data on activities that disturbed birds, such as aircraft and humans on beaches, and disturbances of harbor seals primarily by motorized and non-motorized boats, vehicles, humans on foot, and clamming activity. There was no discernible trend for these indicators. Oiling and entanglement of wildlife in the sanctuary's estuaries were not observed (Lindquist & Roletto, 2022b). There is a lack of data pertaining to human activities that are not associated with wildlife disturbance, making it difficult to determine the percent of activities associated with disturbances.

References (Q4)

Bureau of Ocean Energy Management, & National Oceanic and Atmospheric Administration. (2022). *Marine cadastre* [Data set]. U.S. Department of the Interior and U.S. Department of Commerce. https://marinecadastre.gov

California Department of Fish and Wildlife. (2020a). *California commercial landing receipt data, 1994–2020* [Data set]. https://wildlife.ca.gov/Regions/Marine

California Department of Fish and Wildlife (CDFW). (2022). *Marine region, Whale Safe*. https://wildlife.ca.gov/Conservation/Marine/Whale-Safe-Fisheries#559973256-2021-22-season

California Department of Fish and Wildlife, Office of Spill Prevention and Response (OSPR). (2021). California Department of Fish and Wildlife, Office of Spill Prevention and Response, Petroleum Chemistry Laboratory [Unpublished data]. Petroleum Chemistry Laboratory, Rancho Cordova, CA.

Codde, S. (2020). Pacific harbor seal (*Phoca vitulina richardii*) monitoring at Point Reyes National Seashore and Golden Gate National Recreation Area: 2019 monitoring season. Natural Resource Report NPS/SFAN/NRR—2020/2129. National Park Service, Fort Collins, Colorado. https://irma.nps.gov/DataStore/DownloadFile/640169

Elliott, M., Lipski, D., Roletto, J., Warzybok, P., & Jahncke, J. (2022b). *Applied California Current Ecosystem Studies* [Unpublished data set]. Point Blue Conservation Science.

García-Reyes, M. & Largier, J. (2012). Seasonality of coastal upwelling off central and northern California: New insights, including temporal and spatial variability. Journal of Geophysical Research. 117. 10.1029/2011JC007629.

Greater Farallones National Marine Sanctuary (GFNMS-SPN). (2022). *Seabird Protection Network disturbance database [Unpublished data set]*.

Gulland, F.M.D, Baker, J.D., Howe, M., LaBrecque, E., Leach, L., Moore, S.E., Reeves, R.R., & Thomas, P.O. (2022). A review of climate change effects on marine mammals in United States waters: Past predictions, observed impacts, current research and conservation imperatives. Climate Change Ecology 3: 100054. https://doi.org/10.1016/j.ecochg.2022.100054

Henkel, L.A., Nevins, H., Martin, M., Sugarman, S., Harvey, J.T., & Ziccardi, M.H. (2014). Chronic oiling of marine birds in California by natural petroleum seeps, shipwrecks, and other sources. Marine Pollution Bulletin 79: 155-163.

Ingman, K., Hines, E., Mazzini, P.L.F., Rockwood, R.C., Nur, N., Jahncke, J. (2021). Modeling changes in baleen whale seasonal abundance, timing of migration, and environmental variables to explain the sudden rise in entanglements in California. PLoS ONE 16(4): e0248557. https://doi.org/10.1371/journal.pone.0248557

Jägerbrand, A. K., Brutemark, A., Barthel Svedén, J., & Gren,I. M. (2019). A review on the environmental impacts of shipping on aquatic and nearshore ecosystems. Science of The Total Environment, 695, 133637, https://doi.org/10.1016/j.scitotenv.2019.133637

Lindquist, K., & Roletto, J. (2022a). *Beach Watch database* [Data set]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of National Marine Sanctuaries, Greater Farallones National Marine Sanctuary & Greater Farallones Association. https://bwonline.beachwat.ch/BeachWatchData.php

Lindquist, K., & Roletto, J. (2022b). *Beach Watch database: Supplementary data* [Unpublished data set]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of National Marine Sanctuaries, Greater Farallones National Marine Sanctuary & Greater Farallones Association.

Lindquist, K. (2022). *Marine Protected Area (MPA) Watch Regional Report from Beach Watch: Mendocino, Sonoma, Marin, San Francisco, and San Mateo Counties, January 1, 2022 to June 30, 2022* [Unpublished report]. Greater Farallones Association.

Moore, T.J., Redfern, J.V., Carver, M., Hastings, S., Adams, J.D., & Silber, G.K. (2018). Exploring ship traffic variability off California. Ocean and Coastal Management 163: 515-527. ISSN 0964-5691, https://doi.org/10.1016/j.ocecoaman.2018.03.010.

NOAA Fisheries. (2022). Marine Mammal Stranding Network Database. https://www.fisheries.noaa.gov/national/marine-life-distress/national-stranding-database-public-access#:~:text=Includes%20information%20on%20every%20stranded,%2Fdetermination%2C%20and%20other%20information.

NOAA Fisheries. (2020). West Coast large whale entanglement response program. https://www.fisheries.noaa.gov/west-coast/marine-mammal-protection/west-coast-large-whaleentanglement-response-program

NOAA Southwest Fisheries Science Center (NOAA-SWFSC) (2022). U.S. Pacific marine mammal stock assessments: 2021. NOAA-TM-NMFS-SWFSC. 663 pps. https://doi.org/10.25923/246k-7589

Office of National Marine Sanctuaries (ONMS). (2010). Gulf of the Farallones National Marine Sanctuary Condition Report 2010. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD. 97 pp.

Pacific States Marine Fisheries Commission. (2022). Commercial crab news. https://www.psmfc.org/crab/

Rockwood, R.C., Calambokidis, J., & Jahncke, J. (2017). High mortality of blue, humpback and fin whales from modeling of vessel collisions on the U.S. West Coast suggests population impacts and insufficient protection. PLoS ONE 12(8): e0183052. https://doi.org/10.1371/journal.pone.0183052

Rockwood, R.C., Elliott, M.L., Saenz, B., Nur, N., & Jahncke J (2020). Modeling predator and prey hotspots: Management implications of baleen whale co-occurrence with krill in Central California. PLoS ONE 15(7): e0235603. https://doi.org/10.1371/journal.pone.0235603

Santora, J.A., Mantua, N.J., Schroeder, I.D., Field, J.C., Hazen, E.L., Bograd, S.J., Sydeman, W.J., Wells, B.K., Calambokidis, J., Saez, L., Lawson, D., & Forney, K.A. (2020). Habitat compression and ecosystem shifts as potential links between marine heatwave and record whale entanglements. Nature Communications 11, 536 https://doi.org/10.1038/s41467-019-14215-w

Shaffer, S.A., Cockerham, S, Warzybok, P., Bradley, R.W., Jahncke, J., Clatterbuck, C.A., Lucia, M., Jelincic, J.A., Cassell, A.L., Kelsey, E.C., & Adams, J. (2017). Population-level plasticity in foraging behavior of western gulls (*Larus occidentalis*) Movement Ecology, 5 (27): 1-13. DOI 10.1186/s40462-017-0118-9

Scholz, A., Steinbeck, C., Klain, S., & Boone, A. (2004). Socioeconomic profile of fishing communities associated with the Gulf of the Farallones and Cordell Bank National Marine Sanctuaries. Administrative Report to NOAA, Office of National Marine Sanctuaries, San Francisco, CA. pp122. Electronic document available from: http://archive.ecotrust.org/jmpr/JMPRsocioeco_final.pdf

U.S. Coast Guard Marine Information for Safety and Law Enforcement (USCG MISLE). (2022). Marine Information for Safety and Law Enforcement, Casualty and Pollution Incidents. https://cgmix.uscg.mil/psix/

U.S. Fish and Wildlife Service (USFWS). (2007). Recovery Plan for the Pacific Coast Population of the Western Snowy Plover (*Charadrius alexandrinus nivosus*). In 2 volumes. Sacramento, California. xiv + 751 pages. https://westernsnowyplover.org/pdfs/WSP%20Final%20RP%2010-1-07.pdf

Vanderlaan, A. & Taggart, C. (2007). Vessel collisions with whales: The probability of lethal injury based on vessel speed. Marine Mammal Science. 23. 144 - 156.

Warzybok, P. (2022). *Point Blue Conservation Science: Supplementary data* [Unpublished data set]. Point Blue Conservation Science.

Question 5: What are the levels of human activities that may adversely affect maritime heritage resources and how are they changing?

Maritime heritage resources are the wide variety of tangible and intangible elements (archaeological, cultural, historical properties) that reflect our human connections to Great Lakes and ocean areas. Human activities that pose threats to maritime heritage resources worldwide include looting, inadvertent damage by divers, development, vessel anchoring, vessel groundings, fishing activities, and more. The response to this question focuses on indicators of human activities that may threaten the condition of the known, tangible maritime heritage resources in the sanctuary (see Question 16 for the conditions of maritime heritage resources).

Coastal and Offshore Region (Q5)

Status Rating: Good/Fair	Status Confidence: Medium
Trend Rating: Improving	Trend Confidence: Medium
Status Description: Some potentially damaging activities exist, but they have not been shown to degrade maritime heritage resource condition.	
Rationale: During the rating period, the levels of human activities that may adversely affect maritime heritage resources are not thought to have caused widespread impacts; for some indicators, no adverse impacts are known. Potentially damaging human activities in the coastal and offshore region of the sanctuary have occurred, such as scuba diving and commercial fishing, but are not thought to have caused widespread impacts during the rating period. Anecdotal information from divers indicates a decrease in looting at maritime heritage sites since sanctuary designation with none documented during the rating period. The trend is improving due to the decrease in artifact looting, few observed impacts from fishing, and because there was no new nearshore or offshore development. A few adverse impacts are seen; for example, commercial fishing gear was documented at two shipwreck sites, on the SS *Selja* and the T/V *Puerto Rican*. The threat of climate impacts, which likely are occurring, is of concern, but difficult to measure without comprehensive site baseline data or regular monitoring~~how climate change will affect maritime heritage resources is not known~~. The lack of systematic monitoring of all of the maritime heritage sites, as well as the incomplete inventory of maritime heritage resources in the sanctuary, contributed to scores of medium confidence for both the status and the trend.	

Findings From the 2010 Condition Report

In the 2010 condition report, the status rating for this question was good/fair with an undetermined trend due to a lack of monitoring. Activities considered included trawling, anchoring or dragging of anchors, ship groundings, diving, removal of artifacts from archeological sites, and laying submerged cables, but none appeared to have had an adverse

impact on maritime archaeological resource integrity. Note, however, that the wording of this question has changed slightly since the 2010 report (see Appendix A).

New Information in the 2010–2022 Condition Report

With the sanctuary's expansion in 2015, its boundaries include more shipwrecks, and now doghole port sites,[5] that may be impacted by human uses, based on reviewing data available on, and studies of, such resources within the sanctuary. The review included analysis of the California Historic Resource Information System (CHRIS; contains a wide range of documents and materials relating to historical resources) summary records and other sources. The area added to the sanctuary in 2015 is also now covered by sanctuary regulations, including prohibitions on possessing, moving, removing, or injuring, or attempting to possess, move, remove or injure, a sanctuary historical resource.

For this condition report, seven activities were selected and assessed, and are summarized in the table below: commercial fishing, research allowed by sanctuary permits that involved contact with the submerged lands, vessel anchoring and moorings, discharges, scuba diving, development, and climate change (Table S.HA.5.1).

Table S.HA.5.1. Summaries of human activities that may adversely affect maritime heritage resources in the coastal and offshore region of the sanctuary that were discussed during the July 6, 2022 virtual workshop.

Indicator	Source	Data Summary	Figure
Fishing (commercial: bottom trawling, traps, nets, lines, hooks)	National Centers for Coastal Ocean Science, 2020	Status: From 2011–2020, trawl vessel speed data (proxy) indicated one trawl may have been near one shipwreck, however, impacts are unknown; video has documented fishing debris on two shipwrecks. Trend: Not assessed.	Figure S.HA.5.1. Figure S.HA.5.2.
Research that involves contact with submerged lands	ONMS, 2022a	Status: Between 2014–2021, of 22 projects of this type with sanctuary permits, 11 had activities within 100 ft of known maritime heritage resources; however, no impacts are known. Trend: Not assessed.	Figure S.HA.5.3.
Vessel anchoring and moorings		Status: No data set for anchoring; however, no known anchoring impacts. No vessel moorings. Trend: Not assessed.	
Discharges - accidental or purposeful	USCG Marine Information for Safety and Law	Status: Between 2010–2021 there were no large-volume oil spills, however, smaller discharges of fuel or oil did occur; there were two incidents of lost CONEX containers; zero	

[5] Doghole port sites were so named because they were so small and exposed that mariners joked they were barely large enough for a dog to turn around. The California Redwood Coast landscape is dotted with evidence of how the lumber trade adapted to the rugged marine environment to move lumber by sea, allowing the business to flourish from the mid-19th century into the 20th century (ONMS, 2022b).

	Enforcement (MISLE), 2022; GFNMS, 2022b	full barge-loads of dredged material lost; and eight vessels sunk or grounded, but with no known impacts on maritime heritage resources. Trend: Not assessed.	
Scuba diving	R. Schwemmer/NOAA, personal communication, January 19, 2022; Lindquist & Roletto, 2022b	Status: From 2010–2022 diving occurred at at least three wrecks; no looting documented during period. Trend: Not assessed.	
Development - nearshore or offshore	ONMS, 2022a	Status: Between 2014–2021, there were no permits for new infrastructure; two certifications for existence/maintenance of steel conduits and a submarine cable and water intake/outflow infrastructure; no known effects to maritime heritage resources. Trend: Not assessed.	
Climate change	Roth, 2021	Status: Impacts are of concern, but are not well understood or monitored. Trend: Not assessed.	
Data Gaps: There is no systematic monitoring in this region of known maritime heritage resources and sites or the impacts of human activities on them; thus, there is a lack of information for all of the indicators. For commercial ~~F~~fishing~~.~~, ~~(commercial):~~ actual activity of vessels is unknown; there have been few remotely operated vehicle (ROV) surveys of wreck sites. ~~;~~ There is no information on fishing effects at doghole ports or other sites. For ~~R~~research that involves contact with submerged lands, there are~~:~~ gaps in data sets, as well as lack of knowledge of actual activities, and any impacts. For ~~A~~anchoring and mooring, there is~~:~~ no anchoring data. For ~~D~~impacts from discharges, there are~~:~~ gaps in some of the data sets. For Scuba diving, there is~~:~~ no comprehensive, systematic monitoring data for this indicator. And for ~~C~~climate change, there is~~:~~ no comprehensive, systematic monitoring data yet for effects on maritime heritage resources.			

Commercial Fishing

Commercial fishing can cause mechanical damage to and entanglement on maritime heritage resources from bottom trawling, traps, nets, lines, and hooks. NOAA affiliate and GFNMS staff used NOAA Vessel Monitoring System (VMS) data (from 2011–2020)(National Centers for Coastal Ocean Science, 2020) on fishing vessel locations underway at speeds likely used for trawling (as a proxy for trawl track locations) using Geographic Information Systems (GIS) and also reviewed a limited amount of remotely operated vehicle (ROV) video footage of known wrecks. The vessel speed data indicated only one potential bottom trawl track came within one half mile of a known wreck but did not pass over the wreck location. Examination of video footage documented fishing debris on two shipwrecks. A 2014 ROV video survey of the SS *Selja*, a steel hull vessel that sank after a collision with the SS *Beaver*, showed commercial crab

pots and buoy lines on the wreck (Figure S.HA.5.1 and Figure S.HA.5.2). A brief 2021 ROV video survey of the stern of the T/V *Puerto Rican*, a steel vessel which sank in 1984 after an explosion on board, showed the stern covered in commercial fishing nets. No information on the effects of fishing on other shipwrecks or doghole port sites was available.

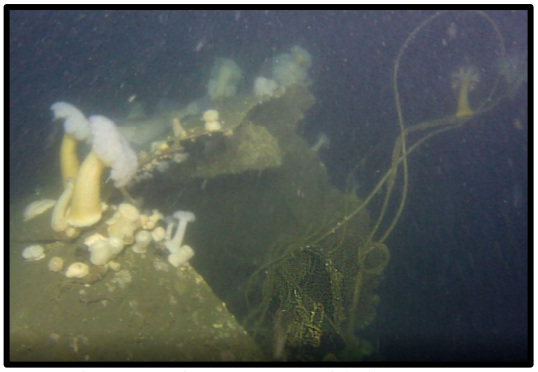

Figure S.HA.5.1. Shipwreck site SS *Selja* surveyed by NOAA 2014 with commercial fishing gear and buoy lines. Photo: NOAA

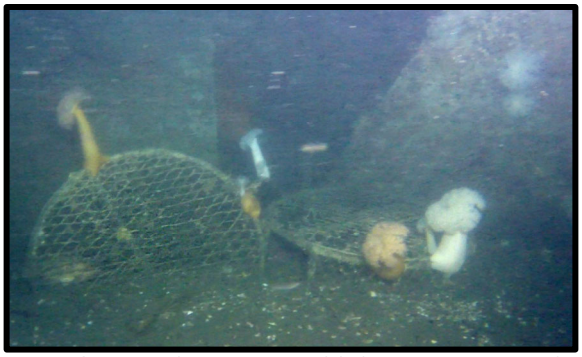

Figure S.HA.5.2 Shipwreck site SS *Selja* surveyed by NOAA in 2014 with commercial crab pots. Photo: NOAA

There are gaps in the data available on the levels of commercial fishing activities at maritime heritage resource sites and on debris from commercial fishing (a proxy) on maritime heritage resources because surveys have not been done of all the known resources in this region. Also, subsequent site monitoring surveys have not yet been conducted on the SS *Selja* and the T/V *Puerto Rican*.

NOAA Fisheries continues to manage Groundfish Essential Fish Habitat (EFH), with stakeholder input (GFNMS, 2022a). Decisions to protect sanctuary habitats from bottom trawling also protect maritime heritage resources within EFH.

Research Involving Contact with the Submerged Lands

Research activities in GFNMS that would alter submerged lands require an ONMS permit. Examining projects allowed under ONMS permits between 2014–2021, 22 of those projects allowed contact with submerged lands, and thus potentially with submerged maritime heritage resources, though it is noted that several years during the rating period in which relevant permits were effective were not mapped (2010–2013 and 2022). Also, the permits often required the permitted researchers to avoid or mitigate damage to maritime heritage resources. The projects, conducted to learn more about fisheries stocks, sea conditions, benthic character, and more, involved bottom trawling; installation, maintenance and removal of buoy moorings and scientific equipment; geological and biological sample collection; ROV bottom contact or placement on the submerged lands; alternative (experimental) fishing gear testing; and abandonment of non-recoverable items.

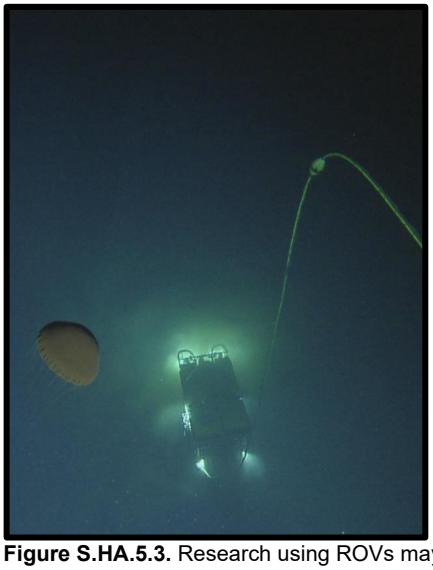

Figure S.HA.5.3. Research using ROVs may involve contact with the bottom and potentially, with submerged maritime heritage resources. Photo: NOAA

Comparing the permitted project areas and the general locations of known maritime heritage resources, eleven of the projects could have included activities on or within 100 feet of known shipwrecks and doghole port sites. There is the possibility that adverse impacts on resources occurred from some of the projects; however, there is no documentation or permittee reports of impacts actually taking place. To date, permit processing has not required pre-permit field surveys by applicants for the presence of maritime heritage resources in the permitted areas, or post-research activity surveys by permittees in GFNMS.

Vessel Anchoring and Moorings

In the 2010 report, anchor damage was considered to be a threat, though it had not been assessed. For the 2010–2022 period, there are no vessel moorings in this region and no adverse impacts from anchoring on maritime heritage resources are known to have occurred. Anchoring does take place in Drakes Bay; however, most of the Drakes Bay nearshore area

where vessels anchor is outside of the sanctuary's boundaries. No data on anchoring by location and frequency is available.

Discharges

Discharges and deposits of items (other than from fishing) were not discussed in the 2010 report. This activity includes large scale spills of crude oil or refined oil products, which could coat or otherwise degrade submerged maritime heritage resources; diesel and gasoline spills are not included for purposes of this report, as those spilled products tend to evaporate quickly. It also includes accidental loss of barge loads of dredge spoil materials, which could bury or damage submerged maritime heritage resources. Similarly, vessel sinkings and groundings could cause physical adverse effects to maritime heritage resources. Though there are some data gaps, no such incidents were documented to occur and there were no adverse impacts from discharges and deposits on maritime heritage resources during the 2010–2021 time period. Smaller-scale, periodic discharges of fuel or oil occurred; two shipping containers were lost; and eight vessels sank or were grounded in the region, but none were in the vicinity of known maritime heritage resources (USCG MISLE, 2022; GFNMS, 2022b).

Scuba Diving

Scuba diving by recreational divers could result in incidental damage to maritime heritage resources through contact with a shipwreck or artifacts (e.g., tanks, fin kicks, touching or moving items); however, no comprehensive data set for this indicator is known which was a concern for some workshop experts, and no data of damage of this type has been found. While there is limited Beach Watch data (Lindquist & Roletto, 2022b) from 2014–2021, which recorded five instances of nearshore scuba diving at different beaches observed from shore, it was not possible to determine from that data if that diving resulted in any impacts on maritime heritage resources. Diving at some sites is thought to have decreased since a kelp forest decline that began around 2014 (D. Jaffke/Far Western Anthropological Research Group, Inc., personal communication, March 1, 2023). The decline in the kelp forest, with less to see, possibly decreased divers' interest in diving sites which formerly had healthy stands of kelp. No looting of sites is known to have been documented in the time period. Anecdotal evidence indicates non-permitted collection of some artifacts and ship debris within the sanctuary may have been done, with beachcombing (though not a selected indicator) also potentially of concern, particularly of artifacts and ship fragments from beaches after big storm surges and king tides (D. Jaffke/Far Western Anthropological Research Group, Inc., personal communication, March 1, 2023). Extensive site looting of shipwreck artifacts occurred before 2010, especially before sanctuary designation in 1981 (R. Schwemmer/NOAA, personal communication, January 19, 2022). Since 2010, it is believed little or no looting has occurred based on 2016–2017 site monitoring of the shipwreck SS *Pomona* and anecdotal information from the sport diving community. Recreational scuba diving occurs at the SS *Pomona*, SS *Norlina*, and SS *Crescent City*, and there is anecdotal information of infrequent diving at other sites with historical resources. The SS *Pomona* is monitored by California State Parks and the SS *Norlina* was documented by the Sonoma Coast Historical & Undersea Nautical Research Society (SCHUNRS). Experts who were consulted were not aware of any documented looting by divers at doghole port sites during the rating period.

Development

No new development in the region, nearshore or offshore, has taken place since 2010. Existing approvals for two ongoing activities were certified by ONMS post-sanctuary expansion. This allowed continuation of activities for an existing submarine cable and a research facility's water intake/outflow infrastructure. No effects on any maritime heritage resources are known to have resulted. Of note is that the sanctuary's regulatory prohibitions, including disturbance of the

submerged lands, which typically occur from development, were extended to the expanded area of the sanctuary in June 2015.

Climate Change

Although there was no existing monitoring of climate change impacts to maritime heritage resources, human-caused climate-related changes to the ocean such as ocean acidification, changing water temperatures, and sea level rise are recognized to have the potential to adversely affect maritime heritage resources in the sanctuary. Impacts on submerged maritime heritage resources could result from ocean acidification increasing rates of deterioration, changing water temperatures, which alter conditions for protective and/or destructive organisms, changing or rising water levels, which may enhance mechanical degradation, and changing weather patterns that may physically alter sites and their protective overburden (Roth, 2021). Climate-related changes are documented to be occurring in the sanctuary but data specific to impacts on maritime heritage resources have not been gathered nor assessed, which was a concern for some workshop experts.

Conclusion

The rating of good/fair was based on the limited human activities in the selected indicators that are likely to affect maritime heritage resources and the limited known adverse impacts on those resources. Human activities that could adversely affect maritime heritage resources include commercial fishing, research involving contact with the submerged lands, vessel anchoring, discharges, scuba diving, development, and climate change. With sanctuary expansion, more maritime heritage resources are now within sanctuary boundaries and protected by sanctuary regulations. Commercial bottom trawl fishing, anchoring, and removal of artifacts, which were concerns previously, are not documented as having affected maritime heritage resources during this study period, though fishing gear was observed on two shipwrecks and anecdotal evidence indicates some non-permitted artifact and ship debris collection occurred. No other adverse effects from human activities are documented, though beachcombing, which was not a selected indicator, was raised by an expert as a potential concern.

There has been no systematic monitoring in this region of known maritime heritage resources and sites or of the impacts of human activities on them, leading to data gaps in all of the indicators, with particular note made by experts of scuba diving data being scant and the lack of information on the effects of climate change on sanctuary maritime heritage resources.

Estuarine and Lagoon Region (Q5)

Status Rating: Good	Status Confidence: Medium
Trend Rating: Improving	Trend Confidence: Medium
Status Description: Few or no activities occur at maritime heritage resource sites that are likely to adversely affect their condition.	
Rationale: There is one known historic maritime heritage resource in estuaries of GFNMS, the shipwreck of the *Oxford*. The remains of the wreck are submerged and buried under sediment, which should provide a measure of protection from human activities. During the	

study period, only one research activity allowing contact with the submerged lands at the shipwreck site was permitted, to confirm the wreck's presence. This research activity likely had negligible adverse impacts on the wreck. The site has not been revisited for further research. Commercial fishing has not resulted in known adverse impacts on the wreck. The *Oxford* is not located where vessels are known to anchor. Conditions appear to have remained unchanged since 2010. There are data gaps for all of the indicators in this region, particularly related to climate change, and there is a need to determine if there are other maritime heritage resources in the region.

Findings From the 2010 Condition Report

In the 2010 condition report, this question was rated good/fair and the trend was undetermined due to a lack of monitoring data. Seven loss records for ships were mentioned, but none had been investigated. At that time, the report noted commercial bottom fishing (primarily for herring), aquaculture, new piers, anchoring, and mooring as activities that could affect the quality of maritime heritage resources. Some potentially relevant human activities existed (e.g., restoration of oysters and seagrass beds, establishment of long-term mooring areas, and removal of derelict vessels), but the judgment then was that they did not appear to have had a negative effect on maritime archaeological resource integrity.

New Information in the 2010–2022 Condition Report

No new estuaries or lagoons were added to the sanctuary as part of the 2015 expansion. A survey conducted in 2014 under an ONMS permit indicated the presence of remains of one shipwreck, the *Oxford*, a wooden sailing ship stranded in 1852 in Tomales Bay, in what is now the sanctuary. Though there are loss records of other shipwrecks in the estuarine and lagoon region, no other known maritime heritage resources have been ascertained.

Indicators that were assessed included commercial fishing impacts, research that involves contact with the submerged lands, vessel anchoring and moorings, discharges, scuba diving , nearshore development, and climate change (Table S.HA.5.2).

Table S.HA.5.2. Summaries of human activities that may adversely affect maritime heritage resources in the estuarine and lagoon region of the sanctuary that were discussed during the July 6, 2022 virtual workshop.

Indicator	Source	Data Summary
Fishing (commercial: bottom trawling, traps, nets, lines, hooks)	California Department of Fish and Wildlife 2020; California Department of Fish and Wildlife, 2022; National Centers for Coastal Ocean Science, 2020	Status: Herring fishing declined in Tomales Bay; the fishery was closed for 2009-2010 season. Take of herring for both sac-roe and fresh fish markets using gill nets allowed; however, no short tons of herring were landed between 2010 and 2017 for the Tomales Bay area. Trend: Not assessed.

Research that involves contact with submerged lands	ONMS, 2022a J. Delgado/NOAA, personal communication, February 6, 2015;	Status: Between 2014–2021, only one research project allowed activities on or within 100' of one wreck; negligible adverse impacts may have occurred during probing. Trend: Not assessed.
Vessel anchoring and moorings	GFNMS, 2022c	Status: Vessel anchoring is likely not impacting wreck and no moorings are near it. Trend: Not assessed.
Discharges - accidental or purposeful	USCG MISLE, 2022; GFNMS, 2022b	Status: Between 2010–2021, there were no large-volume oil spills; smaller-scale, periodic discharges of fuel or oil occurred with no effects thought to wreck; no containers or full barge-loads of dredged material lost; four vessels sunk or grounded. Trend: Not assessed.
Scuba diving	Lindquist and Roletto, 2022b	Status: Little or no diving is thought to occur in the region. Trend: Not assessed.
Development - nearshore	ONMS 2022a	Status: Between 2014–2021, one sanctuary permit was issued for replacing an existing sea wall; no maritime heritage resources are known to be present. Trend: Not assessed.
Climate change	Roth, 2021	Status: Impacts are of concern, but are not well understood or monitored. Trend: Not assessed.
Data Gaps: There is no systematic monitoring in this region of the known maritime heritage resource or the impacts of human activities on it; thus, there is a lack of information for all of the indicators. For commercial ~~F~~fishing~~ (commercial):~~ there is a lack of relevant data on possible impacts from other fisheries. For ~~R~~research that involves contact with submerged lands, there is~~:~~ no video or other surveys of the *Oxford* aside from one hydraulic probe survey; there are gaps in data set of permitted research. For ~~A~~anchoring and moorings, there is~~:~~ no anchoring data. For impacts from ~~D~~discharges, there are~~:~~ gaps in some data sets. For Scuba diving, there are~~:~~ no comprehensive, systematic monitoring data for this indicator. And for ~~C~~climate change, there are~~:~~ no comprehensive, systematic monitoring data for effects on the maritime heritage resource.		

Commercial Fishing

From 2010–June 2022, no commercial herring fishing catch reports were posted by the California Department of Fish and Wildlife (California Department of Fish and Wildlife, 2022) and there was no commercial bottom trawling for fish in Tomales Bay or the other estuaries and lagoon in this region (National Centers for Coastal Ocean Science, 2020). Herring fishing declined in Tomales Bay from higher levels previously and the fishery was closed for the 2009-2010 season. Take of herring for both sac-roe and fresh fish markets using gill nets was allowed, up to 350 tons quota in Tomales Bay (California Department of Fish and Wildlife, 2022); however, no short tons of herring were landed between 2010 and 2017 for the Tomales Bay area according to the 2019 *California Pacific Herring Fishery Management Plan* in a

summary of landing data from 1972-2017 (California Department of Fish and Wildlife, 2020). No data was obtained by staff on other fisheries in the region. The remains of the *Oxford* were determined to be submerged under four feet of water at high tide and underneath a mud and sand shoal (J. Delgado/NOAA, personal communication, February 6, 2015). No impacts from commercial fishing to the wreck remains are known and because of its location, it is unlikely that such activities have had an adverse impact.

Research Involving Contact with the Submerged Lands

Research activities in GFNMS that would alter submerged lands require an ONMS permit, which often require permitted researchers to avoid or mitigate damage to maritime heritage resources. From 2014–2021 only one research project was permitted, in 2014, allowing research that could disturb the estuary bottom within 100' of the *Oxford* (ONMS, 2022a). The purpose of the permitted project was for a team led by NOAA archaeologists to determine the presence of the *Oxford*; the method used was a systematic hydraulic probe survey of the site. The probe holes, on average, went 12 feet (3.6 meters) below the mudline for approximately 105 feet (32 meters). The probing indicated contact was made not with solid wood, but rather a "crunchy" mass, consistent with other site formation processes of other buried wooden vessels observed by the project lead (Delgado et al., 2020). Negligible adverse physical impacts on the wreck may have occurred as a result of the approximately twenty or fewer probe holes, which were 3/4 inch in diameter (J. Delgado/NOAA, personal communication, February 6, 2015). Expert opinion provided at the workshop was that the probing probably introduced some oxygen, which could increase the rate of the wreck's physical degradation, into the *Oxford* site on a short-term basis until the sediment filled in again. The wreck site has not been revisited by researchers since 2014, so the extent of any adverse impacts on the wreck from the research or other activities is undetermined.

Vessel Anchoring and Moorings

No effects on the *Oxford* from anchoring or mooring are thought to have occurred during the rating period because it is submerged under a shoal and it is not in a location where vessels are known to anchor (GFNMS, 2022a). Following the creation of a mooring plan in 2013 (Basta and Bamford, 2013), mooring areas were designated in Tomales Bay where vessels could moor if they met specified criteria. No mooring areas were in the vicinity of the wreck and the environmental assessment found no adverse effects to archaeological, paleontological, or cultural resources. No anchoring data sets were available for this region. There were no designated mooring areas in other parts of this region (GFNMS, 2022c).

Discharges, Scuba Diving, Development and Climate Change

There were no large-volume accidental spills of oil from vessels in estuaries or Bolinas Lagoon. Smaller-scale discharges of fuel or oil occurred periodically; but no effects to the *Oxford* were deemed to have occurred (USCG MISLE, 2022; GFNMS, 2022b). There were no losses of containers or dredged material for this region. Four vessels sank or grounded (some salvaged or partially salvaged), but none of these were near the *Oxford*. Scuba diving is not documented at the *Oxford* site (Lindquist and Roletto, 2022b), with site conditions, including turbidity, not thought to be conducive to diving in that area. A review of sanctuary permit records for the rating period indicated no nearshore development was permitted near the *Oxford* (ONMS, 2022a). Human-caused climate-related changes to the ocean such as ocean acidification, changing water temperatures, and sea level rise are recognized to have the potential to have adverse impacts on maritime heritage resources (Roth 2021), including on the *Oxford*; however, there are no known impacts on this sanctuary maritime heritage resource from climate change due to no monitoring of changes to the shipwreck's condition.

Conclusion

Overall, the status of these human activities is good based on only one human activity identified during the rating period that might have had negligible adverse impacts on the one known tangible maritime heritage resource, the shipwreck of the *Oxford*. That activity was the research survey that determined its presence using a hydraulic probe. There is an improving trend, as declining levels of these human activities occurred. There was no herring fishing, bottom trawling, or nearshore development in the region, and no known scuba diving near the *Oxford*. Noted data gaps and the fact that there was just one survey of the *Oxford* site contributed to scores of medium confidence for both the status and the trend. There is a lack of information for all of the indicators for this question, with a highlight by the workshop experts on the data gap of climate change impacts on the maritime heritage resource and there a need to determine if there are other maritime heritage resources in the region.

References (Q5/Both Regions)

Basta, Daniel J. and Bamford, Holly A., Gulf of the Farallones National Marine Sanctuary and California State Lands Commission. (2013). *Tomales Bay Vessel Management Plan*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration. https://nmsfarallones.blob.core.windows.net/farallones-prod/media/archive/eco/tomales/pdf/tbvmp_ea-is_final-8-27-2013-WM.pdf.

California Department of Fish and Wildlife. 2020. *Pacific Herring Fishery Management Plan*. Web. https://wildlife.ca.gov/Fishing/Commercial/Herring/FMP.

California Department of Fish and Wildlife. (2022). *State-Managed California Commercial Pacific Herring Fishery*. Retrieved March 18, 2022, from https://wildlife.ca.gov/Fishing/Commercial/Herring.

Delgado, J. P., Schwemmer, R.V., and Brennan, M.L. (2020). Shipwrecks and the Maritime Cultural Landscape of the Gulf of the Farallones. *Journal of Maritime Archaeology*. 15(2), 131-163. 10.1007/s11457-020-09254-0

Greater Farallones National Marine Sanctuary (GFNMS). (2022a). *Bottom habitat conservation areas in Greater Farallones National Marine Sanctuary*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration. https://farallones.noaa.gov/eco/seafloor/.

Greater Farallones National Marine Sanctuary. (2022b). Emergency response incidents from 2010-2021, unpublished data. U.S. Department of Commerce, National Oceanic and Atmospheric Administration.

Greater Farallones National Marine Sanctuary. (2022c). Tomales Bay Interactive Map. U.S. Department of Commerce, National Oceanic and Atmospheric Administration. https://farallones.noaa.gov/eco/tomales/map.html.

Lindquist, K., & Roletto, J. (2022b). Beach Watch database: Supplementary data [Unpublished data set]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of National Marine Sanctuaries, Greater Farallones National Marine Sanctuary & Greater Farallones Association.

National Centers for Coastal Ocean Science. (2020). *Vessel monitoring system data* [Unpublished data set]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service.

ONMS. (2022a). Permit database [Unpublished data set]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration.

ONMS, Greater Farallones National Marine Sanctuary. (2022b). *Doghole Ports*. Retrieved August 25, 2022, from https://farallones.noaa.gov/heritage/doghole.html.

Roth, M. (2021). *Draft Climate Change Impacts to Maritime Heritage Resources: Gap Analysis.* Department of Commerce, NOAA, Office of National Marine Sanctuaries. Unpublished internal agency document.
State of California, Office of Habitat Preservation (2022). California Historical Resources Information System (CHRIS) database: Supplementary data. https://ohp.parks.ca.gov/?page_id=1068
USCG Marine Information for Safety and Law Enforcement (MISLE). (2022). Marine Information for Safety and Law Enforcement, Casualty and Pollution Incidents. https://cgmix.uscg.mil/psix/.

Status and Trends of Sanctuary Resources

This section provides summaries of resource status and trends in two regions of the sanctuary: the offshore and nearshore region and the estuarine and lagoon region. Resources are directed at four areas: water quality, habitat, living resources, and maritime heritage resources. Virtual expert workshops were convened by GFNMS staff on various dates from May–July, 2022 (see Appendix A and Appendix C) to discuss the series of questions about each resource area. It is important to note that, in general, the assessments of the status and trends of key habitat indicators in GFNMS are for some portion of the period from 2010–2022. Answers for each question are supported by data and the rationale is provided at the end of each section for each resource area. Where published or additional information exists, the reader is provided with appropriate references and web links. Workshop discussions and ratings were based on data available at the time (e.g., through 2022). However, in some instances, sanctuary staff later incorporated newly available data in order to more accurately describe the current status and trends of resources. We have noted where more recent data (e.g., 2023) became available during editing of this report. Situations where data were used by sanctuary staff to support a rating, but were not presented or discussed during the workshop, are noted in the text.

In order to effectively assess the considerable differences in sanctuary resources, key indicators and relevant data sets for each of the 16 questions were assessed for two separate regions of the sanctuary: the coastal and offshore region and the estuarine and lagoon region (see Figures SS.1 and SS.8). Each of these regions include a variety of habitat types.

The coastal and offshore region includes the rocky shore, sandy shore, kelp forest, and open ocean. The estuarine and lagoon region in the sanctuary includes Estero Americano, Estero de San Antonio, Bolinas Lagoon, and Tomales Bay. These areas are characterized by habitats that include bays, mudflats, and marshes.

Status and Trends of Water Quality (Questions 6–9) 1
Question 6: What is the eutrophic condition of sanctuary waters and how is it changing? 2
Coastal and Offshore Region (Q6) 2
Estuarine and Lagoon Region (Q6) 7
Question 7: Do sanctuary waters pose risks to human health and how are they changing? 12
Coastal and Offshore Region (Q7) 12
Estuarine and Lagoon Region (Q7) 20
Question 8: Have recent, accelerated changes in climate altered water conditions and how are they changing? 27
Coastal and Offshore Region(Q8) 27
Estuarine and Lagoon Region (Q8) 38
Question 9: Are other stressors, individually or in combination, affecting water quality, and how are they changing? 44
Coastal and Offshore Region (Q9) 44
Estuarine and Lagoon Region (Q9) 54

Status and Trends of Water Quality (Questions 6–9)

The following provides an assessment of the status and trends of key water quality indicators in GFNMS for the period from 2010–2022. We have noted where more recent data (e.g., 2023) became available during editing of this report.

Question 6 focuses on eutrophic conditions and their influence on primary production in sanctuary waters. Eutrophication is the accelerated production of organic matter, particularly algae, usually caused by an increase in the amount of nutrients (primarily nitrogen and phosphorus) from human sources in surface waters. Eutrophication can impact the condition of sanctuary resources, for example, by promoting nuisance and toxic algal blooms or impacting dissolved oxygen levels.

Question 7 focuses on parameters affecting public health. Human health concerns can arise from water or seafood contamination (bacteria, chemicals, and biotoxins). Indications of health impacts may include fishery closures and shellfish consumption advisories. Such impacts can be devastating, both ecologically and economically, in affected coastal communities.

Question 8 focuses on shifts in water quality due to climate drivers. Climate indicators include indices of large-scale climate patterns, upwelling intensity, water and air temperature, dissolved oxygen, and acidity. Shifts in water temperature can affect species growth rates, phenology, distribution, and susceptibility to disease. Acidification can affect organism survival, growth, and reproduction. Upwelling influences oxygen content and nutrient cycling.

Question 9 assesses biotic and abiotic stressors not addressed in other questions that, individually or in combination, may influence sanctuary water quality. Examples include nonpoint source contaminants and hard-to-quantify stressors that influence the condition of habitats and living resources. Such inputs may include industrial discharges and emissions.

Because of the considerable differences in environmental pressures and responses between the coastal and offshore region and the estuarine and lagoon region, each question is assessed twice in order to represent these two environment types separately.

Question 6: What is the eutrophic condition of sanctuary waters and how is it changing?

Coastal and Offshore Region (Q6)

Status Rating: Good	Status Confidence: High
Trend Rating: Undetermined	Trend Confidence: Medium
Status Description: Eutrophication has not been documented, or does not appear to have the potential to negatively affect ecological integrity.	
Rationale: Eutrophication was not detected in coastal or offshore areas of GFNMS based on data on nutrients, phytoplankton, chlorophyll a, and NPP. There is no evidence to suggest that there are major influxes of nutrients into these areas of the sanctuary.	

Findings From the 2010 Condition Report

In the 2010 condition report, the rating for this question was good and the trend was not changing (Table S.WQ.6.1). There was no known eutrophication in the coastal and offshore zones of GFNMS; therefore, conditions did not appear to have the potential to negatively affect living resources or habitat quality. In addition, the phytoplankton assemblage in the sanctuary was typical of surrounding coastal areas (ONMS, 2010). However, the 2010 report was limited by a lack of long-term, in situ data for phytoplankton and nutrients (ONMS, 2010).

New Information in the 2010–2022 Condition Report

GFNMS staff and subject matter experts assessed the current status and trend for eutrophication and concluded that eutrophication in coastal and offshore waters of GFNMS has not occurred and does not threaten ecological integrity. The current report provides new information and analysis for critical indicators of eutrophication, including: nutrients (nitrate and nitrite, phosphate, and silicate), phytoplankton relative abundance index (diatoms/dinoflagellates RAI), chlorophyll a, net primary productivity (NPP), and dissolved oxygen (Table S.WQ.6.1). However, experts also identified data and analysis gaps for key indicators like in situ chlorophyll a and harmful algal blooms (HAB).

Table S.WQ.6.1. Summaries for the key indicators related to eutrophication in the coastal and offshore region that were discussed during the May 16, 2022 virtual status and trends workshop.

Indicator	Source	Data Summary	Figures
Nutrients (nitrate, nitrite,	Elliott et al., 2022a	Status: Low nutrient concentrations from 2014 to present.	S.WQ.6.1

phosphate, silicate)		Trend: Decreasing, with mainly negative anomalies from 2014–2020.	
Phytoplankton Relative Abundance Index (RAI) (diatoms/dinoflagellates)	Elliott et al., 2022a	Status: Low RAI for diatoms and dinoflagellates in 2019 and 2021. Trend: Apparent increase in RAI from 2010–2017 followed by a decrease through 2021. Ratio of diatoms to dinoflagellates decreased.	S.WQ.6.2
Chlorophyll a concentration	NOAA Fisheries, 2020; O'Brien & Oakes, 2020	Status: Mainly positive anomalies in the last 10 years. Trend: No significant change over the last 10 years.	S.WQ.6.3
Net Primary Productivity	NOAA Fisheries, 2020; O'Brien & Oakes, 2020	Status: Positive anomalies in the last 10 years. Trend: Last 10 years showed an increasing trend but it was not significant	
Data gaps	Chlorophyll a in situ data		
Analysis gaps	The California-Harmful Algae Risk Mapping (C-HARM) Model, and the California HAB Bulletin		

The ACCESS project (see Text Box 1 in Q3) collects surface water samples for nutrients and physical and biological parameters in the sanctuary (Elliott et al., 2022a; Figure S.P.3.2). Nutrients, including nitrate (NO_3^-), nitrite (NO_2^-), phosphate (PO_4^{3-}), and silicate (SiO_4^{4-}), were measured at the surface, and mean concentrations were calculated for the monitoring stations in GFNMS. Nitrate, nitrite, phosphate, and silicate concentrations have been low since mid-2014, coinciding with a marine heat wave (MHW), and the low concentrations continued to 2021. Concentrations of all nutrients have decreased during the study period (Figure S.WQ.6.1). Additionally, ACCESS monitoring revealed low nutrient concentrations (negative monthly anomalies) associated with warm water events in 2005–2006 and MHWs in 2014–2016 and 2019. In contrast, high concentrations (positive monthly anomalies) were associated with cold water regimes in 2007–2008 and early 2009 (Elliott et al., 2022a).

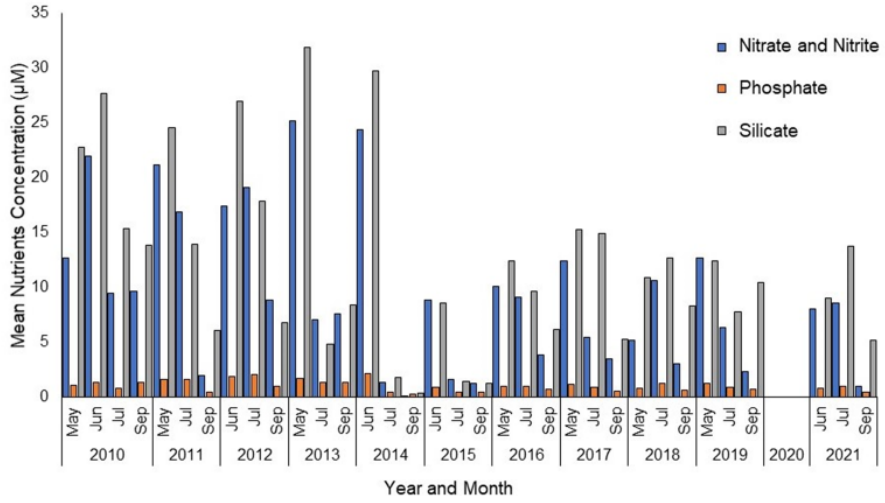

Figure S.WQ.6.1. Mean nutrient (nitrate and nitrite, phosphate, and silicate) concentration in micromoles (µM) in surface water at ACCESS monitoring stations in GFNMS from 2010–2021.Source: Elliott et al., 2022a.

Phytoplankton was sampled by ACCESS at the same oceanographic lines as nutrients and analyzed by the California Department of Public Health (CDPH) to evaluate HAB species and phytoplankton community composition. The composition of the phytoplankton community provides insight into ecosystem productivity, where fewer diatoms than dinoflagellates could indicate low-productive ocean waters. CDPH uses the RAI to monitor temporal changes in diatoms and dinoflagellates in surface water. The RAI in GFNMS increased from 2010–2017, peaking in 2017, then decreasing through 2021 (Figure S.WQ.6.2). The elevated RAI in 2017 was due to an abundance of the HAB diatom *Pseudo-nitzschia* spp. at one sampling site; *Pseudo-nitzschia* spp. produce domoic acid, a neurotoxin that causes Amnesic Shellfish Poisoning (ASP).

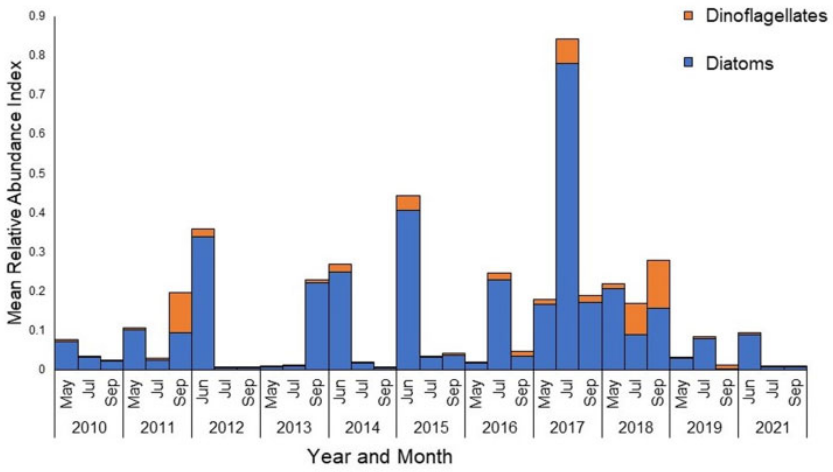

Figure S.WQ.6.2. Mean Relative Abundance Index (RAI) for phytoplankton (diatoms and dinoflagellates) in surface water at ACCESS monitoring stations inside GFNMS from 2010 to 2021. RAI is defined as (a*b)/c, where a is % composition, b is settled volume, and c is tow length. Source: Elliott et al., 2022a

The California Harmful Algal Bloom Monitoring and Alert Program (HABMAP) started monitoring *Pseudo-nitzschia* spp in 2019, with three sampling stations in the coastal and offshore region of the GFNMS (Bodega Marine Lab intake, Horseshoe Cove, and Bodega Marine Lab buoy). Despite the high occurrence in 2017, available data from 2020 to 2022 showed that abundances at these stations were below the blooming threshold of 10,000 cells/L (Largier, 2022).

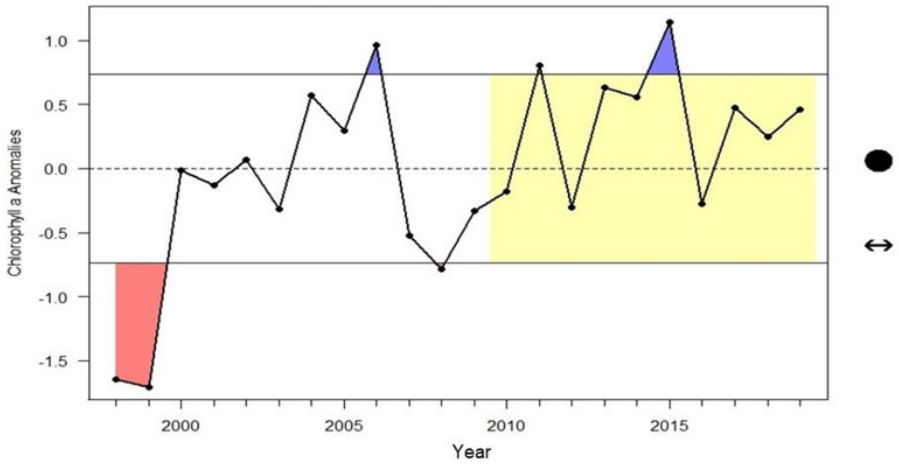

Figure S.WQ.6.3. Annual chlorophyll a anomalies for the coastal and offshore region of GFNMS. The shaded area in yellow represents the last 10 years used for the trend analysis, where the mean was within the one standard deviation (●) of the long-term mean and the trend was neutral (↔). Red and blue shaded areas show years for which the indicator value is below or above one standard deviation from the mean, respectively. Source: NOAA Fisheries, 2022; O'Brien & Oakes, 2020. Image: Mandy Karnauskas & Ayman Mabrouk/NOAA

Data on chlorophyll a concentration in surface water was acquired from the Spatiotemporal Data and Time Series Toolkit, which relies primarily on satellite data (NOAA Fisheries, 2020; O'Brien & Oakes, 2020). Data acquired from the toolkit encompassed offshore areas of GFNMS and CBNMS. Annual chlorophyll a anomalies were mainly positive over the last 10 years, with a neutral trend (Figure S.WQ.6.3).

Net primary productivity (NPP), which indicates how much carbon is generated from marine phytoplankton, was also measured. Positive NPP anomalies occurred from 2011 to 2020, excluding 2017. There was no significant temporal trend in NPP. Additionally, upwelling (not eutrophication) was thought to be the main reason for low bottom dissolved oxygen and hypoxia observed inside the sanctuary (please see Question 8 for more detail).

Conclusion

From 2010–2021, eutrophic conditions in the coastal and offshore region of GFNMS did not occur and there was only one HAB that was detected during this study period, therefore conditions were rated as good with high confidence. Some data that were used to determine eutrophication, were limited, such as year round sampling nutrients, phytoplankton and NPP. The trend of NPP was undetermined with medium confidence because year round measurements were not available.The ACCESS project (Box 1) collects nutrients and phytoplankton samples three times per year. From the available data, levels of phytoplankton and chlorophyll a, were within normal levels, and nutrients decreased during the study period. RAI showed variability but no clear trend, and chlorophyll a and NPP had no significant changes. While the availability of certain datasets helped increase confidence in these ratings,

there are data and analysis gaps for GFNMS, including a lack of the extent, duration, and frequency of HABs, as well as in situ chlorophyll a concentration data.

Reference (Q6/Coastal and Offshore)

Largier, J. (2022, September 22). *Bodega Bay Data*. California Harmful Algal Bloom Monitoring and Alert Program. https://calhabmap.org/bodega-bay

Elliott, M., Lipski, D., Roletto, J., Warzybok, P., & Jahncke, J. (2022a). Ocean climate indicators status report: 2021. Contribution No. 2422. Point Blue Conservation Science. http://www.accessoceans.org/wp-content/uploads/2022/09/Ocean_Climate_Indicators_Report_2021.pdf

NOAA Fisheries. (2022). COPEPODITE: Spatiotemporal data and time series toolkit. U.S. Department of Commerce, National Oceanic and Atmospheric Administration. https://www.st.nmfs.noaa.gov/copepod/toolkit/

O'Brien, T. D., & Oakes, S. A. (2020). Visualizing and exploring zooplankton spatio-temporal variability. In M. A. Teodósio & A. B. Barbosa (Eds.), Zooplankton ecology (pp. 192–224). CRC Press. https://doi.org/10.1201/9781351021821

Office of National Marine Sanctuaries.(2010). Gulf of the Farallones National Marine Sanctuary Condition Report 2010. U.S. Department of Commerce, National Oceanic and Atmospheric Administration Office of National Marine Sanctuaries, Silver Spring, MD. 97 pp.

Estuarine and Lagoon Region (Q6)

Status Rating: Good/Fair	Status Confidence: Medium
Trend Rating: Undetermined	Trend Confidence: Medium
Status Description: Eutrophication is suspected and may degrade some attributes of ecological integrity, but has not yet caused measurable degradation.	
Rationale: Data documenting eutrophication are lacking, but there are no signs of negative effects on ecological integrity. However, GFNMS estuaries are still listed as impaired water bodies due to high levels of nutrients.	

Findings From the 2010 Condition Report

In the 2010 condition report, the rating for this question was good/fair and the trend was undetermined. There were high levels of nutrients in GFNMS estuaries, but there had been no known mortality events among fish or invertebrates due to eutrophication. There were anecdotal

reports of macroalgae eutrophication in sanctuary estuaries, but no regular surveys to properly assess this (ONMS, 2010).

New Information in the 2010–2022 Condition Report

Data used to assess eutrophication included chlorophyll a in Tomales Bay, phytoplankton RAI in Tomales Bay and Bolinas Lagoon, and nutrients and dissolved oxygen in Tomales Bay watershed (Walker Creek and Lagunitas Creek), while, data gaps included nutrients, chlorophyll a, and dissolved oxygen in all the GFNMS estuaries (Table S.WQ.6.2)

Table S.WQ.6.2. Summaries for the key indicators related to eutrophication in the estuarine and lagoon region that were discussed during the May 16, 2022 virtual status and trends workshop.

Indicator	Source	Data Summary	Figures
Chlorophyll a concentration	BOON, 2022	Status: There was an annual pattern of high chlorophyll a in spring that peaked in July. In recent years, two annual peaks were detected. Trend: Increasing.	S.WQ.6.4
Phytoplankton RAI (diatoms/dinoflagellates)	CDPH, 2022 [unpublished data set]	Status: High RAI in Tomales Bay compared to Bolinas Lagoon, especially in 2016 and 2017. Trend: Tomales phytoplankton RAI increased (significant increase in dinoflagellates), while Bolinas phytoplankton showed no trend.	S.WQ.6.5
Nutrients (total nitrogen and total phosphorus)	CSWRCB, 2019a; CSWRCB, 2019b	Status: High nutrient levels were observed in Walker Creek and its tributaries, but low levels at Lagunitas Creek. Trend: N/A	S.WQ.6.6
Dissolved oxygen	CSWRCB, 2019b	Status: Minimum dissolved oxygen conditions for cold water fish were not met for Walker Creek. Poor dissolved oxygen conditions were observed upstream of Lagunitas Creek. Trend: N/A	
Data Gaps	Nitrogen, phosphorus, and silicate concentrations in all GFNMS estuaries Chlorophyll a levels in all GFNMS estuaries Dissolved Oxygen levels in all GFNMS estuaries		

Data on chlorophyll *a* concentration was obtained from the Tomales Bay buoy for 2013–2021, although some 2016 data were missing (Bodega Ocean Observing Node [BOON], 2022). There was a pattern of high chlorophyll a concentrations that peaked mainly in July 2013, 2014, 2017, 2018, and 2019, with a high risk of exceeding the eutrophication thresholds from 25-40 µg/l (Sutula et al. 2017). Trend analysis indicated a potential increase in chlorophyll a concentration over time (Figure S.WQ.6.4).

Commented [1]: Here and everwhere else the "a" in chlorophyll a should be italicized. Why I don't know but it is the standard...

Formatted: Font: Italic

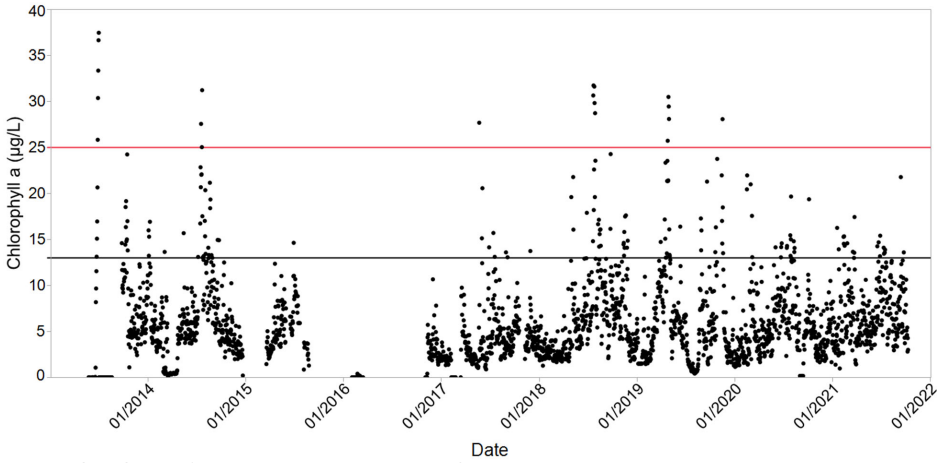

Figure S.WQ.6.4. Chlorophyll a concentration from the Tomales Bay buoy 2013–2021. Black line is the protective threshold (13 µg/l) below which the probability of eutrophication is reduced and the red line is the at-risk threshold (25 µg/l) above which the eutrophication probability is high (Sutula et al. 2017) Source: BOON, 2022; Image: A. Mabrouk/NOAA

Phytoplankton RAI was measured by CDPH in Tomales Bay and Bolinas Lagoon. CDPH uses the RAI to monitor temporal changes in diatoms and dinoflagellates in surface water. RAI in Tomales Bay was high, especially in 2016 and 2017, but no algal bloom was recorded (Figure S.WQ.6.5). In Bolinas Lagoon, RAI was low compared to Tomales Bay (Figure S.WQ.6.6).

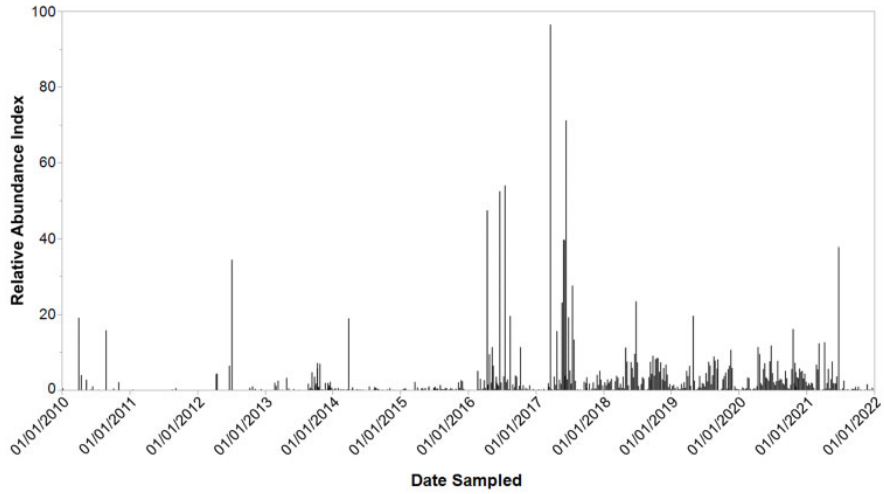

Figure S.WQ.6.5. Tomales Bay phytoplankton RAI from 2010 to 2021. Few samples (9 to 18 per year) were collected from 2010–2013; from 2013–2021 samples ranged from 53 to 90 per year. The dashed line represents the trend (no significant trend was detected). Source: V. Zubkousky-White/CDPH; Image: A. Mabrouk/NOAA

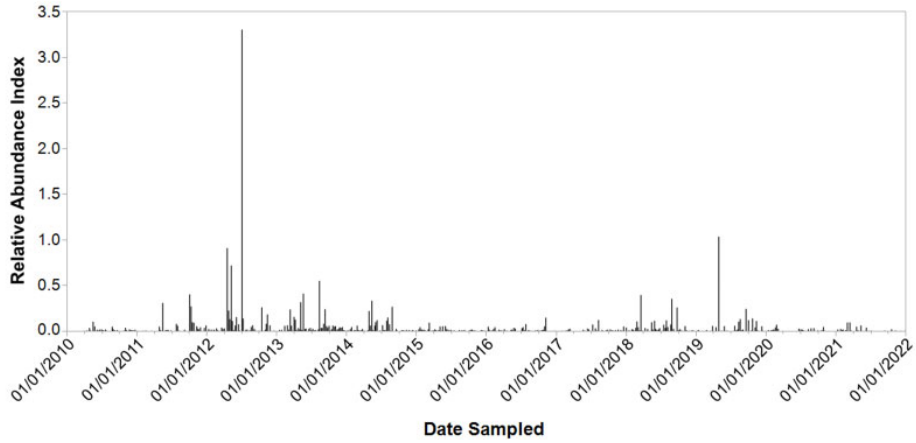

Figure S.WQ.6.6. Bolinas Lagoon phytoplankton RAI from 2010 to 2021. A high number of samples (273 to 665 samples per year) were collected compared to Tomales Bay. RAI values were low compared to Tomales Bay (note the difference in the y-axis scale on graphs), but seasonal patterns were similar, with high RAI in spring peaking in July (2012). No trend was detected over the study period. Source: V. Zubkousky-White/CDPH; Image: A. Mabrouk/NOAA

Tomales Bay, Estero Americano, and Estero de San Antonio had high nutrient levels, originating from dairy farms and runoff, and as a result, these estuaries were listed as impaired water under the Clean Water Act (ONMS, 2010). These estuaries were also listed by the California Water Board as impaired due to high nutrient levels in its last three integrated reports (California Water Board, 2016, 2018, 2022). Although nutrients are one of the main indicators of eutrophication in the sanctuary's estuaries, long-term datasets were not available and are considered data gaps (Table S.WQ.6.2). Data on nutrients (total phosphorus and total nitrogen) were available only for Tomales Bay's watershed (Walker Creek, and Lagunitas Creek) through the California Water Board report cards released in 2019. The report cards assessed nutrients and other eutrophication indicators in both creeks based on the water samples collected in 2017. The report cards revealed high nutrient levels in Walker Creek and its tributaries, exceeding the threshold for eutrophication, but low levels in Lagunitas Creek (CSWRCB, 2019a & 2019b).

Eutrophication can lead to low dissolved oxygen or hypoxia. Data on dissolved oxygen for the estuaries and lagoons of GFNMS are sparse and considered data gaps (Table S.WQ.6.2). However, the California Water Board report cards for the Tomales Bay watershed, show that dissolved oxygen at Walker Creek and Lagunitas Creek did not meet requirements for cold

water fish (coho salmon and steelhead trout) exceeding the eutrophication threshold (CSWRCB, 2019a & 2019b).

Conclusion

The status of eutrophic conditions in the estuarine and lagoon region of GFNMS from 2010–2022 was good/fair based primarily on the designation of Tomales Bay, Estero Americano, and Estero de San Antonioas as impaired water body due to high nutrient levels and the high levels of nutrients in Walker Creek, a tributary of Tomales Bay. The trend was undetermined because of a lack of time series data in nutrients and dissolved oxygen. Although there were more and newer datasets in this assessment than the 2010 assessment, these were limited to Tomales Bay and Bolinas Lagoon. Specific data gaps include a lack of long-term in situ data for phytoplankton abundance, macroalgae cover, chlorophyll a concentration, and nutrient concentration in all GFNMS estuaries.

References (Q6/Estuarine and Lagoon)

Commented [2]: entries will of course need formatting to match other chapters. Or...references are formatted differently in chaps 6 onwards compared to earlier chapters?

Bodega Ocean Observing Node (2022). *Tomales Bay Buoy Seawater Chlorophyll Daily, 2013-2021*[Data set].University of California, Davis, Bodega Marine Laboratory https://boon.ucdavis.edu/data-access/products/tbb/tbb_seawater_chlorophyll_daily

California State Water Resources Control Board. (2019a). Water quality report card: Walker Creek Nutrient Impairment Analysis. San Francisco Bay, Region 2. https://www.waterboards.ca.gov/about_us/performance_report_2021/plan_assess/docs/fy1819/r2_walkernutrients.pdf

California State Water Resources Control Board. (2019b). Water quality report card: Lagunitas Creek Nutrient Impairment Analysis. San Francisco Bay, Region 2. https://www.waterboards.ca.gov/about_us/performance_report_1819/plan_assess/docs/fy1819/r2_lagunitas_nutrients.pdf

NOAA Fisheries. (2022). COPEPODITE: Spatiotemporal data and time series toolkit. U.S. Department of Commerce, National Oceanic and Atmospheric Administration. https://www.st.nmfs.noaa.gov/copepod/toolkit/

O'Brien, T. D., & Oakes, S. A. (2020). Visualizing and exploring zooplankton spatio-temporal variability. In M. A. Teodósio & A. B. Barbosa (Eds.), Zooplankton ecology (pp. 192–224). CRC Press. https://doi.org/10.1201/9781351021821

Office of National Marine Sanctuaries. (2010). Gulf of the Farallones National Marine Sanctuary Condition Report 2010. U.S. Department of Commerce, National Oceanic and Atmospheric Administration Office of National Marine Sanctuaries, Silver Spring, MD. 97 pp.

Sutula, M., Kudela, R., Hagy, J. D., Harding, L. W., Senn, D., Cloern, J. E., . . . Beck, M. (2017). Novel analyses of long-term data provide a scientific basis for chlorophyll-a thresholds in San Francisco Bay. Estuarine, Coastal and Shelf Science, 197, 107-118. doi:https://doi.org/10.1016/j.ecss.2017.07.009

Question 7: Do sanctuary waters pose risks to human health and how are they changing?

Coastal and Offshore Region (Q7)

Status Rating: Fair	Status Confidence: Medium
Trend Rating: Mixed	Trend Confidence: Medium
Status Description: Water quality problems have caused measurable human impacts, but effects are localized and not widespread or persistent.	
Rationale: The fair rating is attributed to the presence of biotoxins and the subsequent fishery closures. In addition, some beaches had swimming advisories due to contaminants but were not listed as impaired. Mercury and Polychlorinated Biphenyls (PCBs) were below thresholds except for one year (Mercury: 2010; PCBs: 2015). The trend is mixed based on some improvements in beach water quality and some worsening levels of biotoxins and fishery closures.	

Findings From the 2010 Condition Report

In the 2010 condition report, the status for this question was good/fair and the trend was not changing. This rating recognized large inputs from urbanization to coastal and offshore waters of the sanctuary that have the potential to affect human health, as well as the lack of reported incidences of disease. It also considered the concentration of domoic acid in shellfish, impaired water at the beaches and beach closures, and organic pollutants in sediment. It is important to note that HABs and biotoxins in shellfish are naturally occurring in the sanctuary and result in periodic shellfish closures.

New Information in the 2010–2022 Condition Report

The data considered in this condition report were biotoxin levels in bivalves and crabs, shellfisheries closures, impaired water bodies, beach closures for swimming, and heavy metals and organic pollutant contaminants crab (Table S.WQ.7.1). Also of note is that Marin County Public Health had one confirmed case of illness from PSP from eating mussels from Dillon beach in 2018. This case was recorded, although a CDPH advisory warned the public about the extremely high level of PSP toxins in mussels.

Commented [3]: "...in crabs" ?

Table S.WQ.7.1. Summaries for the key indicators related to sanctuary waters posing a risk to human health in the coastal and offshore region that were discussed during the May 16, 2022, virtual status and trends workshop.

Indicator	Source	Data Summary	Figures
Biotoxins (domoic acid/PSP in bivalves and	CDPH, unpublished data	Status: PSP toxins in bivalves exceeded regulatory thresholds set by the federal Food and Drug Administration to protect humans at different years with the highest level in 2018. Domoic acid was below these	S.WQ.7.1; S.WQ.7.2

domoic acid in Dungeness crab)		thresholds in bivalves except in Dungeness crab (HAB event 2015–2016). Trend: PSP toxins in bivalves increased significantly	
Shellfish fishery closures (Dungeness crab)	CDPH, CDFW, Chris Free	Status: Annual closures July–Nov., delays in fishery opening; 142 days 2015–2016, 18-55 days 201-2017 and 23 days 2018. Trend: fishing opening days delayed decreased over 2015-2020	
Impaired water 303 (d) List	CSWRCB, 2022	Status: All beaches and outside of the Golden Gate were assessed and not listed, with Bolinas Beach delisted. Trend: Improvement in beach condition because Bolinas Beach was delisted as an impaired water body in the last three integrated assessment reports for the CA Water Board.	
Beach advisory days due to bacteria	EPA, 2022	Status: High advisory days in Marin County and low in Sonoma County Trend: Decreased in Sonoma County but a trend not clear in Marin County	S.WQ.7.3
Contaminants in shellfish	SFPUC, 2014 & 2021	Status: Mercury in Dungeness crab tissues was generally below the California contaminant limit. PCBs in Dungeness crab hepatopancreas exceeded the FDA limits in 1998 and 2015, but were below the limit in muscle tissue. DDT was higher in hepatopancreas than in muscle, but did not exceed FDA or EPA limits. Trend: No clear trend for the last 10 years but longer term trends decreased.	S.WQ.7.5; S.WQ.7.6
Data Gap	Organic pollutants and heavy metals in crabs, mussels, and fish in the sanctuary.		
Analysis Gap	Only two of 13 heavy metals in sediments were analyzed and organic pollutants in sediments still need to be extracted and analyzed.		

Biotoxins: Paralytic Shellfish Poisoning in Bivalves, Domoic Acid, and Fishery Closures

A harmful algal bloom (HAB) refers to the rapid growth or accumulation of algae in freshwater or marine ecosystems, leading to harmful effects on the environment, human health, or other organisms. These blooms are often caused by the excessive growth and proliferation of certain species of algae, primarily phytoplankton. These phytoplankton produce toxins that accumulate in shellfish and can cause illness when ingested by humans. HABs continue to be a concern for human health and the regional economy in California. The most concerning HAB phytoplankton are the dinoflagellates of the genus *Alexandrium* that produce the neurotoxin saxitoxin that causes paralytic shellfish poisoning (PSP) and diatoms of the genus *Pseudo-nitzschia* (PN) that produce the neurotoxin domoic acid that causes amnesic shellfish poisoning (ASP) (Anderson et al., 2008 and ONMS, 2010). HABs occur naturally in GFNMS, and the biotoxins ASP and PSP are periodically detected in shellfish, sometimes resulting in trophic transfer of biotoxins to predators like marine mammals and seabirds (ONMS, 2010).

The CDPH manages a coastal shellfish monitoring program that measures the concentrations of the biotoxins domoic acid and PSP toxins in shellfish. PSP toxin concentration in mussels, clams, and oysters from 2010–2022 exceeded the regulatory threshold of 80 ug/100g for all years except 2010 and 2011 with the highest values in 2018. The trend seems to be worsening (CDPH, 2022 [unpublished data set]; Figure S.WQ.7.1). Domoic acid in the viscera of crabs was also at concentrations that exceeded the regulatory threshold (30 ppm). The highest levels were recorded in 2015–2016, and this caused the longest closure of the Dungeness crab fishery since the HAB related 2005–2006 exceptional closure event (Moor et al., 2019; CDPH, 2022 [unpublished data set]; Figure S.WQ.7.2).

Commented [4]: Might want to put the word "seasonally" before this...the way it is written makes it seems like this occurrs all the time...same for below with Domoic Acid...

The California Department of Fish and Wildlife (CDFW), which manages the Dungeness crab fishery in California, implements an annual quarantine for the Dungeness crab commercial and recreational fishery from July to November. The annual quarantine was extended into the open season; these extensions were 142 days in 2015–2016, 18–55 days in 2016–2017, and 23 days in 2018 (Moor et al., 2019; Free, 2022).

Because of the coordinated management efforts by the California Department of Public Health (CDPH), the California Department of Fish and Wildlife (CDFS), and the California Office of Environmental Health Hazard Assessment to monitor and implement advisories and closures, actual human health impacts have been minimized. Only one case of PSP illness from eating mussels from Dillon Beach was confirmed by Marin County Public Health (V. Zubkousky, personal communication, May 16, 2022).

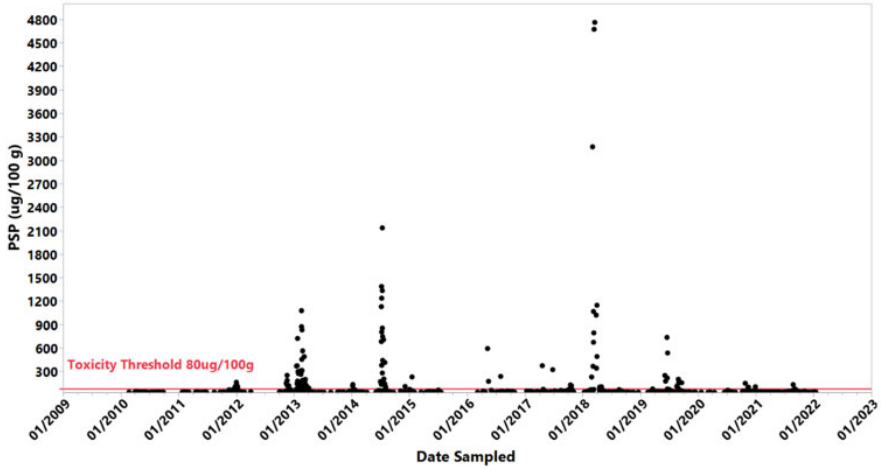

Figure S.WQ.7.1. PSP toxin concentration in bivalves (mussels, clams, and oysters) for Sonoma and Marin counties from 2010–2020. The red line is the regulatory limit (>80 ug/100g) for the California Department of Public Health (CDPH), 0 records represent non-detected PSP toxin. Source: CDPH. Image: A. Mabrouk/NOAA

Commented [5]: This figure is a little funny because of just a few very high data points. I would either put it on a log scale (confusing in it's own right) or limit the Y-axis from 0-1000 and note there were a few data points not included in the plot.

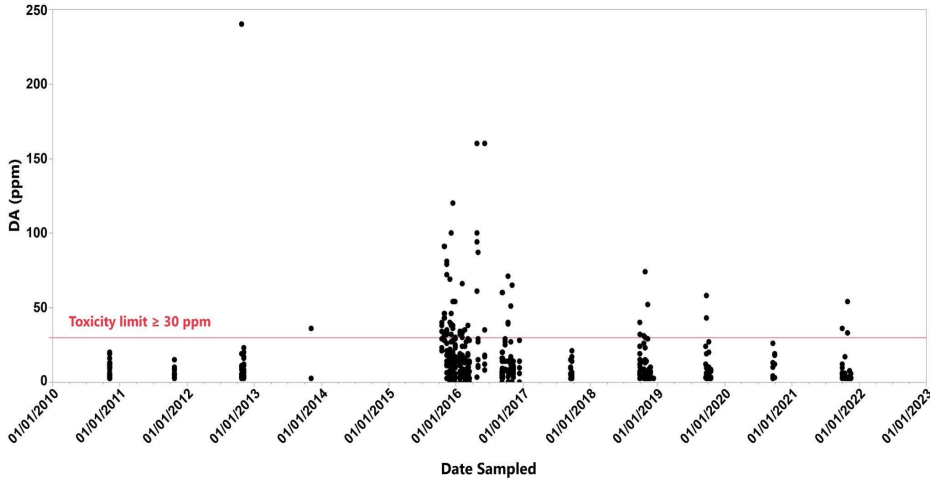

Figure S.WQ.7.2. Domoic acid levels in Dungeness and Rock crab viscera for Sonoma and Marin counties from 2010–2021. The red line is the regulatory limit (>30 ppm) for the California Department of Public Health (CDPH). Data Credit: CDPH. Figure credit: A. Mabrouk/NOAA

Impaired Water 303 (d) List and Beach Advisory/Closures

The California State Water Resources Control Board's integrated assessment reports for the years 2014–2016, 2018, and 2020–2022 showed that beaches along the sanctuary coast that were assessed for water quality were not listed as impaired bodies of water on the 303(d) listing (CSWRCB, 2022). This is an improvement from the 2010 condition report when Bolinas Beach was listed as an impaired water body. However, regular water quality monitoring of the coastal beaches in Sonoma and Marin counties resulted in advisory days due to elevated pathogenic bacteria that exceeded the health standards for swimming. In Sonoma County, of the beaches regularly monitored, only Black Point Regional Park Beach had a number of advisory days (192) that occurred in 2010. Since then, there have only been two advisory days at Doran Regional Park Beach in 2016. Bolinas and Stinson Beaches in Marin County often had advisory days ranging from 5 to 7 days each year with no clear trend (U.S. EPA, 2022; Figure S.WQ.7.3).

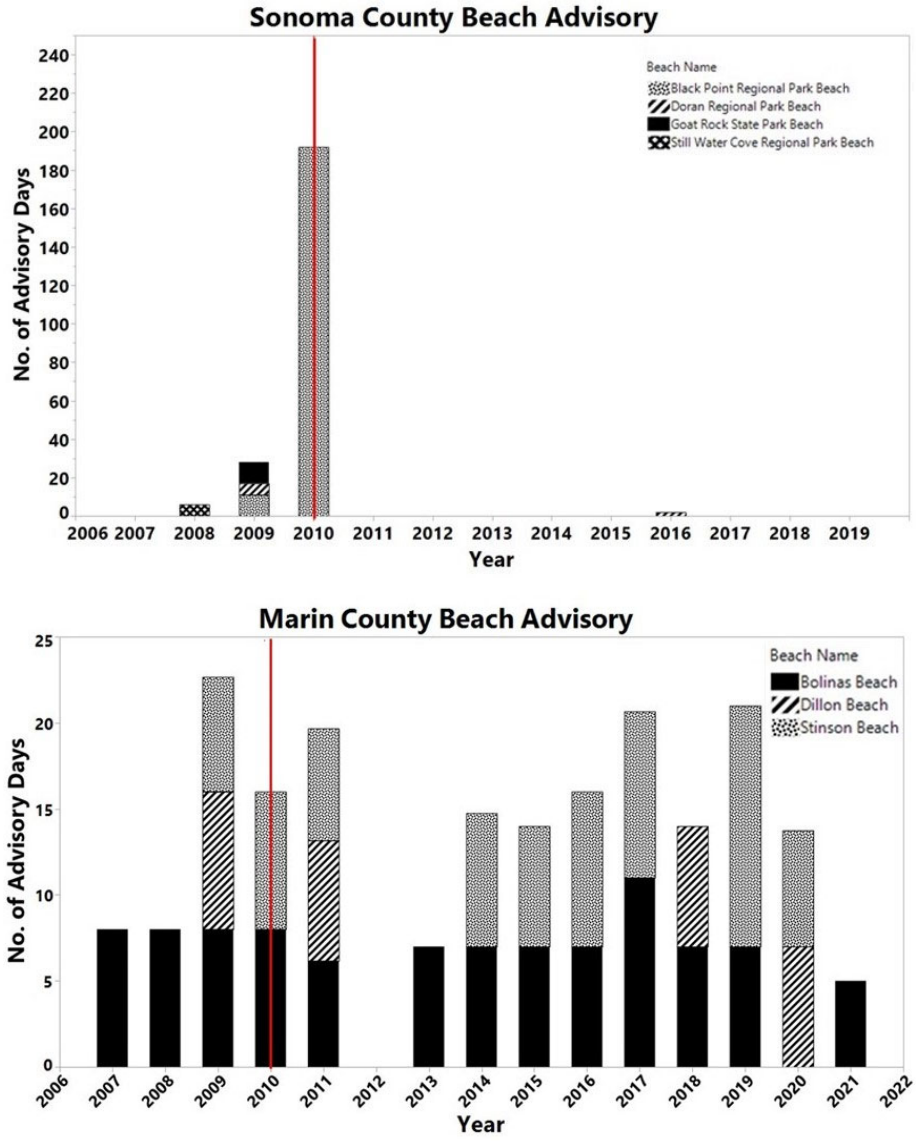

Figure S.WQ.7.3. Sonoma county beach advisory (number of days with elevated pathogenic bacteria) (top); Marin county beach advisory (bottom). The vertical red line indicates the year of the last GFNMS condition report (2010). Source: EPA BEACON 2.0 - Beach Advisory and Closing On-line Notification; Image: A. Mabrouk/NOAA

Contaminants in Sediments and Shellfish

Since 1997, the San Francisco Public Utilities Commission (SFPUC) has monitored organic and heavy metals pollutants in Dungeness crab as part of the Southwest Ocean Outfall Regional Monitoring Program (SWOO), to detect the environmental impacts of the discharge of treated combined sewer effluent from the offshore Southwest Ocean Outfall and shoreline facilities. There are 5 monitoring sites in GFNMS out of a total of 44 monitoring sites in the region.

Commented [6]: I guess this is the type of discussion I was looking for under the status of pressures...here under status and trends. Makes more sense here?

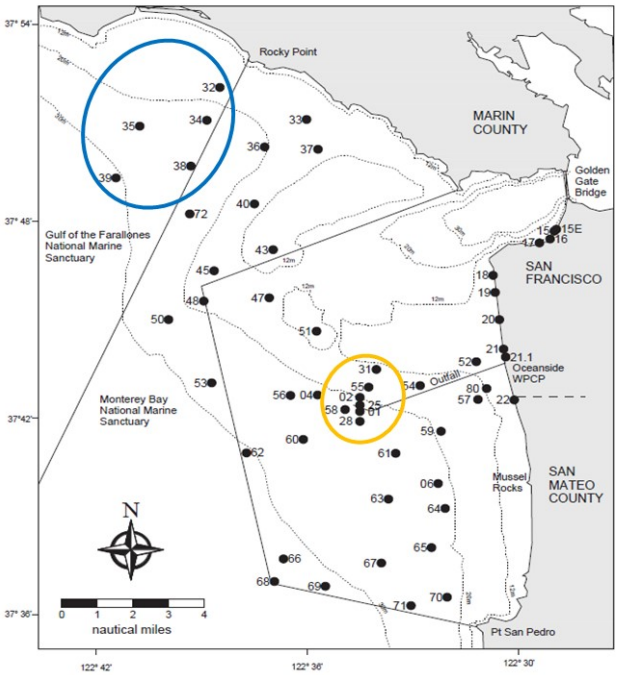

Figure S.WQ.7.4. Locations of monitoring stations of the South Ocean Outfall Regional Monitoring program. The program monitors the environmental impact of the discharged treated water from the offshore outfall at 44 sampling stations, five of them in the sanctuary (blue oval), and seven in close proximity to the outfall (gold oval). The rest of the sites are considered reference stations. Figure modified from San Francisco Public Utilities Commission, 2021

For Dungeness crab, organic pollutants and heavy metals were measured in crab muscle and hepatopancreas at the outfall site 01 and at reference site 06 only. Both were outside the sanctuary (Figure S.WQ.7.4). Since 2001, mercury concentrations have been below the California fish contaminant goal (0.22 ppm), with the exception of 2010 when mercury levels in crab hepatopancreas at the outfall site exceeded the fish contaminant goal (Figure S.WQ.7.5). Polychlorinated Biphenyls (PCBs) concentrations were high in the hepatopancreas and exceeded the U.S. Food and Drug Administration (FDA) limits (200 ppb) in 1998 and 2015, but in muscles were very low and below the limit (Figure S.WQ.7.6). Additionally,

Dichlorodiphenyltrichloroethane, commonly known as DDT, was also higher in hepatopancreas than in muscle but didn't exceed FDA and EPA limits (5000 ppb).

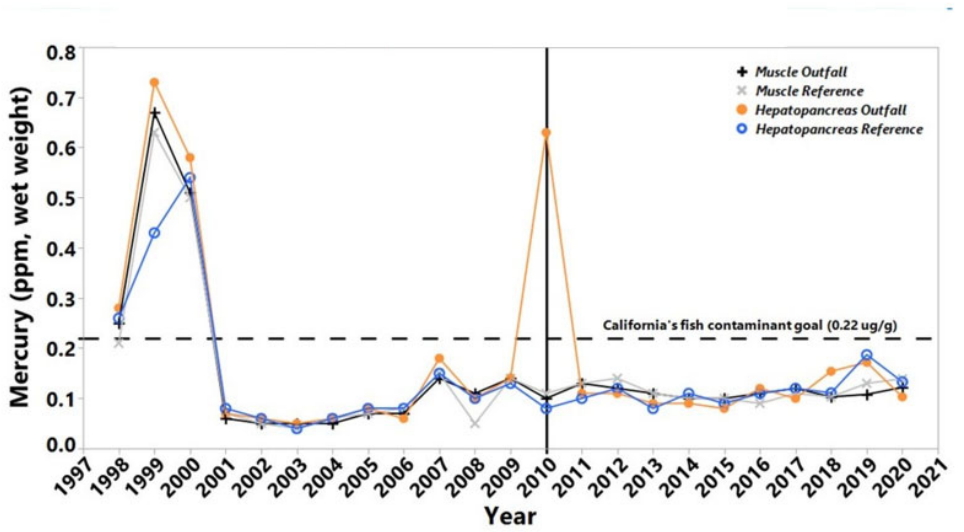

Figure S.WQ.7.5. Mercury (Hg) concentration in Dungeness crab at outfall station 01 and reference station 06 from 1997–2020. The vertical black line indicates the year of last condition report (2010), while the horizontal dashed black line is California's fish contaminant goal for Hg (0.22 ug/g). Data Credit: SFPUC/SWOO 2021. Figure: A. Mabrouk/NOAA

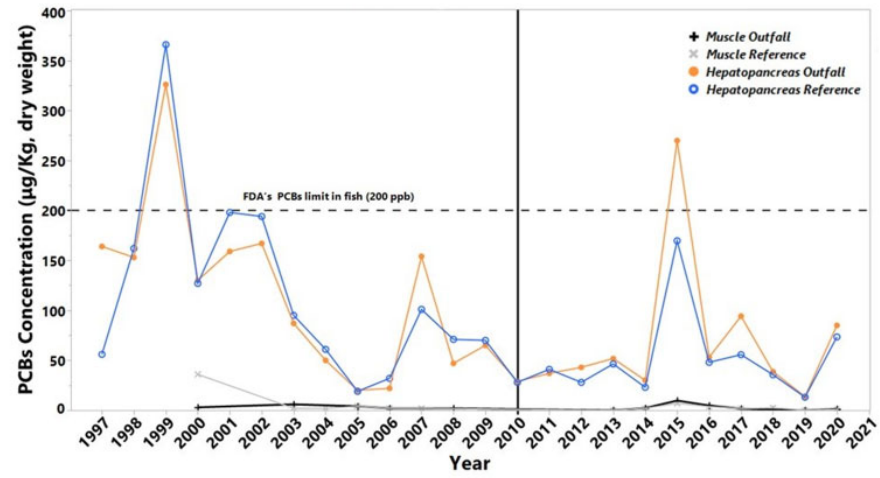

Figure S.WQ.7.6. Organic pollutant (PCBs) concentration in Dungeness crab at outfall station 01 and reference station 06 from 1997–2020. The vertical black line indicates the year of the last condition report (2010), while the horizontal dashed black line is the FDA's PCBs limit in fish (200 ppb). Data Credit: SFPUC/SWOO 2021. Figure: A. Mabrouk/NOAA

Conclusion

The status of sanctuary waters in the coastal and offshore region and their threat to human health was rated fair based largely on a documented PSP illness case in 2018 and shellfish closures in 2015–2016 caused by a biotoxin in bivalves and crabs. The California State Water Resources Control Board's beach assessment showed that the sanctuary's beaches were not listed in the impaired water body; however, a few beaches in Marin County did have elevated counts of pathogenic bacteria but were not high enough to result in beach closures. The mixed trend is based on some improvements, such as delisting Bolinas Beach from the impaired water bodies and the number of beach advisories and closures in some areas, while other indicators were worsening, such as biotoxins in shellfish. Although there were more indicators and data assessed in the current report than in the 2010 condition report, there are still data gaps, such as levels of organic and heavy metals pollutants in crabs, mussels, and fish from the sanctuary; the only data available for this report were for Dungeness crab and locations south of the sanctuary.

References (Q7/Coastal and Offshore)

Anderson, C. R., Berdalet, E., Kudela, R. M., Cusack, C. K., Silke, J., O'Rourke, E., . . . Morell, J. (2019). Scaling Up From Regional Case Studies to a Global Harmful Algal Bloom Observing System. Frontiers in Marine Science, 6(250). doi:10.3389/fmars.2019.00250

California State Water Resources Control Board. (2022, October 5). Surface Water Quality Assessment. https://www.waterboards.ca.gov/water_issues/programs/water_quality_assessment/#impaired

Dalton, M., S. Chisholm Hatfield, P. Mote, D. Sharp, K. Serafin, P. Ruggiero, N. Cohn, M. Conlin, G. Reeves, B. Lee, M. Case, and J. Lawler. (2016). Climate Change Vulnerability Assessment for the Treaty of Olympia Tribes. A Report to the Quinault Indian Nation, Hoh Tribe, and Quileute Tribe. Prepared by The Oregon Climate Change Research Institute. 236 pp. Online: https://www.cakex.org/documents/climate-change-vulnerability-assessment-treaty-olympia-tribes (Accessed June 6 2022).

U.S. Environmental Protection Agency. (2022). BEACON 2.0 - Beach Advisory and Closing On-line Notification Reports [Data set]. Retrieved July 1, 2022, from https://watersgeo.epa.gov/beacon2/reports.html

Free, Christopher M. (2022, September 22). Table of advisory and closure announcements: advisories | closures. Domoic acid closures in California fisheries. https://marine.rutgers.edu/~cfree/domoic-acid-closures-in-california-fisheries/

Horner, R. A., Garrison, D. L., and Plumley, F. G. (1997). Harmful algal blooms and red tide problems on the US west coast. Limnol. Oceanogr. 42, 1076–1088. doi: 10.4319/lo.1997.42.5_part_2.1076

Moore, S. K., Cline, M. R., Blair, K., Klinger, T., Varney, A., & Norman, K. (2019). An index of fisheries closures due to harmful algal blooms and a framework for identifying vulnerable fishing communities on the U.S. West Coast. Marine Policy, 110, 103543. doi:https://doi.org/10.1016/j.marpol.2019.103543

Office of National Marine Sanctuaries. 2010. Gulf of the Farallones National Marine Sanctuary Condition Report 2010. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD. 97 pp.

San Francisco Public Utilities Commission (2014).SOUTHWEST OCEAN OUTFALL REGIONAL MONITORING PROGRAM SIXTEEN-YEAR SUMMARY REPORT 1997–2012. April 2014.

San Francisco Public Utilities Commission (2021).SOUTHWEST OCEAN OUTFALL REGIONAL MONITORING PROGRAM 2020 DATA REPORT. August 2021.

Shaffer, A., J. Wray, B. Charles, V. Cooke, E. Grinnell, C. Morganroth III, L.M. Morganroth, M. Peterson, V. Riebe, and A. Smith. (2004). Native American Traditional and Contemporary Knowledge of the Northern Olympia Peninsula Nearshore. A Cooperative Study by the Olympic Peninsula Intertribal Cultural Advisory Committee and the Coastal Watershed Institute. 55 pp.

Estuarine and Lagoon Region (Q7)

Status Rating: Fair	Status Confidence: High
Trend Rating: Undetermined	Trend Confidence: High
Status: Description: Water quality problems have caused measurable human impacts, but effects are localized and not widespread or persistent.	
Rationale: Paralytic shellfish poisoning exceeded thresholds in some years in Tomales Bay. Shellfish fishery closures were enacted in most years on Tomales Bay due to rainfall, norovirus, vibrio, or PSP. A norovirus outbreak in Tomales Bay's oyster farms sickened 44 people in 2018–2019. Tomales Bay, Estero Americano, and Estero de San Antonio were listed as impaired bodies of water, and beach advisories were present for Tomales Bay throughout the study period without a clear trend. Mercury contaminant levels were high for fish in Tomales Bay and consumption advisories were in effect. Most data indicators were variable with no clear trend.	

Findings From the 2010 Condition Report

In the 2010 condition report, the status for this question in the estuarine and lagoon region was fair/poor and the trend was undetermined. This rating was based mainly on the impaired water bodies 303(d) list that listed Tomales Bay, Estero Americano, and Estero de San Antonio, the number of shellfish fishery closures due to rainfall, and the norovirus outbreaks in Tomales Bay.

New Information in the 2010–2022 Condition Report

This question considered biotoxins (PSP toxin and domoic acid) in bivalves, shellfish harvesting closures, beach advisories, pathogenic bacteria (fecal coliform), the impaired water bodies 303(d) list, and mercury (Hg) contamination in sediment and biota. This assessment was largely focused on Tomales Bay, where data was available for the selected indicators (Table S.WQ.7.2). There was no available data on many of these indicators for the other GFNMS's estuaries (Estero Americano and Estero de San Antonio) or Bolinas lagoon.

Table S.WQ.7.2. Summaries for the key indicators related to sanctuary waters posing a risk to human health in the estuarine and lagoon region that were discussed during the May 16, 2022, virtual status and trends workshop.

Indicator	Source	Data Summary	Figures
Biotoxin (domoic acid/PSP toxin) in Bivalves	CDPH, unpublished data	Status: PSP toxin high mainly in 2014, 2018, and 2019; domoic acid below the detection limit. Trend: No clear trend.	S.WQ.7.7
Shellfish Closures (# of closures days due to rainfall, PSP toxin, Vibro, and Norovirus)	CDPH, unpublished data	Status: High number of days for rainfall closures and low number of days for PSP toxin and Vibrio; norovirus closures were only in 2019. Trend: PSP toxin and Vibrio closures days were decreasing.	S.WQ.7.8
Impaired Water	CSWRCB, 2022	Status: All assessed estuaries are still listed as impaired water bodies. From 2010–2021, there were 131 exceedances of fecal coliform levels. In 2019, there were two norovirus outbreaks that led to shellfish harvesting closures, but the source was not found. Trend: No change.	
Beach Advisory days	EPA, 2022	Status: The number of advisory days was the lowest in 2015, but high in recent years 2018, 2020 & 2021). Trend: No clear trend, but relatively high number in three of the last four years.	S.WQ.7.9
Contaminants: Mercury in Biota	CSWRCB, 2022	Status: Fish advisory limits fish and crab consumption due to high levels of mercury concentrations. Trend: Mercury decreased in sediment at Walker Creek.	S.WQ.7.10; S.WQ.7.11
Data Gap		Long-term data on organic pollutants and heavy metals in crabs, mussels, and fish from the sanctuary's estuarine and lagoon habitats.	

Biotoxins: Domoic Acid and Paralytic Shellfish Poisoning in Bivalves and Shellfisheries Closures

HAB biotoxins (i.e., PSP toxin and domoic acid), norovirus outbreaks, pathogenic bacteria (i.e., fecal coliform and E. coli), are the main threats to water quality and human health (through seafood consumption) in the estuarine and lagoon region, particularly in Tomales Bay (ONMS, 2010). In Tomales Bay PSP toxins were measured in cultured oysters and mussels where toxin concentration exceeded the regulatory threshold (80 ug/100g), in 2013, 2014, 2017, 2018, and 2019, and there was no clear trend (V. Zubkousky-White/CDPH, unpublished data; Figure S.WQ.7.7). In the few bivalves samples tested from Tomales Bay (97 samples from 2010–2022), domoic acid was below the detection limit of 2.5 ug/100g. However, four types of shellfish closures (rainfall[1], PSP, Vibro, and norovirus closures) occurred in Tomales Bay based on the annual sanitary survey update reports from the CDPH. Closure days were calculated for the four types from the CDPH patrol logs and summary reports (Rankin, 2022; Figure S.WQ.7.8). Closure days due to rainfall were the highest in numbers and occurred annually with an undetermined trend, while norovirus closures happened only in 2018–2019 (Dec./Jan./Apr.) due to a norovirus outbreak in Tomales Bay oyster aquaculture. This outbreak caused illness in 44 people who ate oysters from Tomales Bay that caused the California Department of Public Health to close oyster harvesting in Tomales Bay (Larsen, 2019)., Additional impacts on human health were minimized by effective monitoring and closures instituted by the California Department of Public Health (CDPH) with cooperation from the commercial shellfish aquaculture companies operating in Tomales Bay.

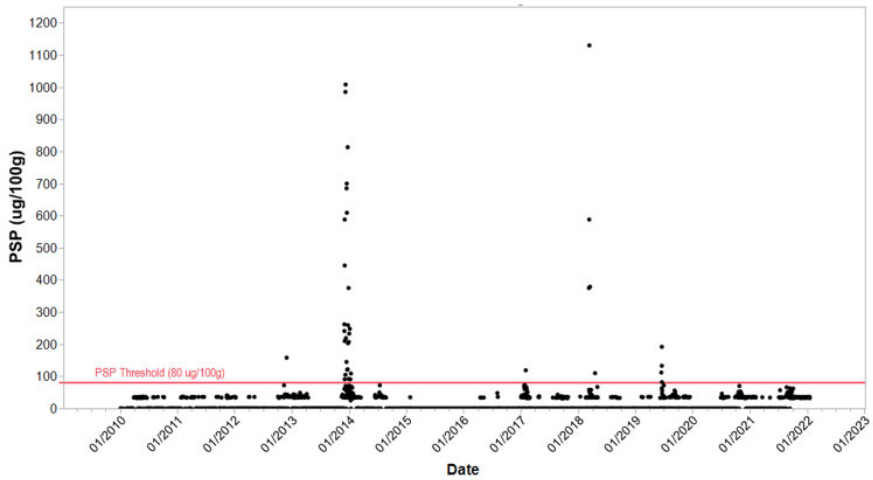

Figure S.WQ.7.7. PSP toxin concentration in mussels and oysters cultured in Tomales Bay from 2010–2022. The red line is the regulatory threshold (80 ug/100g) for the CDPH, 0 records represent non-detected PSP. Data credit: CDPH. Figure credit: A. Mabrouk/NOAA

[1] Heavy rainfall can lead to increased runoff and pollutants from land in coastal waters, which accumulate in shellfish. Rainfall closures are preemptive based on forecasts and previous testing data to protect human health from consuming these contaminated shellfish (Rankin, 2022).

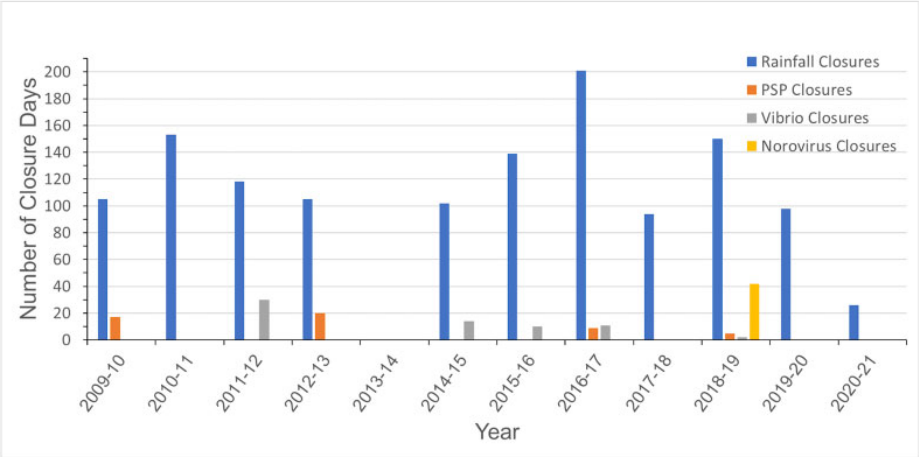

Figure S.WQ.7.8. Tomales Bay shellfish closures based on the annual sanitary survey update reports from the CDPH. Four types of closure days were calculated. Rainfall closures (blue bars), PSP closures (orange bar), Vibrio closures (gray bar), and norovirus closures (yellow bar). Data for 2013–2014 was missing. Source: Rankin, 2022; Image: A. Mabrouk/NOAA

Impaired Water 303 (d) List and Beach Advisory/Closures

The 2018 and 2020–2022 California State Water Resources Control Board integrated assessment reports showed that Tomales Bay, Estero Americano, and Estero de San Antonio were listed as impaired water bodies on the 303(d) list, while Bolinas was not assessed. Tomales Bay was listed due to sedimentation/siltation, nutrients, mercury, and pathogens, while Estero Americano and Estero de San Antonio were listed due to nutrients and sedimentation. Regular water quality monitoring of Tomales Bay beaches for pathogenic bacteria led to advisory days due to elevated pathogenic bacteria that exceeded the health standards for swimming. From 2010–2021, there were 131 exceedances of fecal coliform levels. In 2019, there were two norovirus outbreaks that led to shellfish harvesting closures, but the source was not found. The number of advisory days was the highest in 2011, decreased to its lowest in 2015, and then increased recently, especially at the Chicken Ranch beach (U.S. EPA, 2022; Figure S.WQ.7.9).

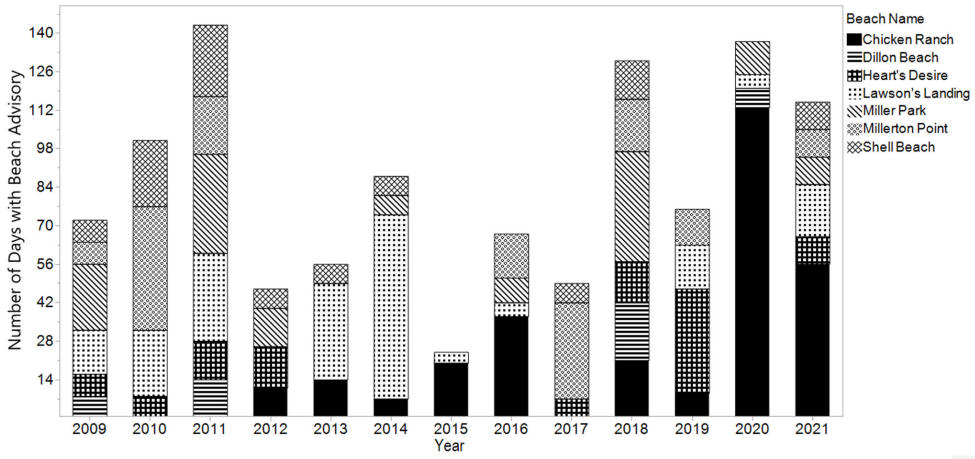

Figure S.WQ.7.9. Tomales Bay beach advisory showing the numbers of days with pathogenic bacteria exceeded the standard limit at Tomales Bay beaches 2009–2021. Data credit: EPA BEACON 2.0. Figure credit: A. Mabrouk/NOAA

Contaminants: Mercury in biota

The California Office of Environmental Health Hazard Assessment (CA OEHHA) developed a fish advisory for Tomales Bay that restricts fish consumption for the public based on consumers' sex and age. This restriction was mainly due to the high concentration of mercury in fish and shellfish (Gassel et al., 2004). Some species, like rays and sharks, should not be eaten regardless of the consumer's age and sex (see the red category in Figure S.WQ.7.10). Others can be eaten with restrictions, like California Halibut, Red Rock Crab, Jacksmelt, and Surfperch (CA OEHHA, 2018; see yellow and green categories in Figure S.WQ.7.10).

The main source of the high mercury concentration in Tomales Bay's biota is the former Gambonini Mercury Mine upstream of Walker Creek. Mercury concentrations in biota and sediment were assessed before and after the mercury mine cleanup and remediation project at the Walker Creek Delta. The results showed that oysters had a mercury concentration below the California State Water Resources Control Board goal (0.22 ug/g), although it was higher in 2019-2020 than before the cleanup. California Halibut consistently had mercury concentrations at or below the goal and decreased in 2019-2020. In contrast, Leopard shark had high mercury concentrations exceeding the goal and higher in 2019-2020 than before the cleanup (CWB, 2021; Figure S.WQ.7.11). However, mercury levels in surface sediment at Walker Creek delta declined significantly over time, from 1.7 ppm in 2000 to 0.94 ppm in 2009, to 0.52 ppm in 2018, where the TMDL allocated for Walker Creek is 0.5 ppm (CWB, 2019).

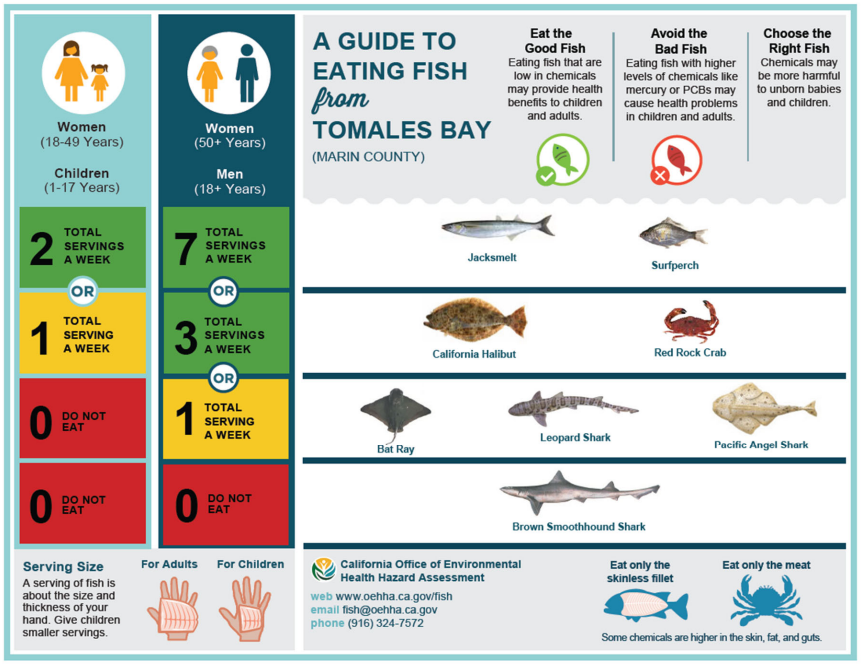

Figure S.WQ.7.10. Tomales Bay fish advisory that restricts fish and shellfish consumption. Image: California Office of Environmental Health Hazard Assessment.

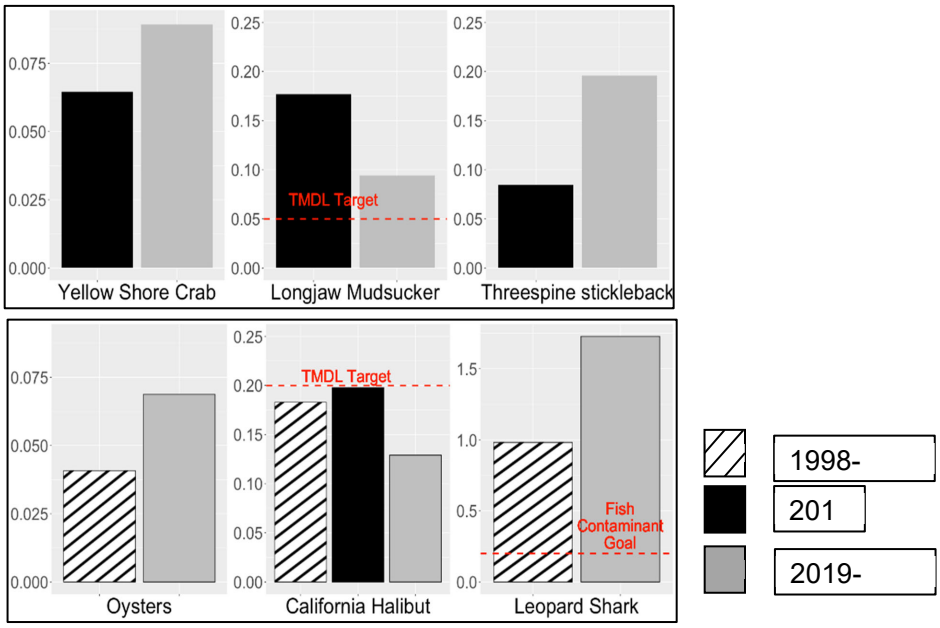

Figure S.WQ.7.11. Mercury levels in biota sampled by the RWQCB (µg/g, wet weight, ppm) near the Walker Creek Delta prior to remediation (1998–2001), after the remediation (2010), and from 2019–2020. The total maximum daily load (TMDL) and Fish Contaminant Goal are the acceptable levels of contaminants set by the CSWRCB. Note that the vertical axis scale varies. Source: adapted from CSWRCB, 2021

Conclusion

The status of sanctuary waters posing a threat to human health in the estuarine and lagoon regions was rated fair, with a mixed trend. Water quality problems have caused measurable human impacts; notably in one incident, 44 persons became sick with norovirus in late 2018 and 2019 after eating oysters from Tomales Bay. This effect was localized and not widespread or persistent. Additionally, there have been intermittent restrictions on fish and shellfish consumption at Tomales Bay due to PSP, norovirus, vibrio, rainfall, and mercury. Tomales Bay, Estero Americano, and Estero de San Antonio were listed as impaired bodies of water, and beach advisories were in place for Tomales Bay. By necessity, this assessment is focused mainly on Tomales Bay, where datasets for the question's indicators were available. However, data gaps that include long-term data on organic pollutants and heavy metals in biota from the other estuaries and lagoons in the sanctuary and regular water quality monitoring will be needed to conduct a comprehensive assessment.

References (Q7/Estuarine and Lagoon)

California State Water Resources Control Board. (2019). Water Quality Report Card. Mercury in Tomales Bay.

https://www.waterboards.ca.gov/about_us/performance_report_1819/plan_assess/docs/fy1819/r2_tomalesbayhg.pdf

California State Water Resources Control Board. (2021). Water Quality Report Card. Mercury in Tomales Bay. https://www.waterboards.ca.gov/about_us/performance_report_2021/plan_assess/docs/fy2021/tom-bay_final.pdf

California Office of Environmental Health Hazard Assessment (2018). A GUIDE TO EATING FISH from TOMALES BAY (MARIN COUNTY) [Infographic]. Retrieved June 15, 2022, from https://oehha.ca.gov/media/downloads/advisories/tomalesbayposter072018.pdf

Gassel, M., Klasing, S., Brodberg, R.K. (2004). HEALTH ADVISORY: GUIDELINES FOR CONSUMPTION OF FISH AND SHELLFISH FROM TOMALES BAY (MARIN COUNTY). California Environmental Protection Agency. October 2004. https://oehha.ca.gov/media/downloads/advisories/tomalesbayguidef.pdf

Larsen, L. (2019, January 16)Tomales Bay Oyster Norovirus Outbreak Sickens 44 in California. Food Poisoning Bulletin https://foodpoisoningbulletin.com/2019/tomales-bay-oyster-norovirus-outbreak/#:~:text=The%20California%20Department%20of%20Public,sold%20the%20Hog%20Island%20oysters.

Rankin, S. (2022). *Tomales Bay shellfish closures* [Unpublished data set]. California Department of Public Health.

U.S. Environmental Protection Agency. (2022). BEACON 2.0 - Beach Advisory and Closing Online Notification Reports [Data set]. Retrieved July 1, 2022, from https://watersgeo.epa.gov/beacon2/reports.html

Question 8: Have recent, accelerated changes in climate altered water conditions and how are they changing?

Coastal and Offshore Region (Q8)

Status Rating: Fair	Status Confidence: High
Trend Rating: Worsening	Trend Confidence: Medium
Status Description: Climate-related changes have caused measurable but not severe degradation in some attributes of ecological integrity.	
Rationale: Increase in the SST positive anomalies associated with two marine heatwaves (MHWs) events during the study period. The marine heatwave in 2014–2016 MHW caused unprecedented HABs and shellfish fisheries closures and shifts in the pelagic ecosystem. Low dissolved oxygen was observed at shallow sites, and hypoxic events were observed at a deeper site. Corrosive conditions were observed at deeper locations. The habitat compression index was low during the 2014–2016 and 2019 MHW but there was no change from the long-	

term mean.

Findings From the 2010 Condition Report

This question is new and was not assessed in the 2010 condition report. However, the topic of climate change was included in 2010 in the response to Question 1: “Are specific or multiple stressors, including changing oceanographic and atmospheric conditions, affecting water quality?” The question did account for oceanographic indicators related to climate change and was rated good/fair and not changing (ONMS, 2010).

New Information in the 2010–2022 Condition Report

This question was rated fair and worsening based on key climate change indicators, including climate and basin scale indices, upwelling indices, sea surface temperature (SST), marine heatwave measurements, hypoxia, ocean acidification indicators (aragonite saturation), and the habitat comparison index (Table S.WQ.8.1).

Table S.WQ.8.1. Summaries for the key climate indicators in the coastal and offshore region that were discussed during the June 6, 2022 virtual status and trends workshop.

Indicator	Source	Data Summary	Figures
Basin-scale indices	CCIEA 2022	Status: Recent means for the Pacific Decadal Oscillation (PDO) and North Pacific Gyre Oscillation (NGPO) were within one standard deviation of the long-term mean Trend: The PDO trend is neutral, and the NGPO trend is decreasing.	S.WQ.8.1; S.WQ.8.2
Upwelling indices	CCIEA 2022	Status: Recent means for the Length of Upwelling Season Index (LUSI) and the Coastal Upwelling Transport Index were within one standard deviation of the long-term mean. Trend: Both trends were neutral.	
Water temperature (SST)	NOAA NMFS, 2022; O’Brien & Oakes, 2020; Eliott et al., 2020a	Status: Positive anomalies were observed from 2014 to the present. Trend: No significant trend for the study period (2010–2022).	S.WQ.8.3
Marine heatwaves	IEA MHWT, 2022	Status: Marine heatwaves occurred in 2014–2016 and 2019. Trend: Two marine heatwaves in the last 10 years	S.WQ.8.4
Dissolved oxygen and hypoxia	Elliott et al., 2022a	Status: Near-hypoxia at 25 m and 100 m. Hypoxic events were observed and occurred more frequently in deep water (>100 m). Trend: No apparent trend.	S.WQ.8.5

Aragonite saturation	Elliott et al., 2022a	Status: Corrosive condition at 100m and 25m depths, and less frequent at 10m depth Trend: No apparent trend.	S.WQ.8.6
Habitat compression index (HCI)	CCIEA 2022	Status: The recent mean was within one standard deviation of the long-term mean. Trend: last 10 years' trend is neutral (→)	S.WQ.8.7
Data gaps	Bottom temperature, salinity		

The central California Current Ecosystem naturally experiences exceptional climate variability due to upwelling and has also experienced climate change impacts such as marine heatwaves (Elliott al., 2022a; Harvey et al., 2021). Climate change impacts on coastal and offshore habitats, such as coastal erosion from increased wave action, increased riverine sediment loads, increased water temperature, and ocean acidification, have multi-faceted impacts on wildlife due to their synergistic and cascading effects, and the connectivity and fluidity of the coastal marine environment. Climatological disturbances to GFNMS ecosystems could potentially result in habitat loss and degradation and declines in abundance or redistribution of important marine species. Climate and ocean indicators, such as regional upwelling indicators, and water chemistry indicators, can support characterizing ecosystem productivity and ecological integrity in GFNMS.

Basin Scale Climate Indices

GFNMS waters are influenced by both large-scale and local conditions. Two basin scale indices that affect productivity in GFNMS were used to portray large-scale variability in the region. These are the Pacific Decadal Oscillation (PDO) and the North Pacific Gyre Oscillation (NPGO). Positive PDO values indicate warmer water and lower productivity, while positive NPGO values are associated with increased equatorward flow and higher surface salinities, nutrients, chlorophyll a, and productivity (Harvey et al., 2019). PDO and NPGO mean for the last 10 years were within one standard deviation of long-term means. During the same time period, the PDO trend was neutral while NPGO decreased, resulting in reduced productivity overall (CCIEA 2022; Figure S.WQ.8.1, S.WQ.8.2).

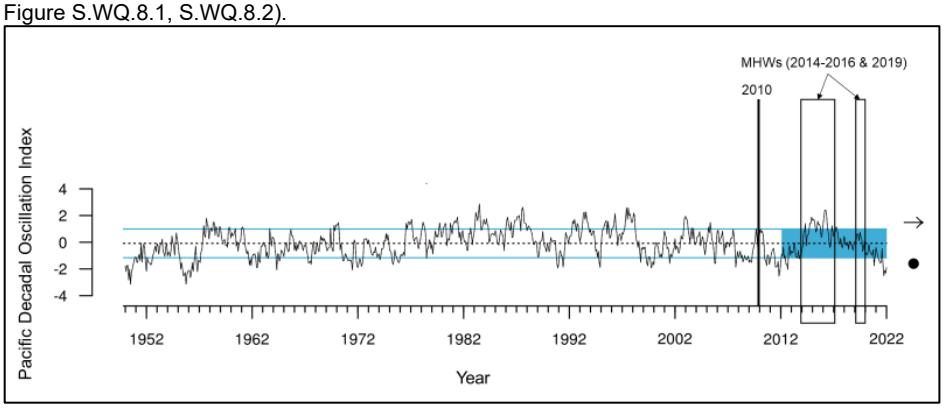

Figure S.WQ.8.1. Monthly PDO index. The vertical black line indicates the year of the last condition report (2010). The mean for the last 10 years (blue area) was within one standard deviation of the long-term mean since 1950. (black dot) and the trend for the last 10 years was neutral (→). The dashed black line represents the long-term mean and the blue lines are ± one standard deviation. The black rectangles show the marine heatwaves of 2014–2016 and 2019. Data source: CCIEA 2022

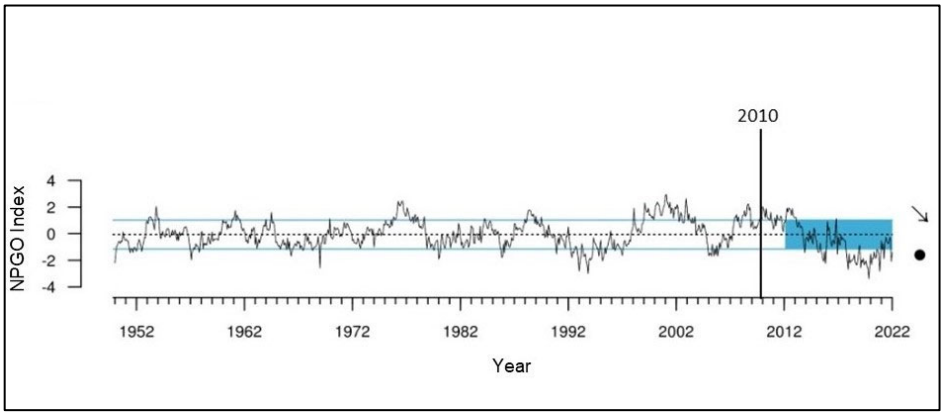

Figure S.WQ.8.2. Monthly NPGO index. The vertical black line indicates the year of the last condition report (2010). The mean for the last 10 years (blue area) was within one standard deviation of the long-term mean since 1950 (black dot) and the trend for the last 10 years trend was decreasing (↘). The dashed black line represents the long-term mean and the blue lines are ± one standard deviation. Data source: CCIEA 2022

Upwelling Indices

Two indices were used to describe upwelling in GFNMS, the Length of Upwelling Season Index (LUSI) and the Coastal Upwelling Transport Index (CUTI). LUSI is defined as the total number of days between the observed start date and the observed end date of the upwelling season. The lowest number of upwelling days in the last 10 years was associated with the 2014–2016 marine heatwave. However, the mean LUSI for the last 10 years was within 1 standard deviation of the long-term mean, and the trend was neutral. CUTI estimates vertical transport near the coast. A positive index indicates upwelling, and a negative index indicates weak upwelling or downwelling conditions. The mean CUTI for the last 10 years was also within 1 standard deviation of the long-term mean, and the trend was neutral (CCIEA, 2022).

Sea Surface Temperature and Marine Heatwaves

In 2014–2016, the central California Current Ecosystem experienced an extensive marine heatwave. This event caused rapid and abundant positive sea surface temperature (SST) anomalies that began in early 2014 and persisted through mid-2016 (Figure S.WQ.8.3, S.WQ.8.4). This heatwave overlapped with the 2015–2016 El Niño event (Gentemann et al., 2017; Jacox et al., 2019), resulting in the largest marine heatwave detected since NOAA satellites started keeping track in 1981 (NMFS, 2020). Another smaller, shorter-lived marine heatwave developed offshore of GFNMS in 2019. Figure S.WQ.8.3 shows SST monthly anomalies based on local buoy data in GFNMS and CBNMS (Elliott et al., 2022a) and it shows that the positive anomalies are increasing in number and magnitude since 2014, associated with

prolonged and more frequent MHWs, while figure S.WQ.8.4 shows marine heatwave coverage, intensity, and cumulative intensity at GFNMS from satellite data.

Marine heatwaves caused severe impacts on marine life in the California Current Ecosystem (Holbrook, 2019). Warmer water associated with the MHW also contributed to an unprecedented HAB on the coast in GFNMS in 2015–2016. This HAB event, caused by the diatom *Pseudo-nitzschia*, resulted in increasing domoic acid toxins in shellfish, especially Dungeness crab, leading to the most prolonged shellfisheries closure since 2006 in 2015–2016 and poisoning seabirds and marine mammals (Trainer et al., 2017, 2020; Anderson et al., 2019). The MHW also caused other ecological changes in GFNMS. The geographic distributions of many southern coastal species shifted northward along the California coast (Sanford et al., 2019; Beas-Luna et al., 2020, Micheli et al., 2020). Krill and forage fish abundance declined, and as a result, humpback whale feeding shifted from offshore (where they normally consume krill) to inshore (anchovy). This resulted in more whale entanglements in crab traps (NMFS, 2020).

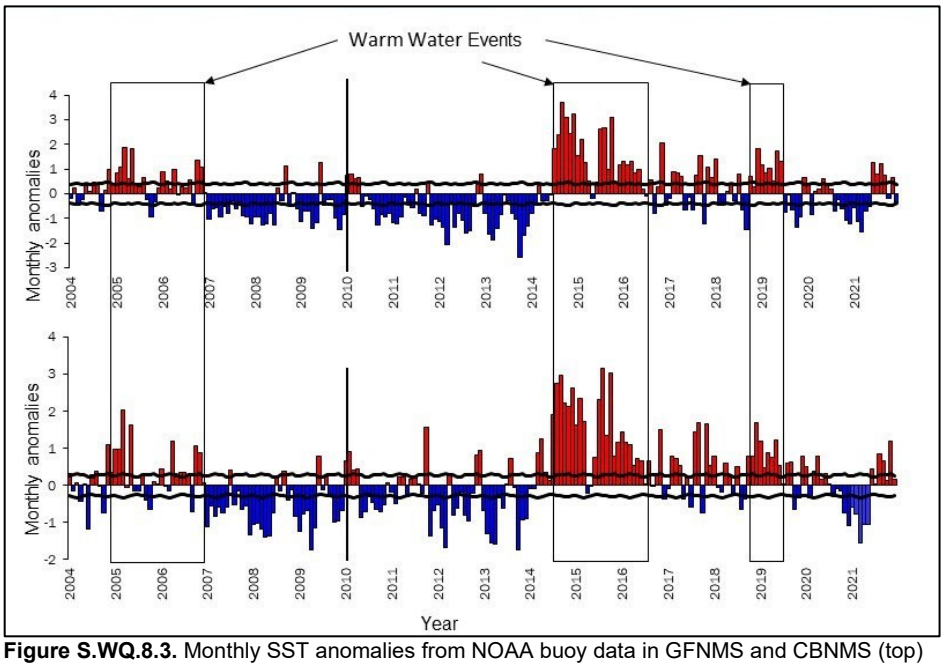

Figure S.WQ.8.3. Monthly SST anomalies from NOAA buoy data in GFNMS and CBNMS (top) and Southeast Farallon Island (bottom). Black rectangles show the warm water events associated with positive anomalies. The vertical black lines indicate the year of the last condition report (2010), while the horizontal black lines represent 99% confidence intervals around the long-term monthly means. Data source: Elliott et al., 2022a

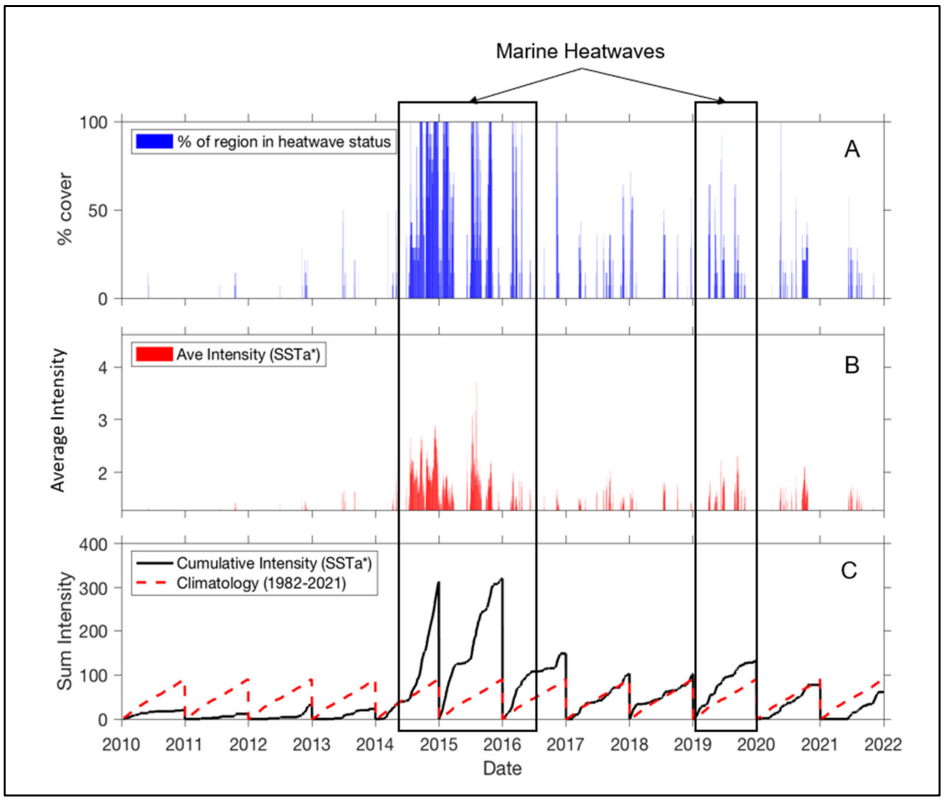

Figure S.WQ.8.4. Marine heatwave measurements for the surface water of GFNMS, including (A) daily % cover, (B) daily intensity, and (C) cumulative intensity (accumulated heat in the sanctuary over the year [solid black line] compared to the climatology average [red dashed line]. Black rectangles indicate marine heatwave events in 2014–2016 and 2019. The highest marine heatwave cover, intensity, and cumulative intensity occurred in 2014 and 2015. Image: Andrew Leising/NOAA. Data source: CCIEA-MHWT, 2022

Habitat Compression Index

The habitat compression index (HCI) tracks the cooler upwelling habitat area in the California Current Large Marine Ecosystem, which may be compressed by marine heatwaves (Schroeder et al., 2022). Cooler, low-compression conditions support high biodiversity and abundance of coastal organisms like young of the year groundfish and krill. In the central California Current Ecosystem, such conditions were present in 2007, 2008, and early 2009. A shift in the pelagic ecosystem occurs under high-compression conditions, which supports an increase in the abundance and distribution of forage species like anchovy and a decrease in krill abundance and distribution decrease. This shift was observed during the marine heatwaves in 2014–2016 and 2019, and also during El Niño Southern Oscillation (ENSO) in 1982–1983 and 1997–1998

(IEA, 2022; Santora et al., 2021). The trend analysis for the HCI showed that the recent mean was within one standard deviation of the long-term mean. The trend during the last 10 years was neutral (Figure. S.WQ.8.5).

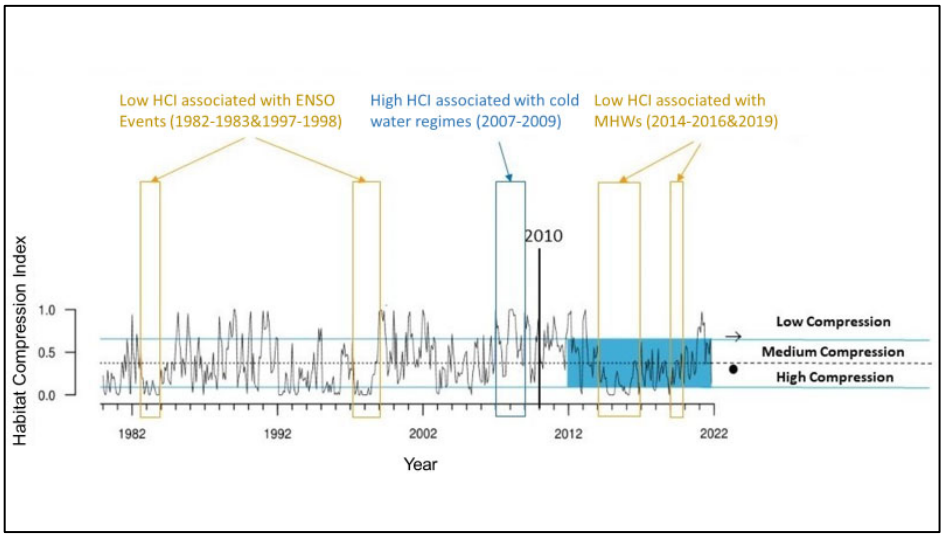

Figure S.WQ.8.5. Habitat compression index (HCI) for the central California Current Ecosystem. The vertical black line indicates the year of the last condition report (2010). The mean habitat area for the last 10 years (shaded area) was within one standard deviation of the long-term mean (indicated by the black dot) and the trend for the last 10 years was neutral (→). The dashed line is the long-term mean and the solid blue lines are ± one standard deviation. The orange rectangles indicate warm water events associated with ENSO (1982–1983, 1997–1998) and marine heatwaves (2014–2016, 2019). Image: Modified from CCIEA, 2022; Santora et al., 2021

Dissolved Oxygen and Hypoxia

Dissolved oxygen (DO) in the region is affected by upwelling that usually occurs from May to July (Garcia-Reyes & Largier, 2012; J. Largier/University of California Davis, personal communication, June 6, 2022). Upwelled water from deeper ocean sources tends to be low in DO, and microbial decomposition of organic matter increases overall system respiration and oxygen consumption, particularly closer to the seafloor (Harvey et al., 2021). DO concentrations at ACCESS stations 6-E (nearshore) and 6-W (offshore) were always above the hypoxia threshold (2 mg/L) at both sites (see Figure S.P.3.2 for station locations). However, DO was often only slightly above the threshold, generally between 2 mg/L and 5 mg/L, in deeper water, especially at a depth of 100 m at the offshore site. In contrast, DO at a depth of 10 m at the offshore site was higher than that of the nearshore site. Of note, the nearshore site had near-hypoxia in 2011 and 2018 (Figure S.WQ.8.6). Additionally, hypoxic events were observed more frequently in deeper water (>125m) in spring and summer at the offshore site.

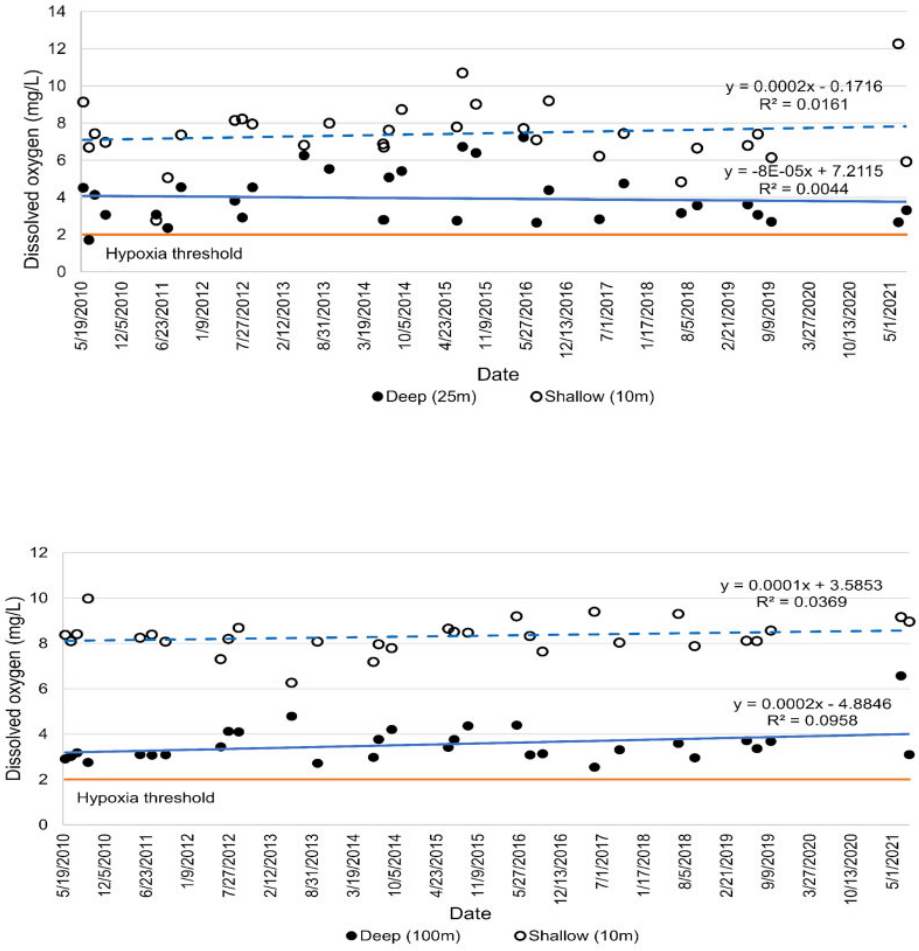

Figure S.WQ.8.6. DO concentrations at station 6-E (top) and station 6-W (bottom). The blue solid line is the linear trend for deep DO at (25 m at Station 6-E, and 100 m at Station 6-W), while the dashed blue line is the linear trend for shallow DO (10 m at both sites). The orange line is the threshold for hypoxia (2 mg/L). Source: adapted from Elliott et al., 2022a

Ocean Acidification

Ocean acidification results from oceanic absorption of carbon dioxide (CO_2) from the atmosphere, reducing pH and carbonate ion levels in seawater. This process increases acidity

and decreases carbonate availability. Aragonite saturation is considered a key indicator of ocean acidification. It is a form of calcium carbonate that is more sensitive to increasing CO_2 than calcite. Acidification slows the growth of calcium carbonate structures and can dissolve these structures faster than they form, impacting many California Current Ecosystem species, like oysters, crabs, and pteropods when aragonite saturation is <1.0 (considered corrosive conditions, Flee et al., 2008; Barton et al., 2012; Bednaršek et al., 2014; Marshall et al., 2017; Hodgson et al., 2018).

Corrosive conditions were characteristic of the deep depths (25 m) at ACCESS nearshore station 6-E, except for some records in the years 2014–2016 that were associated with the marine heatwave. Aragonite saturation also consistently indicated corrosive conditions at deep depths (100 m) at offshore station 6-W (Figure S.WQ.8.6). At shallow depths (10 m), both stations had higher aragonite, and corrosive conditions were less frequent (Figure S.WQ.8.7).

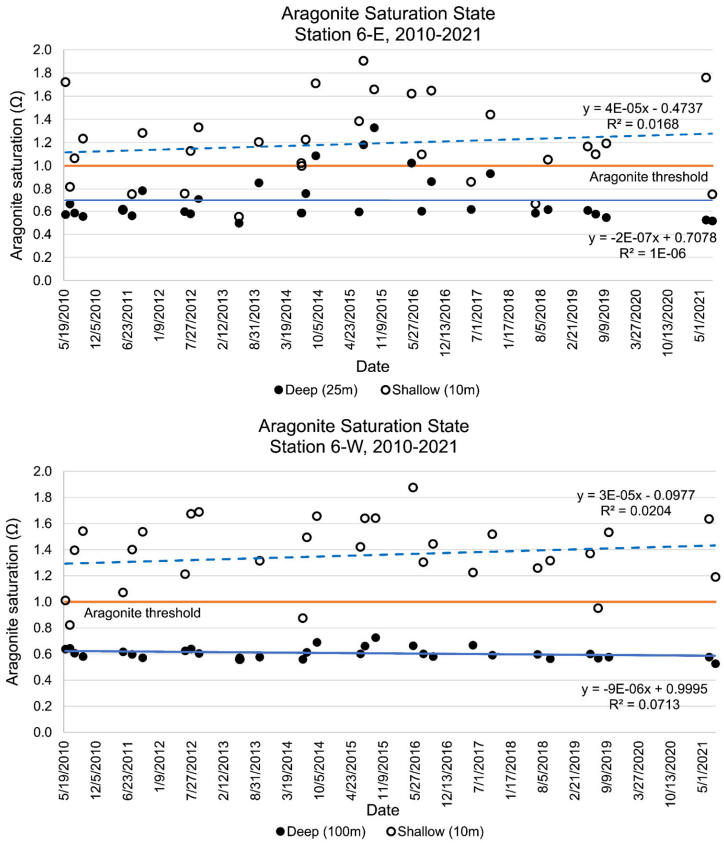

Figure S.WQ.8.7. Aragonite saturation (Ω) at station 6-E (top) and station 6-W (bottom). Blue solid line is the linear trend for aragonite at 25 m and 100 m (closed circles), while the dashed

blue line is the linear trend for aragonite at 10 m (open circles). Orange line is the threshold for aragonite saturation (values below this threshold indicate corrosive conditions). Source: Elliott et al., 2022a

Conclusion

In 2022, the status of climate-altered water conditions in GFNMS was rated fair with high confidence and the trend was worsening with medium confidence. The status was based on the occurrence of two significant marine heatwaves in the last 10 years. The 2014–2016 MHW was more prolonged and intense than the 2019 heatwave and it caused a severe impact on the Dungeness crab fishery due to HABs and a shift in the pelagic ecosystem. Habitat compression was observed during the MHW. No hypoxic events were observed from sampling at 10 m, 25 m, or 100 m. However, DO was low and near-hypoxic at 25 m and 100 m. Hypoxia occurred only offshore at depths >125 m. Aragonite saturation state reflected corrosive conditions at a depth of 100 m offshore, but these conditions were less frequent nearshore at a depth of 25 m. The worsening trend was mainly based on the increase in the number and magnitude of the SST monthly positive anomalies that were associated with an increase in MHWs. Still, data gaps that include long-term data on sea surface salinity and bottom temperature are needed for more inclusive assessment.

References (Q8/Coastal and Offshore)

Anderson, C. R., Berdalet, E., Kudela, R. M., Cusack, C. K., Silke, J., O'Rourke, E., . . . Morell, J. (2019). Scaling Up From Regional Case Studies to a Global Harmful Algal Bloom Observing System. Frontiers in Marine Science, 6(250). doi:10.3389/fmars.2019.00250

Barton, A., B. Hales, G. G. Waldbusser, C. Langdon, and R. A. Feely. (2012). The Pacific oyster, Crassostrea gigas, shows negative correlation to naturally elevated carbon dioxide levels: Implications for near-term ocean acidification effects. Limnology and Oceanography 57:698–710.

Bednaršek, N., R. A. Feely, J. C. P. Reum, B. Peterson, J. Menkel, S. R. Alin, and B. Hales. (2014). Limacina helicina shell dissolution as an indicator of declining habitat suitability owing to ocean acidification in the California Current Ecosystem. Proceedings of the Royal Society B–Biological Sciences 281:20140123.

California Current Integrated Ecosystem Assessment. (2022). CCIEA Indicator Data Plotting Tool. [graphs]. NOAA. Retrieved May 12, 2022, from https://oceanview.pfeg.noaa.gov/cciea-plotting/?opentab=0&ind=71

California Current Integrated Ecosystem Assessment - Marine Heat Wave Tracker (CCIEA-MHWT). (2022). https://www.integratedecosystemassessment.noaa.gov/regions/california-current/california-current-marine-heatwave-tracker-blobtracker

COPEPODITE. (2020). Spatiotemporal Data & Time Series Toolkit. Online: https://www.st.nmfs.noaa.gov/nauplius/media/html/subform_ite-geopick-box.html (Retrieved 20 February 2020).

Elliott, M., Lipski, D., Roletto, J., Warzybok, P., & Jahncke, J. (2022a). Ocean Climate Indicators Status Report: 2021. Unpublished Report. Point Blue Conservation Science (Contribution No.

2422), Petaluma, CA. http://www.accessoceans.org/wp-content/uploads/2022/08/Ocean_Climate_Indicators_Report_2021.pdf

Feely, R., Chris, S., Hernandez-Ayon, J., Ianson, D., & Hales, B. (2008). Evidence for Upwelling of Corrosive " Acidified" Water onto the Continental Shelf. Science (New York, N.Y.), 320, 1490-1492. doi:10.1126/science.1155676

García-Reyes, M., and J. L. Largier (2012), Seasonality of coastal upwelling off central and northern California: New insights, including temporal and spatial variability, J. Geophys. Res., 117, C03028, doi:10.1029/2011JC007629

Gentemann, C. L., Fewings, M. R., and García-Reyes, M. (2017). Satellite sea surface temperatures along the West Coast of the United States during the 2014–2016 northeast Pacific marine heat wave. Geophys. Res. Lett. 44, 312–319. doi: 10.1002/2016gl071039

Hales, B., T. Takahashi, and L. Bandstra. (2005). Atmospheric CO2 uptake by a coastal upwelling system. Global Biogeochemical Cycles, 19: 1-11.

Harvey, C. J., N. Garfield, G. D. Williams, and N. Tolimieri, editors. (2021). Ecosystem Status Report of the California Current for 2020–21: A Summary of Ecosystem Indicators Compiled by the California Current Integrated Ecosystem Assessment Team (CCIEA). U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-170.

Hodgson, E. E., I. C. Kaplan, K. N. Marshall, J. Leonard, T. E. Essington, D. S. Busch, E. A. Fulton, C.J. Harvey, A. J. Hermann, and P. McElhany. (2018). Consequences of spatially variable ocean acidification in the California Current: Lower pH drives strongest declines in benthic species in southern regions while greatest economic impacts occur in northern regions. Ecological Modeling 383:106–117.

Holbrook, N. J., Scannell, H. A., Sen Gupta, A., Benthuysen, J. A., Feng, M., Oliver, E. C. J., . . . Wernberg, T. (2019). A global assessment of marine heatwaves and their drivers. Nature Communications, 10(1), 2624. doi:10.1038/s41467-019-10206-z

Jacox, M. G., Tommasi, D., Alexander, M. A., Hervieux, G., & Stock, C. A. (2019). Predicting the Evolution of the 2014–2016 California Current System Marine Heatwave From an Ensemble of Coupled Global Climate Forecasts. Frontiers in Marine Science, 6(497). doi:10.3389/fmars.2019.00497

Marshall, K. N., I. C. Kaplan, E. E. Hodgson, A. Hermann, D. S. Busch, P. McElhany, T. E. Essington, C.J. Harvey, and E. A. Fulton. (2017). Risks of ocean acidification in the California Current food web and fisheries: Ecosystem model projections. Global Change Biology 23:1525–1539.

Office of National Marine Sanctuaries. 2010. Gulf of the Farallones National Marine Sanctuary Condition Report 2010. U.S. Department of Commerce, National Oceanic and Atmospheric Administration Office of National Marine Sanctuaries, Silver Spring, MD. 97 pp.

NOAA NMFS. (2020). New Marine Heatwave Emerges off West Coast, Resembles "the Blob". Online: https://www.fisheries.noaa.gov/feature-story/new-marine-heatwave-emerges-west-coast-resembles-blob (Accessed May 10, 2022).

Sanford, E., Sones, J.L., García-Reyes, M. et al. (2019). Widespread shifts in the coastal biota of northern California during the 2014–2016 marine heatwaves. Sci Rep 9, 4216 . https://doi.org/10.1038/s41598-019-40784-3

Santora, Schroeder, I., Bograd, S., Chavez, F., Cimino, M., Fiechter, J., Hazen, E., Kavanaugh, M., Messié, M., Miller, R., Sakuma, K., Sydeman, W., Wells, B., & Field, J. (2021). PELAGIC BIODIVERSITY, ECOSYSTEM FUNCTION, AND SERVICES: AN INTEGRATED OBSERVING AND MODELING APPROACH. Oceanography (Washington, D.C.), 34(2), 16–37. https://doi.org/10.5670/oceanog.2021.212

Trainer, V. L. , Adams, N. G., Bill, B. D., Ayres, D. L., Forster, Z. R., Odell, A., Eberhart, B. and Haigh, N. (2017). Pseudo-nitzschia blooms in the northeastern Pacific Ocean. In Vera L.Trainer (Ed.), Conditions Promoting Extreme Pseudo-nitzschia Events in the Eastern Pacific but not the Western Pacific (pp.37-48). PICES Sci. Rep. No. 53.

Trainer, V. L., Kudela, R. M., Hunter, M. V., Adams, N. G., & McCabe, R. M. (2020). Climate Extreme Seeds a New Domoic Acid Hotspot on the US West Coast. Frontiers in Climate, 2. doi:10.3389/fclim.2020.571836

Estuarine and Lagoon Region (Q8)[2]

Status Rating: Fair	Status Confidence: Low
Trend Rating: Undetermined	Trend Confidence: Medium
Status Description: Climate-related changes have caused measurable but not severe degradation in some attributes of ecological integrity.	
Rationale: Positive SST anomalies associated with MHW events in 2014-2016, and 2019 and low aragonite saturation in Tomales Bay.	

Findings From the 2010 Condition Report

This question is new and was not assessed in the 2010 condition report. However, climate change was included in response to Question 1, “Are specific or multiple stressors, including changing oceanographic and atmospheric conditions, affecting water quality?” Data on oceanographic indicators related to climate change were not considered and the question was rated fair with an undetermined trend (GFNMS, 2010).

New Information in the 2010–2022 Condition Report

The current assessment was based on sea surface temperature (SST), ocean acidification (aragonite saturation), salinity, and stream flow (Table S.WQ.8.2).

[2] Status and trend ratings and associated confidence scores were not determined during the expert workshop. Following the workshop, GFNMS staff re-evaluated the indicators, datasets, and expert input that was received during the workshop, and made a final determination for the status and trend ratings and associated confidence scores

Table S.WQ.8.2. Summaries for the key climate indicators in the estuarine and lagoon region that were discussed during the June 6, 2022, virtual status and trends workshop.

Indicator	Source	Data Summary	Figures
SST	CeNCOOS, 2022a; BOON, 2022a	Status: Positive SST anomalies in Tomales Bay associated with marine heatwaves in 2014–2016 and 2019. Trend: SST significantly increasing.	S.WQ.8.8
Aragonite saturation	CeNCOOS, 2022b	Status: Seasonal pattern increase in summer and decrease in winter to below saturation threshold Trend: Significantly increasing.	S.WQ 8.9
Stream flow	USGS, 2022a&b	Status: High in the wet season (winter); highest in 2017 and 2019. Low in summer; lowest in 2020 and 2021, values for which were both below the median daily statistic (38 years). Trend: Significantly decreasing.	S.WQ 8.10
Salinity	BOON, 2022b	Status: Decreases observed in winter (wet season); lowest values were observed in 2017 and 2019. Trend: Significantly increasing.	S.WQ8.11
Data gap	Lack of long-term data and trend analysis for SST, aragonite saturation, DO, and hypoxia for estuarine and lagoon habitats in GFNMS.		

Sea Surface Temperature

The assessment of SST for Tomales Bay was based on data from the Tomales Bay Buoy, south of Hog Island. This oceanographic buoy is a cooperative project between the UC Davis Bodega Marine Laboratory, Point Reyes National Seashore, and NOAA (BOON, 2022a). Buoy data were available from 2013 to 2021 (Figure S.WQ.8.8); however, some data were missing or did not pass quality assurance and quality control (CeNCOOS, 2022a). Positive SST anomalies were associated with MHW in 2014–2016 and 2019. Further analysis of the buoy data showed a seasonal pattern of increasing SST that peaked in summer and was lowest in winter. Linear trend analysis indicated that SST was increasing significantly (BOON, 2022a).

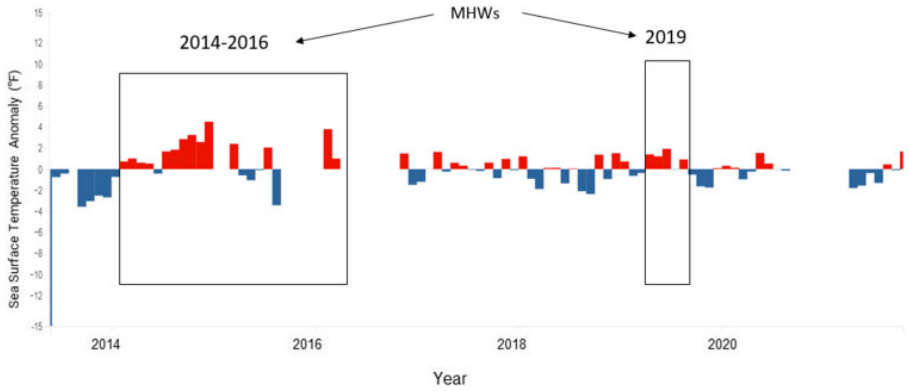

Figure S.WQ.8.8. Monthly SST anomalies in Tomales Bay. The black rectangles highlight marine heatwaves that were associated with positive anomalies (red bars). Blue bars represent negative anomalies. Image: Modified from CeNCOOS, 2022a

Aragonite Saturation

Aragonite saturation was measured in Tomales Bay at Hog Island Oyster Hatchery Station. From 2014–2019, daily mean aragonite saturation shows a seasonal pattern, increasing in summer, then decreasing in winter, dipping below the aragonite saturation threshold (<1.0; CeNCOOS, 2022b). Aragonite saturation conditions <1.0 are more corrosive and make shell-forming more difficult. However, linear trend analysis for the daily mean data showed a significant increase since 2014, indicating that the overall trend is towards higher aragonite saturation, which is more favorable for shell forming organisms (Figure S.WQ.8.9).

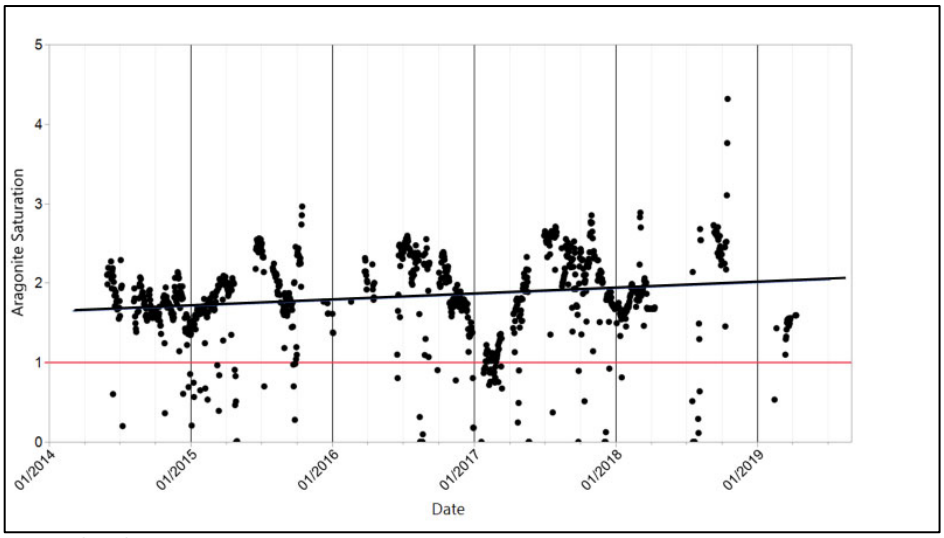

Figure S.WQ.8.9. Daily mean aragonite saturation at Hog Island Hatchery, Tomales Bay 2014-2020. The black line shows the linear trend and the red line shows the aragonite saturation threshold. Source: CeNCOOS, 2022b; Image: Ayman Mabrouk/NOAA

Stream Flow and Salinity

Annual precipitation levels vary considerably in the sanctuary region depending on weather patterns and climate conditions. Precipitation regulates streamflow in Tomales Bay which in turn influences salinity levels.

Stream flow for Tomales Bay was assessed as the amount of water discharged (cubic feet per second) from the two main tributaries of Tomales Bay, Walker Creek and Lagunitas Creek, into Tomales Bay, from data obtained from the USGS National Water Information System. For Walker Creek, stream flow had a seasonal pattern of high discharge in winter (highest in 2017 and 2019) and low discharge in summer (lowest in 2014, 2020, and 2021, and below the median daily discharge for the last 38 years; USGS, 2022a). The same seasonal pattern was found at Lagunitas Creek (discharge was also highest in 2017 and 2019 and was lowest and below the median daily in 2020 and 2021; USGS, 2022b). Additionally, the trend analysis for both streams showed that discharge decreased over time (Figure S.WQ.8.10).

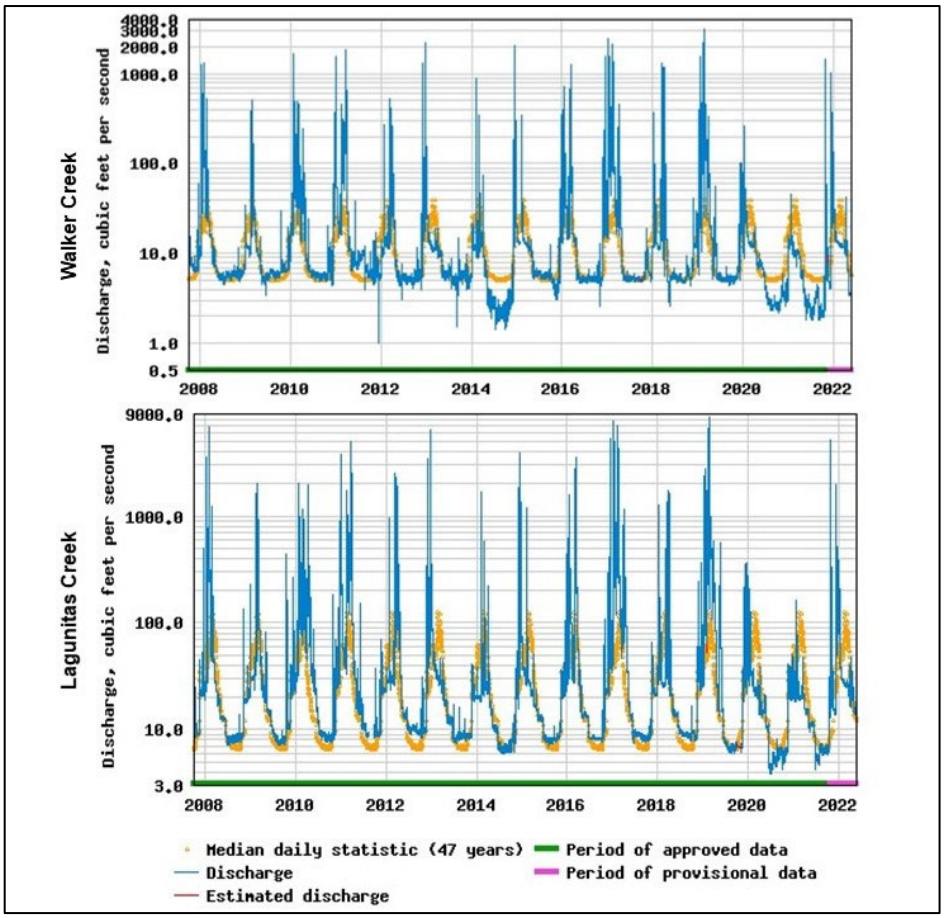

Figure S.WQ.8.10. Stream flow as discharge by cubic feet per second for Walker Creek and Lagunitas Creek, 2008–2022. Source: USGS, 2022a, 2022b

Salinity levels can have impacts on estuarine fauna as prolonged exposure to low salinity is known to be significantly and positively correlated with oyster mortality from studies in Galveston, Texas (Du et al., 2021). Daily mean salinity from the Tomales Bay buoy from 2013–2022 showed a seasonal pattern in which salinity decreased in winter (the wet season). Salinity was lowest in 2017 and 2019 due to high precipitation in those years. However, salinity didn't reach the minimum level (10 ppt) for survival and production for the commonly cultured species in the bay, the Pacific Oyster (*Crassostrea gigas*). Additionally, the linear trend for salinity showed a statistically significant increase (BOON, 2022b; Figure S.WQ.8.10), consistent with the decrease in discharge from reduced streamflow described above.

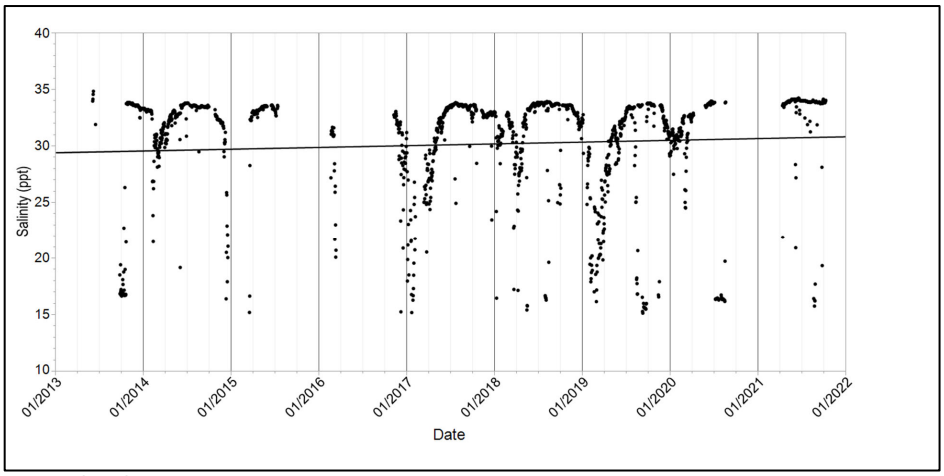

Figure S.WQ.8.11. Daily mean salinity at Tomales Bay, 2013–2022. The black line shows the linear trend for salinity. Source: BOON, 2022b; Image: Ayman Mabrouk/NOAA

Conclusion

In 2022, the status of climate-altered water conditions in GFNMS estuarine and lagoon habitats was fair based on high-SST anomalies associated with MHW events in 2014–2016, and 2019 and low aragonite saturation in Tomales Bay. Aragonite saturation and salinity in Tomales Bay seems to be affected by the water discharged from Walker Creek and Lagunitas Creek, and although the Aragonite saturation exceeded the threshold, salinity did not and the trend for both was increasing while the water discharge from the two streams into Tomales Bay was decreasing. This assessment was based on limited evidence. Available data were mainly for Tomales Bay, and were incomplete. Data gaps remain for the other estuaries (Estero Americano and Estero de San Antonio) and Bolinas Lagoon.

References (Q8/Estuarine and Lagoon)

Bodega Ocean Observing Node. (2022a). Tomales Bay Buoy Seawater Temperature Hourly [Data set]. UC Davis Coastal and Marine Sciences Institute. Bodega Marine Laboratory. Retrieved May 18, 2022. https://boon.ucdavis.edu/data-access/products/tbb/tbb_seawater_salinity_daily

Bodega Ocean Observing Node. (2022b). Tomales Bay Buoy Seawater Salinity Daily [Data set]. UC Davis Coastal and Marine Sciences Institute. Bodega Marine Laboratory. Retrieved May 18, 2022. https://boon.ucdavis.edu/data-access/products/tbb/tbb_seawater_salinity_daily

CeNCCOS. (2022a). Water Temperature. Tomales Bay Buoy. [Graph]. UC Davis Coastal and Marine Sciences Institute. Bodega Marine Laboratory. Retrieved May 20, 2022. https://data.caloos.org/#map

CeNCCOS. (2022b). Hog Island Oyster. Omega Aragonite. [Data set]. UC Davis Coastal and Marine Sciences Institute. Bodega Marine Laboratory. Retrieved May 20, 2022. https://data.caloos.org/#metadata/52552/station/101/sensor?start=2014-05-31T17:29:11Z&end=2019-04-12T21:29:11Z

Du, J., Park, K., Jensen, C., Dellapenna, T. M., Zhang, W. G., & Shi, Y. (2021). Massive oyster kill in Galveston Bay caused by prolonged low-salinity exposure after Hurricane Harvey. Science of The Total Environment, 774, 145132. doi:https://doi.org/10.1016/j.scitotenv.2021.145132

USGS. (2022a). USGS 11460750 WALKER C NR MARSHALL CA [Data set]. National Water Information System: Web Interface. USGS Water Resources. Retrieved May 19, 2022. https://waterdata.usgs.gov/nwis/uv?site_no=11460750

USGS. (2022b). USGS 11460600 LAGUNITAS C NR PT REYES STATION CA [Data set]. National Water Information System: Web Interface. USGS Water Resources. Retrieved May 15, 2022. https://waterdata.usgs.gov/nwis/uv?site_no=11460750

Question 9: Are other stressors, individually or in combination, affecting water quality, and how are they changing?

Coastal and Offshore Region (Q9)[3]

Status Rating: Good/Fair	Status Confidence: Low
Trend Rating: Mixed	Trend Confidence: Medium
Status Description: Selected stressors are suspected and may degrade some attributes of ecological integrity, but have not yet caused measurable degradation.	
Rationale: Water quality impacts of microplastics, exhaust gas cleaning system discharges, and greenhouse gas emissions in the sanctuary have not been quantified, resulting in a lack of certainty about their impacts. While there are no data to show direct impacts or their absence, concerns about potential impacts are based on scientific evidence from other locations. Greenhouse gases increased, while other emissions-related stressors to water quality appeared stable. Sediments illegally discharged from barges transiting to a deep ocean disposal site have decreased significantly. Vessel discharges and oil spills have been observed, but large spills have not occurred recently. The amount of oil spilled decreased since the 2010 condition report. Changes in sediment erosion and accretion associated with	

[3] A status rating and associated confidence score was not determined during the expert workshop. Following the workshop, GFNMS staff re-evaluated the indicators, datasets, and expert input that was received during the workshop, and made a final determination for the status rating and associated confidence score.

development can affect nearshore areas throughout the sanctuary, causing disruptions in natural sediment movement and increased turbidity.

Findings From the 2010 Condition Report

A direct comparison to the 2010 condition report is not possible because the sanctuary expanded in 2015, during the time period for this assessment. The expansion added new locations that were not assessed in the 2010 condition report. In the 2010 condition report, the status for this question in the coastal and offshore region was good/fair and the trend was not changing. Ratings were based on observing few harmful algal blooms, continued nonpoint source discharges from San Francisco Bay and Russian River, new coastal 303(d) listings, decreased oil pollution, and decreased sediment spills from barges.

New Information in the 2010–2022 Condition Report

Microplastics, cruise ship discharges, dredged material discharges, oil and other vessel spills, and emissions are the stressors most likely to affect water quality in GFNMS (Table S.WQ.9.1). There are no long-term monitoring studies in the sanctuary for these indicators, so there are limited data available. Sediment transport and discharges from U.S. Coast Guard operations (which are exempted from sanctuary restrictions) were also considered. Experts considered data that are available, including the numbers of reports related to these problems, and personal experience.

Table S.WQ.9.1. Summaries for the key indicators related to other stressors in the coastal and offshore region that were discussed during the May 19, 2022 virtual status and trends workshop.

Indicator	Source	Data Summary	Figure
Microplastics	San Francisco Estuary Institute 2019; Sutton et al., 2019	Status: Lower than San Francisco Bay and similar to the open ocean. Trend: No trend data available.	S.WQ.9.1
U.S. Coast Guard Vessel Discharges	NOAA, 2018	Status: The amount of discharge is low Trend: The number and type of ships and training activities, and the amount of discharge, has been stable over the past several decades.	
Cruise Ship Discharges	Blank Rome LLP, 2017	Status: Over 190 documented violations of discharge regulations by cruise ships from 2017-2019. Trend: Limited time series data on discharges	S.WQ.9.2; S.WQ.9.3
Dredged Material Discharges	Etrac, 2022	Status: Barges transiting GFNMS to dump dredged material at the SF-DODs offshore disposal site had minimal spills and leaks. Trend: Downward trend on dredged material discharges since 2010 from leaking barges.	S.WQ.9.4

Oil & Other Vessel Discharges	GFNMS, 2022; USCG MISLE, 2022	Status: The majority of oil and other discharges were small diesel fuel spills, but these are chronic and can have localized effects on water quality. Trend: Downward oil spill trend, no trend data regarding discharge of other materials from vessels.	
Emissions	NOAA, NCEI, 2023; USEPA, 2021	Status: Greenhouse gas emissions impacted ocean temperature and water quality. EGCS (scrubber) discharges are a concern, but data are lacking. Trend: Increasing greenhouse gas levels have resulted in increased global ocean heat content anomalies.	S.WQ.9.5; S.WQ.9.6;
Sediment transport	Kordesch et al., 2019	Status: Coastal development has altered patterns of sediment transport along the coast. Trend: No trend data for sediment imbalances.	
Data gaps	Trend data for microplastics, cruise ship discharges, scrubbers (EGCS), other discharges from vessels, and sediment imbalances.		

Microplastics

Concerns about microplastics focus primarily on their effects on water quality, organisms that consume them, and human health when they are present in seafood. They are found in nearly every environment on Earth (Thompson et al., 2004). Plastic debris of all sizes in the marine environment, including microplastics, contains organic contaminants, some added during manufacturing, and some absorbed from surrounding seawater (Teuten et al., 2009). Particles may carry microorganisms, adsorbed chemicals, or other potentially hazardous materials (Danopoulos et al., 2020).

San Francisco Estuary Institute collected microplastics using manta trawls from 2017–2018 in three California marine sanctuaries (CBNMS, GFNMS, MBNMS) as well as in San Francisco Bay (Sutton et al., 2019). Four sites sampled in GFNMS during the wet and dry seasons showed microparticles (excluding fibers), including plastics, are present in GFNMS, but abundance levels were much lower than in San Francisco Bay and slightly lower than MBNMS in wet weather, and were comparable to other open ocean marine settings (Figure S.WQ.9.1). Fibers were excluded because of logistical challenges in enumerating them and uncertainty about the representativeness of the fiber sample from the Manta trawl (Sutton et al., 2019).

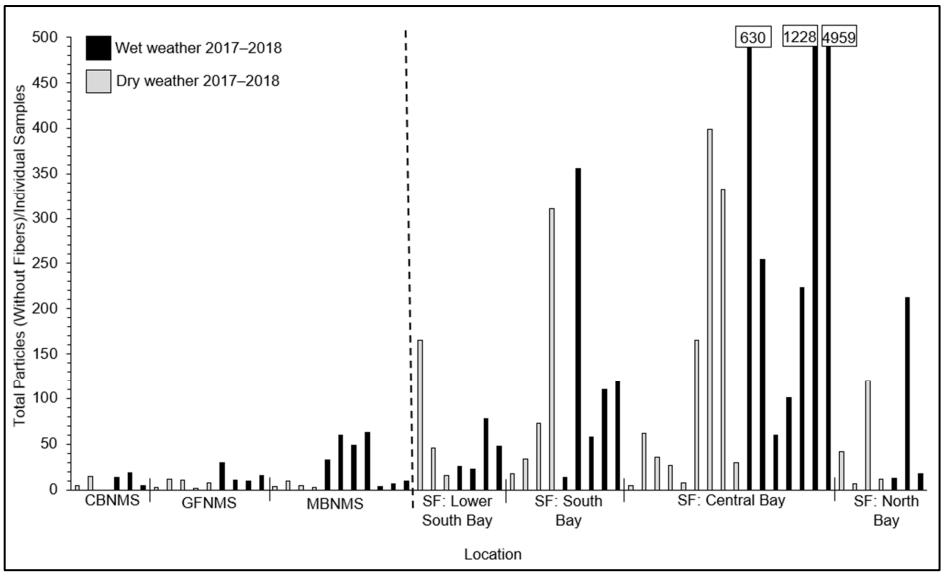

Figure S.WQ.9.1. Particles (excluding fibers) in individual samples from CBNMS, GFNMS, MBNMS, and San Francisco (SF) Bay in the dry and wet seasons 2017–2018. Numbers in boxes indicate values exceeding the axis maximum. Data: Adapted from Sutton et al., 2019.

U.S. Coast Guard Discharges

As part of its mission, the U.S. Coast Guard (USCG) supports resource protection efforts by providing routine surveillance and enforcement of the NMSA and other environmental laws and their implementing regulations (14 U.S.C. §§ 2 and 89), supports resource protection in national marine sanctuaries and facilitates public and private uses, such as leading planning and response activities for oil spills and other incidents within its area of jurisdiction, and through search and rescue missions, strives to minimize the loss of life, injury, and property damage or loss at sea (USCG, 2012).

USCG vessels and aircraft can discharge material and other matter as part of their operations within GFNMS federal waters (beyond three nautical miles of the shoreline). Materials discharged include ammunition and pyrotechnic materials while conducting mission-critical training, and untreated wastewater (including blackwater and greywater) when on patrols. A total of three protector patrol boats, two buoy tenders, and three cutters use GFNMS waters for these activities. The amount of discharge from these activities each year was low, has occurred within GFNMS since its designation, and was determined through a NOAA Final Environmental Assessment published in 2018 to not have a significant impact on water quality or sanctuary resources. The level of discharge was stable over the past several decades. No adverse impacts were documented on any sanctuary resources or uses as a result of USCG discharges of untreated vessel sewage, non-clean vessel graywater, or ammunition or pyrotechnic materials (NOAA, 2018). Additionally, there are federal and state regulations that the USCG must adhere to that minimize impacts to coastal waters.

Cruise Ship Discharge

As discussed previously in Question 2, the high number of people on cruise ships creates a concentration of human waste, greywater, and trash, all of which pose risks to water quality. Illegal discharges by cruise ships are likely underreported due to a lack of oversight during transit in the United States Exclusive Economic Zone (e.g., United States District Court Southern District of Florida, Case No. 16-20897-CR-SEITZ), but there is no evidence of any trends in reporting levels. However, between June 11, 2015 and April 11, 2017 a total of 190 discharges were reported to NOAA from five cruise ships operated by the defendant in the case cited above, as part of a 2016 plea agreement. The total reported release of 8,409,151 gallons of waste streams included; 1) EGCS effluent, 2) untreated and treated black and greywater, including sewage sludge and 3) ground food waste (Blank Rome LLP, 2017; Figure S.WQ.9.2). An estimated 95% of the total released was within GFNMS (Figure S.WQ.9.3). The five cruise ships responsible for the discharges have the capacity to carry over 16,000 passengers who each generate up to 10 gallons of sewage and 85 gallons of gray water daily. A typical cruise ship with 3,000 passengers and crew can produce 30,000 gallons of sewage and up to 255,000 gallons of gray water every day (The Ocean Conservancy, 2002). The largest ship, Grand Princess, which was responsible for 103 of the 190 violations, has the largest capacity for passengers—2,600 guests and 1,150 crew (https://www.princess.com/ships-and-experience/ships/ap-grand-princess/).

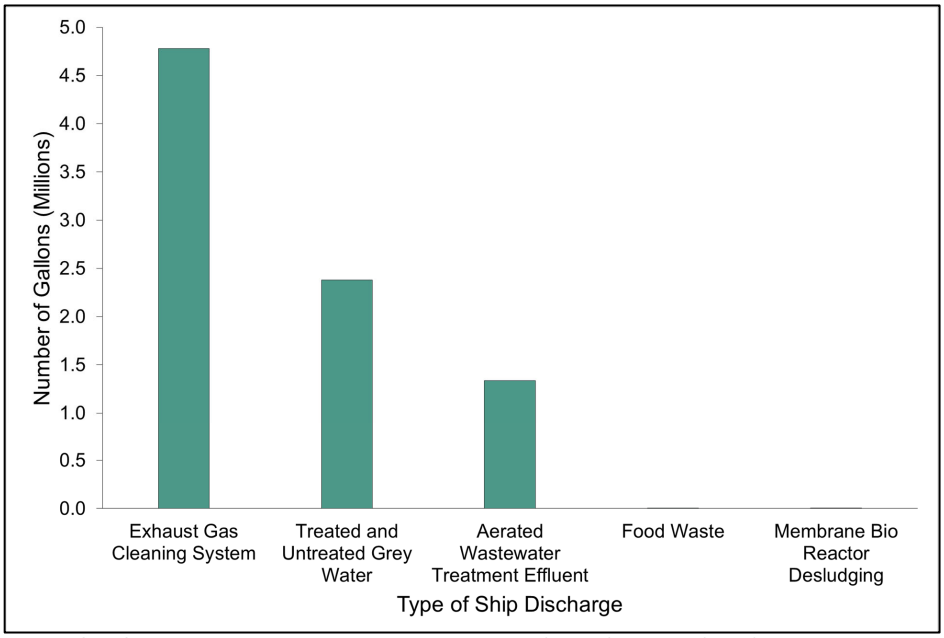

Figure S.WQ.9.2. Illegal waste stream discharges into GFNMS by type from four Princess Cruise Line and one Holland America Line vessels between 2015–2017. Food waste and membrane bio reactor desludging values are negligible (<7,000 gallons). Source: Blank Rome LLP, 2017

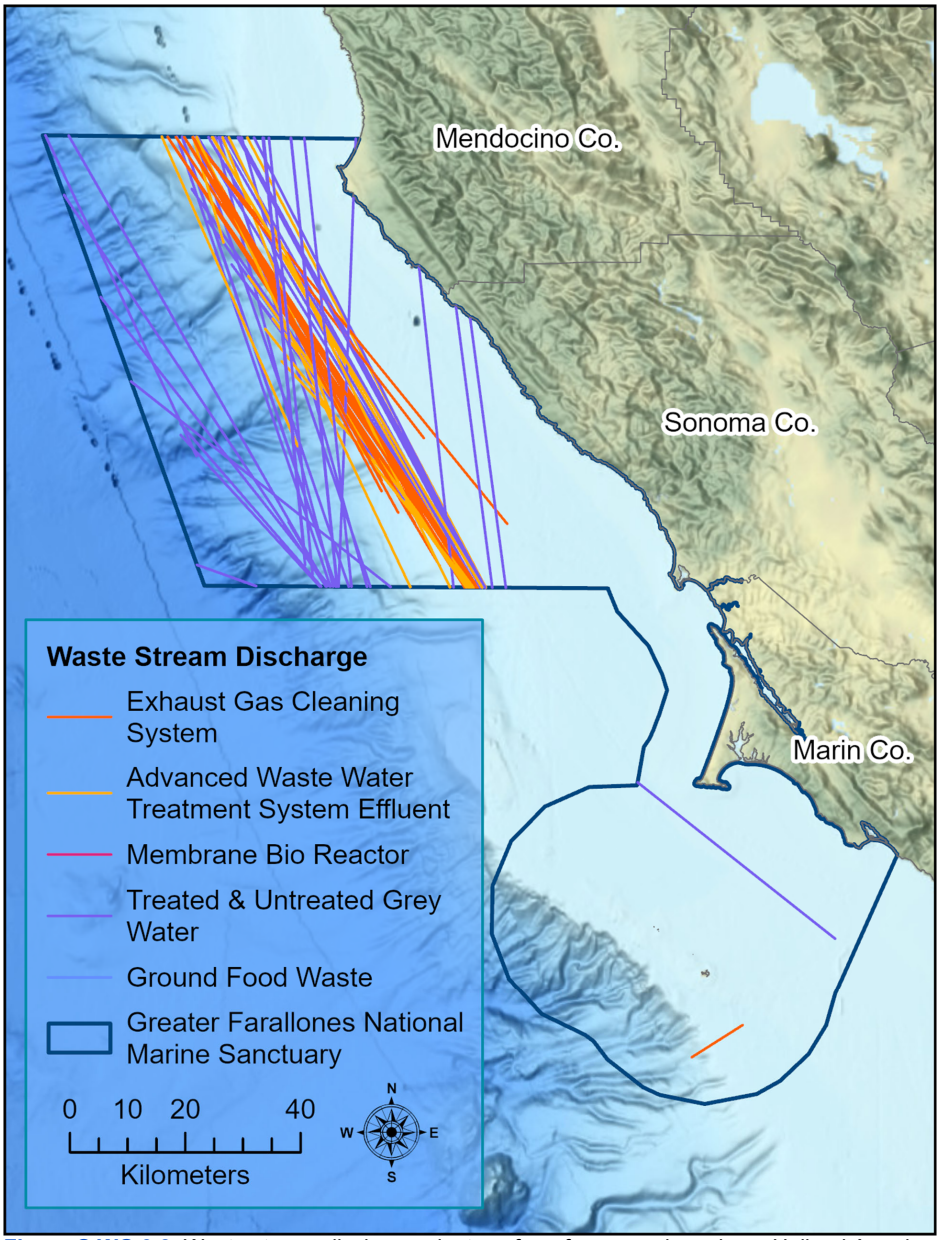

Figure S.WQ.9.3. Waste stream discharges by type from four vessels and one Holland America Line vessel between 2015–2017 were estimated from the start and end points of the ship's

transit, provided by the cruise ship companies. In some cases, the straight line connecting the start and end points artificially appears to show ship transits close to land, which was not the case. Image: NOAA; Source: Blank Rome LLP, 2017; Esri, 2020

Over half of the volume discharged originated from EGCS, better known as scrubbers. Scrubbers remove harmful substances from vessel exhausts; however, some of those substances are transferred to the water used to wash the exhaust. After 2012, EGCS were no longer used in California State waters because of low sulfur fuel requirements, but they are allowed in federal waters not prohibited by other laws and regulations (these locations are all outside of sanctuaries). Please see the section below on emissions for additional information on the effects of EGCS.

Most discharge is treated or contained, but when released, discharges can have localized impacts. Nutrients and other harmful compounds remaining in the waste streams even after treatment can degrade water quality (USEPA 2008; USEPA 2012).The untreated and treated[4] black water and greywater waste streams have similar constituents but pose different levels of risk. Untreated and treated black and greywater was illegally discharged within GFNMS and both types contain micro-pollutants, which are biological or chemical contaminants in trace quantities that can accumulate in the marine environment. Maritime vessels are considered to be significant sources of micro-pollutants especially if the ship carries many passengers, such as cruise ships (Westhof et al., 2016). The illegal discharges that occurred between 2015–2017 within GFNMS included micro-pollutants that can impact water quality.

Dredge Material Discharges

Since 1999, a computerized recording system aboard dredge barges and scows has documented and notified the sanctuary of the location of accidental spillage or premature dumping when it occurs outside the SF-DODS disposal site (LTMS, 1998). During the reporting period for the previous condition report, the total volume of dredged material spills was estimated to be 91,158 cubic yards.[5] Between 2011 and 2016 there were no incidents of leaks and spills within GFNMS. Between 2017 and 2021 there were 15 barge leaks reported within GFNMS that resulted in approximately 21.5 cubic yards of dredged materials leaked, which is a significant decrease in the impact to water quality (Figure S.WQ.9.4).

[4] “Treated” sewage includes Advanced Wastewater Treatment System and Membrane Bio Reactor permeate discharges.

[5] One cubic yard is approximately the size of a standard home washing machine.

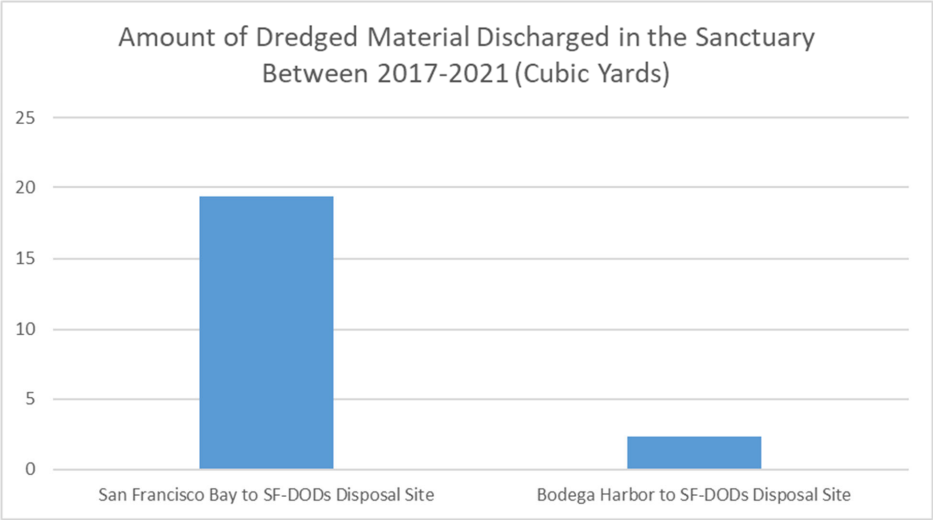

Figure S.WQ.9.4. Estimated dredged material discharged within GFNMS from leaking and spilling barges between 2017–2021. Calculations are based on the proportion of the trip that occurred in sanctuary waters (57.4% of the total reported amount lost along the route from San Francisco Bay to SF-DODS disposal site and 43.1% of the total reported amount lost along the route from Bodega Harbor to SF-DODS disposal site is within GFNMS) . A consistent rate of loss over time was assumed (Etrac, 2022).

Oil and Other Discharges

Materials discharged or dumped from vessels, whether solid or liquid, can contain toxic chemicals including asbestos, lead, polychlorinated biphenyls (PCBs), heavy metals, petroleum hydrocarbons, and petroleum metabolites. When heavy metals such as copper, lead, and zinc are introduced to aquatic environments, they may interfere with the ecology of a marine environment (Bryan, 1971). At higher concentrations, these pollutants tend to accumulate in the bottom sediments and can have adverse effects on organisms in the vicinity of the pollutant resulting in inhibition of growth, reduced fecundity, and even death (Ansari et al., 2004). PCBs are highly persistent environmental pollutants known to bioaccumulate when consumed by aquatic and terrestrial wildlife and humans. Such accumulation is of concern, because it may lead to body burdens that adversely affect health in humans and wildlife, as they can be toxic and carcinogenic, impairing biological processes or causing genetic abnormalities (Beyer & Biziuk, 2009; Watanabe, 2001).

No major oil pollution event was reported for this study period. The amount of leaks and spills from small vessels are unknown. Although there have been no large vessel-based spills for this study period, small oil releases and discharges of other materials (e.g., polystyrene, plastic, solvents, paint, other cleaning products) occurred from 2010–2021 as a result of small to medium sized vessel groundings (see Question 2 for more information). The full extent of such releases, including types of materials and trends, is not known.

Emissions

Greenhouse gas (GHG) emissions are stressors causing impacts to global ocean temperatures and ocean chemistry. As a result of GHG emission-caused warming and increasing GHG gas levels (Figure S.WQ.9.6), global ocean heat content anomalies (Figure S.WQ.9.5) have been increasing over time (NCEI, 2023) . Both in emissions in the air that deposit relatively close to the source vessel and become dissolved or suspended in the surface ocean or as carbon dioxide in the atmosphere, about 30% of which has been absorbed by the global ocean which has resulted in a reduction in global mean surface ocean pH and a 2-degree increase in global average surface temperature since the industrial revolution.

The use of scrubbers (EGCS) to reduce emissions can require discharges that promote localized acidification and concentrations of the same materials that otherwise would be released to the air. Emissions occur from both a ship smokestack and scrubber wash water system at the ship-air-water interface. The atmospheric deposition into the ocean from the smokestack can include nutrients, trace metals and particles. Scrubber wash water can include pollutants, nutrients, and trace metals, some of which (arsenic, copper, lead, nickel, and selenium) have been shown to exceed EPA's National Recommended Water Quality Criteria for the protection of aquatic life (NRWQC) for saltwater organisms (USEPA, 2011). Scrubber wash can also alter water temperature, pH, oxygen levels, and turbidity below the sea surface (USEPA, 2011). These are all potential effects on atmospheric chemistry and marine ecosystems in the surface ocean (Endres et al., 2018). The EPA Office of Wastewater Management described the types and concentrations of substances contained in EGCS effluents from ships (USEPA, 2011). Of particular note are the levels of polycyclic aromatic hydrocarbons (PAHs) in EGCS effluent. PAHs are known to be extremely toxic to early life stages (e.g., eggs and larvae) of a wide range of fish and invertebrate species, with thresholds for lethality, delayed mortality, and sublethal effects in fish (as evidenced by abnormal heart development). Embryonic exposure to 0.22 ppb of petrogenic PAHs is shown to cause permanent structural and functional changes to the fish heart, with resulting reductions in growth, swimming speed, and other endpoints (Incardona et al., 2015).

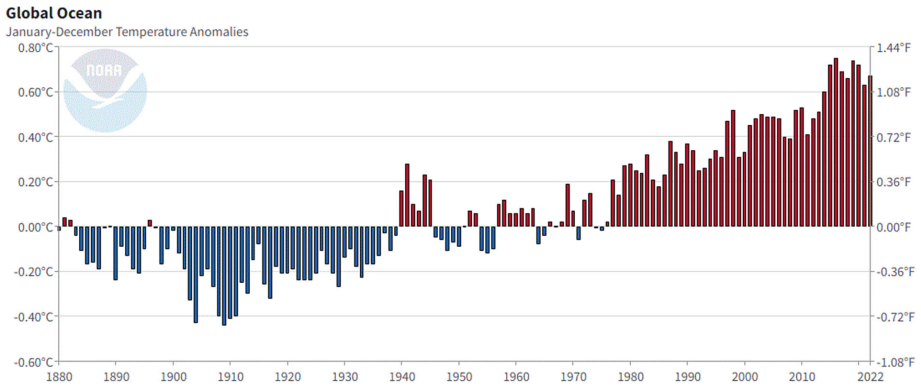

Figure S.WQ.9.5. Annual Global Ocean Surface Temperature Anomalies 1880 – 2012. Source: https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/global/time-series/globe/ocean/12/12/1880-2022; NCEI, 2023

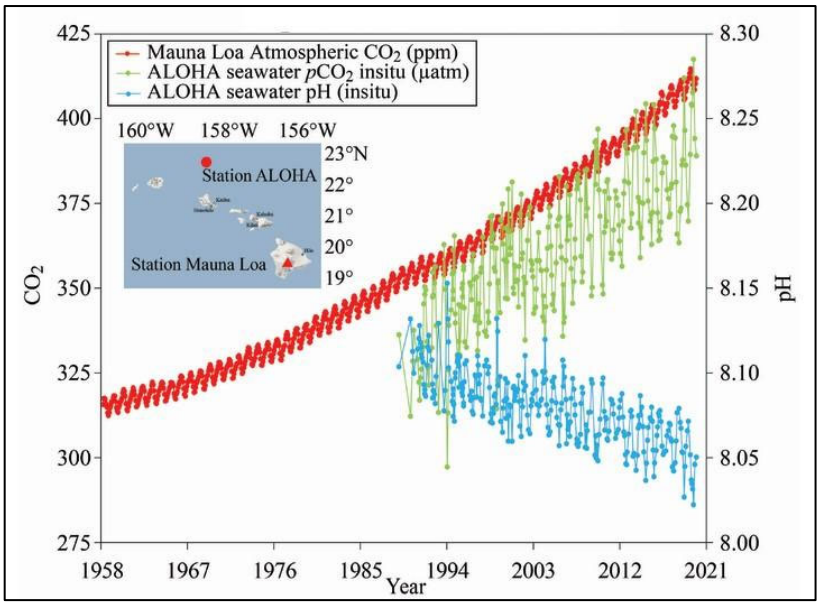

Figure S.WQ.9.6. Carbon dioxide and pH measurements in the north Pacific Ocean. Data: Mauna Loa , ALOHA (http://hahana.soest.hawaii.edu/hot/hot-dogs/bextraction.html), ALOHA pH & pCO2 are calculated at in-situ temperature from DIC & TA (measured from samples collected on Hawaii Ocean Time-series (HOT) cruises) usings co2sys (Pelletier, v25b06) with constants: Lueker et al., 2000; KS04: Dickson, Total boron: Lee et al., 2010, & KF: seacarb. Source: Tans & Keeling, 2021; Adapted from Dore et al., 2009; Image: NOAA

Sediment Transport

Sediment transport through the sanctuary impacts turbidity (suspended sediments). Suspended sediments can be harmful to eggs and larvae through burial or encasement of eggs in fine particles occupying interstitial spaces (NOAA, 2023). High suspended sediment levels can also cause a reduction in dissolved oxygen (DO) levels which can have lethal and sub-lethal effects on fish species (Servizi and Martens, 1992). Deposited particles can indirectly impact biota as a vector for pollutants and contaminants and can directly impact biota by decreasing light penetration and suppressing primary production in algae and macrophytes (Noe et al., 2020).

Changes to sediment transport rates can occur through shoreline and upland development and human activities such as shoreline hardening including seawalls and riprap (Kordesch et al., 2019). However, limited information is available on specific changes to turbidity and sedimentation resulting from sediment imbalances within GFNMS, and there are no data to support any assessment of trends. Since 2010, interventions to prevent excess sediment discharge have occurred, but are limited to culvert cleaning under several roads adjacent to GFNMS (Kordesch et al., 2019).

Conclusion

This question was rated good/fair indicating selected stressors are suspected and may degrade some attributes of ecological integrity, but have not yet caused measurable degradation, based on moderate levels of known or suspected impacts from microplastic levels, U.S. Coast Guard vessel discharges, dredged material discharges, and vessel oil spills. However, cruise ship discharges during the study period were high. A mixed trend was assigned to reflect the declining number of oil spills and unauthorized dredged material discharge incidents, and the increase in cruise ships transiting the sanctuary when the Port of San Francisco opened its new terminal in 2014, as well as reported cases of illegal discharges by cruise ships. Furthermore, it is likely that discharges of most types are underreported, particularly those of the many small vessels using the sanctuary. Some point source discharges have declined because of the use of technology (dredge disposal barge monitoring). Data gaps included trend data for microplastics, cruise ship discharges, other discharges from vessels, and sediment imbalances.

Estuarine and Lagoon Region (Q9)

Status Rating: Fair	Status Confidence: High
Trend Rating: Undetermined	Trend Confidence: Low
Status Description: Selected stressors have caused measurable but not severe degradation in some attributes of ecological integrity.	
Rationale: Pathogens from human-waste and land use related pollutants are prevalent in Tomales Bay and multiple sources were identified for ongoing inputs however, management actions have improved conditions. Oil spills and other discharges from vessels and vehicles occur in Tomales Bay, with unknown impacts based on a lack of data on discharge quantities. Plastic from aquaculture operations in Tomales Bay is prevalent although some clean up activities have occurred. There have been measurable improvements in sediment transport and tidal prism in Bolinas Lagoon due to restoration activities. There is a lack of information on trends for most of these indicators.	

Findings From the 2010 Condition Report

A direct comparison to the 2010 condition report is not possible because the sanctuary expanded in 2015. The expansion added new locations that were not assessed in the 2010 condition report. The ratings in 2010 were based on land use pressures and mercury, (which are covered in question 2 in the current report) and fecal coliform. The 2010 condition report also noted the loss of eelgrass beds in Bolinas Lagoon that occurred before 2010 and has not recovered or changed since 2010. Trend data was not provided for any of the indicators.

New Information in the 2010–2022 Condition Report

The indicators evaluated for Tomales Bay included sewage-related stressors, beach water quality, sources of pathogens, oil and other discharges, and marine debris. Sediment and sediment transport was evaluated for Bolinas Lagoon (Table S.WQ.3.1). Microplastics and

marine debris are ecological stressors that were not considered in the 2010 condition report because data was not available. These indicators were considered in this assessment because they can degrade water quality and impact fish, wildlife, and the ecosystem.

Table S.WQ.9.2. Summaries for the key indicators related to other stressors in the estuarine and lagoon region that were discussed during the May 19, 2022 virtual status and trends workshop.

Indicator	Data Source/data visualization	Data Summary	Figure
Pathogen levels	California Department of Public Health; Marin County; Regional Water Quality Control Board; Tomales Bay Watershed Council	Status: In Tomales Bay, sewage, particularly human fecal coliform has been identified as a source of water quality impairment. Trend: No clear trend	
Beach Water Quality Monitoring	Marin County, the National Park Service, or the Environmental Action Committee of West Marin, depending on the location	Status: Advisories and beach closures occurred in Tomales Bay. Trend: Data not analyzed for trend	
Wastewater treatment facilities	CDPH	Status: Eight waste water treatment facilities exist within the Tomales Bay watershed but no evidence that they have impacted water quality in Tomales Bay. Trend: Stable	
Human waste from campers and boater	CDPH	Status: No data on waste quantities from campers and boaters. Trend: No data on the trend of waste quantities. The addition of a waste receptacle and increased enforcement and outreach may indicate a slight improvement.	
Other discharges	CDPH, 2023	Status: Non-point source pollution has been documented in Tomales Bay through tracking rainfall related closures of commercial shellfish operations. Trend: Undetermined due to lack of data about discharge volumes and point	

		sources. No trend in the numbers of discharge incidents.	
Sediment/ Sediment Transport	Caltrans/ Marin County	Status: Changes to sediment transport have impacted the hydrological function of Bolinas Lagoon. Trend: Restoration efforts have increased water flow, with benefits to water quality.	
Microplastic and Plastic Debris	San Francisco Estuary Institute/ The Coastodian	Status: Plastic debris is found in Tomales Bay. Trend: No trend data available, but cleanup efforts have increased since 2014.	
Data Gap	Trend data for most indicators, information on sediment transport in the Esteros and Tomales Bay.		

Sewage-related Stressors

Indicators for sewage-related stressors included pathogen levels monitored by the Regional Water Quality Control Board, monitoring for aquaculture and shellfish harvest levels, and monitoring for water quality at beaches to determine safe swimming conditions.

Pathogen Levels

Water borne pathogens include bacteria and viruses that can reduce water quality and cause disease in humans (addressed in Q7) and wildlife (RWQCB, 2005; Miller et. al., 2023). In 2007, the Tomales Bay Watershed Pathogen TMDL was developed in response to monitoring that showed exceedances of the bacteria numeric standard for the uses of shellfish harvesting and recreation (RWQCB, 2005). Pathogens in Tomales Bay are of fecal origin. Potential sources include agricultural runoff (from dairies and ranch lands), runoff from residential areas, failing septic systems or small wastewater treatment facilities, discharges from boats, and wildlife. The Tomales Bay Pathogen TMDL includes a broad-based strategy for reducing pathogen sources to the Bay, including increased regulation of grazing lands through waste discharge requirements, required actions to reduce polluted runoff and boat discharges, education and outreach, and monitoring to evaluate progress (RWQCB, 2022a).

As part of the RWQCB's TMDL Water Quality Monitoring Program, fecal coliform data have been collected since 2004 at approximately 30 stations in Tomales Bay and tributaries leading to the bay (RWQCB 2022a). Sampling is conducted by staff of RWQCB, National Park Service, Tomales Bay Watershed Council and the Inverness Public Utility District.

Since 2010 in Tomales Bay, there were 131 water quality samples exceeding thresholds for fecal coliform, from 16 sampling locations in tributaries to Tomales Bay that are monitored by RWQCB (RWQCB, 2022). These include: Inverness 1st Valley, Inverness 2nd Valley, Inverness 3rd Valley, Lagunitas at Gallagher Ranch, Millerton Creek, East Shore MP 36.16, Walker Creek Ranch, Upper Keys at Tomales, Walker Creek at Hwy 1, Upper Chileno Creek, Olema above Randall Gulch, Olema John West Fork, Olema at 5 Brooks, Olema Davis Boucher Tributary, Olema at Bear Valley Rd. Bridge, and Olema Below Pasture Flow (Ghodrati, 2022).
Tomales Bay continues to be listed as an impaired water body under section 303(d) of the Clean Water Act despite conservation measures set by the Regional Water Quality Control Board (RWQCB) and land-based property owners including federal and state parks. The presence of pathogens in Tomales Bay is inferred from high fecal coliform bacteria concentrations and prior illness outbreaks from consumption of contaminated shellfish. In addition to potential health risks from pathogens, animal and human waste contain nutrients that can promote eutrophication and make ecosystems vulnerable to impacts from invasive species and harmful algal blooms (RWQCB, 2005).

Norovirus is another human waste related pathogen and is monitored for risks to human health through aquaculture operations in Tomales Bay. Since 2010, norovirus has continued to be an issue for the aquaculture operations on Tomales Bay, however outbreaks were infrequent during this period. An April 2019 norovirus illness outbreak led to a 21-day closure of all Tomales Bay shellfish growing areas (CDPH, 2020). Another outbreak led to closures in Dec. 2018–Jan. 2019. A source was not identified for either of these outbreaks (CDPH, 2021).

Actions that have been implemented since the Tomales Bay Watershed Pathogen TMDL was developed in 2007 to reduce pathogens include Best Management Practices (BMPs) on grazing lands and at dairies, and construction of a community wastewater treatment system to collect and treat septage from more than 50 individual septic systems (RWQCB, 2016). However, since 2016, there has not been any reports on the status of these activities or a determination if conditions are still improving.

Beach Water Quality

Beach water quality measurements provide an indicator of water quality impairment through measurements of pathogens that cause risks to human health. State of California regulations require specific sampling and reporting requirements for local beach water quality, for beaches that are visited by more than 50,000 people annually, and for beaches located in an area adjacent to a storm drain that flows in the summer. In Marin County water quality monitoring is carried out by the County, the National Park Service, or the Environmental Action Committee of West Marin, depending on the location. This includes six locations within GFNMS estuaries sampled since the 2010 condition report; these locations, all within Tomales Bay waters, include Lawson's Landing, Miller Park, Millerton Point, Chicken Ranch Beach, Shell Beach, and Hearts Desire Beach. These locations are sampled once a week from April 1 through October 31 to determine if a beach meets the California water quality standards for recreational water contact. In addition to the six locations on the bay, sampling also occurs at one intermittent creek (Chicken Ranch Ditch) at Chicken Ranch Beach when there is enough water for sampling. However, this site does not directly connect to Tomales Bay unless there are sustained high water flow events (i.e., multiple heavy storms). Total coliform, *Escherichia coli*, and

Enterococcus density are used as indicators of fecal contamination, and high levels can prompt closures of recreational water sites. Advisories are issued when *Enterococcus* exceeds 104 MPN/100 ml or *E. coli* exceeds 400 MPN/100 ml (A. Kundu/County of Marin personal communication, March 09, 2022). Since the 2010 condition report, advisories and beach closures have continued to occur in Tomales Bay. Monitoring results have shown elevated total coliform levels at Chicken Ranch Beach Ditch on the west shore. However, the exceedances at the Chicken Ranch Ditch may not significantly affect water quality in Tomales Bay, as the advisories were based on total coliform and not *Enterococcus* or *E. coli* and the waters in the ditch rarely discharge into the bay. No water quality sampling currently occurs in the esteros or Bolinas Lagoon (P. Kulkarni/North Coast Regional Water Quality Control Board, personal communication, May 05, 2022; A. Kundu/County of Marin personal communication, September 19, 2022).

Pathogen Sources

Sewage discharges from a variety of sources have the potential to adversely impact water quality in GFNMS estuaries. Sources include malfunctions at wastewater treatment facilities or septic systems in proximity to the estuaries, direct discharges from recreational vessels, dairy and ranching activities, equestrian facilities, runoff, and illegal camping (CDPH, 2021).

Wastewater Treatment Facilities

There are eight wastewater treatment facilities within the Tomales Bay watershed that are a potential source of pathogens to the bay. None of the eight wastewater treatment facilities within the watershed discharge directly to Tomales Bay; rather, they employ evaporation ponds, irrigation fields (seasonally), or large septic systems. But discharge of untreated or partially treated effluents to streams can be caused by malfunctions, including the breaching of ponds, a break in a sewage line, or land application at times when the soil is saturated (CDPH, 2021). Between August 2010 and June 2021, no spills or discharges by these facilities to the waters of Tomales Bay were reported to CDPH (CDPH Annual Sanitary Survey Update Reports, 2010-2021). The Marshall Community Wastewater System was completed in 2016 to provide wastewater treatment for 50 properties on the eastern shore of the bay and address water quality issues due to failing septic systems (CDPH 2021, RWQCB 2022a). From July 2016 to June 2017 there were three effluent violations at the Marshall Community Wastewater System, when the fecal coliform 7-day mean exceeded 2.0 most probable number (MPN) (11/1/16 = 110 MPN; 2/14/17 = 240 MPN; 4/12/17 = 500 MPN). However, the leach field was working properly during this time, so the violations do not pose a risk to the aquaculture growing areas (CDPH, 2017). Thus, since the 2010 condition report was completed, data suggests that these treatment facilities have not adversely affected water quality of the bay.

Human Waste from Campers and Boaters

Wastewater discharges from campers and boaters into Tomales Bay were identified as a potential source of water quality impairment (CDPH, 2021). No data is available on the status and trends or impacts of these sources. However, several developments have improved the status of wastewater discharges into Tomales Bay from campers and boaters. In 2012, restrooms and a waste receptacle station for campers and vessels without holding tanks were installed at Marin County's Miller Park Boat Launch. Prior to the installation of the waste receptacle station, there were no vessel-related sewage services located on Tomales Bay. While this is an improvement, the bay still does not have any sewage pump out services for boats with holding tanks. The closest pumpout station is located in Bodega Harbor and requires vessels to leave Tomales Bay over the sand bar, which is tide and weather dependent. To address concerns, starting in 2020, CDPH began working with federal, state, and local agencies, law enforcement, elected officials, and local NGOs to increase

monitoring,enforcement, and public outreach efforts, and to develop new policy and regulatory initiatives (CDPH, 2021).

Other Discharges

In addition to oil release events in Tomales Bay (discussed in Question 2), the type of pollution most likely to adversely affect water quality in Tomales Bay originates from nonpoint sources (CDPH, 2023). These pollutants can come from domestic animal waste, residences, wildlife, vessels, and decentralized onsite sewage disposal systems serving residences, restaurants, and businesses surrounding the bay (CDPH, 2023). One indicator of water quality impairment from nonpoint source pollution are the rainfall related closures of commercial shellfish operations, which are enacted to mitigate fecal coliform impacts to human health (discussed in Question 7). From 2009 to 2021, 1,291 days of rainfall closures were implemented (Figure S.WQ.7.8), indicating significant non-point source pollution to Tomales Bay.

Sediment and Sediment Transport

Sediment levels and sediment transport are not measured in most estuaries and lagoons in GFNMS. However, studies from Bolinas Lagoon showed that since the early 19th century, human land uses have altered the shoreline and watershed, changing the proportion of human-caused sediment reaching the lagoon, threatening water quality and altering the rate at which natural processes shape the lagoon. The result is a human-induced acceleration and alteration in the natural processes, resulting in a loss of tidal prism (the volume of water entering and exiting the lagoon during a tidal cycle) and changes in composition of plants, animals and habitats (GFNMS, 2008). Since 2010, multiple actions focused on culvert and road repairs and removal of invasive species that contributed to limiting Bolinas Lagoon's hydrological function resulted in increased the tidal prism. A comparison of bathymetric data from 1998, 2012, and 2016 found that the Bolinas Lagoon tidal prism increased from approximately 3.7 million cubic yards (MCY) in 1998 to 4.0 MCY in 2016 (Marin County Parks and Open Space District, 2017). These data also help scientists track shifts in habitat and sediment supply, which informs planning and prioritization of future restoration projects.

Microplastics and Plastic Debris

Sediment samples were collected at 20 sites in both San Francisco Bay and Tomales Bay to assess baseline conditions of microplastics in sediment, and evaluate spatial distribution, including the influence of urban stormwater and wastewater discharges. Samples were collected from Tomales Bay and San Francisco Bay for evaluation of urban influences (Box & Cummins, 2019). Tomales Bay sediment contained microparticles and microplastics, but they were among the lowest observed compared to areas within San Francisco Bay. In addition, samples from anchovy and topsmelt indicated microfibers were commonly found in these species, both of which are prey species that could be indicators of water quality contaminants (Box & Cummins, 2019).

Conclusion

This question on the status of other water quality stressors was rated fair, indicating selected stressors have caused measurable but not severe degradation in some attributes of ecological integrity, based mainly on the ongoing prevalence of pathogens, specifically fecal coliform, from water monitoring programs at tributary locations, beaches, and aquaculture facilities in Tomales Bay. Several sources were identified as ongoing pathogen contributors including wastewater treatment facilities, boaters and campers, and non-point source pollution from land runoff. In addition, oil discharges from vessel and vehicle incidents occurred in Tomales Bay and plastic debris is present in Tomales Bay .Non-point source pollution has been documented in Tomales

Bay. Changes from human land use may have reduced water quality in Bolinas Lagoon. The trend is undetermined based on no clear trends or because of a lack of time series data available for several indicators. There is no trend data available for the volume of oil spills from vessels in the bay or for marine debris. Sediment transport into Bolinas Lagoon has decreased. Most of the data indicators were available only for Tomales Bay, except for measurements of tidal prism, which was only available for Bolinas Lagoon.

References (Q9/Both Regions)

Ansari, TM, Marr, IL and Tariq, N. (2004). Heavy Metals in Marine Pollution Perspective–A Mini Review. Journal of Applied Sciences, 4: 1-20. DOI: 10.3923/jas.2004.1.20 URL: https://scialert.net/abstract/?doi=jas.2004.1.20

Blank Rome LLP. (2017). Letter to NOAA Special Agent Don Tanner. RE: Response to request for Information from NOAA dated May 31, 2017 related to the self-reported discharge events in the Cordell Bank and Greater Farallones National Marine Sanctuaries by four Princess vessels and one Holland America Line vessel.

Beyer A, Biziuk M. (2009). Environmental fate and global distribution of polychlorinated biphenyls. Rev Environ Contam Toxicol. 2009;201:137-58. doi: 10.1007/978-1-4419-0032-6_5. PMID: 19484591.

Box, C., and Cummins, A. 2019. *San Francisco Bay Microplastics Project Science-Supported Solutions and Policy Recommendations*. Prepared by The 5 Gyres Institute.

Bryan, GW. (1971). The effects of heavy metals (other than mercury) on marine and estuarine organismsProc. R. Soc. Lond. B.177389–410.

California Department of Public Health (CDPH). (2010-2021). *Environmental Management Branch Preharvest Shellfish Program Annual Sanitary Survey Update Reports*, *2010-2021*.

California Department of Public Health (CDPH). (2017). Triennial *Sanitary Survey Update Report: 2014-2017.*

California Department of Public Health (CDPH). (2020). *Annual Sanitary Survey Update Report: 2018-2019.*

California Department of Public Health (CDPH). (2021). *Annual Sanitary Survey Update Report: 2020-2021.*

California Department of Public Health (CDPH). (2023). *Management Plan for Commercial Shellfishing in Tomales Bay, California.*

Chin, J.L. and A. Ota. 2001. Disposal of dredged materials and other wastes on the continental shelf and slope. In: Karl, H.A., J.L. Chin, E. Ueber, P.H. Stauffer, J.W. Hendley, J.W. (eds.) 2001. Beyond the golden gate—oceanography, geology, biology, and environmental issues in the Gulf of the Farallones. U.S. Geological Survey Circular 1198. 84 pp. Electronic document available from: http://pubs.usgs.gov/circ/c1198/

County of Marin Ocean and Bay Water Quality Testing Program Website. (2022). Retrieved

December 10, 2022, from https://www.marincounty.org/depts/cd/divisions/environmental-health-services/beach-monitoring#:~:text=The%20EHS%20beach%20hotline%3A%20(415,Beach%20Water%20Quality%20Information

Crew Center. (2022). San Francisco Cruise Ship Calendars. https://crew-center.com/san-francisco-california-cruise-ships-schedule-2019 Accessed March 25, 2022

Danopoulos E, Jenner LC, Twiddy M, Rotchell JM. (2020). Microplastic contamination of seafood intended for human consumption: a systematic review and meta-analysis. Environ Health Perspect128(12):126002, PMID: 33355482, 10.1289/EHP7171.

Dore, J. E., Lukas, R., Sadler, D. W., Church, M. J., & Karl, D. M. (2009). Physical and biogeochemical modulation of ocean acidification in the central North Pacific. *Proceedings of the National Academy of Sciences*, *106*(30), 12235–12240. https://doi.org/10.1073/pnas.090604410

Endres, S., Maes, F., Hopkins, F., Houghton, K., Mårtensson, E. M., Oeffner, J., Quack, B., Singh, P., & Turner, D. (2018). A new perspective at the ship-air-sea-interface: The environmental impacts of exhaust gas scrubber discharge. Frontiers in Marine Science 5(139), 1–13. https://doi.org/10.3389/fmars.2018.00139

Etrac. (2022). The eTrac barge monitoring system for EPA required barge tracking. [Unpublished data set]

Ghodrati, Farhad, Regional Water Quality Control Board (RWQCB), San Francisco Bay Region. (2022). Tomales Bay Fecal Coliform Dataset Excel file titled *TB Data for GFNMS (2004-2021)*.

Greater Farallones National Marine Sanctuary (GFNMS). (2008). *Bolinas Lagoon Ecosystem Restoration Project: Recommendations for Restoration and Management (Locally Preferred Plan)*.

Incardona, J., Carls, M., Holland, L. (2015). Very low embryonic crude oil exposures cause lasting cardiac defects in salmon and herring. Sci Rep 5, 13499. https://doi.org/10.1038/srep13499

Johnson, A. (2018). The Effects of Turbidity and Suspended Sediments on ESA-Listed Species from Projects Occurring in the Greater Atlantic Region. Greater Atlantic Region Policy Series 18-02. NOAA Fisheries Greater Atlantic Regional Fisheries Office. 106p. www.greateratlantic.fisheries.noaa.gov/policyseries/.

Kordesch, W.K., M. Delaney, S. Hutto, M. Rome, and S. Tezak. (2019). *Coastal Resilience Sediment Plan*. Report of Greater Farallones National Marine Sanctuary. NOAA. San Francisco, CA. 104 pp. https://nmsfarallones.blob.core.windows.net/farallones-prod/media/docs/20191101-coastal-resilience-and-sediment-plan.pdf.

LTMS (Long-Term Management Strategy). (1998). Long-term management strategy for bay area dredged material final environmental impact statement/environmental impact report. Prepared by Ogden Beeman & Associates with Jones & Stokes Associates, Inc. and Moffatt & Nichol Engineers, Inc.

Marin County Parks and Open Space District. (2017). Conceptual Design Report, Bolinas Lagoon North End Restoration Project.

Miller, Melissa & Batac, Francesca & Greenwald, Katherine & Reed, Angelina & Young, Colleen & Harris, Michael. (2023). Newly detected, virulent Toxoplasma gondii COUG strain causing fatal steatitis and toxoplasmosis in southern sea otters (Enhydra lutris nereis). Frontiers in Marine Science. 10. 10.3389/fmars.2023.1116899.

Noe, G.B., M. Cashman, K. Skalak, A. Gellis, K. Hopkins, D. Moyer, J. Webber, A. Benthem, K.Maloney, J. Brakebill, A. Sekellick, M. Langland, Q. Zhang, G. Shenk, J. Keisman, C. Hupp,and D. Hogan. (2020). A review of sediment sources, transport, delivery, and impacts inthe Chesapeake Bay watershed: a guide for management. Wiley Interdisciplinary Reviews: Water, 7:e1454. https://doi.org/10.1002/wat2.1454.

NOAA, National Centers for Environmental Information (NCEI). 2023. Climate at a Glance: Global Ocean https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/global/time-series/globe/ocean/12/12/1880-2022. Accessed February 22, 2023.

NOAA. (2018). Environmental Assessment of Regulation of United States Coast Guard Vessel and Training Discharges in Greater Farallones and Cordell Bank National Marine Sanctuaries.

NOAA (2021). Office of General Counsel, Enforcement Section Civil Administrative Enforcement Actions. Princess Cruise Lines, Ltd., NOAA Case No. NW1703667A, and Holland America Line N.V., NOAA Case No. NW1703667B.Princess Cruise Lines, Grand Princess. (2023). https://www.princess.com/ships-and-experience/ships/ap-grand-princess/ (Accessed January 18, 2023)

NOAA. (2023). “Not Likely to Adversely Affect” Programmatic for NPDES Permits in U.S.Environmental Protection Agency Region 1 (EPA NLAA Programmatic). February 24, 2023. https://www.fisheries.noaa.gov/s3/2023-04/LOC-EPA-NLAA-Programmatic-final-508-Signed.pdf

Regional Water Quality Control Board (RWQCB), San Francisco Bay Region. (2005). Staff Report, Pathogens in Tomales Bay Watershed Total Maximum Daily Load (TMDL), December 2005.

Regional Water Quality Control Board (RWQCB). (2016). Water Quality Report Card for Pathogens in Tomales Bay Tributaries, 2016

Regional Water Quality Control Board (RWQCB). (2022). This is the RWQCB data for tributaries to Tomales Bay only. This comes from the excel file titled: TB Data for GFNMS (2004-2021).

Regional Water Quality Control Board (RWQCB). (2022a). Tomales Bay TMDL Website. Retrieved December 10, 2022, from https://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/TMDLs/tomalesbaypathogenstmdl.html

Sutton, R., Franz, A., Gilbreath, A., Lin, D., Miller, L., Sedlak, M., Wong, A., Box, C., Holleman, R., Munno, K., Zhu, X., & Rochman, C. (2019). Understanding microplastic levels, pathways, and transport in the San Francisco Bay region. San Francisco Estuary Institute.

Tans, P., & Keeling, R. (2021). *Trends in atmospheric carbon dioxide: Mauna Loa, Hawaii* [Data set]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Global Monitoring Laboratory, Earth System Research Laboratories. https://gml.noaa.gov/ccgg/trends/data.html

Teuten, E. L., Saquing, J. M., Knappe, D. R. U., Barlaz, M. A., Jonsson, S., Björn, A., Rowland, S. J., Thompson, R. C., Galloway, T. S., Yamashita, R., Ochi, D., Watanuki, Y., Moore, C., Viet, P. H., Tana, T. S., Prudente, M., Boonyatumanond, R., Zakaria, M. P., Akkhavong, K., Ogata, Y., Kirai, H., Iwasa, S., Mizukawa, K., Hagino, Y., Imamura, A., Saha, M., & Takada, H. (2009). Transport and release of chemicals from plastics to the environment and to wildlife. Philosophical Transactions of the Royal Society B, 364(1526), 2027–2045. http://doi.org/10.1098/rstb.2008.0284

The Ocean Conservancy. (2002). Cruise Control: A Report on How Cruise Ships Affect the Marine Environment (Washington, DC: , pp. 13, 15) https://books.google.com/books/about/Cruise_Control.html?id=D2wVAQAAIAAJ. Accessed on March 30, 2023.

Thompson, R. C., Olsen, Y., Mitchell, R. P., Davis, A., Rowland, S. J., John, A. W. G., McGonigle, D., & Russell, A. E. (2004). Lost at sea: Where is all the plastic? Science, 304(5672), 838-838. http://doi.org/10.1126/science.1094559

United States Coast Guard. (2012). Coast Guard Publication 3-0. Operations. Washington, DC

U.S. Environmental Protection Agency. (2008). Cruise Ship Discharge Assessment Report. EPA842-R-07-005. December 29.

U.S. Environmental Protection Agency. (2011). Exhaust Gas Scrubber Washwater Effluent. EPA-800-R-11-006. November.

U.S. Environmental Protection Agency. (2012). Petroleum Hydrocarbons And Chlorinated Solvents Differ In Their Potential For Vapor Intrusion. Office of Underground Storage Tanks, Washington, D.C. 20460. March 2012

U.S. Environmental Protection Agency. (2021, July 13). Greenhouse Gas Reporting Program (GHGRP) Emissions by Location. U.S. Environmental Protection Agency. https://www.epa.gov/ghgreporting/ghgrp-emissions-location

Watanabe, K. (2001). Microorganisms relevant to bioremediation. Curr. Opin. Biotechnol., 12 , pp. 237-241, 10.1016/S0958-1669(00)00205-6.

Westhoff, L., Koster, S., Reich, M. (2016) Occurance of micropollutants in wastewater streams of cruise ships. Emerging Contaminants 2. 178-184.

Status and Trends of Habitat (Questions 10–11) 1
Question 10: What is the integrity of major habitat types and how are they changing? 1
Coastal and Offshore Region (Q10) 1
Estuarine and Lagoon Habitats and Offshore Regions (Q10) 11
Question 11: What are contaminant concentrations in sanctuary habitats and how are they changing? 20
Coastal and Offshore Region (Q11) 20
Estuarine and Lagoon Region (Q11) 24

Status and Trends of Habitat (Questions 10–11)

The following sections provide an assessment of the status and trends of key habitat indicators in GFNMS for the period from 2010–2022. We have noted where more recent data (e.g., 2023) became available during editing of this report.

Question 10 focuses on the integrity of major habitats within the sanctuary, including biologically (biogenic) and abiotically (physical) structured habitats. Physical habitats are abiotic structures (e.g. rocky reefs), while biogenic habitats (e.g. corals) are composed of species that form structures used by other living marine resources. Biogenic habitats are layered on top of, and are often associated with, specific physical habitat types. Changes to both biotic and abiotic habitat can significantly alter the diversity of living marine resources and ecosystem services.

Question 11 examines concentrations and variability of contaminants in major sanctuary habitats. Like the other condition report questions, the status and trend ratings represent assessments by subject matter experts given readily available habitat data.

Question 10: What is the integrity of major habitat types and how are they changing?

Coastal and Offshore Region (Q10)

Status Rating: Fair	Status Confidence: Medium
Trend Rating: Mixed	Trend Confidence: Medium
Status Description: Selected habitat loss or alteration has caused measurable but not severe degradation in some attributes of ecological integrity.	
Rationale: There has been a significant loss of kelp canopy cover, stipe density, and understory algae and a proliferation of urchin barrens during the assessment period, which has created a decline in habitat integrity for other kelp forest and dependent species (such as abalone). Sediment imbalances occurred along sandy beach habitat. Shoreline armoring was stable during the study period. Structure forming species within the rocky intertidal habitat	

appear to be stable. Sunken marine debris was found. Data gaps include the need for additional sandy beach habitat, rocky intertidal habitat, and deep-sea coral and sponge habitat assessments and pressures.

Findings From the 2010 Condition Report

The 2010 report assessed major habitat types and biogenic habitats separately. In the GFNMS 2010 report, the status of habitat integrity in the offshore and coastal environment was rated as good/fair and conditions were thought to be Improving. At the time, selected habitat loss or alteration from years past had not caused substantial or persistent degradation in living resources or water quality. Reductions in trawling prior to 2010 had reduced impacts to biologically structured habitats. Management of dredge disposal practices had reduced the input of contaminants into the sanctuary. In general, the 2010 Condition Report ~~generally~~ lacked a quantitative assessment of offshore and coastal habitat integrity.

New Information in the 2010–2022 Condition Report

In this report, all major habitat types are assessed collectively (Table S.H.10.1). The area of the sanctuary more than doubled in size in 2015, adding deep water habitats off the continental slope, including Arena Canyon, and surrounding pelagic habitat. This assessment derived new data from several sources, which provides quantitative information on shoreline armoring, sandy beach habitat, rocky intertidal habitat, kelp canopy cover and persistence, kelp stipe and understory (algal) density, deep-sea coral abundance in new offshore areas, and deep sea marine debris on the seafloor.

Table SH.10.1. Summaries for the key indicators related to habitat integrity in the coastal and offshore region of the sanctuary that were discussed during the June 9, 2022 virtual status and trends workshop.

Indicator	Source	Data Summary	Figures
Shoreline Armoring	CCC, 2022	Status: A very small percentage of GFNMS coastal shoreline is armored. Trend: No new armoring has occurred in GFNMS (i.e., below mean high water) since 2010 and the trend is stable.	
Sandy Beach	NOAA 2006; NOAA 2008; Vos et al., 2019	Status: GFNMS has a significant length of sandy beach along its coastal shoreline. Trend: Shoreline rates of change data at some locations in GFNMS indicate erosion (i.e., beach loss) is occuring while at other sites accretion or sediment imbalances are occurring. More data is needed to assess long-term trends across the sanctuary.	
Rocky Intertidal	MARINe, 2021	Status: Several important habitat-forming species appear to be generally stable. Trend: There is some variability in recent trends for key species at three monitoring sites in GFNMS. California mussels percent cover declined during the assessment period but	S.H.10.1

		appears to be trending toward recovery at all sites. Acorn barnacles and dwarf/golden rockweed appear to be stable while turfweed algae and Northern rockweed have declined.	
Kelp Canopy Cover	CDFW, 2019; Bell et al., 2023	Status: Annual total kelp canopy area was high before 2014 and low after 2014. Trend: Kelp Canopy cover has declined significantly during the study period (2010-2022).	S.H.10.2
Kelp Stipe Density	PISCO, 2022	Status: Annual kelp density was high before 2014 and low after 2014. Trend: Kelp stipe density has declined significantly during the study period (2010-2022) at most long-term monitoring locations.	
Understory Kelp and Algal Density	PISCO, 2022, Freiwald, 2020	Status: Annual understory percent cover is less after 2014 than before 2013 with the level of decline dependent on species. Trend: Annual understory cover has declined during the assessment period (2010-2022).	
Deep-Sea Corals and Sponges	Etnoyer, 2014; Graiff et al. 2016; Graiff et al. 2021	Status: Healthy coral and sponge colonies have been documented at several surveyed locations during 4 cruises since 2010. Trend: The trend is undetermined due to a lack of data for the study period (2010-2022).	S.H.10.3
Deep-Sea Marine Debris	Etnoyer, 2014; Graiff et al. 2016; Graiff et al. 2021	Status: Deep-sea debris has been documented on all research surveys conducted by GFNMS since 2010. Trend: The trend is undetermined due to a lack of data for the study period (2010-2022).	
Data Gaps	More monitoring plots are needed to fully assess trends for rocky intertidal habitat throughout the sanctuary. More data are needed to better assess the status and trends for sandy beach habitat. More data is needed on deep-sea coral and sponge habitat and sunken marine debris.		

Shoreline Armoring

Shoreline armoring can be an indicator of habitat integrity, because human-made structures can alter habitat in a variety of ways, including direct replacement, changing natural sediment dynamics and transport, hastening the loss of sandy beach seaward of and exacerbating erosion “downstream” of armored structures, and blocking in-land migration of certain habitats as sea level rises, resulting in loss of rocky intertidal habitats, upper beaches, and estuarine marsh habitats (Dugan et al., 2008; Von Holle et al., 2019; IWR and USACE 2021). As of 2018, 13.9% of the entire state of California’s coastline is armored, a 5.5-fold increase over 47 years (Griggs and Patsch, 2019), reducing sand supply in the state by an average of 11% (IWR and USACE 2021).

GFNMS regulations prohibit the placement of new structures below the mean high water line. However, armoring does occur adjacent to and above the mean high water line (i.e., above the GFNMS boundary line). Further, historic armoring exists below the mean high water line inside

sanctuary boundaries at numerous locations. From the northern boundary to the southern boundary of GFNMS, there are2.7 221 instances of armoring, totaling 5.39 miles (8.67 kilometers), which includes 5 armoring locations totaling 102.3 meters within Point Reyes National Seashore, where the sanctuary boundary is 1/4 mile offshore (California Coastal Commission, 2022). Of the remaining 216 instances of armoring within GFNMS boundaries (totaling 5.33 miles [8.58 kilometers]), 165 are in Marin County, 50 are in Sonoma County, and 6 are in Mendocino County. The area with the most armoring is Tomales Bay, which has 125 instances, totalling 2.75 miles (4.43 kilometers). Common types of armoring include: revetment, seawall, retaining wall, other, bulkhead, and surface armoring. Since 2010, no new armoring has been constructed within GFNMS, and all maintenance of existing armoring has stayed within the existing footprints; thus the trend is stable.

Commented [1]: unclear..."are2.7 221 instances..."

Commented [2]: the convention seems to be miles (km) and feet (m), but is convention consistent throughout CR document?

Sandy Beach Habitat

There has not been a sediment characterization survey conducted for the entire shoreline since 2008, and this is a data gap identified by the North Central California Coast Sediment Coordination Committee. More studies are also needed on littoral transport and sediment dynamics both locally and regionally to better understand the physical factors that affect beach habitat integrity at different locations throughout the sanctuary.

A 2019 assessment of two coastal sites (Doran Beach and Stinson Beach) in GFNMS suggest erosion is threatening beach and dune habitat while other sandy beaches, like Salmon Creek Beach, may be accreting (Vos et al., 2019). The trend appears to be mixed at some locations. With worsening impacts from climate change and sea level rise, sandy beach habitat has been identified as one of the most vulnerable habitats that may experience erosion and sand loss (Hutto et al., 2015). More shoreline change data is needed to better understand long-trend trends and more beaches need to be surveyed to fully assess the status of sandy beach habitat in the sanctuary.

Rocky Intertidal

The health of key habitat-forming species in a region is a good indicator of rocky habitat integrity. Information on rocky intertidal communities is collected and shared through the MARINe program which monitors over two hundred sites from Alaska to Mexico. Rocky intertidal sites in GFNMS span a variety of conditions such as substrate types, wave energy, and exposure and results from one site may not be reflective of conditions throughout the sanctuary. Long-term monitoring data was assessed from three sites in the sanctuary: Sea Ranch, Bodega Marine Life Refuge, and Bolinas Point (Figure S.H.10.1). Not all sites monitor all key habitat-forming species. California mussel (*Mytilus californianus*) declined after the 2014–2016 MHW but appeared to be recovering in Marin and Sonoma Counties. For more information on the decline and recovery, see Question 13, California Mussels section and Figure S.LR.13.6 (MARINe, 2022). Annual percent cover for acorn barnacles (*Chthamalus fissus, C. dalli, Balanus glandula*) and dwarf/golden rockweed (*Pelvetiopsis spp.*) is monitored at two or three of the sites and they have shown some variability in recent surveys but generally have remained stable since 2010. Annual percent cover of turfweed algae (*Endocladia muricata*) was monitored at two sites and was observed to be stable at Sea Ranch but declining at Bodega Marine Life Refuge. Cover of Northern rockweed (*Fucus* spp.) declined substantially at Bolinas Point and was very low in plots at Bodega Marine Life Refuge during the current assessment period. Surfgrass (*Phyllospadix* spp.) abundance appears stable but was only monitored at one site (MARINe 2022). Some rocky intertidal monitoring data has also been collected at Southeast Farallon Island. However, status and trends were not available for this site. In general, more

Commented [3]: numerals convention generally seems to be spelling out one-nine and then 10, 201 etc. (with exceptions for lists, tables, decimals...) but is convention consistent throughout?

intertidal monitoring sites are needed in GFNMS and more data is needed to determine the long-term trends for each of these habitat-forming species throughout the sanctuary.

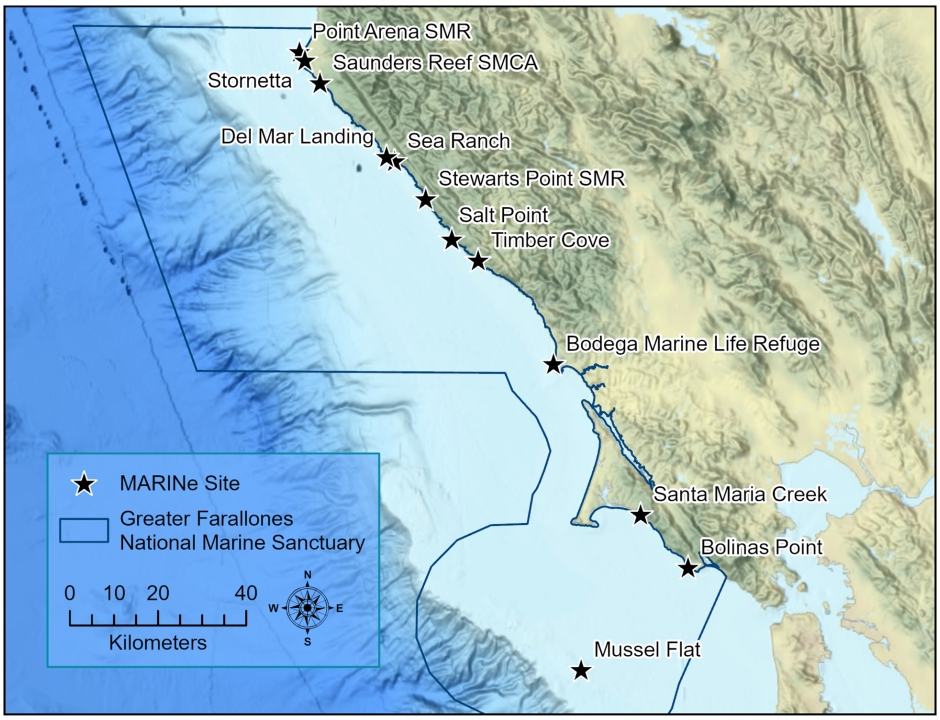

Figure S.H.10.1. Map of Greater Farallones National Marine Sanctuary indicating long-term monitoring and biodiversity survey locations conducted by the Multi-Agency Rocky Intertidal Network (MARINe), CDFW, and PISCO. Not all core or target species are sampled at every location. Only locations where intertidal or subtidal data were used in this report, are shown on this map. Image: NOAA; Source: Multi-Agency Rocky Intertidal Network (MARINe), 2021; Esri, 2020

Kelp Forests

The nearshore rocky habitat along Northern California is dominated by the canopy-forming bull kelp (*Nereocystis luetkeana*), which forms dense underwater forests that marine organisms depend on for shelter and food (Springer et al., 2010 and Hohman et al., 2019). An annual species, bull kelp exhibits strong spatial and temporal variability in distribution and abundance, and under ideal conditions can grow up to 6 cm per day (Springer et al., 2010). However, significant stressors on the ecosystem, such as the marine heatwave of 2014-2016, can elicit a state shift from a kelp forest to an urchin-dominated state, subsequently impacting nearshore ecosystems and fisheries (Rogers-Bennett and Catton, 2019 and McPherson et al., 2021). Urchin barrens in northern California are characterized by higher than average densities of purple sea urchin, low biodiversity, and little to no macroalgae (Beas-Luna et al., 2020). Kelp

Commented [4]: see note on imperial vs metric convention above

forests may substantially contribute towards carbon sequestration and subsequently are vitally important for blue carbon assessments (Hutto et al., 2021). Kelp forests may also provide a benefit in mitigating ocean acidification effects (Pfister et al., 2019).

Long-term monitoring data on kelp canopy cover is available at various sites throughout GFNMS (Bell et al., 2022). Greater than 90% of bull kelp forest habitat in northern California has been lost since 2014 due to compounding ecological stressors. Beginning in 2013, the Sea Star Wasting Syndrome led to widespread mass mortalities of 20 sea star species in northern California (and more generally the entire Eastern Pacific), some of which are predators of urchins (Schultz et al., 2016, McPherson et al., 2021). A marine heatwave (MHW) in 2014–2016 (Di Lorenzo and Mantua, 2016; Bond et al, 2015; Gentemann et al., 2017; Elliott et al., 2022a), which overlapped with strong El Niño conditions (2015–2016), followed by another MHW in 2019 (See Figure S.WQ.8.3, S.WQ.8.4) contributed to the dieoff of kelp (Roger-Bennett & Catton, 2019; McPherson et al., 2021; Bell et al., 2023). The area and densities of bull kelp were greatly reduced and revealed widespread recruitment failure, resulting in the development of both habitat and food limitations for associated species within the ecosystem (Cavanaugh et al., 2019; Beas-Luna et al., 2020). In addition, purple urchin recruitment yielded populations that increased to greater than sixty times normal levels (Rogers-Bennett and Catton, 2019; Okamoto et al., 2020) and shifted behavior from passive feeding on algal detritus to active grazing on kelp and other marine algae, effectively outcompeting other herbivores such as abalone and red urchin. Following the decimation of the benthic “fleshy” algae, purple urchins then began grazing on the long-lived and slow-growing crustose coralline algae, thus creating large swathes of bare rock, which are unsuitable for post-larvae settlement of abalone. Aerial surveys revealed a significant bull kelp canopy extent was lost and subtidal surveys confirmed a state shift to urchin-dominated conditions (CDFW, 2019). Recreational red abalone (*Haliotis rufescens*) and commercial red sea urchin fisheries in the region have collapsed, and deleterious cascading effects for other nearshore fisheries are expected in the coming years.

Commented [5]: see note on numbering convention above

Kelp Canopy Cover

Since the extreme MHW of 2014–2016, nearly 95% of the primary kelp forest species in northern California, bull kelp (*Nereocystis luetkeana*), has been lost (CDFW 2019; Roger-Bennett & Catton, 2019; Bell et al., 2023; Figure SH.10.2). A slight increase in kelp canopy cover was observed in 2021, but there has been no significant recovery of kelp forests in GFNMS as of 2022 (Bell et al., 2023). Historical kelp persistence, or areas where kelp canopy occurred more frequently than surrounding areas prior to 2014, was determined using remote sensing data such as Landsat and aerial plane-based surveys. From 2014–2022, kelp persistence was nearly nonexistent in the sanctuary due to extremely sparse growth (CDFW 2019; Bell et al., 2023).

Kelp Stipe Density

Kelp stipe (the single stalk of each bull kelp) density data has been collected sporadically since 2008 by divers at multiple sites in GFNMS. The PISCO program collected data in 2010 and 2011 and then again in 2016–2019; they also collected data at Point Arena in 2021. RCCA monitoring data is available from 2007–2019 for four~~4~~ sites and 2011–2019 for ~~2~~two sites. Based on the limited data available, it appears most sites in GFNMS were experiencing high interannual variability until 2013 at which point a significant decline in kelp stipe density occurred (PISCO, 2022). Very little data exists after 2019, however, the 2021 Point Arena data does show that stipe density continues to be low at this site. This decline is consistent with patterns observed in kelp canopy cover. No significant increase or recovery of stipe density has been observed as of 2022.

Understory Kelp and Algal Density

Understory algal density for two dominant species, *Pterygophora californica* and Setchell's kelp (*Laminaria setchellii*), has declined since 2014, likely as a result of overgrazing by purple urchins, which have increased over the same time period (PISCO, 2022). The density of erect coralline red algae has decreased, crustose red algae has increased, and fleshy red algal has shown more variability since 2010. Thus, red algal groups have a mixed trend over this assessment period (PISCO, 2022; Freiwald et al., 2020).

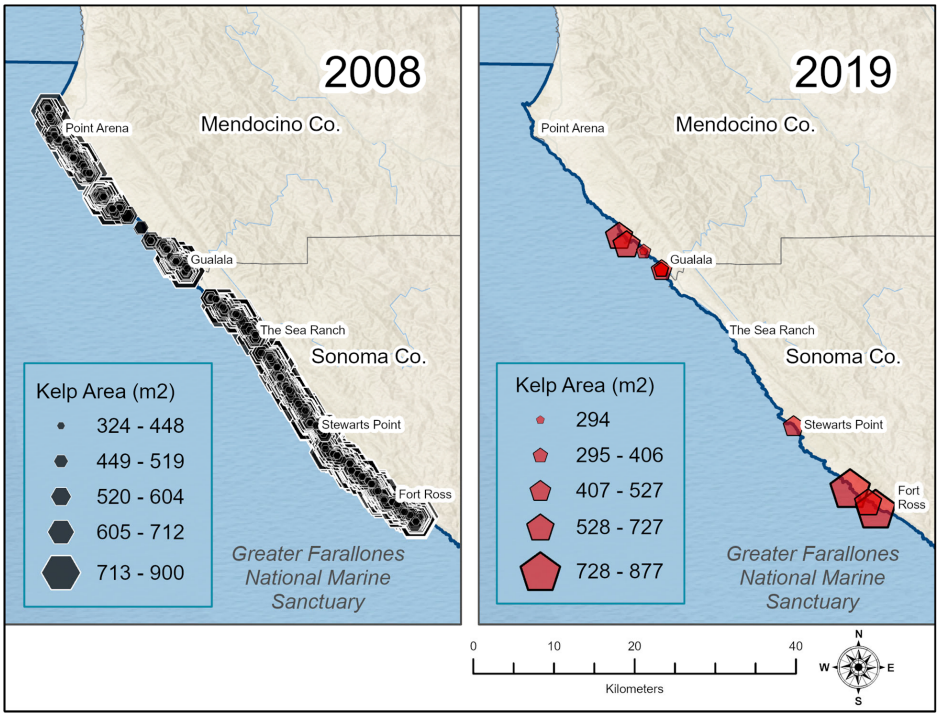

Figure S.H.10.2. Changes in bull kelp fractures (canopy coverage) along the Sonoma Coast between 2008 and 2019. Image: NOAA; Source: Bell, T. K. et al., 2023; Esri, 2016.

Deep-Sea Corals and Sponges

Four coral research cruises have been completed since 2010 using a remotely operated vehicle (ROV) to visually ground-truth habitat types predicted from multibeam sonar data. However, the areas that have been visually surveyed in the deep sea (50 meters or deeper as defined by NOAA's Deep Sea Coral Research and Technology Program (DSCRTP~~)~~) account for less than 1% of GFNMS waters. Of all the sites visually surveyed, Rittenburg Bank exhibited the highest density of sponges (Etnoyer et al., 2014; Table SH.10.2). Many small corals and sponges were observed, suggesting recent recruitment to the coral and sponge populations, which can be an indication of health of the benthic invertebrate community at that location. A new species of gorgonian coral was identified from material collected during the survey in Rittenburg Bank (Etnoyer et al., 2014). The highest densities of large sponges were observed in areas of highest

rugosity, which are also areas where trawling is not likely to occur. Since the early 2000's there have been several mandated changes to the size of trawl roller gear and footrops that prevent the trawl gear from accessing areas of high relief that can damage the gear in areas of high rugosity. Impacts of historic commercial fishing to benthic habitat were evident, including the presence of derelict fishing gear, like lines and ropes tangled on the rocks at a groundfish Essential Fish Habitat No-trawl conservation area at Point Arena South established in 2005 and a fixed gear (hook and line) rockfish conservation area closure offshore off Point Arena established in 2006 (Graiff, 2021). In general, data on the locations of corals and sponges across GFNMS is limited to locations that have been explored with a ROV and more exploration is needed to fully establish a baseline characterization of the habitat and species present in the offshore environment of GFNMS, especially in the northern area of the sanctuary, which was expanded in 2015.

Figure S.H.10.3. Remotely operated vehicle survey locations: Point Arena Biogenic Area, The Football, Rittenburg and Cochrane Banks, and the Farallon Escarpment. Image: NOAA; Source: Etnoyer, 2014; Graiff et al. 2016; Graiff et al. 2021; Esri, 2020.

Table SH.10.2. Survey sites from the four NOAA deep sea ROV cruises since 2010; locations are shown in Figure S.H.10.3, above. Source: Etnoyer, 2014; Graiff et al. 2016; Graiff et al. 2021

Site / Cruise Year	Area Surveyed (sq meters)	Corals and Sponge Density (per 1,000 sq meter)
Rittenburg Bank (2012)	14,561	60 corals; 184 sponges
Cochrane Bank (2012)	8,626	30 corals; 64 sponges
Farallon Escarpment (2012)	2,229	26 corals; 29 sponges
The Football (2016)	5,632	6 corals/sponges[1]
Point Arena South (2019)	15,914	0.01-17.9 corals; 0.01-0.43 sponges [2],[3]
Southern Point Arena South (2019)	14,859	0.01-0.27 corals; 0.01-0.42 sponges [4]
TOTAL	61,821	NA

Deep-Sea Marine Debris

Marine debris counts were recorded during the four deep-sea coral cruises since 2010. Debris was documented throughout the survey areas with a rate of observation of one piece of debris every 1.06 km. It has been found in all benthic habitats on the bank, shelf, and deep canyons (Etnoyer et al., 2014, Graiff et al., 2016, and Graiff et al., 2021). The most prevalent marine debris is derelict commercial fishing gear, including longlines, gill nets, and crab gear (including pots and lines). It has been observed entangled on the sanctuary's benthic structures and various rocky and mixed habitats that include corals and sponges, which can damage the associated biological communities. Such gear can also be an entanglement hazard to other pelagic marine life if it extends into the water column. Marine debris was found in all locations on these cruises except the Farallons Escarpment, however, only a small fraction of the Escarpment was surveyed.

[1] The data report for this surveyed area reported corals and sponge counts as a combined number.
[2] The density of corals and sponges observed were not reported as a total average density for each area but separately by genus or by transect. Therefore, the table above shows a range of densities depending on genus and transect location at that site.
[3] NOTE: the unit of measurement for the reported densities is per 100 square (not per 1,000 square meters).
[4] The density of corals and sponges observed were not reported as a total average density for each area but separately by genus or by transect. Therefore, the table above shows a range of densities depending on genus and transect location at that site.

Conclusion

The status for this question was rated as fair indicating there was measurable but not severe degradation of ecological integrity. The main driver of the rating was the severe loss of kelp canopy cover, stipe density, and understory algae during the assessment period, which decreased the habitat integrity for other kelp forest and dependent species (such as abalone). Sandy beach habitat is extensive through GFNMS but sediment imbalances and/or erosion are occurring at some sites. Shoreline armoring has not changed over the assessment period and is stable. There is some variability in recent trends for rocky intertidal habitat and many structure forming species appear to be stable. Very little of the sanctuary has been mapped for corals and sponges. Sunken marine debris has been found during each of the NOAA research cruises conducted during this assessment period. More data is needed to better assess status and trends for sandy beach habitat. More monitoring sites and data is needed to assess long-term trends for rocky intertidal species across the sanctuary. More data is needed on deep-sea coral and sponge habitat and sunken marine debris.

Estuarine and Lagoon Habitats and Offshore Regions (Q10)

Status Rating: Fair/Poor	Status Confidence: Medium
Trend Rating: Not changing	Trend Confidence: High
Status Description: Selected habitat loss or alteration has caused severe degradation in some but not all attributes of ecological integrity.	
Rationale: Based on the findings in the 2010 condition report, estuarine and lagoon habitat have experienced significant historic habitat degradation compared to historic levels. There is no evidence marsh or mudflat habitat has worsened since the last assessment and some restoration projects (e.g., Giacomini Ranch in Tomales Bay, Kent Island Restoration, and the Caltrans Culvert Replacement Project in Bolinas) may be slightly improving the integrity of these habitats. Native oysters are low compared to historic levels but appear stable based on anecdotal data. Eelgrass extent has been documented in three estuarine locations; eelgrass has healthy density in Tomales Bay and may be improving slightly due to the removal of numerous moorings from the Bay and other management measures. At the workshop in June 2022 discussing this question, experts agreed that all indicators appear generally stable over the assessment period. More data is needed to better understand any specific quantitative changes in mudflat, marsh, and eelgrass over time. More data is needed on native oyster populations in all estuaries, especially Tomales Bay.	

Findings From the 2010 Condition Report

In the GFNMS 2010 report, the status of habitat integrity in the estuarine and lagoon environment was fair/poor, and conditions were not changing. Selected habitat loss or alteration had caused or was likely to cause severe declines in some but not all living resources or water quality; substantial levels of habitat loss had occurred due to erosion, accretion, and habitat conversion (e.g., lost wetland area due to diking, mining, dredging, filling and reclamation; increased sedimentation due to logging, agriculture, construction in floodplains; reduced freshwater input due to dams and water extraction). Loss of eelgrass in Bolinas Lagoon was

due to watershed issues causing sedimentation and elevation of mudflats. Loss of native oyster beds in Tomales Bay was due to sedimentation, roadside maintenance activities, anchoring, and mooring. The 2010 Condition Report generally lacked a quantitative assessment of estuarine and lagoon habitats.

New Information in the 2010–2022 Condition Report

This condition report provides new quantitative information on the marsh extent, mudflat extent, and eelgrass extent (Table S.H.10.3). Status and trend data is also included for eelgrass beds in Tomales Bay.

Table S.H.10.3. Summaries for the key indicators related to habitat integrity in the estuarine and lagoon region of the sanctuary that were discussed during the June 9, 2022 virtual status and trends workshop workshop.

Indicator	Source	Data Summary	Figures and Tables
Marsh and Mudflat Extent	NPS, 2020	Status: Mudflat and marsh habitats occur in all four estuaries and lagoon locations and is most prevalent in Tomales Bay and Bolinas Lagoon. Trend: Not changing. Restoration projects have resulted in improvements in these habitats in Bolinas Lagoon and Tomales Bay.	Table S.H.10.3
Olympia oysters	Wasson et al., 2015; Grosholz, 2022.	Status: Olympia oysters have declined dramatically along the west coast. Anecdotal data indicates low abundance of oysters in Tomales Bay. Trend: There has been a long-term decline of native oysters along the West Coast.	
Eelgrass	CDFW, 2013; GFNMS, 2022	Status: Eelgrass was documented in three~~3~~ estuaries in GFNMS. In Tomales Bay eelgrass appears healthy and at high densities. Trend: Not changing. Eelgrass may be improving slightly in Tomales Bay. Substantial interannual variability has occurred for the total extent of eelgrass in both Estero Americano and Estero de San Antonio making it difficult to determine trends.	Table S.H.10.4; Figure S.H.10.4
Data Gaps	More data is needed to better understand specific quantitative changes in mudflat, marsh, and eelgrass over time. More data is needed on native oyster populations in Tomales Bay.		

Marsh and Mudflat Extent

There are four estuaries within GFNMS boundaries: Estero de Americano, Estero de San Antonio, Tomales Bay, and Bolinas Lagoon. The 2010 conditions report found that estuarine habitats in GFNMS have experienced significant historic habitat degradation (ONMS, 2010). The amount of marsh habitat has been severely reduced from historic levels and habitat integrity has been degraded (ONMS 2010). The National Park Service Golden Gate National

Recreation Area (GGNRA) completed an assessment of habitat types across Marin County in 2020, including these estuaries. Data was compiled mainly from aerial ortho imagery collected in 2018 and LiDAR data collected in 2019–2020. GGNRA combined the sources to produce a fine scale mapping data layer and created an online viewer in 2020 (NPS, 2020). Table S.H.10.3 shows the total acreages of each habitat type in the four estuaries. The largest habitat type in the estuaries is mudflat (the extent reported in the table does not include channels).

Table S.H.10.3. Extent coverage of habitat types in the four estuaries within GFNMS boundaries. Source: NPS, 2020; GFNMS, 2022.

Estuary	Marsh Extent (square meters)	Mudflat Extent (square meters)
Estero Americano and Estero de San Antonio	186,964.80	50,181.0
Tomales Bay	2,577,038.20	3,845,727.7
Bolinas Lagoon	793,993.23	3,037,975.1
Totals	3,557,996.20	6,933,883.8

More data is needed to determine the trend for marsh and mudflat habitats in the estuaries. Some activities since 2010 have likely improved habitat integrity in Bolinas Lagoon and Tomales Bay. In 2011, the Caltrans Culvert Replacement Project (2011) removed some structures and reconfigured culverts in Bolinas Lagoon, creating approximately a tenth of an acre of restored marsh and improving water quality and circulation. The Kent Island Restoration Project in Bolinas Lagoon has also removed invasive vegetation from the island, allowing natural habitats to recover, and likely causing a slight increase in marsh habitat and mudflats. In Tomales Bay, marsh restoration has occurred at the southern end of the bay at Giacomini Ranch since 2008, which has resulted in improved hydrology across 51 acres of marsh floodplain and new tidal channels being formed (Parsons and Ryan, 2015).

Olympia Oysters

The Olympia oyster (*Ostrea lurida*) is a habitat forming species, and the only oyster species native to the west coast of North America, north of Baja California Sur, Mexico. The population has declined significantly along the west coast over the last century, but the historical extent of Olympia oysters in GFNMS is not well documented so status and trends cannot be determined. Anecdotal reports from Tomales Bay suggest native oysters once were abundant enough to provide an important ecosystem function; oysters can benefit ecosystems by improving water quality through filter feeding and providing a structure (i.e. a reef comprised of shells) to help buttress fragile shoreline habitat against waves, storm surge, or future sea level rise. It is unknown if native oysters are providing these ecosystem functions at current abundances.

Eelgrass

Eelgrass was documented at three of the four estuarine habitats in the sanctuary: Estero Americano, Estero de San Antonio, and Tomales Bay (Table SH.10.4). A survey in 1994 (Sherman & DeBruyckere, 2018) and anecdotal observations since then indicate eelgrass is absent in Bolinas Lagoon. Assessment and monitoring of the abundance and distribution of eelgrass are limited, are of eelgrass extent only, and do not include assessments to determine

ecosystem functions, invertebrate interactions, or severity of and persistence to eelgrass wasting disease. Further, substantial interannual variability may occur for the total extent of eelgrass in each estuary (CDFW, 2023) (See Table S.H.10.4).

Table S.H.10.4. Amount of eelgrass in each estuary. Not all estuaries were assessed in the same year or used the same technique. Numbers reported are from estuary-wide surveys; surveys were conducted in Tomales Bay in other years for only a portion of the bay and thus have not been included in this table. Source: Svejkovsky, 2013; CDFW, 2013; CDFW 2023; Merkle and Associates, 2017; Sherman and DeBruyckere, 2018

Estuary	**Amount of Eelgrass (m^2)**	**Year of Survey**	**Survey Performed By**	**Survey Technique**
Estero Americano	22,298	2010	Ocean Imaging	Field survey GPS points analyzed with multi-spectral aerial Imagery
Estero Americano	16,779	2014	CDFW	Field survey GPS points analyzed with multi-spectral aerial Imagery
Estero Americano	7,104	2016	CDFW	Field survey GPS points analyzed with multi-spectral aerial Imagery
Estero Americano	13,120	2017	CDFW	Field survey GPS points analyzed with multi-spectral aerial Imagery
Estero Americano	9,999	2018	CDFW	Field survey GPS points analyzed with multi-spectral aerial Imagery
Estero de San Antonio	5,261	2010	Ocean Imaging	Multi-spectral aerial Imagery
Estero de San Antonio	1,362	2016	CDFW	Field survey GPS points analyzed with multi-spectral aerial Imagery
Estero de San Antonio	7,108	2017	CDFW	Field survey GPS points analyzed with multi-spectral aerial Imagery
Estero de San Antonio	7,017	2018	CDFW	Field survey GPS points analyzed with multi-spectral aerial Imagery
Tomales Bay	5,213,710	2013	CDFW	Multi-spectral aerial Imagery with accuracy

				assessment/ground truthing
Tomales Bay	6,180,412.40	2017	Merkel and Associates	Side-scan

Figure SH.10.4 shows the maximum known extent of eelgrass in Tomales Bay based on multiple datasets collected using different methods between 2013 and 2017 (CDFW 2013; Merkel 2017). Surveys in the bay from 2013 and 2017 may indicate an increase in the area, although different methods were used (Table S.H.10.4).

Commented [6]: possible for a bit more info on the different methods used and how that may affect the findings?

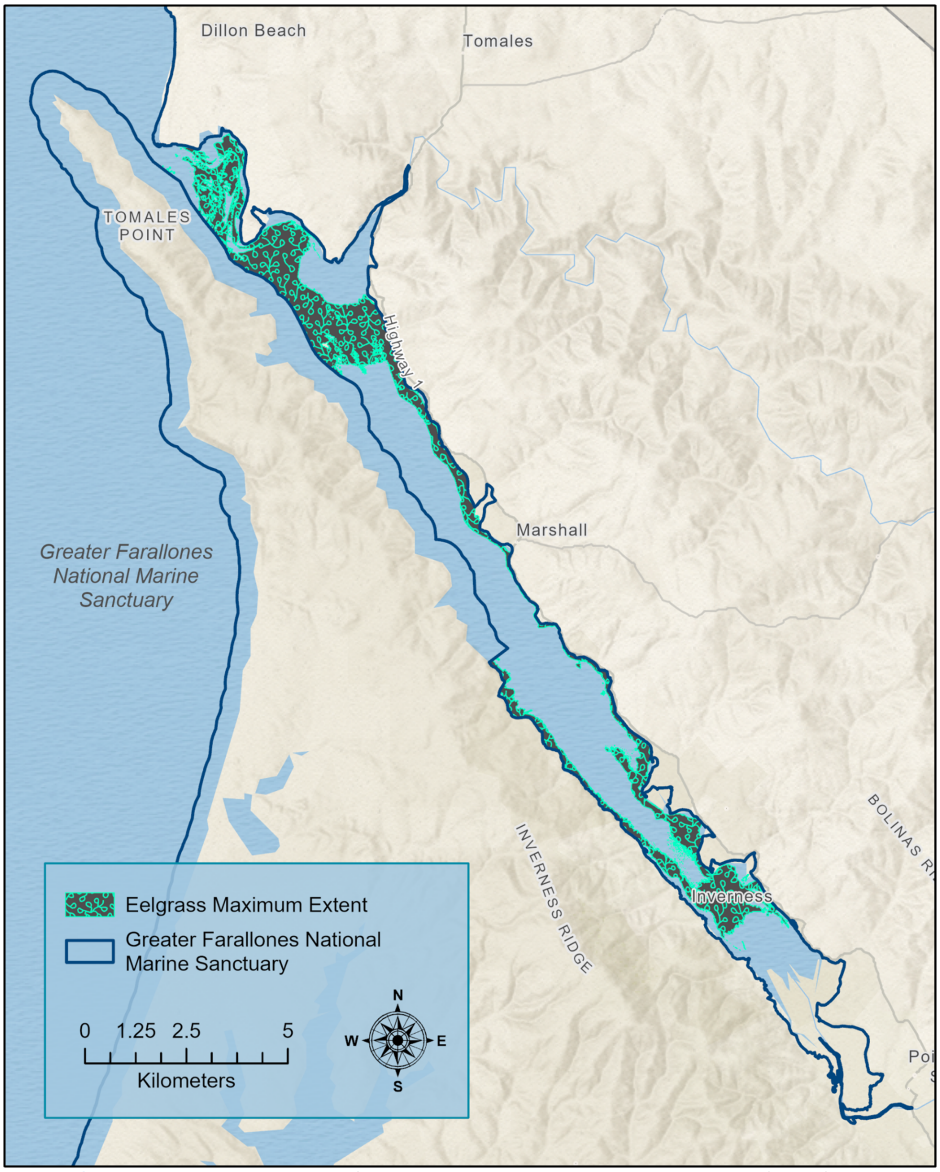

Figure S.H.10.4. Maximum extent of eelgrass beds in Tomales Bay. Image: NOAA; Source: California Department of Fish & Wildlife, 2013; Esri, 2016; Merkel & Associates, Inc., 2017.

Conclusion

Estuarine and lagoon habitat have experienced significant historic habitat degradation compared to historic levels but there is no evidence marsh or mudflat habitat has worsened since the last assessment. Restoration projects have improved the integrity of these habitats in Bolinas Lagoon and Tomales Bay. Native oysters have declined along the West Coast. Eelgrass beds in Tomales Bay are generally healthy with fairly high density, and there is a reasonable understanding of its maximum extent. Eelgrass may be improving in Tomales Bay. Substantial interannual variability has occurred for the total extent of eelgrass in both Estero Americano and Estero de San Antonio making it difficult to determine trends. At the workshop in June 2022 discussing this question, experts agreed that all indicators appear generally stable over the assessment period. More data is needed to better understand any specific quantitative changes in mudflat, marsh, and eelgrass over time. More data is needed on native oyster populations in all estuaries, especially Tomales Bay.

References (Q10/Both Regions)

Beas-Luna R, Micheli F, Woodson CB, Carr M, Malone D, Torre J, Boch C, Caselle JE, Edwards M, Freiwald J, Hamilton SL, Hernandez A, Konar B, Kroeker KJ, Lorda J, Montano-Moctezuma G, Torres-Moye G. (2020). Geographic variation in responses of kelp forest communities of the California Current to recent climatic changes. Global Change Biology 26:6457-6473.

Bell, T.K., Cavanaugh, D., & Siegel. (2022). SBC LTER: Time series of quarterly NetCDF files of kelp biomass in the canopy from Landsat 5, 7 and 8, since 1984 (ongoing) ver 14. Environmental Data Initiative. https://sbclter.msi.ucsb.edu/data/catalog/package/?package=knb-lter-sbc.74

Bond, N. A., Cronin, M. F., Freeland, H., & Mantua, N. (2015). Causes and impacts of the 2014 warm anomaly in the NE Pacific. Geophysical Research Letters, 42(9), 3414–3420. https://doi.org/10.1002/2015GL063306

California Coastal Commission. (2022). Shoreline armoring data [unpublished data set].

California Coastal Records images from 2009-2019 and data from 2005-2021.

California Department of Fish and Wildlife (CDFW). (2013). Eelgrass habitats in northern California's bays and estuaries. https://map.dfg.ca.gov/metadata/ds2795.html

California Department of Fish and Wildlife (CDFW). (2019). LandSat aerial data of kelp forests along the north central coast, 2008-2019. https://wildlife.ca.gov/Conservation/Marine/Kelp/Aerial-Kelp-Surveys.

California Department of Fish and Wildlife (CDFW). (2023). Biogeographic Information Observation System (BIOS). https://apps.wildlife.ca.gov/bios6/. Accessed on July 25, 2023.

Cavanaugh KC, Reed DC, Bell TW, Castorani MN, Beas-Luna R. (2019). Spatial Variability in the Resistance and Resilience of Giant Kelp in Southern and Baja California to a Multiyear Heatwave. Frontiers in Marine Science 6:413.

Di Lorenzo, E. and Mantua, N., 2016. Multi-year persistence of the 2014/15 North Pacific marine heatwave. Nature Climate Change, 6(11), pp.1042-1047.

Dugan, Jenifer & Hubbard, David & Rodil, Iván & Revell, David & Schroeter, Stephen. (2008). Ecological effects of coastal armoring on sandy beaches. Marine Ecology. 29. 160 - 170. 10.1111/j.1439-0485.2008.00231.x.

Etnoyer, P. J., G. Cochrane, E. Salgado, K. Graiff, J. Roletto, G. Williams, K. Reyna, and J. Hyland. 2014. Characterization of deep coral and sponge communities in the Gulf of the Farallones National Marine Sanctuary: Rittenburg Bank, Cochrane Bank and the Farallon Escarpment. NOAA Technical Memorandum NOS NCCOS 190. NOAA National Centers for Coastal Ocean Science, Charleston, SC. 32 pp.

Freiwald, J. (2020). Reef Check kelp forest long-term MPA monitoring: Algae data [Data set]. California Ocean Protection Council Data Repository. https://doi.org/10.25494/P65K5W

Gentemann, C. L., Fewings, M. R., & García-Reyes, M. (2017). Satellite sea surface temperatures along the West Coast of the United States during the 2014–2016 northeast Pacific marine heat wave. Geophysical Research Letters, 44(1), 312–319. https://doi.org/10.1002/2016GL071039

Graiff, K., D. Lipski, P. Etnoyer, G. Cochrane, G. Williams, E. Salgado. (2016). Benthic Characterization of Deep-Water Habitat in the Newly Expanded Areas of Cordell Bank and Greater Farallones National Marine Sanctuaries. Marine Sanctuaries Conservation Series ONMS-16-01. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD. 38 pp.

Graiff, K., J. Roletto, S. Tezak, G. Williams, and G. Cochrane. (2021). Characterization of deep-sea coral and sponge communities in Greater Farallones National Marine Sanctuary: Point Arena South Essential Fish Habitat Conservation Area and New Amendment 28 Areas. National Marine Sanctuaries Conservation Science Series ONMS-21-03, San Francisco, CA. 42 pp.

Greater Farallones National Marine Sanctuaries (GFNMS). (2022). California Department of Fish and Wildlife Aerial Surveys (1992-2013). GFNMS Tomales Bay interactive Map Viewer, Hosted at: https://farallones.noaa.gov/eco/tomales/map.html. Accessed May 2022.

Griggs, G. and Patsch, K. (2019). The protection/hardening of California's coast: Times are changing. Journal of Coastal Research, 35(5), 1051–1061. Coconut Creek (Florida), ISSN 0749-0208.

Grosholz, E.D. (2022). Restoration of Native Olympia Oysters Under Climate Change**.** http://www.des.ucdavis.edu/faculty/grosholz/research.htm#OlympiaOysters.

Hohman, R., Hutto, S., Catton, C., and Koe, F. (2019). Sonoma-Mendocino Bull Kelp Restoration Plan. Plan for the Greater Farallones National Marine Sanctuary and the California Department of Fish and Wildlife. Greater Farallones Association. San Francisco, CA. 166 pp. https://farallones.org/wp-content/uploads/2019/06/Bull-Kelp-Recovery-Plan-2019.pdf

Hutto, S.V., K.D. Higgason, J.M. Kershner, W.A. Reynier, D.S. Gregg. (2015). Climate Change Vulnerability Assessment for the North-central California Coast and Ocean. Marine Sanctuaries Conservation Series ONMS-15-02. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD. 473 pp.

Hutto, S. H., Hohman, R., and Tezak, S. (2021). Blue carbon in marine protected areas: Part 2; A blue carbon assessment of Greater Farallones National Marine Sanctuary. National Marine Sanctuaries Conservation Series ONMS-21-10. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries.

McPherson ML, Finger DJI, Houskeeper HF, Bell TW, Carr MH, Rogers-Bennett L, Kudela RM. (2021). Large-scale shift in the structure of a kelp forest ecosystem co-occurs with an epizootic and marine heatwave. Communications Biology 4:1-9

Merkel and Associates. (2017). Tomales Bay Eelgrass Habitat Evaluation and Site Monitoring in Areas Affected by Vessel Moorings, Tomales, Bay, CA. December 2017. Unpublished Report to Greater Farallones National Marine Sanctuary. 35 pps.

Multi-Agency Rocky Intertidal Network (MARINe). (2021). Long-term monitoring and biodiversity surveys [Data set]. MARINe: Multi-Agency Rocky Intertidal Network. https://marine.ucsc.edu/index.html

National Park Service (NPS), Golden Gate National Recreation Area. (2020). Marin County Fine-Scale Vegetative Mapping Project. Website accessed April 2022. https://parksconservancy.maps.arcgis.com/apps/webappviewer/index.html?id=4ef2881436bc4365be881b17f69ab067

Okamoto, D.K., Schroeter, S.C., & Reed, D.C. (2020). Effects of ocean climate on spatiotemporal variation in sea urchin settlement and recruitment. Limnology and Oceanography, 65, 2076–2091.

Office of National Marine Sanctuaries (ONMS). (2010). Gulf of the Farallones National Marine Sanctuary Condition Report 2010. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD. 97 pp.

NOAA, Office of Response and Restoration, ESI Atlas for Central California. (2006).

NOAA, Office of Response and Restoration, ESI Atlas for Northern California. (2008).

NOAA. (2022). Deep Sea Coral Research and Technology Program (DSCRTP) web portal. Accessed May 2022.

Parsons, L., and A. Ryan. (2015). Year Five of the Giacomini Wetland Restoration Project: Analysis of Changes in Physical and Ecological Conditions in the Project Area. Point Reyes National Seashore, National Park Service.

Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO). (2022). Data portal. https://www.piscoweb.org/data-access. Accessed June 3, 2022.

Pfister, C. A., Altabet, M. A., and Weigel, B. L. (2019). Kelp beds and their local effects on seawater chemistry, productivity, and microbial communities. *Ecology* 100(10):e02798.

Ridlon AD, Wasson K, Waters T, Adams J, Donatuto J, Fleener G, et al. (2021) Conservation aquaculture as a tool for imperiled marine species: Evaluation of opportunities and risks for Olympia oysters, Ostrea lurida. PLoS ONE 16(6): e0252810. https://doi.org/10.1371/journal.pone.0252810

Rogers-Bennett, L. and Catton, C.A. (2019). Marine heat wave and multiple stressors tip bull kelp forest to sea urchin barrens. Scientific Reports 9: 1. https://doi.org/10.1038/s41598-019-51114-y

Schultz, J.A., R.N. Cloutier, and I.M. Côté. (2016). Evidence for a trophic cascade on rocky reefs following sea star mass mortality in British Columbia. PeerJ 4:e1980; DOI 10.7717/peerj.

Sherman, K. and L.A. DeBruyckere. (2018). Eelgrass habitats on the U.S. West Coast. State of the Knowledge of Eelgrass Ecosystem Services and Eelgrass Extent. A report prepared by the Pacific Marine and Estuarine Fish Habitat Partnership for The Nature Conservancy. 67pp. file:///D:/Condition%20Report/GFNMS%20Condition%20Report%202021-22/Status%20and%20Trends/Q12%20Keystone%20spp%20write%20up/EelGrass_Report_Final_ForPrint_web.pdf.

Springer, Y., C. Hays, M. Carr, and M. Mackey. (2010). Toward ecosystem-based management of marine macroalgae—the bull kelp, Nereocystis Luetkeana. Oceanography and Marine Biology Oceanography and Marine Biology: An Annual Review 48:1-42.

Svejkovsky, J. (2013). High Resolution Nearshore Substrate Mapping and Persistence Analysis with Multi-spectral Aerial Imagery. Annual Report submitted to the California Sea Grant Program, Grant No. MPA 09-015, CA Sea Grant Account #: SEA 4995, Project Number R/MPA-17. https://caseagrant.ucsd.edu/sites/default/files/17_Svejkovsky.pdf

Vos, K., M.D.Harley, K.D.Splinter, J.A. Simmons, I.L.Turner. Water Research Laboratory, School of Civil and Environmental Engineering, UNSW Sydney, 110 King Street, Manly Vale, NSW, 2093, Australia. (2019). CoastSat Accessed March 2022.

Wasson, K., Zabin, C., Bible, J., Briley, S., Ceballos, E., Chang, A., Cheng, B., Deck, A., Grosholz, T., Helms, A., Latta, M., Yednock, B., Zacherl, D., & Ferner, M. (2015). *A guide to olympia oyster restoration and conservation*. http://www.sfbaysubtidal.org/OYSTERGUIDE-FULL-LORES.pdf

Question 11: What are contaminant concentrations in sanctuary habitats and how are they changing?

Coastal and Offshore Region (Q11)

Status Rating: Good/Fair	Status Confidence: High
Trend Rating: Mixed	Trend Confidence: High
Status Description: Selected contaminants are suspected and may degrade some attributes of ecological integrity, but have not yet caused measurable degradation.	
Rationale: Mercury is present in sediments and levels are increasing. Data from Dungeness crab samples, mercury, PAH, and DDT were all below regulatory thresholds. Mercury and PAH were stable and DDT decreased in crabs. PCBs in Dungeness crab were above FDA limits in 2015 but are decreasing over the long term and were stable over the past 10 years. There were no major oil pollution events during the study period. Tarballs have decreased, except for one isolated event observed in the winter of 2015–2016.	

Commented [7]: I'm not sure the math works out with that timeline..."decreased and have been stable for 8 years"?

Findings From the 2010 Condition Report

In the GFNMS 2010 report, there was little information available on the status of contaminants in the sanctuary's coastal and offshore region, therefore, the status was rated as undetermined. Conditions were thought to be improving. At the time, there had been declines in legacy pollutants in Steller sea lions and it was thought that because of prohibitions for most types of vessel discharges, there was a reduction in oil pollution and discharges of legacy pollutants. There was a significant data gap and the lack of consistent monitoring for heavy metals and legacy pollutants.

New Information in the 2010–2022 Condition Report

The majority of data considered for this assessment were from two projects: 1) offshore sediment and biota monitoring sampling performed by the San Francisco Public Utilities Commission, Natural Resources and Lands Management Division (SFPUC; Figure S.WQ.7.4) and 2) shoreline tarball and tar patty data collected by surveyors with the Beach Watch project (Table S.H.11.1; see Beach Watch text box in Question 3 human activities influencing habitats).

Table S.H.11.1. Summaries for the key indicators related to contaminants in the coastal and offshore region of the sanctuary that were discussed during the May 19, 2022 virtual status and trends workshop.

Indicator	Source	Data Summary	Figures
Contaminant Levels in Sediment–Mercury	SFPUC, 2022	Status: Mercury concentrations in seafloor sediment samples were usually below the Sediment Effect Concentration value of 0.71 ppm, the threshold level for adverse effects in biota. Trend: Mercury concentrations increased at all stations in GFNMS; the increase was significant at one station.	S.WQ.7.5

Contaminant Levels in Crabs–Mercury	SFPUC, 2022	Status: Levels of mercury in Dungeness crab are below the CA threshold of 0.22 ppm. Trend: There was no apparent trend for the past 10 years.	S.H.11.1
Contaminant Levels in Crabs–PAH, PCB, DDT	SFPUC, 2022	Status: Since 2010, Polycyclic aromatic hydrocarbons (PAH) levels in Dungeness crab are well below alert levels but a peak was observed in 2015. Trend: PAH levels were stable. Status: The highest levels of polychlorinated biphenyls (PCB) were found in Dungeness crab hepatopancreas, which peaked in 2015 and were above FDA limits for food (0.2– 3 ppm). Trend: PCB ~~D~~decreasing over the long term and stable for the past 10 years. Status: The highest levels of DDT were found in Dungeness crab hepatopancreas, which peaked in 2015 but were well below FDA safety limits for food (≥ 5000 ppb). Trend: Dichlorodiphenyltrichloroethane (DDT) levels have been decreasing in Dungeness crab over the past 20 years. In the past ten years the trend is stable with some peaks observed.	
Tarballs and Patties	Lindquist and Roletto, 2022b; OSPR, 2021	Status: The presence of tarballs and tar patties was low since the lightering of the S/S *Jacob Luckenbach*~~,~~ in 2002, with an anomalous peak in 2016. No major oil spills occurred during the last 10 years. Trend: Tarball deposition decreased on coastal beaches.	S.P.4.9
Data Gap: There is a lack of consistent sampling for legacy pollutants, such as organic pollutants and trace metals in fish and mussel, and for pollutants discharged from leaking, grounded, and sunken vessels and aircraft.			

The SFPUC annually monitors the nearshore and offshore areas of the Gulf of the Farallones region surrounding the Southwest Ocean sewage outfall. They sample sediment as well as invertebrates for levels of legacy pollutants, such as polycyclic aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB), dichlorodiphenyltrichloroethane (DDT), and mercury. Data for these legacy pollutants were aggregated from the 2010–2020 annual reports (SFPUC, 2022). In some cases data for contaminants in the sediment were not readily available, therefore we used benthic organisms as a surrogate for sediment. Since 2010, mercury concentrations in seafloor sediment samples were usually below the Sediment Effect Concentration value of 0.71 ppm (MacDonald et al., 2000), the threshold levels set by the EPA the State Water Resources

Control Board for adverse effects in biota. Levels of mercury in seafloor sediments have been slowly increasing over the past 10 years. Increases have been most pronounced at the GFNMS sampling stations, which are closer to the mouth of San Francisco Bay than to the Southwest Ocean sewage outfall. However, mercury in Dungeness crab tissues has remained low with the exception of 2010, when some samples from the outfall site exceeded the state limit for contaminants in fish (Figure S.WQ.7.5). Also, since 2010, PAH levels in Dungeness crab have been well below alert levels set by the Federal Food and Drug Administration (FDA). Peaks of PAH levels detected by the SFPUC in 2015 coincided with higher than average tarball deposition on the nearby sanctuary shoreline in 2015–2016 (SFPUC, 2022; Lindquist and Roletto, 2022b, Figure S.P.2.2). The source of the tarballs is thought to be from natural seeps (OSPR, 2021), so the authors question if tarballs from natural seeps may be the source of the higher levels of PAH. The highest levels of PCB were found in Dungeness crab hepatopancreas. PCB levels in crab hepatopancreas also peaked in 2015 and were above FDA limits for food (0.2–3 ppm; SFPUC, 2022). DDT levels have been decreasing in Dungeness crab for over ten years. The highest levels were in Dungeness crab hepatopancreas, which also peaked in 2015, but were well below FDA safety limits for food (≥ 5000 ppb; Figure S.H.11.1).

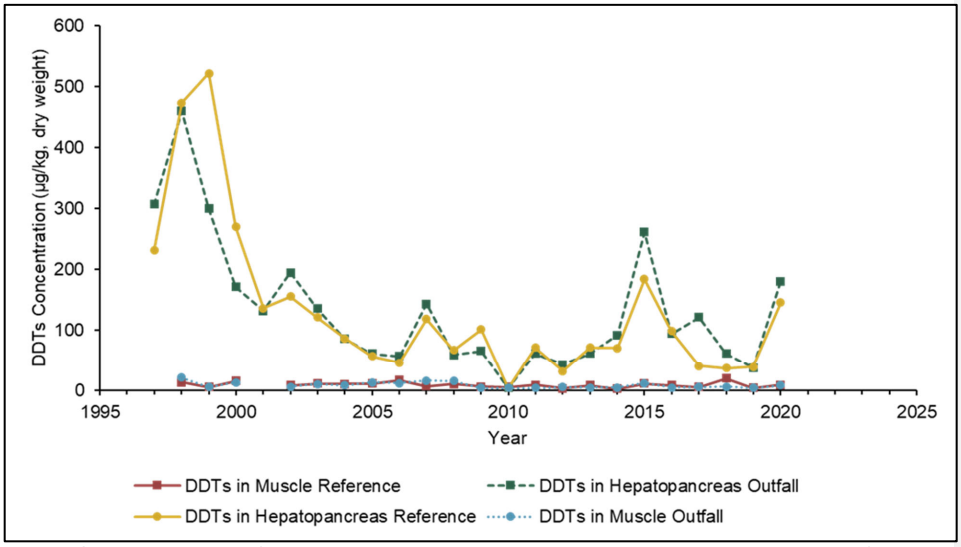

Figure S.H.11.1. Levels of DDTs in Dungeness crab hepatopancreas and muscle tissue from areas near the Southwest Ocean sewage outfall (outfall) and the reference station, which is >4

km southwest of the outfall. Levels are well below the FDA limit of ≥ 5000 ppb (i.e., µg/kg) in the edible portion. Source: Adapted from SFPUC, 2022

In the 1990s and 2000s, oil pollution events were an ongoing management issue for GFNMS. Since the lightering of the S/S *Jacob Luckenbach* in 2002, the deposition rates of tarballs and tar patties (i.e., discrete accumulations of oil) have greatly decreased. From 2010–2021, low levels of tarballs and patties were encountered on sanctuary beaches (0–2.2/km), except in the winter of 2015–2016 when over 10,000 tarballs were documented at one beach (Lindquist and Roletto, 2022b; see Figure S.P.2.2). This deposition event correlated with the increased levels of PAH, PCB and DDT detected by the SFPUC in 2015. For additional information regarding tarballs, see question #4, in this report.

Conclusion

This question was rated good/fair because no major chemical pollution events occurred during the study period of the report. Legacy pollutants are present and an oil pollution event (tarballs on one beach) that occurred in 2015–2016, is thought to be from natural seeps. Contaminants are found in seafloor sediments and benthic biota, but are generally not above regulatory thresholds for concern and did not trigger advisories for consumption of benthic biota, (with one exception for PCBs in 2015). The trend was mixed based on some improving conditions such as declines in oil pollution and DDT. However, mercury increases were detected in sediment samples. Other indicators were stable, such as tissue measurements in crabs for mercury, PAHs, and PCBs. Also, PAH, PCB, and DDT levels increased sharply in 2015, as did the deposition of tarballs and patties, but this was a discrete event during the study period followed by a return to previous levels.There is a lack of consistent sampling for legacy pollutants, such as organic pollutants and trace metals in fish and mussel, and for pollutants discharged from leaking, grounded, and sunken vessels and aircraft.

Estuarine and Lagoon Region (Q11)

Status Rating: Fair	Status Confidence: Low
Trend Rating: Mixed	Trend Confidence: Low
Status Description: Selected contaminants have caused measurable but not severe degradation in some attributes of ecological integrity.	
Rationale: There is ongoing mercury pollution in sediments in the Walker Creek delta and in wildlife in Tomales Bay from the Walker Creek Mine site. Mercury levels in sediment were reduced but exceedances in TMDL were still observed. Vessels and cars sinking in the sanctuary's estuaries continues to occur. The volume and trend of contaminants released from the sinkings is not known. There were no incidences of tarballs, patties, or oiled wildlife on Tomales Bay or Bolinas Lagoon Beaches during the study period. There is little to no monitoring of contaminants in most resources in Estero Americano, Estero de San Antonio or Bolinas Lagoon.	

Findings From the 2010 Condition Report

In the GFNMS 2010 report, there was little data to determine the status or trend of contaminants in the sanctuary's estuarine and lagoon regions and there was a lack of understanding of how contaminants impacted birds foraging in the sanctuary's estuaries. Therefore, both the status and trend rating were undetermined.

New Information in the 2010–2022 Condition Report

Indicators considered for this assessment included mercury levels in sediments, fish, and bivalves, and oil pollution (Table S.H.11.2). Data for legacy pollutants (PCB and DDT) in fish and invertebrates were not available for any of the sanctuary's estuaries or lagoons. The Regional Water Quality Control Board (RWQCB) report cards include mercury level data in Tomales Bay, including the Walker Creek delta.

Table S.H.11.2. Summaries for the key indicators related to contaminants in the estuarine and lagoon region of the sanctuary that were discussed during the May 19, 2022 virtual status and trends workshop.

Indicator	Source	Data Summary	Figures
Contaminant Levels in Sediment–Mercury	CSWRCB, 2017	Status: Mercury levels in surface sediment at Walker Creek Delta in Tomales Bay were lower after mine site remediation but still exceeded TMDL. Trend: No clear trend is detected. Levels of mercury in sediments at Walker Creek were greatly reduced since the Gambonini mine site was remediated, but mercury levels show an increase since 2014.	S.H.11.2
Contaminant Levels in Fish and bivalves–Mercury	CSWRCB, 2021	Status: Of six species tracked for human consumption in the Walker Creek region, longjaw mudsucker and leopard sharks were above safe levels for human consumption during the study period. Trend: No clear trend in the available data.	S.WQ.7.11
Oil Pollution Incidents–Tarballs and Patties	Lindquist and Roletto, 2022b	Status: There were nine incidents of vessels and cars sinking or grounding in Tomales Bay and two in Bolinas Lagoon. There were no tarballs or patties in Bolinas Lagoon or Tomales Bay from 2010–2021. Trend: Vessel and vehicle incidents appear stable. The trend in oil pollution is unknown due to a lack of data on volume. There was no change in the rate of tarballs and patties.	
Data Gap: There is a data gap in monitoring and the understanding of biomagnification of mercury in the estuarine food web. There is a lack of data to quantify oil discharges and other pollutants from leaking, grounded or sunken vessels or vehicles in estuaries. There continues to be a data			

gap in monitoring and understanding biomagnification of mercury in the estuarine food web. There is little to no monitoring of contaminants in most resources in Bolinas Lagoon, Estero Americano, or Estero de San Antonio.

Contaminant Levels in Sediment–Mercury

Mercury mining in the Walker Creek watershed occurred in the 1960s and ceased by 1972. The Gambonini Mine was the largest mercury mine in the watershed, operating from 1964–1970. Other mine sites that are no longer active in the Walker Creek watershed include the Franciscan, Cycle, and Chileno Valley mines. Prior to the establishment of the TMDL, the Water Board and U.S. EPA conducted an emergency superfund cleanup at the Gambonini Mine site, which was the greatest source of mercury in the watershed (CSWRCB, 2021). These efforts resulted in reductions of mercury pollution coming from the mine site (Figure S.H.11.2). Conditions appear to be improving, although more information is needed (CSWRCB, 2021).

Monitoring of sediment and biota In Tomales Bay, in particular the Walker Creek delta and watershed, has been intermittent and inconsistent over the past 20 years. Monitoring did increase after the cleanup at the Gambonini Mine site, which was the greatest source of mercury in the watershed (CSWRCB, 2021). There are no data available between 2003–2013. The levels of mercury in food for human consumption is 0.22 ppm; safe levels in bird forage species is 0.05 ppm. Data on invertebrates and fish were available for three time periods:1998–2001, 2010, and 2019–2020 (Figure S.H.11.2). The data shows that the remediation significantly decreased the mercury loads in sediment, from 1.7 µg/g in 2000 just after the remediation in 2000, to 0.52 µg/g in 2018 (CSWRCB, 2017). Although mercury decreased, exceedances of TMDL allocation were still observed in 2014, 2016, and 2017 (Figure S.H.11.2). The levels of mercury in species consumed by humans were below the state's cautionary level, except for leopard sharks and longjaw mudsuckers (Figure S.WQ.7.11). Levels of mercury in bird forage species are mixed, with some samples above and some below the state's cautionary level (Figure S.H.11.2, CSWRCB, 2021).

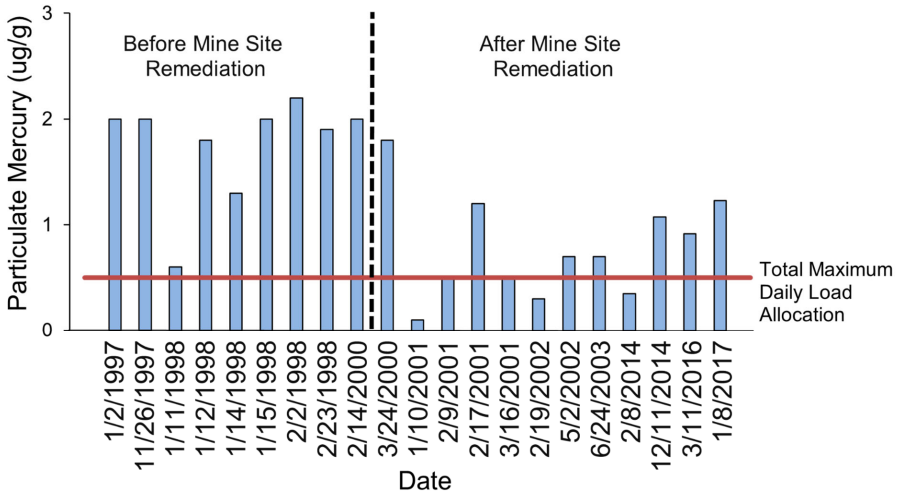

Figure S.H.11.2. Mercury concentration in sediment samples at Walker Creek and delta before and after site remediation. Source: adapted from CSWRCB, 2017

Oil Pollution Incidents–Tarballs and Patties

From 2010-2021, there were nine incidents of vessels and cars sinking or grounding in Tomales Bay and two in Bolinas Lagoon (USCG MISLE, 2022). There is no apparent trend in the numbers of incidents and the trend in volume of contaminants released from vessels and cars cannot be determined. A review of the encounter rates of oil pollution in Bolinas Lagoon and Tomales Bay for this study period, shows no oil pollution in the form of tarballs, tar patties, or on wildlife (Lindquist and Roletto, 2022b and Box 2).

Conclusion

This question was rated fair based on ongoing mercury pollution in sediments in the Walker Creek delta and in wildlife in Tomales Bay from the Walker Creek Mine site. The levels in sediment were reduced compared to before mine site remediation, but exceedances in TMDL were still observed in the three most recent years sampled. Some fish species exceeded mercury levels for safe human consumption. Incidences of vessel and vehicle groundings and sinkings occurred, but the amount of petroleum pollution is not known. However, oil pollution from tarballs, tar patties, or on wildlife were not observed. The trend was mixed based on some conditions improving such as reduced mercury pollution in sediment and no major oil pollution events, but some conditions were still problematic, such as exceedances in mercury TMDL in sediments and safe levels in fish for human consumption. There is a data gap in monitoring and the understanding of biomagnification of mercury in the estuarine food web. There is a lack of data to quantify oil discharges and other pollutants from leaking, grounded or sunken vessels or vehicles in estuaries. There continues to be a data gap in monitoring and understanding biomagnification of mercury in the estuarine food web. There is little to no monitoring of contaminants in most resources in Estero Americano, Estero de San Antonio, or Bolinas Lagoon.

References (Q11)

California Department of Fish and Wildlife, Office of Spill Prevention and Response (OSPR). (2021). California Department of Fish and Wildlife, Office of Spill Prevention and Response, Petroleum Chemistry Laboratory [Unpublished data]. Petroleum Chemistry Laboratory, Rancho Cordova, CA.

California State Water Resources Control Board (CSWRCB). (2017). *Water quality report card: Mercury in Tomales Bay, Walker Creek Watershed, Update*. San Francisco Bay, Region 2. https://www.waterboards.ca.gov/about_us/performance_report_1920/plan_assess/docs/fy1617/11112_r2_walker_creek_hg_reportcard.pdf

California State Water Resources Control Board (CSWRCB). (2021). *Water quality report card: Mercury in Tomales Bay*. San Francisco Bay, Region 2. https://www.waterboards.ca.gov/about_us/performance_report_2021/plan_assess/docs/fy2021/tom-bay_final.pdf

Lindquist, K., and Roletto, J. (2022b). *Beach Watch database: Supplementary data* [Unpublished data set]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of National Marine Sanctuaries, Greater Farallones National Marine Sanctuary and Greater Farallones Association.

MacDonald, D.D., Dipinto, L.M., Filed, J., Ingersoll, C.G, Long, E.R., and Swartz, R.C. (2000). Development and evaluation of consensus-based sediment effect concentrations for polychlorinated biphenyls. Environmental Toxicology and Chemistry 19(5): 1403-1413.

San Francisco Public Utilities Commission (SFPUC). (2022). SFPUC Water Resources Annual Reports. [Unpublished data]. SFPUC. https://sfpuc.org/about-us/reports/water-resources-annual-report

USCG MISLE (2022). Marine Information for Safety and Law Enforcement, Casualty and Pollution Incidents. https://cgmix.uscg.mil/psix/

Status and Trends of Living Marine Resources (Questions 12–15) 1
Question 12: What is the status of keystone and foundation species & how is it changing? .. 2
Coastal and Offshore Region (Q12) 2
Estuarine and Lagoon Region (Q12) 9
Question 13: What is the status of other focal species and how is it changing? 13
Coastal and Offshore Region (Q13) 13
Estuarine and Lagoon Region (Q13) 23
Question 14: What is the status of non-indigenous species and how is it changing? 30
Coastal and Offshore Region (Q14) 30
Estuarine and Lagoon Region (Q14) 37
Question 15: What is the status of biodiversity and how is it changing? 46
Coastal and Offshore Region (Q15) 46
Estuarine and Lagoon Region (Q15) 55

Status and Trends of Living Marine Resources (Questions 12–15)

The following information describes the status and trends of living marine resources inside GFNMS from 2010–2022. We have noted where more recent data (e.g., 2023) became available during editing of this report. The term “living marine resources” encompasses a range of organisms in GFNMS, including keystone, foundation, focal, and non-indigenous species. The status for a species describes changes to their abundance compared to their historical abundance. The historical time period used for comparison depends on data availability and differs across indicators. The trend for a species describes changes to their abundances from 2010–2022. Each of the living marine resource questions focus on specific groups of species in GFNMS.

Question 12 evaluates changes to foundation and keystone species which are critical to maintaining GFNMS’s ecosystem structure, function, and stability over time.

Question 13 is centered around focal species which may not be abundant or be key to GFNMS’s ecosystem function, but their presence and health is important for the provision of economic, cultural, spiritual, recreational, ecological, or conservation-related values and services.

Question 14 focuses on the impacts of non-indigenous species which are not native to the region. Also called alien, exotic, non-native, or introduced species, these are animals or plants living outside their endemic geographical range. Often having arrived in the sanctuary as a result of human activity, either deliberately or accidentally, their abundance in sanctuary habitats along with any known ecological impacts will be discussed. These species are of concern because they have the potential to impact GFNMS’s ecosystem structure and function, at which point they are considered invasive species.

Lastly, Question 15 addresses the status of biodiversity, which is defined as variation of life at all levels of biological organization and commonly encompasses diversity within species

Commented [1]: not sure why this is an "other" as definition of focal species is different from keystone or foundation

Commented [2]: So I take it that foundation and keystone terms are synonymous, and are defines by being critical to ecosystem structure, function, and stability. So, why two terms? Any further definition?

Commented [3]: I'm fine with the definition but am simply curious...how do we really know most of the NIS in GFNMS have arrived by human activity? Data for NIS are limited. Is this partially an assumption? simply no imaginable natural pathway?

Commented [4]: and services

(genetic diversity), among species (species diversity), and comparative diversity among ecosystems (ecosystem diversity). Biodiversity can be measured in many ways. The simplest measure is to count the number of species found in a certain habitat or ecosystem, termed species richness. Other indices of biodiversity couple species richness with relative abundance to provide a measure of evenness and heterogeneity. When discussing “biodiversity” in response to Question 15, the report primarily refers to species richness and diversity indices, and the abundance of species that influence the integrity of food webs and other aspects of ecosystem function. Non-indigenous species were not included in estimates of native biodiversity.

Commented [5]: So is 15 all about native biodiversity? or, that's only one discussion within 15...

Because of the considerable differences in environmental pressures and responses between the coastal and offshore region and the estuarine and lagoon region, each question is assessed twice in order to represent these two environment types separately.

Question 12: What is the status of keystone and foundation species and how is it changing?

Coastal and Offshore Region (Q12)

Status Rating: Fair/Poor	Status Confidence: High
Trend Rating: Mixed	Trend Confidence: High
Status Description: The status of keystone and foundation species suggests severe degradation in some but not all attributes of ecological integrity.	
Rationale: Kelp beds in the sanctuary have significantly declined due to a series of events, including the 2014–2016 marine heat wave (MHW) and a historic imbalance within the kelp forest ecosystem. Sea star wasting syndrome led to the loss of the predators of purple urchins, e.g., sunflower sea star and giant sea star, allowing the purple urchin population to increase significantly, thus a persistent loss of kelp beds. During the 2014–2016 MHW, habitat compression also occurred, resulting in a redistribution of forage species, like krill and anchovy, from primarily being distributed along the shelf break (100–200 m depth) to being distributed from the shelf break to across the Gulf of the Farallones shelf region and closer to shore. During cooler water conditions and stronger upwelling periods, the proportion of krill to gelatinous zooplankton (i.e., such as salps, which are typically less nutritious than krill) increased. During warmer water conditions, the proportion of gelatinous zooplankton increased and krill decreased.	

Keystone species are organisms on which a large number of other species in the ecosystem depend (Paine, 1969). Their contribution to ecosystem function is disproportionate to their abundance or biomass. They can be habitat creators (e.g., kelp, corals), predators that control food web structure (e.g., sea otters, certain sea stars), herbivores that regulate benthic recruitment (e.g., certain sea urchins), and species involved in critical symbiotic relationships (e.g., cleaning or cohabitating species). Foundation species are single species that create

locally stable conditions for other species (Dayton, 1972). These are typically dominant biomass producers (e.g., mussels, hake, anchovy, krill) in an ecosystem and strongly influence the abundance and biomass of many other species. Changes in either keystone or foundation species may transform ecosystem structure through disappearances of, or dramatic increases in, the abundance of dependent species.

Commented [6]: Ah, there it is. Maybe a single sentence in the intro above on question 12 could foreshadow this more detailed definition (need for two terms)

Findings From the 2010 Condition Report

A direct comparison between the current rating and the 2010 condition report is not possible because this specific question was not previously addressed. However, there were two questions in the 2010 condition report that assessed the status and condition and health of "key species." In 2010, the status of key species was rated fair with an undetermined trend and the condition or health of key species was rated good/fair with an improving trend. In 2010, the ratings were based on the variable status of 49 key species and populations with varying states of integrity. See Appendix A for an explanation on changes to the resource questions since the previous report.

New Information in the 2010–2022 Condition Report

The status rating for this assessment was based primarily on new information and expert opinions about known changes in specific keystone and foundation species abundances since 2010 (Table S.LR.12.1). Data were derived from projects monitoring the kelp forest, rocky intertidal ecosystems (Bell et al., 2022; PISCO, 2022), and forage species (NOAA IEA, 2022; Elliott et al., 2022a) in the region. Keystone species considered include bull kelp (*Nereocystis luetkeana*), purple urchins (*Strongylocentrotus purpuratus*), and kelp forest apex predators like sunflower sea stars (*Pycnopodia helianthoides*) and giant sea stars (*Pisaster giganteus*). Foundation species include krill (*Euphausia* sp., *Thysanoessa* sp., and other zooplankton), and northern anchovy (*Engraulis mordax*).

Table S.LR.12.1. Summaries for the key indicators related to keystone and foundation species in the coastal and offshore region that were discussed during the June 7, 2022 virtual status and trends workshop.

Indicator	Source	Data Summary	Figures
Keystone Species			
Kelp	Bell et al., 2022; Rogers-Bennett & Catton, 2019	Status: Annual kelp canopy area is at historic lows; in most locations >90% less than historic average. Trend: Since 2013, the decline of kelp canopy has persisted, with a slight increase in a few locations in 2021 and 2022.	Figure S.LR.12.1
Kelp Grazer–Purple urchin	PISCO, 2022; Rogers-Bennett & Catton, 2019	Status: Purple urchins have high densities, >1,000 urchins per sq meter along the Sonoma and Mendocino County coast since 2013.	Figure S.LR.12.2

		Trend: There has been a dramatic increase of purple urchins since 2013–2014, average of 23-35 urchins per sq meter in 2010–2011, to >1,000 urchins per sq meter in some GFNMS locations in 2020.	
Kelp Forest Apex Predators–Sea Stars	PISCO, 2022; Rogers-Bennett & Catton, 2019	Status: Sunflower sea star and giant sea star densities along the Sonoma and Mendocino County coast are nearly zero. Trend: There has been a dramatic decline in sea stars since 2013–2014, i.e., giant sea stars throughout northern California declined from an average peak density of 9/m^2 in some areas to less than 1/m^2.	Figure S.LR.12.2
Foundation Species			
Forage Species–Krill and Anchovy	Elliott et al., 2022a; Santora et al., 2021; NOAA IEA, 2022	Krill Status: Krill were abundant in GFNMS and variable with oceanographic conditions. From 2010-2021, krill CPUE was above or near average in 9 of 12 years (-0.63 CPUE to 1.39 CPUE). Krill Trend: From 2016–2021 average krill CPUE declined throughout the CCE, highest in 1.39 CPUE in 2013 and the lowest in 2019 -2.46 relative CPUE. Relative abundance in relation to gelatinous zooplankton decreased during warm water years (2014–2016) in GFNMS. Anchovy Status: In recent years of the study, anchovy were abundant forage species in GFNMS. From 2018-2022, anchovy CPUE was above or near average, ranging from 1.63 to 2.33 CPUE). Anchovy Trend: Anchovies were trending below average from 2010-2017. From 2018–2021 anchovy abundance increased by several orders of magnitude throughout the California Current.	Figure S.LR.12.3; Figure S.LR.12.4
Data Gap: There is a need for detailed data on the condition and density of krill across the shelf of the Gulf of the Farallones region. Kelp canopy cover data collected with consistent methods are needed so canopy cover can be compared across Marin, Sonoma, and Mendocino Counties and time periods.			

Commented [7]: So these are standardized anomalies of CPUE, not CPUE itself- that should be clarified in the text. Stated in the figure caption but probably should be referenced here (particularly as the anomalies reflect log-scale relative abundance- so the magnitude of the variability is pretty substantial). More details on krill, including a comparison of trawl-based and acoustic- based estimates for this time period are available in Dorman et al. 2023. Dorman, J.G., Sydeman, W.J., Thompson, S.A., Warren, J.D., Killeen, H.J., Hoover, B.A., Field, J.C. and Santora, J.A., 2023. Environmental variability and krill abundance in the central California current: Implications for ecosystem monitoring. Frontiers in Marine Science, 10, p.1099482.

Commented [8]: For context, this represents an increase of several orders of magnitude for anchovy in this region relative to say the 2010-2014 period, as that increase permeated through top predators, may be contributing to thiamine deficiency complex in salmon, could be contributing to those lower krill levels seen in 2019-2020 and other years- adding some context on the magnitude of this increase would be appropriate in my opinion.

Commented [9]: and more southern counties? SF and San Mateo?

Keystone Species

Kelp, Purple Urchins, and Sea Stars

Since 2013, bull kelp in Sonoma and Mendocino Counties has not reproduced and grown to previous summer time levels. For an explanation of the environmental influences impacting and limiting the regrowth of bull kelp in northern California, see the Kelp Forests section in Question 10. In summary, since the extreme MHW of 2014–2016 (MHW), >90% of bull kelp has been lost and has not recovered (Roger-Bennett & Catton, 2019; Bell et al., 2022; Figures S.LR.12.1 and S.H.10.2). Contributing to the suppression of kelp forest growth is the loss of urchin predators, particularly sunflower sea stars (*Pycnopodia helianthoides*) and giant sea stars (*Pisaster giganteus*). Prior to and during the MHW there was a west coast-wide outbreak of the sea star wasting syndrome (Konar et al., 2019), which resulted in the loss of several species of sea stars (see two examples in Figure S.LR.12.2) – densities of giant sea stars throughout northern California declined from an average peak density of 9/m^2 in some areas to less than 1/m^2 in northern California (PISCO, 2022). These predators feed on, and have the capacity to control the population of purple urchins (*Strongylocentrotus purpuratus*). Purple urchins are kelp grazers along the Sonoma and Mendocino coast. The loss of their predators was most likely a driving factor of the increase in the purple urchin population, from an average of 23-35 urchins per sq meter in 2010–2011, to >1,000 urchins per sq meter in Sonoma and Mendocino Counties in 2020 (no data was available 2012–2015) (PISCO, 2022; Figure S.LR.12.2). Since the MHW event, purple urchins have overgrazed the kelp forests and understory algae of the sanctuary, leading to a historic imbalance of the kelp forest ecosystem functions and persistent loss of kelp beds (Rogers-Bennett & Catton, 2019).

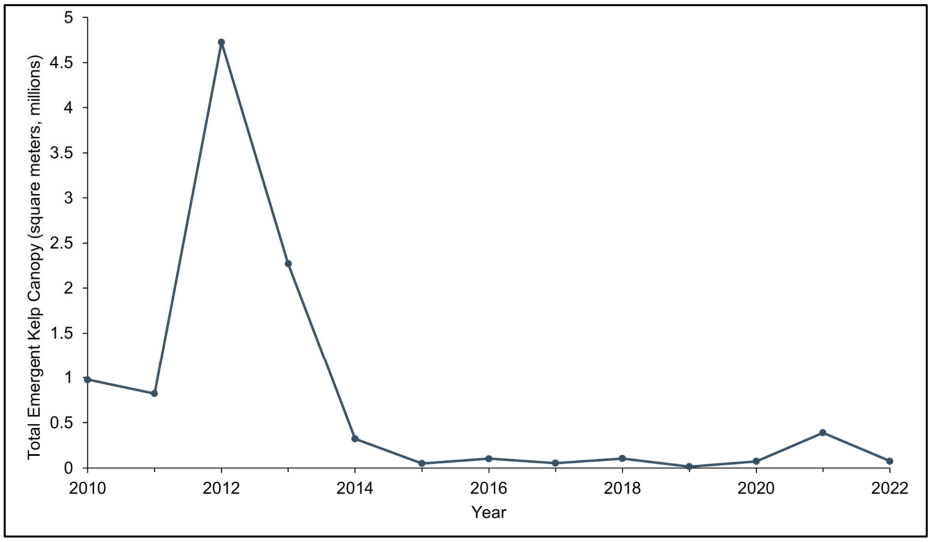

Figure S.LR.12.1. Total emergent kelp canopy in Sonoma and Mendocino Counties in millions of square meters, 2010–2022. Source: Bell et al., 2022.

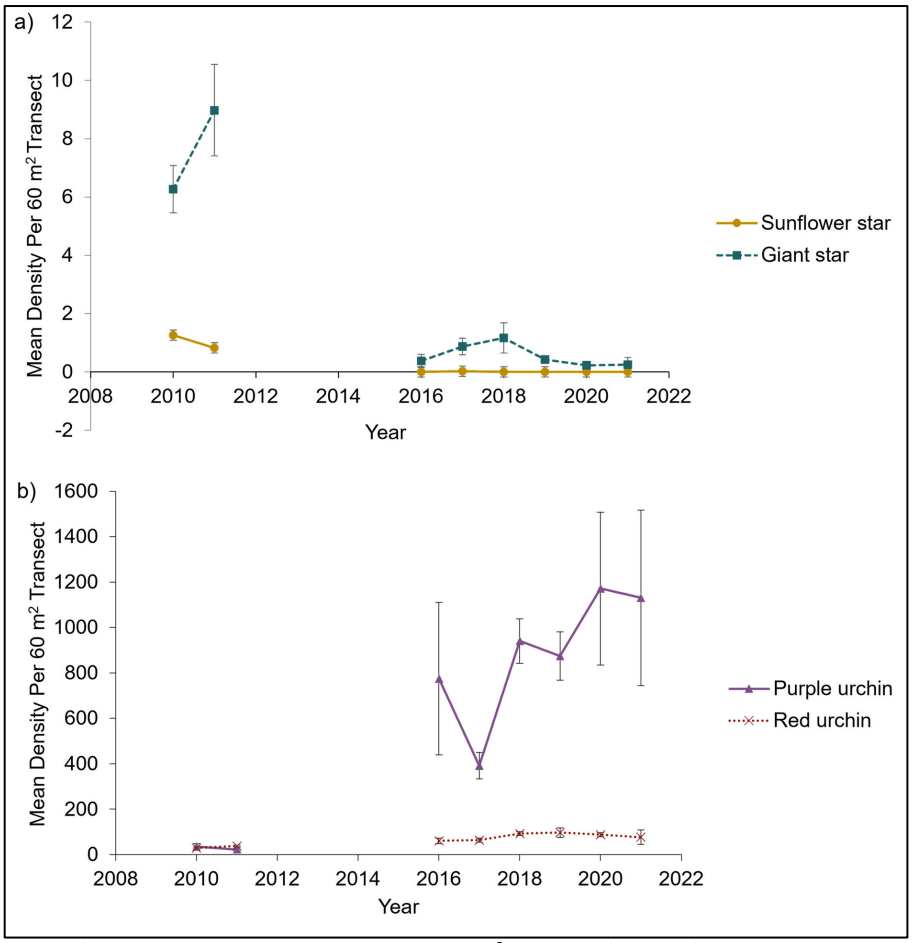

Figure S.LR.12.2. The average densities per 60 m^2 transect of the sunflower sea star and the giant sea star (top graph) and purple urchins (bottom graph) at monitoring sites: Point Arena, Salt Point, Stewart's Point, Del Mar Landing, Saunders Reef, Sea Ranch, Bodega Marine Life Refuge, and Bolinas Point) in northern California. Note that sampling effort varied between locations and years. See Figure S.H.10.1 for a map of these locations. Source: PISCO, 2022

Foundation Species

Krill and Anchovy

Krill samples collected by the Rockfish Recruitment Ecosystem Assessment Surveys (RREAS) from Point Reyes through Monterey Bay (see core sampling area in Santora et al., 2021) during the spring months from 2010–2021 showed an overall decline of krill species relative abundance and an overall increase in anchovy relative abundance, (measured by catch per unit effort, an indirect measurement of relative abundance) though both are within 1 standard

deviation of the long term mean (NOAA IEA, 2022; Figure S.LR.12.3). In six out of 12 years, the relative abundance of krill was at or above average, ranging from 0.94 CPUE to 1.39 CPUE. In three of the past 12 years, krill CPUE was at or near average ranging from 0.60 CPUE to -0.63 CPUE. In two of the past 12 years, the CPUE was below average ranging from -0.90 CPUE to -2.5 CPUE (NOAA IEA, 2022). From 2010–2017 anchovies were below average in the Gulf of the Farallones regions, ranging from -0.81 CPUE to -1.01 CPUE. From 2018-2021, anchovy abundance increased, ranging from 1.63 CPUE to 2.33 CPUE (NOAA IEA, 2022; Figure S.LR.12.3). In the Gulf of the Farallones region krill and forage fish, such as anchovies, are important to the productivity and survival of locally breeding and migratory seabirds, marine mammals, and predatory fish species. The abundance of krill fluctuates annually and is greatly influenced by environmental conditions.

Commented [10]: See comments above- re, reminding readers that these are standardized relative abundance levels, and that the change in anchovies represents several orders of magnitude change (good source for that would be the 2021 PFMC stock assessment of northern anchovy, as I don't think it's explicitly stated in the CCIEA- see Kuriyama, P.T., Zwolinski J.P., Teo, S.L.H, and Hill, K.T. 2021. Assessment of the Northern 18 anchovy (Engrualis mordax) central subpopulation in 2021 for U.S. management in 2021-2022.
19 Pacific Fishery Management Council, Portland, OR. Available from
20 https://www.pcouncil.org/coastal-pelagic-species/stock-assessment-and-fishery-evaluation-safe21
documents/

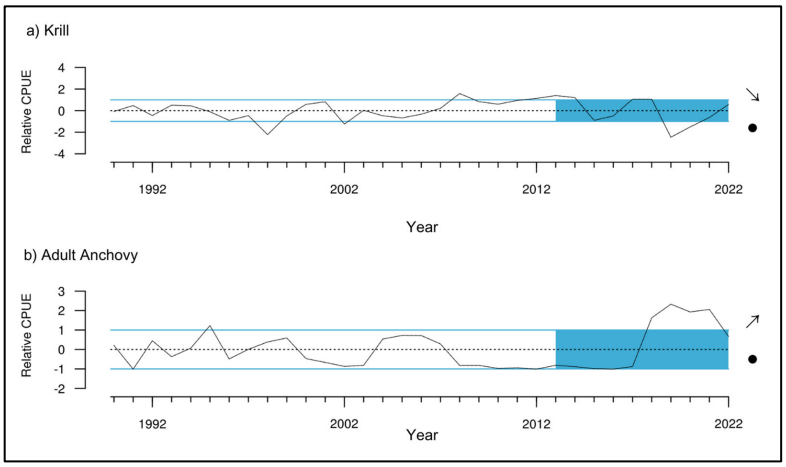

Figure S.LR.12.3. Relative catch per unit effort (CPUE) of a) krill (top graph) in the Gulf of the Farallones region, and relative CPUE of b) adult anchovy (bottom graph), 2012–2021. Blue shading includes the years analyzed for trend 2013–2021. The trend is indicated by the arrow. Black dot indicates the mean is within 1 standard deviation. Source: NOAA IEA, 2022

MHWs and extended El Niño-Southern Oscillation events can compress the typical distribution of krill and forage fish (see Pressures chapter). During the 2014–2016 MHW, habitat compression occurred, resulting in a redistribution of forage species, like krill and anchovy, from primarily being distributed along the shelf break (100–200 m depth) to being distributed from the shelf break to across the Gulf of the Farallones shelf region and closer to shore (Santora et al., 2021).

In addition to changes in spatial distribution, changes in species composition of zooplankton were observed. During warm water conditions, such as low upwelling periods and warmer than average sea surface temperatures, the proportion of krill to gelatinous zooplankton (e.g., salps) was reduced within the Gulf of the Farallones region (Elliott et al., 2022a; see Box 1 for additional information), (Figure S.LR.12.4). During cooler water conditions and stronger upwelling periods, the proportion of krill increased, for example, as seen in 2010–2013 and

2017–2019, and gelatinous zooplankton increased during the 2014–2016 MHW (Figure S.LR.12.4). The proportion of krill to gelatinous zooplankton is significant because gelatinous zooplankton species, such as salps, are typically less nutritious than krill (Elliott et al., 2022a).

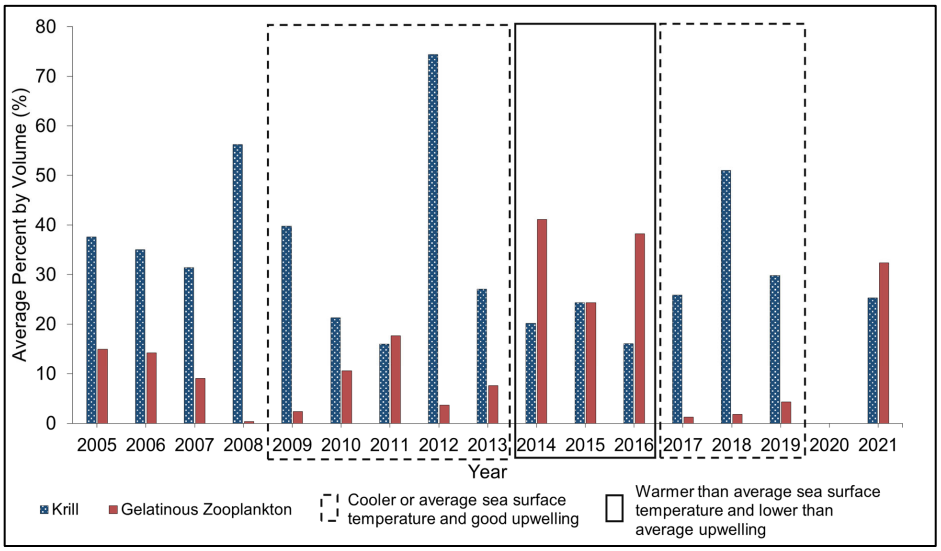

Figure S.LR.12.4. Average percent by volume of krill species and less nutritious gelatinous zooplankton species in ACCESS midwater sampling, 2010–2021, within the Gulf of the Farallones region. Years with dashed outline signify cooler or average sea surface temperatures and good upwelling. Years with solid outline signify warmer than average sea surface temperature and lower than average upwelling. Source: Elliott et al., 2022a

Conclusion

The fair/poor rating was primarily due to the decimation of bull kelp (*N. luetkeana*) along the Sonoma and Mendocino coast during the 2014–2016 MHW and a lack of significant recovery since then. Bull kelp loss is attributed to a decline to very low numbers of sea stars, driven by sea star wasting syndrome, which allowed purple urchins to increase unchecked to very high numbers and overgraze kelp and other algae. Krill and anchovy are abundant foundation species in GFNMS and vary with environmental conditions. Habitat compression during the 2014–2016 MHW changed the distribution of forage species from the shelf break to coastal waters, as seen in the increase of the relative abundance of anchovy 2018–2021. The trend for this question was mixed based on declines, increases, and variable trends for indicators. Bull kelp and sea stars declined in GFNMS, while throughout the Gulf of the Farallones region south to Monterey Bay, krill decreased and anchovy increased during the study period. The trend in species composition of krill and gelatinous zooplankton is variable, with a higher proportion of krill in cooler years (2010–2013, 2017–2010) and a higher proportion of gelatinous zooplankton in warm water years (2014–2016). Details of zooplankton data, specifically from the Gulf of the Farallones region is needed, including densities, distribution changes, fat content of copepods and gelatinous zooplankton, and comparison of samples collected by various projects sampling

Commented [11]: I'm not sure I would equate the distributional changes to the abundance changes- not necessarily the same drivers nor dynamics.

Commented [12]: I think caloric value or lipid content or something even more simple, such as nutritional value, might make more sense here?

in the region. Kelp canopy cover data collected with consistent methods are needed so canopy cover can be compared across Marin, Sonoma and Mendocino Counties and time periods.

Estuarine and Lagoon Region (Q12)[1]

Status Rating: Fair	Status Confidence: Medium
Trend Rating: Undetermined	Trend Confidence: Medium
Status Description: The status of keystone or foundation species suggests measurable but not severe degradation in some attributes of ecological integrity.	
Rationale: Eelgrass was documented in Tomales Bay, Estero Americano and Estero de San Antonio. Ad hoc observations noted the continued absence of eelgrass in Bolinas Lagoon. There are dense eelgrass beds in Tomales Bay, which generally appear to be healthy but time series data is limited. Wasting disease, caused by the marine protist, *Labyrinthula zosterae,* is present in Tomales Bay, but the extent and impacts are unknown. The presence of wasting disease in Tomales Bay is of concern.	

Findings From the 2010 Condition Report

A direct comparison between the current rating and the 2010 condition report is not possible because this specific question was not previously addressed. However, there were two questions in the 2010 condition report that assessed the status and condition and health of "key species." Eelgrass existed in all of the sanctuary's estuaries when it was designated in 1981. Prior to 2010, eelgrass has not been found in Bolinas Lagoon, most likely due to impairment of hydrologic function and increased siltation due to watershed practices and the invasion of non-native vegetation on Kent Island, such as beach grass, acacia, iceplant, French broom, cypress, and pine trees (Baye & Carmen, 2012).

New Information in the 2010–2022 Condition Report

In this condition report, only eelgrass (*Zostera marina*) is considered due to its role as a foundation species in the sanctuary's estuaries (Table S.LR.12.2). Eelgrass was documented in Estero Americano, Estero de San Antonio, and Tomales Bay, but continues to be absent in Bolinas Lagoon.

Table S.LR.12.2. Summaries for the key indicators related to keystone and foundation species in the estuarine and lagoon region that were discussed during the June 7, 2022 virtual status and trends workshop.

[1] Status and trend ratings and associated confidence scores were not determined during the expert workshop. Following the workshop, GFNMS staff re-evaluated the indicators, datasets, and expert input that was received during the workshop, and made a final determination for the status and trend ratings and associated confidence scores

Indicator	Source	Data Summary	Figures & Tables
Eelgrass	Spratt, 1989; Svejkovsky, J. 2013; CDFW, 2013; Merkle & Associates, 2017; Sherman & DeBruyckere, 2018	Status: Eelgrass beds were documented in three of four estuaries in GFNMS. Eelgrass beds in Tomales Bay were dense and healthy. However, wasting disease was documented but the extent and impacts are unknown. Trend: Eelgrass beds in Tomales Bay may be stable or expanding, but the lack of consistent mapping makes it difficult to determine a trend.	Figure S.H.10.4; Table S.H.10.4
Data Gap: Consistent mapping to measure change in eelgrass extent, research and monitoring on the ecosystem functions of eelgrass habitat, and studies of the extent and impacts of wasting disease are needed.			

Eelgrass is an important foundation species in the sanctuary's estuaries. Eelgrass is a supportive habitat, providing foraging areas as well as nurseries and shelter for many species of invertebrates, birds, and fish. Eelgrass rhizomes and roots help retain sediment, thus reducing erosion, dampens wave action, and can ameliorate carbon. For this study period, eelgrass has been documented in three of the four estuarine habitats in the sanctuary: Estero Americano, Estero de San Antonio, and Tomales Bay (Figure S.H.10.4). The most recent survey for eelgrass in Bolinas Lagoon was in 1994 (Sherman & DeBruyckere, 2018). Since then, ad hoc observations for eelgrass in Bolinas Lagoon, indicate that eelgrass continues to be absent from the lagoon.

Quantification of eelgrass in the sanctuary has been limited to a small number of surveys conducted since the late 1980s by county, state and sanctuary agencies and their contractors (Spratt, 1989; Svejkovsky, 2013; CDFW, 2013; Merkle & Associates, 2017; Sherman & DeBruyckere, 2018). Table S.H.10.4 lists surveys and acreage of eelgrass in the sanctuary's estuaries since 2010. Earlier surveys to map eelgrass beds used multispectral aerial imagery and more recent surveys used interferometric side-scan, which is considered to be a more accurate method to quantify submerged eelgrass.

Tomales Bay is recognized as one of the top five estuaries with prominent eelgrass beds along the west coast (Sherman & DeBruyckere, 2018) and the eelgrass beds in Tomales Bay are considered to be dense and generally appear to be healthy (M. Ward/Marin County Open Space District, personal communication, June 7, 2022). The majority of the eelgrass in GFNMS occurs in the northern and southern portions of Tomales Bay, with over 6 km^2 of eelgrass covering these regions. In most areas where eelgrass does occur in Tomales Bay the percent coverage is well over 40%. Surveys in Tomales Bay since 2013 indicate an increase in eelgrass area, but different methods were used making a direct comparison difficult. In 2015, GFNMS implemented the Tomales Bay Vessel Mooring Program which designated specific mooring zones in areas where no eelgrass is likely to grow. And in recent years, GFNMS, worked with NOAA Office of Law Enforcement and the California State Lands Commission to remove moorings from eelgrass beds and relocate them. Both of these actions have likely contributed to recovery in those impacted areas.

Eelgrass wasting disease is caused by a marine slime mold, a marine protist (*Labyrinthula zosterae*). Eelgrass wasting disease can have devastating effects on eelgrass beds as it can result in lesions on eelgrass blades, thus reducing its ability to photosynthesize (Graham et al., 2021). Since approximately 2007, eelgrass wasting disease has been detected along the west coast of North America and has had effects ranging from limited to severe in eelgrass ecosystems (Merkel and Associates, 2017). Studies have shown that temperatures above 27° C may result in infections of eelgrass wasting disease in some species of eelgrass (Brakel et al., 2019).

In 2015 and 2017, researchers observed the presence of eelgrass wasting disease on shed leaves that were floating (Merkel & Associates, 2017). The extent of wasting disease in Tomales Bay or the Esteros is unknown, as well as the impacts it may have on ecosystem function, including impacts to eelgrass community health and composition (e.g., fish and invertebrates). As rising temperatures may exacerbate wasting disease, this is a growing concern and data gap.

Conclusion

This statusquestion was rated fair based on the limited data indicating that eelgrass beds are present in three of the four estuaries in the sanctuary, Estero Americano, Estero de San Antonio and dense beds in Tomales Bay, and the beds may be expanding in Tomales Bay. There are no recent surveys in Bolinas Lagoon but ad hoc observations indicated that eelgrass continued to be absent in Bolinas Lagoon. Although there were dense eelgrass beds in Tomales Bay, which appeared to be healthy, the presence of eelgrass wasting disease is of concern. Management actions to remove moorings from eelgrass beds in Tomales Bay may be improving eelgrass extent. Assessment and monitoring of the abundance and distribution of eelgrass is limited and surveys do not include assessments to determine ecosystem functions, invertebrate interactions, or severity of and persistence to eelgrass wasting disease. The trend was undetermined due to a lack of time series data. A comprehensive monitoring plan is needed to assess the effectiveness of management actions, impacts from climate change, and the severity of disease that may be caused by *L. zosterae.*

Literature Cited

Bell, T.K., Cavanaugh, D., & Siegel. (2022). SBC LTER: Time series of quarterly NetCDF files of kelp biomass in the canopy from Landsat 5, 7 and 8, since 1984 (ongoing) ver 14. Environmental Data Initiative. https://sbclter.msi.ucsb.edu/data/catalog/package/?package=knb-lter-sbc.74.

Baye, P. & Carmen, W. (2012). Kent Island Vegetation Management. Report prepared for Marin County Open Space District. https://www.parks.marincounty.org/projectsplans/land-and-habitat-restoration/kent-island-restoration?tabnum=2

Brakel, J., Jakobsson-Thor, S., Bockelmann, A.C., & Reusch, T.B.H. (2019). Modulation of the eelgrass – *Labyrinthula zosterae* interaction under predicted ocean warming, salinity change and light limitation. Frontiers in Marine Science. https://doi.org/10.3389/fmars.2019.00268

California Department of Fish and Wildlife (CDFW). (2013). Eelgrass habitats in northern California's bays and estuaries. https://map.dfg.ca.gov/metadata/ds2795.html

Dayton, P. K. (1972). Toward an understanding of community resilience and the potential effects of enrichments to the benthos at McMurdo Sound, Antarctica. In B. C. Parker (Ed.), *Proceedings of the colloquium on conservation problems in Antarctica* (pp. 81–96). Allen Press.

Elliott, M., Lipski, D., Roletto, J., Warzybok, P., & Jahncke, J. (2022a). *Ocean climate indicators status report: 2021*. Contribution No. 2422. Point Blue Conservation Science. http://www.accessoceans.org/wp-content/uploads/2022/09/Ocean_Climate_Indicators_Report_2021.pdf

Graham, O.J., Aoki, L.R., Stephens, T., Stokes, J., Dayal, S. Rappazzo, B., Gomes, C.P., & Harvell, C.D. (2021). Effects of seagrass wasting disease on eelgrass growth and belowground sugar in natural meadows. Frontiers in Science. https://www.frontiersin.org/articles/10.3389/fmars.2021.768668/full

Konar, B., Mitchell, T.J, Iken, K., Coletti, H., Dean, T., Esler, D., Lindberg, M. Pister, B., and B. Weitzman. (2019). Wasting disease and static environmental variables drive sea star assemblages in the Northern Gulf of Alaska. Journal of Experimental Marine Biology and Ecology 520: 151209.

Merkel & Associates. (2017). Tomales Bay Eelgrass Habitat Evaluation and Site Monitoring in Areas Affected by Vessel Moorings, Tomales, Bay, CA. December 2017. *Unpublished Report* to Greater Farallones National Marine Sanctuary. 35 pps.

NOAA Integrated Ecosystem Assessment (NOAA IEA). (2022). California Current Integrated Ecosystem Assessment Indicators. https://www.integratedecosystemassessment.noaa.gov/regions/california-current/california-current-iea-indicators

Office of National Marine Sanctuaries (ONMS). (2010). *Gulf of the Farallones National Marine Sanctuary: 2010 condition report.* U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service. https://sanctuaries.noaa.gov/science/condition/gfnms/

Office of National Marine Sanctuaries (ONMS). (2014). Gulf of the Farallones National Marine Sanctuary, Final Management Plan, Updated December 2014. San Francisco, CA. pps. 296. https://farallones.noaa.gov/manage/management_plan.html

Paine, R. T. (1969). A note on trophic complexity and community stability. *The American Naturalist*, *103*(929), 91–93. https://doi.org/10.1086/282586

Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO). (2022). Data portal. https://www.piscoweb.org/data-access

Rogers-Bennett, L. & Catton, C.A. (2019). Marine heat wave and multiple stressors tip bull kelp forest to sea urchin barrens. Scientific Reports 9: 1. https://doi.org/10.1038/s41598-019-51114-y

Santora, J.A., Rogers, T.L., Cimino, M.A., Sakuma, K.M., Hanson, K.D., Dick, E.J., Jahncke, J., Warzybok, P. and Field, J.C. (2021). Diverse integrated ecosystem approach overcomes pandemic-related fisheries monitoring challenges. Nature communications 12(1): 6492. https://doi.org/10.1038/s41467-021-26484-5

Sherman, K. & L.A. DeBruyckere. (2018). Eelgrass habitats on the U.S. West Coast. State of the Knowledge of Eelgrass Ecosystem Services and Eelgrass Extent. A report prepared by the Pacific Marine and Estuarine Fish Habitat Partnership for The Nature Conservancy. 67pp. https://www.pacificfishhabitat.org/wp-content/uploads/2017/09/EelGrass_Report_Final_ForPrint_web.pdf

Spratt, J.D. (1989). The distribution and density of eelgrass, *Zostera marina*, in Tomales Bay, California. California Fish and Game 75:204–212

Svejkovsky, J. (2013). High Resolution Nearshore Substrate Mapping and Persistence Analysis with Multi-spectral Aerial Imagery. Annual Report submitted to the California Sea Grant Program, Grant No. MPA 09-015, CA Sea Grant Account #: SEA 4995, Project Number R/MPA-17. https://caseagrant.ucsd.edu/sites/default/files/17_Svejkovsky.pdf

Question 13: What is the status of other focal species and how is it changing?

Commented [13]: not sure why the "other" see note above

Coastal and Offshore Region (Q13)

Status Rating: Fair	Status Confidence: Medium
Trend Rating: Mixed	Trend Confidence: Medium
Status Description: Selected focal species are at reduced levels, but recovery is possible.	
Rationale: While ~~T~~the 2014–2016 MHW greatly impacted abundance and distribution of the previously mentioned ~~many~~ focal species, ~~, but~~ other species are stable or increasing. After high abundances from 2013–2016, pelagic juvenile rockfish, a primary forage species throughout the region, has been declining in the CCE. The regional abundance of white sharks increased in Central California. Humpback whale populations showed gradual increases on the west coast, and densities in the sanctuary increased and fluctuated with krill densities in GFNMS. Since the 2014–2016 MHW, densities of whales and krill have increased slightly, particularly across the shelf region of the sanctuary. Habitat compression of forage species, such as anchovies, is a likely factor affecting the distribution of focal species, such as seabirds and whales, across the shelf and closer to shore. Seabird densities are increasing but there is a decline in shorebird observations within the sanctuary. Sea palm and abalone	

Commented [14]: This sentence is confusing because of the use of "focal" and "other"...not sure what the take home point is...particularly considering "Question 13" use of "other focal species"

Commented [15]: I think there must be a better way to say this- pelagic juvenile rockfish are life history stages available only seasonally, and are not a species but rather an assemblage of multiple species, the trends in pelagic juvenile abundance don't reflect population trends of the adults but rather recruitment. Potentially a bit complex to fully explain, but definitely don't call them a forage species, perhaps "a critical component of the forage assemblage" or something like that..

Commented [16]: Something better might be to say "in many years, habitat compression is a key driver of the distribution of..." and then "as observed with anchovy and krill, as described above"

densities declined during the 2014–2016 MHW; sea palm showed signs of recovery but abalone abundances remained very low.

This question targets species of particular interest from the perspective of GFNMS sanctuary management, local partners, and experts. These "focal species" may not be abundant or control ecosystem function, but their presence and health is important for the provision of economic, cultural, recreational, ecological, and/or conservation-related values and services. Some species considered here are also threatened or endangered and are protected by state and/or federal laws.

Findings From the 2010 Condition Report

In 2010, this question was included as the status of key species. In 2010, the status of key species in the offshore and coastal region was rated as fair and the trend was undetermined. The rating was based on the status of 49 key species and populations that were in varying states of integrity. Nearly all locally breeding seabird species and the abundance of threatened and baleen whale species were stable or increasing within the sanctuary. Some shorebird populations, such as snowy plover, were declining.

New Information in the 2010–2022 Condition Report

In this report, the question has been split to separately address the status of keystone and foundation species, found in question 12, and the status of other focal species (see Appendix A for an explanation on changes to the resource questions since the previous report). Of the 1,140 species known to occur in GFNMS (ONMS, 2014), 92 are considered to be focal species in this report i.e., species and taxa that require close attention from the perspective of sanctuary management and may be targeted for special protection (Appendix D). Of the 92 focal species of highest concern to sanctuary management, 15 taxa were selected as indicators of the status and trends of our focal species and taxa (Tables S.LR.13.4 and S.LR.13.5, for offshore and coastal regions of the sanctuary, estuarine and lagoon regions of the sanctuary, respectively). The indicator species represent species or taxa that forage at different trophic levels and breed in the sanctuary; these include seabird species such as the Cassin's auklet (a planktivore), Brandt's cormorant (a piscivore), and common murre (a planktivore and piscivore). The selected indicator species may also be federally listed as endangered or threatened, such as the snowy plover, or are important prey species for birds and mammals, such as juvenile rockfish. Indicator species may also be highly dependent on the sanctuary during their non-breeding season for foraging, such as shorebirds, humpback whales, and white sharks, or are important contributors to habitat integrity, such as mussels, abalone, and algae.

Commented [17]: the difference between foundation and keystone and focal species is getting a little...complicated. Maybe appendix D sorts it out.

Commented [18]: interesting use of indicator species..perhaps be more clear that they are indicators of the health of the environment and sustainable populations within the GFNMS, not just of other focal species

Table S.LR.13.4. Summaries for the key indicators related to focal species that were discussed during the virtual June 7, 2020 status and trends workshop.

Indicator	Source	Data Summary	Figures
Juvenile Rockfish	NOAA IEA, 2022; PISCO, 2022	Status: The abundance of juvenile rockfish has varied, with peak abundance during 2013–2016 in the offshore regions and peaked abundance in kelp forest prior to 2016. Trend: Offshore juvenile rockfish declined in the Gulf of the Farallones region in	S.LR.13.1

		2016–2019, but in 2021, abundance was at the long-term mean. Juvenile rockfish in the kelp forest appear to have decreased since the 2014–2016 MHW.	
White Shark	Kanive et al., 2021; Sanford et al., 2019; Tanaka et al., 2021	Status: White sharks are abundant seasonally in GFNMS. Trend: Estimates of white sharks increased during this study timeframe.	
Humpback Whale	Elliott et al., 2022a; Carretta et al., 2022	Status: Humpback whales are abundant in the sanctuary, particularly spring through fall. Trend: Humpback whale abundance in GFNMS, increased. The distribution within the sanctuary shifted closer to shore since the 2014–2016 MHW and the onset of habitat compression.	S.LR.13.2; S.LR.13.3
Seabirds–Brandt's Cormorant, Cassin's Auklet, Common Murre	Johns et al., 2020; Elliott et al., 2022b	Status: Populations of breeding seabirds Brandt's cormorants, Cassin's auklets, and common murres are abundant in GFNMS. Trend: Populations of Brandt's cormorant and Cassin's auklet increased and the common murre population was stable on the South Farallon Islands.	
Shorebird– Snowy Plover & Willet	Lau, 2020: Lindquist & Roletto, 2022a	Status: The number of nesting snowy plovers in PRNS was low, estimated to be 39 adults in 2020. Encounter rates of willets were low. Trend: There has been a significant increase of breeding snowy plovers in PRNS as well as encounter rates of plovers throughout the sanctuary. Total shorebird encounter rates have been stable or slightly increased for most shorebird species, with a few exceptions, such as willet.	S.LR.13.4
Algae–Sea Palm	MARINe, 2022; Raimondi & Smith, 2022	Status: Sea palm densities varied, with the most recent densities at moderate levels. Trend: The overall trend of sea palm density has been declining since 2008, from a high of >86/m^2 in 2008 with an extreme drop to nearly zero since the 2014–2016 MHW. Densities appear to be slowly recovering in some, but not all regions.	S.LR.13.5

Commented [19]: fair to say that humpback whale abundance increased throughout the California Current, including in the GFNMS? Is it worth mentioning some apparent shift in the seasonality of migrations (many whales are arriving earlier and/or staying longer)

Invertebrates–California Mussel, Red Abalone	MARINe, 2022; Rogers-Bennett et al., 2019; Rogers-Bennett & Catton, 2019	Status: Abundance of mussels at three sites in the sanctuary varies but are generally high and stable. Red abalone are at extremely low levels of abundance, in Marin and Sonoma Counties densities are 43–96% below average. Trend: There was a slight decline of mussels in Sonoma County, which began during the MHW of 2014–2016 and continued for a few years. Since 2020, it appears that California mussels are recovering in Sonoma and Marin counties. Red abalone experienced severe declines during the study period.	S.LR.13.6
Data Gap: Additional shorebird population data are needed for subspecies to adequately determine the extent that shorebirds use the sanctuary as population expands and ranges change. Information on trends will be enhanced with additional monitoring locations within Marin and Sonoma Counties for densities of juvenile rockfish in kelp beds, mussels, and sea palm.			

density of red abalone in Sonoma County was 0.5/m^2 (Rogers-Bennett et al., 2019). In 2011, a harmful algal bloom caused by a dinoflagellate, *Gonyaulax* spp., caused a large mortality event of red abalone in Sonoma County. In 2012–2013, abalone density declined 30-35%, to 0.35 abalone/m^2 (Rogers-Bennett et al., 2019) but were still considered to be relatively abundant, ranging from 0.24–1.01/m^2 in 2014 (Rogers-Bennett & Catton, 2019). The 2014-2016 MHW and the sea star wasting syndrome disrupted the historic ecosystem balance between kelp, urchins, urchin predators (sea stars), and abalone in northern California kelp forests, resulting in a decline of red abalone by 43–96%.

Commented [20]: is there content missing here? Paragraph seems to start midsentence

Commented [21]: Definitely something missing but I am glad the red abalone decline is acknowledged.

Juvenile Rockfish

Juvenile rockfish (*Sebastes* spp.), especially the shortbelly rockfish (*S. jordani*), are a primary forage taxon for many seabirds, piscivorous fishes (such as salmon and lingcod) and other predators. There was a peak in abundance of juvenile rockfish in the offshore regions of the Gulf of the Farallones and Monterey Bay from 2013–2016 (Figure S.LR.13.1). In 2016–2020, the relative abundance of juvenile rockfish declined in the Gulf of the Farallones and Monterey Bay region (NOAA IEA, 2022). Since the 2014-2016 MHW, juvenile rockfish within the kelp forests along Sonoma and Mendocino County have also declined and remained suppressed (PISCO, 2022).

Commented [22]: just seems worth emphasizing they are important prey to many predators, not just the seabirds (sea lions among the key predators)

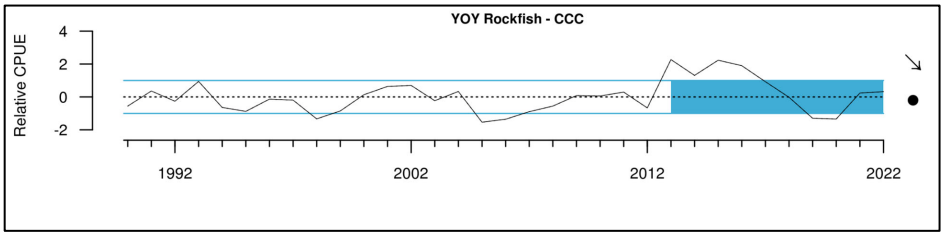

Figure S.LR.13.1. Mean catch per unit effort (CPUE) of young of the year rockfish throughout the Gulf of the Farallones and Monterey Bay region, 1990–2021. Blue shading indicates the years analyzed for trend (2013–2022); the trend is indicated by the arrow. Black dot indicates the mean is within 1 standard deviation. Source: NOAA IEA, 2022

Commented [23]: shows recovery not decline since 2016 (?), not what narrative says or trend arrow

White Sharks

White sharks (*Carcharodon carcharias*) have been an iconic species in the sanctuary since its designation because the Farallon Islands are~~is~~ known as an aggregation location. Since 1994, they have been protected against take by the state and in 2009 the sanctuary established regulations to protect white sharks from disturbance, i.e., approaching and attracting using chumming or decoys. From 2011–2018, the estimated overall abundance of white sharks in central California (i.e., between Tomales Bay, the South Farallon Islands, and Año Nuevo Island) based on a mark-recapture model increased from a low estimate of 184 individuals in 2011, to a high estimate of 261 individuals in 2018; standard errors varied for each age group assessed (Kanive et al., 2021). The estimated increase of white sharks is correlated with the reduction of take at the juvenile stage from fisheries and increase in abundance of pinnipeds, their primary forage species in GFNMS (Kanive et al., 2021). Previously unobserved aggregations of juvenile white sharks (approximately one to three years old) began appearing in Monterey Bay along with other range shifting taxa (Sanford et al., 2019) following the heatwave in 2014. Habitat modeling and preliminary observations indicate this new demographic partially extends into GFNMS waters (Tanaka et al., 2021).

Humpback Whales

The humpback whale (*Megaptera novaeangliae*) population in the WA, OR and CA stock is increasing at an annual rate of about 8% per year (Carretta et al., 2022). Their seasonality, abundance, and distribution within the sanctuary are influenced by ocean conditions and the presence of their forage species, such as krill and anchovy (Ingman et al., 2021; Santora et al., 2020; Gulland et al., 2022). Krill are more abundant in the sanctuary during times of cooler than average sea surface temperatures and higher than average Upwelling Index (Schroeder et al., 2018; Santora et al., 2020, Santora et al, 2021; Elliott et al. 2022a; Figures S.LR.12.3 and S.LR.12.4). Humpback whale densities are correlated with densities of krill in GFNMS and have been higher in recent years, particularly after 2015 when the 2014-2016 MHW subsided (Figure S.LR.13.2; Elliott et al., 2022a). Humpback whales forage primarily along the shelf break between 100–200 meters depth. In the period prior to the 2014–2016 MHW, only 5% of whales were observed nearshore. During the 2014–2016 marine heatwave, 9% of humpback whales were observed nearshore. In the years following the 2014–2016 MHW, 21% of observed humpback whales were observed nearshore (Elliott et al., 2022b; Figure S.LR.13.3). The movement of more whales closer to shore increases the co-occurrence of whales with large ships and commercial fishing traps (particularly Dungeness crab traps), making them more vulnerable to collisions with ships and entanglement in fishing gear (Figures S.P.4.9 and S.P.4.6, Table S.P.4.2). The seasonality and timing of the arrival of most humpback whales in the Gulf of the Farallones region has shifted to an earlier arrival in the spring months (Ingman et al., 2021). On average, in comparison to 1993, humpback whales are arriving 120 days earlier, increasing the number of days whales are present in the sanctuary during the commercial Dungeness crab fishery, November through June (Ingman et al., 2021). Humpback whales are particularly vulnerable to entanglement in the vertical lines and surface buoys of Dungeness crab traps (e.g., in 2015, Figures S.P.4.9 and S.P.4.6, Table S.P.4.2; NOAA Fisheries, 2020). Observations of dead whales reported to have been entangled in fishing gear occurred throughout northern California but were concentrated within the Gulf of the Farallones region (Figure S.P.4.6).

Commented [24]: do you want to mention from two stocks? one threatened one endangered?

Commented [25]: but they can be very broadly distributed- I might open with that?

Commented [26]: You mention the fishery later but don't specify that entanglements are primarily an issue with crab fishery gear in this region.

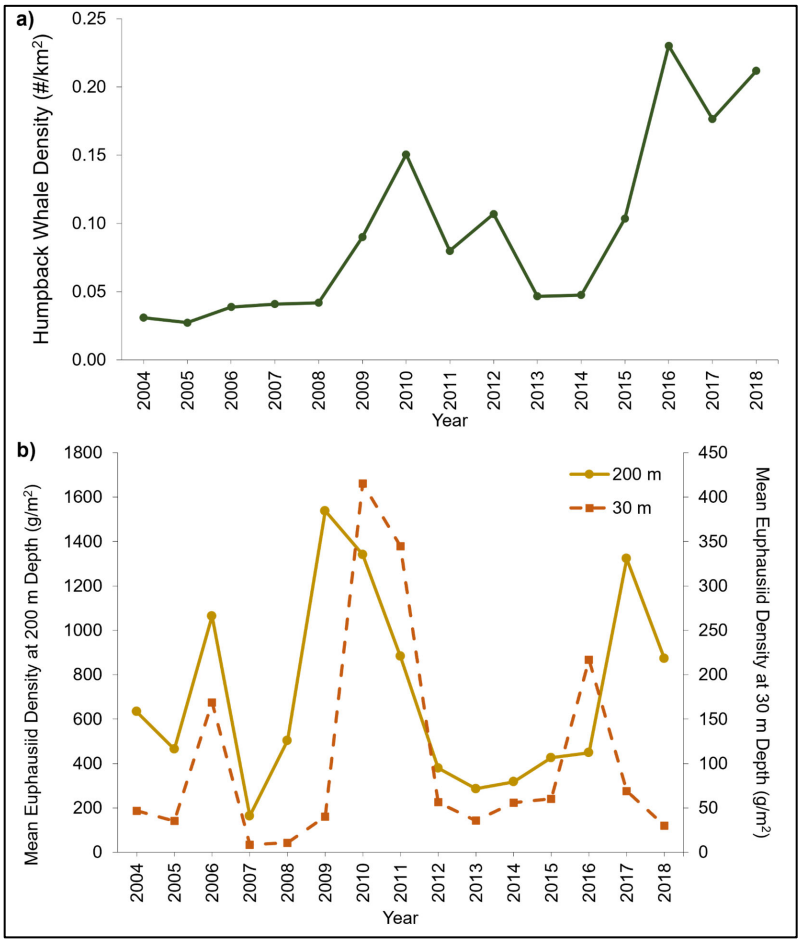

Figure S.LR.13.2. Density of humpback whales (top graph) and density of krill within the sanctuary (bottom graph) 2004–2018. Source: Elliott et al., 2022a

Commented [27]: Is this standardized by effort? There are some gaps/constraints on the Access line that could alter or bias results if that isn't done (I would assume that it was though).

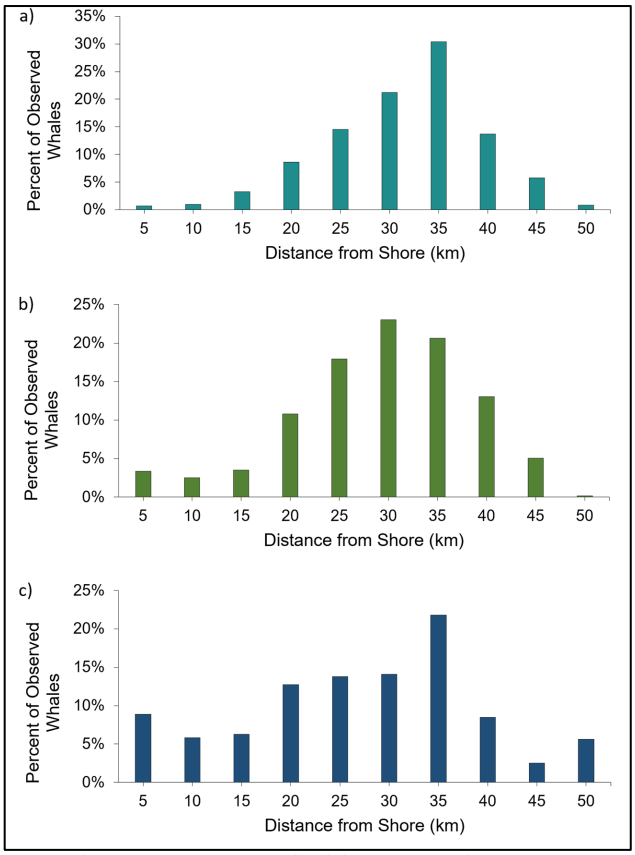

Figure S.LR.13.3. Distances (km) from shore of humpback whales during ACCESS research cruises. Top graph (a) is 2010–2013. Middle graph (b) is 2014–2016. Bottom graph (c) is 2017–2019. Source: Elliott et al., 2022b

Seabirds – Brandt's Cormorants, Cassin's Auklets, Common Murres

At the heart of the sanctuary are the South Farallon Islands (SFI), designated as Farallon Islands National Wildlife Refuge, where over 365,000 birds breed, including 12 species of seabirds and one species of shorebird. Locally breeding seabirds are good indicators of sanctuary condition, as they quickly respond to environmental changes throughout the coastal and offshore regions of the sanctuary (Piatt et al., 2007). Three species of locally breeding seabirds, each representing a different trophic level, were selected for this assessment: Brandt's cormorant (*Urile penicillatus*) are piscivorous, Cassin's auklet (*Ptychoramphus aleuticus*) are planktivorous; and common murre (*Uria aalge*) are primarily piscivorous but also forages on zooplankton.

The Brandt's cormorant breeding population on the SFI was over 20,000 birds in 2007. Following a population crash in 2008 (Ainley et al., 2018) the Brandt's cormorant population on

the islands was reduced to only 5,132 breeding birds by 2010. More recently, the breeding population has been slowly recovering and was approximately 10,408 breeding birds in 2021 (Spears et al., 2022). The Brandt's cormorant population size and breeding success on the SFI is closely related to the abundance of juvenile rockfish and anchovy in the Gulf of the Farallones region (Ainley et al., 2018).

Likewise, the Cassin's auklet breeding population declined between 2005 and 2009, with a low population estimated at 13,000 breeding birds in 2010. Since then, the breeding population has gradually recovered much of that loss and the population was approximately 23,000 in 2021 (Spears et al., 2022).

The common murre breeding population experienced a stable increase since the mid-1990s since the elimination or reduction of incidental fishing mortality, disturbance, oil pollution, and gillnetting (Spears et al. 2022; Capitolo, 2021). In 2000, the breeding population of common murres on the SFI was approximately 60,000. By 2010, the population was 250,000. In 2021, the population stabilized and was estimated to be approximately 300,000 breeding birds (Spears at al., 2022).

The seasonal distribution of Cassin's auklets mirrored the change in distribution that was observed in baleen whales during the 2014–2016 MHW (Hobday et al., 2016; Elliott et al., 2022a). Auklets and whales were more broadly distributed across the shelf during the 2014–2016 MHW, rather than where they are more typically concentrated along the shelf break, at the 100–200 m depth contours (Elliott et al., 2022a). Brandt's cormorants and common murres are typically distributed across the shelf in the Gulf of the Farallones region and did not appear to follow a similar change to forging further to the east (Elliott et al., 2022b; Johns et al., 2020).

Point Reyes Headlands also hosts large colonies of Brandt's Cormorants and Common Murres, where they have been monitored since 1996 (Scopel et al. 2023; Capitolo, 2021). Trends in cormorant and murre abundance have reflected those at the South Farallon Islands. Elsewhere, common murres have been expanding and reestablishing their breeding colonies along the Sonoma coast, which until recently held no breeding murres (Capitolo, 2021, Johns et al., 2020).

Shorebirds – Willets & Snowy Plovers

In general, data from Beach Watch surveys indicated that the presence of shorebirds has been stable or decreasing until recent years (2018-2019; Lindquist & Roletto, 2022a; Lindquist & Roletto, 2022b; Figure S.LR.13.4). Encounter rates of all shorebird taxa in the sanctuary ranged from 74/km in the 1990s to 21/km in 2021 (Figure S.LR.13.4). Even though encounter rates of willet (*Tringa semipalmata*) within the sanctuary have declined, many shorebird species are stable or increasing throughout their ranges, suggesting a shift in distribution rather than decline in total numbers (International Union for Conservation of Nature, 2022). For example, the encounter rate for willet in the sanctuary ranged from 7/km survey surveyed in the 1990s to 0.8/km in 2021 (Figure S.LR.13.4), but the North American populations, western and eastern populations combined, have been stable or are increasing in most of its breeding area (International Union for Conservation of Nature, 2022; Cornell Lab of Ornithology, 2022). Because the decline within the sanctuary is substantial, future regional population estimates of the western subspecies of willet, is warranted.

Snowy plovers (*Charadrius nivosus*), which are federally listed as threatened, are present and breed in low but significantly increasing numbers (39 adults in 2020) within PRNS, a regionally significant breeding area (Lau, 2020). Encounter rates of snowy plovers throughout the

sanctuary have ranged from 1 plover/km surveyed to 3 plover/km and have slightly increased over the past decade. Since 2010, year-round encounter rates of snowy plover have slightly increased on sanctuary beaches (Lindquist & Roletto, 2022a).

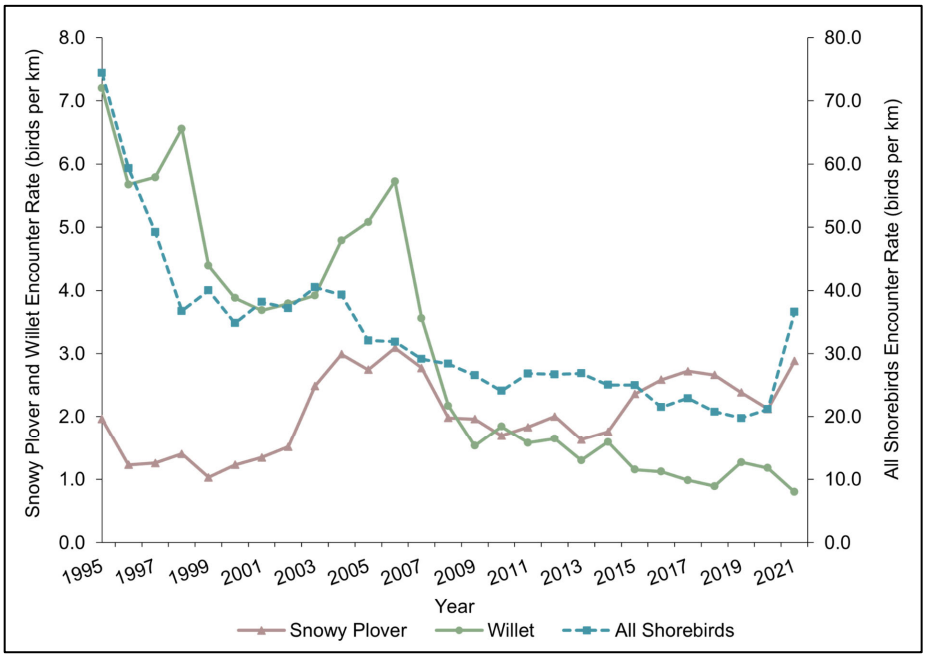

Figure S.LR.13.4. Annual observation rates of snowy plover, willet, and all shorebirds in GFNMS, 1995–2021. Source: Lau, 2022; Lindquist & Roletto, 2022a

Algae—Sea Palm

Algae are important indicators of the health of the rocky intertidal habitat. For this status and trend review, we used sea palm (*Postelsia palmaeformis*) as an indicator species because it shows differential responses to natural and anthropogenic disturbances and it is a species of concern for the state. The abundance of sea palm for three intertidal locations in Sonoma and Marin Counties (specific locations are not available due to the protected species status from the state) ranged from a high of >86/m^2 in 2008 to virtually zero in 2015 and 2016, during the 2014–2016 MHW (MARINe, 2022; Figure S.LR.13.5). It appears that sea palm is slowly recovering since the MHW. In 2021, researchers recorded an average seasonal density of 29.6/m^2 in Sonoma County and higher densities in the state's north-central marine protected areas (i.e., MPAs within and adjacent to GFNMS) as compared to areas that do not have stronger take regulations (Raimondi & Smith, 2022).

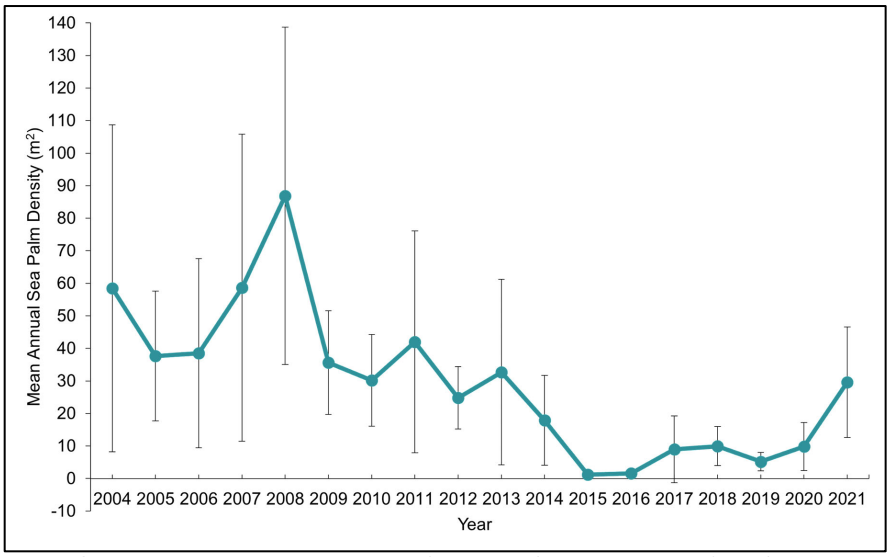

Figure S.LR.13.5. Mean annual densities of sea palm (*Postelsia palmaeformis*) measured at three sites in GFNMS, 2004–2021. Source: MARINe, 2022

California Mussels and Red Abalone

The percent cover of California mussel (*Mytilus californianus*) at three sites in Marin and Sonoma Counties ranged from a high of nearly 100% cover to a low of nearly 80% cover over the past ten years (Figure S.LR.13.6). At Bodega Marine Life Refuge, mussel cover declined during the 2014–2016 MHW. Mussel declines were also observed between 2016-2020 at Sea Ranch and Bolinas Point, but as of 2022, cover at all three sites appears to be trending toward recovery (MARINe, 2022).

The relative abundance of red abalone (*Haliotis rufescens*) in Marin, Sonoma, and Mendocino Counties fluctuated over the past 10 years. Prior to 2011, the population of red abalone remained relatively stable and supported a recreational fishery. Due to significant population declines, the California Fish and Game Commission closed the recreational fishery in 2017. In 2011, the density of red abalone in Sonoma County was 0.5/m^2 (Rogers-Bennett et al., 2019). In 2011, a harmful algal bloom caused by a dinoflagellate, *Gonyaulax* spp., caused a large mortality event of red abalone in Sonoma County. In 2012–2013, abalone density declined 30-35%, to 0.35 abalone/m^2 (Rogers-Bennett et al., 2019) but were still considered to be relatively abundant, ranging from 0.24–1.01/m^2 in 2014 (Rogers-Bennett & Catton, 2019). The 2014-2016 MHW and the sea star wasting syndrome disrupted the historic ecosystem balance between kelp, urchins, urchin predators (sea stars), and abalone in northern California kelp forests, resulting in a decline of red abalone by 43–96%. In 2018, red abalone densities in northern California ranged from nearly zero at Caspar Cove, which is north of GFNMS to nearly 0.2/m^2 at Timber Cove, within GFNMS. Densities of red abalone have decreased to the point that state fishery managers predict that it will take decades for the red abalone population to recover after the kelp population has recovered (Rogers-Bennett & Catton, 2019).

Commented [28]: This text seems to be oddly interjected above on p16 right before juvenile rockfish

Formatted: Highlight

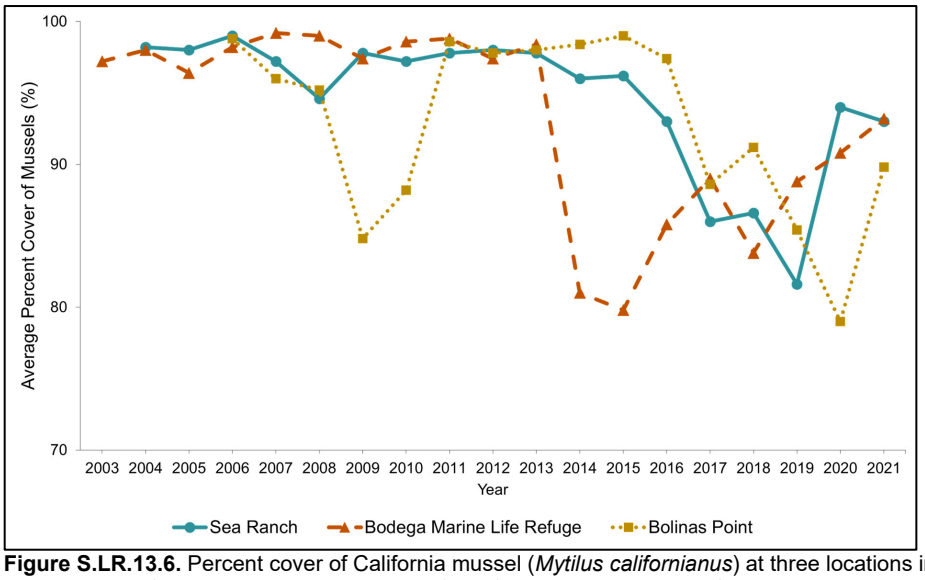

Figure S.LR.13.6. Percent cover of California mussel (*Mytilus californianus*) at three locations in the sanctuary, Sea Ranch, Bodega Marine Life Refuge, and Bolinas Point). Note that the range for y-axis is 70%-100%. Source: MARINe, 2022

Conclusion

This question was rated fair, indicating selected focal species are at reduced levels, but recovery is possible. This rating was mainly based on impacts to species from the 2014–2016 MHW, such as severe declines in red abalone and sea palm and the change in distribution of whales and Cassin's auklets from the shelf break to closer to shore. The trend was mixed with some taxa in decline, others flourishing and increasing in abundance, and others that appeared stable. Taxa that declined included juvenile rockfish, abalone, and sea palm. Encounter rates of shorebirds in the sanctuary declined, but their coastwide populations appear stable. Species that increased included white sharks, humpback whales, Brant's cormorants, and Cassin's auklets. Mussels and common murres appeared to be stable. Additional shorebird population data are needed for some species to adequately determine the extent that shorebirds use the sanctuary as population expands and ranges change. Information on trends could be enhanced with additional monitoring locations within Marin and Sonoma Counties for densities of juvenile rockfish in kelp beds, mussels, and sea palm.

Estuarine and Lagoon Region (Q13)

Status Rating: Fair/Poor	Status Confidence: Medium
Trend Rating: Undetermined	Trend Confidence: Low

Status Description: Selected focal species are at substantially reduced levels, and prospects for recovery are uncertain.
Rationale: Data are lacking on focal species populations and potential range shifts in the sanctuary's estuaries. Anecdotal observations suggest that Olympia oysters, a native species, are present in Tomales Bay and Bolinas Lagoon, possibly in low numbers. Recent observations of brant and shorebirds in the sanctuary are lower than in previous decades, but it is undetermined if the lower numbers reflect the worldwide population trends or if there is a range shift for brant and most shorebird species.

Commented [29]: maybe define what brant is? I didn't know and found this a bit confusing...probably because of similarity in name to Brandt's Cormorants....is it a seabird? If so, why called out separately?

Findings From the 2010 the Condition Report

In the 2010 condition report, this question was included as part of the "status of key species" question and the status rating for the estuarine and lagoon region was fair with a declining trend. The rating was based on the loss of eelgrass in Bolinas Lagoon due to habitat degradation from watershed influences and reduced circulation in the lagoon, thus increasing siltation. Despite the trend rating, there was a discernible increase in the population of brant; low abundances had been a concern when the sanctuary was first designated. And even though eelgrass was absent from Bolinas Lagoon, conditions were thought to be improving due to the control, reduction and extirpation of non-indigenous species, and the creation of improved habitat for brant and potentially tidewater goby.

New Information in the 2010–2022 Condition Report

Focal species considered in this report include Olympia oysters, brant, and shorebirds as a group (Table S.LR.13.3).

Commented [30]: its a small goose, but i agree, why separate, is it a focal species?

Table S.LR.13.5. Summaries for the key indicators related to other focal species that were discussed during the virtual June 7, 2020 status and trends workshop.

Indicator	Source	Data Summary	Figures
Olympia Oysters	Grosholz, 2022; Wasson et al., 2015	Status: Anecdotal data indicate that native oysters are present in Tomales Bay but numbers or densities have not been assessed in recent years. Trend: There has been a long-term decline of native oysters along the West Coast.	
Brant, All Shorebirds	Lindquist & Roletto, 2022a	Status: Brant abundances are low (1–7 per km) and all shorebird abundances are moderate (20–40 per km) in the estuarine and lagoon habitats in the sanctuary compared to historic abundances. Trend: Encounter rates of brant suggest a long-term increase in the sanctuary, but since 2014, numbers have declined. Long-term observations of all shorebird species in the sanctuary indicate a decline of encounter rates, until 2018, but the trend has been fairly stable over the past decade.	S.LR.13.7; S.LR.13.8

Data Gap: No current data on abundance or distribution of tidewater goby in sanctuary estuaries. Monitoring projects for native and non-native species of oysters, mud snails, and drills are needed. A comparison of abundance and distribution within the sanctuary, foraging and breeding areas are needed for shorebirds and brant.

Olympia Oysters

Regionally, Olympia oysters have greatly declined throughout the West Coast of North America (Wasson et al., 2015; Grosholz, 2022). Data are lacking for focal species, such as mud snails and native oysters, in the sanctuary's lagoon and estuaries. Minimal information on the presence of native oysters is available from researchers studying non-indigenous species in Tomales Bay (Kornbluth et al., 2022). Olympia oysters (*Ostrea lurida*) are present and Tomales Bay and Bolinas Lagoon, however, their population numbers for the study period are unknown (E.D. Edwin D. Grosholz/U.C. Davis, personal communication, May 24, 2022). The last study on Olympia oysters in Tomales Bay was conducted in 2006 and this work was described in the 2010 GFNMS Condition Report (Kimbro et al., 2006; ONMS, 2010).

Brant and Shorebirds

The brant (*Branta bernicla*) population has been a concern to management since sanctuary designation. Brant use the sanctuary's estuarine habitat to forage on eelgrass during their migration to and from their breeding areas in the arctic tundra. The North American population fluctuated over the past several decades and is now thought to be declining throughout its range (Sedinger et al., 2019). Encounter rates of brant in the sanctuary also fluctuated, with rates as high 6.7 birds/km in 2014 to a low of 1 bird/km in 2021 (Lindquist & Roletto, 2022a; Figure S.LR.13.7). Worldwide populations of all shorebird species have declined over the past 20 years. For many species that breed in the arctic, populations declined by 70% (Munro, 2017). Encounter rates of all shorebird species throughout the sanctuary also declined over the past two decades, from a peak encounter rate of 74 birds/km in 1994 to a low of 20 birds/km in 2019 but have been fairly stable over the past decade, and an increase since 2018 (Lindquist & Roletto, 2022a; Figure S.LR.13.8). The declines of these birds in GFNMS coastal and estuarine habitats may be reflecting the overall decline in these populations or may be due range shifts in.

Commented [31]: somewhat explained, but if all shorebirds are declining, why this one specifically mentioned

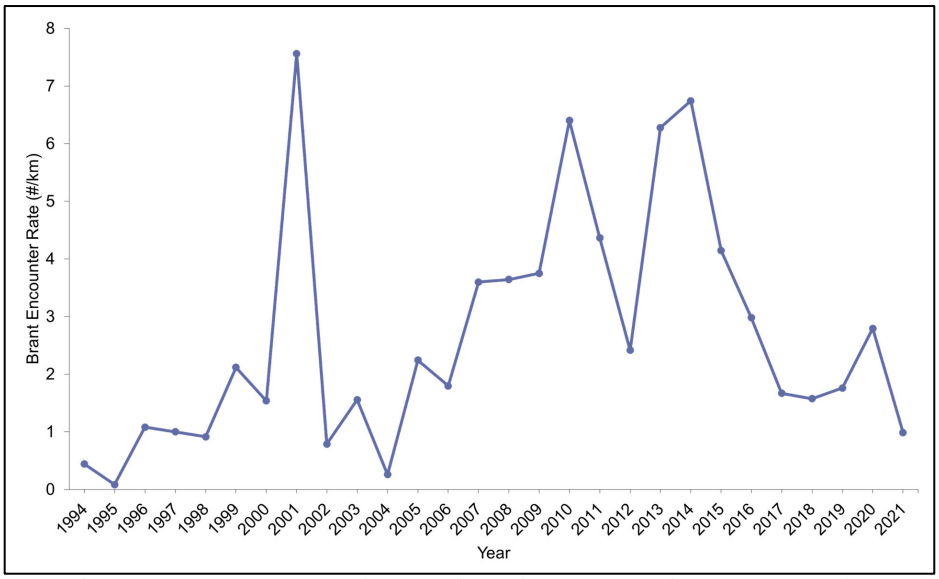

Figure S.LR.13.7. Encounter rates of brant in GFNMS, 1994–2021. Source: Lindquist & Roletto, 2022a

Commented [32]: no image

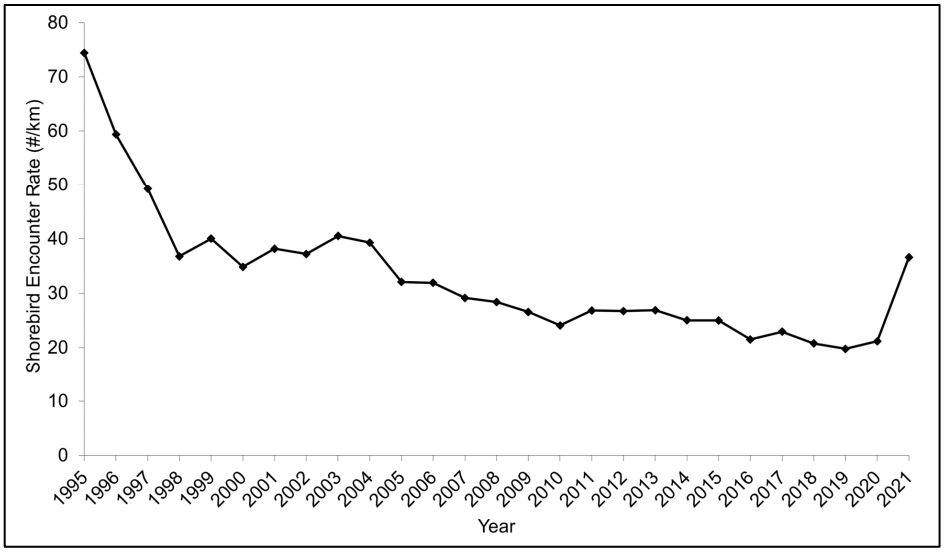

Figure S.LR.13.8. Encounter rates of shorebirds in estuarine habitat in GFNMS 1994–2021. Source: Lindquist & Roletto, 2022a

Conclusion

This statusquestion was rated fair/poor indicating selected focal species are at substantially reduced levels, and prospects for recovery are uncertain. This reflects that abundance of native oysters is thought to be low and the presence of non-native oyster drillsdrill potentially affecting recovery of native oysters in the sanctuary's estuaries and lagoon. Very little information is available other than anecdotal. Worldwide brant and shorebird populations were low compared to historic levels and declined over the past ten years. Encounter rates of brant and total shorebirds species within the sanctuary have also declined, reflecting the worldwide trends of those populations. However, the trend was undetermined based primarily on the lack of information on the density and distribution of native oysters and the levels of oyster drills impacting native oysters. Implementation of monitoring for native and non-native species of oysters, mud snails, and drills are needed. Recent observations of brant and shorebirds in the sanctuary are lower than in previous decades, but it is undetermined if the lower numbers reflect the worldwide population trends or if there is a range shift for brant and most shorebird species. A comparison of abundance and distribution within the sanctuary, foraging and breeding areas are needed for shorebirds and brant.

References (Q13/Both Regions)

Ainley, D.G., Santora, J.A., Capitolo, P.J., Field, J.C., Beck, J.N., Carle, R.D., Donnelly-Greenan, E., McChesney, G.J., Elliott, M.E., Bradley, R.W., Lindquist, K., Nelson, P., Roletto, J., Warzybok, P., Hester, M.M. & Jahncke, J. (2018). Ecosystem-based management affecting Brandt's Cormorant resources and populations in the central California Current region. *Biological Conservation*, *217*, 407–418.

Capitolo, P.J. (2021). An Update on the Abundance and Distribution of Breeding Common Murres, Brandt's Cormorants, and Double-crested Cormorants from Point Arena to Tomales Point, California, through 2020. Unpublished Report. Institute of Marine Sciences, University of California, Santa Cruz, California.

Carretta, J.V., Oleson, E.M., Forney, K.A., Muto, M.M., Weller, D.W., Lang, A.R., Baker, J., Hanson, B., Orr, A.J., Barlow, J., Moore, J.E., & Brownell, B.L. (2022). Jr. 2022. U.S. Pacific marine mammal stock assessments: 2021. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-663. https://doi.org/10.25923/246k-7589

Cornell Lab of Ornithology. (2022). Birds on Line, All about birds. https://www.allaboutbirds.org/

Elliott, M., Lipski, D., Roletto, J., Warzybok, P., & Jahncke, J. (2022a). *Ocean climate indicators status report: 2021*. Contribution No. 2422. Point Blue Conservation Science. http://www.accessoceans.org/wp-content/uploads/2022/09/Ocean_Climate_Indicators_Report_2021.pdf

Elliott, M., Lipski, D., Roletto, J., Warzybok, P., & Jahncke, J. (2022b). [Unpublished data]. Applied California Current Ecosystem Studies. Point Blue Conservation Science, Petaluma, CA.

Grosholz, E.D. (2022). Restoration of Native Olympia Oysters Under Climate Change. http://www.des.ucdavis.edu/faculty/grosholz/research.htm#OlympiaOysters

Gulland, F.M.D., Baker, J.D., Howe, M., LaBrecque, E., Leach, L., Moore, S.E., Reeves, R.R., & Thomas, P.O. (2022). A review of climate change effects on marine mammals in United States waters: Past predictions, observed impacts, current research and conservation imperatives. Climate Change Ecology 3: 100054. https://doi.org/10.1016/j.ecochg.2022.100054

Hobday, A.J., Alexander, L.V., Perkins, S.E., Smale, D.A., Straub, S.C., Oliver, E.C.J., Benthuysen, J.A., Burrows, M.T., Donat, M.G., Feng, M., Holbrook, N.J., Moore, P.J., Scannell, H.A., Sen Gupta, A., Wernberg, T. (2016). A hierarchical approach to defining marine heatwaves. Progress in Oceanography, 141, 227–238. ISSN 0079-6611. https://doi.org/10.1016/j.pocean.2015.12.014.

Ingman, K., Hines, E., Mazzini, P.L.F., Rockwood, R.C., Nur, N., Jahncke, J. (2021). Modeling changes in baleen whale seasonal abundance, timing of migration, and environmental variables to explain the sudden rise in entanglements in California. PLoS ONE 16(4): e0248557. https://doi.org/10.1371/journal.pone.0248557

International Union for Conservation of Nature. (2022). IUCN Red List. https://www.iucnredlist.org/species/

Johns, M.E., Spears, A. & Warzybok, P. 2020. Population Size and Reproductive Performance of Seabirds on Southeast Farallon Island, 2020. *Unpublished report* to the U.S. Fish and Wildlife Service. Point Blue Conservation Science, Petaluma, California. Point Blue Conservation Science Contribution Number 2336. http://www.prbo.org/refs/search.php

Kanive, P.E., Rotella, J.J., Chapple, T.K., Anderson, S.D., White, T.D., Block, B.A., & Jorgensen, S.J. (2021). Estimates of regional annual abundance and population growth rates of white sharks off central California. Biological Conservation 257 (2021) 109104. https://www.sciencedirect.com/science/article/pii/S0006320721001567

Kimbro, D.L. & Grosholz, E.D. (2006). Disturbance influences oyster community richness and evenness, but not diversity. Ecology, 87(9), 2378–2388.

Kornbluth, A., Perog, B.D., Crippen, S., Zacherl, D., Quintana, B., & Grosholz, E.D. (2022). Mapping oysters on the Pacific coast of North America: A coast-wide collaboration to inform enhanced conservation. PLoS ONE 17(3): e0263998. https://doi.org/10.1371/journal.pone.0263998

Lau, M. (2020). Breeding Western Snowy Plover Monitoring at Point Reyes National Seashore, Marin County, California, 2020 Annual Report. *Unpublished report*, Point Reyes National Seashore, Point Reyes Station, CA.

Lindquist, K., & Roletto, J. (2022a). *Beach Watch database* [Data set]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of National Marine Sanctuaries, Greater Farallones National Marine Sanctuary & Greater Farallones Association. https://bwonline.beachwat.ch/BeachWatchData.php

Multi-Agency Rocky Intertidal Network (MARINe). (2022). GIS Interactive Map and Data Display. https://marine.ucsc.edu/explore-the-data/interactive-map/index.html

Munro, M. (2017). What's killing the world's shorebirds? Nature 541, 16–20 (2017). https://doi.org/10.1038/541016a

NOAA Fisheries. (2020). West Coast large whale entanglement response program. https://www.fisheries.noaa.gov/west-coast/marine-mammal-protection/west-coast-large-whaleentanglement-response-program

NOAA Integrated Ecosystem Assessment (NOAA IEA). (2022). California Current Integrated Ecosystem Assessment Indicators. https://www.integratedecosystemassessment.noaa.gov/regions/california-current/california-current-iea-indicators

Office of National Marine Sanctuaries (ONMS). (2010). *Gulf of the Farallones National Marine Sanctuary: 2010 condition report.* U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service. https://sanctuaries.noaa.gov/science/condition/gfnms/

Office of National Marine Sanctuaries (ONMS). (2014). Gulf of the Farallones National Marine Sanctuary, Final Management Plan, Updated December 2014. San Francisco, CA. pps. 296. https://farallones.noaa.gov/manage/management_plan.html

Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO). (2022). Data portal. https://www.piscoweb.org/data-access

Piatt, J. F., Sydeman, W. J., & Wiese, F. (2007). Introduction: a modern role for seabirds as indicators. *Marine Ecology Progress Series*, *352*, 199–204. http://www.jstor.org/stable/24872144

Raimondi, P. & J. Smith. (2022). Assessment of Rocky Intertidal Habitats for the California Marine Protected Area Monitoring Program: Decal Report. Unpublished report to Ocean Protection Council and U.C. Sea Grant. 360 pps. https://caseagrant.ucsd.edu/sites/default/files/MPA_Rocky_Intertidal_decadal_report_FINAL_1_12_2022.pdf

Rogers-Bennett, L. & Catton, C.A. (2019). Marine heat wave and multiple stressors tip bull kelp forest to sea urchin barrens. Scientific Reports 9:15050 https://doi.org/10.1038/s41598-019-51114-y

Rogers-Bennett, L., Kashiwada, J.V., Taniguchi, I.K., Kawana, S.K., & Catton, C.A. (2019). Using density-based fishery management strategies to respond to mass mortality events. Journal of Shellfish Research, 38(2): 485–495. https://doi.org/10.2983/035.038.0232

Sanford, E., Sones, J.L., García-Reyes, M., Goddard, J.H.R., & Largier, J.L. (2019). Widespread shifts in the coastal biota of northern California during the 2014–2016 marine heatwaves. Scientific Reports 9:1–14.

Santora, J.A., Mantua, N.J., Schroeder, I.D., Field, J.C., Hazen, E.L., Bograd, S.J., Sydeman, W.J., Wells, B.K., Calambokidis, J., Saez, L., Lawson, D., & Forney, K.A. (2020). Habitat compression and ecosystem shifts as potential links between marine

heatwave and record whale entanglements. Nature Communications 11, 536 https://doi.org/10.1038/s41467-019-14215-w

Schroeder, I.D., Santora, J.A., Bograd, S.J., Hazen, E.L., Sakuma, K.M., Moore, A.M., Edwards, C.A., Wells, B.K., and Field, J.C. (2019). Source water variability as a driver of rockfish recruitment in the California Current Ecosystem: implications for climate change and fisheries management. Canadian Journal of Fisheries and Aquatic Sciences. https://doi.org/10.1139/cjfas-2017-0480

Sedinger, J.S., Riecke, T.V., & Ward, D.H. (2019). The black brant population is declining based on mark recapture. The Journal of Wildlife Management 83(3):627–637; 2019; DOI: 10.1002/jwmg.21620

Scopel, L.C., Bednar, C.M., McCheseny, G.J., Baran, M.A., Swanson, N.J., Balitbit, M.V., Birch, M., Mang, A.S., & Golightly, R.T. (2023). *Restoration of common murre colonies in central California: Annual report 2021* [Unpublished report]. U.S. Department of the Interior, U.S. Fish and Wildlife Service, San Francisco Bay National Wildlife Refuge Complex and Humboldt State University, Department of Wildlife.

Spears, A., Johns, M.E., & Warzybok, P. (2022). Population Size and Reproductive Performance of Seabirds on Southeast Farallon Island, 2021. Unpublished report to the U.S. Fish and Wildlife Service. Point Blue Conservation Science, Petaluma, California. Point Blue Conservation Science Contribution Number 2411. http://www.prbo.org/refs/simple_search.php

Tanaka, K.R., Van Houtan, K.S., Mailander, E., Dias, B.S., Galginaitis, C., O'Sullivan, J., Lowe, C.G., & Jorgensen, S.J. (2021). North Pacific warming shifts the juvenile range of a marine apex predator. Scientific Reports 11:3373.

Wasson, K., Zabin, C., Bible, J., Briley, S., Ceballos, E., Chang, A., Cheng, B., Deck, A., Grosholz, T., Helms, A., Latta, M., Yednock, B., Zacherl, D., & Ferner, M. (2015). *A guide to olympia oyster restoration and conservation*. http://www.sfbaysubtidal.org/OYSTERGUIDE-FULL-LORES.pdf

Commented [33]: The actual publication "date" was in 2018 but the volume is June 2019 so the formal citation should be 2019.

Question 14: What is the status of non-indigenous species and how is it changing?

Coastal and Offshore Region (Q14)

Status Rating: Good	Status Confidence: Low
Trend Rating: Undetermined	Trend Confidence: Medium
Status Description: Non-indigenous species are present but do not appear to affect ecological integrity (full community development and function).	

Rationale: Non-indigenous species continue to be present within the coastal/offshore region of GFNMS but evidence suggests limited impacts. However, abundance, density and spatial distribution status and trend data about non-indigenous species are limited, and more long-term monitoring and systematic surveys are needed. Existing data show an increase in non-indigenous species detections, but do not indicate density or impact.

Findings From the 2010 Condition Report

The status and trend of non-indigenous species in the coastal and offshore region in the 2010 condition report was good and not changing (ONMS, 2010). This rating reflected knowledge that non-indigenous species, such as *Codium fragile* spp.), were present in this region of the sanctuary but species of concern did not appear to be affecting ecosystem integrity. The report also identified the need for more monitoring.

New Information in the 2010–2022 Condition Report

Updated information on the numbers of non-indigenous species and the presence of species of concern in or near the sanctuary were evaluated. Information on six species of concern (*Caulacanthus okamurae*, *Watersipora* spp., *Didemnum* spp., *Codium fragile*, *Sargassum muticum*, and *Undaria pinnatifida*) were considered. These species were identified due to their inclusion in the 2010 report and input from subject matter experts.

Table S.LR.14.1. Summaries for the key indicators related to non-indigenous species in the coastal and offshore region that were discussed during the May 24, 2022 virtual status and trends workshop.

Indicator	Source	Data Summary	Figures
Species richness	Fofonoff et al., 2022	Status: Non-indigenous species were present within sanctuary, but limited data on these species were available. Trend: Increasing	S.LR.14.1
Caulacanthus okamurae (algae)	Zabin et al., 2018; MARINe, 2021	Status: First observed near Santa Maria Creek in 2014 and at Bodega Marine Life Refuge 2018, 2019, and 2020; also present at MARINe's Santa Maria Creek site in 2018 and 2021 Trend: Undetermined. Time series and density data limited.	S.H.10.1; S.LR.14.2
Watersipora spp. (bryozoans)	Mackie et al., 2012; MARINe, 2021; Zabin et al., 2018	Status: Limited studies. First observed near Santa Maria Creek in 2014, but recently detected in 2021 at Santa Maria Creek MARINe site. Trend: Undetermined. Time series and density data limited.	S.H.10.1

Didemnum spp. (tunicates)	MARINe, 2021	Status: Present within sanctuary Mussel Flat SFI and at multiple MARINe sites in nearby areas outside the sanctuary Trend: Undetermined. Time series and density data limited.	S.H.10.1
Codium fragile spp. (algae)	MARINe, 2021	Status: Present within sanctuary at Mussel Flat SFI and the Santa Maria Creek survey site Trend: Undetermined. Time series and density data limited.	S.H.10.1; S.LR.14.2
Sargassum muticum (Japanese wireweed)	Freiwald, 2020; MARINe, 2021	Status: Recently observed within the sanctuary in 2021, the first documentation since 1973 Trend: Undetermined. Time series and density data limited.	S.H.10.1
Undaria pinnatifida (wakame)	Freiwald, 2020	Status: Not present within the sanctuary; Limited non-targeted monitoring efforts; Prevalent in nearby regions Trend: Undetermined. Time series and density data limited.	
Data gap: Data are limited for long-term monitoring of density and geographic extent for most non-indigenous species.			

While information is limited in the coastal and offshore region of GFNMS, non-indigenous species (NIS) of concern are present and are known to have localized impacts. NIS are documented in the coastal and offshore region of GFNMS primarily by the Multi-agency Rocky Intertidal Network (MARINe) at six long-term monitoring sites and through some targeted NIS surveys. These data are for presence only, and do not indicate abundance or persistence (see MARINe [2021] for detailed methodology). As of 2020, 84 non-indigenous species have become established (reproducing) within the sanctuary (Fofonoff et al., 2022; Figure S.LR.14.1; Table S.LR.14.2) and 22 of those are found in the coastal and offshore habitat. Of the 22 species, three species (*Megasyllis nipponica*, *Perophora japonica*, and *Watersipora n*. spp. haplotype) were documented solely in the coastal and offshore habitat while 19 species, representing nine taxonomic groups, were documented in both the coastal and offshore and estuarine and lagoon regions of the sanctuary (Fofonoff et al., 2022). The remainder (n = 61) were found in estuarine and lagoon habitat only, and are discussed further in the following question. The number of NIS within the sanctuary region has increased greatly over the last century, but during the study period the rate of increase has slowed (Figure S.LR.14.1).

Overall, there have been fewer observations of non-indigenous species in the coastal and offshore region, as compared to the estuarine and lagoon region. This difference can be explained by a variety of potentially attributing factors. In the coastal and offshore region, higher energy, wave-swept habitats may hinder the establishment of some non-indigenous invertebrates, such as those that are transported from an estuarine habitat and are thus not well adapted to characteristics of the offshore environment (e.g., food availability, predation, temperature, etc.; Preisler et al., 2009; Ruiz et al.,1997; Zabin et al., 2018). Further, offshore areas are often too inaccessible or expensive to survey routinely, limiting the spatial and

temporal coverage of monitoring efforts. Alternatively, the lower energy waters of estuarine and lagoon regions have been monitored more frequently over time due to an ease of access for surveys, as well as a known niche availability and presence of common vectors (e.g., shipping and aquaculture) for non-indigenous species of interest (Bailey et al., 2020; Preisler et al., 2009; Ruiz et al., 1997; Ruiz et al., 2009; Wasson et al., 2005; Zabin et al., 2018).

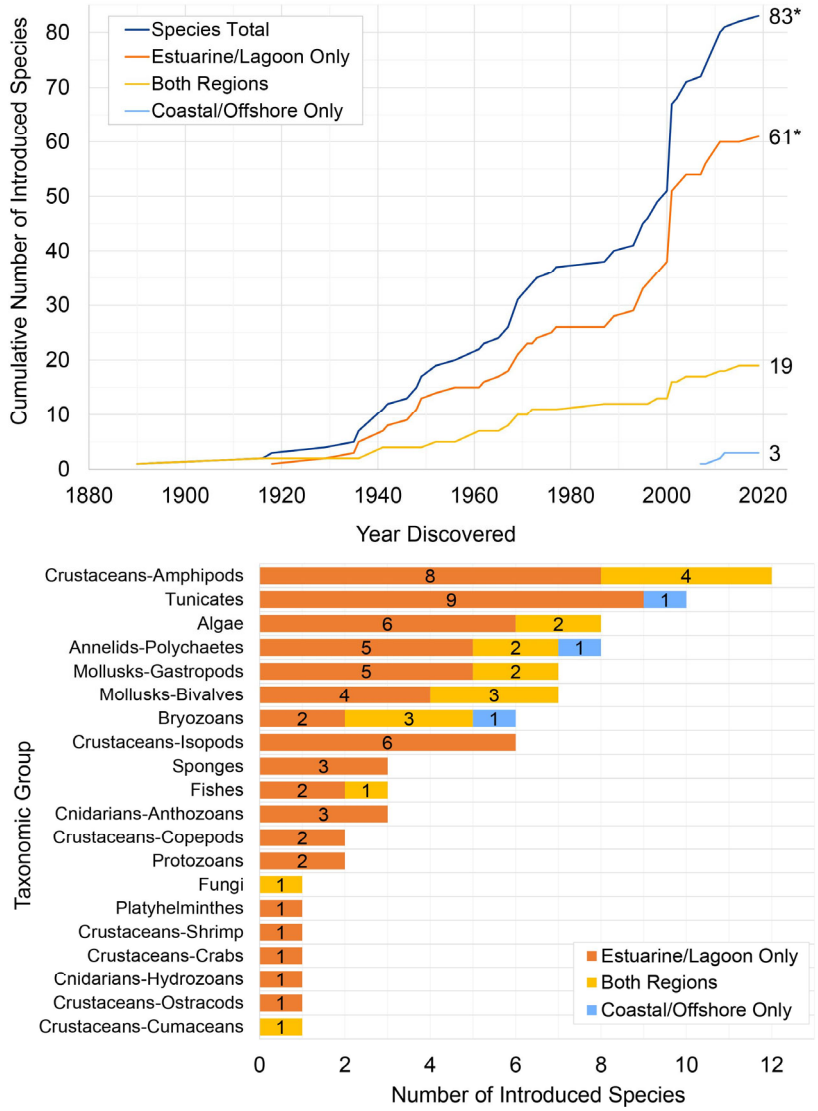

Figure S.LR.14.1. Cumulative non-indigenous species richness, based on year of first observation (top) sanctuary-wide and by region within GFNMS; and by taxonomic group in GFNMS (bottom). Asterisk (*) indicates that one record within the estuarine region had no year associated with the observation and was thus not included in the figure; the total number is 84. Survey records and effort were not equally distributed across the regions. Source: Fofonoff et al., 2022

Table S.LR.14.2. List of 84 established non-indigenous species in GFNMS from observations made since 1890. One asterisk (*) indicates species observed in both habitats, two asterisks (**) indicate species observed in coastal/offshore only, all others are estuarine/lagoon only. Source: Fofonoff et al., 2022

Taxonomic Group	**Species**	
Algae	*Agarophyton vermiculophyllum**	*Gelidium vagum*
	*Caulacanthus okamurae**	*Pyropia suborbiculata*
	Codium fragile ssp. *fragile*	*Sargassum muticum*
	Fucus spiralis	*Ulva australis*
Annelids-Polychaetes	*Alitta succinea*	*Polydora cornuta*
	Heteromastus filiformis sp. complex	*Pseudopolydora cf. kempi**
	*Megasyllis nipponica***	*Pseudopolydora paucibranchiata**
	Neodexiospira brasiliensis	*Streblospio benedicti*
Bryozoans	*Bugula neritina**	*Schizoporella japonica**
	*Bugulina stolonifera**	*Watersipora n.* sp.**
	Cryptosula pallasiana	*Watersipora subatra*
Cnidarians-Anthozoans	*Diadumene franciscana*	*Nematostella vectensis*
	Diadumene lineata	
Cnidarians-Hydrozoans	*Climacocodon ikarii*	
Crustaceans-Amphipods	*Ampelisca abdita*	*Incisocalliope derzhavini*
	Ampithoe valida	*Jassa marmorata**
	Caprella mutica	*Monocorophium acherusicum**
	Corophium alienense	*Monocorophium insidiosum**
	Corophium heteroceratum	*Monocorophium uenoi*
	*Grandidierella japonica**	*Paracorophium* sp.
Crustaceans-Copepods	*Mytilicola orientalis*	*Pseudodiaptomus marinus*
Crustaceans-Crabs	*Carcinus maenas*	
Crustaceans-Cumaceans	*Nippoleucon hinumensis**	
Crustaceans-Isopods	*Gnorimosphaeroma rayi*	*Niambia capensis*
	Iais californica	*Pseudosphaeroma* sp. A
	Limnoria quadripunctata	*Sphaeroma quoianum*
Crustaceans-Ostracods	*Spinileberis quadriaculeata*	
Crustaceans-Shrimp	*Upogebia major*	
Fishes	*Acanthogobius flavimanus*	*Morone saxatilis**

	Alosa sapidissima	
Fungi	*Claviceps purpurea var. spartinae**	
Mollusks-Bivalves	*Arcuatula senhousia**	*Mytilus galloprovincialis**
	Gemma gemma	*Ruditapes philippinarum*
	Geukensia demissa	*Theora lubrica*
	*Mya arenaria**	
Mollusks-Gastropods	*Batillaria attramentaria**	*Philine auriformis**
	Haminoea japonica	*Philine orientalis*
	Myosotella myosotis	*Urosalpinx cinerea*
	Ocinebrellua inornatus	
Platyhelminthes	*Cercaria batillariae*	
Protozoans	*Ancistrocoma pelseneeri*	*Trochammina hadai*
Sponges	*Cliona sp.*	*Hymeniacidon perlevis*
	Halichondria bowerbanki	
Tunicates	*Ascidia zara*	*Didemnum vexillum*
	Botrylloides violaceus	*Diplosoma listerianum*
	Botryllus schlosseri	*Molgula manhattensis*
	Ciona robusta	*Perophora japonica***
	Ciona savignyi	*Polyandrocarpa zorritensis*

The non-indigenous alga *Caulacanthus okamurae* was first observed in GFNMS in 2011 in Tomales Bay (Miller et al., 2011), and was observed for the first time in the coastal and offshore region in 2014 near Santa Maria Creek in Drakes Bay (Zabin et al., 2018). There has been an observed increase in the frequency of detection at the Santa Maria Creek in the Point Reyes National Seashore (2018, 2021) and Bodega Marine Life Refuge (2018–2020) MARINe long-term monitoring sites in recent years (MARINe, 2021). *C. okamurae* is known to displace some invertebrates (e.g., mussels, barnacles) in upper intertidal zone habitats where it has been observed (Figure S.LR.14.2). However, this species may increase habitat complexity and biodiversity in areas where such complexity is not often available, providing refuge, food, and other important ecological benefits to animals and algae in the upper intertidal zone (Smith et al., 2014; MARINe, 2021).

The bryozoan *Watersipora* spp. and tunicate *Didemnum* spp. have been recorded in targeted coastal and offshore studies since the early 2000s (Mackie et al., 2012; Zabin et al., 2018; MARINe, 2021), and while they are present within the sanctuary and contribute to the increase in non-indigenous species composition and distribution, they have little to no known impact within this region of the sanctuary. *Didemnum* spp. are also found within the estuarine and lagoon region of GFNMS and will be discussed in the following section.

Codium fragile (not subspecies-specific)—an invasive green algae known to interfere with commercial fishing gear by fouling gear surfaces and aquaculture by interfering with scallop movement or attaching to shellfish then floating away, taking the animal with it (Fofonoff et al., 2022; Figure S.LR.14.2), and overgrow bivalves and seagrass beds—has been observed at

MARINe long-term monitoring sites at Mussel Flat in 2005 and 2017, and at Santa Maria Creek in 2010 (Figure S.H.10.1; MARINe, 2021), but continues to have unknown status or impact. *Sargassum muticum* is a non-indigenous species of concern at a number of locations on the West Coast—including San Francisco, the Channel Islands, and Washington—due to its potential negative impact to understory algae in kelp habitats (MARINe, 2021; ONMS, 2022). *S. muticum* was previously observed in the estuarine region of the sanctuary in 1973, but was observed off the coast at Point Arena SMR for the first time in 2021 (MARINe, 2021).

FigureS.LR.14.2. (left) photo of invasive red algae *Caulacanthus* spp. Photo: MARINe; (right) photo of the green algae *Codium fragile*. Photo: S. Lonhart, NOAA

Japanese kelp or wakame (*Undaria pinnatifida*) is a non-indigenous species that has not yet been observed within GFNMS, but was considered for the 2010–2022 assessment due to its prevalence and impact in nearby areas and the rapid rate at which it spreads to various habitats. It is listed as one of the world's 100 worst invasive alien species by the International Union for the Conservation of Nature (IUCN; GISD, 2023a, 2022). It is known to overgrow and compete with native algae species (particularly native kelp), and can attach to both natural (shells of abalone,bivalves, algae, etc.) and other hard surfaces (commercial fishing equipment, boat hulls, piers, etc.) in the marine environment (Lowe et al., 2000; De Poorter, 2009). Despite its absence within GFNMS, *U. pinnatifida* is present in nearby regions outside of the sanctuary, including San Francisco Bay, Monterey Bay National Marine Sanctuary, and Channel Islands National Marine Sanctuary (Miller & Engle, 2009; Hastings, 2020).

Conclusion

This question was rated good indicating non-indigenous species are present but do not appear to affect ecological integrity. This is based on the known presence of 22 species in the coastal and offshore environment. However, the known presence of non-indigenous species is not high enough to produce noticeable impacts, but some algae species have the potential to become problematic. The trend was undetermined based on the lack of detailed time series data on NIS. However, documented NIS increased in the sanctuary over the long term, although the rate of increase was slower during the study period compared to the previous century. More systematic and long-term surveys are needed, as well as an increased focus on early detection in order to mitigate and/or prepare for potential negative impacts.

Estuarine and Lagoon Region (Q14)

Status Rating: Fair	Status Confidence: Medium
Trend Rating:Mixed	Trend Confidence: High
Status Description: Non-indigenous species have caused measurable but not severe degradation in some attributes of ecological integrity.	
Rationale: Non-indigenous species continued to be present within the estuarine and lagoon region of GFNMS and these species caused measurable degradation at the local level. In particular, green crabs in Tomales Bay and Bolinas Lagoon and non-native snails in Tomales Bay have had impacts on native species. Non-indigenous species increased over time, but the rate of increase slowed during the study period compared to the last century. Some species declined, such as Spartina spp., while others remained stable (green crabs), or had variable or undetermined trends (snails). Data for most non-indigenous species are limited, and more long-term monitoring and systematic surveys are needed.	

Findings From the 2010 Condition Report

The status and trend of non-indigenous species in the estuarine and lagoon region for the 2010 condition report were fair/poor and undetermined (ONMS, 2010). This rating was based on the high number of non-indigenous species in this region of the sanctuary (e.g., European green crab, Japanese mud snail, smooth cordgrass). The rating of fair/poor indicated that non-indigenous species caused severe degradation in some but not all attributes of ecological integrity (ONMS, 2010).

New Information in the 2010–2022 Condition Report

Updated information on the numbers of non-indigenous species and the presence of species of concern in or near the sanctuary were evaluated. Some new data sets that were not available for the 2010 report were included, such as those on oyster drills and mud snails. Information on five species of concern (*Carcinus maenas*, *Spartina* spp., *Batillaria attramentaria*, *Ocinebrellus inornatus*, and *Urosalpinx cinerea*) were considered. These species were identified due to their inclusion in the 2010 report and input from subject matter experts.

Table S.LR.14.3. Summaries for the key indicators related to non-indigenous species in the estuarine and lagoon region that were discussed during the May 24, 2022 virtual status and trends workshop.

Indicator	Sources	Data Summary	Figures and Tables
Species richness	Fofonoff et al., 2022	Status: Non-indigenous species present within sanctuary. Trend: Increasing	S.LR.14.1

Carcinus maenas (Green crab)	Grosholz et al., 2021	Status: Present in the sanctuary Trend: Not changing; no evidence of elevated recruitment in Tomales Bay and Bolinas Lagoon	S.LR.14.3; S.LR.14.4; S.LR.14.5
Invasive *Spartina* spp. (Cordgrass)	Rohmer & Kerr, 2021	Status: Present in the sanctuary Trend: Improving; mostly eradicated over past 10 years	S.LR.14.3
Ocinebrellus inornatus (Japanese oyster drill)	Rubinoff & Grosholz, 2022a	Status: Present in the sanctuary Trend: Mixed; variable trends in abundance	S.LR.14.3; S.LR.14.6; S.LR.14.7
Urosalpinx cinerea (Atlantic oyster drill)	Rubinoff & Grosholz, 2022a	Status: Present in the sanctuary Trend: Mixed; Variable trends in abundance	S.LR.14.3; S.LR.14.6; S.LR.14.7
Batillaria attramentaria (Japanese mud snail)	Rubinoff & Grosholz, 2022a	Status: Present in the sanctuary Trend: Undetermined. Time series and density data limited to 2015–2019.	S.LR.14.3; S.LR.14.6; S.LR.14.7
Data gaps	Data availability is limited for long-term monitoring, density, and geographic extent of most non-indigenous species.		

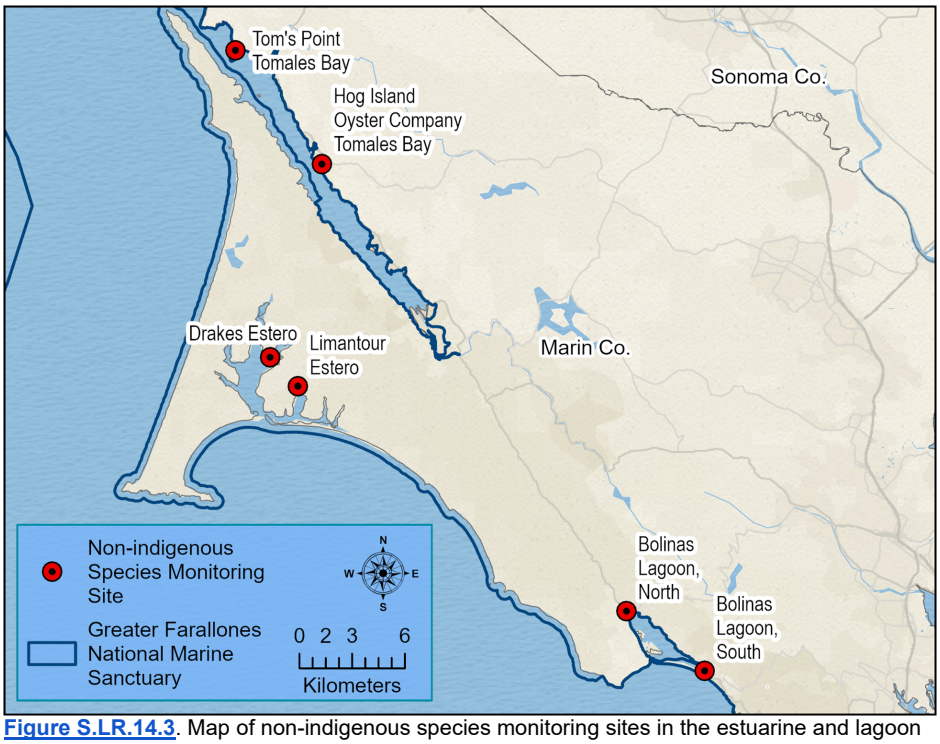

Figure S.LR.14.3. Map of non-indigenous species monitoring sites in the estuarine and lagoon region of GFNMS and adjacent sites in Point Reyes National Seashore at Drakes Estero and Limantour Estero. Image: NOAA; Source: Grosholz et al., 2021; Rohmer & Kerr, 2021; Rubinoff & Grosholz, 2022a; Esri, 2016

As of 2020, 84 established non-indigenous species from 20 different taxonomic groups were observed within the sanctuary, and 81 of those are located in estuarine and lagoon habitats. Of those 81 species, 61 are found only in estuarine and lagoon habitat, and 19 are found in both estuarine and lagoon and coastal and offshore habitat (Fofonoff et al., 2022; Figure S.LR.14.1). Of the 61 species in estuarine and lagoon habitat, five were evaluated as data indicators for this question.

The European green crab (Figure S.LR.14.4), listed on IUCN's Global Invasive Species Database as one of the world's worst invasive species (GISD, 2023b, 2022), first became established in San Francisco in 1989–1990 and spread rapidly, gaining a foothold in shallow, warm estuaries and nearshore lagoon habitats throughout the West Coast of the U.S. (Cohen et al., 2005; Jamieson et al., 1998; Grozholz et al., 2021). They are notably present in Tomales Bay, Bolinas Lagoon, and nearby Bodega Bay (outside GFNMS), where they impact shorebirds and other native species by competing for food. The abundance of European green crabs in the sanctuary suggests they are unlikely to be eradicated, however they have not exhibited evidence of elevated recruitment (Figure S.LR.14.5). Furthermore, while European green crabs have been shown to negatively affect eelgrass in British Columbia (Howard et al. 2019), there has been no such impact observed in GFNMS, where eelgrass density is lower.

Figure S.LR.14.4. Photo of the European green crab (*Carcinus maenas*). Photo: Emily Grason/Univ. of Washington

Alt text: Image of European green crab sitting in an exposed algal bed.

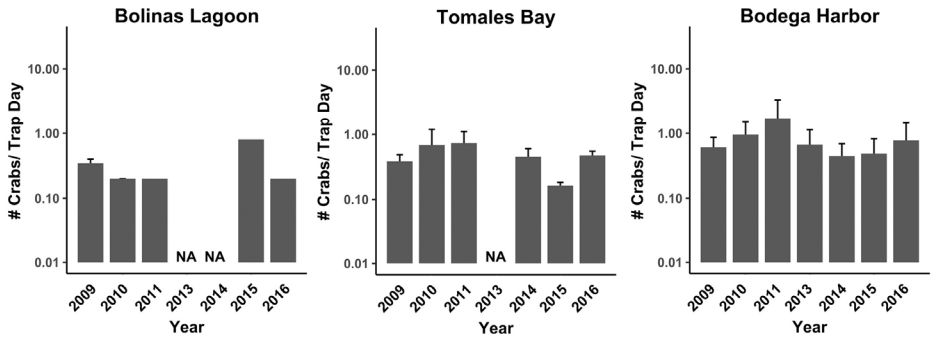

Figure S.LR.14.5. Catch per unit effort of European green crabs from 2009 to 2016 within Bolinas Lagoon (left), Tomales Bay (center), and Bodega Harbor (right) (located outside the GFNMS boundary). Data were not collected in Bolinas Lagoon or Tomales Bay in 2013, or in Bolinas Lagoon in 2014. Catch per unit effort values represent the mean of 10 baited traps in each location over a three-day period, and error bars represent one standard error. Source: Modified from Grosholz et al., 2021 (Copyright 2021 National Academy of Sciences)

The 2010 report identified cordgrass (*Spartina alterniflora*/hybrid and *S. densiflora*), a highly impactful invasive species, as a particular concern for GFNMS due to its interference with local

taxa and ecosystem functions, including filling in mudflats and tidal flats, thus causing loss of habitat for some native species. However, the near eradication of these species is in large part due to the efforts of the San Francisco Estuary Invasive Spartina Project, a monitoring and treatment program that began collecting data, mapping the distribution of the introduced species, and treating them in 2000 (Rohmer & Kerr, 2021). This effort resulted in the near complete removal of *Spartina* in GFNMS and surrounding estuarine habitats in 2018, which has considerably reduced concern for Tomales Bay, Drakes Estero, and Bolinas Lagoon (Rohmer & Kerr, 2021). For example, *S. densiflora* persisted in very low levels (0.02 m^2) in Tomales Bay in 2020.

Japanese oyster drill (*Ocinebrellus inornatus*), mud snail, Atlantic oyster drill (*Urosalpinx cinerea*), and Japanese mud snail), another group of non-indigenous species considered to have negative impacts on the sanctuary's estuary and lagoon habitats, were also included in the status and trend rating for this assessment (Figure S.LR.14.6). The Japanese oyster drill was first observed in Tomales Bay in 1941 (Fofonoff et al., 2022), and the Atlantic oyster drill, initially recorded in San Francisco in 1890, was first observed in Tomales Bay in 1935 (Fofonoff et al., 2022). Both oyster drill species are known to severely impact commercial shellfisheries and reduce native oyster populations (Buhle & Ruesink, 2009; Kimbro et al., 2009; Fofonoff et al., 2022). The Japanese mud snail, a known competitor with native snails, was introduced along with the Pacific oyster (*Crassostrea gigas*) in the early 1900s in Washington, and was first collected in Bolinas Lagoon in 1955, Tomales Bay in 1973, and Drakes Esteros in 1996 (Byers, 1999; Fofonoff et al., 2022). Data presented for this assessment are from a study in Tomales Bay that was initiated to examine the effects of introduced species on native oysters and was then continued as a long-term monitoring effort (2009–2019) (Rubinoff & Grosholz, 2022a; Figure S.LR.14.7). Trends for the Japanese mud snail and Atlantic oyster drill varied from 2009–2019; however, after a sharp increase in abundance from 2012 to 2013, the Japanese oyster drill notably decreased in 2015 and has remained low since (Rubinoff & Grosholz, 2022a). A lack of sampling in 2014 precludes a full understanding of this shift; however, the decrease in abundance may be linked to the 2014–2015 MHW (B. Rubinoff/Washington Sea Grant-University of Washington, personal communication, January 11, 2023), as the temperatures may have increased beyond their threshold.

Figure S.LR.14.6. Photos of the invasive species Japanese mud snail (*Batillaria attramentaria)* at Point Reyes National Seashore (top left). Photo: L. Zentall; Atlantic oyster drill (*Urosalpinx cinerea)* (top right). Photo: E. Grason/Univ. of Washington; Japanese oyster drill (*Ocinebrellus inornatus)* (bottom left). Photo: E. Grason/Univ. of Washington; and a Japanese oyster drill "drilling" into a *Batillaria* sp (bottom right). Photo: E. Grason/Univ. of Washington

Alt text: Top left image shows submerged japanese mud snails in shallow water; top right shows atlantic oyster drill attached to exposed rock and algae; bottom left image shows single Japanese oyster drill against a black background; and bottom right image shows a Japanese oyster drill "drilling" into a *Batillaria* snail in sandy bottom of shallow water.

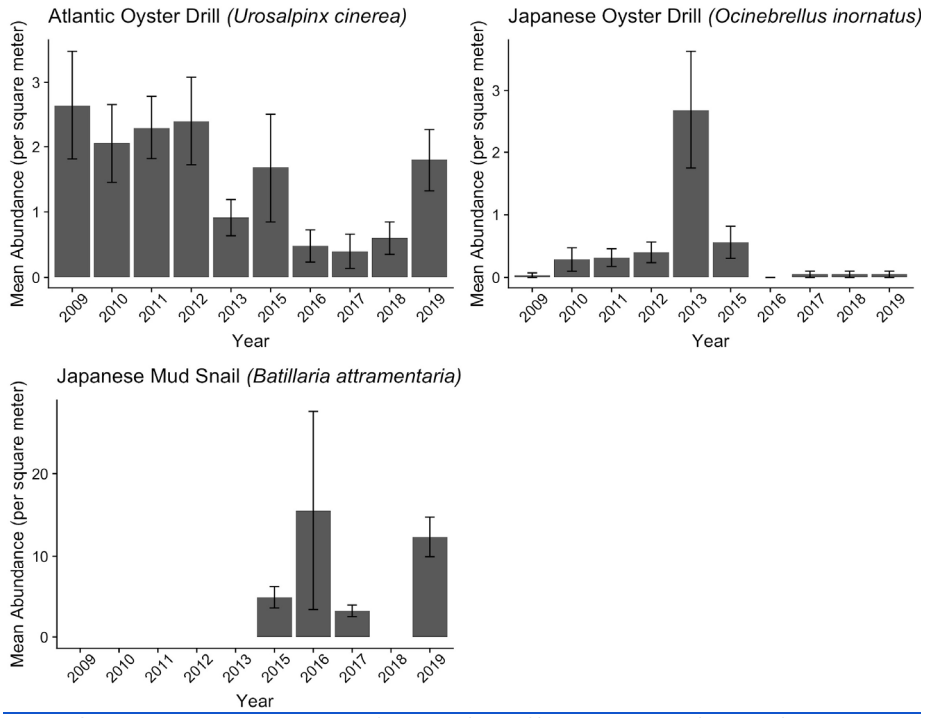

Figure S.LR.14.7. Mean abundance of Atlantic (top left) and Japanese (top right) oyster drills and Japanese mud snail (bottom) from a long-term monitoring effort in Tomales Bay. Note that data collection for the Japanese mud snail did not begin until 2015. Source: Rubinoff & Grosholz, 2022a

Investigative studies on a variety of additional impactful invasive species, such as *Didemnum* spp., *Watersipora subtorquata*, *Molgula manhattensis*, *Arcualtula senhousi*a, and others (Table S.LR.14.2) exist (e.g., Kimbro et al., 2009; Deck, 2010; Long & Grosholz, 2015; Rubinoff & Grosholtz, 2022a); however, gaps in information on the density/abundance or spatial distribution of these species in GFNMS prevent incorporation into status and trend ratings.

Conclusion

In the estuarine and lagoon region of GFNMS, the status of non-indigenous species for 2010–2022 is fair. There were a few species that had considerable impacts on attributes of ecological integrity at a local level. In particular, the continued presence of non-indigenous species such as the European green crab (*Carcinus maenas*) and Japanese mud snail (*Batillaria attramentaria*) within the sanctuary contributed to the fair rating, as both species can cause measurable impacts, but are restricted to specific locations. The improvement to fair, compared to the fair/poor rating in the 2010 report was attributed to the near eradication of *Spartina* and impacts to ecological integrity have not been severe. The trend is mixed based on the overall increase of NIS during the study period, in contrast to improvements in Spartina spp., no change in green crabs, and variable or undetermined trends in snails in Tomales Bay. Although more evidence

was available to support this rating compared to the coastal and offshore region, data availability was still limited due to the lack of long-term monitoring. Most of the available non-indigenous species data only provide species presence/absence information, precluding the assessment of trends in abundance, spatial distribution, or impacts.

References (Q14/Both Regions)

Bailey, S. A., Brown, L., Campbell, M. L., Canning-Clode, J., Carlton, J. T., Castro, N., Chainho, P., Chan, F. T., Creed, J. C., Curd, A., Darling, J., Fofonoff, P., Galil, B. S., Hewitt, C. L., Inglis, G. J., Keith, I., Mandrak, N. E., Marchini, A., McKenzie, C. H., Occhipinti-Ambrogi, A., … Zhan, A. (2020). Trends in the detection of aquatic non-indigenous species across global marine, estuarine and freshwater ecosystems: A 50-year perspective. *Diversity and Distributions*, *26*(12), 1780–1797. https://doi.org/10.1111/ddi.13167

Buhle, E. R., & Ruesink, J. L. (2009). Impacts of Invasive Oyster Drills on Olympia Oyster (*Ostrea lurida* Carpenter 1864) Recovery in Willapa Bay, Washington, United States. *Journal of Shellfish Research*, *28*(1), 87–96.

Cohen, A. N., Carlton, J. T., & Fountain, M. C. (1995). Introduction, dispersal and potential impacts of the green crab *Carcinus maenas* in San Francisco Bay, California. *Marine Biology*, *122*, 225–237. https://doi.org/10.1007/BF00348935

De Poorter, M. (2009). *Marine menace: Alien invasive species in the marine environment*. IUCN Global Marine Programme. https://www.iucn.org/sites/default/files/import/downloads/marine_menace_en_1.pdf

Deck, A. K. (2010). *Effects of interspecific competition and coastal oceanography on population dynamics of the Olympia oyster,* Ostrea lurida, *along estuarine gradients* (Publication No. 1493647). [Masters dissertation, University of California, Davis]. ProQuest Dissertations.

Fofonoff, P. W., Ruiz, G. M., Steves, B., Simkanin, C., & Carlton, J. T. (2022, June 16). National Exotic Marine and Estuarine Species Information System (NEMESIS). https://invasions.si.edu/nemesis/

Freiwald, J. (2020). *Reef Check kelp forest long-term MPA monitoring: Algae data* [Data set]. California Ocean Protection Council Data Repository. https://doi.org/10.25494/P65K5W

Global Invasive Species Database (GISD). (2023a, March 9). *Species profile* Undaria pinnatifida. IUCN/SSC Invasive Species Specialist Group (ISSG). http://www.iucngisd.org/gisd/speciesname/Undaria+pinnatifida

Global Invasive Species Database (GISD). (2023b, March 9). *Species profile* Carcinus maenas. IUCN/SSC Invasive Species Specialist Group (ISSG). http://www.iucngisd.org/gisd/speciesname/Carcinus+maenas

Global Invasive Species Database (GISD). (2022, Sept. 20). *100 of the World's Worst Invasive Alien Species*. http://www.iucngisd.org/gisd/100_worst.php

Grosholz, E., Ashton, G., Bradley, M., Brown, C., Ceballos-Osuna, L., Chang, A., de Rivera, C., Gonzalez, J., Heineke, M., Marraffini, M., & McCann, L. (2021). Stage-specific overcompensation, the hydra effect, and the failure to eradicate an invasive predator. *Proceedings of the National Academy of Sciences*, *118*(12), e2003955118. https://doi.org/10.1073/pnas.2003955118

Hastings, S. (2020, Oct. 30). *When control is constrained to containment: Undaria pinnatifida in the Channel Islands, California* [Session presentation]. Cal-IPC Symposium 2020, California Invasive Plant Council. https://www.cal-ipc.org/wp-content/uploads/2020/12/Cal_IPC_Symposium_2020_Sean_Hastings_Undaria-pinnatifida-in-the-Channel-Islands-when-control-is-constrained-to-containment.pdf

Jamieson, G. S., Grosholz, E. D., Armstrong, D. A., & Elner, R. W. (1998). Potential ecological implications from the introduction of the European green crab, *Carcinus maenas* (Linneaus),

to British Columbia, Canada, and Washington, USA. *Journal of Natural History*, *32*(10–11), 1587–1598. https://doi.org/10.1080/00222939800771121
Kimbro, D. L., Grosholz, E. D., Baukus. A. J., Nesbitt, N. J., Travis, N. M., Attoe, S., & Coleman-Hulbert, C. (2009). Invasive species cause large-scale loss of native California oyster habitat by disrupting trophic cascades. *Oecologia*, *160*, 563–575.
Long, H. A., & Grosholz, E. D. (2015). Overgrowth of Eelgrass by the Invasive Colonial Tunicate Didemnum Vexillum: Consequences for Tunicate and Eelgrass Growth and Epifauna Abundance. J*ournal of Experimental Marine Biology and Ecology*, *473*, 188–194. https://doi.org/10.1016/j.jembe.2015.08.014
Lowe, S., Browne, M., Boudjelas, S., & De Poorter, M. (2000). *100 of the World's Worst Invasive Alien Species A selection from the Global Invasive Species Database* [Updated and reprinted version, November 2004]. The Invasive Species Specialist Group (ISSG), Species Survival Commission (SSC), World Conservation Union (IUCN). https://portals.iucn.org/library/sites/library/files/documents/2000-126.pdf
Miller, K. A. & Engle, J. M. (2009). The natural history of *Undaria pinnatifida* and *Sargassum filicinum* at the California Channel Islands: Non-native seaweeds with different invasion styles. In: C. C. Damiani & D. K. Garcelon (Eds.), *Proceedings of the 7th California Islands Symposium* (pp. 131–140). Institute for Wildlife Studies: Arcata, California.
Miller, K. A., Aguilar-Rosas, L. E., & Pedroche, F. F. (2011). A review of non-native seaweeds from California, USA and Baja California, Mexico. *Hidrobiológica*, *21*(*3*), 365–379.
Multi-Agency Rocky Intertidal Network (MARINe). (2021). Long-term monitoring and biodiversity surveys [Data set]. MARINe: Multi-Agency Rocky Intertidal Network. https://marine.ucsc.edu/index.html
Office of National Marine Sanctuaries (ONMS). (2022). *Olympic Coast National Marine Sanctuary Condition Report: 2008–2019*. National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries.
Preisler, R. K., Wasson, K., Wolf, J. W., & Tyrrell, M. C. (2009). Invasions of estuaries vs. the adjacent open coast: a global perspective. In G. Rilov & J. A. Crooks (eds.), *Biological invasions in marine ecosystems: ecological, management and geographic perspectives* (pp. 587–617). Springer, Berlin.
Rohmer, T. & Kerr, D. (2021). *San Francisco Estuary Invasive Spartina Project 2019–2020 Monitoring and Treatment Report*. Prepared for the State Coastal Conservancy San Francisco Estuary Invasive Spartina Project. https://www.cal-ipc.org/wp-content/uploads/2021/07/2019_2020_ISP_Monitoring_Treatment_Report_Full.pdf
Rubinoff, B. G., & Grosholz, E. D. (2022a). Unpublished data.
Rubinoff, B. G., & Grosholz, E. D. (2022b). Biological Invasions Alter Consumer–Stress Relationships along an Estuarine Gradient. *Ecology*, *103*(6), e3695. https://doi.org/10.1002/ecy.3695
Ruiz, G. M., Carlton, J. T., Grosholz, E. D., & Hines, A. H. (1997). Global invasions of marine and estuarine habitats by non-indigenous species: mechanisms, extent and consequences. *American Zoologist*, *37*(6), 621–632. https://doi.org/10.1093/icb/37.6.621
Ruiz, G. M., Freestone, A. L., Fofonof, P. W., & Simkanin, C. (2009). Habitat distribution and heterogeneity in marine invasion dynamics: the importance of hard substrate and artifcial structure. In M. Wahl (Ed.), *Marine hard bottom communities* (pp. 321–332). Springer, Berlin.
Smith, J. R., Vogt, S. C., Creedon, F., Lucas, B. J., & Eernisse, D. J. (2014). The non-native turf-forming alga *Caulacanthus ustulatus* displaces space-occupants but increases diversity. *Biological Invasions*, *16*(10), 2195–2208. https://doi.org/10.1007/s10530-014-0658-5
Wasson, K. W., Fenn, K., & Pearse, J. S. (2005). Habitat differences in marine invasions of central California. *Biological Invasions*, *7*, 935–948. https://doi.org/10.1007/s10530-004-2995-2

Zabin, C. J., Marraffini, M., Lonhart, S. I., McCann, L., Ceballos, L., King, C. , Watanabe, J., Pearse, J. S., & Ruiz, G. M. (2018). Non-native species colonization of highly diverse, wave swept outer coast habitats in Central California. *Marine Biology*, *165*, 31. https://doi.org/10.1007/s00227-018-3284-4

Question 15: What is the status of biodiversity and how is it changing?

Coastal and Offshore Region (Q15)

Status Rating: Good/Fair	Status Confidence: High
Trend Rating: Mixed	Trend Confidence: High
Status Description: Selected biodiversity loss or change is suspected and may preclude full community development and function, but has not yet caused measurable degradation.	
Rationale: Biodiversity was altered compared to near pristine conditions, but its status during the study period was likely within the expected range of long-term natural variability. This is with the possible exception of range shifts and changes in species composition caused by the 2014–2016 marine heatwave, which, exacerbated by climate change, may have exceeded natural levels of variation. Benthic infauna abundance and species richness were high compared to areas near San Francisco Bay outflow areas. Rocky shore community stability was high. Kelp community indicators (fish, invertebrates, and understory species richness) varied. Forage fish diversity was high and remained stable over time. Groundfish species density was consistent with long-term means and was stable during the study period.	

While the definition of biodiversity includes the full spectrum of species, communities, and genetic diversity, in this report we focus our evaluations on subsets of biodiversity. Specifically we evaluate status and trends for functional groups of species and recognized significant communities, such as kelp communities or forage fish assemblages. This practical approach enables us to apply monitoring information from a variety of sources to evaluate status and trends.

Findings From the 2010 Condition Report

In the 2010 condition report the status of biodiversity for the coastal and offshore region of the sanctuary was rated as good/fair and the trend was not changing. The report considered rocky intertidal community structure and rockfish recruitment as important factors for tracking biodiversity in the sanctuary. It was noted that conditions are neither pristine nor significantly degraded and indicated that long-term trends in physical oceanographic patterns are affecting species distributions and abundance.

New Information in the 2010-2021 Condition Report

Status and trend information for biodiversity was addressed within ecologically defined and measurable groups. We analyzed the status of biodiversity for distinct components of the ecosystem as indicators of the biodiversity of the sanctuary. In addition to the data provided by individual monitoring programs, subject matter experts considered additional factors, such as the 2014–2016 MHW. The effects of the MHW included species distribution shifts, which could affect the biodiversity of the sanctuary in both positive and negative ways. The MHW is described in further detail in the Pressures chapter.

The specific ecological groupings considered in this report include:

- Benthic Infauna (abundance and species richness)
- Rocky shore community stability
- Birds and Mammals
- Kelp communities
- Young of Year Rockfish
- Forage fish diversity
- Groundfish diversity

Table S.LR.15.1. Summaries for the key indicators related to biodiversity in the coastal and offshore region that were discussed during the June 9, 2022 virtual status and trends workshop.

Indicator	Source	Data Summary	Figures
Benthic Infauna (Abundance & Species Richness)	San Francisco Public Utilities Commission (SFPUC 2014, 2021)	Status: High species richness Trend: Stable at 4 of 5 sites	S.LR.15.1
Rocky Shore Community Stability	MARINe (MARINe, 2021)	Status: High diversity Trend: Stable community diversity	
Birds and Mammals Species richness and encounter rates	Lindquist & Roletto, 2022a	Status: Diversity is consistent with long term levels Trend: Stable species richness for birds and mammals	S.LR.15.2
Kelp Community: Estimated Species Richness for Fish, Invertebrates, & Understory Species	PISCO, 2022	Status:Mixed Trend: Species richness varied substantially across species groups and years.	S.LR.15.3
Young of Year Rockfish (abundance): Midwater Trawl	RREAS, (Field et al., 2020)	Indicator discussed in S.LR.13.	S.LR.13.1
Forage Fish: Midwater Trawl	RREAS (Field et al., 2020)	Status: High Trend:Stable	

Commented [34]: no summary here? S.LR.13.4? S.LR.13.4?

Groundfish species per trawl	WCGBTS (NOAA NWFSC, 2021)	Status: Species per trawl consistent with long term levels Trend: In the last five years decreasing on the slope and stable on the upper shelf	S.LR.15.4
Groundfish mean trophic level	WCGBTS (NOAA NWFSC, 2021)	Status: Stable Trend: Stable	S.LR.15.5
Data Gaps: No data gaps were identified for Coastal and Offshore biodiversity			

Benthic Infauna

Benthic infauna abundance and species richness are tracked as one component of the Southwest Ocean Outfall Monitoring Program, which is described in more detail in Question 7. A map of survey site locations is included in chapter 7, Figure S.WQ.7.4. These data indicated that species richness was high within the sanctuary (stations 32, 34, 35, 36, 39) when compared to surrounding areas (not shown). There was a stable trend for species richness at most sites within the sanctuary, with the exception of one site (station #32), which showed a statistically significant decline from 2010–2020 (Figure S.LR.15.1). Additionally, we considered data on total infauna abundance, diversity and evenness, and no clear trends were found.

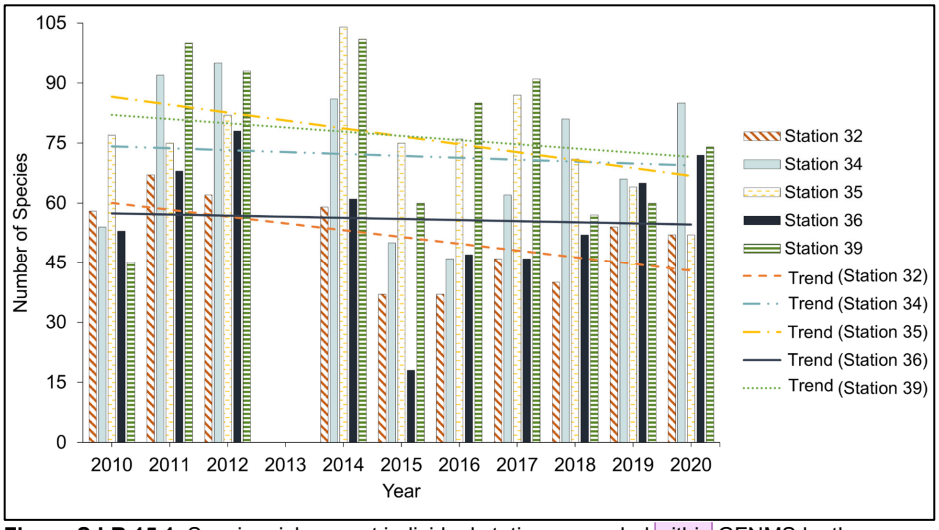

Figure S.LR.15.1. Species richness at individual stations recorded within GFNMS by the Southwest Ocean Outfall Monitoring Program. Source: SFPUC, 2021

Commented [35]: kinda hard to read this figure, but its not yours so..otherwise, perhaps put the trends on another graph

Rocky Shore Community Stability

Information on rocky intertidal communities is collected and shared through the Multi-Agency Rocky Intertidal Network (MARINe). This organization monitors over two hundred sites from

Alaska to Mexico. Here we focus on four monitoring sites within the sanctuary (Site names: Sea Ranch, Bodega Marine Life Refuge, Santa Maria Creek & Bolinas Point, note: Santa Maria Creek is within Point Reyes National Seashore but is included in this analysis because its location within the sanctuary provides ecosystem context for the sites within the sanctuary). Community diversity metrics showed that species communities at Bodega Marine Life Refuge, Bolinas Point, and Santa Maria Creek were remarkably stable over time while Sea Ranch varied more (plots in earlier years contained high cover of the turfweed (*Endocladia muricata*), black pine (*Neorhodomela larix*), and acorn barnacles (*Chthamalus/Balanus* spp.), and more recent years shifted to higher cover of rockweed (*Pelvetiopsis limitata*).

Commented [36]: map or table?

Birds and Mammals

Marine mammals and avian species are monitored by the sanctuary through the Beach Watch program (see Box 2: Beach Watch). Beach Watch data provided bird and mammal species richness as a potential measure of biodiversity on outer coast beaches. Data for marine mammal and avian species richness showed stability over time, but did indicate an apparent drop in species richness for birds in 2020, but that may be an artifact of reduced survey effort that year due to the COVID-19 pandemic. (Figures S.LR.15.2)

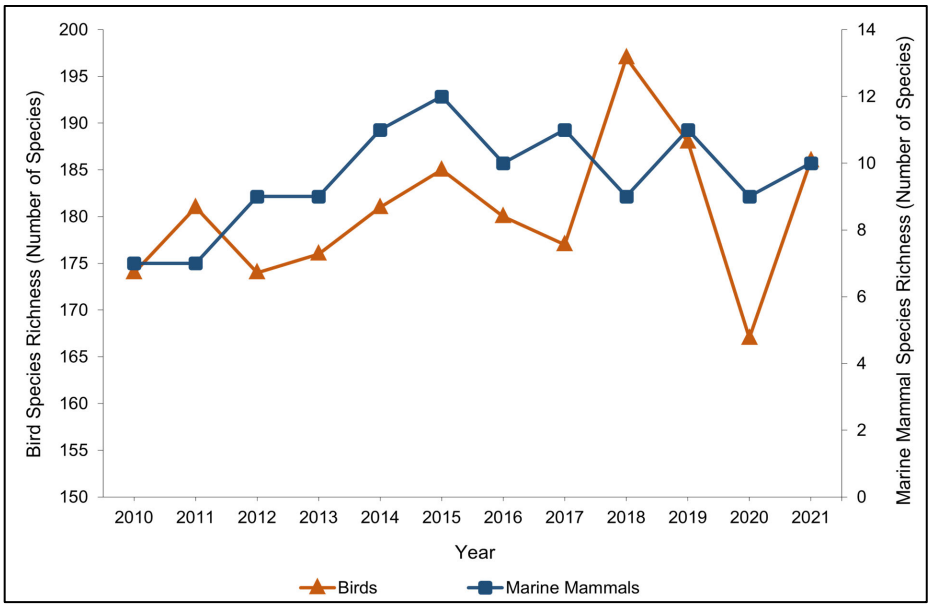

Figure S.LR.15.2. Bird and mammal species richness (# of species) from the Beach Watch Monitoring Program. The 2020 anomaly was likely due to greatly reduced survey effort. Source: Lindquist & Roletto, 2022b

Kelp Community

The Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO), is a long term scientific program led by scientists from four partnering universities. This program includes kelp forest community monitoring. Information on kelp fish biodiversity, invertebrate species

biodiversity, and understory kelp species biodiversity were evaluated. No data is available for 2012–2015, but from 2016–2020, experts noted an apparent consistent decline in kelp forest fish species richness following the marine heat wave, and a slight increase in 2021 (Figure S.LR.15.3). This trend is not seen in the information on invertebrate species biodiversity or understory kelp species biodiversity (Figure S.LR.15.3). This creates a mixed signal from this indicator.

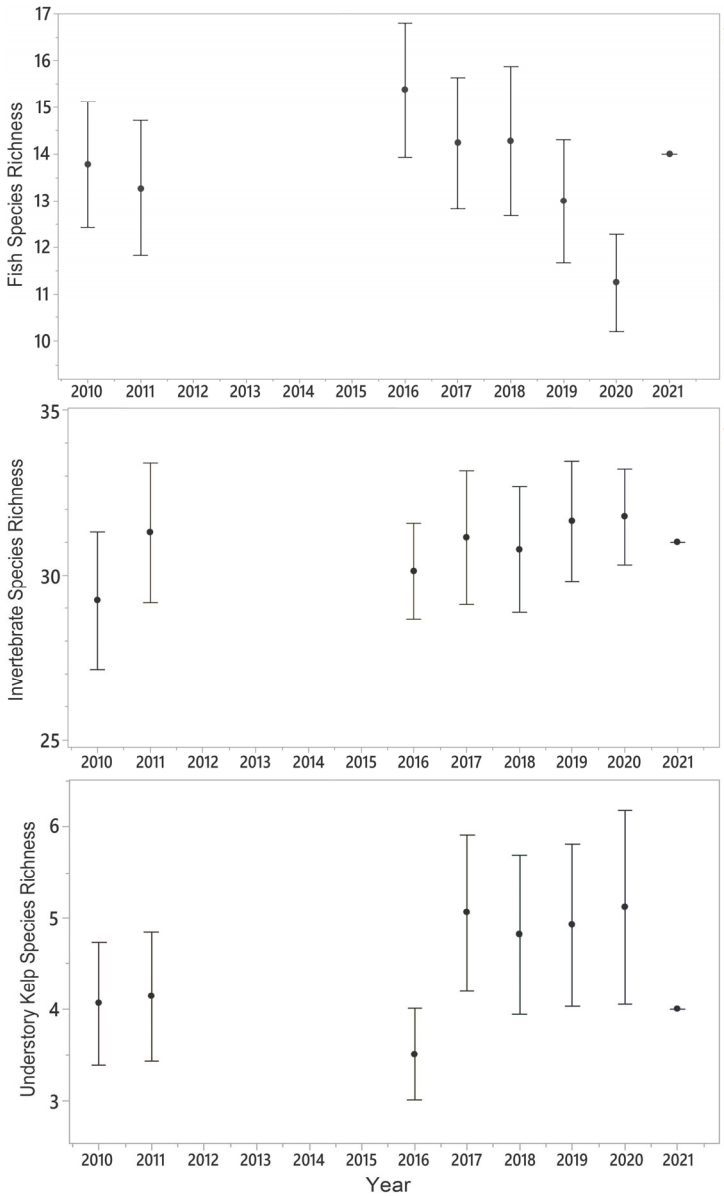

Figure S.LR.15.3. Estimated fish (top), invertebrate (middle), and understory kelp (bottom) species richness across sites within the kelp community of the sanctuary. Data was standardized to 2021 sample size to avoid sampling effort bias and included sites from Pt.

Arena State Marine Reserve, Saunders Reef State Marine Conservation Area, Stewarts Point State Marine Reserve, and reference areas. Because we had widely different numbers of transects done in different years, and at different sites within those years, we used a resampling approach to estimate species richness for the region as a whole. Source: Adapted from PISCO (2022).

Rockfish (Young of Year)

Rockfish are an important biodiversity indicator because of their role in the food web and as recreational and commercial fisheries. This metric is discussed in S.LR.13.

Commented [37]: Still, a brief recap could be used here

Forage Fish: Mid-Water Trawl (Rockfish Recruitment and Ecosystem Assessment Survey)

The Fisheries Ecology Division of NOAA's Southwest Fisheries Science Center (SWFSC) has conducted the Rockfish Recruitment Ecosystem Assessment Survey (RREAS) since 1983. This survey incorporates mid-water trawl surveys, conductivity temperature depth (CTD) surveys, acoustic surveys of the water column, visual surveys of mammals and seabirds, and plankton surveys. For a more complete description of how all of these components can be used together to track biodiversity see Pelagic Biodiversity, Ecosystem Function, and Services in Oceanography, Vol. 34, No.2 (Santora et al 2021).Forage fish species richness was an indicator of biodiversity and assessed through midwater trawl monitoring data from the RREAS core study region.The midwater trawl data enabled us to track a component of biodiversity which may be experiencing shifts due to human or natural effects. Forage fish species richness is high and the trend stable. Whereas all taxa biodiversity from the mid-water trawl showed a decreasing trend (see Santora et al figure 3b).

Groundfish

NOAA's National Marine Fisheries Service (NMFS) conducts the West Coast Groundfish Bottom Trawl Survey (WCGBTS) to collect fishery-independent data used for stock assessments and groundfish management. Groundfish include more than 90 different types of groundfish, flatfish, rockfish, sharks, and skates off the U.S. West Coast. Groundfish primarily live on or near the seafloor. Trawl datasets from the continental shelf (55–200 m) and upper slope (201–400 m) within the sanctuary, were derived from the West Coast Groundfish Bottom Trawl Survey (NOAA NWFSC, 2021) and analyzed by the California Current Integrated Ecosystem Assessment team (CCIEA) based on the approaches used in NOAA's California Current Ecosystem Status Report (Harvey et al., 2021). The number of species per trawl provides a measure of species density (Figure S.LR.15.4). Species density was stable on the continental shelf from 2016–2021, but species density for the upper slope decreased by more than one standard deviation of the long-term mean over the same period.

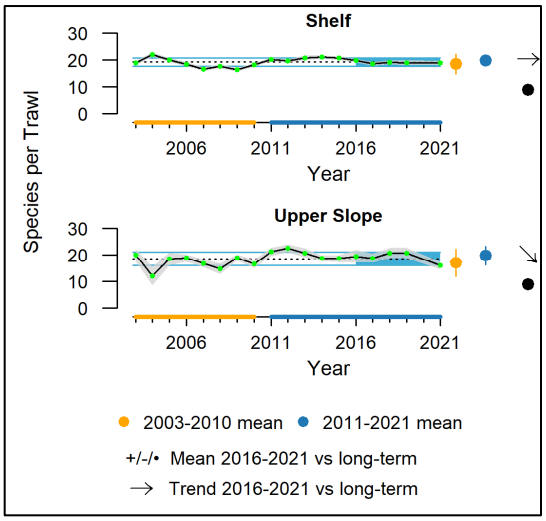

Figure S.LR.15.4. Groundfish species density (# species per trawl) within the sanctuary. Data is shown relative to the mean (black dotted horizontal line) and 1.0 s.d. (solid blue lines) of the full time series. Dotted black trend line indicates missing data, and points (when included) indicate data. Points to the right of the figure indicate the mean ± 95% confidence interval for the time periods indicated by the corresponding color along the x-axis. The arrow at the right indicates if the trend over the evaluation period (shaded blue) increased (↗), decreased (↘) by more than 1.0 s.d. of the full time series or whether there was no change (→). The symbol at the lower right indicates if the recent mean was greater than (+), less than (-), or within (•) 1.0 s.d. of the long-term mean. Time series indicate observation error (gray envelope), defined as +/- one standard error.
Figure from the West Coast Groundfish Bottom Trawl Survey. Source: NOAA NWFSC, 2021

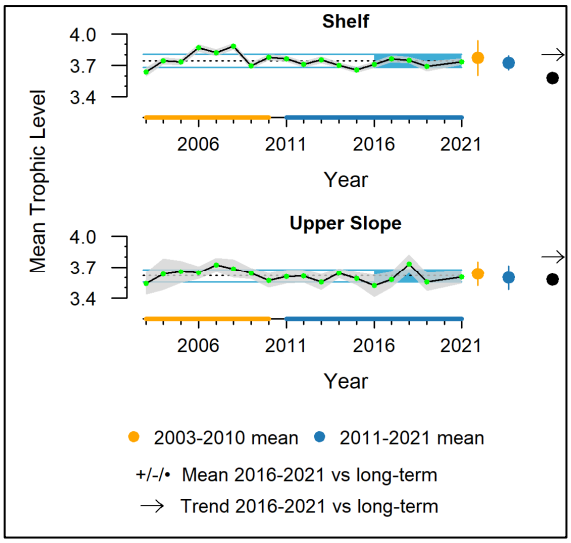

Figure S.LR.15.5. Groundfish Mean Trophic Level. Figure from the West Coast Groundfish Bottom Trawl Survey. Source: NOAA NWFSC, 2021

In addition to evaluating species density, we consider mean trophic level (MTL) as a biodiversity indicator. MTL provides us with information on community structure, which is an important component of biodiversity. Changes in MTL indicate changes in the trophic structure of the assemblage. On the shelf MTL ranged from 3.64 to 3.88. While variable, over the last five years MTL has been around the long-term mean since 2016. On the upper slope, MTL ranged from 3.52 to 3.73. MTL increased from its lost level in 2016 to around its long-term average in 2021, but this increase was within 1.0 s.d. of the long-term mean[2] (Figure S.LR.15.5).

Conclusion

Though some biodiversity loss is suspected within the sanctuary ~~compared to unaltered conditions~~, most indicators were within the expected range of long-term natural variation. The trend over the study period was mixed based on the variety of responses observed in the ecological groups evaluated. Benthic infauna showed high diversity compared to the surrounding area. Most sites within the sanctuary had a stable trend, but one of the five sites had a statistically significant decrease.. The rocky intertidal community also showed high diversity and a stable trend based on information from the Multi-Agency Rocky Intertidal Network. Kelp forest species composition surveys from PISCO provided a mixed signal both for status and trends with a decline in kelp forest fish species from 2016–2021 but stable trends in invertebrates and understory kelp species during the same time period. Based on data from mid-water trawls, forage fish species richness was high with a stable trend. Groundfish species density was stable on the continental shelf and decreased on the upper slope from 2016–2021.

Commented [38]: Is there a basis or definition here for "pristine" (used earlier) or "unaltered" conditions? I'm always curious (and suspicious) when I see those terms, on what that means or how it is determined.

Commented [39]: Is it worth mentioning that this seems counterintuitive relative to the overall negative impacts/condition/trends in kelp forest communities described earlier?

[2] While MTL was not presented at the expert workshop, it is shown here in place of Catch Per Unit Effort (CPUE) as it is considered to have greater relevance to evaluating biodiversity status and trends.

Estuarine and Lagoon Region (Q15)

Status Rating: Undetermined	Status Confidence: High
Trend Rating: Undetermined	Trend Confidence: High
Status Description: Status is undetermined.	
Rationale: There are no known comprehensive surveys of biodiversity across the sanctuary's estuarine and lagoon region. Some information on aquatic vegetation distribution and avian fauna exists, but the data were not sufficient to assess biodiversity status or trends for this component of the sanctuary.	

Findings From the 2010 Condition Report

In the previous condition report biodiversity in the estuarine and lagoon region of the sanctuary was rated fair/poor with a worsening trend. This was based on loss of eelgrass habitat, particularly in Tomales Bay.

New Information in the 2010–2022 Condition Report

While there are no comprehensive surveys or consistent monitoring across the four estuary/lagoon habitats, there is some information from monitoring efforts for eelgrass and shoreline habitats. The following indicators were presented to experts for consideration of determining status and trends across the estuarine and lagoon region.

Table S.LR.15.2. Summaries for the key indicators related to biodiversity in the estuarine and lagoon region that were discussed during the June 9, 2022 virtual status and trends workshop.

Indicator	Source	Data Summary	Figures and Tables
Shorebirds & Mammals	Lindquist & Roletto, 2022a	Status: Biodiversity is consistent with long term levels Trend: Seabird species richness stable, marine mammal species richness variable and possibly increasing	Figure S.LR.15.6
Wintering Shorebirds	Warnock et al., 2021	Status: Not available Trend: Not available	
Data Gaps: There are currently no surveys addressing the biodiversity of the estuaries and lagoons of the sanctuary. Eelgrass monitoring, fish monitoring, invertebrate monitoring, benthic infauna, habitats and water quality should all be addressed.			

Shorebirds and Mammals

The Beach Watch Program conducts bi-monthly, effort-based shoreline surveys of bird and mammal species at three locations in Tomales Bay and Bolinas Lagoon (see Box 2: Beach Watch). Bird species richness is stable over the study period. Species richness of marine mammals is more variable over time, with a possible increasing trend. The dip in 2020 for both groups is likely a result of a reduction in effort due to the COVID-19 pandemic.

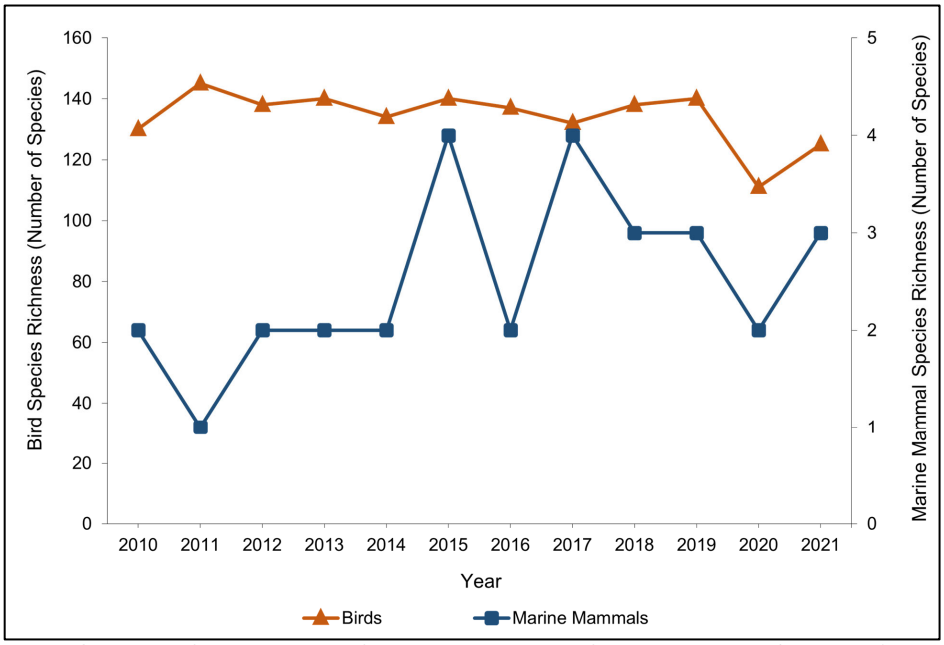

Figure S.LR.15.6. Species richness for birds and mammals from Beach Watch (Lindquist & Roletto, 2022a).

Other data indicators

Other data indicators selected included diversity for: eelgrass communities, wintering shorebirds, fish, and invertebrates. However, no relevant biodiversity data were available. Data is available on eelgrass extent and is included in Q 3, Q 10, and Q 13 but biodiversity information is not available for eelgrass habitat communities.The Audubon Canyon Ranch on Tomales Bay monitors wintering shorebird abundance, but there is no biodiversity data available for other lagoons and estuaries. No data were available on fish or invertebrate diversity in estuarine and lagoon habitat. Surveys on herring in Tomales Bay ended in 2007.

Conclusion

While some evidence is available, it is not sufficient to make a determination on the status and trends for biodiversity in estuaries and lagoons in GFNMS, thus both the status and trend are undetermined. The only diversity data available were for seabirds and marine mammal species richness. Seabird species richness was stable and marine mammal species richness was more variable and possibly increasing. Data on biodiversity was not available for eelgrass communities, wintering shorebirds, fish, or invertebrates.

Commented [40]: too bad more surveys aren't being done here!

References (Q15/Estuarine and Lagoon Region)

Field, J. C., Miller, R. R., Santora, J. A., Tolimieri, N., Haltuch, M. A., Brodeur, R. D., Auth, T. D., Dick, E. J., Monk, M. H., & Wells, B. K. (2021). Spatiotemporal patterns of variability in the abundance and distribution of winter-spawned pelagic juvenile rockfish in the California Current. *PloS ONE*, *16*(5), e0251638. https://doi.org/10.1371/journal.pone.0251638

Harvey, C. J., Garfield, N., Williams, G. D., Tolimieri, N. (Eds.). (2021). *Ecosystem status report of the California Current for 2020–21: A summary of ecosystem indicators compiled by the California Current Integrated Ecosystem Assessment Team*. Technical Memorandum NMFS-NWFSC-170. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Science Center. https://doi.org/10.25923/x4ge-hn11

Lindquist, K., & Roletto, J. (2022a). *Beach Watch database* [Data set]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of National Marine Sanctuaries, Greater Farallones National Marine Sanctuary & Greater Farallones Association. https://bwonline.beachwat.ch/BeachWatchData.php

Multi-Agency Rocky Intertidal Network (MARINe). (2021). Long-term monitoring and biodiversity surveys [Data set]. MARINe: Multi-Agency Rocky Intertidal Network. https://marine.ucsc.edu/index.html

Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO). (2022). Data Access [Data portal].Partnership for Interdisciplinary Studies of Coastal Oceans. https://www.piscoweb.org/data-access

Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO). (2022). Data Access [Data portal].Partnership for Interdisciplinary Studies of Coastal Oceans. https://www.piscoweb.org/data-access

San Francisco Public Utilities Commission. (2014). Southwest Ocean Outfall Regional Monitoring Program: Sixteen-year Summary Report 1997–2012. Submitted to U.S. Environmental Agency, Region 9 and California Regional Water Quality Control Board, San Francisco Bay Region. San Francisco Public Utilities Commission.

San Francisco Public Utilities Commission (2021). Southwest Ocean Outfall Regional Monitoring Program: 2020 Data Report. Submitted to U.S. Environmental Agency, Region 9 and California Regional Water Quality Control Board, San Francisco Bay Region. San Francisco Public Utilities Commission.

Warnock, N., Jennings, S., Kelly, J. P., Condeso, T. E., & Lumpkin, D. (2021). Declining wintering shorebird populations at a temperate estuary in California: A 30 year perspective. *Ornithological Applications*, *123*(1), https://doi.org/10.1093/ornithapp/duaa060

West Coast Groundfish Bottom Trawl Survey. (2021). *Survey data, 2012–2021* [Unpublished data set]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, NOAA Fisheries, Northwest Fisheries Science Center, Fishery Resource Analysis and Monitoring Division.

Status and Trends of Maritime Heritage (Questions 16) 1
Question 16: What is the condition of known maritime heritage resources and how is it changing? 1
Coastal and Offshore Region (Q16) 1
Estuarine and Lagoon Region (Q16) 11

Status and Trends of Maritime Heritage (Questions 16)

Question 16: What is the condition of known maritime heritage resources and how is it changing?

The Maritime Heritage Resources section of this report addresses the condition of maritime heritage resources and properties in the sanctuary. Maritime heritage can encompass a wide variety of cultural, archaeological, and historical resources. Archaeological and historical resources are material evidence of past human activities and include vessels, aircraft, structures, habitation sites, and objects created or modified by humans. Cultural resources may include specific locations associated with traditional beliefs or where a community has traditionally carried out economic, artistic, or other cultural practices important to maintaining its historic identity. The majority of existing site information currently describes shipwreck (archaeological/historical) resources. Question 16 assesses the integrity of known, tangible maritime heritage resources in the sanctuary. The integrity of a heritage resource refers to its ability to convey information about the past, and can be impacted by both natural events and human activities. Archaeological integrity is generally linked to the condition of the resource, whereas historical significance may rely on other factors.

Because of considerable differences in environmental pressures and responses between the coastal and offshore region and the estuarine and lagoon region, this question is assessed twice in order to represent these two environment types separately.

Coastal and Offshore Region (Q16)

Status Rating: Good/Fair	Status Confidence: Medium
Trend Rating: Not changing	Trend Confidence: Low
Status Description: Selected maritime heritage resources exhibit indications of natural or human disturbance, but there appears to have been little or no reduction in aesthetic, cultural, historical, archaeological, scientific, or educational value.	
Rationale: Historic sites, properties, and artifacts associated with shipwrecks and doghole ports are known to exist within the sanctuary boundaries. The 2015 expansion of the	

sanctuary increased the number of maritime heritage resources within its boundaries. Summary findings of condition can be made for 13 of the 33 known shipwrecks; all 13 show structural degradation. Some impacts to condition are due to physical processes while others relate to human interactions, although the latter do not appear to be significant. Two shipwrecks show signs of fishing gear on them; however, trawling is not known to have impacted any shipwrecks during the rating period. Impacts from recreational scuba diving are thought to have diminished as looting by divers has not been documented. Twenty four historic doghole port sites are documented in or adjacent to GFNMS. Climate change may increase degradation due to swells and storms, but data is not available at this time to confirm that effects to date can be attributed to climate change. Other than the described known resources, no other maritime heritage properties are documented within sanctuary boundaries, though more are likely. The trend is not changing, but expert confidence was low in making this determination because of limited evidence due to lack of systematic site assessment and monitoring data. It was noted that it is difficult to ascertain natural versus human impacts on a resource, and the general opinion was that any condition changes that occurred were mainly due to natural causes. There are data gaps for resources, beyond the small amount of information gathered on a limited number of known, tangible maritime heritage resources.

Findings From the 2010 Condition Report

In the 2010 condition report, both the status and trend ratings were undetermined because little was known about the existence or condition of shipwreck resources in the sanctuary and archaeological surveys and monitoring needed to be conducted. Also, in the 2010 condition report only shipwrecks and their condition were discussed. At that time, of 180 records of losses of historic shipwrecks and aircraft, 31 shipwreck sites were known. One shipwreck in the region, the SS *Jacob Luckenbach*, was assessed.

New Information in the 2010–2022 Condition Report

Four indicators of known, tangible maritime heritage resources were selected and assessed: shipwrecks (the only indicator discussed in the 2010 report), aircraft, doghole ports, and other maritime heritage properties (inclusive of locations and resources) (Table S.MH.16.1). Note, however, that the wording of this question has changed slightly since the 2010 report (see Appendix A). The 2015 expansion of the sanctuary increased the number of maritime heritage resources within its boundaries. Only shipwrecks and doghole ports have been documented to be within GFNMS; however, future analysis of California Historical Resources Information System (CHRIS, CA Office of Historic Preservation) records and other sources could indicate the presence of other types of maritime heritage resources (prehistoric or historic).

Table S.MHR.16.1. Summaries for the key indicators related to the condition of maritime heritage resources in the coastal and offshore region of the sanctuary that were discussed during the July 6, 2022 virtual workshop.

Indicator	Source	Data Summary	Figures & Tables

Shipwrecks	R. Schwemmer/NOAA, March 8, 2022; Schwemmer, 2022; Delgado and Haller, 1989; California Department of Parks and Recreation, 2021; Delgado et al 2020	Status: 33 shipwrecks are known in the coastal and offshore region, with 16 documented by federal, state, private partners. Loss records indicate there could be more. Findings about the condition of 13 of the 16 documented shipwrecks indicate all have experienced physical degradation. Trend: Not assessed.	Figures S.MHR.16.1. S.MHR.16.2. Table S.MHR.16.2.
Aircraft	R. Schwemmer/NOAA, March 8, 2022; Schwemmer, 2022	Status: There are no documented historic aircraft in the coastal and offshore region, although loss records indicate there could be some. Trend: Not applicable.	
Doghole ports	R. Schwemmer/NOAA personal communication, March 8, 2022; Marx and Jaffke, 2021; D. Jaffke/Far Western Anthropological Research Group, Inc., personal communication, August 11, 2022; California Department of Parks and Recreation, 2021	Status: 24 doghole port sites are documented in or adjacent to GFNMS in the coastal and offshore region. Remnants (submerged artifacts/features) have been located at 3 sites. Trend: Not assessed.	Figures S.MHR.16.3. S.MHR.16.4. S.MHR.16.5.
Other maritime heritage properties	H. Van Tilburg/NOAA, personal communication, June 16, 2022; State of California, Office of Habitat Preservation, 2022; Terrell, 2007; BOEM, 2013	Status: Of 70 sites or features returned by a CHRIS database search for GFNMS, 20 sites may be in the coastal and offshore region of the sanctuary. Trend: Not assessed.	
Data Gaps:	Shipwrecks - gaps in assessments; climate change may increase degradation due various factors, including swells and storms, but no data was available on climate change effects to shipwrecks Doghole ports - CHRIS site reports and gaps in assessments; no data was available on climate change effects to doghole ports Other maritime heritage properties - CHRIS site reports and gaps in assessments		

Shipwrecks

As of June 2022, for all of GFNMS (both the offshore and coastal region and estuarine and lagoon region), historical documents indicate there were 408 losses of historic ships and aircraft, with 87 shipwrecks recorded as rescued or salvaged (some partial remains or cargo items could still be on site). In the coastal and offshore region, there are 33 known, documented shipwreck locations (Figure S.MHR.16.1). A few reported as known in within the sanctuary in 2010 are not now included in the list of 33 known as it was determined that they are outside

sanctuary boundaries; for example, the cargo steamer SS *Hartwood*, the cargo steamer SS *Munleon*, and the steam-schooner SS *Pomo* (R. Schwemmer/NOAA, personal communication, March 8, 2022; Schwemmer, 2022). Others have been removed from the list of known shipwrecks as their location is inexact or unverified; for example, the galleon *San Augustin*, the oldest known West Coast shipwreck, which sank in 1595 in Drake's Bay (Terrell, 2007) at an unknown location within the bay (P. Engel/NPS, personal communication, February 25, 2022).

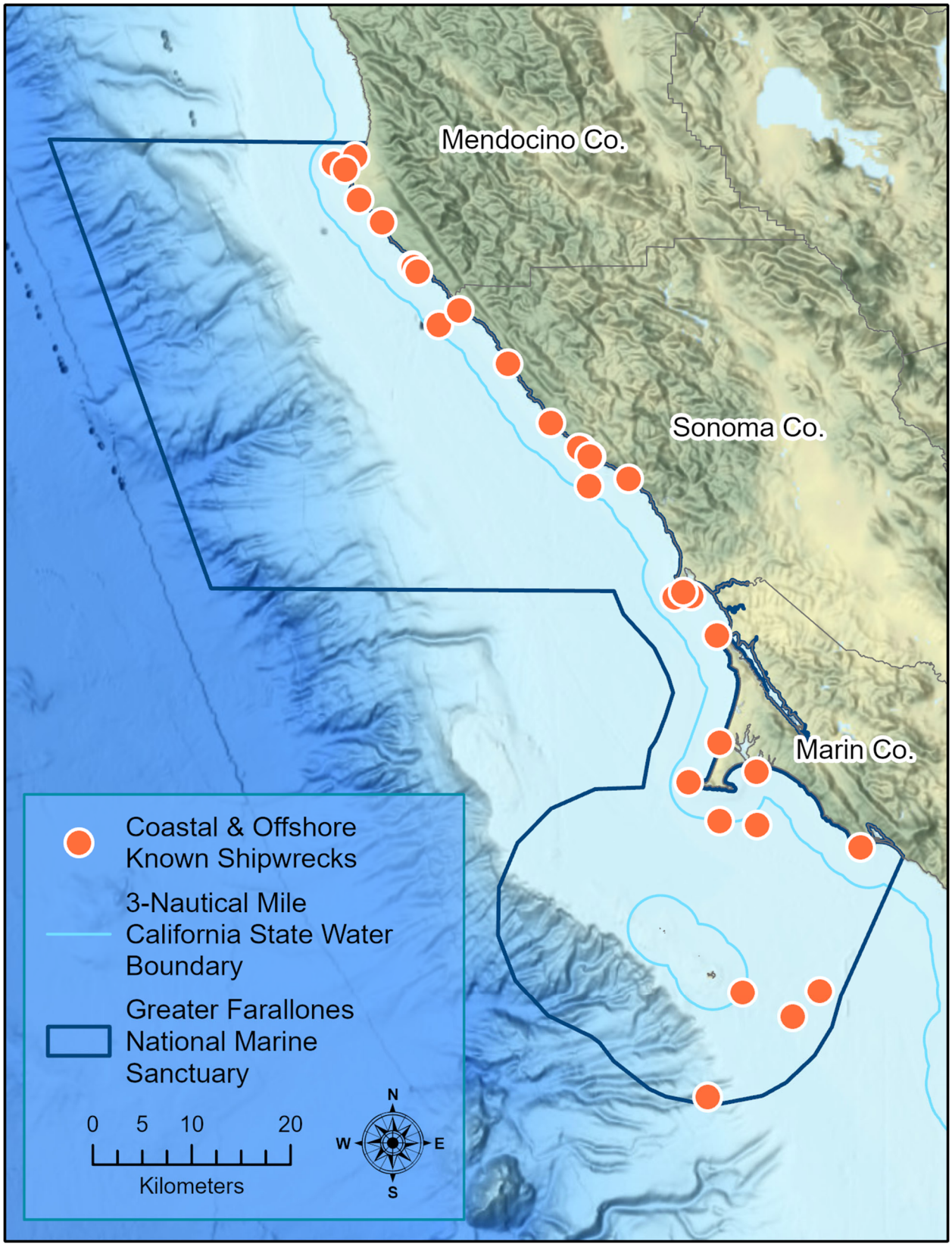
Mendocino Co.
Sonoma Co.
Marin Co.
Coastal & Offshore Known Shipwrecks
3-Nautical Mile California State Water Boundary
Greater Farallones National Marine Sanctuary
0 5 10 20
Kilometers
N
W
E
S

Figure S.MHR.16.1. Known historic shipwrecks in the coastal and offshore region of GFNMS. Image: NOAA; Sources: R. Schwemmer/NOAA personal communication, March 8, 2022; Schwemmer, 2022; Delgado and Haller, 1989; Delgado et al, 2020; Esri, 2020.

Of the 33 known shipwrecks in this region, 17 were located by the sport diving community with high reliability but not formally documented; 16 were documented by federal, state, or private sector partners. Summary findings about the condition of 13 shipwrecks are available, including what structure remains and if any human impacts are known (Table S.MH.16.2). All of the 13 shipwrecks have experienced physical degradation. In some cases wooden hulls or structures are largely missing, some metal hulls are complete, and others are collapsed or collapsing. Variables that impact maritime heritage resource condition can be due to both natural processes and human impacts. Some include: the year of loss and submergence, ship materials (wood, iron, steel), artifact material, depth at site location, oceanographic factors, cause of loss, and human activities. Some variables relate to physical and natural processes, with metal materials usually more durable than wooden materials; others relate to human interactions, including full or partial salvage, looting, and deposition of lost fishing gear. Trawling is not known to have impacted any shipwrecks during the rating period. Some human impacts on some wrecks have been observed or via anecdotal evidence are thought to have occurred (D. Jaffke/Far Western Anthropological Research Group, Inc., personal communication, March 1, 2023), but workshop participants felt they were not significant for the rating period, nor for the whole suite of maritime heritage resources.

Table S.MHR.16.2. Summary of condition of 13 shipwreck sites in the coastal and offshore region of GFNMS, listed from most recently lost.

Name	**Year Lost**	**Location Lost Coastal or Offshore**	**Site Condition**
TV *Puerto Rican* (stern)	1984	Offshore	Stern section (steel) covered in fishing gear.
SS Jacob Luckenbach	1953	Offshore	Steel hull degradation and separation. Looting occurred in the past.
SS *Dorothy Wintermote*	1938	Offshore	Steel hull collapsed. No known human impacts
Norlina *	1926	Coastal	Scattered steel remains - structural and machinery Some past salvage
Isaac Reed	1924	Offshore	Extreme wooden hull degradation; no known human impacts.
USS *Conestoga* *	1921	Offshore	Lower steel hull complete, upper wooden structure missing. No known human impacts.

SS *Klamath*	1921	Coastal	No wooden hull structure recorded, artifact distribution Looting occurred in the past
SS *Ituna*	1920	Offshore	Lower iron hull degradation & collapsing No known human impacts.
SS *Selja*	1910	Offshore	Steel hull inverted. Signs of fishing gear
SS *Pomona* *	1908	Coastal	Steel hull degradation Looting occurred in the past
J. Eppinger SS *Whitelaw* *Joseph S. Spinney*	1898 1893 1892	All: Coastal	All: No wooden hull structures recorded, artifact distribution. Looting occurred in the past.
* Listed on National Register of Historic Places			

Surveys were done on some of the sites during the review period. Most were done by remotely operated vehicle (ROV) and video documentation. The USS *Conestoga*, which is on the National Register of Historic Places (NRHP) (ONMS, 2022), was surveyed by ROV in 2014 and 2015. The SS *Ituna* was surveyed by ROV in 2015 and 2016; the cause of degradation of this resource has not been determined. The *Isaac Reed* was surveyed by ROV in 2015. The stern of the T/V *Puerto Rican* was surveyed by ROV in 2021. The SS *Pomona*, which is on the NRHP (NPS 2022a), was surveyed in 2016 and 2017 by magnetometer as part of the Sonoma Doghole Ports Project, snorkel and scuba diver visual surveys, along with the *Norlina* subsequently added to the NRHP (D. Marx/independent contractor, personal communication, October 7, 2022; NPS 2022b), the SS *Klamath* and the *Joseph S. Spinney* and other wreck sites (California Department of Parks and Recreation, 2021; Marx and Jaffke, 2021).

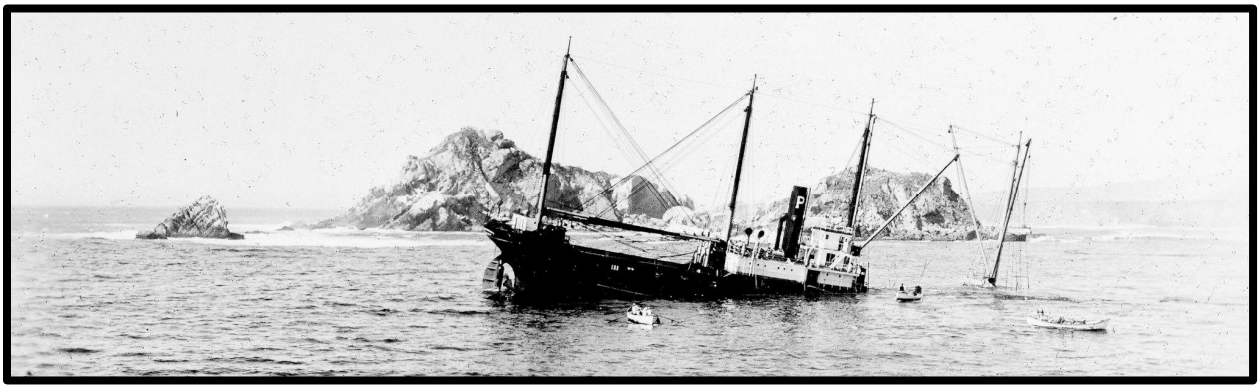

Figure S.MHR.16.2. SS *Dorothy Wintermote*, lost in 1938. Photo: San Francisco Maritime National Historic Park

Aircraft

There are loss records in the coastal and offshore region for historic aircraft, but no locations have been discovered (R. Schwemmer/NOAA, personal communication, March 8, 2022; Schwemmer, 2022) and thus no surveys or assessments of condition have been done.

Doghole ports

After the expansion of the sanctuary in 2015, doghole port sites in the coastal waters of Sonoma County and southern Mendocino County were included (Figure S.MHR.16.3). Records indicate there are 24 sites within sanctuary boundaries[1] (R. Schwemmer/NOAA, personal communication, March 8, 2022; California Department of Parks and Recreation, 2021; Marx and Jaffke, 2021); three of the locations are approximate and based on historical records (D. Jaffke/Far Western Anthropological Research Group, Inc., personal communication, August 11, 2022). Surveys were conducted at the 14 Sonoma County sites by federal and state partners to document both underwater and terrestrial remnants of the ports (along with shipwrecks) for the Sonoma Doghole Ports project. A few port remnants were documented by magnetometer, snorkel, and scuba diver visual surveys within the sanctuary at three sites (California Department of Parks and Recreation, 2021; Marx and Jaffke, 2021). Substantial archaeological evidence of the chutes and associated maritime commerce at the ports were recorded (Figure S.MHR.16.4). Anchors and heavy chains, no longer *in situ*, were documented nearby on land, along with other artifacts (Figure S.MHR.16.5; California Department of Parks and Recreation, 2021; Marx and Jaffke, 2021). Subsequent documentation of doghole ports by nonprofit partners indicates there are 10 sites in Mendocino County that are within the sanctuary (Marx and Jaffke, 2021); they have not been surveyed.

[1] Sanctuary boundaries do not include Arena Cove. The ocean portion of Arena Cove, though geographically close, is east of and adjacent to sanctuary boundaries.

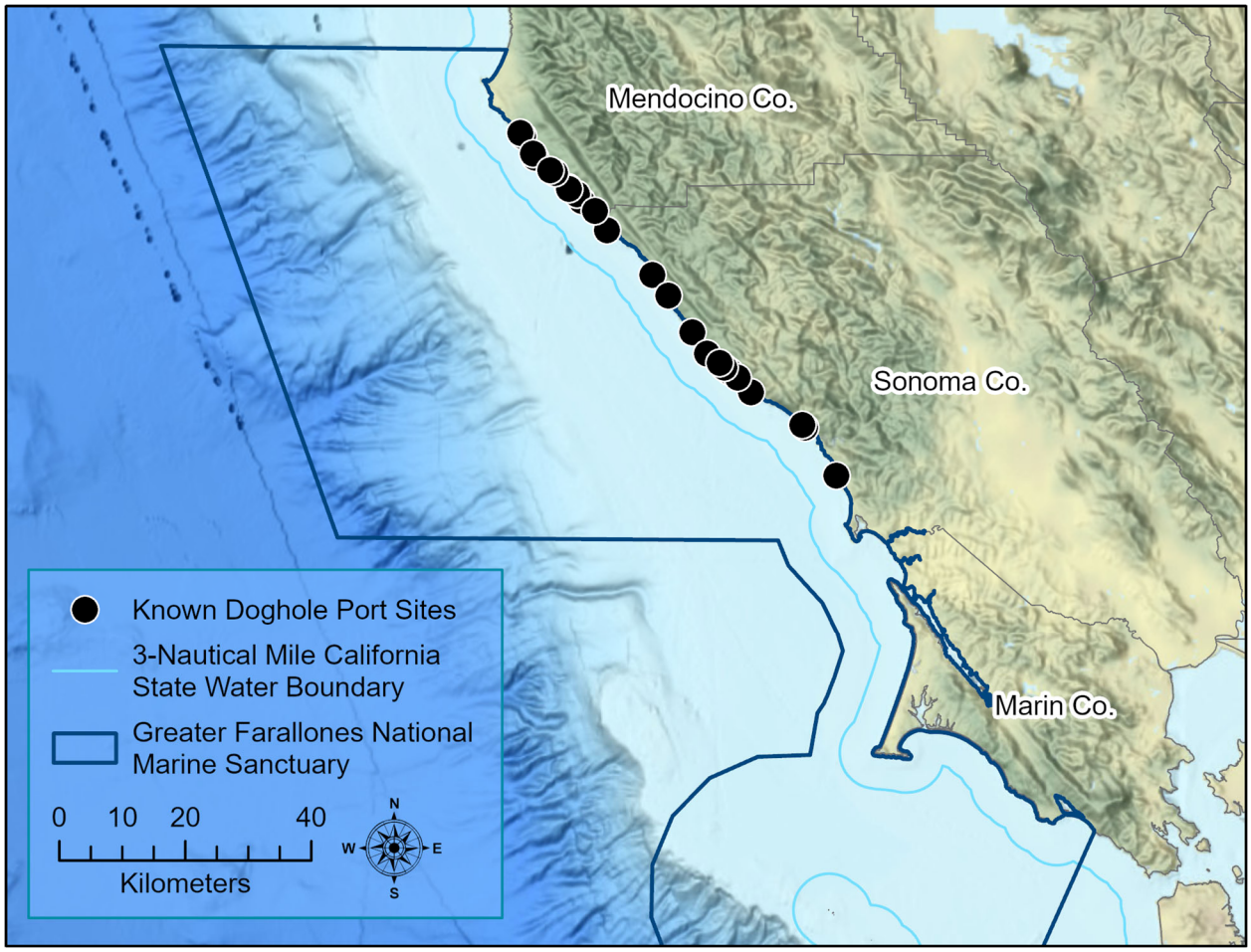

Figure S.MHR.16.3. Doghole ports in the coastal and offshore region of GFNMS. Image: NOAA; Sources: R. Schwemmer/NOAA personal communication, March 8, 2022; California Department of Parks and Recreation, 2021; Marx, D. and Jaffke, D. 2021; Esri, 2020.

Figure S.MHR.16.4. Trough chutes at Stewart's Point Landing, a doghole port, and unknown schooner loading tanbark. Photo: San Francisco Maritime National Historical Park SAFR 21374

Figure S.MHR.16.5. Mooring hardware; a section of stud link chain pile at a doghole port site within the sanctuary. Photo: NOAA and California Department of Parks and Recreation

In 2021, the National Park Service (NPS) accepted a Northern California Doghole Ports Maritime Cultural Landscape Multiple Property Submission (MPS[2]) of 57[3] doghole ports for consideration for listing on the NRHP, and listed the Salt Point Landing Historical and Archaeological District in the NRHP (D. Marx/independent contractor, personal communication, April 17, 2022; NPS, 2022c). Fort Ross Landing Historical and Archaeological District (Northern California Doghole Ports Maritime Cultural Landscape MPS) was subsequently listed in April 2023 in the NRHP (NPS, 2022d). A NRHP listing recognizes resources of community, state and national significance as worthy of preservation. Federal, Tribal, state, and local laws establish important rules for historic preservation. Workshop experts indicated they were not aware of condition changes at doghole port sites from looting port remnants during the report timeframe.

Other Maritime Heritage Properties

Similar to the findings in the 2020 condition report, there is the possibility of other archaeological sites and resources in this region that are not associated with historic shipwrecks, aircraft, or doghole ports. These could include prehistoric or historic areas of human activity (e.g., habitation sites and artifacts), remnants of historic vessel landings or wharves, or other maritime heritage properties. The 2010 condition report made reference to the potential for exposure of submerged cultural material associated with Native American terrestrial sites in the nearshore environment as a result of coastal land erosion (Terrell, 2007; BOEM, 2013).

---

[2] A MPS covers a grouping of individual properties characterized by common physical and/or associative attributes, tied to a historic context. The cover form contains much of the context for evaluation, which does not have to be repeated in individual nominations submitted as part of the group. It facilitates evaluations of significance for related resources, enabling easier assessment of National Register of Historic Preservation eligibility for individual properties.

[3] Only 24 of the 57 ports sites included in the MPS (for which the cover documentation was approved in April 2022) are within GFNMS. The others, in Mendocino County, are outside the sanctuary's boundaries.

Twenty of 70 archaeological sites returned in a CHRIS database search may be within, or have elements within, this GFNMS region (H. Van Tilburg/NOAA, personal communication, June 16, 2022); however, the extent to which they are adjacent to and/or extend into the sanctuary is not yet determined. Taking a landscape approach to understanding the history of the sanctuary and its associated communities could also yield information about sanctuary maritime heritage resources and their condition.Gaining more understanding of this topic, by examining site-level documentation and reports in the CHRIS and other sources are identified data and analysis needs that would inform this question.

Conclusion

The status is good/fair for the maritime heritage resources in the coastal and offshore region of GFNMS based on the existing assessments for 33 shipwrecks and 24 doghole port sites. Neither looting nor commercial bottom trawl damage are thought to have occurred within the rating period. The tangible presence of aircraft or other maritime heritage properties was unknown. However, more information was gained about the presence of maritime heritage resources and their condition than was known in the 2010 condition report, and the expansion of the sanctuary resulted in the inclusion in its boundaries of a number of additional shipwrecks and doghole ports. The trend is not changing based on no evidence of significant changes. However, there was a lack of quantitative data for many of the resources that would have enabled tracking condition changes, and limited qualitative data was available, with one expert noting no significant changes were seen in resource conditions over many years of scuba diving in the region. The lack of resources for regular monitoring was a factor in the lack of condition data. As a general statement, when changes in maritime heritage resources are observed, it is unclear in most cases if the observed deterioration is from natural processes or human activities, though in this region it is likely such changes are mainly from natural causes.

There is only a small amount of information known about the maritime heritage resources within the sanctuary; there are data gaps for each indicator, and much of the information that is available is qualitative and not quantitative. Data gaps exist due to a lack of comprehensive, standardized baseline site assessments for many of the resources as well as a lack of monitoring data from periodic, standardized subsequent assessments of the resources' condition in the field. One need is to review and assess the information on potential prehistoric and historic locations and features (e.g., geographic coordinate data) listed in the CHRIS, and examine associated site-level documentation. This would need to be coordinated with similar efforts in the estuarine and lagoon region.

Estuarine and Lagoon Region (Q16)

Status Rating: Good	Status Confidence: Medium
Trend Rating: Not changing	Trend Confidence: Low
Status Description: Known maritime heritage resources appear to reflect little or no unexpected natural or human disturbance.	
Rationale: The one known resource, the shipwreck *Oxford*, located in Tomales Bay, is buried by mud, which makes both natural and anthropogenic deterioration less likely. The trend is	

therefore considered not changing, but expert confidence was low in making this determination because it was based on one site and a single survey. Aircraft, doghole ports, and other maritime heritage resources were investigated as data indicators but no known resources were identified. Data gaps for shipwrecks, doghole ports, and other maritime heritage resources were noted.

Findings From the 2010 Condition Report

In the 2010 condition report, the status and trend ratings for this question were undetermined because archaeological surveys to investigate vessel losses and monitoring had not been conducted. In the 2010 condition report, seven records of losses of historic shipwrecks, all in Tomales Bay, were mentioned, but no sites were known or assessed.

New Information in the 2010–2022 Condition Report

Four indicators of known, tangible maritime heritage were selected and assessed: shipwrecks (the only indicator discussed in the 2010 report), aircraft, doghole ports, and other maritime heritage properties (inclusive of locations and resources) (Table S.MHR.16.3).

Table S.MHR.16.3. Summaries for the key indicators related to the condition of maritime heritage resources in the estuarine and lagoon region of the sanctuary that were discussed during the July 6, 2022 virtual workshop.

Indicator	Source	Data Summary	Figures & Tables
Shipwrecks	R. Schwemmer/NOAA, personal communication, March 8, 2022; Schwemmer, 2022; Delgado and Haller, 1989; Delgado et al, 2020	Status: One shipwreck, the *Oxford*, is known and documented within the estuarine and lagoon region; a hydraulic probe survey was conducted of the wreck; however, it was not fully assessed. Loss records indicate there could be additional shipwrecks. Trend: Not assessed.	Figures S.MHR.16.6. S.MHR.16.7. Table S.MHR.16.4.
Aircraft	R. Schwemmer/NOAA, March 8, 2022; Schwemmer, 2022	Status: There are no documented historic aircraft in the estuarine and lagoon region of GFNMS. Trend: Not applicable.	
Doghole ports	R. Schwemmer/NOAA, personal communication, March 8, 2022	Status: There are no documented doghole ports in the estuarine and lagoon region of GFNMS. Trend: Not applicable.	
Other maritime heritage properties	H. Van Tilburg/NOAA, personal communication, June 16, 2022; State of California, Office of Habitat Preservation, 2022	Status: 10 archaeological sites returned by CHRIS database search (after terrestrial sites excluded) may be within, or have elements within, this GFNMS region; how many contain prehistoric features is unclear. Trend: Not assessed.	

Data Gaps	Shipwrecks - gaps in assessments Doghole ports - CHRIS site reports and gaps in assessments Other maritime heritage properties - CHRIS site reports and gaps in assessments

Shipwrecks

There are 408 records of losses of historic ships and aircraft within all of GFNMS (both regions), with 87 shipwrecks recorded as rescued or salvaged (some partial remains or cargo items could still be on site). In the estuarine and lagoon region of GFNMS there is one documented shipwreck, the *Oxford* (R. Schwemmer/NOAA, personal communication, March 8, 2022; March 10, 2022; Schwemmer, 2022; Delgado and Haller, 1989) (Figure S.MHR.16.6). It was located in Tomales Bay by a team led by NOAA archaeologists.

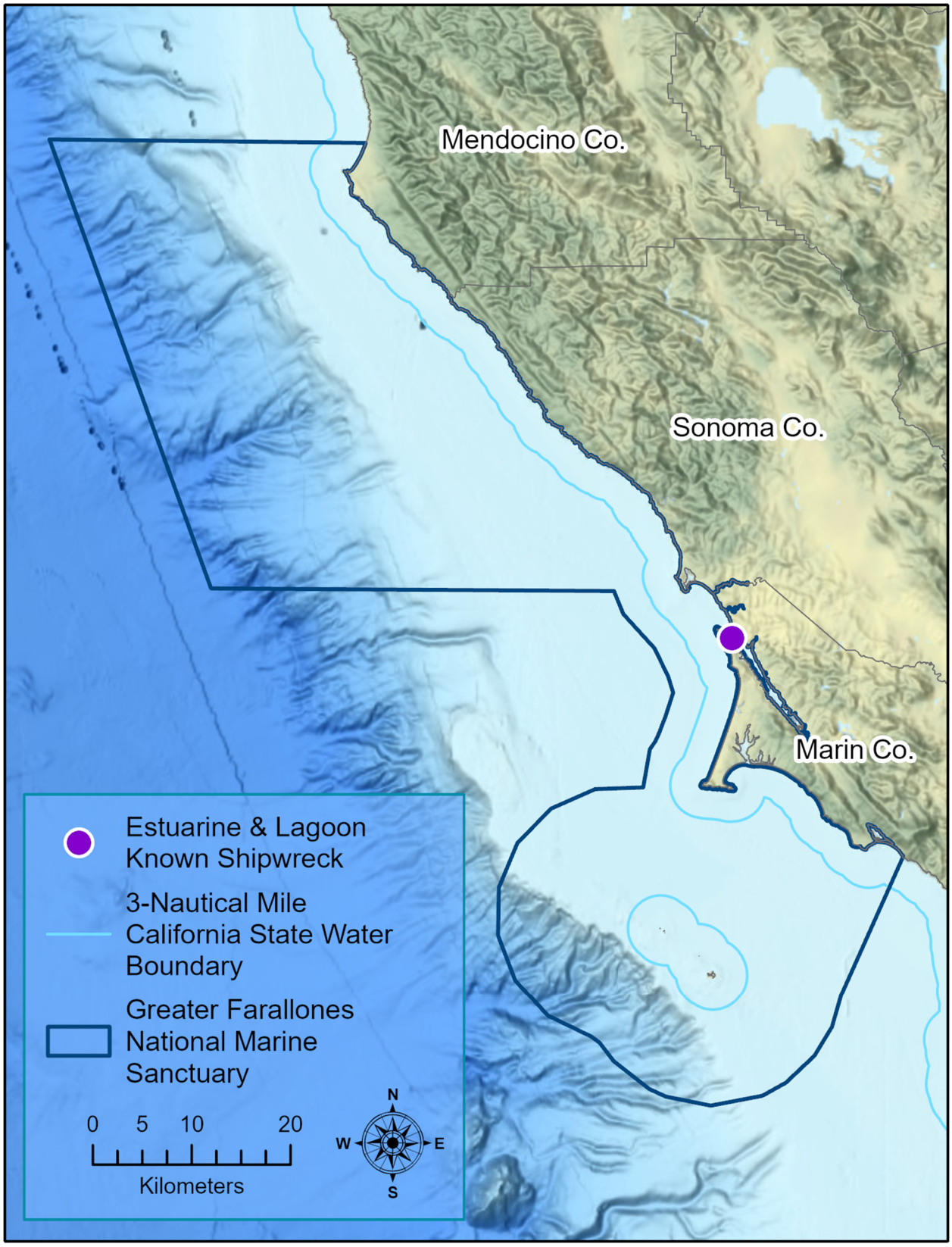
Mendocino Co.
Sonoma Co.
Marin Co.
Estuarine & Lagoon
Known Shipwreck
3-Nautical Mile
California State Water
Boundary
Greater Farallones
National Marine
Sanctuary
0 5 10 20
Kilometers
N
W
E
S

Figure S.MHR.16.6. Known historic shipwreck in the estuarine and lagoon region of GFNMS. Image: NOAA; Sources: R. Schwemmer/NOAA personal communication, March 8, 2022; Schwemmer, 2022; Delgado and Haller, 1989; Delgado et al, 2020; Esri, 2020.

The only survey of the wreck of the *Oxford* (Table S.MHR.16.4) was a hydraulic probe survey to determine its location in 2014 (Figure S.MHR.16.7).

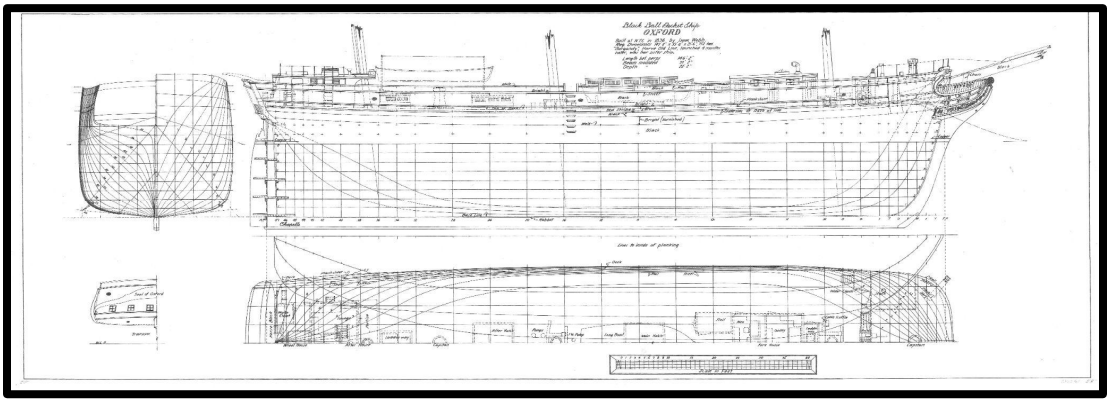

Figure S.MHR.16.7. Ship plans of the *Oxford*. Image: Smithsonian Institution

Delgado et al. (2020) reported a "crunchy" mass buried under a mud and sand shoal. Human impacts on the wreck are not known, other than those due to the research activity (J. Delgado/NOAA, personal communication, February 6, 2015) that determined the wreck's location; hydraulic probing resulted in twenty or fewer probe holes and probable introduction of some oxygen (Question 5). This could have had an effect on the wreck's condition, but the nature and extent of that is undetermined. Workshop experts indicated that the fact that the structure is buried by mud makes both natural and anthropogenic deterioration less likely.

Table S.MHR.16.4. Summary of condition of one shipwreck site in the estuarine and lagoon region of GFNMS.

Name	Year Lost	Location Lost Estuarine or Lagoon	Site Condition
Oxford	1852	Estuarine	Crunch mass, buried under a mud and sand shoal. No known human impacts, beyond possible survey probe holes and temporary introduction of oxygen.

Aircraft and Doghole Ports

No historic aircraft or doghole ports have been documented within this region in GFNMS (R. Schwemmer/NOAA, personal communication, March 8, 2022; Schwemmer, 2022).

Other Maritime Heritage Properties

Experts believe there is the possibility of other archaeological sites and resources in this region that are not associated with historic shipwrecks, aircraft, or doghole ports. These could include prehistoric or historic areas of human activity (e.g., habitation sites and artifacts) and remnants

of historic vessel landings or wharves. Ten of 70 archaeological sites returned in a CHRIS database search may be within this GFNMS region, all in Tomales Bay (H. Van Tilburg/NOAA, personal communication, June 16, 2022; State of California, Office of Habitat Preservation, 2022). The extent to which these properties are adjacent to and/or extend into the sanctuary is not yet determined and is an identified area for analysis. Gaining more understanding of this topic by examining geographic coordinates of sites listed in the CHRIS and by looking at any site-level documentation and reports, as well as integrating information by taking a landscape approach, are identified as data and analysis needs that would inform this question.

Conclusion

The status for this question is good, based on the condition of the one known shipwreck in this region, the *Oxford*. Little information is available on its condition, but because it is submerged underwater in mud, its status is presumed to be good. Other shipwrecks may exist within the region based on loss records, but the presence of tangible remains have not been ascertained. Three other indicators were investigated (aircraft, doghole ports, and other maritime heritage properties) but no other maritime heritage resources have been verified to be within the sanctuary. The trend is not changing based on the presumed stable condition of the *Oxford*, other than potentially negligible adverse effects caused by the hydraulic probe survey used to determine its presence. It is not likely to be subjected to natural deterioration or be adversely affected by human activities, though further field research could disturb the resource. One need is to review and assess the information on potential prehistoric and historic locations and features (e.g., geographic coordinate data) listed in the CHRIS, and examine associated site-level documentation. This would need to be coordinated with similar efforts in the coastal and offshore region.

References (Both Regions)

Bureau of Ocean Energy Management (BOEM). (2013). Inventory and Analysis of Coastal and Submerged Archaeological Site Occurrence on the Pacific Outer Continental Shelf. U.S. Department of the Interior, BOEM, Pacific OCS Region. OCS Study BOEM 2013-0115.

Delgado, J.P. and Haller, S. A. (1989). Submerged Cultural Resources Assessment Golden Gate National Recreation Area, Gulf of the Farallones National Marine Sanctuary and Point Reyes National Seashore. Southwest Cultural Resources Center. Professional Papers. Number 18.

Delgado, J. P., Schwemmer, R.V., and Brennan, M.L. (2020). Shipwrecks and the Maritime Cultural Landscape of the Gulf of the Farallones. Journal of Maritime Archaeology. 15(2), 131-163.

California Department of Parks and Recreation. (2021). Maritime Cultural Landscape of Sonoma's Doghole Ports, by NOAA's Office of National Marine Sanctuaries and California State Parks. Publications in Cultural Heritage. Number 37.

Marx, D. and Jaffke, D. (2021). National Register of Historic Places Multiple Property Listing (MPL) in a National Park Service Multiple Property Documentation Form (MPDF), Northern California Doghole Ports Maritime Cultural Landscape. Unpublished internal agency document.

National Park Service (NPS). (2022a). *NP Gallery: Digital Asset Management System*. Retrieved September 7, 2022, from https://npgallery.nps.gov/AssetDetail/ccfbdd80-825d-46b4-97e3-3ef5e9942656

NPS. (2022b). National Park Service. *National Register of Historic Places*. Pending List 2022 08 27. Retrieved September 21, 2022, from https://www.nps.gov/subjects/nationalregister/pending-list-2022-08-27.htm

NPS. (2022c). National Park Service. *National Register of Historic Places. Weekly List 2022 04 15*. Retrieved September 7, 2022, from https://www.nps.gov/subjects/nationalregister/weekly-list-2022-04-15.htm
NPS. (2022d). National Park Service. National Register of Historic Places. Weekly List 2023 04 14. Retrieved April 21, 2023, from https://www.nps.gov/subjects/nationalregister/weekly-list-2023-04-14.htm
Naval History and Heritage Command. (2022). Naval History and Heritage Command. *USS Conestoga*. Retrieved March 15, 2023, from https://www.history.navy.mil/content/history/museums/nmusn/explore/photography/ships-us/ships-usn-c/uss-conestoga-sp-1128-at-54.html
ONMS. (2022). Office of National Marine Sanctuaries. *USS Conestoga - 100 Years since Departure*. Retrieved September 7, 2022, from https://sanctuaries.noaa.gov/conestoga/
Schwemmer, R. (2022). ONMS West Coast Historic Shipwreck and Aircraft database: Supplementary data [Unpublished data set].
Terrell, B.G. (2007). *Fathoming Our Past – Historical Contexts of the National Marine Sanctuaries.* National Marine Sanctuary Program. Silver Spring. https://sanctuaries.noaa.gov/library/alldocs.html

Status and Trends of Ecosystem Services 1
Science — The capacity to acquire and contribute information and knowledge 4
Education — the capacity to acquire and provide intellectual enrichment 14
Heritage — Recognition of historical and heritage legacy and cultural practices 25
Sense of Place — Aesthetic attraction, spiritual significance, and location identity 36
Consumptive Recreation — Recreational activities that result in the removal of or harm to natural or cultural resources 42
Non-Consumptive Recreation — Recreational activities that do not result in intentional removal of or harm to natural or cultural resources 51
Commercial Harvest — The capacity to support commercial market demands for seafood products 56
Coastal Protection — Flow regulation that protects habitats, property, coastlines, and other features 68

Status and Trends of Ecosystem Services

This section summarizes the status and trends of ecosystem services. Virtual expert workshops were convened by GFNMS staff on various dates from June–July, 2022 (see Appendix B and Appendix C) to discuss ecosystem services. It is important to note that, in general, the assessments of the status and trends of key indicators in GFNMS are for the period from 2009–2022. During the virtual workshops, indicators for each topic were presented, accompanied by datasets ONMS compiled prior to the meeting. Attendees were then asked to review the indicators and datasets, identify data gaps or misrepresentations, and suggest any additional datasets that may be relevant. Once all datasets were reviewed, experts were asked to provide status and trend recommendations and supporting arguments. After assigning status and trend ratings, experts were asked to assign a level of confidence for each value by characterizing: (1) the sources of information they used to make judgments; and (2) their agreement with the selected status and trend ratings. The evidence and agreement ratings were then combined to determine the overall confidence ratings. Appendix C provides a detailed description of the report development methods.

The following responses for each ecosystem service summarize the key indicators, supporting data sets, and rationale for each status and trend rating. Where published or additional information exists, the reader is provided with appropriate references and web links. Workshop discussions and ratings were based on data available at the time (e.g., through summer 2022). However, in some instances, sanctuary staff later reevaluated and/or incorporated newly available data in order to more accurately describe the current status and trends of resources. Situations where post-workshop rating decisions were made and/or data were used by sanctuary staff to support a rating, but were not presented or discussed during the workshop, are noted in the text.

Ecosystem Services: A Brief Introduction
Ecosystem services are the benefits that humans receive from natural and cultural resources. Generally, the taxonomy of the Millennium Ecosystem Assessment (2005) is used in ONMS

condition reports. The Millennium Ecosystem Assessment (2005) was an initiative of the United Nations to assess ecosystem services, including cultural, provisioning, regulating, and supporting services. Categories of ecosystem services include “final” services, which are directly valued by people, and “intermediate” services, which are ecological functions that support final services (Boyd & Banzhaf, 2007). In ONMS condition reports, only final ecosystem services are rated, which is consistent with the anthropogenic focus of the reports and highlights priority management successes and challenges in sanctuaries. The complete definitions of ecosystem services considered by ONMS are included in Appendix B.

***<<<GRAY TEXT WILL BE A TEXT BOX TITLED* Intermediate and Final Ecosystem Services>>>**

There are two categories of ecosystem services: intermediate and final. Ecosystem services that are evaluated in condition reports are final ecosystem services. Intermediate services support other ecosystem services, whereas a good or service must be directly enjoyed by a person to be considered a final ecosystem service. For example, nutrient balance leads to clearer water and higher visibility for snorkeling and scuba diving. Nutrient balance is an intermediate service that supports the final ecosystem service of non-consumptive recreation via snorkeling and scuba diving.

***<<<GRAY TEXT WILL BE ANOTHER TEXT BOX TITLED* Ecosystem Services>>>**

Thirteen final ecosystem services may be rated in ONMS condition reports

Cultural (non-material benefits)

1. Science — The capacity to acquire and contribute information and knowledge
2. Education — The capacity to acquire and provide intellectual enrichment
3. Heritage — Recognition of historical and heritage legacy and cultural practices
4. Sense of Place — Aesthetic attraction, spiritual significance, and location identity
5. Consumptive recreation — Recreational activities that result in the removal of or harm to natural or cultural resources
6. Non-consumptive recreation — Recreational activities that do not result in intentional removal of or harm to natural or cultural resources

Provisioning (material benefits)

7. Commercial harvest — The capacity to support commercial market demand for seafood products
8. Subsistence harvest — The capacity to support non-commercial demand for food and utilitarian products
9. Water — Providing water for human use by minimizing pollution, including nutrients, sediments, pathogens, chemicals, and trash
10. Ornamentals — Resources collected for decorative, aesthetic, or ceremonial purposes
11. Biotechnology — Medicinal and other products derived or manufactured from sanctuary animals or plants for commercial use
12. Energy — Use of ecosystem-derived materials or processes for the production of energy

Regulating (buffers to change)

13. Coastal protection — Flow regulation that protects habitats, property, coastlines, and other features

Notably, some consider consumptive recreational fishing as a provisioning service, but it is included here as a cultural ecosystem service. Also, even though biodiversity was listed as an ecosystem service by the Millennium Ecosystem Assessment (2005), ONMS decided to remove it, recognizing that biodiversity is an attribute of the ecosystem on which many final ecosystem services depend (e.g., recreation, harvest); therefore, it is addressed in the State of the Resources section of this report. Lastly, although ONMS listed climate stability as an ecosystem service in 2015, it is no longer considered an ecosystem service in ONMS condition reports because national marine sanctuaries are not large enough to influence climate stability on a large scale (Fisher & Turner, 2008; Fisher et al., 2009).

For GFNMS, eight of the 13 final ecosystem services were rated during virtual workshops held in June and July 2022: science, education, heritage, sense of place, consumptive recreation, non-consumptive recreation, commercial harvest, and coastal protection. The other five ecosystem services were evaluated by staff, but were determined to not be applicable to the site.

Ecosystem Services Indicators
The status and trends of ecosystem services are best evaluated using a combination of three types of indicators: economic, non-economic, and resource. Economic indicators may include direct measures of use (e.g., person-days of recreation, catch levels) that result in spending, income, jobs, gross regional product, tax revenues, and non-market economic values (the difference between what people pay to use a good/service and what they would be willing to pay). Non-economic indicators can be used to complement economic indicators and include importance-satisfaction ratings for natural and cultural resources, facilities and services for recreation uses, limits of acceptable change for resource conditions, social values and preferences (measured by polls), social vulnerability indicators, perceptions of resource conditions in the present and expectations for the future, and access to resources. Finally, resource indicators are considered in determining status and trend ratings for each ecosystem service. Resource indicators are used to determine if current levels of use are sustainable or are causing resource degradation. If resources cannot support levels of use, this may downgrade a rating that may otherwise be higher based on economic and non-economic indicators alone. Together, these three types of indicators are considered when assessing the status and trends of ecosystem services in national marine sanctuaries.

Cultural Services (non-material benefits)

Science — The capacity to acquire and contribute information and knowledge

Status Rating: Good/Fair	Status Confidence: High
Trend Rating: Improving	Trend Confidence: Low
Status Description: The capacity to provide the ecosystem service is compromised, but performance is acceptable.	
Rationale: Long-term scientific data on resources in the sanctuary have been collected for 20-30 years and in some areas have been expanded over time. Data are publicly available through data portals, publications, reports, and sanctuary supported symposia. However,	

staffing and funding levels are not adequate to support science activities and data collection in the expanded area of the sanctuary. Monitoring and research is minimal in estuarine and lagoon habitats and there are significant challenges to accessing the western and northern portions of the sanctuary due to weather, white sharks (for diving operations), and limited vessel capabilities.

Understanding the health of the sanctuary through exploration, characterization, research, and monitoring has been of the highest priority to sanctuary management since 1991. Science at GFNMS has ensured a healthy and resilient sanctuary by assessing the effectiveness of sanctuary management actions and regulations. Science activities collected data to provide a baseline from which we have measured the positive and negative impacts of management decisions, environmental influences, anthropogenic pressures, and detected anomalous changes in species seasonality, abundance, and distribution. Sanctuary science projects forecasted near-term and long-term effects of physical, chemical, and biological processes and ecological interactions on the health of the sanctuary. The science program at GFNMS has promoted the sanctuary as a sentinel site for research, monitoring, and habitat characterization. Science findings were integrated into sanctuary management actions (i.e., adaptive management actions). The science program at GFNMS also offered community-based scientists the opportunity to learn about the sanctuary and to actively collect data essential for management, which led to increased stewardship and protection of the sanctuary.

Seven indicators were assessed to determine the status and trend of the GFNMS science program: 1) research permits issued each year, 2) the number of partnerships that rely on sanctuary data and provide in-kind and financial support for our science projects, 3) the number of exploration, characterization, and monitoring projects, 4) the level of funding from the site's budget and funds from outside sources and partnerships, 5) community-based science projects, 6) publications, and 7) the challenges that limit our capacity to acquire and share data and information (Table ES.S.1).

Table ES.S.1. Summaries for the key indicators related to science in the sanctuary that were discussed during the June 10, 2022 virtual workshop. Blank cells in the "Source" column indicate that data internal to GFNMS are referenced.

Commented [1]: for consistency, would it be possible to simply put "internal GFNMS data" in those cells?

Indicator	Source	Data Summary	Figures & Tables
Research Permits	ONMS, 2022	Status:157 active research permits in the sanctuary from 2010–2021. Trend: No apparent trend	Table ES.S.2
Science Funding		Status: GFNMS budget funds for science projects has averaged $400,000 per year, with a peak of $536,000 in 2021, which was primarily due to combining the GFNMS and CBNMS budgets. Trend: Science funding levels have remained relatively stable and increased in 2021 when the GFNMS and CBNMS budgets were combined.	Figure ES.S.1
Partnerships		Status: GFNMS partners with at least 34 federal, state and county governments, academic, and	Figure ES.S.2

		research institutions on science projects, data sharing, in-kind support, and vessel support. Trend: No trend data available.	
Research Cruises, Monitoring & Expeditions		Status: During this study period, GFNMS has led or participated in 13 seafloor cruises. In 2015, when the sanctuary expanded, 15 additional sandy beach monitoring sites and two rocky intertidal sites were added to the GFNMS monitoring projects. Trend: The number of seafloor exploration cruises and shoreline monitoring surveys increased since 2010. The number of pelagic cruises remained stable, except during the pandemic.	Table ES.S.3
Community-Based Science	Lindquist & Roletto, 2022b; LiMPETS, 2022	Status: Volunteers were engaged in eight science projects for shoreline surveys, the majority of hours (84%) were for Beach Watch ranging from 6,324 hours in 2011 to 12,240 hours in 2018. Trend: The number of volunteers, the number of sites monitored by volunteers, and contributed volunteer hours increased since 2010, except for 2020-2021, during the pandemic.	Figure ES.S.3
Publications		Status: Approximately 222 publications, including conference and symposium abstracts, peer-reviewed papers, and ONMS Conservation Science Series reports. Trend: The number of publications remained stable during this study period.	Table ES.S.4
Limitations & Challenges: Limitations on staffing (1 FTE, prior to 2021) and funding for science; limited ability to support (funding and staffing) students and external researchers; limited weather window for vessel-based surveys; vessel crew and scientist lodging limitations; no suitable overnight anchorages north of Bodega Head.			

Research Permits

The sanctuary issues research permits for science projects that benefit management but violate a sanctuary regulation. For example, permits are issued for low overflights that may disturb wildlife, yet they yield status and trend data on seabird populations. Permit special conditions allow staff to provide strict requirements on the type of aircraft and number of passes over a particular colony, which minimizes or eliminates the likelihood of disturbance. Other projects that violate sanctuary regulations, such as disturbance to the seabed, release of man-made objects discharged into the sanctuary, and projects that disturb seabirds, marine mammals, or white sharks, provide vital data on habitats and health of species while minimizing negative impacts. From 2010–2021, the sanctuary had 157 active research permits (Table ES.S.2, ONMS, 2022). Since the expansion of the sanctuary in 2015, the number of new research permits slightly increased, but most permits were expanded to include new areas protected in Sonoma and Mendocino Counties.

Commented [2]: ??? Odd. I think the regulation prohibits disturbance or discharge unless reviewed/approved through the permitting process...in which case conducting research like this is not a violation. "Permit special conditions allow..." means it is not a violation. Not sure why the negative take of research permits here, is not directly related to evaluating the science ES, out of context.

Commented [3]: same comment

Table ES.S.2. From 2010–2021, the sanctuary issued 157 permits for research activities that included activities that otherwise would have violated sanctuary regulations. Source: ONMS, 2022

Year	Active Research Permits	Types of Research
2010	11	Benthic invertebrate assessments, benthic surveys fish, climate impacts estuarine Invertebrates, intertidal surveys rocky habitat, invertebrate assessment sandy shores, non-indigenous species impacts, tagging white sharks, water quality buoy deployment
2011	9	Acoustic monitoring of southern resident killer whales, non-indigenous species impacts, tagging white sharks, water quality buoy deployment
2012	8	Habitat assessment wave glider and expendable bathythermograph (XBT), ocean acidification (OA) impacts to eelgrass, seabird aerial surveys, tagging white sharks
2013	8	Benthic fish assessment, climate impacts to estuarine marsh, habitat assessment XBT, intertidal habitat assessment, white shark tag-receiver moorings, tagging whales
2014	20	Marine mammal aerial surveys, maritime heritage, non-indigenous species impacts, OA impacts to eelgrass,white shark tag-receiver moorings, water quality buoy deployment
2015	6	Benthic fish assessment, maritime heritage, white shark tag-receiver moorings, water quality buoy deployment
2016	17	Acoustic assessments of marine mammals, aerial surveys and tagging marine mammals, benthic fish assessment, intertidal habitat assessment, invertebrate assessment, maritime heritage mapping XBT, seabird attractants, white shark tag-receiver moorings, water quality buoy deployment, waterfowl aerial surveys
2017	10	Acoustic assessments of marine mammals, benthic fish assessment, biodiversity invertebrates, climate impacts eelgrass, crab gear assessment, eelgrass assessment, intertidal subtidal habitat assessments, intertidal surveys marsh habitat, mapping XBT, marine mammal assessments, non-indigenous species impacts, seabird aerial surveys, white shark tag-receiver moorings, waterfowl aerial surveys
2018	10	Clamming impacts using uncrewed aircraft systems (UAS), crab gear assessment, estuarine eelgrass assessment using UAS, intertidal subtidal habitat assessments, mapping XBT, water quality buoy deployment, water quality wave glider
2019	32	Aerial surveys and tagging marine mammals and turtles, aerial surveys marine mammals, benthic fish assessment, benthic habitat assessment, benthic invertebrate assessments, climate impacts to eelgrass, contaminants assessment, crab gear assessment, intertidal habitat assessment, intertidal subtidal habitat assessments, UAS assessment of kelp canopy, larval fish and invertebrate assessment, mapping XBT, maritime heritage, non-indigenous species impacts to seagrass, white shark tag-receiver moorings, water quality buoy deployment

2020	11	Crab gear assessment, intertidal habitat assessment, UAS assessment of kelp canopy, larval fish and invertebrate assessment, white shark tag-receiver moorings, water quality buoy deployment
2021	15	Acoustic monitoring marine mammals, aerial surveys and tagging marine mammals and turtles, aerial surveys turtles, benthic fish assessment, benthic habitat assessment, eelgrass assessment, intertidal habitat assessment, intertidal subtidal habitat assessments, invertebrate assessment sandy shores, kelp assessment and seeding research, UAS assessment of kelp canopy, water quality wave glider

Science Funding

Funding for science projects is limited and has not kept pace with inflation or the expansion of the sanctuary in 2015 (Figure ES.S.1), therefore GFNMS relies~~we rely~~ on strong partnerships to help support and fund science projects of highest priority to sanctuary management. GFNMS~~Our~~ science programs also provided in-kind support to many other natural resource management agencies.

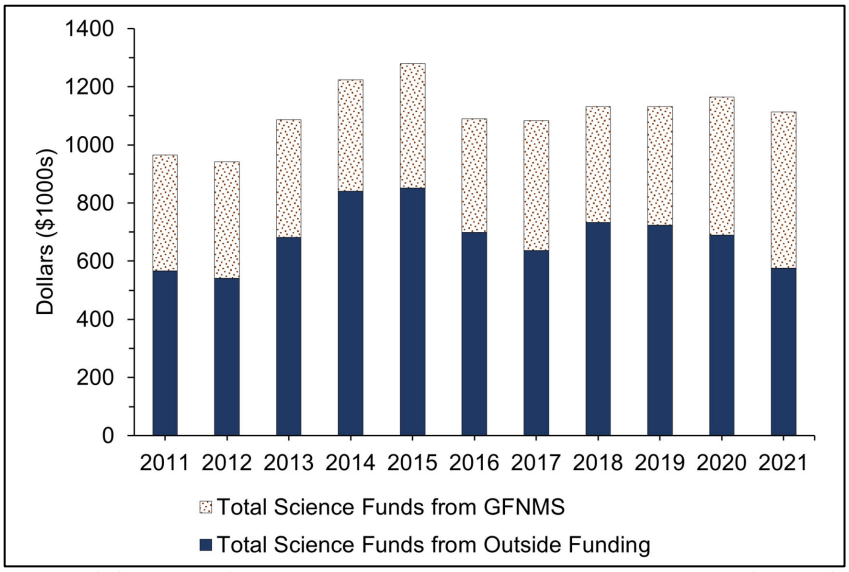

Figure ES.S.1. Funds for science projects in the sanctuary, including in-kind funding (e.g., staff, office space, amenities), and outside funding (i.e., funds not coming from the sanctuary's budget) that supports GFNMS science projects. Source: GFNMS

Partnerships

In order to fill the funding gaps for science projects GFNMS relies on partners. Our partners provide more than half of the funds for our science projects, either through grants used to support sanctuary led projects or through in-kind funding supporting our science volunteers, analysis, and publishing data (Figure ES.S.1). From 2010–2021, GFNMS worked with at least 34 partners from federal, state and county governments and academic and research institutions (Figure ES.S.2). Our strong partnerships also promote sanctuary awareness and expand

Commented [4]: Is it feasible or possible to track funds used to support research projects within sanctuary waters but not directly associated with the sanctuary? That seems as though it would also be helpful, and I might guess it would have a bit more of an upward trend given increasing funds provided by the state (Prop 1, OPC, other). But it might be a bit much to dig up and compile..

Commented [5]: Tone has shifted here from GFNMS previously in the CR report to "our"...from more objective evaluation to something more promotional. Maybe OK, but might want to consider consistency in tone.

stewardship and our knowledge about sanctuary resources. GFNMS provided funding for five projects with a science component; 12 partners provided funding for science projects; 29 provided in-kind funding in the form of data and in-kind support (e.g., staffing, analyses, writing reports and papers); 28 partners used GFNMS science data for natural and cultural resource management, violation detection, outreach, interns, and students. GFNMS supported at least 28 partners with in-kind support from science staff and GFNMS provided vessel support to eight partners.

Figure ES.S.2. Logos of the sanctuary science partners. Source: GFNMS

Research Cruises, Monitoring & Expeditions

Exploration, characterization, and monitoring are at the heart of the GFNMS science program. From 2010–2021, GFNMS worked with our NOAA partner agencies, the National Marine Fisheries Service and National Centers for Coastal and Ocean Science, to support 13 exploratory and research cruises to map and characterize the sanctuary seafloor habitats (i.e., quantification of biota and confirming substrate type). Along with staff from CBNMS and Point Blue Conservation Science, GFNMS co-led 33 pelagic surveys as part of the ACCESS project (see Box 1) to quantify abundance and distribution of birds, mammals, zooplankton, marine debris, and drift algae (Elliott et al., 2022b). Also, with the Greater Farallones Association, GFNMS conducted over 16,000 shoreline surveys to quantify coastal birds, mammals, human activities, and marine debris, and to quantify invertebrate and algal species in sandy beach and rocky intertidal habitats (Table ES.S. 3). Most of the shoreline surveys were performed by well-trained volunteers for the Beach Watch (see Box 2) project (Lindquist & Roletto, 2022b).

Table ES.S.3. Number and type of monitoring projects, research and exploration cruises led or co-led by sanctuary science staff, 2010–2021. Source: GFNMS

Year	NMS Led & Co-Led (Seafloor)	Partner Led (Seafloor)	NMS Led & Co-Led (Pelagic)	NMS Led & Co-Led (Coastal and Estuarine)	Partner Led (Coastal and Estuarine)
2010	1		3	1,275	32
2011			3	1,275	32
2012	1		3	1,274	50

Commented [6]: For at-sea surveys, both the number of surveys and the numbers of days at sea for research could be more informative metrics- given that the scale of the different columns is highly variable.

2013			3	1,274	50
2014		1	3	1,638	50
2015			3	1,639	50
2016	1		3	1,638	50
2017		1	3	1,639	50
2018	2	1	3	1,638	34
2019	1	2	3	1,638	38
2020	1			320	
2021	1		3	1,638	38
TOTAL	8	5	33	16,886	474

Community-Based Science

Community-based scientists (i.e., volunteers) contribute a significant amount of sampling effort along the coast of the sanctuary. Eight science projects used volunteers for shoreline surveys that collect data on various metrics including: human activities; the abundance and distribution of birds, mammals, invertebrates, algae; oil pollution; and if the mouth of a stream or lagoon is open or closed to the ocean (Figure ES.S.3). The majority, (84%) of volunteer hours are contributed from the Beach Watch project and ranged from 6,324 hours in 2011 to 12,240 hours in 2018 (Lindquist & Roletto, 2022b; Figure ES.S.3). Annual sampling hours on the Beach Watch project fluctuated due to levels of funding obtained by the Greater Farallones Association (GFA) for recruitment and training of new volunteers. GFA also obtained non-NOAA funding in 2014 just prior to the sanctuary expansion, to recruit and train more volunteers to survey beaches in the expansion area. GFA also provided funds and staffing for the Long-term Monitoring Program and Experiential Training for Students (LiMPETS) project (LiMPETS, 2022). In 2015 LiMPETS added seasonally dependent surveys at one sandy beach (total of six beaches) and two surveys at rocky intertidal beaches (total of 5 beaches). LiMPETS conducts sampling four times a year at each site. Due to the COVID-19 pandemic, sampling by all volunteers was limited in 2020–2021. Prior to the pandemic, there had been an increase in the total number of volunteer hours contributed to sanctuary science projects (Figure ES.S.3).

Commented [7]: "contributed" yes? CRs are backward looking assessments for specific periods...consistency in tense?

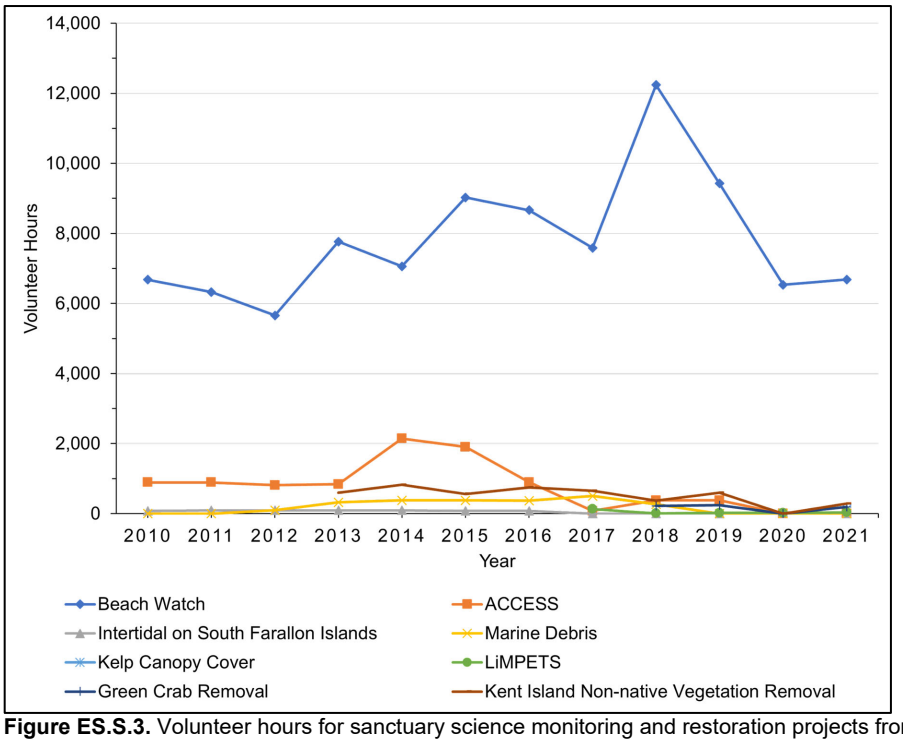

Figure ES.S.3. Volunteer hours for sanctuary science monitoring and restoration projects from 2010–2021.

Publications

At least 222 publications have been produced from science projects supported by the sanctuary. Publications included abstracts produced for conferences and symposia, —peer-reviewed papers in journals,the ONMS Conservation Science Series, book chapters, and technical reports produced after major events, incidents, or research cruises (Table ES.S.4). The number of abstracts produced each year is dependent on the number of conferences and symposia that are held each year and available funding.

Table ES.S.4. Abstracts produced from 2010–2021 for various conferences and symposia, peer-reviewed papers in journals, the ONMS Conservation Science Series, chapters in books, and technical reports based on data collected by sanctuary science projects.

Type of Publication	Number of Publications
Peer-reviewed Papers	59
Technical Reports	54
Dissertations & Theses	10
Abstracts, Presentations, & Posters	95

Cruise Reports	2
Books & Chapters	2
Total	222

Between 2010 and 2022, the sanctuary supported two research symposia, “Beyond the Golden Gate Research Symposium” in 2016 and 2022. These symposia provided a venue for regional researchers, students, and science educators to collaborate and exchange information about their projects with each other, with educators, and with members of the public. Symposium topics were relevant to marine resource management, such as climate change impacts and indicators, restoration and mitigation activities, defining and identifying ecological hotspots, oceanographic patterns, the integration of biological and physical observations, habitat characterization, and the importance of long-term monitoring of marine and estuarine habitats and species. The goal of the symposia was to increase our understanding and protection of regional marine and estuarine ecosystems and to support and guide wise management of the environment. Each symposium produced publicly available proceedings that included 40–60 abstracts summarizing current research and monitoring projects.

Sanctuary data are available through GFNMS staff but also through several types of data portals, including those of partners, such as Greater Farallones Association, Central and Northern California Ocean Observing Systems, Deep Sea Coral Research and Technology Programs, SW ERMA, Federal Geographic Data Committee, and National Centers for Environmental Data.

Limitations & Challenges

There were significant limitations and funding challenges, particularly given the sanctuary expansion in 2015. Weather and sea state conditions limited our ability to access our northern and offshore areas due to the size (67’) of our primary research vessel, R/V *Fulmar*. The R/V *Fulmar* is too large to safely anchor overnight in harbors or dog-hole-ports north of Bodega Head and is too small to access the offshore and northern portions of the sanctuary during the rough seas that often occur November through April. The R/V *Fulmar’s* home port is more than 80 miles from the southern sampling locations in the sanctuary. Since there are no crew that are housed near the San Francisco Bay or Bodega Bay ports, we do not have the opportunity to mobilize a cruise during an opportunistic weather window of good sea state and safe conditions. Weather and the significant number of white sharks limited our ability to safely conduct scuba research dives June through September. Funding was limited to one full-time research position, prior to 2022, and also limited our science projects to our highest priority habitats, such as pelagic, rocky shores, and sandy shores. Limited funding has also placed a higher burden on our partners, who support a significant amount of staffing and funding for our science projects.

Conclusion

The status of science ecosystem services is good/fair indicating the capacity to provide the ecosystem service is compromised, but performance is acceptable based on the abundance of data collected, partnerships, and publications. Data have been collected by researchers in the sanctuary for over 30 years. Partnerships are numerous and provided more than half of the science staff and funding for research and monitoring projects in the sanctuary. Data are publicly available and staff have supported data accessibility. There were numerous opportunities for publications and data exchange through sanctuary supported symposia, reports, and peer-reviewed papers. Some limitations exist, such as access to larger vessels that can operate in rough sea conditions. Access to larger vessels is improving. Although staffing and funding levels have not increased at the rate of inflation or with the addition of more sanctuary areas, some science projects have expanded. The use of well-trained volunteers and

strong partnerships have allowed the sanctuary science program to expand and serve the sanctuary's resource protection, education, and outreach programs.

(Lit Cited for ES Science)

Elliott, M., Lipski, D., Roletto, J., Warzybok, P., & Jahncke, J. (2022b). *Applied California Current Ecosystem Studies* [Unpublished data set]. Point Blue Conservation Science.

Long-term Monitoring Program and Experiential Training for Students (LiMPETS). (2022). *What is LiMPETS?* Greater Farallones Association. https://limpets.org/what-is-limpets/

Lindquist, K., & Roletto, J. (2022b). *Beach Watch database: Supplementary data* [Unpublished data set]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of National Marine Sanctuaries, Greater Farallones National Marine Sanctuary & Greater Farallones Association.

Office of National Marine Sanctuaries (ONMS). (2022). *Permit database* [Unpublished data set]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration.

Education — the capacity to acquire and provide intellectual enrichment

Status Rating: Good/Fair	Status Confidence: Very high
Trend Rating: Improving	Trend Confidence: Very high
Status Description: The capacity to provide the ecosystem service is compromised, but the performance is acceptable.	
Rationale: Evaluations of education programs provided by or supported by the sanctuary were ranked as excellent. Programs reached a wide range of economic levels, geographies, and ages. Educational partnerships were strong and with additional financial support could be expanded to reach more target audiences. The diversity of programs offered and the number of participants and collaborators were robust. Program data showed steady or increasing numbers of people served; steady numbers were linked to limited staff capacity rather than ecosystem function or community desire for programs. There was limited capacity for staff to match the community demand for intellectual enrichment. The ecosystem was perceived as healthy and conducive to educational enrichment.	

Education as an ecosystem service is defined as the capacity to acquire and provide intellectual enrichment. This is accomplished by engaging the public in both informal and formal programs that increase ocean literacy and better prepare participants to make informed decisions that affect the marine environment. Informal education was defined as public programs, while formal education was defined as programs for students and teachers. The following narrative addresses both (Table ES.E.1 and Table ES.E.3).

The status and trends for education were measured by evaluating a number of indicators including:

- Number of educators and students receiving formal school education
- Number of participants receiving informal public education
- Number of visitors to exhibits featuring Greater Farallones NMS
- Willingness to pay for education programs
- Number of volunteer hours supporting the education programs
- Number and type of educational programs offered

Informal Education

Informal education occurs outside of a school or university setting. Sanctuary staff worked with strategic partners to develop and deliver a wide variety of programs to engage the public in ocean and coastal science and recreation. Programs imparted sanctuary messages and the value of marine protected areas. Programs with fees had scholarships available.

Table ES.E.1. Summaries for the key indicators related to informal education that were discussed during the June 15, 2022 virtual workshop. The data is from GFNMS recorded in NOAA's annual education accomplishments database. External exhibit visitorship numbers were provided by the partner institutions and organizations and reference their total visitorship.

Indicator	Data Summary for 2011 - 2021
Exhibits about Greater Farallones National Marine Sanctuary	Seven exhibit partnerships served over 28 million visitors, based on partner reporting. Six of the seven exhibits have been updated or refreshed, indicating partners also value the stories the exhibits impart.
Docents, Interns, and Volunteers	Intern, docent, and volunteer programs support 20,623 service hours, valued at $588,580 which greatly increased program capacity and reach. Volunteers gain knowledge, experience, and skills.
Get Into Your Sanctuary Series	3,787 individuals participated in monthly exploration series to discover sanctuary habitats and wildlife.
Art and Science Lecture Series	6,759 adults participated in the Sanctuary Soiree series, which included renowned scientists that shared the latest research on sanctuary marine life.
Family Workshops	5,635 families with children, ages 4–10 years, explored special topics (e.g. crabs in the sanctuary) by participating in two hour workshops at the Pier Classroom on the sanctuary campus in San Francisco.
Summer Camps	2,180 youth, ages 8–12 years, participated in week-long camps that included field trips to sanctuary habitats and marine science activities.
Sharktoberfest	An annual event with over a dozen education, research, and conservation partners attracted 10,248 adults and families to celebrate the annual return of white sharks.

Naturalist Classes and Courses	768 naturalists were trained for partner organizations and the Sanctuary Naturalist Course program trained 43 GFNMS naturalists.
Outreach - Social Media, Partner Events and lectures	68,726 people attended partner outreach events. There has been steady growth in followers for the GFNMS Facebook and Twitter programs.

Exhibits about GFNMS

Seven exhibits in five California counties feature GFNMS, including the GFNMS' own visitor center (Table ES.E.2). The exhibits brought sanctuary places, stories, and marine life to people, through aquaria, touch tanks, murals, dioramas, mounted specimens, life-size marine life models, interactive learning stations (Figure ES.E.1), sound, film, photography, and maps. Over 28 million visitors experienced these exhibits from 2011–2021. Five of the six partner exhibits have been updated and refreshed, indicating our partners also valued the sense of place and stories the exhibits impart.

Table ES.E.2. Summaries for the key indicators related to informal exhibit education that were discussed during the June 15, 2022 virtual workshop. The data is from GFNMS recorded in NOAA's annual education accomplishments database. Partner exhibit visitorship numbers were provided by the partner institutions and organizations and reference their total visitorship.

Institution or Organization	**Year Exhibit Opened Followed by Year(s) Refreshed**	**Location by County**	**Visitorship 2011–2021**
Aquarium of the Bay	2007	San Francisco	6,323,089
Bodega Marine Laboratory/UC Davis	1998, 2008	Marin	48,443
California Academy of Sciences	2008, 2014, 2017	San Francisco	16,224,518
GFNMS Visitor Center	1998, 2006, 2017	San Francisco	171,004
Pigeon Point Light Station/California State Parks	2004, 2016	San Mateo	1,186,187
Point Reyes National Seashore	2007, 2016, 2022	Marin	3,562,824
Randall Museum	2010, 2016	San Francisco	775,000
Total Exhibit Visitorship	**2011-2021**		**28,291,065**

Figure ES.E.1. Students in GFNMS Visitor Center on a field trip. Photo: Justin Holl/NOAA

Docents, Interns and Volunteers

Docents and volunteers support the Greater Farallones NMS Visitor Center and public and partner programs. Their support greatly increases program capacity and reach. In turn, volunteers and interns gain experience, skills, and knowledge about the sanctuary. From 2011–2021, a total of 20,623 hours of volunteer service were provided at a value of $588,580 (based on a volunteer rate as of April, 2021 of $28.54/hour).

Get Into Your Sanctuary Series

Sanctuary staff hosted a Get Into Your Sanctuary exploration series for the public to discover their national marine sanctuary on foot, by boat, or paddling. A total of 3,787 individuals experienced this monthly exploration series that combines recreation and education to discover sanctuary habitats and wildlife, such as spring gray whale migrations or winter elephant seal mating, etc., from 2011–2021.

> *"Thank you SO much for the experience of a lifetime. Everything, from the light, the air, the sound and sight of the waves, the birds, the islands, the whales, felt profound. The crew and naturalists were extraordinary. Guests kept busy sighting whales on every side of the Salty Lady!" -Alice, Farallon Islands & Whale Watch Trip Participant, 2017*

Art and Science Lecture Series

The Art and Science Lecture Series was a bi-annual series for adults to learn from renowned scientists about sanctuary habitats and wildlife, create ocean-themed art, and participate in social learning activities. From 2011–2021, 6,759 adults participated in the series, with more participants each year, including during the COVID-19 pandemic when the series went virtual.

“Laurence Doyle's presentation last year was perhaps the most enthralling - and yes, mind bending - talks I've ever heard!” Bill Brick, a humpback whale soiree participant

Family Workshops

GFNMS offered two hour family workshops from 2011 through 2021, 5,635 families with children ages 4–10 participated. Before the COVID-19 pandemic, the participation trend was increasing. In 2018 and 2019, an outside evaluation consultant was hired to assess a subset of family workshop programs. Some of the evaluators findings are depicted in Figure ES.E.2.

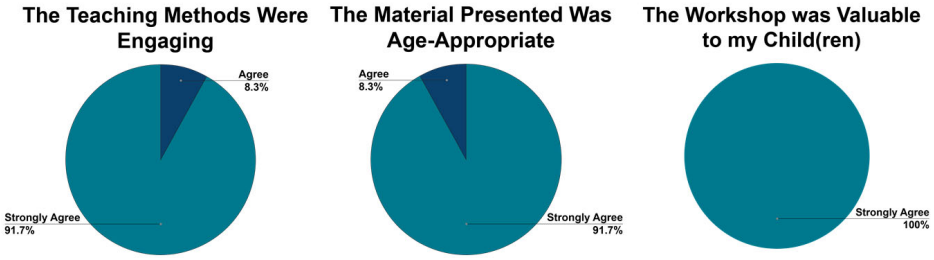

Figure ES.E.2. Sample of 2018 and 2019 Family Workshop evaluation assessment findings
Source: Indira Phukan, Evaluation Consultant

Summer Camps

Week-long camps for youth included field trips to sanctuary habitats, ocean science, kayaking, and exploring, all in a fun-filled environment. From 2011–2021, 2,180 campers participated in the program. The summer camp roster fills every year with a wait list nearly equal to the participant list, indicating that participation could double if staff capacity was increased to meet the demand. Outcomes of pre/post surveys for camp showed that 96% of students had an increased understanding of marine life from the first day of camp to the last day of camp. During every Marine Explorers Camp session, there are numerous students and parents that tell us that this camp is "the best summer camp" they've ever experienced.

Sharktoberfest

Sharktoberfest was an annual event GFNMS coordinated with over a dozen education, research, and conservation partners. The event was co-hosted by Shark Stewards and Greater Farallones Association to celebrate the return of the white sharks each year. A total of 10,248 people of all ages participated in the event from 2011–2021. Twelve partners were involved in the program since its inception, including during the COVID-19 pandemic when the program was virtual. Prior to the pandemic participation numbers steadily increased. During the first year of the pandemic when we launched the program virtually, participation numbers doubled; however, by the second year of the pandemic when the program was still offered virtually, the program numbers dropped significantly (Figure ES.E.3.). Many of our in-person programs that were pivoted to virtual programs during the pandemic had this same trend, which seems to

indicate pandemic burn-out of virtual programs.

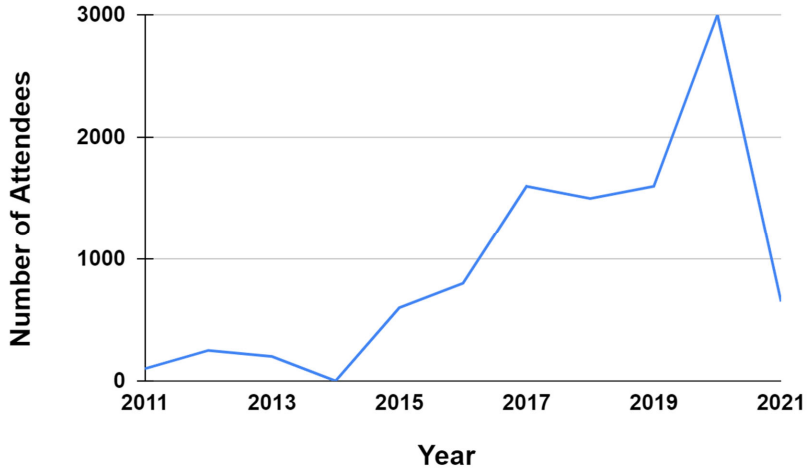

Figure ES.E.3. Graph showing Sharktoberfest attendance from 2011–2021. Event was canceled in 2013 due to a government shutdown. Source: GFNMS program education database

Commented [8]: Those who do not carefully read the text above might need to be reminded in the figure caption that 2020 and 2021 attendance was virtual not in person due to the covid 19 pandemic.

Naturalist Classes and Courses

GFNMS staff provided naturalist training for partner organizations. The training included natural history, sanctuary messaging, and the latest science. We offered these training sessions to whale watching organizations and local park docent programs, such as at Fitzgerald Marine Reserve. These classes trained 768 naturalists, who in turn amplified sanctuary messaging to thousands of people recreating in the sanctuary. In addition, in 2020, the sanctuary launched a new, more comprehensive 22-hour naturalist course designed to train GFNMS volunteer naturalists. This sanctuary volunteer naturalist course trained 43 adults. A participant from the first sanctuary naturalist course said:

> *"This class was incredibly well thought out. Great balance of exercises and playful exploration with very rich material. I couldn't wait to get here every week, and then I couldn't wait to tell other people what I learned." - Audrey*

Outreach via Social Media, Partner Events, and Lectures

Facebook and Twitter have shown steady growth from 2015–2021 and 2016–2021, respectively (Figure ES.E.4, Figure ES.E.5).

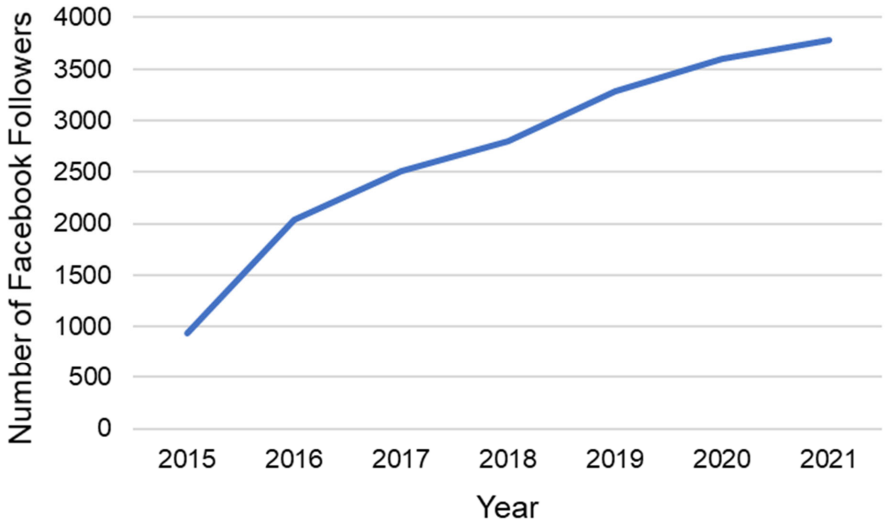

Figure ES.E.4. Facebook followers from 2015–2021. Source: Facebook, 2022

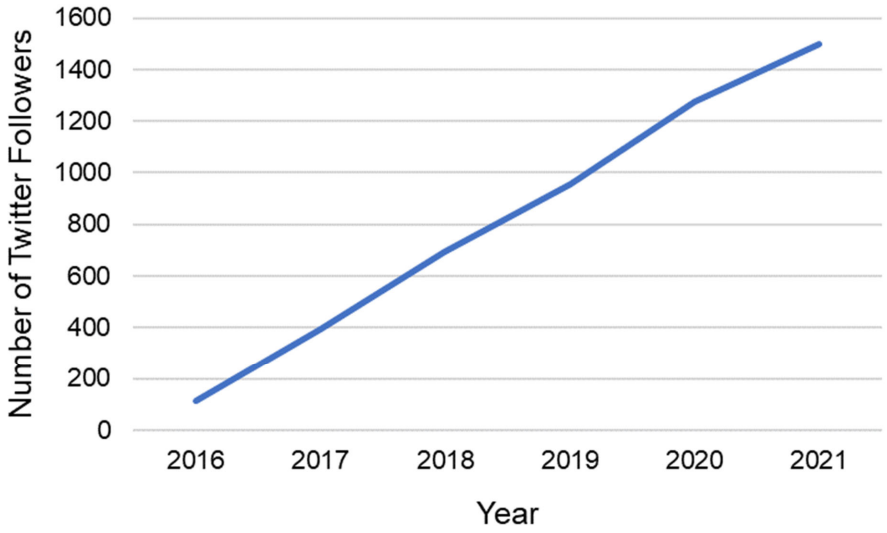

Figure ES.E.5. Twitter followers from 2016–2021. Source: Twitter, 2022

Outreach - Lectures & Tabletop Exhibits at Events

Sanctuary staff provided lectures to multiple organizations such as the American Cetacean Society, Yacht Clubs, and Rotary Clubs. From 2011–2021, 2,041 people participated in sanctuary lectures. In addition, sanctuary staff participated in partner educational programs such as Ocean Exploration Trust's *Nautilus* Live, California Academy of Sciences Nightlife events, and the San Francisco Zoological Gardens World Ocean Day. From 2011–2021, 68,726 people participated in the in-person and online sanctuary talks and engaged with the sanctuary at exhibit booths at community events.

Formal Education

Sanctuary staff worked with strategic partners to develop and deliver a wide variety of programs for K–16 students and teachers to increase ocean literacy. Scholarships were available for programs with fees.

Table ES.E.3. Summaries for the key indicators related to formal education that were discussed during the June 15, 2022 virtual workshop. The data is from GFNMS recorded in NOAA's annual education accomplishments database.

Indicator	Data Summary for 2011-2021
K–16 GFNMS Visitor Center Field Trips	18,990 students participated in field trips that are 90 minutes long, interactive, grade specific, correlate to state standards, and include indoor and outdoor components.
K–16 Farallones Virtual Programs	5,609 students participated in interactive, multimedia programs on multiple marine topics. Programs were 90 minutes long, grade specific, and correlated to state standards.
K–16 Teacher Workshops	1,300 educators received professional development on multiple topics that included grade specific standards-based curriculum and resources.
K–12 At Your School Programs	32,457 students had ocean science delivered to their classrooms. The 60-minute, interactive, grade specific programs correlate to state standards.
7th–12th Fisherman In The Classroom	5,543 students had a commercial fisherman or woman and sanctuary staff co-teach an interdisciplinary 90-minute program.
6th–16th LiMPETS	20,014 LiMPETS (Long-term Monitoring Program and Experiential Training for Students) students participated in rocky shore and sandy beach intertidal monitoring.
3rd–5th Oceans After School	4,359 students participated in 8–10, two hour sessions of hands-on marine science after school.

GFNMS Visitor Center Field Trips (Serving Kindergarten–University Students)
Programs at the GFNMS visitor center, delivered by sanctuary educators, were 90 minutes long, interactive, grade specific, correlate to state standards, and include indoor and outdoor components. From 2011–2021, 18,990 Kindergarten – University students participated in visitor center field trips. Post-trip evaluations showed that 100% of students believe that national marine sanctuaries protect the ocean. From 2015–2021, 44% of the students served were from families that are low income (as indicated by participation in the state's free and reduced-price meal program.)

Figure ES.E.6. Students observing seabird behaviors at Crissy Beach in San Francisco. Photo: J. Holl/NOAA

Farallones Virtual School Programs (Serving Kindergarten–University Students)
During the COVID-19 pandemic, new, interactive, multimedia virtual programs on marine topics were developed. The virtual programs were launched for the FY21 school year and had 5,609 students, of which 38% were from families that are low income (as indicated by participation in the state's free and reduced-price meal program.) The programs were 90 minutes long, grade specific, and correlated to state standards. A participating teacher provided this feedback:

> *"Most of my students, who are English language learners, have not developed the skill of asking questions. This awesome program was so interesting for my students that during the questioning part of the presentation, many students raised their hands because they wanted to know more about the animals. This was such a positive experience, especially for my shy students, who wanted to get their questions answered!" - Gordon Lau Elementary School*

Teacher Workshops (Serving Kindergarten–University Teachers)
From 2011–2021, 1,300 teachers participated in workshops on climate change, ocean acidification, deep sea corals, and training for teachers in the Long-term Intertidal Monitoring Program & Experiential Training for Students (LiMPETS) program. Workshops included the latest science information, grade specific classroom activities, and necessary resources (Figure ES.E.7). Outcomes of post-workshop surveys in 2019 showed:

- 100% of teachers believed that people are changing the climate

- 100% of teachers believed that people need the ocean
- 100% of teachers knew how climate change has impacted the ocean

Pre-workshop survey results varied considerably.

Figure ES.E.7. Teachers discuss plankton collected from net tows projected on the screen. Photo: J. Holl/NOAA

At Your School Program (Serving Kindergarten–12th Grade Students)
GFNMS delivered ocean science programs to classrooms. The programs included immersive activities, artifacts, specimens, models, visuals, and presentations from sanctuary staff. Programs were 60 minutes long, interactive, grade specific, and correlated to state standards. From 2011–2021, 32,457 students participated and from 2015–2021, 41% were from families that are low income (as indicated by participation in the state's free and reduced-price meal program.)
. A program evaluation consultant, Indira Phukan, Stanford Graduate Education Program, was hired to assess the Leatherback Turtle program for 5th grade students, an excerpt of her report stated:

100% of the teachers surveyed said:
- The program was valuable to my students
- The teaching methods were effective
- The pace of the program was suitable
- The material presented was age-appropriate
- That they would recommend the program
- The program was "very good" (the highest rating)

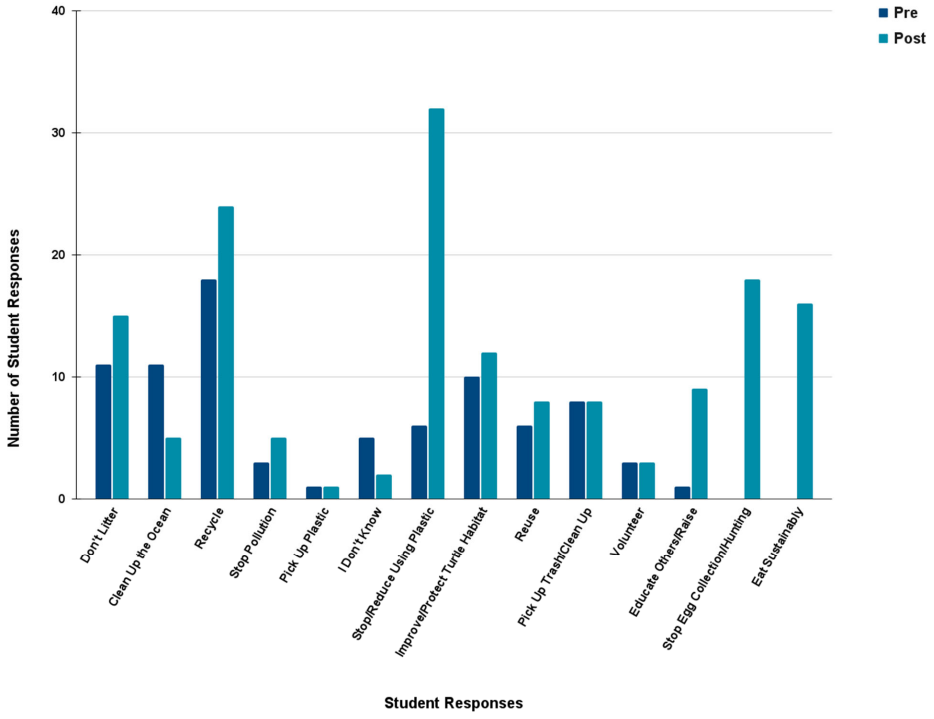

Figure ES.E.8. Pre/Post Student responses to: "What can you do to help protect the Leatherback Turtle?" Credit: I. Phuken, Stanford Graduate School of Education

Fisherman In the Classroom (Serving 7th–12th Grade Students)

Sanctuary staff, along with a commercial fisherman or woman, co-taught an interdisciplinary 90-minute program that included subjects such as climate change, economics, oceanography, and sustainable fisheries (Figure ES.E.9). From 2011–2021, 5,543 students participated in the program, and from 2015–2021, 42% of the students served were from families that are low income (as indicated by participation in the state's free and reduced-price meal program.) Evaluations from a sample of 43 teachers indicated that following student participation in the program 92% of their students understood national marine sanctuaries protect ocean habitats and 96% of their students understood we obtain food from the ocean.

Commented [9]: commercial fishers...isn't that what we've adopted? haha

Figure ES.E.9. Fisherman shows students how a Dungeness crab trap works. Photo: M. McIntosh/NOAA

LiMPETS (Serving 6th Grade–University Students)

LiMPETS (Long-term Monitoring Program and Experiential Training for Students) is a rocky shore and sandy beach intertidal monitoring and education program for students, educators, and volunteer groups. From 2011-–2021, 20,014 students participated in the program and from 2015–2021, 28% of students served were from families that are low income (as indicated by participation in the state's free and reduced-price meal program.)

The 2018–2021 Greater Farallones LiMPETS BWET (Bay Watershed Education and Training) program reported:

- Student pre/post-tests reveal 75% of students experienced an improvement in their knowledge about the ocean and the importance of scientific monitoring.
- 100% of teachers participating in the LiMPETS Climate Literacy Project agreed or strongly agreed that they developed a deeper understanding of the "practice" of science, gained more confidence in facilitating students in the "practice" of science, and had a positive experience through their participation in the program.

Oceans After School (Serving 3rd–5th Grade Students)

Oceans After School programs were delivered to students enrolled in after school programs with either their school or local recreation centers. From 2011–2021, 8–10 two-hour sessions of experiential marine science were delivered to 4,359 students, resulting in 16–20 contact hours of after-school science for youth. From 2015–2021, 57% of the students served were from families that are low income (as indicated by participation in the state's free and reduced-price meal program.) A staff person from one of the After School sites had this to say about the program:

> *"I have never participated in a program with children that was this engaging. Each and every week I could tell that the students were actually learning and happy to learn. The experiments were also very fun for the kids and out of all the programs we run they were*

most excited to participate in Oceans." - Booker T. Washington Community Service Center

Conclusion

The ecosystem service education is good/fair indicating capacity to provide the ecosystem service is compromised, but the performance is acceptable. This was based on the responses from program participants, the diverse offerings, and the geographic and socioeconomic reach of the education and outreach program at Greater Farallones National Marine Sanctuary, which was rated excellent by the condition report workshop expert panelists. The programs resulted in an increase in the ocean literacy of participants in both the school and public programs. The investment of time and resources in forging strong partnerships with multiple education organizations was recognized as an effective strategy to ensure sustained education engagement in multiple communities. However, the demand for sanctuary programs exceeded the capacity of GFNMS staff and funding, limiting the ability to reach new audiences and fully engage the diverse communities of the San Francisco Bay Area in ocean protection. Program data showed steady or increasing numbers of people served; steady numbers of people served were linked to limited staff capacity rather than ecosystem function or community desire for programs. Closing the gap between the capacity to deliver education programs and the unmet demand would increase the opportunity for GFNMS to use sanctuary education and outreach programs and visitor centers to highlight the value of sanctuaries and other MPA systems as solutions to climate impacts and other threats.

Figure ES.E.10. Logos of primary sanctuary education partners GFNMS has worked with to produce education programming for multiple years.

Facebook. (2022). *Analytics for GFNMS Facebook account, 2015 to 2021* [Unpublished data set].
Twitter. (2022). *Analytics for GFNMS Twitter account, 2016 to 2021* [Unpublished data set].

Heritage — Recognition of historical and heritage legacy and cultural practices

Status Rating: Good	Status Confidence: High
Trend Rating: Improving	Trend Confidence: High
Status Description: The capacity to provide the ecosystem service has remained unaffected or has been restored.	
Rationale: There has been a gradually increasing amount of~~, and continues to be, a great deal of~~ recognition by sanctuary staff, community members, and some government agencies of the importance of ~~maritime~~ heritage. The expansion of the sanctuary in 2015 approximately doubled its size, thus potentially associating with it a broader set of communities and additional aspects of maritime heritage (inclusive of historical and heritage legacy and cultural practices). The ecosystem service to provide and support events, stories, and visits to historic places, managed by various parks and agencies, was already well established prior to 2010. GFNMS supports shared~~New partnerships and~~ exhibits on ~~maritime~~ heritage and has initiated new partnerships in the heritage field~~continued to be established.~~ ~~; these new connections are particularly notable for the communities adjacent to the northern area of the sanctuary, including coastal tribal and Indigenous~~ ~~communities~~. GFNMS ~~gA g~~ap areas include:~~is~~ the inclusion of more experts in assessing this ecosystem service, particularly tribal communities; heritage partnerships with coastal tribal and Indigenous communities; lack of maritime heritage staff within the ONMS west coast region.~~.~~	

Commented [10]: This seems pretty optimistic. MHP in Silver Spring gone from 5 to 2. No archaeologist or historian at GFNMS. 1 (soon 0) MHP staff on west coast, no regular monitoring of heritage sites in GFNMS, no assessment of CHRIS data (yet), no inclusion of tribes in CR workshops...

Commented [11]: ???
Heritage partnerships established with the tribes? I thought that was still pending...

National marine sanctuaries are iconic and have long been recognized, used, and valued by the communities that are near them as well as by those in more distant communities. Shared history and heritage creates the unique cultural character of many present-day coastal communities, and can also be an important part of the current economy. Recognition of the past through exhibits, artifacts, records, stories, songs, and chants provide a link to the history of these areas and a way to better understand the maritime and cultural heritage within the environment itself. This ecosystem service category defines benefits from resources primarily attached to historical and heritage legacy and culture. Tangible and intangible aspects of heritage blend together to contribute to the history and legacy of the sanctuary. ONMS has been making efforts, with partners, to document, describe, and protect for future generations the historic and potentially historic sites within the sanctuary (see Question 16), with efforts increasing since the sanctuary expanded in 2015.

The ~~maritime~~ heritage of the GFNMS region is long, varied, and complex, with a number of historical shifts in resource use patterns. As such, the five selected indicators are intended to serve as a gauge for the heritage ecosystem service, rather than be comprehensive (Table ES.H.1). However, other ecosystem services may also include information on efforts to promote heritage (e.g., Education) or the influences heritage may have (e.g., Sense of Place).

Table ES.H.1. Summaries for key indicators related to heritage that were discussed during the July 6, 2022 virtual workshop.

Indicator	Data Summary	Figures
Heritage-related community events	Status: Events, including new ones added to the data set as a result of the 2015 expansion, were held throughout the time period. Trend: Not assessed.	
Iconic heritage locations	Status: Iconic maritime heritage locations include Fort Ross, Point Reyes, the Northern California Doghole Ports Maritime Cultural Landscape (includes multiple sites) and locales with heritage place names. Additional locations were added due to the 2015 expansion. Trend: Not assessed.	Figure E.S.H.1.
Iconic ships and shipwrecks	Status: Iconic shipwrecks include the SS *Pomona*, USS *Conestoga*, and iconic ships include lumber schooners/steam schooners. Additional wrecks were included in sanctuary boundaries due to its expansion in 2015. Trend: Not assessed.	Figure E.S.H.2.
Heritage museum outreach	Status: Outreach through museums and exhibits occurred, among other places, at San Francisco Maritime National Historical Park, Point Arena Lighthouse and Museum, and the Point Reyes National Seashore Lighthouse and Bear Valley Visitor Centers. Due to the sanctuary expansion in 2015, additional pertinent museums and exhibits were included in the overall list of those neighboring to the sanctuary. Trend: Not assessed.	Figure E.S.H.3.
Indigenous heritage	Status: Tribal and Indigenous heritage is strongly recognized and represented in the sanctuary community~~,~~: with three federally-recognized tribes in the sanctuary coastal community; one prior to sanctuary expansion and two more included within the community due to its expansion in 2015. Trend: Not assessed.	Figure E.S.H.4.
Data Gaps:	Iconic heritage locations - additional place names Iconic ships and shipwrecks - gaps in shipwreck location data and assessments of shipwreck records Indigenous heritage - publications describing tribal histories and learning more directly from tribes and Indigenous peoples.	

The GFNMS region has a long history that is relevant to the heritage service. Some of the earliest travelers through and inhabitants of this coastal area, the ancestors of modern day Pomo and Miwok peoples, would have used the natural resources of the sea and coasts.

European contact with Indigenous people in this area began with Sir Francis Drake of England in 1579. This and subsequent settlement changed the earlier ways of life and traditional sea and land uses. Spaniards, Russians, Chinese, and many others came (with more arriving as visitors or new residents), comprising groups such as settlers, traders, loggers, farmers, ranchers, fishermen. Recognition and celebration of heritage is shaped by present-day communities, and this region continues to attract people with diverse interests and backgrounds, including small business owners, marine transportation owners, recreational enthusiasts, scientists, educators, homeland security and military branches, and more (ONMS, 2014a; ONMS, 2014b). Descendants of the first peoples and groups who arrived later continue to live in the area today.

Heritage-related Community Events

Many heritage-related public community events in the region focus on commercial fishing and fish, general heritage, and Indigenous heritage, and demonstrate to attendees the enduring maritime connections the community has with the expansive ocean area encompassed by GFNMS. Examples of events held between 2010–2022 adjacent to or in locations near the sanctuary are in Table ES.H.2. These events have been held by various organizers in the community regularly since 2010, with some exceptions and the number of events held annually generally increased prior to the COVID-19 pandemic, at which time health concerns about the virus caused a number to be delayed or canceled.

Table ES.H.2. Examples of heritage-related public community events held between 2010–2022 adjacent to or in locations near the sanctuary, listed geographically from south to north.

Event Name	Inaugural Date	Source
Sausalito Herring Festival	2013	Sausalito Community Boating Center, 2022a and 2022b; R. Gorum/Sausalito Community Boating Center, personal communication, February 4, 2022
Big Time Festival at Kule Loklo	1980	NPS 2022a and 2022b; MarinArts 2022; P. Engel/NPS, personal communication, February 25, 2022; C. Arreglo/NPS, personal communication, April 27, 2022
Bodega Bay Fisherman's Festival	1973[1]	Bodega Bay Fisherman's Festival, 2022
Fort Ross Festival	more than five decades ago	Fort Ross Conservancy, 2022a; S. Sweedler/Fort Ross Conservancy, personal communication, February 22, 2022
Fort Ross Harvest Festival	2011	Fort Ross Conservancy, 2022b; S. Sweedler/Fort Ross Conservancy, personal communication, February 22, 2022

[1] 1973 was the first year of this festival with this name; its origin was as a celebration of the start of the Salmon fishing season and the annual Blessing of the Fleet in previous decades.

Alaska Native Day	2015	Fort Ross Conservancy, 2022c (2015, 2017, 2019 and 2021 pages) and 2022d; S. Sweedler/Fort Ross Conservancy, personal communications, February 23, 2022; L. Peters, U.C. Davis, personal communication, March 2, 2022
Metini Day	2013[2]	Fort Ross Conservancy, 2022c (2016, 2018 and 2019 pages); Metini Day 2017, 2022; Scully 2013; S. Sweedler/Fort Ross Conservancy, personal communications, February 23 and March 2, 2022
Sonoma Mendocino Coast Whale and Jazz Festival	2002	K. Stillman/Gualala Arts, personal communications, February 17 and 18, 2022
Point Arena Harbor and Seafood Festival	1999	City of Point Arena 2022; Point Arena Merchants Association, 2022; P. Anderson/City of Point Arena, personal communication, March 2, 2022
Acorn Festival	2016[3]	McLaughlin, 2016; Coastal Pomo Acorn Festival 2017, 2022; Coastal Pomo Acorn Festival 2018, 2022; and SmallTownPapers Inc., 2022

As a result of the 2015 sanctuary expansion, additional coastal communities now border the sanctuary, from north of Bodega Bay in Sonoma County to Manchester Beach in the southern part of the Mendocino County coast, resulting in including additional maritime heritage-related events in the overall data set.

Iconic Heritage Locations

Iconic heritage locations within the sanctuary or in the communities near it are significant because of their importance and connections to maritime history and for some, their continued use today, including for cultural purposes or recreation (e.g., beachgoing, scuba diving). Several of the most iconic are described below.

Fort Ross State Historic Park has an active visitor center with exhibits and historic structures. The park also hosts cultural events that provide information about a thriving Russian-American Company settlement from 1812 to 1841, where the first shipbuilding in California was done (California Department of Parks and Recreation, 2022). A doghole port was located at Fort Ross (California Department of Parks and Recreation, 2021), so the historical significance of Fort Ross includes maritime connections with what is now GFNMS as well as northern states, including Alaska; Alaskan Native and Indigenous peoples; and early North Pacific sailing routes.

[2] In 2013 the event was called Big Time at Metini.

[3] The last traditional festival prior to 2016 was held circa a hundred years earlier.

Point Reyes National Seashore also has multiple connections with maritime heritage and the nearby ocean waters of GFNMS[4] as it includes coastal Indigenous villages, Sir Francis Drake's presumed landing site (NPS, 2022c), the location of an early life saving station at Ten Mile Beach in Point Reyes, the still-present Lifeboat Station and Lifeboat on Drake's Bay (Figure ES.H.1; NPS, 2022d). The Point Reyes Lighthouse, Lighthouse Visitor Center, and Bear Valley Visitor Center all have heritage information and maritime exhibits (NPS, 2022e). The two visitor centers also include information on national marine sanctuaries (Office of National Marine Sanctuaries [ONMS] 2022a).

Figure ES.H.1. The Historic Point Reyes Lifeboat Station's Boathouse in 2013. Photo: R. Schwemmer, NOAA

Twenty four doghole ports in the sanctuary along the Sonoma and southern Mendocino coasts were once centers of maritime activity and trade, and there are opportunities to read about them and view artifacts in parks and other locations at or near the former ports as well as on the GFNMS website. All are important historical sites that have the potential to be officially recognized for their national significance; they were included in a broader NRHP Northern California Doghole Ports Maritime Cultural Landscape Multiple Property Listing accepted by the NPS in 2021 (Marx and Jaffke 2021). One, Salt Point Landing Historical and Archaeological District, was recognized and listed in the NRHP in 2022 (D. Marx/independent contractor, personal communication, April 17, 2022; NPS, 2022f).

Place names that reflect history, including tragic events, also can reflect the maritime heritage of the region. For example, Windermere Point is named after the wreck of the *Windermere* and Franconia Bay the wreck of the *Franconia*. An identified data gap is determining additional iconic place names, including any Indigenous place names, associated with the sanctuary's maritime heritage.

Iconic Ships and Shipwrecks

Historic ships and shipwrecks sometimes gain enough popularity to serve as iconic features, in addition to being archaeological properties. An example of an iconic ship in San Francisco is the

[4] The GFNMS boundary is mostly ¼ mile from the shoreline in this portion of the sanctuary adjacent to Point Reyes National Seashore, except that it follows the Mean High Water Line in a small portion of Tomales Bay. See https://www.ecfr.gov/current/title-15/subtitle-B/chapter-IX/subchapter-B/part-922#922.80.

C. A. Thayer, a lumber schoonership that operated in GFNMS in its day and is afloat at San Francisco Maritime National Historical Park. The floating museum ship, *C. A. Thayer*, a wooden-hulled, three-masted schooner designed for carrying lumber, was built in 1895 in Northern California and was the last commercial sailing vessel in operation on the West Coast. It is typical of the ships that visited doghole ports and it also traveled far beyond the California coast carrying cargoes to and from other West Coast States and foreign ports (NPS 2022g). West coast coastal steamships ("steam schooners") are also associated with the area and have a recognized history and heritage. Examples within the sanctuary of iconic shipwrecks are the wrecks of the SS *Pomona* and the USS *Conestoga* ((Figure ES.H.2). These are all listed on the NRHP. The SS *Pomona* (Fort Ross Conservancy, 2022e) struck rocks in 1908 while steaming north in heavy seas, then hit wash rocks in Fort Ross Cove. This wreck is still visited by scuba divers (ONMS, 2022b; ONMS, 2022c); and Fort Ross State Historic Park Visitor Center displays artifacts from it. The USS *Conestoga*, a U.S. Navy tug, was lost at sea with 56 sailors in 1921. It was one of the top unsolved maritime mysteries in U.S. Naval history until the wreck was discovered in 2009 and its identity confirmed in 2015 (ONMS 2022d).

Figure ES.H.2. Modern painting of the USS *Conestoga* (AT 54) on its final voyage pounding through large waves during a gale off Southeast Farallon Island in March 1921. Image: Artist D. Frka, Naval History Heritage Command

Heritage Museum Outreach

Heritage museum outreach is a broad term encompassing maritime heritage exhibits and other information at regional museums and other venues. In addition to the sanctuary visitor center and partner exhibits, almost every national, state, and regional park in the neighboring counties to the sanctuary provides heritage information associated with the area (Figure ES.H.3).

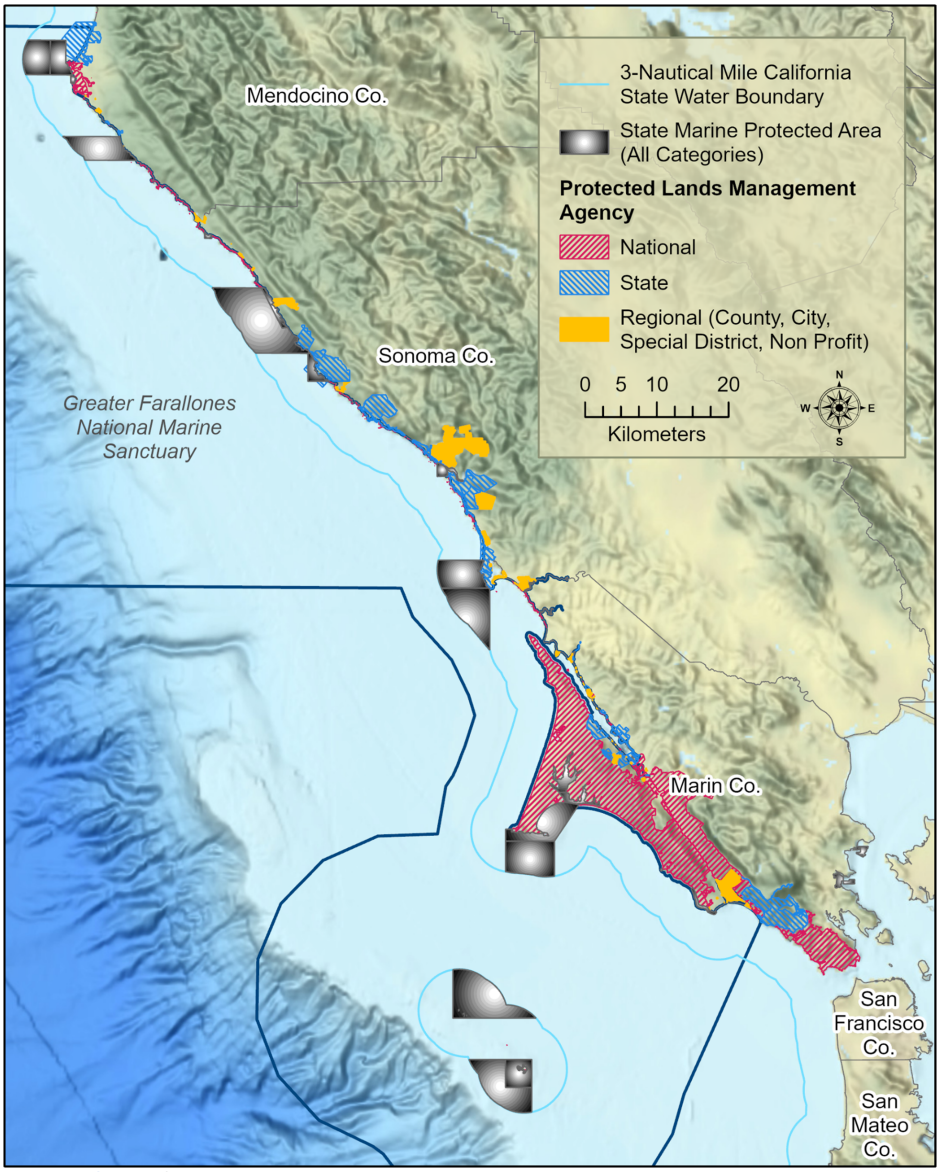

Figure ES.H.3. Coastal parks in the counties adjacent to, and marine protected areas in, the sanctuary. Image: NOAA; Sources: California Protected Areas Database, 2021b; California Marine Protected Areas [ds582], 2023; Esri, 2020.

San Francisco Maritime National Historical Park, Point Reyes National Seashore, and Point Arena Light Station and Lighthouse (owned by Point Arena Lighthouse Keepers, Inc.) are examples of places with museums or visitor centers where people may learn about regional ~~maritime~~ heritage. The ~~maritime~~ heritage exhibits and events at San Francisco Maritime National Historical Park cover California's seafaring past. ~~Among the many features and properties at this park is the lumber schooner *C. A. Thayer*.~~ The park also has information on local tribes, regional shipwrecks, cargo shipping, whaling, coastal navigation, and sea shanty singing. Prior to the COVID-19 pandemic, the park offered ranger tours and received four million visitors per year. The San Francisco Maritime National Park Association supports public programming, and over the past decade, its membership increased 400% (B. Ho/NPS, personal communications, January 12–31, 2022; D. Plumtree/San Francisco Maritime National Park Association, personal communication, April 1, 2022). Good visitation numbers were also seen at Point Reyes National Seashore's Lighthouse Visitor Center and Bear Valley Visitor Center. Between 2009–2020, over three million people visited the centers (ONMS, 2022e). The Point Arena Lighthouse complex includes a museum and lodging and offers an interactive experience in the exchange between history, science, and natural beauty. By many accounts, public interest in maritime heritage has been steadily increasing.

Commented [12]: already mentioned

Indigenous Heritage

Indigenous heritage is intrinsic to the coastal region bordering GFNMS. Thousands of years prior to first contact with Europeans, the ancestors of Pomo and Miwok peoples inhabited the area. Later, Alaskan Indigenous peoples were brought to the region by Russian fur traders and their descendants remain.[5] The three local coastal tribes with GFNMS ~~maritime~~ heritage connections are: the Federated Indians of Graton Rancheria, comprised of Coast Miwok and Southern Pomo (Federated Indians of Graton Rancheria, 2022); the Kashia Band of Pomo Indians of Stewarts Point Rancheria (Kashia Band of Pomo Indians, 2022); and the Manchester Band of Pomo Indians of the Manchester Rancheria (Manchester-Point Arena Band of Pomo Indians, 2022). Multiple tribes, with a complex history of travel and trade relationships, are located throughout California (State of California, Native American Heritage Commission, 2022).

Tribal and Indigenous people have used and do use a wide variety of marine resources for food or other purposes, including fish, shellfish, kelp and salt (NPS, 2022h; California Indian Museum & Cultural Center, 2022; California Marine Sanctuary Foundation, 2022). Local public festivals celebrate Indigenous traditional cultures; and places close to GFNMS, at public lands, on tribal lands, or an area representative of a traditionally used place (e.g., Kule Loklo at Point Reyes National Seashore) (Figure ES.H.4), are sites where events promote culture, religion and/or education.

[5] The tribal and Indigenous heritage described in this report relies on publicly available and published sources. This summary information is acknowledged as often partial and incomplete, and not intended to speak for or on behalf of the tribes or Indigenous communities or peoples regarding their varied histories and past and current traditions and values.

Figure ES.H.4. Kule Loklo, a recreated village at Point Reyes National Seashore. Photo: National Park Service

As part of a 2015 event celebrating the expansion of Cordell Bank and Greater Farallones national marine sanctuaries, Kashia elders shared a name for the GFNMS ocean waters along the coastline, "Ahqa Pilili walli", that translates to “place of churning waters.” This event was attended by local tribal members and tribal elders, along with other groups, officials, and sanctuary staff.

Identified data and assessment gaps include the need for collaborative~~additional~~ publications describing tribal histories and learning more directly from the tribes and Indigenous peoples connected to GFNMS.

Conclusion

The status of heritage as an ecosystem service is good, indicating the capacity to provide the ecosystem service has remained unaffected or has been restored and is based on the rich ~~maritime~~ heritage in the region that includes tribal and indigenous connections, maritime trade and transit history, shipwrecks and artifacts and the abundant opportunities to connect to GFNMS maritime heritage through heritage-related community events, iconic heritage locations, iconic ships and shipwrecks, heritage museum outreach, and Indigenous heritage. The complex and broad topic of GFNMS ~~maritime~~ heritage is well represented and recognized within GFNMS and in the region. The trend is improving, partly due to the inclusion of additional historic and potentially historic sites within the sanctuary and ONMS efforts with partners to document, describe and protect them for future generations; and partly due to other factors, such as increasing opportunities for people to attend public heritage festivals and rising public interest in learning about ~~maritime~~ heritage at museums and visitor centers. Recognition of tribal and Indigenous heritage has been strong for a long time in this region. That recognition is increasing among the sanctuary staff, particularly after the expansion of the sanctuary in 2015, and is also

increasing among the community at large. More information, collaboration, and partnership is needed regarding iconic heritage locations, locations and assessment of shipwrecks, and Indigenous heritage. GFNMS heritage partnerships could be considered for inclusion in future condition reports as a new indicator to better inform this question.

References (Heritage)

Bodega Bay Fisherman's Festival. (2022). *About Bodega Bay Fish Fest*. Retrieved January 14, 2022, from http://www.bbfishfest.org/about/about-fish-fest/.

California Marine Protected Areas [ds582]. 2023. California Department of Fish and Wildlife, Marine Region. March 3, 2023.

California Department of Parks and Recreation. 2022. *Fort Ross State Historic Park*. Retrieved September 15, 2022 from https://www.parks.ca.gov/?page_id=449.

California Department of Parks and Recreation. (2021). Maritime Cultural Landscape of Sonoma's Doghole Ports, by NOAA's Office of National Marine Sanctuaries and California State Parks. Publications in Cultural Heritage. Number 37.

California Indian Museum & Cultural Center. (2022). *Pomo Tribal History Newsletter*. Retrieved March 18, 2022, from chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/http://cimcc.org/wp-content/uploads/2012/10/Pomo-Tribal-History-Newsletter.pdf.

California Marine Sanctuary Foundation. (2022). *Marine Protected Areas: Protecting California's Marine Resources and Kashia Pomo Way of Life*. Retrieved January 26, 2022, from https://californiampas.org/wp-content/uploads/2020/03/Kashia-Poster-1.png.

California Protected Areas Database (CPAD). 2021b. GreenInfo Network. www.calands.org. December 2021.

City of Point Arena. (2022). City of Point Arena. *20th Annual Harbor & Seafood Festiva*l. Retrieved February 16, 2022, from https://pointarena.ca.gov/2019/08/1943/.

Coastal Pomo Acorn Festival 2017. (2022). *Coastal Pomo Acorn Festival 2017*. Retrieved February 1, 2022, from https://m.facebook.com/events/point-arena-air-force-station/coastal-pomo-acorn-festival-2017/2010096049276758/.

Coastal Pomo Acorn Festival 2018. (2022). *Coastal Pomo Acorn Festival 2018*. Retrieved February 1, 2022, from https://www.facebook.com/events/point-arena-air-force-station/coastal-pomo-acorn-festival-2018/514644725648343/.

Federated Indians of Graton Rancheria. (2022). *Our Story: A Restored Tribe Serving Marin and Sonoma Counties*. Retrieved January 26, 2022, from https://gratonrancheria.com/.

Fort Ross Conservancy. (2022a). Fort Ross Conservancy. *Fort Ross Festival*. Retrieved February 23, 2022, from https://www.fortross.org/festival/.

Fort Ross Conservancy. (2022b). Fort Ross Conservancy. *Fort Ross Harvest Festival*. Retrieved February 18, and June 23, 2022, from https://www.fortross.org/harvest/.

Fort Ross Conservancy. (2022c). Fort Ross Conservancy. *Past Events at Fort Ross State Historic Park* (2015, 2016, 2017, 2018, 2019, and 2021) Retrieved February 23, 2022, from https://www.fortross.org/past-events/.

Fort Ross Conservancy. (2022d). Fort Ross Conservancy. *Alaska Native Day 2014*. Retrieved

Fort Ross Conservancy. (2022e). Fort Ross Conservancy. *SS-Pomona*. Retrieved September 13, 2022, from https://www.fortross.org/ss-pomona/.

Gualala Arts. (2022). Gualala Arts. *Search Results for: Whale and Jazz Festival 2022*. Retrieved February 16 and June 23 2022, from https://gualalaarts.org/?s=Whale%20and%20Jazz%20Festival%202.

Kashia Band of Pomo Indians. (2022). *About the Kashia Band of Pomo Indians*. Retrieved January 26, 2022 from: https://www.stewartspoint.org/wp2/.

Manchester Point Arena Band of Pomo Indians. (2022). *Manchester Point Arena Band of Pomo Indians*. Retrieved December 27, 2022, from https://mpapomotribe.org/.
McLaughlin, S. (2016, October 28). Humboldt Redwood Company, LLC (2022). Independent Coast Observer, October 28, 2016. *Pomo Acorn Festival celebrated on Point Arena mountaintop*. Retrieved January 31, 2022, from https://www.hrcllc.com/wp-content/uploads/2016/11/Pomo-Acorn-Festival.pdf.
MarinArts. (2022). MarinArts. *38th Annual Big Time Festival*. Retrieved January 26, 2022, from https://www.marinarts.org/event/38th-annual-big-time-festival/.
Metini Day 2017. (2022). *Metini Day 2017*. Retrieved March 2, 2022, from https://www.facebook.com/events/fort-ross-state-historic-park/metini-day/373744959691116.
National Park Service (NPS) (2022a). Point Reyes. *Big Time Festival*. Retrieved, January 26 and April 25 2022, from https://www.nps.gov/pore/planyourvisit/events_bigtime.htm.
NPS. (2022b). *Thirty-ninth Annual Big Time Festival*. Retrieved January 26, 2022, from https://www.nps.gov/pore/planyourvisit/events_bigtime.htm.
NPS. (2022c). Point Reyes. *History and Culture*. Retrieved September 15, 2022, from https://www.nps.gov/pore/learn/historyculture/index.htm.
NPS. (2022d). Point Reyes. *Then & Now: U.S. Life-Saving Service*. Retrieved September 13, 2022, from https://www.nps.gov/pore/learn/photosmultimedia/photogallery_thenandnow_uslss.htm.
NPS. (2022e). Point Reyes. *Visitor Centers*. Retrieved September 15, 2022, from https://www.nps.gov/pore/planyourvisit/visitorcenters.htm.
NPS. (2022f). National Register of Historic Places. *Weekly List 2022 04 15*. Retrieved September 7, 2022, from https://www.nps.gov/subjects/nationalregister/weekly-list-2022-04-15.htm.
NPS (2022g). San Francisco Maritime. *CA Thayer History*. Retrieved September 13, 2022, from https://www.nps.gov/safr/learn/historyculture/ca-thayer-history.htm.
NPS (2022h). *Coast Miwok at Point Reyes*. Retrieved April 25, 2022, from https://www.nps.gov/pore/learn/historyculture/people_coastmiwok.htm.
Office of National Marine Sanctuaries. (ONMS) (2022a). Greater Farallones National Marine Sanctuary. *Visitor Center*. Retrieved September 15, 2022, from https://farallones.noaa.gov/heritage/doghole.html.
ONMS. (2022b). Greater Farallones National Marine Sanctuary. *Shipwrecks*. Retrieved September 13, 2022, from https://farallones.noaa.gov/heritage/shipwrecks.html.
ONMS. (2022c). Greater Farallones National Marine Sanctuary. *Shipwrecks of Greater Farallones & the Narrows of the Golden Gate*. Retrieved September 13, 2022, from https://farallones.noaa.gov/heritage/shipwreck-storymap.html.
ONMS. (2022d). *USS Conestoga - 100 Years since Departure*. Retrieved September 7, 2022, from https://sanctuaries.noaa.gov/conestoga/.
ONMS. (2022e). *Time and Tide: A History of the Sanctuary System*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries. Written by Elizabeth Moore.
ONMS. (2014a). *Gulf of the Farallones National Marine Sanctuary Final Management Plan*: Updated in Response to the Sanctuary Expansion. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries. https://sanctuaries.noaa.gov/library/alldocs.html
ONMS. (2014b). *Cordell Bank and Gulf of the Farallones National Marine Sanctuaries Expansion Final Environmental Impact Statement*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries. https://sanctuaries.noaa.gov/library/alldocs.html.

Point Arena Merchants Association. (2022). Point Arena Merchants Association. *Point Arena Harbor & Seafood Festival*. Retrieved February 16, 2022, from https://pointarena.net/point-arena-harbor-seafood-festival/.
Sausalito Community Boating Center. (2022a). Sausalito Community Boating Center. *News and Events. Upcoming Events*. Retrieved February 3, 2022, from https://www.sausalitocommunityboating.org/news-and-events.
Sausalito Community Boating Center. (2022b). Sausalito Community Boating Center. *Past Events*. Retrieved February 3, 2022, from https://www.sausalitocommunityboating.org/past-events.
Scully, S. (2013, June 5). *Kashia Pomo culture on display at Fort Ross 'Bigtime' gathering*. The Press Democrat.com. Retrieved March 2, 2022, from https://www.pressdemocrat.com/article/news/kashia-pomo-culture-on-display-at-fort-ross-bigtime-gathering/.
SmallTownPapers Inc. (2022). SmallTownPapers, Inc. *Newspaper Archive of Independent Coast Observer, Gualala, California*. October 19, 2019. Retrieved January 31, 2022, from http://ico.stparchive.com/Archive/ICO/ICO10182019p20.php.
State of California, Native American Heritage Commission. (2022). *Digital Atlas of California Native Americans*. Retrieved June 23 2022, from https://nahc.ca.gov/cp/.

Sense of Place — Aesthetic attraction, spiritual significance, and location identity

Status Rating: Good/Fair	Status Confidence: High
Trend Rating: Improving	Trend Confidence: High
Status Description: The capacity to provide the ecosystem service is compromised, but performance is acceptable.	
Rationale: Many communities have deep connections to the sanctuary and recognize the unique power of the place that sustains, nurtures, and inspires. While environmental conditions are highly variable and increasingly unpredictable due to climate change, the aesthetic attraction remains uncompromised, and the sanctuary offers inspiration for these individuals, communities, and visitors. Most of the regional exhibits about the sanctuary are being renewed, and there has been an increase in coastal recreation activities. Although community awareness of the sanctuary has increased since its expansion in 2015, there is still a need for more national recognition and a connection to how these designated protections provide benefits that are both tangible and sometimes ephemeral but always essential.	

Sense of place is the aesthetic and spiritual attraction and level of recognition and appreciation that humans derive from a location. The indicators below provide insight into the extent to which sense of place affects people of the community and the broader public.

Designations form a foundation for Sense of Place

Special designations in and around the sanctuary are important and can indicate the area's level of regional, state, national, and international significance. In 1981, Congress designated Greater Farallones a national marine sanctuary to protect the largest assemblage of breeding seabirds in the contiguous United States as well as to protect large concentrations of marine mammals that use the sanctuaries' productive waters. In 1988, the United Nations Educational, Scientific and Cultural Organization, Man and the Biosphere Programme established the Golden Gate Biosphere Reserve, which includes the sanctuary along with Point Reyes National Seashore and Golden Gate Recreation Area. Bolinas Lagoon was recognized under the Ramsar Convention as Wetlands of International Importance in 1998, followed by Tomales Bay in 2002. The state of California established a series of marine reserves and marine conservation areas that included state waters of the sanctuary under the state's Marine Life Protection Act of 1999. Also, the state designated Areas of Special Biological Significance within the sanctuary that are monitored and maintained for water quality by the State Water Resources Control Board. The North-Central Coast set of marine reserves and conservation areas, extending from Pigeon Point north to Point Arena, was created in 2009, with 21 Marine Protected Areas (MPAs) covering 153 square miles, with about 11% in fully protected reserve status and six special closures to protect sensitive seabird breeding and marine mammal haul-out sites. In 2015, recognizing one of the most biologically important ecosystems in the world, the federal government expanded the sanctuary to encompass the nutrient-rich upwelling zone off of Point Arena that flows south into the original sanctuary. The sanctuary lies adjacent to diverse and complex urban and rural communities.

Place Identity and Place Attachment

The discussion of factors that influence a sense of place is personal, nuanced, generational and complex. Although there may be tangible places or measurements discussed here, quantifying place identity is highly subjective. Place identity and the related concept of place attachment are crucial descriptors of the connection between peoples and the ecosystem. Place identity, a component of personal identity, is defined as a process by which people describe themselves as belonging to a specific place (Hernández et al., 2007). Identification between self, family, community, and place develops over the long term and can run very deep, particularly where lineage is place based, with genealogy going back many generations. Place identity is often expressed in reciprocal human-ecosystem relationships. This reciprocal relationship emphasizes that people are inseparable from the ecosystem, a common belief among Indigenous cultures; people derive benefits from the ecosystem (ecosystem services) and also contribute to the maintenance or enhancement of the ecosystem (services to ecosystems). Also inherent in a sense of place is an intrinsic stewardship value - where the individuals recognize their role in the care of the resource, not simply due to the reciprocal dynamic but also because of love of a place.

Commented [13]: lower case

Place attachment is defined as a connection to a location that may develop and change over time, reflected in aesthetic attraction (e.g., books, film, artwork), architecture, therapeutic rejuvenation, and even national iconic symbols (Hernández et al., 2007). At both the personal and societal level, place attachment may evolve into place identity; however, the timeframe over which this may occur is highly variable. To address this complexity the Sense of Place indicators were discussed by a diverse group of stakeholders with deep connections to the sanctuary. The working group included: a commercial fisherwoman, a surfer, a naturalist, a diver, a conservationist, a boat captain, a sanctuary staff member, and an artist.

Commented [14]: might have to check consistency of capitalization of ES categories

The indicators for rating sense of place at Greater Farallones National Marine Sanctuary included measures associated with exhibits, film, photography, books, direct experiences in the

sanctuary, people who recreate and/or make a livelihood in the sanctuary, and people who engage with the sanctuary mission. The sense of place created by these measures is central to the sanctuary's mission of protecting the sanctuary.

Table ES.SP.1. Summaries for key indicators related to sense of place that were discussed during the June 15, 2022 virtual workshop.

Indicator	Data Source	Data Summary
Exhibits	GFNMS recorded in NOAA's annual education accomplishments database.	Six exhibit partnerships as well as the GFNMS visitor center feature GFNMS resulting in over 28 million exhibit visitors 2011–2021. Partner exhibit data is based on partner reporting for the past ten years. Five of the six partner exhibits have been updated and refreshed indicating our partners also value the sense of place and stories the exhibits impart.
Film, Video, Photography	GFNMS website and education database.	Films – Sanctuary in the Sea, Beach Watch, and Cool Water Haven Videos – over fifteen videos on various topics such as shark research, kelp monitoring, deep sea coral, shipwrecks, etc. Photo Contests – Annual participation in GIYS photo contests
Sanctuary Explorations	GFNMS recorded in NOAA's annual education accomplishments database.	Get Into Your Sanctuary exploration series for the public to discover their marine sanctuary on foot, by boat or paddling. Telepresence programs that broadcast sanctuary research live as it is happening
Books inspired by experiences in GFNMS	Online research and books in GFNMS Library	Several books have been created about experiences in Greater Farallones National Marine Sanctuary, one a widely acclaimed bestseller – Devil's Teeth by Susan Casey
People who recreate and/or have livelihoods in GFNMS	Workshop members	Multiple groups of people have deep experiences by being in the physical sanctuary itself, and through that experience have unique memories, appreciation, and reverie shared with others
People who engage with the sanctuary mission and/or the	GFNMS Beach Watch and Volunteer Databases	Volunteers and staff stay with the sanctuary a long time. Some volunteers and some staff have served the Sanctuary for 20+ years. Education partners approach staff to design and deliver joint programs and/or exhibits, some partners have worked with the Sanctuary for 20+ years

Commented [15]: hmm...heritage exhibits covered above in the heritage ES. Here, we're listing them again. Maybe need to address more explicitly the different approach or interpretation under sense of place?

For instance, these sense of place exhibits focus wholly on the nature and identity of GFNMS...whereas the exhibits described under heritage ES are supported by varied agencies/parks, and address the heritage/history of the area broadly...

Commented [16]: While certainly not as widely read, another was "The whale that lit the world" by Josh Churchman, based on his experiences fishing in the Gulf of the Farallones and Cordell Bank for many decades (published 2018)..

place		

Exhibits

Seven exhibit partnerships in five California counties, including the GFNMS visitor center, feature the nature and identity of GFNMS~~, including the GFNMS visitor center~~. The exhibits bring sanctuary places and marine life to people, through aquaria (Figure ES.SP.1), touch tanks, murals, dioramas, mounted specimens, life-size marine life models, interactive learning stations, sound, film, photography, stories, and maps. Over 28 million visitors experienced these exhibits from 2011–2021. Six of the seven exhibits have been updated and refreshed indicating our partners also value the sense of place and stories the exhibits impart. See Table ES.E.2.

Commented [17]: see comment above

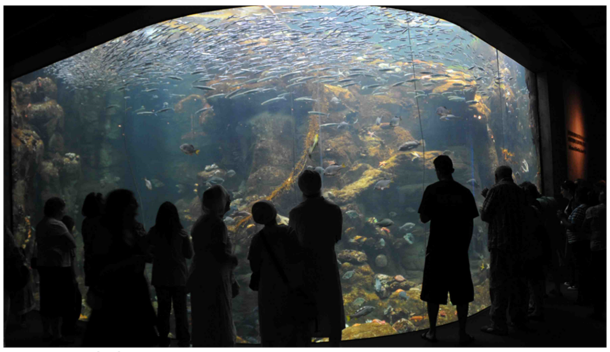

Figure ES.SP.1. Visitors peer into a 100-gallon, three-story high Greater Farallones National Marine Sanctuary tank at the California Academy of Sciences' Steinhart Aquarium. Photo: California Academy of Sciences

Film, Video, Photography

Many films and videos have been created about GFNMS and shown at multiple film festivals, such as the International Ocean Film Festival and Point Arena Film Festival. Some of the films were screened regularly in partner exhibits at highly visited institutions such as Aquarium of the Bay and California Academy of Sciences. Tens of thousands of people have watched the following films about GFNMS: Sanctuary in the Sea, Beach Watch, Cool Water Haven, and Blue Serengeti. Sanctuary staff produced a film, "Beach Watch," which was entered into the International Ocean Film Festival and won an award in 2018. "Sanctuary in the Sea" has over 10,000 views online and "Cool Water Haven" plays daily in the Dive Into Your National Marine Sanctuaries exhibit at Aquarium of the Bay; their visitorship between 2011–2021 was 6,323,089 people. In addition, over 15 videos on various topics such as shark research, kelp monitoring, deep sea coral, and shipwrecks, air on the GFNMS and/or ONMS websites, plus many of the videos are used in sanctuary programs such as the bi-annual lecture series and various school programs. The Office of National Marine Sanctuaries hosts an annual Get Into Your Sanctuary photo contest and GFNMS has been the subject of several winning photos.

Sanctuary Explorations

Connecting physically to a place can increase a sense of place. Sanctuary staff hosted a Get Into Your Sanctuary exploration series for the public to discover their marine sanctuary on foot, by boat, or paddling (Figure ES.SP.2). From 2011–2021, a total of 3,787 adults and families

experienced the monthly exploration series to discover special sanctuary habitats and seasonal events, such as spring gray whale migrations or winter elephant seal mating, etc.

> *"I will carry the memory of this trip in my heart." Carol, Tomales Bay Kayak, 2017*
> *"The paddle we did was an amazing experience. Words fail. I settled on magical as my word to describe the paddle." David, Bioluminescence Kayak, 2017*

Figure ES.SP.2. Kayaking in a sanctuary estuary. Photo: K. McLaughlin

Sanctuary staff delivered GFNMS programming at partner outreach events and lectures. Outreach programs included telepresence that broadcast research occurring in the sanctuary live as it was happening, and/or highly engaging talks with stunning visuals. Between 2011–2021, GFNMS staff had 68,726 participants at multiple partner events, such as *Nautilus* Live, and 2,041 participants at staff lectures at many partner institutions such as the San Francisco Zoological Gardens.

Books inspired by experiences in GFNMS

Many books have been created about experiences in Greater Farallones National Marine Sanctuary. The books have been geared for multiple audiences including children, naturalists, wildlife enthusiasts, history buffs, and birders. Here is a sampling of some of the books that depict natural history in the sanctuary:

Devil's Teeth, Susan Casey - a New York Times bestseller
Neighborhood Sharks: Hunting with the Great Whites of California's Farallon Islands, Katherine Roy - an illustrated children's book
The Farallon Islands: Sentinels of the Golden Gate, Peter White - a history book with 80 archival photographs, maps and drawings.
Ocean Birds of the Nearshore Pacific, Rich Stallcup- a guide for birders that includes bird field marks and behaviors
The Intertidal Wilderness: A Photographic Journey through Pacific Coast Tidepools, Anne Wertheim Rosenfeld, Robert T. Paine - a photographic book for seashore explorers

Food Venues inspired by the Gulf of the Farallones

Devil's Teeth Baking Company with two locations in San Francisco, uses the iconic Farallon Islands and white sharks in their branding and products. Farallon Restaurant was a renowned

restaurant in San Francisco for 23 years; unfortunately, it closed during the COVID-19 pandemic. The restaurant's furnishings included jelly sculptures, urchin test lights, and other sea life decor inspired by the Gulf of the Farallones.

People with a Deep Engagement in the Sanctuary

Multiple groups of people have deep experiences by visiting or working in the sanctuary itself, over a long period of time. Through these experiences, these folks have unique memories and a deep appreciation of the place. This includes scientists, divers, naturalists, birders, commercial and recreation fisherfolk, surfers, artists, film makers, volunteers, and sanctuary staff.

Two sanctuary staff members have over 20 years of service and five others have over 15 years of service. The Beach Watch program has 15 volunteers with over 25 years of service and 45 volunteers with over 20 years of service. From 2011–2021, volunteers in the Beach Watch (Figure ES.SP.3) and education and outreach programs contributed 114,265 hours of service. Sanctuary Advisory Council and Greater Farallones Association Board members contributed 29,071 hours of service from 2011–2021.

Figure ES.SP.3. Sanctuary volunteers working on their Beach Watch survey. Photo: D. Devlin/NOAA/GFA/Beach Watch

The Sense of Place experts who participated in the workshop all have a deep engagement with the sanctuary through their livelihood, and/or a lifetime passion of recreation and/or conservation. To further explore and provide insight into the concept of Sense of Place they were asked two questions:

Commented [18]: capitalized

What would you miss if you couldn't be in the sanctuary?
Why do you care about Greater Farallones National Marine Sanctuary?

Here is a sample of their responses:

- "Everything about the sanctuary, it is our food source."
- "Observing seasonal patterns."
- "Recreating and observing others recreating."
- "The feeling of cold water and extraordinary wildlife experiences."

- “My buffer to a busy and challenging world.”
- “Getting in the water as a reset.”
- “A challenging place to sail, which brings satisfaction and pride.”
- “The sanctuary is important for nourishment of individuals, food security, incomes in our fleet - all contribute to deeper health of coastal communities.”

Conclusion

The sense of place ecosystem service is rated good/fair indicating the capacity to provide the ecosystem service is compromised, but performance is acceptable based on the strong connections that people have made and the many opportunities that have been available for people to establish a sense of place with the sanctuary. These include exhibits, films, books, and excursions. Through the deep engagement of longtime volunteers and staff, a strong sense of place is evident. The trend is improving based on the increased community awareness since the 2015 GFNMS expansion and increased human recreational activities on sanctuary shores during the pandemic, although there are emerging threats to the health of GFNMS. The main threat to the sanctuary’s sense of place is climate change, which is negatively impacting fisheries, livelihoods, and coastal communities, as well as favorite diving, beach combing, and tidepooling locations. Degradation of the sanctuary environment is detrimental to a strong, positive sense of place.

Literature Citation ES Sense of Place:
Hernández, B., Hidalgo, M. C, Salazar-Laplace, M. E., & Hess, S. (2007). Place attachment and place identity in natives and non-natives. Journal of Environmental Psychology, 27(4), 310–319. https://doi.org/10.1016/j.jenvp.2007.06.003

Provisioning Services (Material Benefits)

Consumptive Recreation — Recreational activities that result in the removal of or harm to natural or cultural resources

Status Rating: Fair	Status Confidence: High
Trend Rating: Undetermined	Trend Confidence: Low
Status Description: The capacity to provide the ecosystem service is compromised, and existing management would require enhancement to enable acceptable performance.	
Rationale: Though data are limited, there is evidence that commercial passenger fishing vessel (CPFV) fishing activity and shoreline angling have increased over the past decade. The sport abalone fishery has been compromised by multiple stressors, including loss of kelp cover and fishing pressure.	

The status of consumptive recreation in Greater Farallones NMS is fair with an undetermined trend. Consumptive recreation includes recreational activities that result in the removal of or damage to natural and cultural resources (Table ES.CR.1). In GFNMS, this activity is primarily

recreational fishing, either from private or rental vessels, CPFV, or shore-based fishing. Diving for abalone is another culturally and economically significant recreational activity within the sanctuary and broader region (Reid et al., 2016). NOAA Fisheries and the California Department of Fish and Wildlife manage recreational fishing activities; recreational fisheries are not managed by the sanctuary.

Table ES.CR.1. Summaries for the key indicators related to consumptive recreation in the sanctuary that were discussed during the July 7, 2022 virtual workshop.

Indicator	Source	Data Summary	Figures
Species kept by CPFVs	CDFW, 2020	Status: Unspecified rockfish is the most frequently kept catch, followed by Dungeness crab, blue rockfish, lingcod, black rockfish, Chinook salmon, and several other rockfish species Trend: Rockfish catch remained stable or slightly increased over decade, excepting black rockfish; Dungeness crab catch generally increased, except for a dip in 2015 due to domoic acid advisory; the number of lingcod kept peaked in 2015 then decreased	ES.CR.1 and ES.CR.2
Annual number of CPFVs in GFNMS	CDFW, 2020	Status: Annual average of 76 vessels per year Trend: The number of CPFVs in GFNMS increased significantly by around 3.3 vessels per year from 2010 to 2019	
Annual number of CPFV angler-days	CDFW, 2020	Status: Over 33,000 angler-days per year in the sanctuary Trend: Angler-days increased significantly by over 1600 angler days per year from 2010 to 2019	
Beach Watch fishing rates	Lindquist & Roletto, 2022b	Status: Data do not indicate overall level of activity Trend: Fishing encounter rates increased over the study period	
RecFIN recreational effort by district	PSMFC, 2022	Status: Data do not indicate level of effort in sanctuary Trend: Private/rental vessel effort varied without trend	
Sacramento River winter-run Chinook salmon	NOAA Fisheries, 2020	Status: Endangered Trend: Increase in winter-run Chinook returns	
Red abalone harvest	CDFW, 2015	Status: Fishery closed in 2017 and will likely remain closed at least until 2026 Trend: Red abalone harvest consistently declined through 2015 and the fishery was closed in 2017	ES.CR.3
Groundfish populations	NMFS; PFMC	Status: 9 of 10 depleted groundfish species have recovered or are recovering Trend: stable/increasing population size	
Data Gap: Private and rental vessel fishing effort specifically within the sanctuary. There is also a lack information about how the take of groundfish influences the recovery of groundfish stocks.			

Commented [19]: I don't think I would say this- there is a lot of information about this- it is in stock assessments and (until they were formally declared rebuild) the rebuilding plans for all of these populations- quantifying the trade-offs between recovery time and the need to allow some take to enable fisheries for co-occurring species to be permitted. As pointed out just above this line, 9/10 stocks that were formally declared overfished at one point have rebuilt- so clearly groundfish take was not so great as to prevent recovery. But the main point is that there is very robust analyses of commercial and recreational catches as related to population abundance and dynamics- it takes some work to dig into the documents- but it is not a data gap.

There are several types of fishing modes that may be used in recreational fishing: private, rental, charter, and party boats. A private boat belongs to an individual, not for rent and not with paying passengers. A rental boat is rented by an individual, without crew or a guide. A commercial passenger fishing vessel (CPFV) may be in one of two categories: a charter boat operates under charter for a specified price, time, etc.; a party boat provides fishing space and privilege for a fee per recreational fishermen (Leeworthy & Schwarzmann, 2015).

Commercial Passenger Fishing Vessels (CPFVs)

The top ten most kept species by CPFVs are shown in Table ES.CR.2. From 2015 to 2019, the most commonly retained catch was unspecified rockfish, with an annual average of 86,800 kept fish. Dungeness crab was the second most commonly retained species, with nearly 70,600 kept each year. Over 48,000 blue rockfish were kept by CPFV anglers each year. Other common species kept by CPFVs include lingcod, black rockfish, Chinook salmon, canary rockfish, widow rockfish, copper rockfish, and yellowtail rockfish.

Commented [20]: So the "unspecified rockfish" is a bit misleading- clearly the data used here are coming from the CPFV logbooks- and that is how they report many of the rockfish caught. But CDFW observers (onboard) as well as dockside biologists also sample many trips, get the species composition, and use that to estimate the species composition of all trips- so there is- in other places- estimates of catch to the species level (may be a few unspecified at times, but most of those unspecified are ultimately identified to species level). It is typically relatively straightforward to get those numbers by port, although not necessarily by CDFW fishing block- but it is worth acknowledging that at some point in the process, the species composition of these rockfish is estimated based on fairly robust data.

Table ES.CR.2. Top ten most kept species by CPFVs (five-year average, 2015–2019). Source: CDFW, 2020

Species	Average Number Kept	Rank
Unspecified rockfish	86,802	1
Dungeness crab	70,596	2
Blue rockfish	48,227	3
Lingcod	16,473	4
Black rockfish	14,242	5
Chinook salmon	13,021	6
Canary rockfish	9,883	7
Widow rockfish	8,712	8
Copper rockfish	6,300	9
Yellowtail rockfish	2,445	10

Figure ES.CR.1 shows trends in the numbers of each species retained by CPFV anglers from 2010 to 2020 for the top six most frequently kept species. The top ranked species kept was unspecified rockfish and there was a statistically significant increase in the number kept by CPFVs from 2010 to 2020 (Generalized Linear Model (GLM); coefficient = 2715, p = 0.02) (CDFW, 2020). The number of Dungeness crab, the second ranked species kept, also

increased significantly (GLM; coefficient = 8915 , p < 0.01) (CDFW, 2020). The low level of Dungeness crab catch in 2015 coincides with health advisories to avoid consumption of crab viscera due to high concentrations of domoic acid (Joint Committee on Fisheries and Aquaculture, 2016; CDFW, 2018). Although there is no formal stock assessment for Dungeness crab, the stock appears to be healthy as commercial landings have fluctuated around a stable long-term mean for around 40 years (CDFW, 2022a; OPC, 2013). The number of blue rockfish, the third ranked species kept by CPFVs increased gradually through 2019, then declined in 2020 as the COVID-19 pandemic and response impacted for-hire vessel activity (CDFW, 2020). An assessment of the blue and deacon rockfish complex off California was conducted in 2017; results were consistent with the 2007 blue rockfish assessment and indicated that the population had increased to target levels of unfished spawning output by 2017 (Dick et al., 2017). Lingcod, the fourth ranked species, increased from under 3,000 fish to a peak of over 25,000 fish retained in 2015, then declined in subsequent years (CDFW, 2020). According to the Pacific Fishery Management Council (PFMC), the west coast lingcod stock was successfully rebuilt as of 2005, following historical declines in the stock (PMFC, 2021a). The number of black rockfish retained peaked in 2013 and 2014 with over 60,000 landed in both years (CDFW, 2020).

Commented [21]: There was also a lingcod assessment for California lingcod conducted in 2021 (on council website), I guess I would suggest that it would not be that difficult to put together a graph of the population trends for some of these stocks from the assessments available at PFMC, as combined with the catch data it provides some context on how sustainable those catches are/should be (even though the assessments typically aggregate abundance at larger spatial scales).

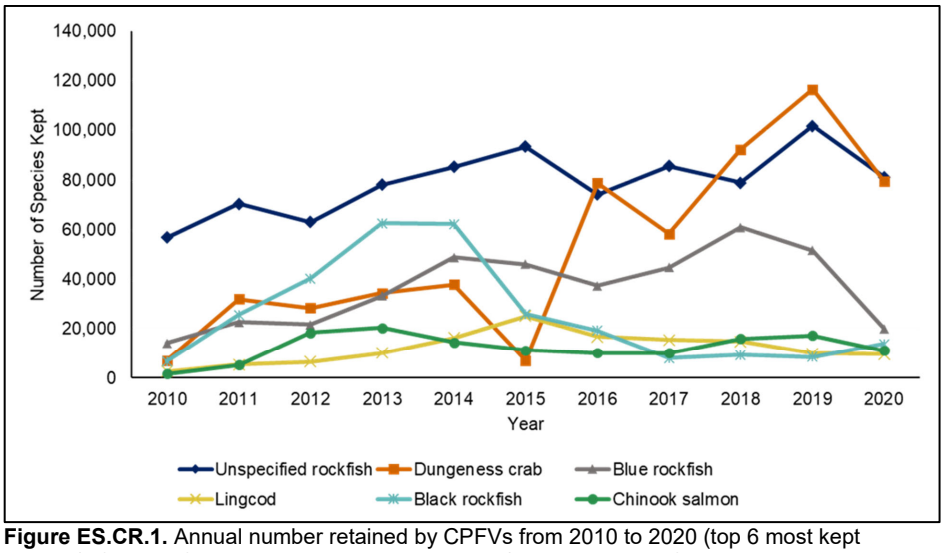

Figure ES.CR.1. Annual number retained by CPFVs from 2010 to 2020 (top 6 most kept species). Source: CDFW, 2020; Image: Jack Eynon/National Marine Sanctuary Foundation

Beach Watch Data

Beach Watch monitoring data indicate how levels of human activities have changed over time along sanctuary beaches. Beach Watch surveyors recorded counts of activities along roughly 51 kilometers of GFNMS beaches (Lindquist & Roletto, 2022b; see Box 2).[6] Methods for

[6] Twelve new Beach Watch sampling sites were added in 2014, totalling almost 19 km. The beaches added in 2014 are more remote (i.e. less frequently used) than the original 1993 beaches. To avoid obscuring trends in the analysis of activity rates (by adding more survey kilometers with less use observed), the two groups of sites were treated as separate data threads.

recording consumptive recreational activities on Beach Watch surveys changed in 2014. Thus, in order to analyze trends for 2010–2022, all consumptive recreational activities were grouped into one activity type, a general “fishing” category, encompassing “clam digging”, “hand collection of biota", “consumptive diving”, and fishing with hooks, traps, nets, and spears. There were statistically significant increases in fishing across all sets of survey sites analyzed, including beaches sampled since 1993 (GLM; coefficient = 0.032 encounters/km, p-value < 0.01) and sampling sites initiated in 2014 (GLM; coefficient = 0.024, p-value < 0.01) (Lindquist & Roletto, 2022b). Further, isolating hook-and-line fishing as an activity type, there was also a statistically significant increase from 2010 to 2022 (GLM; coefficient = 0.03, p-value < 0.01) (Lindquist & Roletto, 2022b). Notably, during this time period a new method of crab trapping was popularized: a rod and reel with a small trap attached to the line (Lindquist & Roletto, 2022b). This crabbing method is not always distinguishable from hook-and-line fishing and may have been enumerated as such on surveys (K. Lindquist/Greater Farallones Association, personal communication, July 5, 2022). The method may have opened up new areas to crabbing that were not previously viable.

Recreational Private/Rental Effort

Data on the number of private and rental vessel fishing trips in two California Recreational Fisheries Survey (CRFS) districts are summarized here as a proxy for private and rental vessel effort in the sanctuary. CRFS districts 4 and 5 comprise the following counties: Mendocino, Sonoma, Marin, Napa, Solano, Contra Costa, Alameda, Santa Clara, San Mateo, and San Francisco.[7] The number of private and rental vessel trips from those ten counties varied without trend from 2010 to 2021 (PSMFC, 2022).

Chinook salmon

The trend in the number of Chinook salmon retained reflected a rebuilding of the fishery after a statewide closure of the ocean fishery in 2008 and 2009 and an 8-day season in 2010 (CDFW, 2020; ONMS, 2011). The peaks in 2012-2013 and 2018–2019 track harvest trends in the commercial fishery as well as the Sacramento Index (SI), a metric representing the total number of adult fall-run Chinook salmon in the ocean that will be harvested or that will escape to spawn in the Central Valley (PFMC, 2020). Chinook salmon stocks that seasonally inhabit the sanctuary (California Coastal, Central Valley spring-run, Central Valley fall and late-fall, and Sacramento River winter-run) are listed as either endangered, threatened, or species of concern, and stocks have shown mixed progress toward recovery (CDFW, n.d.; NMFS, 2016a; NMFS, 2016b; NOAA Fisheries, 2020).

Figure ES.CR.2 shows trends in CPFV effort, in angler-days,[8] in the sanctuary from 2010 to 2019. Effort in the sanctuary increased significantly by over 1600 angler-days per year over the ten years (GLM; coefficient = 1618, p-value = 0.03) (CDFW, 2020). Similar to the commercial fishery, the recreational salmon fishery was severely curtailed in 2008, 2009, and 2010, so much of the increase in the early years is likely a result of the for-hire salmon sector resuming activity. CPFV effort peaked in 2014, declined in 2015 (at which time there were health advisories for Dungeness crab), continued to decline through 2017, then increased again in 2018 and 2019 (Figure ES.CR.2). On average from 2015–2019, there were over 33,000 angler-days per year in the sanctuary and about 76 CPFVs reporting catch (CDFW, 2020).

---

[7] Of these ten counties, six—Contra Costa, Marin, Mendocino, San Francisco, Solano, and Sonoma—are considered to be within the GFNMS study area (Leeworthy and Schwarzmann, 2015). Napa, Alameda, Santa Clara, and San Mateo are therefore “extra” counties.

[8] An angler-day is defined as one person fishing for any part of one day

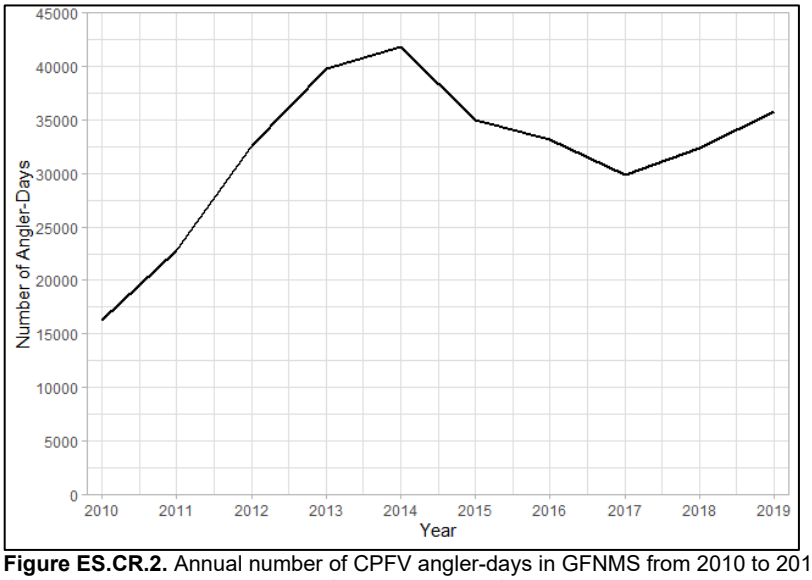

Figure ES.CR.2. Annual number of CPFV angler-days in GFNMS from 2010 to 2019. Source: CDFW, 2020; Image: Jack Eynon/National Marine Sanctuary Foundation

Red Abalone

Red abalone stocks in Northern California declined dramatically following the 2014–2016 marine heatwave, which resulted in population shifts, reductions in nutrients and productivity, and changes to kelp forest ecosystems (Rogers-Bennett et al., 2021). In response, the recreational red abalone fishery was closed in 2017 and will remain so until 2026 (CDFW, 2022b). The impacts of the closure are substantial; a study by Reid at al. (2016) estimated that, as of 2013, approximately 31,000 fishers in Northern California derived between $26.8 million and $51.2 million (in 2021 dollars) of recreational value per year from the fishery. Beginning in 2000, recreational harvesters were required to record their red abalone catch and effort, including date and location of harvest (CDFW, 2015). Even before the 2017 closure, there was a clear decline in sport abalone catch from reporting locations within GFNMS (Figure ES.CR.3). The five-year average catch in GFNMS from 2005–2009 was nearly 150,000 abalone per year.

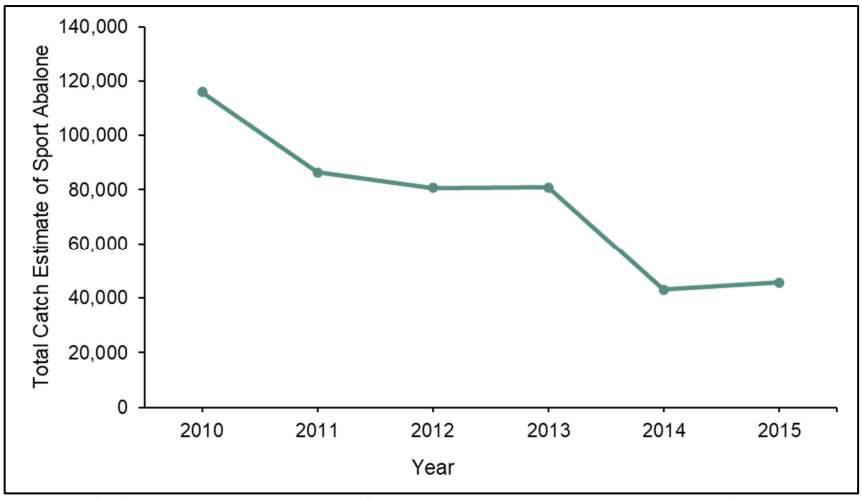

Figure ES.CR.3. Red abalone catch from reporting locations within GFNMS, 2010–2015. Source: CDFW, 2015; Image: Jack Eynon/National Marine Sanctuary Foundation

Conclusion

The status of consumptive recreation in GFNMS is fair indicating the capacity to provide the ecosystem service is compromised, and existing management would require enhancement to enable acceptable performance. This is based on the reduced fishing opportunities for salmon, Dungeness crab, and red abalone due to health advisories and listing species as endangered or threatened and closures. The 2014-2016 marine heatwave severely impacted populations of red abalone, a culturally significant species in the region. Despite missing data on private and rental vessel fishing effort specifically within the sanctuary, there seems to be stable or increasing participation across all recreational fishing sectors (i.e., for-hire, private/rental vessels, and shoreline fishing). Trends in the number of rockfish and Dungeness crab increased from CPFV increased, as did the number of CPFV angler-days, red abalone harvest declined and the number of lingcod decreased. The opposing trends in addition to the lack of information about take of groundfish that influences the recovery of groundfish stocks (PFMC, 2021b) which may allow for increased catch and effort for several recreational targets, resulted in an undetermined trend.

References (Consumptive Recreation)

Lindquist, K., & Roletto, J. (2022b). *Beach Watch database: Supplementary data* [Unpublished data set]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of National Marine Sanctuaries, Greater Farallones National Marine Sanctuary & Greater Farallones Association.

National Marine Fisheries Service (NMFS). (2016a). 5-Year Review : Summary & Evaluation of California Coastal Chinook Salmon and Northern California Steelhead. Retrieved from https://repository.library.noaa.gov/view/noaa/17016.

National Marine Fisheries Service (NMFS). (2016b). 5-Year Review : Summary & Evaluation of Central Valley Spring-run Chinook Salmon Evolutionarily Significant Unit. Retrieved from https://repository.library.noaa.gov/view/noaa/17018.

California Department of Fish and Wildlife. (2015). Estimated sport abalone catch, in number of abalone by report card location (preliminary estimate for 2015). Retrieved from https://wildlife.ca.gov/Conservation/Marine/Invertebrates/Abalone/Abalone-Report-Card

California Department of Fish and Wildlife. (2018). Southern commercial Dungeness crab season delayed in ocean waters north of bodega head due to public health hazard. CDFW News. Retrieved from https://cdfgnews.wordpress.com/2018/11/09/southern-commercial-dungeness-crab-season-delayed-in-ocean-waters-north-of-bodega-head-due-to-public-health-hazard/

California Department of Fish and Wildife. (2020). Commercial passenger fishing vessel (CPFV) log data, 1980-2020 [Data set]

California Department of Fish and Wildlife. (2022a). Dungeness crab enhanced status report [website]. Retrieved from https://marinespecies.wildlife.ca.gov/dungeness-crab/true/

California Department of Fish and Wildlife. (2022b). California Recreational Ocean Fishing Regulations - Invertebrate Fishing Regulations. Retrieved from https://wildlife.ca.gov/Fishing/Ocean/Regulations/Sport-Fishing/Invertebrate-Fishing-Regs#:~:text=NOTE%3A%20The%20red%20abalone%20season,closed%20until%20April%201%2C%202026.

California Department of Fish and Wildlife (CDFW). (n.d.). Chinook salmon. CDFW. Retrieved from https://wildlife.ca.gov/Conservation/Fishes/Chinook-Salmon

Dick, E.J., A. Berger, J. Bizzarro, K. Bosley, J. Cope, J. Field, L. Gilbert-Horvath, N. Grunloh, M. Ivens-Duran, R. Miller, K. Privitera-Johnson, and B.T. Rodomsky. (2017). The Combined Status of Blue and Deacon Rockfishes in U.S. Waters off California and Oregon in 2017. Pacific Fishery Management Council, Portland, OR. Available from http://www.pcouncil.org/groundfish/stock-assessments/

Key, M., MacCall, A. D., Aseltine-Neilson, D., Lynn, K. (2008). The 2007 assessment of blue rockfish (Sebastes mystinus) in California. Retrieved from https://www.pcouncil.org/documents/2008/01/the-2007-assessment-of-blue-rockfish-sebastes-mystinus-in-california-january-2008.pdf/

Leeworthy, V., & Schwarzmann, D. 2015. Economic Impact of the Recreational Fisheries on Local County Economies in California's National Marine Sanctuary 2010, 2011 and 2012. Marine Sanctuaries Conservation Series ONMS-2015-07. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD. 27 pp.

Lindquist, K., & Roletto, J. (2022b). Beach Watch database: Supplementary data [Unpublished data set]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of National Marine Sanctuaries, Greater Farallones National Marine Sanctuary & Greater Farallones Association.

NOAA Fisheries. (2020). Endangered winter-run Chinook salmon increase with millions of offspring headed to sea. NOAA. Retrieved from https://www.fisheries.noaa.gov/feature-story/endangered-winter-run-chinook-salmon-increase-millions-offspring-headed-sea

Ocean Protection Council. (2013). Rapid Assessments for Selected California Fisheries - Dungeness Crab. Retrieved from https://www.opc.ca.gov/webmaster/ftp/project_pages/Rapid%20Assessments/Dungeness%20Crab.pdf

Office of National Marine Sanctuaries. (2011). Voices of the Bay - Chinook Salmon. Retrieved from https://nmssanctuaries.blob.core.windows.net/sanctuaries-prod/media/archive/education/voicesofthebay/pdfs/chinooksalmon.pdf

Pacific Fishery Management Council (PFMC). (2020). Review of 2019 ocean salmon fisheries. Retrieved from https://www.pcouncil.org/documents/2020/02/review-of-2019-ocean-salmon-fisheries.pdf/

Pacific Fishery Management Council (PFMC). (2021a). Pacific Coast Groundfish Fishery Management Plan for the California, Oregon, and Washington Groundfish Fishery - Appendix F: Overfished Species Rebuilding Plans. Retrieved from https://www.pcouncil.org/documents/2020/11/groundfish-fmp-appendix-f-overfished-species-rebuilding-plans.pdf/

Pacific Fishery Management Council (PFMC). (2021b). Council news: Rigorous management practices have led to successful rebuilding of several west coast groundfish stocks. Pacific Fishery Management Council. Retrieved from https://www.pcouncil.org/council-news-rigorous-management-practices-have-led-to-successful-rebuilding-of-several-west-coast-groundfish-stocks/

Pacific State Marine Fisheries Commission Recreational Fisheries Information Network (RecFIN). (2022). Recreational fishery effort estimate report: number of angler trips and boat trips by district, 2004-2022 [unpublished data set].

Reid, J., Rogers-Bennett, L., Lavín, F., Pace, M., Catton, C., and Taniguchi, I. (2016). The economic value of the recreational red abalone fishery in northern California. California Fish and Game. 102. 119-130.

Rogers-Bennett, Laura & Klamt, Robert & Catton, Cynthia. (2021). Survivors of Climate Driven Abalone Mass Mortality Exhibit Declines in Health and Reproduction Following Kelp Forest Collapse. Frontiers in Marine Science. 8. 725134. 10.3389/fmars.2021.725134.

Samson, D. B. (2007). The status of black rockfish off Oregon and California in 2007. Retrieved from https://www.pcouncil.org/documents/2007/02/the-status-of-black-rockfish-off-oregon-and-california-in-2007.pdf/

Joint Committee on Fisheries and Aquaculture. (2016). August 10, 2016 progress reports on crab season, Domoic Acid and disaster declaration. August 10, 2016 Progress Reports on Crab Season, Domoic Acid and Disaster Declaration. Retrieved from https://fisheries.legislature.ca.gov/content/august-10-2016-progress-reports-crab-season-domoic-acid-and-disaster-declaration

Non-Consumptive Recreation — Recreational activities that do not result in intentional removal of or harm to natural or cultural resources

Status Rating: Good/Fair	Status Confidence: Medium
Trend Rating: Mixed	Trend Confidence: Medium
Status Description: The capacity to provide the ecosystem service is compromised, but performance is acceptable.	
Rationale: Many types of recreational activities take place, and the capacity of the sanctuary to provide non-consumptive recreational services seems robust. Common activities included wildlife viewing, surfing, other board sports, paddleboarding, kayaking, and tidepooling. The decline of kelp likely contributed to a decrease in diving services in the northern portion of the sanctuary. The COVID-19 pandemic and response have obscured trends in non-consumptive recreation, but trends overall appear mixed, as some activities have seen increases in participation whereas others, like diving in kelp forests, decreased.	

Commented [22]: I am surprised that diving is not listed here. I was a CA diver for a long time, we'd go up to the north coast and have great recreational non-consumptive dives.

Commented [23]: listed here as decreasing, but not otherwise considered?

Recreational activities that do not result in the intentional removal of, or damage to, natural and heritage resources are considered non-consumptive. The status of non-consumptive recreation in Greater Farallones NMS is good/fair, and the trend is mixed. The sanctuary contains estuarine, beach, nearshore, and offshore environments, presenting a variety of opportunities for recreation. Non-consumptive recreational activities occurring in or adjacent to GFNMS include wildlife viewing, especially marine mammal and bird watching, sailing and boating, diving, surfing and boogie boarding, tidepooling, paddling, swimming, and beachgoing (GFNMS, n.d.-a, Table ES.NCR.1).

Table ES.NCR.1. Summaries for the key indicators related to non-consumptive recreation that were discussed during the July 7, 2022 virtual status and trends workshop.

Indicator	Source	Data Summary	Figure
Wildlife viewing industry	A. Jaramillo/Alvaro's Adventures; M.J. Schramm/NOAA, personal communication, July 7, 2022	Status: Wildlife viewing trips by at least four operators occurred regularly in the sanctuary Trend: Increasing based on smaller vessels entering the industry and greater public interest in the activity.	
eBird reports	eBird, 2021	Status: Top species reported - western gull, common murre, California gull, Brandt's Cormorant, brown pelican Trend: Number of reports and number of eBird	ES.NCR.1

		users increased overall; reports per user declined by half, then increased to highest level in 2020	
Whale populations	NMFS, 2022	Status: Endangered and threatened species Trend: Evidence for increasing (Eastern North Pacific gray whales and California/Oregon/Washington humpbacks) or stable/increasing (Eastern North Pacific blue whales) populations, still facing threats	
Whale density models	Becker et al., 2020	Status: Blue whale and humpback whale density is high in GFNMS Trend: No trend data	
Whale density - ACCESS	Elliott, 2022a	Status: Blue whales and humpback whales are common in GFNMS Trend: Increasing density based on observation data	
Seabirds	Elliott, 2022a	Status: Cassin's auklet, black-footed albatross, sooty shearwaters, pink-footed shearwater are common in GFNMS Trend: Variable, no trend	
“Person on Beach” encounter rates	Lindquist & Roletto, 2022b	Status: Beach Watch data does not inform overall level of activity (e.g., total number of participants or effort) Trend: Varied without trend	
Surfing encounter rates	Lindquist & Roletto, 2022b	Status: Beach Watch data do not inform level of activity Trend: Varied without trend for original Beach Watch sites; Increased for 2014 Beach Watch sites	
Board sports (excl. surfing) encounter rates	Lindquist & Roletto, 2022b	Status: Beach Watch data does not inform level of activity Trend: Increased for original Beach Watch sites	
Paddle boat encounter rates	Lindquist & Roletto, 2022b	Status: Beach Watch data does not inform level of activity Trend: Varied without trend at original Beach Watch sites	
Kayak encounter rates	Lindquist & Roletto, 2022b	Status: Beach Watch data does not inform level of activity Trend: Varied without trend at original Beach Watch sites	
Tidepooling encounter rates	Lindquist & Roletto, 2022b	Status: Beach Watch data does not inform level of activity Trend: Varied without trend	
Wildlife viewing	Lindquist & Roletto, 2022b	Status: Beach Watch data does not inform level of activity	

encounter rates		Trend: Varied without trend on sandy shore; increased on rocky shore for combined original/2014 sites	
AIS data	OCM, 2022	Status: Recreational boating is concentrated around San Francisco Bay, Bodega Bay, Point Reyes, and Point Arena Trend: Distance traveled by recreational boats peaked in 2018, then declined in 2019 and 2020 (based on data for 2016–2020)	P.2

Wildlife Viewing

Greater Farallones provides unique opportunities for wildlife viewing throughout the year. Between December and February, wintering seabirds are present in the open ocean, and the California gray whale migration peaks in mid-January (GFNMS, n.d.-b). The upwelling season in March–August creates opportunities to view humpbacks, blue whales, sharks, and seabirds (GFNMS, n.d.-b). Species like *Mola mola*, dolphins, porpoise, sea turtles, and sharks can be seen in September through November (GFNMS, n.d.-b). Additionally, blue whale and humpback whale density is high in GFNMS and are commonly seen (NMFS, 2022; Becker et al., 2020; Elliot 2022a).

There are at least four tour operators specializing in whale or seabird watching who regularly make trips to GFNMS. These operations are based in San Francisco, Marin County, and Half Moon Bay. Two other tour operators specialize in shark diving or viewing in GFNMS and the surrounding region (ONMS, 2023). Apart from the more established operators, multiple experts noted an increase in the number of small charter vessels conducting wildlife tours (A. Jaramillo/Alvaro's Adventures and M.J. Schramm/NOAA, personal communication, July 7, 2022). Small vessels are able to engage in "pop-up" whale watching as whale populations moved closer to shore in response to warmer ocean conditions (Santora et al., 2020). One expert noted that the younger generation of charter fishing captains are showing greater interest in diversifying their businesses by "moonlighting" as wildlife tour operators (A. Jaramillo/tour operator, personal communication, June 30, 2022). In addition to pandemic-related disruptions, experts cited rising overhead as a challenge, especially higher fuel prices, which have caused some operators to raise their rates (A. Jaramillo/tour operator, personal communication, July 7, 2022). Another challenge is the growing difficulty of chartering fishing vessels to operate tours, driven by an apparent decline in the size of the party boat fleet (A. Jaramillo/tour operator, personal communication, June 30, 2022).

With over 160 bird species and more than 400,000 breeding seabirds (McChesney et al., 2013), the sanctuary provides excellent opportunities for birdwatching. Cassin's auklet, black-footed albatross, sooty shearwaters, pink-footed shearwater are common in GFNMS (Elliott, 2022a). One popular birding app, eBird, allows users to record information about bird sightings. From 2010 to 2020, the five most common species recorded on eBird in GFNMS were, in order of frequency, western gulls, common murres, California gulls, Brandt's cormorants, and brown pelicans (eBird, 2021). Two other frequently recorded pelagic species were pelagic cormorants and sooty shearwaters (eBird, 2021). Key species of interest on pelagic trips include tufted puffins on or near Southeast Farallon Island, as well as pelagic shearwaters, albatross, storm-petrels, alcids, skuas, and jaegers. For information on population trends for these species, see Johns & Warzybok (2019). The annual number of reported sightings in the sanctuary grew steadily from around 15,000 reports in 2010 to over 45,000 in 2020 (eBird, 2021). In part, that increase was due to a growing number of app users: the annual number of eBird observers in

GFNMS rose from over 100 in 2010 to a peak of nearly 500 users in 2019 (eBird, 2021). In 2020, the annual number of eBird users in the sanctuary declined from the previous year, likely due to the added challenges of accessing the sanctuary during the COVID-19 pandemic, while the average number of reports per user increased (eBird, 2021). One expert reported an increase in the number of people interested in going on for-hire pelagic birding trips (A. Jaramillo/tour operator, personal communication, July 7, 2022).

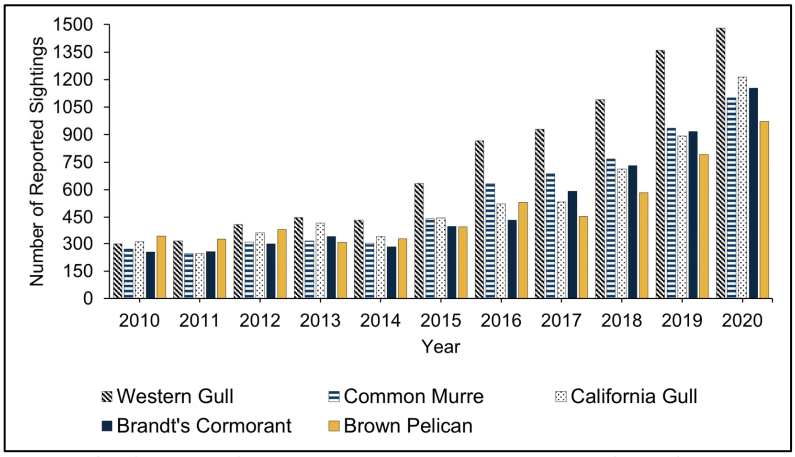

Figure ES.NCR.1. Top five seabird species report on eBird in GFNMS, 2010-2020. Source: eBird, 2021; Image: Jack Eynon/National Marine Sanctuary Foundation

Shoreline Use

Beach Watch monitoring data indicate how participation in recreational activities has changed over time along sanctuary beaches. Beach Watch surveyors record counts of human activities along roughly 51 kilometers of GFNMS beaches.[9] Among the non-consumptive recreational activities enumerated are tidepooling, kayaking, surfing, board sports (excluding surfing), wildlife viewing (both rocky shoreline and sandy shoreline), and a general category for "person on beach." Over the period from 2010 to 2020, there was a statistically significant trend in the encounter rate (counts per km) for only three of these activities (Lindquist & Roletto, 2022b). At a 95% confidence level, there was a significant increase in the rate of surfing[10] over the decade (seasonal Mann-Kendall test (SMK); coeff. = 0.05 encounters/km/year, p-value = 0.03). This increase may be driven by surfing at one site, Miwok Beach, which was sparsely used until the pandemic (K. Lindquist/Greater Farallones Association, personal communication, July 5). The rate of board sports (excluding surfing) also increased significantly from 2010 to 2020 (SMK; coeff. = 0.03, p-value < 0.01), which coincides with the growing popularity of stand-up paddle boarding during that period (Kirsten Lindquist, personal communication, July 5, 2022). There

[9] Twelve new Beach Watch sampling sites were added in 2014, totalling almost 19 km. The beaches added in 2014 are more remote (i.e. less frequently used) than the original 1993 beaches. To avoid obscuring trends in the analysis of activity rates (by adding more survey kilometers with less use observed), the two groups of sites were treated as separate data threads.

[10] Though surfing at survey sites initiated in 2014 increased significantly, no trend was detected at sites initiated in 1993.

was also an increasing trend in wildlife viewing on rocky shorelines (SMK; coeff. = 0.04 encounters/km/year, p-value < 0.01)(K. Lindquist/Greater Farallones Association, personal communication, July 7, 2022). The encounter rates for all other listed non-consumptive recreational activities varied without trend (Lindquist & Roletto, 2022b). Although jet skiing and shore-based scuba diving are enumerated in Beach Watch surveys, there were too few observations in the survey data to analyze their trends. Information on diving is a data gap for this ecosystem service. Anecdotally, diving has been negatively impacted by losses of kelp forest, especially in the northern part of the sanctuary.

Recreational Boating

Automatic Identification System (AIS) data from 2016–2020 provides some indication of trends in recreational boating in the sanctuary as well as where boating activity is concentrated. But because AIS is not required on recreational vessels, it cannot be used to determine the level of recreational boating activity. The total distance traveled by pleasure craft and sailing vessels carrying AIS in the sanctuary increased from around 1,800 nm in 2016 to nearly 2,500 nm in 2018 (OCM, 2022). The increased distance may be the result of additional vessels carrying AIS though. Following the peak in 2018, the distance traveled fell to just over 1,200 nm in 2019 then a low of around 900 nm in 2020 (OCM, 2022). Recreational boating is largely concentrated around the mouth of San Francisco Bay, Point Reyes, Bodega Bay, and Point Arena (Figure P.2).

Conclusion

Non-consumptive recreation as an ecosystem service in GFNMS is rated good/fair. Despite disruptions due to the COVID-19 pandemic and response, there was continued engagement across all categories of recreation. The productive ocean ecosystem in GFNMS supported wildlife viewing businesses and opportunities to see whales and seabirds. Surfing, other board sports, paddle boarding, kayaking, and tidepooling were all common activities observed. The trend is mixed based on different activities having different trends. There was increasing interest in offshore wildlife viewing. Engagement in recreational activities like surfing, stand-up paddle boarding, whale watching from shore, and pelagic birding appear to be increasing in GFNMS.

References (Non-Consumptive Recreation)

eBird. (2021). eBird: An online database of bird distribution and abundance [web application].

eBird, Cornell Lab of Ornithology, Ithaca, New York. Available: http://www.ebird.org.

Elliott, M., Lipski, D., Roletto, J., Warzybok, P., & Jahncke, J. (2022a). *Ocean climate indicators status report: 2021*. Contribution No. 2422. Point Blue Conservation Science.

Suggest adding ACCESS dta citation here:

Greater Farallones Association. (2022). Birds in the Sanctuary. Retrieved from https://farallones.org/sanctuary-wildlife/birds/

GFNMS. (n.d.-a). Things to do. Activities you can do in the Greater Farallones National Marine Sanctuary. Retrieved from https://farallones.noaa.gov/visit/activities.html

GFNMS. (n.d.-b). Seasons of the sea. Retrieved from https://farallones.noaa.gov/visit/seasons-of-the-sea.html

Johns, M., and Warzybok, P. (2019). Population size and reproductive performance of seabirds on Southeast Farallon Island, 2019. Report to the U.S. Fish and Wildlife Service, Farallon Islands NWR. Retrieved from http://www.prbo.org/refs/files/12679_Johns2019.pdf

Lindquist, K., & Roletto, J. (2022b). *Beach Watch database: Supplementary data* [Unpublished data set]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of National Marine Sanctuaries, Greater Farallones National Marine Sanctuary & Greater Farallones Association.

McChesney, G. J., Carter, H. R., Bechaver, C. A., Rhoades, S. J., Bradley, R. W., Warzybok, P. M., Golightly, R. T., & Capitolo, P. J. (2013). Seabird breeding population sizes within the North Central Coast Study Region of the California Marine Life Protection Act Initiative, 2010–2012. In G. J. McChesney & D. Robinette (Eds.), *Baseline characterization of newly established marine protected areas within the North Central California Study Region—seabird colony and foraging studies* (pp. 78–110) [Unpublished report]. U.S. Fish and Wildlife Service, San Francisco Bay National Wildlife Refuge Complex, and Point Blue Conservation Science.

National Marine Fisheries Service (NMFS) Southwest Fisheries Science Center. (2022). U.S. Pacific marine mammal stock assessments: 2021. NOAA-TM-NMFS-SWFSC; 663. https://doi.org/10.25923/246k-7589

Office for Coastal Management (OCM). (2022). Nationwide Automatic Identification System 2016-2020. https://marinecadastre.gov/ais/.

Office of National Marine Sanctuaries. (2023). OSPREY permit database [Unpublished data set]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service

Santora, J.A., Mantua, N.J., Schroeder, I.D. et al. (2020). Habitat compression and ecosystem shifts as potential links between marine heatwave and record whale entanglements. Nat Commun 11, 536. https://doi.org/10.1038/s41467-019-14215-w

Commercial Harvest — The capacity to support commercial market demands for seafood products

Status Rating: Good/Fair	Status Confidence: Medium
Trend Rating: Mixed	Trend Confidence: High
Status Description: The capacity to provide the ecosystem service is compromised, but performance is acceptable.	

Rationale: The Dungeness crab fishery, which is by far the most valuable fishery within the sanctuary, was subject to shortened seasons during and following the large marine heatwave due to elevated levels of domoic acid and management actions to reduce wildlife entanglement risk. Despite seasons being curtailed, fishermen were able to gather a large percentage of the resource in a short time. Abundance and harvest of ocean Chinook salmon were low relative to historical levels. Although restrictions have impacted commercial harvest of some high-value species, there appears to be stable participation across a variety of fisheries.

Commercial harvest is defined as the capacity to support commercial market demand for seafood products. These products may include fish, shellfish, other invertebrates, roe and algae. In Greater Farallones, commercially-targeted species include Dungeness crab, Chinook salmon, market squid, and several species of groundfish, among others (Table ES.CH.1, Table ES.CH.2). Although certain high-value fisheries have been impacted by management interventions and environmental pressures, stock assessments and catch trends indicate satisfactory performance across most key fisheries in the sanctuary.

Table ES.CH.1. Summaries for the key indicators related to commercial harvest that were discussed during the July 7, 2022 virtual status and trends workshop.

Indicator	Source	Data Summary	Figure
Top species by harvest revenue	CDFW, 2020a	Status: Commercially-important species include Dungeness crab, Chinook salmon, market squid, several groundfish species, and coonstriped shrimp Trend: Data does not indicate trend	
Monthly harvest revenue by species	CDFW, 2020a	Status: Dungeness crab generates the most revenue in the winter and spring, Chinook salmon in the summer months Trend: In latter half of the 2010s, Dungeness crab revenue decreased around valuable holiday markets, and peak Chinook salmon revenue shifted later in the summer	
Dungeness crab catch trends	CDFW, 2020a	Status: Fishery affected by closures due to domoic acid and wildlife entanglement Trend: Low levels of harvest in later years due to closures	ES.CH.1
Chinook salmon catch trends	CDFW, 2020a	Status: Harvest rebounded following closures in late 2000s Trend: Peaks in 2012–2013 and 2019	ES.CH.1
Market squid catch trends	CDFW, 2020a	Status: Episodic fishery in GFNMS - low level of harvest in most years Trend: Harvest peaked in 2014 and 2015 then declined to near zero	
California halibut catch trends	CDFW, 2020a	Status: 4th most valuable fishery by harvest revenue in GFNMS with $345,000 generated annually Trend: Peaks in harvest in 2014 and 2015	
Sablefish catch trends	CDFW, 2020a	Status: Targeted with multiple gears, with most catch by trawl (46%) or longline (40%)	

		Trend: Catch peaked in 2011, declined to a low in 2014, and since has been relatively stable	
Petrale sole catch trends	CDFW, 2020a	Status: Common catch in trawl gear Trend: Catch generally increased or was stable from year to year, except for a decline from 2015–2016	
Dover sole catch trends	CDFW, 2020a	Status: Most common target species caught by trawl Trend: Gradual, statistically significant decrease over the decade	
Lingcod catch trends	CDFW, 2020a	Status: Species targeted using multiple gears, mostly trawl Trend: Catch increased by about 7,000 pounds per year over the decade	
Hagfish catch trends	CDFW, 2020a	Status: Trap fishery that is driven by export market in South Korea Trend: Catch increased from near zero in 2010–2011 to peaks of around 285,000 pounds in 2015 and 333,000 pounds in 2018, then declined to 130,000 pounds in 2019	
Coonstriped shrimp catch trends	CDFW, 2020a	Status: Sometimes targeted by Dungeness crab fishermen (season complements Dungeness crab season); trap fishery Trend: Catch trend shows peaks in 2012–2013 and 2016–2017; otherwise caught at low levels	
Catch trends by gear type	CDFW, 2020a	Status: The top gear types by harvest revenue are pots/traps, troll, trawl, other seines/dip nets, and longlines; Trawl gear is used to target several groundfish species; longlines are used to target sablefish primarily; a variety of species are caught by hook and line, especially lingcod and halibut Trend: Catch by trawl declined from 2014–2017, then increased to the highest levels of the decade in 2018–2020; Total pounds harvested by longline dipped dramatically in 2013 and 2020; Catch by hook and line spiked in 2011, declined, then increased to a decadal high in 2020	
Number of vessels reporting catch from GFNMS	CDFW, 2020a	Status: The number of vessels reporting catch rebounded following total closures of the salmon fishery in the end of the previous decade Trend: The number of vessels varied without trend from 2010–2020	
Rockfish populations	NMFS	Status: Most Sspecies recovered or recovering Trend: increasing population size	
Lingcod stock assessment	PFMC, 2021	Status: Below, but close to, management targets; high uncertainty Trend: Spawning biomass trending upward for past decade	
Sacramento River fall-run	CDFW, 2022b	Status: Species of concern	

Commented [24]: it is rather variable and there are some recent exceptions (quillback rockfish appears to be declining based on a 2021 assessment)

Chinook salmon		Trend: Fall-run Chinook salmon escapement (run size) was increasing in the beginning of the 2010s, peaked in 2013, declined to very low levels in 2017 and 2017, then increased through 2019	
Sablefish stock assessment	PFMC, 2021	Status: Estimated to be above target stock size in 2021 Trend: Stock assessment models show a declining trend in biomass since the 1970s followed by an increase in 2020 and 2021	
Petrale sole stock assessment	NOAA Fisheries, 2022	Status: Above maximum sustainable yield biomass Trend: Estimated spawning biomass more than doubled from 2010–2020	
Dover sole stock assessment	NOAA Fisheries, 2022	Status: Spawning biomass well above management targets Trend: Spawning stock biomass estimates varied without trend from 2010–2020	
Aquaculture leases in Tomales Bay	CDFW, 2021	Status: Currently, less than a third of the total acreage leased for aquaculture in Tomales Bay is actively farmed Trend: Data does not indicate trend	
Data Gaps: The level of satisfaction (either by the general public or by those employed in the seafood sector) with how well sanctuary resources support seafood production and livelihoods is unknown.			

Target Species

The top ten species by harvest revenue are presented in Table ES.CH.2. Values for harvest revenue and pounds represent five-year averages from 2015–2019, and revenue values are provided in 2020 US dollars. The top ten species harvested from GFNMS are Dungeness crab, Chinook salmon, sablefish, petrale sole, Dover sole, longspine thornyhead, market squid, shortspine thornyhead, chilipepper rockfish, and hagfish (CDFW, 2020a). Collectively, these ten species account for over 96% of the catch value from the sanctuary and over 90% of the weight landed from the sanctuary. Three species of rockfish not listed in the table depicting harvest revenue—chilipepper rockfish, bocaccio, and longspine thornyhead—rank in the top ten species by pounds landed (in 7th, 8th, and 9th, respectively). The species captured represent an array of target depths and locations, from shallow/nearshore species (e.g., California halibut and Dungeness crab) to pelagic species (e.g., market squid) to deepwater species (e.g., sablefish). Fishermen employ a variety of gear types, including pots/traps, troll gear, trawls, seines, longlines, and hook and line (CDFW, 2020a).

Table ES.CH.2. Top ten species captured in GFNMS by harvest revenue (five-year average, 2015–2019). Source: CDFW, 2020a

Species Name	Harvest Revenue	Pounds Landed	Avg. Price/lb	Revenue Rank	Pounds Rank
Dungeness crab	$9,924,777	3,245,162	$3.06	1	1
Chinook salmon	$1,769,327	263,818	$6.71	2	3

Market squid	$448,480	1,557,449	$0.29	3	2
California halibut	$345,091	71,363	$4.84	4	11
Sablefish	$341,942	154,272	$2.22	5	6
Hagfish	$161,668	238,234	$0.67	6	4
Petrale sole	$104,114	89,769	$1.16	7	10
Coonstriped shrimp	$88,026	18,776	$4.69	8	17
Dover sole	$79,489	194,230	$0.41	9	5
Lingcod	$78,814	45,484	$1.73	10	13

Dungeness crab

From 2015–2019, the Dungeness crab fishery accounted for nearly 72% of harvest revenue from GFNMS (CDFW, 2020a). Dungeness crab catch varied without a clear trend over the past decade. Since at least the 1970s, researchers have documented a cyclic fluctuation in the abundance and catch (Botsford et al., 1982), now believed to be caused by favorable oceanographic conditions for larval recruitment (Shanks & Roegner, 2007). The first thorough population estimate of West Coast Dungeness stocks showed a rapid increase in pre-fishing season abundance in Central California during the past decade, following a long period of low abundance (Richerson et al., 2020). The Central California abundance estimates over the last two decades are nearly five times the estimates from 1970 to 2000, despite a high rate of exploitation over that time (Richerson et al., 2020).

The Dungeness crab fishery has been subject to several management actions in recent years. During the 2015–2016 season, the fishery start was delayed from November to March as elevated levels of domoic acid, a neurotoxin produced by a harmful algal bloom (HAB), triggered health advisories (California Ocean Science Trust, 2016) (see Figure ES.CH.1). Then, the fishery was subject to delays and closures in 2019, 2020, and 2021 due to elevated risk of whale and sea turtle entanglement in the trap gear configurations used by the fleet (CDFW, 2019; CDFW, 2020b; CDFW, 2021a; CDFW, 2021b). Although delays and closures are disruptive to seafood markets, impacts on the overall level of harvest may be limited given the derby nature of the fishery and the fleet's ability to harvest a majority of the resource in a short time (D. Ogg/commercial fisherman, personal communication, July 7, 2022). That said, condensed seasons also have the potential to affect safety at sea by encouraging risk-taking behaviors such as fishing in poor weather and operating under fatigue (Pfeiffer et al., 2022; Petursdottir et al., 2001).

Commented [25]: An opportunity here to link back to the discussion of how the large marine heatwave was largely responsible for that domoic acid event, that the delay led to the fishery opening as whales were returning to coastal waters, and that the low krill abundance and habitat compression led to more of the whales prey being located nearshore thus increasing the number of entanglements- as discussed in chapter 8. Santora et al. 2020 is basis for much of this understanding- cited in chapter 8- probably should be cited here as that laid out the basis for the risk analysis that the state has been using to decide whether and when to open and close the fishery.

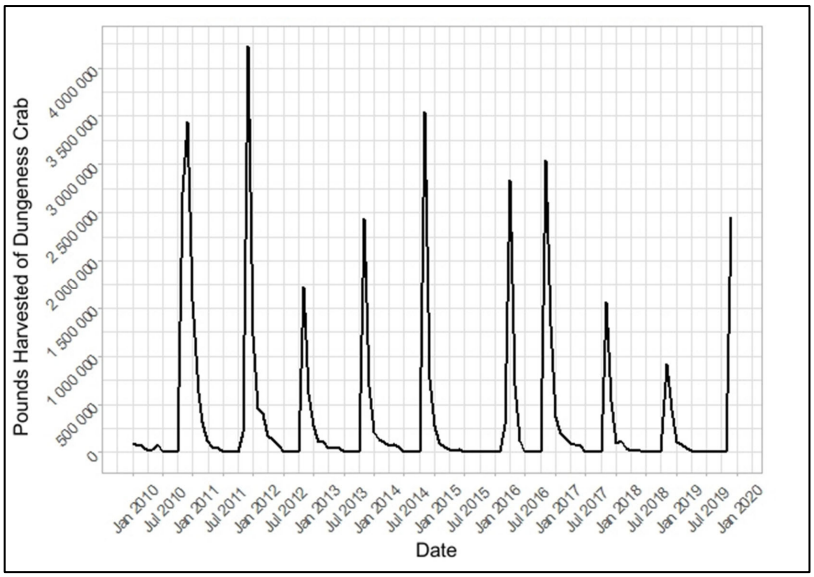

Figure ES.CH.1. Monthly harvest of Dungeness crab, in pounds, from 2010–2020. Source: CDFW, 2020a; Image: Jack Eynon/National Marine Sanctuary Foundation

Chinook salmon

The next most valuable fishery in the sanctuary, accounting for nearly 13% of catch value, is Chinook salmon. Several distinct populations of Chinook salmon may inhabit the sanctuary for part of their life cycles, including California Coastal, Central Valley spring-run, Central Valley fall and late-fall, and Sacramento River fall-run and winter-run salmon (ONMS, 2014). These populations are all listed as either endangered, threatened, or species of concern, and stocks have shown mixed progress toward recovery (CDFW, n.d.; NMFS, 2016a; NMFS, 2016b; NOAA Fisheries, 2020). In 2008 and 2009, for the first time in state history, the Pacific Fishery Management Council closed the commercial salmon fishery entirely in response to the collapse of Sacramento River fall Chinook (SRFC) (PFMC, 2009). The collapse has been attributed to environmental conditions resulting in poor performance of the 2004 and 2005 broods of SRFC, on top of long-term degradation of freshwater and estuarine environments (Lindley et al., 2009). In 2010, the commercial season was severely shortened again, and less than 2,500 pounds were landed in the sanctuary (CDFW, 2020a). Chinook salmon catch increased through 2012, as vessels reentered the fishery, then declined to fairly low levels again in 2016–2018 (CDFW, 2020a; Figure ES.CH.2). Landings rebounded in 2019, possibly due to high flow conditions in 2017 (PFMC, 2019). Overall, commercial harvest tracks closely with the Sacramento Index (SI), a metric representing the total number of adult fall-run Chinook salmon in the ocean that will be harvested or that will escape to spawn in the Central Valley (PFMC, 2020; CDFW, 2022b).

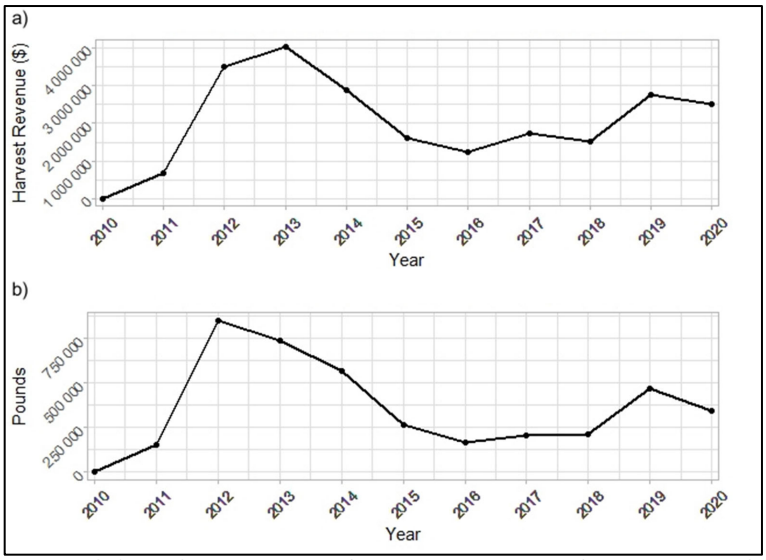

Figure ES.CH.2. Chinook salmon a) harvest revenue and b) pounds landed from GFNMS, 2010–2020. Source: CDFW, 2020a; Image: Jack Eynon/National Marine Sanctuary Foundation

Market squid

Of the species harvested in GFNMS from 2015–2019, market squid ranks 3rd in terms of harvest revenue and 2nd in terms of pounds landed (CDFW, 2020a). Market squid harvest in the sanctuary was episodic and associated with environmental conditions, with most of the fishing activity in the region concentrated near Monterey Bay in MBNMS (CDFW, 2022a). The squid are caught using drum seines or purse seines. Harvest in GFNMS was near zero from 2010 to 2013 and jumped to over 6 million pounds in 2014 and 2015 before declining to over 1.5 million pounds in 2016 (CDFW, 2020). Catch in the following four years remained near zero, except for a slight jump in landings (less than 1 million pounds) in 2020 (CDFW, 2020a). The majority of market squid catch was landed in Princeton-Half Moon Bay or San Francisco, suggesting those fleets may have shifted effort north in 2014–2016 in response to a changing distribution of squid.

Commented [26]: May not be necessary to add but a recent paper takes a deeper dive into how environmental conditions influence squid abundance and distribution - Suca, J.J., Santora, J.A., Field, J.C., Curtis, K.A., Muhling, B.A., Cimino, M.A., Hazen, E.L. and Bograd, S.J., 2022. Temperature and upwelling dynamics drive market squid (Doryteuthis opalescens) distribution and abundance in the California Current. ICES Journal of Marine Science, 79(9), pp.2489-2509.

California Halibut

The Dungeness crab, Chinook salmon, and market squid fisheries account for roughly 88% of harvest revenue in the sanctuary. Of the remaining top ten species, five are part of the groundfish complex, which, with the exception of California halibut, is managed by the Pacific Fishery Management Council (PFMC). These include California halibut, sablefish, petrale sole, Dover sole, and lingcod. Over 85% of California halibut catch in GFNMS is harvested by trawl, with some catch by hook and line (CDFW, 2020a). California halibut catch appears to have increased gradually from 2010 to 2020 without a statistically significant trend (CDFW, 2020a). Catch peaked in 2014 and 2015 at over 100,000 pounds (CDFW, 2020a). As of a 2011 stock assessment by the state, the California halibut population in Central California was estimated to be well above the biomass associated with maximum sustainable yield, and overfishing was not occurring (CDFW, 2011).

Sablefish

From 2015 to 2019, 46% of sablefish caught in the sanctuary was harvested by trawl, 40% by set longline, and 12% by fish trap (CDFW, 2020a). Sablefish catch varied without a statistically significant trend over the decade beginning in 2010. Harvest revenue peaked in 2011 at over $780,000 (> 246,000 pounds) (CDFW, 2020a). In the same year, NMFS implemented a Catch Share program for the fishery, in response to an assessment indicating that the stock had declined to biomass levels in the “precautionary zone” (OPC, 2013). Sablefish landings decreased to a low of under 85,000 pounds in 2013 and have since hovered around 160,000 pounds per year (CDFW, 2020a).

Sole

Both petrale sole and Dover sole are harvested almost entirely by trawl in GFNMS (CDFW, 2020a). Interestingly, there are statistically significant, but opposite trends in harvest for the two species, with petrale sole catch increasing from 2010 to 2019 (Mann-Kendall test; tau = 0.511, p-value = 0.049) and dover sole catch decreasing over the same period (Mann-Kendall test; tau = -0.689, p-value < 0.01). As of 2019, petrale sole populations were above spawning biomass targets set by fishery managers (Wetzel, 2019). Dover sole populations are also well above biomass targets, and overfishing is not occurring (PFMC, 2021).

Commented [27]: Trawl activity has declined significantly in central CA over last 20 years- and petrale are far more valuable than Dover, Dover co-occur with sablefish in deeper water so will be linked to sablefish trawl effort, petrale are targeted primarily on winter spawning grounds- so just very different dynamics to the fishery, extremely unlikely that this reflects an ecosystem interaction or dynamic (which while not stated seemed to me perhaps to be inferred by the desire to do a statistical test).

Lingcod

Lingcod in the sanctuary are caught by trawl (61% by weight), hook and line (24%), and long line (12%) (CDFW, 2020a). There was a statistically significant, increasing trend in lingcod catch from 2010 to 2019 (Mann-Kendall test; tau = 0.733, p-value < 0.01), driven by a large, sustained jump in landings between 2017 and 2018 (CDFW, 2020a). Spawning biomass has been trending upward over the past decade due to a period of high recruitment that ended in 2013 (Johnson et al., 2021). The current estimated biomass of lingcod is below, but close to, the management target of 40% unfished biomass with uncertainty spanning above and below the targets (Johnson et al., 2021).

Coonstriped Shrimp and Hagfish

Commented [28]: Given that had they been pooled into a single grouping, "rockfish" would likely make the top 10 in value, and they were in the top 10 by volume, and they're rather iconic, I would have thought at least a short paragraph describing rockfish fishery, population trends, etc. would have been included here.

The remaining two species among the top-valued species in GFNMS are coonstriped shrimp and hagfish. Both are trap-based fisheries with relatively few participants (between 0–4 vessels per year for coonstriped shrimp, and between 1–4 vessels per year for hagfish from 2010–2019). Despite the small number of participants, the hagfish fishery ranks 4th in terms of pounds landed from the sanctuary. The fishery developed in response to demand from South Korean buyers (CDFW, 2015). There was a statistically significant increase in hagfish catch from 2010 to 2019 (Mann-Kendall test; tau = 0.556, p-value = 0.03). Coonstriped shrimp ranks 17th in terms of pounds landed, but its high price per pound ($4.69/lb on average from 2015-2019) makes it a top-value fishery in GFNMS (CDFW, 2020a). Around 25,000 pounds of coonstriped shrimp were harvested in 2012 and 2013, followed by a larger peak in harvest (nearly 31,000 and 54,000 pounds) in 2016 and 2017 (CDFW, 2020a). Outside of those four years, landings from GFNMS were below 10,000 pounds (and near zero in 2011 and 2014). Most vessels that target coonstriped shrimp or hagfish also target Dungeness crab (CDFW, 2020a). From 2015–2019, vessels that reported catching hagfish generated an annual average of 57.5% of their revenue from hagfish alone, with much of their remaining revenue coming from Dungeness crab and, to a lesser extent, red rock crab (CDFW, 2020a). From 2016–2018, vessels that caught coonstriped shrimp received an annual average of 16.9% of their revenue from the species, with remaining revenue coming primarily from Dungeness crab, followed by sablefish, Chinook salmon, and some rockfish (CDFW, 2020a). No coonstriped shrimp catch was reported in 2015 or 2019 (CDFW, 2020a).

Commercial Gears

Table ES.CH.3 shows average harvest revenue and pounds landed by gear type, along with the average and standard deviation in the annual number of vessels reporting catch using each gear category. The gears used to target Dungeness crab and Chinook salmon (traps and troll gear) account for a high proportion of harvest revenue and number of vessels. There were no statistically significant trends in pounds harvested for any of the listed gear types. In 2010, as the commercial salmon season was severely shortened for the third consecutive year, there were only 205 vessels reporting catch from the sanctuary (CDFW, 2020a). The number of vessels increased to 510 in 2014, then fluctuated between 300 and 400 from 2015 to 2020 (CDFW, 2020a).

Commented [29]: There is more to the story that can be added- it is worth acknowledging that groundfish fisheries- particularly trawl fisheries- are recovering rapidly in northern CA and Oregon, but the lack of port infrastructure and high cost of operations is constraining comparable recoveries in central California- the increasing concentration of fishing capacity for groundfish to northern ports is discussed in the CCIEA page 29, and elsewhere.

Table ES.CH.3. Top gear types by harvest revenue (2015–2019) with the average and standard deviation in the number of vessels using each gear. Source: CDFW, 2020a

Rank	Gear Type	Harvest Revenue (avg. annual)	Pounds Landed (avg. annual)	Avg. Number of Vessels	Std. Dev. Number of Vessels
1	Pots/Traps	$ 10,285,944	3,542,086	167.8	31.5
2	Troll	$ 1,754,485	263,817	201.6	29.2
3	Trawl	$ 839,564	892,940	8.0	1.6
4	Other Seine/Dip Nets	$ 308,970	1,011,746	4.8	4
5	Longlines	$ 277,289	96,502	19.8	3.2
6	Hook/Line	$ 156,259	34,790	61.8	9.8
7	Purse Seine	$ 144,361	557,064	3.8	3.4
8	Hooka/Diving	$ 50,085	51,693	4.0	3.1

9	Set Gill Net	$ 1,647	9,873	0.6	1.3
10	All Other	$ 1,551	389	0.4	0.5

Aquaculture

In addition to commercial fishing activities, aquaculture also takes place in the sanctuary. A number of aquaculture operations in Tomales Bay grow shellfish, including Pacific, Kumamoto, Eastern and European Flat oysters, Manila clams, and Mediterranean, California Sea, and Bay mussels (CDFW, 2020c). Growers employ multiple shellfish culture methods including bags on groundline, rack-and-bag, rack-and-tray, intertidal longlines, stakes and wires, rafts, floating longlines, and in-ground culture with net cover systems. Tomales Bay holds the greatest number of state bottom water leases in California, with a total of 12 leases operated by seven different businesses (CDFW, 2020c). Of the 520 acres leased in the bay, only 152 acres are currently used (CDFW, 2020c). In 2018, aquaculture in Tomales Bay accounted for 43% of oyster production and 6% of mussel production in the state (CDFW, 2020c). Mussel production in 2018 totalled 5.22 metric tons generating $34,545 in revenue (CDFW, 2020c). No production estimates were identified for oysters. Also in 2018, Tomales Bay was the only location in the state with reported clam production, generating a half ton of clams and $5,120 in revenue (CDFW, 2020c). There is limited information on trends in shellfish production in Tomales Bay.

Commented [30]: I was expecting to see some mention of fight between the Tomales Bay Oyster Co's and the government (NOAA and NPS) re the Aquaculture Act here...seems odd not the factor that in, particularly as we were involved (transparency in government) within the survey period and impacting commercial harvest.

Conclusion

The status of the commercial harvest as an ecosystem service is good/fair indicating capacity to provide the ecosystem service is compromised, but performance is acceptable. This is based on the abundant and diverse fisheries in the region. Regional catch trends for the three highest-value species in the sanctuary—Dungeness crab, Chinook salmon, and market squid—are cyclical and appear to be driven by environmental variability (Botsford et al., 1982; Richerson et al., 2020; Powell et al., 2022; D. Ogg/commercial fisherman, personal communication, July 7, 2022). Climate-driven changes to the California Current System (e.g.,intense harmful algal blooms) drove some of the fluctuations in harvest and disrupted seafood markets.

Commented [31]: These are clearly pretty subjective- I do think that somewhere it could make sense to provide some insight into the magnitude of some of these catches relative to historical catches- e.g., groundfish in the 1980s would have been many fold greater than the past decade..

Recent restrictions on Dungeness crab seasons appear to have had a limited impact on the overall level of harvest, but nonetheless have had negative impacts on the flow of benefits from the fishery (e.g., by limiting supply during the holiday season; by affecting safety at sea). Chinook salmon populations are depleted due to ongoing anthropogenic pressures (Lindley et al., 2009), and resulting management measures have kept commercial salmon boats tied to the docks. The trend in commercial harvest is rated as mixed. Despite recent fishery closures, there has been continued participation across a number of fisheries in the sanctuary, and stock assessments indicate that most target species have stable or increasing populations. Though substantial data exist on catch levels, a significant gap in this assessment is a lack of information on demand for seafood, which would serve as a benchmark for whether the level of commercial harvest is satisfactory. There is also a lack of information on the level of satisfaction (either by the general public or by those employed in the seafood sector) with how well sanctuary resources support seafood production and livelihoods, another possible benchmark.

Commented [32]: While an important reference for the 2008-2009 salmon disaster, which was the focus of that publication, there are better references for California salmon management challenges - such as Atlas, W.I., Sloat, M.R., Satterthwaite, W.H., Buehrens, T.W., Parken, C.K., Moore, J.W., Mantua, N.J., Hart, J. and Potapova, A., 2023. Trends in Chinook salmon spawner abundance and total run size highlight linkages between life history, geography and decline. Fish and Fisheries.

Commented [33]: that is part of it- but the infrastructure for the fishing community is another important part of this (and I suspect that many fishermen would say that this is a constraint that leads to unsatisfactory harvest levels, under-attainment of potential catches, for many groundfish, perhaps some other species.

References (Commercial Harvest)

Botsford, L. W., Methot, Jr., R. D., and Wilen, J. E. (1982). Cyclic covariation in the California King salmon, *Oncorhynchus tshawytscha*, Silver salmon, *O. kisutch*, and Dungeness crab, *Cancer magister*, Fisheries. Retrieved from https://spo.nmfs.noaa.gov/sites/default/files/pdf-content/1982/804/botsford.pdf

Brady, R. X., Alexander, M. A., Lovenduski, N. S., & Rykaczewski, R. R. (2017). Emergent anthropogenic trends in California Current upwelling. Geophysical Research Letters, 44(10), 5044-5052. doi:10.1002/2017GL072945.

California Department of Fish and Wildlife (CDFW). (2011). Stock assessment for California halibut. Retrieved from https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=36262&inline

California Department of Fish and Wildlife (CDFW). (2015). Review of selected California fisheries for 2014: coastal pelagic finfish, market squid, groundfish, pacific herring, Dungeness crab, ocean salmon, true smelts, hagfish, and deep water ROV surveys of MPAs and surrounding nearshore habitat (CalCOFI Rep., Vol. 56, 2015). Retrieved from http://www.calcofi.com/publications/calcofireports/v56/Vol56-Fisheries.web.1-30.pdf

California Department of Fish and Wildlife (CDFW). (2019). California commercial Dungeness crab season will close statewide. Marine Management News. Retrieved from https://cdfwmarine.wordpress.com/2019/04/02/california-commercial-dungeness-crab-season-will-close-statewide-april-15-2019/

California Department of Fish and Wildlife. (2020a). *California commercial landing receipt data, 1994–2020* [Data set]. https://wildlife.ca.gov/Regions/Marine

California Department of Fish and Wildlife (CDFW). (2020b). Declaration of Fishery Season Delay in the Commercial Dungeness Crab Fishery due to Risk of Marine Life Entanglement. Sacramento, CA.

California Department of Fish and Wildlife (CDFW) (2020c). The status of commercial marine aquaculture in California. Retrieved from https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=187229&inline

California Department of Fish and Wildlife (CDFW). (2021a). CDFW News: New Recreational Dungeness Crab Fishery Regulations adopted to manage entanglement risk for whales and sea turtles. CDFW. Retrieved from https://wildlife.ca.gov/News/new-recreational-dungeness-crab-fishery-regulations-adopted-to-manage-entanglement-risk-for-whales-and-sea-turtles

California Department of Fish and Wildlife (CDFW). (2021b). CDFW announces start of commercial crab fishery and recreational use of crab traps in fishing zone 3. CDFW. Retrieved from https://wildlife.ca.gov/News/cdfw-announces-start-of-commercial-crab-fishery-and-recreational-use-of-crab-traps-in-fishing-zone-3

California Department of Fish and Wildlife (CDFW) (2022a). California commercial market squid landing receipt data. Retrieved from https://wildlife.ca.gov/Conservation/Marine/Pelagic/Market-Squid-Landing

California Department of Fish and Wildlife (CDFW). (2022b). California Central Valley Chinook escapement database report. Retrieved from https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=84381

California Department of Fish and Wildlife (CDFW). (n.d.). Chinook salmon. CDFW. Retrieved from https://wildlife.ca.gov/Conservation/Fishes/Chinook-Salmon

California Ocean Science Trust. (2016). Frequently Asked Questions: Harmful Algal Blooms and California Fisheries, Developed in Response to the 2015-2016 Domoic Acid Event. Oakland, CA.

Johnson, K.F., Taylor, I.G., B.J. Langseth, A. Stephens, L.S. Lam, M.H. Monk, J.E. Budrick, M.A. Haltuch. (2021). Status of lingcod (*Ophiodon elongatus*) along the southern U.S. west coast in 2021. Pacific Fisheries Management Council, Portland, Oregon. 212p.

Lindley, S. T., Grimes, C. B., Mohr, M. S., Peterson, W. T., Stein, J. E., Anderson, J. J.,. & Williams, T. H. (2009). What caused the Sacramento River fall Chinook stock collapse.

National Marine Fisheries Service (NMFS). (2016a). 5-Year Review : Summary & Evaluation of California Coastal Chinook Salmon and Northern California Steelhead. Retrieved from https://repository.library.noaa.gov/view/noaa/17016.

National Marine Fisheries Service (NMFS). (2016b). 5-Year Review : Summary & Evaluation of Central Valley Spring-run Chinook Salmon Evolutionarily Significant Unit. Retrieved from https://repository.library.noaa.gov/view/noaa/17018.

Ocean Protection Council. (2013). Rapid assessments for selected California fisheries - Sablefish. Retrieved from https://www.opc.ca.gov/webmaster/ftp/project_pages/Rapid%20Assessments/Sablefish.pdf

Office of National Marine Sanctuaries (ONMS). (2014). Cordell Bank and Gulf of the Farallones National Marine Sanctuaries Expansion Final Environmental Impact Statement. U.S. Department of Commerce, National Oceanic and Atmospheric

Pacific Fishery Management Council. (2009). Pacific Fishery Management Council sets 2009 salmon seasons: most California fisheries still closed; seasons in north improved over last year (News release). Retrieved from https://www.pcouncil.org/documents/2009/04/council-sets-2009-salmon-seasons-most-california-fisheries-still-closed-seasons-in-north-improved-over-last-year-april-2009.pdf/

Pacific Fishery Management Council. (2019). Salmon Rebuilding Plan for Sacramento River Fall Chinook. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

Pacific Fishery Management Council (PFMC). (2020). Review of 2019 ocean salmon fisheries. Retrieved from https://www.pcouncil.org/documents/2020/02/review-of-2019-ocean-salmon-fisheries.pdf/

Pacific Fishery Management Council (PFMC) (2021). Dover sole Stock Assessment Review (STAR) panel report; May 3-7, 2021. Retrieved from

https://www.pcouncil.org/documents/2021/10/dover-sole-stock-assessment-review-star-panel-report.pdf/

Petursdottir, G., Hannibalsson, O., and Turner, J.M.M. (2001). Safety at sea as an integral part of fisheries management. FAO Fisheries Circular. No. 966. Rome, FAO. 39p.

Pfeiffer, L., Petesch, T., & Vasan, T. (2022). A safer catch? the role of fisheries management in Fishing Safety. Marine Resource Economics, 37(1), 1–33. https://doi.org/10.1086/716856

Powell, F., Levine, A. & Ordonez-Gauger, L. (2022). Climate adaptation in the market squid fishery: fishermen responses to past variability associated with El Niño Southern Oscillation cycles inform our understanding of adaptive capacity in the face of future climate change. Climatic Change 173, 1. https://doi.org/10.1007/s10584-022-03394-z

Richerson, K., Punt, A. E., & Holland, D. S. (2020). Nearly a half century of high but sustainable exploitation in the Dungeness Crab (Cancer Magister) fishery. Fisheries Research, 226, 105528. https://doi.org/10.1016/j.fishres.2020.105528

Shanks, A.L. and Roegner, G.C. (2007). Recruitment limitation in Dungeness crab populations is driven by variation in atmospheric forcing. Ecology, 88: 1726-1737. https://doi.org/10.1890/06-1003.1

Wetzel, C.R. 2019. Status of petrale sole (*Eopsetta jordani*) along the U.S. west coast in 2019. Pacific Fishery Management Council, 7700 Ambassador Place NE, Suite 101, Portland, OR 97220

Regulating Services (buffers to change)

Coastal Protection — Flow regulation that protects habitats, property, coastlines, and other features

Status Rating: Fair/Poor	Status Confidence: High
Trend Rating: Undetermined	Trend Confidence: Medium
Status Description: The capacity to provide the ecosystem service is compromised, and substantial new or enhanced management is required to restore it.	
Rationale: Significant external (e.g., dams and culverts) and some internal built infrastructure (shoreline armoring) has disrupted the supply of sediment in numerous areas along this already naturally eroding coastline. The effects have likely been far ranging, and are being exacerbated by changes in climate that directly affect sediment delivery to coastal ecosystems. The extent of the influence is not fully understood, but it is clear that substantial management would be needed to restore natural control of sediment delivery and movement. The trend is undetermined due to a lack of information at the large scale on changes in shoreline hardening and habitat condition during the time period of interest (2010–2022).	

Coastal protection is defined as the flow regulation that protects habitats, property, coastlines, and other features. Saltmarsh, eelgrass beds, and sandy beaches and dunes near GFNMS protect coastlines by dissipating wave energy, resulting in smaller, less destructive waves reaching the coast and inshore areas. These natural buffers also help protect against erosion, which can threaten coastal properties and resources. It is important to note that coastal protection was evaluated based on the ability of natural features (not built infrastructure) to provide protection. However, built infrastructure was considered to the extent that it impacts protection offered by natural features, such as barrier beaches. Where possible, estimates of the economic value of natural habitats for coastal protection were provided. However, these estimates vary greatly depending on local characteristics, and information specific to the sanctuary was limited.

Table ES.CP.1. Summaries for the key indicators related to coastal protection that were discussed during the July 5, 2022 virtual status and trends workshop.

Indicator	Source	Data Summary
FEMA Flood Zones	FEMA, 2022	Status: Properties adjacent to estuarine areas are within flood zones Trend: No trend data
Annual High Tide Flood Days	NOAA/ NOS, 2022	Status: Average of 1.4 annual flood days Trend: Varied without trend from 2010-2022
Bull Kelp Literature Review	Multiple Sources	Status: Negligible evidence of wave attenuation by bull kelp Trend: No trend data
Eelgrass literature review	Multiple Sources	Status: Strong evidence for wave attenuation under certain conditions, varies spatially Trend: No trend data
Eelgrass cover	CDFW, 2018	Status: Over 2000 acres of eelgrass cover in estuarine areas Trend: No trend data. Reported loss of eelgrass in Bolinas Lagoon
Salt marsh literature review	Multiple Sources	Status: Strong evidence for coastal protection by salt marsh habitat; large range in estimated value for coastal protection Trend: No trend data
Salt marsh habitat cover	Tamalpais Lands Collaborative, 2018	Status: Around 880 acres in estuarine areas Trend: No trend data
Sandy beaches literature review	Multiple Sources	Status: Act to attenuate/dissipate waves and reduce flooding, degree varies spatially Trend: No trend data

Shoreline change	George, Hutto, and Delaney, 2018	Status: Coastal processes and SLR threaten to disrupt roads, coastal trails, and critical habitat Trend: Dynamic shorelines near mouths of Russian River, Tomales Bay, and Drakes Bay
Percent hardened shoreline	Griggs & Patsch, 2019; GFNMS	Status: On average, the counties adjacent to GFNMS are much less impacted by shoreline armoring than California overall (13.8% armored); however, a high percentage of shoreline is armored in locations like Bolinas Lagoon (35% armored) Trend: Shoreline hardening trend information was not available
Data gaps	Trend data for most indicators; information on large-scale changes in shoreline hardening and habitat condition	

The coastline of GFNMS is characterized by rocky cliffs, sandy beaches, bays, and estuaries (George et al., 2018). Cliff erosion is occurring along much of the coastline (Swirad and Young, 2022). The region is less densely developed than many portions of coastal California, with agricultural uses dominating much of the area (George et al., 2018). Given its widespread steep slopes and rocky shorelines, recreation tends to be concentrated in pockets of high use in coastal areas protected by these geographical features (George et al., 2018). Popular recreational areas include beaches, like Miwok and Dillon Beach, along with several local, state, and nationally-managed protected areas. Developed areas that are exposed to coastal hazards include communities like Bolinas, Inverness, and Bodega Bay, along with public infrastructure, notably Highway 1 (NOAA OCM, 2022).

Flooding

Coastal vulnerability to flooding along GFNMS shorelines depends on the rate of global and local sea level rise, along with the frequency and intensity of extreme events, like El Niño-Southern Oscillation events, storm waves, and high tides (Griggs & Patsch, 2019). As measured at the NOAA data buoy at Point Reyes, California, the number of high tide flood days varied without trend from 2010–2022 with an annual average of 1.4 flood days[11] and a maximum of seven flood days in 2017 (NOAA NOS, 2022). Data collected at the same Point Reyes buoy indicates a relative sea level rise trend of 2.14 mm/year with a 95% confidence interval of +/- 0.79 mm/year (NOAA NOS, 2022). Research suggests a weakly increasing trend in significant wave height offshore of the west coast and California (Young, et al., 2011; Gemmrich, et al., 2011).

Several areas within and adjacent to the bays and estuaries in GFNMS fall within moderate or high-risk flood zones, as designated by the Federal Emergency Management Agency (FEMA). For example, most of Bolinas Lagoon is classified as a type A flood zone by FEMA

[11] A flood day occurs when verified hourly water levels exceed a flood threshold for at least one hour. The minor flood threshold for this location is 2 feet about MHHW, as defined in the NOAA Technical Report NOS CO-OPS 086: Patterns and Projections of High Tide Flooding Along the U.S. Coastline Using a Common Impact Threshold.

(corresponding to a 1% or greater annual chance of flooding), while the spit enclosing Bolinas Lagoon is designated as either a high-risk, type V flood zone (1% or greater annual chance of flooding with an additional hazard associated with storm waves) or a moderate-risk (0.2% chance of flooding) zone (NOAA OCM, 2022). Similarly, the area within Tomales Bay, including portions of developed areas like Marshall, Inverness, and Point Reyes Station, is designated as either a type A or type V flood zone depending on location (NOAA OCM, 2022).

Saltmarsh and Eelgrass Beds

Vegetated habitats, including saltmarsh and eelgrass beds, can provide coastal protection through flood and erosion control within estuarine environments.[12] Saltmarshes provide coastal protection by attenuating wave energy and stabilizing shorelines (Shepard et al., 2011). They provide additional flood protection by promoting water storage capacity and surface resistance through their plant and soil components (Ballard et al., 2016). No studies have estimated the economic value of saltmarsh for coastal protection specifically within GFNMS or central California. The range of value of wetlands, which includes saltmarsh and other habitats, for flood and storm protection was estimated to be $20/acre to $10,533/acre in 2020 US dollars, based on studies from Colorado (Batker et al., 2014) and southern California (Ballard et al., 2016; Ballard et al., 2017). Other studies in Galveston, TX and Northwest Mexico estimate the flood and storm protection value of saltmarshes to be roughly $7,683/acre and $6,677/acre, respectively (Feagin et al., 2010; Camacho-Valdez et al., 2013). Within GFNMS, there are nearly 880 acres of saltmarsh habitat: 637 acres in Tomales Bay, 196 acres in Bolinas Lagoon, 33 acres in Estero Americano, and 14 acres in Estero de San Antonio (Tamalpais Lands Collaborative, 2018). No data was available to indicate trends in saltmarsh cover from 2010-2022.

In a study of wave attenuation by eelgrass (*Zostera marina*) in South Bay, Virginia, researchers found that wave heights were reduced by 25–49% in eelgrass plots compared to adjacent bare sites (Reidenbach & Thomas, 2018). They also found that wave attenuation was greatest in spring and summer, when eelgrass biomass was greatest (Reidenbach & Thomas, 2018). This implies that eelgrass beds provide less protection during the winter, when significant wave heights are largest. Importantly, reductions in wave energy are greatest when eelgrass beds are broad and when plant size is scaled to water depth (i.e., when plants occupy the entire water column) (Fonseca & Cahalan, 1992), which may occur at low tide or when the plants have long reproductive stems (Koch et al., 2006). Under those conditions, wave attenuation by eelgrass is comparable to that provided by salt marshes (Fonseca & Cahalan, 1992). In addition to reducing wave energy, eelgrass can provide erosion control by trapping sediments and stabilizing the substrate (NOAA Fisheries, 2014), but these effects vary by sediment type and eelgrass bed width (Marin-Diaz et al., 2020).

Within the sanctuary, there is a total of about 2,026 acres of eelgrass cover, of which 2,019 acres is located in Tomales Bay (Figure ES.E.1, Merkel & Associates, 2017; CDFW, 2018). Several shellfish farms operating within Tomales Bay are co-located with eelgrass beds (CDFW, 2011) and may benefit from protection provided by the submerged vegetation. The remaining eelgrass cover is located within Estero Americano (~5.5 acres) and Estero de San Antonio (~1.3 acres) (Merkel & Associates, 2017; CDFW, 2018). Trend data is limited for eelgrass cover in GFNMS within the study period. A small extent of eelgrass beds in Bolinas Lagoon has largely

[12] Kelp forest was investigated as a nearshore habitat type for inclusion in coastal protection. However, there is evidence that bull kelp (*Nereocystis luetkeana*; the predominant species in GFNMS), like other large floating-canopy species, has a negligible effect on wave attenuation (e.g., Friedland & Denny, 1995; Koehl & Alberte, 1988; Hondolero & Edwards, 2017).

disappeared (GFNMS SAC, 2008) but there are no recent surveys. There has not yet been a robust valuation of the benefits of eelgrass habitat for coastal protection (Barbier et al., 2011).

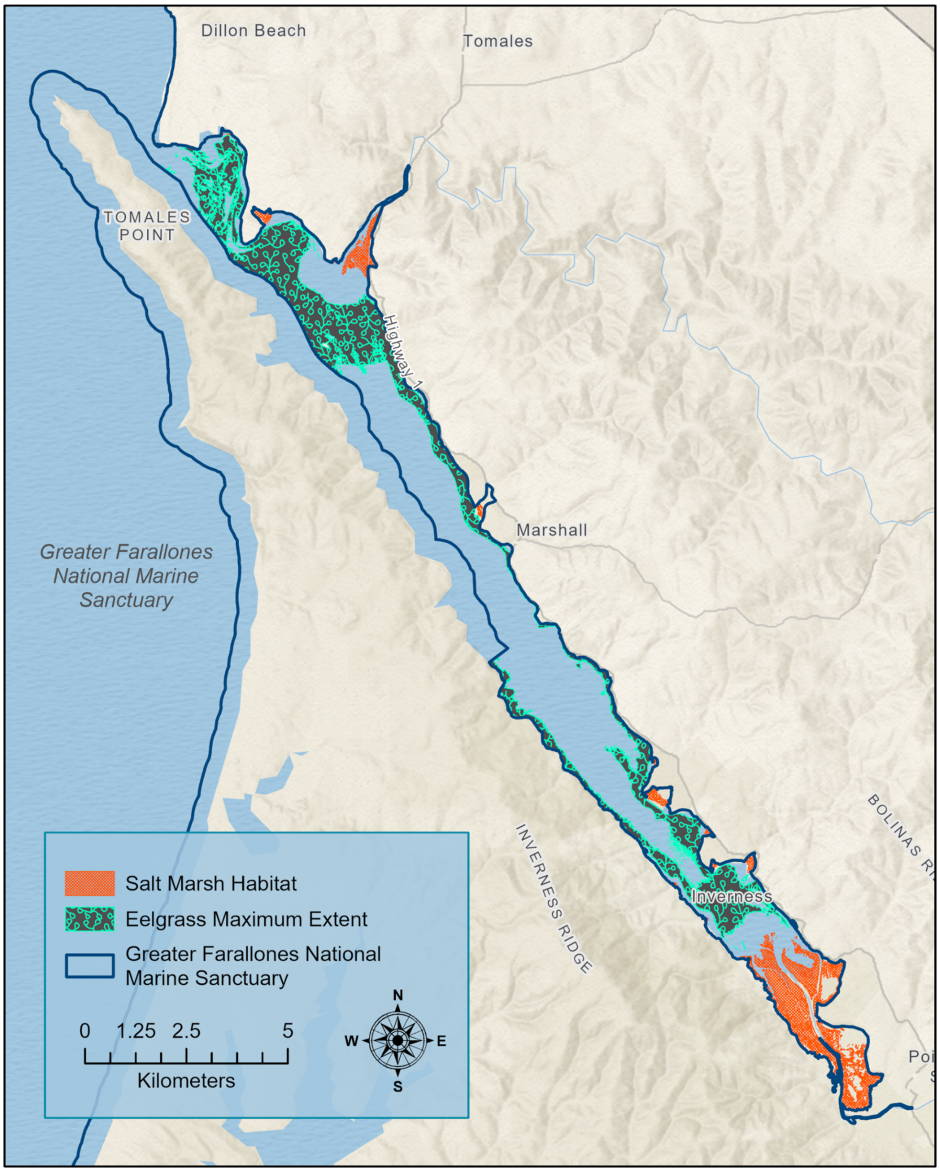

Figure ES.CP.1. Salt marsh and eelgrass cover in Tomales Bay. Image: NOAA; Source: County of Marin et al., 2018; Merkel & Associates, Inc., 2017; California Department of Fish & Wildlife, 2018; Esri, 2016.

Sandy Beaches and Dunes

As waves reach the shore, they are attenuated by the beach slope and, at high tide, by the foredune, the structure forming behind the beach where sand accumulates into mounds or ridges parallel to the shoreline (Barbier et al., 2011). They can also provide erosion protection through sediment stabilization and soil retention in vegetation root structures (Barbier et al. 2011). The degree of wave attenuation afforded by sandy shores depends on the shape of the beach and foredunes, which in turn depends on factors like presence of vegetation and sand supply (Barbier et al., 2011). The economic value of beaches for coastal protection has not been calculated but is substantial (Barbier et al., 2011).

Natural erosion and deposition along sandy beaches at GFNMS have changed because of historic alteration of sediment supplies caused by modification of watersheds and coastal armoring, combined with climate impacts (Kordesch et al., 2019). Dams, culverts and shoreline armoring are among the infrastructure types that have altered sediment delivery by the region's rivers and affected sediment supplies to downstream beaches. Analysis of shoreline change in Sonoma and Marin counties shows that the mouths of the Russian River, Tomales Bay, and Drakes Estero are particularly dynamic (George et al., 2018). Hardened, or armored, shorelines along GFNMS consist of coastal development and highways. Of the entire length of California's shoreline in 2018, 13.8% was armored with seawalls and revetments (Griggs & Patsch, 2019). Comparatively, the coastline of GFNMS is less impacted by armoring, with only 4.7% of Marin County, 1.2% of Sonoma County, and 1% of Mendocino County being hardened (Griggs & Patsch, 2019). There are 216 instances of armoring within GFNMS, totalling 8,577.6 meters (California Coastal Commission, 2022).

Hardened structures can account for a much higher percentage of the shoreline in areas of GFNMS with private development and public infrastructure. In 2019, 35% of Bolinas Lagoon's 24.4 km shoreline consisted of hard armored structures (i.e. transportation structure, man-made bulkhead or seawall, man-made ramp, rip rap, or shoreline protection structure) (California Coastal Commission, 2022). As of 2022, there were 125 instances of armoring in Tomales Bay within GFNMS, and around 4.4 km of the 63 km (or around 7%) of bay's shoreline was armored (California Coastal Commission, 2022).

Data was not available to indicate a trend in shoreline hardening within the specific years evaluated for this condition report (2010–2022). Results from a case study in Imperial Beach in Southern California indicate that coastal armoring provides the least public benefit over time of the evaluated adaptation strategies (i.e. armoring, nourishing, living shorelines, groins, and managed retreat) (Revell et al., 2021). Fifteen sites within GFNMS were identified in the GFNMS Coastal Resilience Sediment Plan as high priority areas for nature-based action in the next ten years (Kordesch et al., 2019), and a number of nature-based restoration projects are currently in the planning phase. The GFNMS Coastal Resilience Sediment Plan provides more detail on sediment management issues, priority sites, and review and assessment of sediment management actions (Kordesch et al., 2019).

Conclusion

Coastal protection ecosystem service is rated fair/poor indicating the capacity to provide the ecosystem service is compromised, and substantial new or enhanced management is required to restore it. This is based on the limited ability of eelgrass and saltmarsh habitats to provide

protection to private development and public infrastructure, because the extent of these habitats are small compared to the entire area of the sanctuary. A small percentage of the uplands and sanctuary shoreline contained built infrastructure to protect property, manage water, and produce power, but it can significantly alter local erosion, and produce cascading downstream impacts. Furthermore, the whole coast is believed to be an actively erosive one, to varying degrees. Thus, high natural rates of erosion have been amplified by the downstream effects of sediment starvation, exacerbated by the influence of climate change on processes like sea level rise and intensifying weather extremes (principally drought and floods). The trend is undetermined due to a lack of time series data for eelgrass and saltmarsh habitat cover or shoreline hardening. Other data gaps include more information needed for Bolinas Lagoon, Tomales Bay and the northern coastline of the sanctuary; site-specific, empirical data on the physical processes, like wave attenuation and erosion control, that modulate coastal protection afforded by natural features; information connecting those physical processes to property value or livelihoods protected; and cumulative effects on deteriorating shorelines.

References (Coastal Protection)

Allan, J. C., & Komar, P. D. (2006). Climate controls on US West Coast erosion processes. Journal of coastal research, 22(3), 511-529.

Balland, J., Pezda, J., and Spencer, D. (2016). An Economic Valuation of Southern California Coastal Wetlands. [Master's Thesis, University of California, Santa Barbara]

Barbier, E.B., Hacker, S.D., Kennedy, C., Koch, E.W., Stier, A.C. and Silliman, B.R. (2011). The value of estuarine and coastal ecosystem services. Ecological Monographs, 81: 169-193. https://doi.org/10.1890/10-1510.1

Batker, D., Christin, Z., Graf, W., Jones, K. B., Loomis, J., Cooley, C., & Pittman, J. (2014). Nature's value in the Colorado River Basin.

Bell, T, K. Cavanaugh, D. Siegel. 2023. SBC LTER: Time series of quarterly NetCDF files of kelp biomass in the canopy from Landsat 5, 7 and 8, since 1984 (ongoing) ver 19. Environmental Data Initiative. https://doi.org/10.6073/pasta/630565d6a8bf54c7cbce6802284dd431.

California Coastal Commission. (2022). Shoreline armoring data [unpublished data set]

California Department of Fish and Wildlife, Marine Resources Region. (2011). Aquaculture Leases: California, 2011. California Department of Fish and Wildlife. Marine Resources Region. Available at: http://purl.stanford.edu/zk621ch0195.

California Department of Fish & Wildlife. (2018). Eelgrass Maximum Observed Extent - California [ds2795]

Camacho-Valdez, V., Ruiz-Luna, A., Ghermandi, A., & Nunes, P. A. (2013). Valuation of ecosystem services provided by coastal wetlands in northwest Mexico. Ocean & Coastal Management, 78, 1-11.

Feagin, R. A., Martinez, M. L., Mendoza-Gonzalez, G., & Costanza, R. (2010). Salt marsh zonal migration and ecosystem service change in response to global sea level rise: a case study from an urban region.

Friedland MT, Denny MW. 1995. Surviving hydrodynamic-forces in a wave-swept environment: consequences of morphology in the feather boa kelp, Egregia menziesii (Turner). Journal of Experimental Marine Biology and Ecology 190: 109–133.

Fonseca, M. S.,and J. A. Cahalan. 1992. A preliminary evaluation of wave attenuation for four species of seagrass. Estuarine, Coastal and Shelf Science 35: 565– 576.

Gemmrich, J., Thomas, B., and Bouchard, R. (2011). Observational changes and trends in northeast Pacific wave records, Geophys. Res. Lett., 38, L22601, doi:10.1029/2011GL049518.

George, D.A., Hutto, S., and Delaney, M. 2018. Sonoma-Marin Coastal Regional Sediment Management Report. Report of the Greater Farallones National Marine Sanctuary. NOAA. San Francisco, CA. 201 pp.

GFNMS Sanctuary Advisory Council Working Group. (2008). Bolinas Lagoon Ecosystem Restoration Project: Recommendations for Restoration and Management. San Francisco, CA. 102 pp.

Griggs, G. and Patsch, K. (2019). The protection/hardening of California's coast: Times are changing. Journal of Coastal Research, 35(5), 1051–1061. Coconut Creek (Florida), ISSN 0749-0208.

Hondolero, D., Edwards, M.S. (2017). Changes in ecosystem engineers: the effects of kelp forest type on currents and benthic assemblages in Kachemak Bay, Alaska. Mar Biol 164, 81. https://doi.org/10.1007/s00227-017-3111-3

Koehl, M.A.R., Alberte, R.S. (1988). Flow, flapping, and photosynthesis of Nereocystis leutkeana: a functional comparison of undulate and flat blade morphologies. Mar. Biol. 99, 435–444. https://doi.org/10.1007/BF02112137

Koch, E. W., J. Ackerman, M. van Keulen,and J. Verduin. 2006. Fluid dynamics in seagrass ecology: from molecules to ecosystems. Pages 193– 225 in A. W. D Larkum R. J Orthand C. M Duarte editors. Seagrasses: biology, ecology and conservation. Springer-Verlag, Heidelberg, Germany.

Kordesch, W.K., M. Delaney, S. Hutto, M. Rome, and S. Tezak. 2019. Coastal Resilience Sediment Plan. Report of Greater Farallones National Marine Sanctuary. NOAA. San Francisco, CA. 104 pp.

Marin-Diaz, B., Bouma, T.J. and Infantes, E. (2020). Role of eelgrass on bed-load transport and sediment resuspension under oscillatory flow. Limnol Oceanogr, 65: 426-436. https://doi.org/10.1002/lno.11312

Merkel & Associates, Inc. in collaboration with National Oceanic Atmospheric Administration (NOAA) Greater Farallones National Marine Sanctuary (GFNMS). (2017). 2017 Tomales Bay Eelgrass Inventory. Tomales Bay, CA

NOAA Fisheries. (2014). The Importance of Eelgrass. https://www.fisheries.noaa.gov/feature-story/importance-

eelgrass#:~:text=By%20trapping%20sediment%2C%20stabilizing%20the,highly%20productive%20marine%20food%20web.

NOAA National Ocean Service. (2022). Inundation Dashboard for 9415020, Point Reyes, CA. https://tidesandcurrents.noaa.gov/inundationdb/inundation.html?id=9415020

NOAA Office for Coastal Management. (2022). Coastal Flood Exposure Mapper. https://coast.noaa.gov/digitalcoast/tools/flood-exposure.html

Reidenbach MA and Thomas EL (2018) Influence of the Seagrass, Zostera marina, on Wave Attenuation and Bed Shear Stress Within a Shallow Coastal Bay. Front. Mar. Sci. 5:397. doi: 10.3389/fmars.2018.00397

Revell D, King P, Giliam J, Calil J, Jenkins S, Helmer C, Nakagawa J, Snyder A, Ellis J, Jamieson M. (2021). A Holistic Framework for Evaluating Adaptation Approaches to Coastal Hazards and Sea Level Rise: A Case Study from Imperial Beach, California. Water. 13(9):1324. https://doi.org/10.3390/w13091324

Shepard CC, Crain CM, Beck MW (2011) The Protective Role of Coastal Marshes: A Systematic Review and Meta-analysis. PLOS ONE 6(11): e27374. https://doi.org/10.1371/journal.pone.0027374

Swirad Z.M. & Young A.P. 2022. Spatial and temporal trends in California coastal cliff retreat. Geomorphology 412: 108318. https://doi.org/10.1016/j.geomorph.2022.108318

Tamalpais Lands Collaborative. (2018). Marin Countywide Fine Scale Vegetation Map.

Wingfield, D. K., & Storlazzi, C. D. (2007). Spatial and temporal variability in oceanographic and meteorologic forcing along Central California and its implications on Nearshore Processes. Journal of Marine Systems, 68(3-4), 457–472. https://doi.org/10.1016/j.jmarsys.2007.02.008

Young, I. R., Zieger, S. & Babanin, A. V. (2011). Global trends in wind speed and wave height. Science (80-.). 332, 451–5.

Response to Pressures on the Sanctuary

The Pressures section of this report describes a variety of issues and human activities occurring within and beyond the sanctuary that warrant attention, tracking, study, and in some cases, specific management actions. Addressing any of these issues requires participation by and coordination with a variety of agencies and organizations. The Office of National Marine Sanctuaries (ONMS) is fortunate to be able to work with many entities that contribute to managing human activities and addressing marine and estuarine conservation issues. In many cases, GFNMS relies on partnerships with federal, state, and local government agencies, businesses, and non-profit organizations to address the pressures on the sanctuary.
This section summarizes activities and management actions that GFNMS has led or coordinated. The activities described below are not exhaustive of all the ways we serve our surrounding community and the ecosystems within GFNMS. The activities highlight significant contributions that are responsive to known or emerging pressures and are focused on responses related to human activities where direct ONMS interventions or GFNMS-led partnerships have protected or restored sanctuary resources.

Recommendations for future actions are not included~~Future actions are not recommended or presented~~ in this section; however, we provide information on potential future needs to address pressures that were not assessed as indicators in this condition report, but are emerging issues that need attention. Current responses outlined in this section will be evaluated against all known pressures to help shape future priority needs for GFNMS management. The next step is management planning, and the findings of this condition report will serve as an important foundation to help GFNMS set future priorities based on known needs.

Commented [1]: "future actions are not recommended" can be misconstrued...!

Introduction

Regulatory Responses

Sanctuary regulations include prohibitions (15 CFR § 922.82), which are intended to limit human activities that are known to cause harm to sanctuary resources. GFNMS has implemented a variety of regulations that are intended to:

- Prevent discharges of solid and liquid materials such as sewage, hazardous chemicals and oil;
- Protect benthic habitat from activities such as dredging or coastal development;
- Prevent disturbance to wildlife including white sharks; and
- Prohibit other specific activities such as oil exploration, introducing non-indigenous species, anchoring in designated seagrass protection zones, deserting a vessel, leaving harmful matter aboard a grounded or deserted vessel, or taking historic resources.

GFNMS is not responsible for enforcing regulations. However, GFNMS worked with enforcement partners, including NOAA Office of Law Enforcement, the U.S. Coast Guard, and other federal and state agencies with authority to enforce sanctuary regulations to conduct training for airmen, boarding officers, wardens, and rangers on sanctuary priorities, projects, and regulations as well as provided technical expertise when violations occurred.

GFNMS also supported the development and use of the electronic Fisheries Information Network System, known as eFINS. This pilot mobile application is a data collection and sharing tool that allows participating marine enforcement partners to electronically record, store, reference, and share geospatial data taken during patrols as they conduct compliance checks with commercial and recreational users of the sanctuary.

Between 2014–2022, GFNMS has documented 502 reported sanctuary violations (GFNMS, 2023a), most of which were forwarded to NOAA's Office of Law enforcement to assist with enforcement case development. Many cases included multiple violations. One of the most significant violations was 190 documented discharges from 2017-2019 from multiple cruise ships (Blank Rome LLP, 2017). GFNMS worked with NOAA's Office of Law Enforcement and General Council for Law Enforcement to fine the cruise ship companies for illegally discharging in the sanctuary.

Non-regulatory Responses

GFNMS developed and maintained partnerships and engaged the community in actions that addressed pressures to sanctuary resources. Projects and programs that sanctuary staff have led, coordinated, or jointly conducted with partners helped address conservation challenges that arose from human activities. Since 2010, GFNMS focused most of its non-regulatory actions to address the following human-caused pressures:

- Climate change;
- Land use;
- Marine Harvest;
- Vessel traffic;
- Wildlife disturbance;
- Marine debris; and
- Non-indigenous species.

The National Marine Sanctuaries Act creates a powerful pathway to engage stakeholders through sanctuary advisory councils. The Sanctuary Advisory Council, as a public advisory body with subcommittees and working groups, has forwarded recommendations to address many of the pressures in the sanctuary. The advisory council served as a forum for consultation and deliberation among its members and as a source of advice and recommendations to the sanctuary superintendent. The advisory council includes governmental (state, local, and federal agencies) and non-governmental (education, conservation, research, fishing, tourism, industry, marine activities, and citizens at large) seats. Since 2010, the advisory council has contributed to recommendations and reports that have helped the sanctuary superintendent respond to climate impacts, including shoreline change and sediment transport; benthic habitat impacts, including vessel groundings and sinkings, and damage from anchors and moorings; vessel traffic impacts, including preventing ship strikes, understanding acoustic impacts, and reducing oil pollution; and marine debris prevention (GFNMS, 2023).

Responses to Pressures on the Sanctuary

Responses to Climate Change

Since 2010, GFNMS has developed a comprehensive approach to better understand and respond to climate-related impacts in an effort to ensure GFNMS resources are resilient. In 2010, the Sanctuary Advisory Council produced the GFNMS Climate Change Impacts Report (Largier et. al, 2010) that identified and synthesized information on potential climate change impacts to habitats and biological communities along the North-Central California coast. The

report was created through a collaborative process involving 16 agencies, organizations, and academic institutions. In 2013, the Sanctuary Advisory Council applied the findings from the Impacts Report and from the 2012 GFNMS Ocean Climate Summit and produced the Ocean Climate Indicators Report (Duncan et. al, 2013). The Indicators Report was informed by more than 50 regional, federal, and state natural resource managers, research scientists, and other partners to develop a set of ocean climate indicators and monitoring objectives and strategies for the North-Ccentral California coast and ocean region. These indicators were used by the U.S. team on the Intergovernmental Panel on Climate Change to develop national and global ocean climate change indicators. The sanctuary and its partners have included the indicators in monitoring projects to track the status and trends of climate impacts in the region. From 2014 to 2015, the sanctuary applied the findings from the Impacts and Indicators Reports as well as input from a 2013 GFNMS Ocean Climate Summit to develop a Climate Change Vulnerability Assessment (Hutto et. al, 2015). With input from over 60 scientists, experts identified how and why various habitats, species, and ecosystem services across the North-Ccentral California coast were likely to be affected by future climate conditions. The vulnerability assessment workshop determined blue whales and coastal habitats with their associated species and ecosystem services were most vulnerable to climate change.

In 2016, GFNMS developed a Climate Adaptation Plan (National Marine Sanctuary Program, 2016) based on recommendations received from the Sanctuary Advisory Council, which outlined actions the sanctuary could take to address the most vulnerable habitats, species, and ecosystem services with the objective of reducing vulnerability of coast and ocean resources in order to build resilience to climate change. GFNMS has advanced many of the recommendations from the plan, including increasing resilience by reducing vessel strikes to endangered and threatened blue, humpback, and fin whales; developing and implementing a coastal resilience plan; actively pursuing and supporting living shoreline and shoreline restoration projects; restoring eelgrass; developing a native oysters living shoreline and restoration plan; supporting additional protections for sanctuary deep sea coral communities; and understanding blue carbon habitats and processes in the sanctuary. In 2017, the Council on Environmental Quality designated the sanctuary as a Resilient Lands and Water site.

In addition, although multiple factors contribute to kelp forest ecosystem health, climate-related drivers have been a major driver in kelp declines in GFNMS since 2014. In response to a 90% decline in bull kelp habitat along the Sonoma and Mendocino coast, the advisory council adopted and forwarded recommended actions to restore sanctuary kelp forests in 2018. These recommendations were incorporated into a Sonoma-Mendocino Bull Kelp Restoration Plan, the first of its kind bull kelp restoration plan published in California, authored by GFA. GFNMS and GFA have partnered on implementing the recommendations to research and restore bull kelp in the sanctuary.

Responses to Land Use

From 2010–2022, GFNMS' focus on land use impacts included reviewing and commenting on environmental compliance documents, plans or regulatory proposals from other agencies that could potentially result in a discharge into the sanctuary. The scope of comments were focused on management plans, action plans, strategic plans, proposals for road maintenance, culvert cleanings, construction projects and proposed regulations that could alter land adjacent to GFNMS.

GFNMS also developed and implemented the Coastal Resilience Sediment Plan. Coastal sediment is a natural resource that contributes to a healthy coastline. GFNMS identified sediment-related adaptation strategies in one-third of the Climate Adaptation Plan recommendations which led to the publication of the Coastal Resilience Sediment Plan (Kordesch et al., 2019) and the establishment of the North-central California Coast Sediment Coordination Committee, a group of 17 federal, state, and local agencies committed to collaborating on coastal resilience initiatives across the region. The plan provides a 50-year road map to help shorelines on the north-central California coast adapt to hazards such as severe storm surge, sea level rise, erosion, flooding, and human impacts and identifies sediment imbalances within the sanctuary caused by land use. GFNMS has been an active partner with Marin County Parks to identify projects to restore historic floodplains and reconnect Bolinas Lagoon wetlands that have been bisected by roads.

Since 2010, GFNMS has implemented actions in the Bolinas Lagoon Ecosystem Restoration Project: Locally Preferred Plan that have specifically focused on improving the hydrological function of the lagoon. The first project, completed in 2011, that contributed to this effort was an extensive culvert replacement on Highway 1 on the east shore of Bolinas Lagoon using porous materials that retain runoff, thus reducing the amounts of sediment and toxins entering the lagoon. This project helped Bolinas Lagoon adjust to tidal fluctuations and storms by preventing additional sediment flow from the watershed. This project also removed invasive species from the east shore of the Lagoon.

GFNMS has also partnered with the Greater Farallones Association (GFA) to initiate design of a living shoreline project along the south end of Bolinas Lagoon to restore wetland habitat that was lost with the creation of the Seadrift Lagoon housing development. In addition, GFNMS has partnered with GFA to coordinate monitoring of the sanctuary shoreline to characterize and understand changes, so that GFNMS can focus on the greatest impacts with the best available information. In addition, based on the recommendations in the Coastal Resilience Plan, the Marin County Development Agency conducted a dune restoration feasibility study to determine if dunes could be used as a living shoreline project to protect development along Stinson Beach.

GFNMS has also pursued restoration of native oyster species, which declined due to a variety of factors, including habitat loss, non-indigenous predators, and historic overharvesting. Restoration efforts aim to support healthy ecosystem function, protect coastal habitats, and reestablish ecosystem services (e.g., recreational harvest). At the request of GFNMS, the Sanctuary Advisory Council convened a working group, which recommended actions to increase the native Olympia oyster population in Tomales Bay and explore coastal protection benefits associated with oyster restoration (GFNMS Advisory Council, 2019). Based on these recommendations, GFNMS developed an Oyster Restoration Plan for Tomales Bay, and the Marin County Development Agency conducted a native oyster living shoreline feasibility study.

Responses to Marine Harvest Activities

The sanctuary encompasses living and non-living habitats such as rocky reefs and kelp beds. Over the last 10 years GFNMS has focused efforts to protect and restore habitats within the sanctuary through commenting on other agency actions that affect sanctuary habitat and partnering on efforts to restore habitat. Prior to 2010, GFNMS participated in the California Department of Fish and Wildlife's Marine Life Protection Act process that established 25 State marine protected areas (MPA) that prohibit impacts to habitat from fishing along the North-central California coast and continued to be an active participant in the MPA Collaboratives Network, a group established to empower diverse communities to engage in MPA stewardship

for a healthy ocean. GFNMS also participated in the Pacific Fishery Management Council's decade-long review of Pacific Coast groundfish Essential Fish Habitat Conservation Areas within sanctuary waters by providing seafloor, coral and sponge and fish assemblage data that was instrumental in protecting sanctuary habitats from bottom trawling impacts. Five areas were closed to bottom trawling throughout the sanctuary and two areas retained their closed status. During deep sea coral and sponge habitat and damage assessment cruises, GFNMS documented marine debris on the seafloor. In response to a dry dock that sank on the border of GFNMS and MBNMS, GFNMS in partnership with MBNMS developed a draft restoration plan that proposes to restore deep sea coral habitat in GFNMS and MBNMS.

Responses to Vessel Activity

Many types of vessels (e.g. commercial, barges, recreational, and research) transit through and in the sanctuary and have impacted sanctuary water quality, habitat, and wildlife. In 1993 in response to recurring oil spill events from vessels in the sanctuary, GFNMS established the Beach Watch community monitoring project. Beach Watch surveyors are trained to collect oil samples and dead oiled wildlife and have often been the first people to observe an oil spill event. Currently, 150 Beach Watch volunteers monitor sanctuary beaches every two to four weeks. The evidence gathered by Beach Watch volunteers has helped the Federal and State government document the damage to wildlife and habitat from oil spills, determine clean up end points, identify birds and mammals at risk from oil pollution, and inform restoration projects.

Based on historic levels of oil and dredge spills, illegal discharges from cruise ships, and the high level of risk these violations pose to sanctuary habitats and wildlife, GFNMS focused on supporting enforcement cases and responding to and preparing for oil spills, boat groundings, and large items (e.g. dry dock, cargo containers, and airplanes) sinking in the sanctuary. As a resource trustee, GFNMS participated as a member of two U.S. Coast Guard led Area Committees and participated in sub-committees to identify sensitive sites and resources at risk, to develop response strategies, and for potential places of refuge for vessels in distress in addition to reviewing draft planning documents and participating in response drills.

GFNMS either facilitated or coordinated the removal of grounded and sunken vessels when feasible by working with emergency responders, responsible parties, and enforcement personnel. Between 2012 and 2022, GFNMS has funded (directly or through cost-sharing with other agency partners) the removal of five vessels that were abandoned, grounded, or sunk in the sanctuary including the F/V *Marian* that grounded in 2019, damaged eelgrass, and subsequently sank in Tomales Bay in 2021.

Following several high-profile ship strikes to whales in 2009, GFNMS, based on recommendations from the Sanctuary Advisory Council, implemented voluntary vessel speed reduction measures. Since 2010, GFNMS has advised operators of vessels of all sizes and classes to watch out for whales and reduce speeds. From 2012–2021, GFNMS further requested vessels 300 gross tons or larger to voluntarily travel at 10 knots or less in the San Francisco Offshore Traffic Separation Scheme (TSS). Beginning in 2022, at the recommendation of the GFNMS and CBNMS Advisory Councils, the voluntary vessel speed reduction zone was expanded throughout the full extent of GFNMS and CBNMS. Since 2015, GFNMS—first in partnership with CBNMS and then later in partnership with ONMS, National Marine Fisheries Service, U.S. Coast Guard, and the Environmental Protection Agency—has analyzed Automatic Identification System (AIS data) for large vessel traffic and has sent letters to shipping companies reporting on vessel speed reduction cooperation. Cooperation by all large vessels with the voluntary requests in the San Francisco region has grown from 28% in

2015 to 61% in 2022. Analyses completed by Point Blue Conservation Science estimate that this level of cooperation has resulted in a reduction in ship strike risk of ~25% for blue and humpback whales in the region, compared to 2014 levels. ACCESS, a GFNMS, CBNMS, and Point Blue Conservation Science partnership monitored the distribution and abundance of whales in the sanctuary, and the data has been used to inform management actions and assess effectiveness of reducing the risk of lethal vessel strikes to whales. (Figure SS.1).

In 2017, in order to motivate greater cooperation with the federal voluntary vessel speed reduction requests from cargo and tanker vessels in the region, GFNMS began partnering with Channel Islands National Marine Sanctuary, the Bay Area Air Quality Management District, and non-profit partners on the Protecting Blue Whales and Blue Skies (BWBS) Program. In early years, the program offered financial incentives for enrolled shipping lines to cooperate with voluntary speed reduction requests to increase protections for endangered whales and reduce air emissions. Since 2017, enrolled shipping lines in the BWBS program have collectively contributed to a reduction in emissions in the San Francisco region of 3 tons of Diesel Particulate Matter (DPM), 487 tons of nitrogen oxides (NOx), and 15,989 metric tons of CO_2.

In 2012 the Sanctuary Advisory Council recommended GFNMS monitor and reduce acoustic impacts to whales. GFNMS worked with CBNMS which initiated a program to characterize the sanctuary's soundscape to better understand acoustic impacts. In 2015 a noise reference station was installed in CBNMS at the GFNMS border to record underwater ambient sound in the two sanctuaries. These data have allowed scientists to create a local low-frequency soundscape profile, identifying the significant sources and intensity of noise and its variability.

In response to water quality concerns in Tomales Bay, GFNMS in partnership with the State Lands Commission implemented the Tomales Bay Vessel Mooring Program in 2015 which removed vessel moorings and unpermitted docks from sensitive eelgrass habitat and designated official mooring zones in areas where eelgrass beds are unlikely to spread. The Mooring Program prohibits installation of moorings in or near eelgrass beds in order to prevent damage to the beds from the anchors and chains. All moorings are subject to annual inspections, liability insurance, current vessel registration, and approved marine sanitation devices. Since 2016, GFNMS has worked with NOAA Office of Law Enforcement and the California State Lands Commission to remove moorings from eelgrass beds and relocate them. The eelgrass beds previously impacted by mooring anchors and chains have begun to show signs of recovery. The small number of moorings known to exist in Bolinas Lagoon are currently in the permit review process conducted by Marin County.

Responses to Wildlife Disturbance

GFNMS continued to lead projects that prevent disturbances to wildlife to ensure healthy populations of sanctuary wildlife. In 2009, GFNMS white shark disturbance and attraction regulations became effective and soon after GFNMS implemented the White Shark Stewardship Project to increase awareness of the regulation and the importance of white sharks to the sanctuary ecosystem. The Project included public and boater outreach, white shark boat tour naturalist training, school education programs, permitting of white shark tours, and monitoring. In September 2022,Governor Gavin Newsom signed into law Assembly Bill 2109, which adds additional protections for white sharks in California waters under the California Fish and Game Code, section 5517 (CDFW 2023a). Effective on January 1, 2023, this new law prohibits the use of shark bait, shark lures or shark chum to attract a white shark (including, but not limited to, blood, fish, or other material upon which sharks may feed, and surface or underwater decoys). This state law should further reduce disturbances to white sharks in sanctuary waters.

Protecting seabird colonies from disturbance increases local seabird population resilience to climate related pressures by reducing the need for seabirds to unnecessarily expend energy. The GFNMS and USFWS led Seabird Protection Network collaborated with multiple federal and state agencies to study, characterize, and address disturbance to seabirds using a combination of regulations and outreach focused on the most vulnerable colony locations. By employing environmental behavior design tools, boaters and pilots, the main sources of disturbance, pledged to avoid disturbing wildlife within the sanctuary.This engagement campaign, combined with NOAA Regulated Overflight Zones and State special closures, proved effective at reducing wildlife disturbances within GFNMS.

Responses to Marine Debris

To reduce marine debris and pollution GFNMS regulations prohibit the discharge of material or matter into the sanctuary, placing or abandoning any structure on sanctuary submerged lands, deserting a vessel aground, at anchor, or adrift in the sanctuary, and leaving harmful matter aboard a deserted vessel (15 CFR 922.82(a)). However, grounded vessels were abandoned by uninsured or underinsured vessel owners. To address this problem, GFNMS staff participated in committees and working groups with partner agencies and the public devoted to addressing vessel incidents. GFNMS also worked with the NOAA Marine Debris Grant Program to track debris, identify potential salvage funding sources, and strategize on future management actions. GFNMS contributed information on grounded and sunken vessels for an ONMS West Coast Regional Office report to the ONMS Director and provided recommendations to improve response and prevent future incidents.The recommendations included seven strategies that aim to track incidents, understand causes, develop best practices, improve insurance coverage, support investigations and seek stable funding.

MBNMS served as the ONMS West Coast representative on the California Dungeness Crab Fishing Gear Working Group established to identify and respond to the elevated risk of whale entanglements in California Dungeness crab fishing gear as a result of changing ocean conditions and habitat compression. A Risk Assessment and Mitigation Program (RAMP) was developed by the Working Group to assess circumstances where entanglement risk may be elevated and, as needed, identify possible management measures to reduce whale entanglements including in GFNMS.

Responses to Non-indigenous Species

Since 2009, GFNMS has worked with GFA, the Smithsonian Environmental Research Center, UC Davis, Portland State University, and community volunteers to implement the Green Crab Removal Project. During the summer, project managers implemented a four week-long removal event, dispersing 90 crab traps each day and recording data (size, sex, physical characteristics) for every crab. Thousands of crabs were removed from Seadrift Lagoon, a water body adjacent to the sanctuary, and donated to local farms to compost for fertilizer. Green crab population numbers in Seadrift Lagoon have stabilized at a reduced number with the goal of limiting the introduction of green crabs into Bolinas Lagoon, a sanctuary United Nation's Wetlands of International Significance.

Starting in 2012, GFNMS partnered with GFA and Marin County to reduce non-indigenous plants on Kent Island, which anchored the island and impacted sediment flow in Bolinas Lagoon. The multiple invasive species, including Monterey pine, European beach grass, iceplant, and French broom that capture and stabilize the island's sands, have anchored the

island in place, preventing it from functioning as a flood shoal island. The project is still in operation and has improved hydrologic function and reduced siltation (Baye & Carmen, 2012).

Conclusion

Greater Farallones National Marine Sanctuary, a nationally and internationally significant marine environment located next to a major metropolitan area of almost 8 million people, faces many pressures locally as well as globally from climate change. Responding to pressures requires a long-term commitment and partnerships with international, national, state, and local entities. To successfully reduce stress on the ecosystem we must conduct scientific research and monitoring, enforce regulations, increase regulatory compliance, identify and address emerging threats, restore degraded habitats and impacted species, and engage communities as stewards to increase ecosystem resilience and health.

The above responses to threats to sanctuary summarize major GFNMS actions from 2010 to 2022. The dynamic and emerging nature of external pressures requires recurring assessment and adaptation as part of the sanctuary's management cycle. This condition report will inform the next sanctuary management plan update by identifying threats and areas of concern, helping the public and sanctuary identify priority actions, and providing a baseline to measure the effectiveness of sanctuary actions in order to manage human activities that allow the sanctuary and the communities that rely on the sanctuary to thrive.

References

Blank Rome LLP. (2017). Letter to NOAA Special Agent Don Tanner. RE: Response to request for Information from NOAA dated May 31, 2017 related to the self-reported discharge events in the Cordell Bank and Greater Farallones National Marine Sanctuaries by four Princess vessels and one Holland America Line vessel.

Baye, P., & Carmen, W. (2012). *Kent Island vegetation management: Project design plan*. Report prepared for Marin County Open Space District. https://www.parks.marincounty.org/-/media/files/sites/marin-county-parks/projects-and-plans/restoration-and-fire-prevention/kent-island-restoration-bolinas/project_kentisland_designplan.pdf?la=en

California Department of Fish and Wildlife. (2023). *California marine protected areas (MPAs)*. https://wildlife.ca.gov/Conservation/Marine/MPAs

California Department of Fish and Wildlife. (2023a). *California Outdoors Q & A*. Website accessed on September 22, 2023. https://wildlife.ca.gov/language/en%20US/COQA/tag/white-sharks#gsc.tab=0.

Duncan, B.E., K.D. Higgason, T.H. Suchanek, J. Largier, J. Stachowicz, S. Allen, S. Bograd, R.Breen, H. Gellerman, T. Hill, J. Jahncke, R. Johnson, S. Lonhart, S. Morgan, J. Roletto, F. Wilkerson. 2013. Ocean Climate Indicators: A Monitoring Inventory and Plan for Tracking Climate Change in the North-central California Coast and Ocean Region.Report of a Working Group of the Gulf of the Farallones National Marine Sanctuary Advisory Council. 74pp.

Greater Farallones National Marine Sanctuary. (2023). *Sanctuary Advisory Council actions*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of National Marine Sanctuaries. https://farallones.noaa.gov/manage/sac_actions.html

Greater Farallones National Marine Sanctuary (GFNMS). (2023a). *Reported potential violations of GFNMS regulations data from 2013-2022* [Unpublished data set]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of National Marine Sanctuaries.

Greater Farallones National Marine Sanctuary Advisory Council. (2019). *Resolution of the Greater Farallones National Marine Sanctuary Advisory Council to adopt the recommendations of the Tomales Bay Native Oyster Restoration Working Group*. https://nmsfarallones.blob.core.windows.net/farallones-prod/media/docs/20190827-tomales-bay-native-oyster-restoration-advisory-council-resolution-recommendations.pdf

Hutto, S.V., K.D. Higgason, J.M. Kershner, W.A. Reynier, D.S. Gregg. 2015. Climate Change Vulnerability Assessment for the North-central California Coast and Ocean. Marine Sanctuaries Conservation Series ONMS-15-02. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD. 473 pp.

Kordesch, W. K., Delaney, M., Hutto, S., Rome, M., & Tezak, S. (2019). *Greater Farallones National Marine Sanctuary: Coastal resilience sediment plan*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of National Marine Sanctuaries, Greater Farallones National Marine Sanctuary. https://nmsfarallones.blob.core.windows.net/farallones-prod/media/docs/20191101-coastal-resilience-and-sediment-plan.pdf

Largier, J.L., B.S. Cheng, and K.D. Higgason, editors. 2010. Climate Change Impacts: Gulf of the Farallones and Cordell Bank National Marine Sanctuaries. Report of a Joint Working Group of the Gulf of the Farallones and Cordell Bank National Marine Sanctuaries Advisory Councils. 121pp.

Morten, J., Freedman, R., Adams, J. D., Wilson, J., Rubinstein, A., & Hastings, S. (2022). Evaluating adherence with voluntary slow speed initiatives to protect endangered whales. *Frontiers in Marine Science*, *9*, 833206. https://doi.org/10.3389/fmars.2022.833206

National Marine Sanctuary Program. (2016). *Greater Farallones National Marine Sanctuary: Climate adaptation plan*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service. https://nmsfarallones.blob.core.windows.net/farallones-prod/media/docs/2016-climate-adaptation-plan.pdf

Questions and Rating Schemes for Status and Trends of Sanctuary Resources

Below are descriptions of the questions and possible responses used to report the condition of sanctuary resources in condition reports for all national marine sanctuaries. ONMS and subject matter experts use this guidance, as well as their own understanding of the condition of resources, to make judgments about the status and trends of sanctuary resources.

The resource questions derive from the National Marine Sanctuary System's mission (Office of National Marine Sanctuaries, 2022) and a system-wide monitoring framework (National Marine Sanctuary Program, 2004) developed to ensure the timely flow of data and information to those responsible for managing and protecting resources in the ocean and coastal zone, and to those that use, depend on, and study sanctuary resources. The resource questions are used to guide ONMS and its partners at each unit in the sanctuary system in the development of sanctuary condition reports. Evaluations of resource status and trends are based on the interpretation of quantitative and, when necessary, non-quantitative assessments and observations by scientists, managers, and users.

In 2012, ONMS reviewed and edited the resource questions and their possible responses that were developed for the first round of condition reports (drafted between 2007 and 2014; National Marine Sanctuary Program, 2004). The questions that follow are revised and improved versions of those original questions. Although all questions have been edited to some degree, both in their description and status ratings, the nature and intent of most questions have not changed. Five questions, however, are either new or are significantly altered and are therefore not directly comparable to the original questions posed in the first round of condition reports. For these, a new baseline will need to be established.

- In the Water Quality section, one climate change question was added. This was necessary to address the increasing awareness and attention to the issue following the original design of the condition report process, which began in 2002.
- Two Habitat questions were combined due to feedback received during the development of the first round of reports. A single question regarding the "integrity of major habitat types" has been created and combines prior questions that separately inquired about non-biogenic and biogenic habitats. Experience showed that experts considered the condition of certain species (e.g., kelp, corals, and seagrass) critical to their assessment of most habitat, including those often considered non-biogenic; thus separating the two provided little added value.
- Among the Living Marine Resources questions, one used in the first round of condition reports was removed entirely. It asked about "the status of environmentally sustainable fishing." It was removed for a variety of reasons. First, it was the only question focused on a single, specific human activity rather than a particular resource. Second, considerations of fishing activity are already

included in the question regarding “human activities that may influence living resources.” Finally, living resources that would provide a basis for judgment for this question are typically considered as part of other living resource questions, and need not be covered twice. Another change to the Living Marine Resources questions pertains to the question about the “health of key species,” which was previously addressed in a single question, but is now split into two. The first asks specifically about the status of “keystone and foundation” species, the second about “other focal species.” In both cases, the health of any species of interest can be considered in the judgment of status and trends.

- One of the initial questions addressed potential environmental hazards presented by heritage resources like shipwrecks. While the assessment of such threats is important, it was decided that the question was more appropriately addressed in the water quality and habitat contaminant questions rather than apply specifically to historic maritime properties. Therefore, the question was removed from the Maritime Heritage Resources section of the report and the subject is discussed in the context of other questions.

Ratings for a number of questions depend on judgments of the “ecological integrity” within a national marine sanctuary. This is because one of the foundational principles behind the establishment of sanctuaries is to protect ocean ecosystems. The term ecological integrity is used to imply “the presence of naturally occurring species, populations and communities, and ecological processes functioning at appropriate rates, scales, and levels of natural variation, as well as the environmental conditions that support these attributes” (modified from national park vital signs monitoring [National Park Service, 2021]). Sanctuaries have ecological integrity when they have their native components intact, including abiotic components (i.e., the physical forces and chemical elements, such as water), biotic elements (such as habitats), biodiversity (i.e., the composition and abundance of species and communities), and ecological processes (e.g., competition, predation, symbioses). For purposes of this report, the level of integrity that is judged to exist is based on the extent to which humans have altered specific components of the system, and the effect of that change on the ability of an ecosystem to resist continued change and recover from it. The statements for many questions are intended to reflect this judgment. Reference is made in the rating system to “near-pristine” conditions, for which this report would imply a status as near to an unaltered ecosystem as can reasonably be presumed to exist, recognizing that there are virtually no ecosystems on Earth completely free from human influence.

Not all questions, however, use ecological integrity as a basis for judgment. One focuses on the impacts of water quality factors on human health. Two questions rate the status of keystone and key species compared with that expected in an unaltered ecosystem. One rates maritime heritage resources based on their historical, archaeological, scientific, and educational value. Finally, four ask specifically about the levels of ongoing human activities (i.e., pressures) that could affect resource condition.

During workshops in which status and trends are rated, subject matter experts discuss each resource question and relevant indicators, available data, literature (e.g., published scientific studies, reports), and experience associated with the topic. They

then discuss the statements provided as options for judgments about status; these statements have been customized for each question. Once a particular statement is agreed upon, a color code and status rating (e.g., good, fair, poor) is assigned. Experts can also decide that the most appropriate rating is “N/A” (i.e., the question does not apply), “undetermined” (i.e., resource status is undetermined due to a paucity of relevant information), or “mixed” (i.e., conflicting signals from indicators prevent the selection of a singular status rating). A subsequent discussion is then held about the trend. Conditions are determined to be improving, remaining the same, or worsening over the time since the production of the prior condition report. Symbols used to indicate trends are the same for all questions: “▲”—conditions appear to be improving; “▬”—conditions do not appear to be changing; “▼”—conditions appear to be worsening; “⬍”—conditions appear to be mixed; “?”—trend is undetermined; “N/A”—the question does not apply.

Human Drivers

1. What are the states of influential human drivers and how are they changing?

Driving forces are those characteristics of human societies that influence the nature and extent of pressures on resources. They are the underlying cause of change in coastal marine ecosystems, as they determine human use. Drivers are influenced by demographics (e.g., age structure, population, etc.), demand, economic circumstances, industrial development patterns, business trends, and societal values. They operate at global, regional, and local scales. Examples include increasing global demand for agricultural commodities, which increases the use of chemicals that degrade coastal water quality; difficult economic times that reduce fishing efforts for a period of time within certain regions; or local construction booms that alter recreational visitation trends. Other drivers could be the demands that govern trends, such as global greenhouse gas generation, regional shipping or offshore industrial development, local recreation and tourism, fishing, port improvement, manufacturing, and age-specific services (e.g., retirement). Each of these, in turn, influences certain pressures on natural and cultural resources.

Integrated into this question should be consideration of societal values, which include such matters as levels of conservation awareness, political leanings, opinion about environmental issues relative to other concerns, or changing opinions about the acceptability of specific behaviors (e.g., littering, fishing). Understanding these values gives one a better understanding of the likely future trends in drivers and pressures, as well as the nature of the societal tradeoffs in different uses of the ecosystem resources (e.g., the effects of multiple changing drivers on each other and the resources they affect). This can better inform policy and management responses, and education and outreach efforts that are designed to change societal values with the intention to change drivers and reduce pressures.

In rating the status and trends for drivers, the following should be considered:

- the main driving forces behind each pressure affecting natural resources and the environment
- the best available indicators of each driving force
- the status and trend of each driving force
- societal values behind each driving force
- the best indicators of societal values
- the status and trend of societal values

Good	Few or no drivers occur that have the potential to influence pressures in ways that will negatively affect resource qualities.
Good/Fair	Some drivers exist that may influence pressures in ways expected to degrade some attributes of resource quality.
Fair	Selected drivers are influencing pressures in ways that cause measurable resource impacts.
Fair/Poor	Selected drivers are influencing pressures in ways that result in severe impacts that are either widespread or persistent.
Poor	Selected drivers are influencing pressures in ways that result in severe, persistent, and widespread impacts.

Human Dimensions

2. What are the levels of human activities that may adversely influence water quality and how are they changing?

Among the human activities in or near sanctuaries that affect water quality are those involving direct discharges and spills (vessels, onshore and offshore industrial facilities, public wastewater facilities), those that contribute contaminants to groundwater, stream, river, and water control discharges (agriculture, runoff from impermeable surfaces through storm drains, conversion of land use), and those releasing airborne chemicals that subsequently deposit via particulates at sea (vessels, land-based traffic, power plants, manufacturing facilities, refineries). In addition, dredging and trawling can cause resuspension of contaminants in sediments. Many of these activities can be controlled through management actions in order to limit their impact on protected resources.

Good	Few or no activities occur that are likely to negatively affect water quality.
Good/Fair	Some potentially harmful activities exist, but they have not been shown to degrade water quality.
Fair	Selected activities have caused measurable resource impacts, but effects are localized and not widespread or persistent.
Fair/Poor	Selected activities have caused severe impacts that are either widespread or persistent.
Poor	Selected activities have caused severe, persistent, and widespread impacts.

3. What are the levels of human activities that may adversely influence habitats and how are they changing?

Human activities that degrade habitat quality do so by affecting structural (physical), biological, oceanographic, acoustic, or chemical characteristics of the habitat. Structural impacts, such as removal or mechanical alteration of habitat, can result from various fishing methods (e.g., trawls, traps, dredges, longlines, and even hook-and-line in some habitats), dredging of channels and harbors, dumping dredge spoil, grounding of vessels, anchoring, laying pipelines and cables, installing offshore structures, discharging drill cuttings, dragging tow cables, and placing artificial reefs. Removal or alteration of critical biological components of habitats can occur due to several of the above activities, most notably trawling, groundings, and cable drags. Marine debris, particularly in large quantities (e.g., lost gill nets and other types of fishing gear), can degrade both biological and structural habitat components. Changes in water circulation often occur when channels are dredged, fill is added, coastlines are armored or other construction takes place. Management actions such as beach wrack removal or sand replenishment on high public-use beaches, may impact the integrity of the natural ecosystem. Alterations in circulations can lead to changes in food delivery, waste removal, water quality (e.g., salinity, clarity and sedimentation), recruitment patterns, and a host of other ecological processes. Chemical alterations most commonly occur following spills and can have both acute and chronic impacts. Many of these activities can be controlled through management actions in order to limit their impact on protected resources.

Good	Few or no activities occur that are likely to negatively affect habitat quality.
Good/Fair	Some potentially harmful activities exist, but they have not been shown to degrade habitat quality.
Fair	Selected activities have caused measurable resource impacts, but effects are localized and not widespread or persistent.
Fair/Poor	Selected activities have caused severe impacts that are either widespread or persistent.
Poor	Selected activities have caused severe, persistent, and widespread impacts.

4. What are the levels of human activities that may adversely influence living resources and how are they changing?

Human activities that degrade the condition of living resources do so by causing a loss or reduction of one or more species, by disrupting critical life stages, by impairing various physiological processes, or by promoting the introduction of non-indigenous species or pathogens. (Note: Activities that impact habitat and water quality may also affect living resources. These activities are dealt with in the following human activity questions, and some may be repeated here as they also directly affect living resources).

For most sanctuaries, recreational or commercial fishing and collecting have direct effects on animal or plant populations, either through removal or injury of organisms. Related to this, lost fishing gear can cause extended periods of loss for some species through entanglement and “ghost fishing.” In addition, some fishing techniques are size-selective, resulting in impacts to particular life stages. High levels of visitor use in some places also cause localized depletion, particularly in intertidal areas or on shallow coral reefs, where collecting and trampling can be chronic problems.

Mortality and injury to living resources has also been documented from cable drags (e.g., towed barge operations), dumping spoil or drill cuttings, vessel groundings, or repeated anchoring. Contamination caused by acute or chronic spills or increased sedimentation to nearshore ecosystems from road developments in watersheds (including runoff from coastal construction or highly built coastal areas), discharges by vessels, or municipal and industrial facilities can make habitats unsuitable for recruitment or other ecosystem services (e.g., as nurseries or spawning grounds). And while coastal armoring and construction can increase the availability of surfaces suitable

for hard bottom species, the activity may disrupt recruitment patterns for other species (e.g., intertidal soft bottom animals), and natural habitat may be lost.

Oil spills (and spill response actions), discharges, and contaminants released from sediments (e.g., by dredging and dumping) can all cause physiological impairment and tissue contamination. Such activities can affect all life stages by direct mortality, reducing fecundity, reducing disease resistance, loss as prey and disruption of predator-prey relationships, and increasing susceptibility to predation. Furthermore, bioaccumulation results in some contaminants moving upward through the food chain, disproportionately affecting certain species.

Activities that promote the introduction of non-indigenous species include bilge discharges and ballast water exchange, commercial shipping and vessel transportation. Intentional or accidental releases of aquarium fish and plants can also lead to introductions of non-indigenous species.

Many of these activities are controlled through management actions in order to limit their impact on protected resources.

Good	Few or no activities occur that are likely to negatively affect living resource quality.
Good/Fair	Some potentially harmful activities exist, but they have not been shown to degrade living resource quality.
Fair	Selected activities have caused measurable living resource impacts, but effects are localized and not widespread or persistent.
Fair/Poor	Selected activities have caused severe impacts that are either widespread or persistent.
Poor	Selected activities have caused severe, persistent, and widespread impacts.

5. What are the levels of human activities that may adversely affect maritime heritage resources and how are they changing?

Maritime heritage resources are the wide variety of tangible and intangible elements (archaeological, cultural, historical properties) that reflect our human connections to Great Lakes and ocean areas.

Some human activities threaten the archaeological or historical condition of maritime heritage resources. Archaeological or historical condition is compromised when elements are moved, removed, or otherwise damaged. Threats come from looting, inadvertent damage by recreational divers, improper research methods, vessel anchorings and groundings, and commercial and recreational fishing activities, among others. Other human activities may alter or damage heritage resources by impacting the landscape or viewshed of culturally significant places or locations. Many of these activities can be controlled through management actions in order to limit their impact to maritime heritage resources.

Good	Few or no activities occur at maritime heritage resource sites that are likely to adversely affect their condition.
Good/Fair	Some potentially damaging activities exist, but they have not been shown to degrade maritime heritage resource condition.
Fair	Selected activities have caused measurable impacts to maritime heritage resources, but effects are localized and not widespread or persistent.
Fair/Poor	Selected activities have caused severe impacts that are either widespread or persistent.
Poor	Selected activities have caused severe, persistent, and widespread impacts.

Water Quality

6. What is the eutrophic condition of sanctuary waters and how is it changing?

Eutrophication is the accelerated production of organic matter, particularly algae, in a water body. It is usually caused by an increase in the amount of nutrients (largely nitrogen and phosphorus) being discharged to the water body. As a result of accelerated algal production, a variety of interrelated impacts may occur, including nuisance and toxic algal blooms, depleted dissolved oxygen, and loss of submerged aquatic vegetation (Bricker et al., 1999). Indicators commonly used to detect eutrophication and associated problems include nutrient concentrations, chlorophyll content, rates of water column or benthic primary production, benthic algae cover, algae bloom frequency and intensity, oxygen levels, and light penetration.

Eutrophication of sanctuary waters can impact the condition of other sanctuary resources. Nutrient enrichment often leads to plankton and/or algae blooms. Blooms of benthic algae can affect benthic communities directly through space competition. Indirect effects of overgrowth and other competitive interactions (e.g., accumulation of algal-sediment mats) often lead to shifts in dominance in the benthic assemblage, oxygen depletion, etc. Disease incidence and frequency can also be affected by algae competition and changes in the chemical environment along competitive boundaries. Blooms can also affect water column conditions, including light penetration and plankton availability, which can alter pelagic food webs. HABs, some of which are exacerbated by eutrophic conditions, often affect other living resources, as biotoxins are consumed or released into the water and air, or decomposition depletes oxygen concentrations.

Good	Eutrophication has not been documented, or does not appear to have the potential to negatively affect ecological integrity.
Good/Fair	Eutrophication is suspected and may degrade some attributes of ecological integrity, but has not yet caused measurable degradation.
Fair	Eutrophication has caused measurable but not severe degradation in some attributes of ecological integrity.
Fair/Poor	Eutrophication has caused severe degradation in some but not all attributes of ecological integrity.
Poor	Eutrophication has caused severe degradation in most if not all attributes of ecological integrity.

7. Do sanctuary waters pose risks to human health and how are they changing?

Human health concerns are generally aroused by evidence of contamination (usually bacterial or chemical) in bathing waters or seafood intended for consumption. They also arise when harmful algal blooms are reported or when cases of respiratory distress or other disorders attributable to harmful algal blooms increase dramatically. Any of these conditions should be considered in the course of judging the risk to humans posed by waters in a marine sanctuary.

Some sanctuaries may have access to specific information about beach closures and seafood contamination. In particular, beaches may be closed when criteria for water safety are exceeded. Shellfish harvesting and fishing may be prohibited when contaminant or biotoxin loads or infection rates exceed certain levels. Alternatively, seafood advisories may also be issued, recommending that people avoid or limit intake

of particular types of seafood from certain areas (e.g., when ciguatera poisoning is reported). Any of these conditions, along with changing frequencies or intensities, can be important indicators of human health problems and can be characterized using the descriptions below.

Good	Water quality does not appear to have the potential to negatively affect human health.
Good/Fair	One or more water quality indicators suggest the potential for human health impacts but human health impacts have not been reported.
Fair	Water quality problems have caused measurable human impacts, but effects are localized and not widespread or persistent.
Fair/Poor	Water quality problems have caused severe impacts that are either widespread or persistent.
Poor	Water quality problems have caused severe, persistent, and widespread human impacts.

8. Have recent, accelerated changes in climate altered water conditions and how are they changing?

The purpose of this question is to capture shifts in water quality, and associated impacts on sanctuary resources, due to climate change. Though temporal changes in climate have always occurred on Earth, evidence is strong that changes over the last century have been accelerated by human activities. Indicators of climate change in sanctuary waters include water temperature, acidity, sea level, upwelling intensity and timing, storm intensity and frequency, changes in erosion and sedimentation patterns, and freshwater delivery (e.g., rainfall patterns). Climate-related changes in one or more of these indicators can impact the condition of habitats, living resources, and maritime archaeological resources in sanctuaries.

Increasing water temperature has been linked to changing growth rates, reduced disease resistance, and disruptions in symbiotic relationships (e.g., bleaching on coral reefs), and changes in water temperature exposure may affect a species' resistance or the capacity to adapt to disturbances. Acidification can affect the survival and growth of organisms throughout the food web, as well as the persistence of skeletal material after death (through changes in rates of dissolution and bioerosion). Recent findings also suggest acidification impacts at sensory and behavioral levels, which can alter vitality and species interactions. Sea level change alters habitats, as well as their use and

persistence. Variations in the timing and intensity of upwelling is known to change water quality through factors such as oxygen content and nutrient flow, further disrupting food webs and the natural functioning of ecosystems. Changing patterns and intensities of storms alter community resistance and resilience within ecosystems that have, over long periods of time, adapted to such disturbances. Altered rates and volumes of freshwater delivery to coastal ecosystems affects salinity and turbidity regimes and can disrupt reproduction, recruitment, growth, disease incidence, phenology, and other important processes.

Good	Climate-related changes in water conditions have not been documented or do not appear to have the potential to negatively affect ecological integrity.
Good/Fair	Climate-related changes are suspected and may degrade some attributes of ecological integrity, but have not yet caused measurable degradation.
Fair	Climate-related changes have caused measurable but not severe degradation in some attributes of ecological integrity.
Fair/Poor	Climate-related changes have caused severe degradation in some but not all attributes of ecological integrity.
Poor	Climate-related changes have caused severe degradation in most if not all attributes of ecological integrity.

9. Are other stressors, individually or in combination, affecting water quality, and how are they changing?

The purpose of this question is to capture shifts in water quality due to anthropogenic stressors not addressed in other questions. For example, localized changes in circulation or sedimentation resulting from coastal construction or dredge spoil disposal can affect light penetration, salinity regimes, oxygen levels, productivity, waste transport, and other aspects of water quality that in turn influence the condition of habitats and living resources. Human inputs, generally in the form of contaminants from point or non-point sources, including fertilizers, pesticides, hydrocarbons, heavy metals, and sewage, are common causes of environmental degradation. When present in the water column, any of these contaminants can affect marine life by direct contact or ingestion, or through bioaccumulation via the food chain.

(Note: Over time, accumulation in sediments can sequester and concentrate contaminants. Their effects may manifest only when the sediments are resuspended

during storm or other energetic events. In such cases, reports of status should be made under in the habitat/contaminants question.)

Good	Other stressors on water quality have not been documented, or do not appear to have the potential to negatively affect ecological integrity.
Good/Fair	Selected stressors are suspected and may degrade some attributes of ecological integrity, but have not yet caused measurable degradation.
Fair	Selected stressors have caused measurable but not severe degradation in some attributes of ecological integrity.
Fair/Poor	Selected stressors have caused severe degradation in some but not all attributes of ecological integrity.
Poor	Selected stressors have caused severe degradation in most if not all attributes of ecological integrity.

Habitat

10. What is the integrity of major habitat types and how are they changing?

Ocean habitats can be categorized in many different ways, including water column characteristics, benthic assemblages, substrate types, and structural character. There are intertidal and subtidal habitats. The water column itself is one habitat type (Federal Geographic Data Committee, 2012). There are habitats composed of substrates formed by rocks or sand that originate from purely physical processes. And, there are certain animals and plants that create, in life or after their death, substrates that attract or support other organisms (e.g., corals, kelp, beach wrack, drift algae). These are commonly called biogenic habitats.

Regardless of the habitat type, change and loss of habitat is of paramount concern when it comes to protecting marine and terrestrial ecosystems. Of greatest concern to sanctuaries are changes to habitats caused, either directly or indirectly, by human activities. Human activities like coastal development alter the distribution of habitat types along the shoreline. Changes in water conditions in estuaries, bays, and nearshore waters can negatively affect biogenic habitat formed by submerged aquatic vegetation. Intertidal habitats can be affected for long periods by oil spills or by chronic pollutant exposure. Marine debris, such trash and lost fishing gear, can degrade the quality of many different marine habitats including beaches, subtidal benthic habitats,

and the water column. Sandy seafloor and hard bottom habitats, even rocky areas several hundred meters deep, can be disturbed or destroyed by certain types of fishing gear, including bottom trawls, shellfish dredges, bottom longlines, and fish traps. Groundings, anchors, and irresponsible diving practices damage submerged reefs. Cables and pipelines disturb corridors across numerous habitat types and can be destructive if they become mobile.

Integrity of biogenic habitats depends on the condition of particular living organisms. Coral, sponges, and kelp are well known examples of biogenic habitat-forming organisms. The diverse assemblages residing within these habitats depend on and interact with each other in tightly linked food webs. They may also depend on each other for the recycling of wastes, hygiene, and the maintenance of water quality. Other communities that are dependent on biogenic habitat include intertidal communities structured by mussels, barnacles, and algae and subtidal hard-bottom communities structured by bivalves, corals, or coralline algae. In numerous open ocean areas drift algal mats provide food and cover for juvenile fish, turtles, and other organisms. The integrity of these communities depends largely on the condition of species that provide structure for them.

This question is intended to address acute or chronic changes in both the extent of habitat available to organisms and the quality of that habitat, whether non-living or biogenic. It asks about the quality of habitats compared to those that would be expected in near-pristine conditions (see definition above).

Good	Habitats are in near-pristine condition.
Good/Fair	Selected habitat loss or alteration is suspected and may degrade some attributes of ecological integrity, but has not yet caused measurable degradation.
Fair	Selected habitat loss or alteration has caused measurable but not severe degradation in some attributes of ecological integrity.
Fair/Poor	Selected habitat loss or alteration has caused severe degradation in some but not all attributes of ecological integrity.
Poor	Selected habitat loss or alteration has caused severe degradation in most if not all attributes of ecological integrity.

11. What are contaminant concentrations in sanctuary habitats and how are they changing?

Habitat contaminants result from the introduction of unnatural levels of chemicals or other harmful material into the environment. Contaminants may be introduced through discrete entry locations, called point sources (e.g., rivers, pipes, or ships) and those with diffuse origins, called non-point sources (e.g., groundwater and urban runoff). Chemical contaminants themselves can be very specific, as in a spill from a containment facility or vessel grounding, or a complex mix, as with urban runoff. Familiar chemical contaminants include pesticides, hydrocarbons, heavy metals, and nutrients. Contaminants may also arrive in the form of materials that alter turbidity or smother plants or animals, therefore affecting metabolism and production.

This question is focused on risks posed primarily by contaminants within benthic formations, such as soft sediments, hard bottoms, or structure-forming organisms (see notes below). Not only are contaminants within benthic formations consumed or absorbed by benthic fauna, but resuspension due to benthic disturbance makes the contaminants available to water column organisms. In both cases contaminants can be passed upwards through the food chain. While the contaminants of most common concern to sanctuaries are generally pesticides, hydrocarbons, and nutrients, the specific concerns of individual sanctuaries may differ substantially.

Notes: 1) Contaminants in the water column addressed in the water quality section of this report should be cited, but details need not be repeated here; 2) many consider noise a pollutant, but in the interest of focusing here on more traditional forms of habitat degradation caused by contaminants, ONMS recommends addressing the impacts of acoustic pollution within the living resource section, most likely as it impacts key species.

Good	Contaminants have not been documented, or do not appear to have the potential to negatively affect ecological integrity.
Good/Fair	Selected contaminants are suspected and may degrade some attributes of ecological integrity, but have not yet caused measurable degradation.
Fair	Selected contaminants have caused measurable but not severe degradation in some attributes of ecological integrity.
Fair/Poor	Selected contaminants have caused severe degradation in some but not all attributes of ecological integrity.

Poor	Selected contaminants have caused severe degradation in most if not all attributes of ecological integrity.

Living Resources

12. What is the status of keystone and foundation species and how is it changing?

Certain species are defined as “keystone” within ecosystems, meaning they are species on which the persistence of a large number of other species in the ecosystem depends (Paine, 1966). They are the pillars of community stability (among other things, they strongly affect both resistance and resilience) and their contribution to ecosystem function is disproportionate to their numerical abundance or biomass. Their impact is therefore important at the community or ecosystem level. Keystone species are often called “ecosystem engineers” and can include habitat creators (e.g., corals, kelp), predators that control food web structure (e.g., Humboldt squid, sea otters), herbivores that regulate benthic recruitment (e.g., certain sea urchins), and those involved in critical symbiotic relationships (e.g., cleaning or co-habitating species).

“Foundation” species are single species that define much of the structure of a community by creating locally stable conditions for other species, and by modulating and stabilizing fundamental ecosystem processes (Dayton, 1972). These are typically dominant biomass producers in an ecosystem and strongly influence the abundance and biomass of many other species. Examples include krill and other zooplankton, kelp, forage fish, such as rockfish anchovy, sardine, and coral. Foundation species exhibit similar control over ecosystems as keystone species, but their high abundance distinguishes them.

Changes in either keystone or foundation species may transform ecosystem structure through disappearances of or dramatic increases in the abundance of dependent species. Not only do the abundances of keystone and foundation species affect ecosystem integrity, but measures of condition can also be important to determining the likelihood that these species will persist and continue to provide vital ecosystem functions. Measures of condition may include growth rates, fecundity, recruitment, age-specific survival, contaminant loads, pathologies (e.g., disease incidence, tumors, deformities), the presence and abundance of critical symbionts, or parasite loads.

Good	The status of keystone and foundation species appears to reflect near-pristine conditions and may promote ecological integrity (full community development and function).

Good/Fair	The status of keystone or foundation species may preclude full community development and function, but has not yet led to measurable degradation.
Fair	The status of keystone or foundation species suggests measurable but not severe degradation in some attributes of ecological integrity.
Fair/Poor	The status of keystone and foundation species suggests severe degradation in some but not all attributes of ecological integrity.
Poor	The status of keystone and foundation species suggests severe degradation in most if not all attributes of ecological integrity.

13. What is the status of other focal species and how is it changing?

This question targets other species of particular interest from the perspective of sanctuary management. These “focal species” may not be abundant or provide high value to ecosystem function, but their presence and health is important for the provision of other services, whether conservation, economic, or strategic. Examples include species targeted for special protection (e.g., threatened or endangered species), species for which specific regulations exist to minimize perturbations from human disturbance (e.g., touching corals, riding manta rays or whale sharks, disturbing white sharks, disturbing nesting birds), or indicator species (e.g., common murres as indicators of oil pollution). This category could also include so-called “flagship” species, which include charismatic or iconic species associated with specific locations, ecosystems or are in need of specific management actions, are highly popular and attract visitors or business, have marketing appeal, or represent rallying points for conservation action (e.g., humpback and blue whales, Dungeness crab).

Status of these other focal species can be assessed through measures of abundance, relative abundance, or condition, as described for keystone species. In contrast to keystone and foundation species, however, the impact of changes in the abundance or condition of focal species is more likely to be observed at the population or individual level, and less likely to result in ecosystem or community effects.

Good	Selected focal species appear to reflect near-pristine conditions.
Good/Fair	Reduced abundances in selected focal species are suspected but have not yet been measured.

Fair	Selected focal species are at reduced levels, but recovery is possible.
Fair/Poor	Selected focal species are at substantially reduced levels, and prospects for recovery are uncertain.
Poor	Selected focal species are at severely reduced levels, and recovery is unlikely.

14. What is the status of non-indigenous species and how is it changing?

This question allows sanctuaries to report on the threat posed and impacts caused by non-indigenous species. Also called alien, exotic, non-native, or introduced species, these are animals or plants living outside their native distributional range, having arrived there by human activity, either deliberate or accidental. Activities that commonly facilitate invasions include vessel ballast water exchange, restaurant waste disposal, and trade in exotic species for aquaria. In some cases, climate change has resulted in water temperature fluctuations that have allowed range extensions for certain species.

Non-indigenous species that have damaging effects on ecosystems are called “invasive” species. Some can be extremely destructive, and because of this potential, non-indigenous species are usually considered problematic and warrant rapid response after invasion. For those that become established, however, their impacts can sometimes be assessed by quantifying changes in affected native species. In some cases, the presence of a species alone constitutes a significant threat (e.g., certain invasive algae and invertebrates). In other cases, impacts have been measured, and may or may not significantly affect ecosystem integrity.

Evaluating the potential impacts of non-indigenous species may require consideration of how climate change may enhance the recruitment, establishment, and/or severity of impacts of non-indigenous species. Altered temperature or salinity conditions, for example, may facilitate the range expansion, establishment and survival of non-indigenous species while stressing native species, thus reducing ecosystem resistance. This will also make management response decisions difficult, as changing conditions will make new areas even more hospitable for non-indigenous species targeted for removal.

Good	Non-indigenous species are not suspected to be present or do not appear to affect ecological integrity (full community development and function).

Good/Fair	Non-indigenous species are present and may preclude full community development and function, but have not yet caused measurable degradation.
Fair	Non-indigenous species have caused measurable but not severe degradation in some attributes of ecological integrity.
Fair/Poor	Non-indigenous species have caused severe degradation in some but not all attributes of ecological integrity.
Poor	Non-indigenous species have caused severe degradation in most if not all attributes of ecological integrity.

15. What is the status of biodiversity and how is it changing?

Broadly defined, biodiversity refers to the variety of life on Earth, and includes the diversity of ecosystems, species and genes, and the ecological processes that support them (Convention on Biological Diversity, 2006). This question is intended as an overall assessment of biodiversity compared to that expected in a near-pristine system (one as near to an unaltered ecosystem as people can reasonably expect, given that there are virtually no ecosystems completely free from human influence). It may include consideration of measures of biodiversity (usually aspects of species richness and evenness) and the status of functional interactions between species (e.g., trophic relationships and symbioses). Intact ecosystems require that all parts not only exist, but that they function together, resulting in natural symbioses, competition, predator-prey relationships, and redundancies (e.g., multiple species capable of performing the same ecological role). Intact structural elements, processes, and natural spatial and temporal variability are essential characteristics of community integrity and provide a natural adaptive capacity through resistance and resilience.

The response to this question will depend largely on changes in biodiversity that have occurred as a result of human activities that cause depletion, extirpation or extinction, illness, contamination, disturbance, and changes in environmental quality. Examples include collection of organisms, excessive visitation (e.g., trampling), industrial activities, coastal development, pollution, activities creating noise in the marine environment, and those that promote the spread of non-indigenous species.

Loss of species or changing relative abundances can be mediated through selective mortality or changing fecundity, either of which can influence ecosystem shifts. Human activities of particular interest in this regard are commercial and recreational harvesting. Both can be highly selective and disruptive activities, with a limited number of targeted species, and often result in the removal of high proportions of the populations, as well

as large amounts of untargeted species (bycatch). Extraction removes biomass from the ecosystem, reducing its availability to other consumers. When too much extraction occurs, ecosystem stability can be compromised through long-term disruptions to food web structure, as well as changes in species relationships and related functions and services (e.g. cleaning symbioses). This has been defined as “ecologically unsustainable” extraction (Zabel et al., 2003).

Good	Biodiversity appears to reflect near-pristine conditions and promotes ecological integrity (full community development and function).
Good/Fair	Selected biodiversity loss or change is suspected and may preclude full community development and function, but has not yet caused measurable degradation.
Fair	Selected biodiversity loss or change has caused measurable but not severe degradation in some attributes of ecological integrity.
Fair/Poor	Selected biodiversity loss or change has caused severe degradation in some but not all attributes of ecological integrity.
Poor	Selected biodiversity loss or change has caused severe degradation in most if not all attributes of ecological integrity.

Maritime Heritage Resources

16. What is the condition of known maritime heritage resources and how is it changing?

Maritime heritage resources are the wide variety of tangible and intangible elements (archaeological, cultural, historical properties) that reflect our human connections to Great Lakes and ocean areas.

Maritime heritage resources include archaeological and historical properties, and material evidence of past human activities, including vessels, aircraft, structures, habitation sites, and objects created or modified by humans. The condition of these resources in a marine sanctuary significantly affects their value for science and education, as well as the resource’s eligibility for listing in the National Register of Historic Places. The “integrity” of archaeological/historical resources, as defined within the National Register criteria, refers to their ability to help scientists answer questions about the past through archaeological research. Historical significance of an

archaeological resource depends on its integrity and/or its representativeness of past events that made a significant contribution to the broad patterns of history, its association with important persons, or its embodiment of a distinctive type or architecture.

Maritime heritage resources also include certain culturally significant resources, locations and viewsheds, the condition of which may change over time. Such resources, often more intangible in nature, may still be central to traditional practices and maintenance of cultural identity. The integrity of both cultural resources and cultural locations are included within the National Register criteria.

Section 110 of the National Historic Preservation Act requires federal agencies to inventory, assess, and nominate appropriate maritime heritage resources ("historic properties") to the National Register. The Maritime Cultural Landscape approach, adopted by the sanctuary system, provides a comprehensive tool for the assessment of archaeological, historical and cultural (maritime heritage) resources.

Assessments of heritage resources include evaluation of the apparent condition, which results from deterioration caused by human and natural forces (unlike questions about water, habitat, and living resources, the non-renewable nature of many heritage resources makes any reduction in integrity and condition, even if caused by natural forces, permanent). While maritime heritage resources have intrinsic value, these values may be diminished by changes to their condition.

Good	Known maritime heritage resources appear to reflect little or no unexpected natural or human disturbance.
Good/Fair	Selected maritime heritage resources exhibit indications of natural or human disturbance, but there appears to have been little or no reduction in aesthetic, cultural, historical, archaeological, scientific, or educational value.
Fair	The diminished condition of selected maritime heritage resources has reduced, to some extent, their aesthetic, cultural, historical, archaeological, scientific, or educational value, and may affect the eligibility of some sites for listing in the National Register of Historic Places.
Fair/Poor	The diminished condition of selected maritime heritage resources has substantially reduced their aesthetic, cultural, historical, archaeological, scientific, or educational value, and is likely to affect their eligibility for listing in the National Register of Historic Places.

Poor	The degraded condition of known maritime heritage resources in general makes them ineffective in terms of aesthetic, cultural, historical, archaeological, scientific, or educational value, and precludes their listing in the National Register of Historic Places.

Definitions and Rating Scheme for Status and Trends of Ecosystem Services

The following describes the ecosystem services and possible responses that ONMS considers in condition reports for all national marine sanctuaries. ONMS and subject matter experts use this guidance to make judgments about the status and trends of sanctuary ecosystem services.

ONMS defines ecosystem services in a slightly more restrictive way than some other experts. Specifically, ecosystem services are defined herein as the benefits people obtain from nature through use, consumption, enjoyment, and/or simply knowing these resources exist (non-use). The descriptions below reflect this definition, and therefore, only these ecosystem services are evaluated in sanctuary conditions reports. Intermediate services are not evaluated in the Status and Trends of Ecosystem Services chapter of these reports. Intermediate services, while critical to ecosystem function, are not directly used, consumed, or enjoyed by humans and thus do not meet the ONMS condition report definition of ecosystem services. In other words, these intermediate services support ecosystems but are not final ecosystem services in and of themselves. As an example, biodiversity is often considered as an ecosystem service by experts in the field, but ONMS recognizes biodiversity as an intermediate service of the ecosystem on which many final ecosystem services depend (e.g., consumptive and non-consumptive recreation, commercial and subsistence harvest depend on the status and trend of biodiversity). For this reason, biodiversity is considered an intermediate ecosystem service and it is evaluated in the Status and Trends of Sanctuary Resources chapter of the report. Decomposition and carbon storage are examples of other intermediate services.

In addition, ONMS does not consider climate regulation or stabilization as ecosystem services in condition reports. The impacts of climate change on water quality, habitat, and living resources are considered separately in the Status and Trends of Sanctuary Resources chapter of the report. While sanctuaries are not large enough to influence climate stability, they may locally buffer climate-related factors, such as temperature change and ocean acidity; thus, the extent to which they may locally buffer climate-related factors is reflected in resource conditions in the Status and Trends of Sanctuary Resources chapter.

Finally, some ecosystem services may not be assessed by individual sanctuaries because the activities required to achieve them are prohibited (e.g., collection of ornamentals), the sanctuary is not mandated to manage a specific resource that provides a particular service (e.g., management of fisheries), or there is simply no related activity underway or expected (e.g., renewable energy production).

Below are brief descriptions of the ecosystem services that could be considered within each sanctuary condition report (more complete descriptions are provided below the list).

Cultural **(non-material benefits)**

1. Consumptive recreation — Recreational activities that result in the removal of or harm to natural or cultural resources
2. Non-consumptive recreation — Recreational activities that do not result in intentional removal of or harm to natural or cultural resources
3. Science — The capacity to acquire and contribute information and knowledge
4. Education — The capacity to acquire and provide intellectual enrichment
5. Heritage — Recognition of historical and heritage legacy and cultural practices
6. Sense of Place — Aesthetic attraction, spiritual significance, and location identity

Provisioning **(material benefits)**

7. Commercial Harvest — The capacity to support commercial market demands for seafood products
8. Subsistence Harvest — The capacity to support non-commercial harvesting of food and utilitarian products
9. Drinking water — Providing water for human use by minimizing pollution, including nutrients, sediments, pathogens, chemicals, and trash
10. Ornamentals — Resources collected for decorative, aesthetic, ceremonial purposes
11. Biotechnology — Medicinal and other products derived or manufactured from sanctuary animals or plants for commercial use
12. Renewable energy — Use of ecosystem-derived materials or processes for the production of energy

Regulating **(buffers to change)**

13. Coastal protection — Flow regulation that protects habitats, property, coastlines, and other features

Sanctuaries vary with regard to the ecosystem services they support. To rate the status and trend for each relevant ecosystem service, the following can be considered:

- the best available indicators for each ecosystem service (e.g., economic, human dimension non-economic, resource, traditional ecological knowledge)
- the status and direction of change of each ecosystem service
- the prioritization of each indicator
- whether economic indicators send a false signal about the status and trend of an ecosystem service (namely, conflicting ecological and economic indicators, suggesting that people are sacrificing natural capital for short-term economic gain)

The steps used to rate ecosystem services were adapted from a multi-year study, *Marine and Estuarine Goal Setting for South Florida*, of three south Florida marine

ecosystems, including Florida Keys National Marine Sanctuary (Kelble et al., 2013). The study used integrated conceptual ecosystem models for each ecosystem under the DPSER Model (Nuttle & Fletcher, 2013) and evaluation of three types of indicators for each ecosystem service: 1) economic; 2) human dimension non-economic (Lovelace et al., 2013); and 3) resource.

The evaluation of ecosystem services should consider whether economic and non-economic indicators yield the same conclusions as resource indicators; this will enable consideration of the sometimes conflicting relationship between economic gain and the preservation of natural capital. For example, economic indicators (e.g., dive operator income) may suggest improving recreational services, while resource indicators (e.g., anchor damage to benthic habitat) suggest that natural resources are being sacrificed for short-term gain, thus making the activity unsustainable.

ONMS recognizes that the ecosystem services model is intentionally anthropocentric, designed to elicit a selected type of service-oriented rating useful in resource management decision-making. Connections between ecosystems, culture and heritage, and resource management are often complex, beyond the scope of the condition report. Collectively, stakeholders may have multiple worldviews and ecosystem values equally important to consider, and some ecosystem elements may not be appropriate to rate in the ecosystem services approach (e.g., aspects of heritage and sense of place). Sanctuaries may want to consider the option of including a “context-specific perspective” or narrative (as proposed in Diaz et al., 2018), without assigning a status or trend rating, for the purpose of providing appropriate information for management purposes. Cultural (non-material) ecosystem services are particularly intricate and have been undervalued in the past. Evaluators should remember that deliberative processes engaging local stakeholders and subject matter experts are critical, and adherence to the process demands both flexibility and creativity.

During workshops in which status and trends are determined, subject matter experts discuss each ecosystem service and relevant indicators, available data, literature (e.g., published scientific studies, reports), and experience associated with the topic. They then discuss the statements provided (see table below) as options for judgments about status. Once a particular statement is agreed upon, a color code and status rating (e.g., good, fair, poor) is assigned. Experts can also decide that the most appropriate rating is “N/A” (i.e., the ecosystem service does not apply), “undetermined” (i.e., ecosystem service status is undetermined due to a paucity of relevant information), or “mixed” (i.e., variation across indicators prevents the selection of a single status rating). A subsequent discussion is then held about the trend. Conditions are determined to be improving, remaining the same, or worsening in comparison to the results found in the first round of condition reports. Symbols used to indicate trends are the same for all ecosystem services: “**▲**”—conditions appear to be improving; “**▬**”—conditions do not appear to be changing; “**▼**”—conditions appear to be worsening; “**⬍**” —conditions appear to be mixed; and “**?**”—trend is undetermined; “N/A”—the ecosystem service does not apply.

Rating Scheme for Ecosystem Services

Rating	Status Description
Good	The capacity to provide the ecosystem service has remained unaffected or has been restored.
Good/Fair	The capacity to provide the ecosystem service is compromised, but performance is acceptable.
Fair	The capacity to provide the ecosystem service is compromised, and existing management would require enhancement to enable acceptable performance.
Fair/Poor	The capacity to provide the ecosystem service is compromised, and substantial new or enhanced management is required to restore it.
Poor	The capacity to provide the ecosystem service is compromised, and it is doubtful that new or enhanced management would restore it.

Cultural (non-material benefits)

Consumptive recreation — Recreational activities that result in the removal of or harm to natural or cultural resources

Perhaps the most popular activity that involves consumptive recreation is sport fishing from private boats and for-hire operations. Targeted species and bycatch are removed from the environment, and those that must be released due to regulations and prohibitions (e.g., undersized or out of season) sometimes die due to stress or predation. Nonetheless, fishing for consumptive purposes is a highly valued cultural tradition for many people, as well as a popular recreational activity. Other consumptive recreational activities include beachcombing, clam digs and shell collecting.

Indicators of status and trends for consumptive recreation often include levels of use (direct counts or estimates made from commercial vessel records and catch levels, and fishing license registrations) and production of economic value through job creation, income, spending, and tax revenue. Public polls can also be used to assess non-market indicators, such as importance and satisfaction, social values, willingness to pay, and facility and service availability.

Non-consumptive recreation — Recreational activities that do not result in intentional removal of or harm to natural or cultural resources

Recreational activities, including ecotourism and outdoor sports, are often considered a non-consumptive ecosystem service that provides desirable experiential opportunities. Non-consumptive recreational activities include those on shore or from private boats and for-hire operations, such as relaxing, exploring, diving and snorkeling, kayaking, birdwatching, surfing, sailing, and wildlife viewing. Activities that may have unintentional impacts on habitats or wildlife including catch-and-release fishing and tidepooling which could result in mortality or trampling, respectively, are also considered in this category.

It should be noted that private boating often includes both non-consumptive and consumptive recreational activities (e.g., snorkeling and fishing during a single trip). Thus, field and survey data can be ambiguous, reflecting the heterogeneous preferences of boaters. This also has implications for interpretations of data regarding attitudes and perceptions of management strategies and regulations to protect and restore natural and cultural resources.

Indicators used to assess status and trends in market values for recreation can include direct measures of use (e.g., person-days of use by type of activity) that result in spending, income, jobs, gross regional product, and tax revenues. They can also be non-market economic values (the difference between what people pay to use a good/service and what they would be willing to pay). The data can be used to estimate the value a consumer receives when using a good or service over and above what they pay to obtain the good or service. Indirect measures are also used. For example, populations and per capita incomes at numerous scales influence demand for recreational products and services. Fuel prices can even serve as indirect measures of recreational demand because the levels of use by some recreational users tracks fuel prices.

Science — The capacity to acquire and contribute information and knowledge

Sanctuaries serve as natural laboratories that can advance science and education. NOAA provides vessel support, facilities, and information that is valuable to the research community, including academic, corporate, non-governmental and government agency scientists, citizen scientists, and educators that instruct others using research. Sanctuaries serve as long-term monitoring sites, provide minimally disturbed focal areas for many studies, and provide opportunities to restore or maintain natural systems.

Status and trends for science can be assessed by counting and characterizing the number of research permits and tracking the accomplishments and growth of partnerships, activity levels of citizen monitoring, and participation of the research community in sanctuary management. The number and types of research cruises and other expeditions conducted can also provide useful indicators. Indirect indicators, such as per capita income and gross regional or national product, may be helpful as higher incomes and better economic conditions often result in higher investments in research and monitoring.

Education — The capacity to acquire and provide intellectual enrichment

As with science, national marine sanctuaries' protected natural systems and cultural resources attract educators at many levels for both formal and informal education. Students and teachers often either visit sanctuaries or use curricula and information provided by sanctuary educators.

The status and trends for education can be tracked by evaluating the number of educators and students visiting the sanctuary and visitor centers, the number of teacher trainings, use of sanctuary-related curricula in the classroom, and levels of activity in volunteer docent programs. The number of outreach offerings provided during sanctuary research and education expeditions can also be a good indicator. Education can also follow trends in populations and per capita income locally, regionally, and nationally. Populations create demand for services, and higher incomes lead to investment, making these useful indirect indicators.

Heritage — Recognition of historical and heritage legacy and cultural practices

The iconic nature of many national marine sanctuaries or particular places within them generally means that they have long been recognized, used, and valued. Communities developed around them, traveled through them, and depended on their resources. This shared history and heritage creates the unique cultural character of many present-day coastal communities, and can also be an important part of the current economy. Recognition of the past, including exhibits, artifacts, records, stories, songs, and chants provide not only a link to the history of these areas, but a way to better understand the maritime and cultural heritage within the environment itself. Tangible and intangible aspects of heritage blend together to contribute to the history and legacy of the place.

For some marine sanctuaries, vibrant and active indigenous cultures remain a defining and dominant element of the cultural heritage of these places. Not only are they a direct and priceless connection to the past, but they frame and influence modern-day economies, cultural landscapes, and conservation ethics and practices. Their very existence is intrinsic to the heritage of these places.

Given this broad range of cultural expression, benefits of heritage may take many forms. Additionally, cultural heritage resources will often be part of, or overlap with, other ecosystem service categories, and may be understood from multiple perspectives (such as, a living resource keystone species that may also be identified as a "cultural" keystone species, one of exceptional significance to a culture or a people). The Heritage ecosystem service category defines benefits from resources primarily attached to historical and heritage legacy and culture. Heritage resources, including certain living resources and traditional medicines, may also provide other benefits that can be addressed in other ecosystem service categories.

Economic indicators that reflect status and trends for heritage value as an ecosystem service may include spending, income, jobs, and other revenues generated from visitation, whether it is to dive on wreck sites or patronize museums and visitor centers where artifacts are displayed and interpreted. Non-market indicators, such as

willingness to pay for protection of resources, activity levels for training and docent interpretation, and changes in threat levels (looting and damage caused by fishing), may also be considered. Sites may determine that some aspects of Heritage may simply not be ratable using the framework of condition reports.

Sense of place — Aesthetic attraction, spiritual significance, and location identity

A wide range of intangible meanings can be attributed to a specific place by people, both individually and collectively. Aesthetic attraction, spiritual significance, and location identity all influence our recognition and appreciation for a place, as well as efforts to protect its iconic elements.

Marine environments serve as places of aesthetic attraction for many people, and inspire works of art, music, architecture, and tradition. Many people also value particular places as sources of therapeutic rejuvenation and to offer a change of perspective. Aesthetic aspects are often reflected as motifs in books, film, artworks, and folklore and as part of national symbols, architecture, and advertising efforts. These elements of "place attachment" may develop and change over the short and long term.

Many people, families, and communities consider places as defining parts of their "self identity," especially if they have lived there during or since childhood. The relationship between self/family/community and place can run very deep, particularly where lineage is place-based, with genealogy going back many generations. "Place identity" develops over the long term, and is often expressed in reciprocal human-ecosystem relationships, and locations associated with spiritual significance. The recognition of very long term place-based stewardship, sometimes in excess of 10,000 years, provides a unique aspect of place identity.

Many people even incorporate water or water-related activities as habitual or significant parts of their lives and cultures. Different factors are considered to measure/assess sense of place, including level of uniqueness, recognition, reputation, reliance, and appreciation for a place. Accounting for sense of place can provide strong incentives for conservation, preservation, and restoration efforts.

Despite its value as a cultural ecosystem service, it is difficult to quantify sense of place with direct measures. Examples of indicators may include the quality and availability of opportunities to support rituals, ceremonies and narratives and the level of satisfaction knowing that a place exists. Polls or surveys are often used to evaluate public opinions regarding economic and non-economic values of a place. Non-economic values may include existence or bequest value, which use surveys to estimate the value people would be willing to pay for resources to stay in a certain condition even though they may never actually use them. To comprehensively evaluate sense of place, sites may find it useful to consider subcategories such as place attachment and place identity. Furthermore, sites may determine that some aspects of Sense of Place may simply not be ratable using the framework of condition reports.

Provisioning (material benefits)

Commercial Harvest — The capacity to support commercial market demands for seafood products

Humans consume a large variety and abundance of products originating from the oceans and Great Lakes for nutrition or for use in other sectors. This includes fish, shellfish, other invertebrates, roe, and algae. Seafood is one of the largest traded food commodities in the world. Commercial fishing provides food for domestic and export markets, sold as wholesale and retail for household, restaurant and institutional meals. Seafood based industries include those that fish and harvest directly from wild capture and cultivated resources, as well as other businesses with functions throughout the supply chain including production of commercial gear, processors, storage facilities, buyers, transport and market outlets.

Within this category we also include what many call artisanal fishing, which can include commercial sale, but is also conducted by individuals or small groups who live near their harvest sites and use small scale, low technology, low cost fishing practices. Their catch is usually not processed (although it may be smoked or canned), and is mainly for local consumption or sale. Artisanal fishing uses traditional fishing techniques such as rod and tackle, fishing arrows and harpoons, cast nets, and sometimes small traditional fishing boats.

Fisheries located in national marine sanctuaries are usually encompassed by larger regional fisheries that are regulated by fisheries management plans. Fisheries management plans may include sanctuary-specific restrictions to protect sanctuary habitats, living resources, and archaeological resources, and to fulfill treaty obligations. Data that can be used to assess status and trends for this ecosystem service include: catch levels by species and species groups; and economic contributions in the form of sector-related jobs, income, sales, and tax revenue. Indirect measures include data on licensing, fleet size, fishing vessel types and sizes, days at sea, and commodity prices.

Subsistence Harvest — The capacity to support non-commercial harvesting of food and utilitarian products

Subsistence harvesting is the practice of collecting marine resources (e.g., fish, shellfish, marine mammals, seabirds, roe, and algae) either for food or for creating products that are utilitarian in nature (e.g., traditional medicine, shelter, clothing, fuel and tools) that are not for sale or income generation. Subsistence is conducted principally for personal and family use, and sometimes for community use, and may be distributed through ceremony, sharing, gifting, and bartering. Some people depend on subsistence fishing for food security and may have few other sources of income to provision their food and nutrition needs. Harvesting for subsistence is also a cultural or traditional practice for some people. It typically operates on a smaller and more local scale than commercial fishing. Natural resources that support subsistence harvest may also be used as ceremonial regalia or for cultural traditions, and therefore support other ecosystem services, including Heritage, Sense of Place, and Ornamentals. Data from surveys, tribal and indigenous knowledge and the status of fishery stocks can be used to assess the status and trends of this service.

Drinking water — Providing water for human use by minimizing pollution, including nutrients, sediments, pathogens, chemicals, and trash

Clean water is considered a final ecosystem service when the natural environment is improving water quality for human consumption or other direct use (e.g., irrigation). Although sanctuary ecosystems often function to improve water quality, most do not result in the final ecosystem service of clean water for human use. For most natural resources, improving water quality in a sanctuary is a supporting or intermediate ecosystem service that may, for example, result in better water quality for fish species that are then enjoyed by commercial or recreational anglers, safer water in which to swim, or improved water clarity for diving. These are aspects of other final ecosystem services and the water quality itself is an indicator that is inherently important to them; however, ONMS does not include this aspect of clean water in condition reports because it would result in a double counting of its ecosystem service value. Instead, ONMS evaluates clean water as a final ecosystem service, where the natural environment is improving water for human consumption, such as drinking water, or for irrigation (e.g., through filtration or suitability for desalination). In this way, the benefits of management policies and actions that improve water quality are captured separately, but in relation to the relevant final ecosystem services they support.

Ornamentals — Resources collected for decorative, aesthetic, or ceremonial purposes

In sanctuaries where the collection of ornamental products is not prohibited or is allowed under permit, they are taken for their aesthetic or material value for artwork, souvenirs, fashion, handicrafts, jewelry, or display. This includes live animals for aquaria and trade, pearls, shells, corals, sea stars, furs, feathers, ivory, and more. Some, particularly animals for the aquarium trade, are sold commercially and can be valued like other commodities; others cannot. Some products may be decorative and relatively non-functional, others culturally significant and specifically functional, such as ceremonial regalia. Status and trends for the use of ornamentals can also be evaluated using indicators such as the number of permitted or other collectors, frequency and intensity of collection operations, and sales.

Biotechnology — Medicinal and other products derived or manufactured from sanctuary animals or plants for commercial use

Biochemical and genetic resources, medicines, chemical models, and test organisms are all potential products that can be derived or sourced from national marine sanctuaries. Biochemical resources include compounds extracted from marine animals and plants and used to develop or manufacture foods, pharmaceuticals, cosmetics, and other products (e.g., omega-3 fatty acids from fish oil, or microbes for spill or waste bioremediation). Genetic resources are the genetic content of marine organisms used for animal and plant breeding and for biotechnology. Natural resources can also be used as a model for new products (e.g., the development of fiber optic technology, based on the properties of sponge spicules). Items harvested for food consumption are evaluated in Commercial and Subsistence Harvest.

Collections of products for biotechnology applications may be allowed under permit, and sanctuary permit databases can also be used to gauge demand and collection activity within a given national marine sanctuary. The value of commercially sold products associated with biotechnology may also be available.

Renewable energy — Use of ecosystem-derived materials or processes for the production of energy

In the offshore environment, energy production sources are considered to be either non-renewable (oil and gas) or renewable (wind, solar, tidal, wave, or thermal). While oil and gas technically are ecosystem-sourced and may be renewable over a time frame measured in millions of years, as an ecosystem service, they are not subject to management decisions in human time frames; therefore, they are not considered an ecosystem service in this section. The activities and management actions related to hydrocarbon production are, however, considered elsewhere in condition reports, primarily with regard to resource threats, impacts, and protection measures.

In contrast, “renewable” forms of energy that depend on ecosystem materials and processes operating over shorter time periods are evaluated. Indicators of status and trends for these energy sources include the types and number of permitted or licensed experimental or permanent operations, energy production, revenues generated, and jobs created. Indirect indicators that inform trends and provide some predictive value include social and market trends, energy costs, and expected demand based on service market populations trends.

Regulating (buffers to change)

Coastal protection — Natural features that control water movement and/or wind energy, thus protecting habitat, property, heritage resources and coastlines

Coastal and estuarine ecosystems can buffer the potentially destructive energy of environmental disturbances, such as floods, tidal surges and storm waves, and wind. Wetlands, kelp forests, mangroves, seagrass beds, and reefs of various types all absorb some of the energy of local disturbances, protecting themselves, submerged habitats closer to shore, intertidal ecosystems, and emergent land masses. They also can trap sediments and promote future protection through shoaling. They can also become sources of sediments for coastal dunes and beaches that control flooding and protect coastal properties from wave energy and the impacts of sea-level rise.

The value of coastal protection can be estimated by evaluating the basis of the value of vulnerable coastal properties and infrastructure and modeled estimates of losses expected under different qualities of coastal ecosystems (replacement cost). Levels of historical change under different energy scenarios can be used to support these estimates. Public polls can also reveal information on willingness to pay that is used to value this service.

Appendix C: Methods for Report Development

The process for preparing national marine sanctuary condition reports involves a combination of accepted techniques for collecting and interpreting information gathered from subject matter experts. The approach varies somewhat from sanctuary to sanctuary in order to accommodate different styles for working with partners, however, all include the evaluation of ecosystem indicators which is a well-established method for tracking ecosystem conditions and trends with the purpose of informing ecosystem-based management. The assessment of sanctuary resources and ecosystem services include quantitative measures of ecosystem indicators derived from regional monitoring data, supplemented by qualitative interpretations derived from expert opinions and local knowledge. This approach allows for a transparent and repeatable process.

The first step to assess an ecosystem's condition and health (see Appendices A and B) is to select indicators that reflect the status and trends of key components of the ecosystem. These indicators should be representative of the entire socio-ecological system, including individual components like biophysical indices, human activity, and community vulnerability. Indicators should meet certain criteria in order to be considered usable and appropriate for the condition report. This includes long-term data availability, importance to the ecosystem and culture, responsiveness to changes in environmental conditions, measurability, relevance to sanctuary condition report questions, and responsiveness to management actions. The indicator selection process for the GFNMS condition report began with sanctuary staff conducting a literature review of previous work focused on indicators in the region. Sanctuary staff then reviewed and prioritized each indicator based on the criteria previously described.

Next, ONMS selected and consulted subject matter experts familiar with water quality, habitat, living resources, maritime heritage resources, and socioeconomics in the sanctuary. A list of experts who participated in the GFNMS condition report process is available in the Acknowledgements section of this report. A series of virtual workshops were held with these subject matter experts in May, June, and July, 2022 to discuss and evaluate the series of questions about each resource and ecosystem service: human activities, water quality, habitat, living resources, maritime heritage resources, and ecosystem services (science, education, heritage, sense of place, consumptive recreation, non-consumptive recreation, commercial harvest, and coastal protection). During the virtual workshops, experts were first introduced to the questions and ecosystem services (see Appendices A and B). Next, the indicators for each topic were presented, accompanied by datasets ONMS had collected prior to the meeting.

Attendees were then asked to review the indicators and datasets, identify data gaps or misrepresentations, and suggest any additional datasets that may be relevant. Once all datasets were reviewed, experts were asked to provide status and trend recommendations and supporting arguments. GFNMS's approach in working with workshop experts was closely related to the Delphi Method, a technique designed to organize group communication among a panel of geographically dispersed experts by using questionnaires, ultimately facilitating the formation of a group judgment. This method can be applied when it is necessary for decision makers to combine the testimony of a group of experts, whether in the form of facts, informed opinion, or both, into a single useful statement. The Delphi Method requires experts to respond to questions with a limited number of choices to arrive at the best-supported answers. Feedback

to the experts allows them to refine their views, gradually moving the group toward the most agreeable judgment. In order to ensure consistency with the Delphi Method, a critical role of the facilitator was to minimize dominance of the discussion by a single individual or opinion (which often leads to "follow the leader" tendencies in group meetings) and to encourage the expression of honest differences of opinion. As discussions progressed, the group converged on an opinion for each rating that most accurately described the resource or ecosystem service condition. After an appropriate amount of time, the facilitator asked whether the group could agree on a rating for the question or ecosystem service, as defined by specific language linked to each rating (see Appendices A and B). If an agreement was reached, the result was recorded and the group moved on to consider the trend in the same manner. If agreement was not reached, the facilitator recorded the vote of individuals for each rating category and that information helped to inform the confidence scoring process.

After assigning status and trend ratings, experts were asked to assign a level of confidence for each value by: (1) characterizing the sources of information they used to make judgments; and (2) their agreement with the selected status and trend ratings. The evidence and agreement ratings were then combined to determine the overall confidence ratings, as described in the three steps outlined below.

Step 1: Rate Evidence

Consider three categories of evidence typically used to make status or trend ratings: (1) data, (2) published information, and (3) personal experience.

Limited	Medium	Robust
Limited data or published information, and little or no substantive personal experience.	Data available, some peer reviewed published information, or direct personal experience.	Considerable data, extensive record of publication, or extensive personal experience.

Step 2: Rate Agreement

Rate agreement among those participating in determining the status and trend rating, or if possible, within the broader scientific community. Levels of agreement can be characterized as “low,” “medium,” or “high.”

Step 3: Rate Confidence

Using the matrix below, combine ratings for both evidence and agreement to identify a level of confidence. Levels of confidence can be characterized as “very low,” “low,” “medium,” “high,” or “very high.”

Agreem			
	“Medium” High agreement Limited evidence	“High” High agreement Medium evidence	“Very High” High agreement Robust evidence
	“Low” Medium agreement	“Medium” Medium agreement	“High” Medium agreement

e nt →	Limited evidence	Medium evidence	Robust evidence
	"Very Low" Low agreement Limited evidence	"Low" Low agreement Medium evidence	"Medium" Low agreement Robust evidence

Evidence (type, amount, quality, consistency) →

An initial draft of the report, written by ONMS, summarized information, expert opinions, and levels of confidence expressed by the experts. Comments, data, and citations received from the experts were included, as appropriate, in text supporting the ratings and compiled in three appendices. This initial draft was made available to contributing experts and data providers, which allowed them to review the content and determine if the report accurately reflected their input, identify information gaps, provide comments, or suggest revisions to the ratings and text.

Following the expert review, the document was sent to representatives of partner agencies for a second review. These representatives were asked to review the technical merits of resource ratings and accompanying text, as well as to point out any omissions or factual errors. Upon receiving reviewer comments, ONMS revised the text and ratings as appropriate.

In October 2023, a draft final report was sent to three regional experts for a required external peer review. External peer review became a requirement when the White House Office of Management and Budget (OMB) issued a Final Information Quality Bulletin for Peer Review (OMB Bulletin) that established peer review standards to enhance the quality and credibility of the federal government's scientific information (OMB, 2004). Along with other information, these standards apply to "influential scientific information," which is information that can reasonably be determined to have a "clear and substantial impact on important public policies or private sector decisions" (OMB, 2004, p. 11). Condition reports are considered influential scientific information and are subject to the review requirements of both the Information Quality Act and the OMB Bulletin guidelines; therefore, every condition report is reviewed by a minimum of three individuals who are considered to be experts in their field, were not involved in the development of the report, and are not ONMS employees. Comments and recommendations of the peer reviewers were considered and incorporated, as appropriate, into the final text of this report. Furthermore, OMB Bulletin guidelines require that reviewer comments, names, and affiliations be posted on the agency website, http://www.cio.noaa.gov/. Reviewer comments, however, are not attributed to specific individuals. Comments by the external peer reviewers are posted at the same time as the formatted final document.

In all steps of the review process, experts were asked to review the technical merits of resource ratings and accompanying text, as well as to point out any omissions or factual errors; however, the interpretation, ratings, and text in the condition report are the responsibility of, and receive final approval by, ONMS. To emphasize this important point, authorship of the report is attributed to ONMS; subject matter experts are not authors, though their efforts and affiliations are acknowledged in the report.

Greater Farallones National Marine Sanctuary Confidence Ratings from May, June, and July 2022 Virtual Expert Workshops

Table App.C.1. A summary of ratings and associated confidence levels for the resources in the coastal and offshore region of GFNMS.

Question	Virtual Workshop Date (2022)	Rating	Evidence (Limited, Medium, Robust)	Agreement (Low, Medium, High)	Confidence (Very Low, Low, Medium, High, Very High)
2. Human Activities/Water Quality	July 11	Fair	Medium	Medium	Medium
		Mixed	Medium	High	High
3. Human Activities/Habitat[1]	July 11	Fair/Poor	Medium	High	High
		Undetermined	Limited	High	Medium
4. Human Activities/Living Resources	July 11	Fair	Medium	High	High
		Mixed	Medium	High	High
	July 6	Good/Fair	Limited	High	Medium

[1] During the workshops held in July 2022 to assess status and trends for this question, experts were initially divided on whether to rate the status "fair" or "fair/poor." They chose a final rating of "fair/poor" because effects appear to be widespread or persistent from several indicators, especially marine debris, which is persistent and accumulating over time in habitats. Most experts were also concerned about widespread impacts to benthic and water column habitats from crab pots and to benthic habitats from trawling activities. The experts rated the evidence for this rating as medium and the agreement and confidence both as high. However, GFNMS staff subsequently changed this rating to "fair." While GFNMS concurs that impacts are widespread and causing damage in some areas, the data do not sufficiently show that impacts are severe and therefore the "fair/poor" rating is unwarranted. GFNMS staff also changed the evidence for this status rating to "low" based on the limited data available for these indicators, and the agreement to "medium" given the difference of opinion between experts and staff, resulting in a "low" confidence score.

5. Human Activities/Maritime Heritage Resources		Improving	Medium	Medium	Medium
6. Water Quality/Eutrophication	May 16	Good	Medium	High	High
		Undetermined	Limited	High	Medium
7. Water Quality/Risk to Human Health	May 16	Fair	Medium	Medium	Medium
		Mixed	Medium	Medium	Medium
8. Water Quality/Climate Change	June 6	Fair	Medium	High	High
		Worsening	Medium	Medium	Medium
9. Water Quality/Other Stressors[2]	May 19	Good/Fair	Limited	Medium	Low
		Mixed	Medium	Medium	Medium
10. Habitat/Integrity	June 9	Fair	Medium	Medium	Medium
		Mixed	Limited	High	Medium

[2] A status rating and associated confidence score was not determined during the expert workshop. Following the workshop, GFNMS staff re-evaluated the indicators, datasets, and expert input that was received during the workshop, and made a final determination for the status rating and associated confidence score.

11. Habitat/Contaminants	May 19	Good/Fair	Medium	High	High
		Mixed	Medium	High	High
12. Living Resources/Keystone and Foundation Species	June 7	Fair/Poor	Medium	High	High
		Mixed	Medium	High	High
13. Living Resources/Other Focal Species	June 7	Fair	Medium	Medium	Medium
		Mixed	Medium	High	High
14. Living Resources/Non-indigenous Species	May 24	Good	Limited	Medium	Low
		Undetermined	Limited	High	Medium
15. Living Resources/Biodiversity	June 9	Good/Fair	Medium	High	High
		Mixed	Medium	High	High
16. Maritime Heritage Resources/Condition	July 6	Good/Fair	Limited	High	Medium
		Not changing	Limited	Medium	Low

Table App.C.2. A summary of ratings and associated confidence levels for the resources in the estuarine and lagoon region of GFNMS.

Question	Virtual Workshop Date (2022)	Rating	Evidence (Limited, Medium, Robust)	Agreement (Low, Medium, High)	Confidence (Very Low, Low, Medium, High, Very High)
2. Human Activities/Water Quality	May 17	Fair	Limited	Medium	Low
		Mixed	Limited	Medium	Low
3. Human Activities/Habitat	May 17	Fair	Limited	High	Medium
		Undetermined	Limited	High	Medium
4. Human Activities/Living Resources	May 17	Good/Fair	Limited	High	Medium
		Not changing	Limited	High	Medium
5. Human Activities/Maritime Heritage Resources	July 6	Good	Medium	Medium	Medium
		Improving	Medium	Medium	Medium
6. Water Quality/Eutrophication	May 16	Good/Fair	Limited	High	Medium
		Undetermined	Limited	High	Medium

7. Water Quality/Risk to Human Health	May 16	Fair	Medium	High	High
		Undetermined	Medium	High	High
8. Water Quality/Climate Change[3]	June 6	Fair	Medium	Medium	Low
		Undetermined	Limited	High	Medium
9. Water Quality/Other Stressors	May 19	Fair	Medium	High	High
		Undetermined	Limited	Medium	Low
10. Habitat/Integrity	June 9	Fair/Poor	Limited	High	Medium
		Not changing	Medium	High	High
11. Habitat/Contaminants	May 19	Fair	Limited	Medium	Low
		Mixed	Limited	Medium	Low
	June 7	Fair	Limited	High	Medium

[3] Status and trend ratings and associated confidence scores were not determined during the expert workshop. Following the workshop, GFNMS staff re-evaluated the indicators, datasets, and expert input that was received during the workshop, and made a final determination for the status and trend ratings and associated confidence scores.

12. Living Resources/Keystone and Foundation Species[4]		Undetermined	Limited	High	Medium
13. Living Resources/Other Focal Species	June 7	Fair/Poor	Limited	High	Medium
		Undetermined	Limited	Medium	Low
14. Living Resources/Non-indigenous Species	May 24	Fair	Medium	Medium	Medium
		Mixed	Medium	High	High
15. Living Resources/Biodiversity	June 9	Undetermined	Limited	High	Medium
		Undetermined	Limited	High	Medium
16. Maritime Heritage Resources/Condition	July 6	Good	Limited	High	Medium
		Not changing	Limited	Medium	Low

Table App.C.3. A summary of ratings and associated confidence levels for ecosystem services in GFNMS.

[4] A status rating and associated confidence score was not determined during the expert workshop. Following the workshop, GFNMS staff re-evaluated the indicators, datasets, and expert input that was received during the workshop, and made a final determination for the status rating and associated confidence score.

Ecosystem Services	Virtual Workshop Date	Rating	Evidence (Limited, Medium, Robust)	Agreement (Low, Medium, High)	Confidence (Very Low, Low, Medium, High, Very High)
Science	June 10	Good/Fair	Medium	High	High
		Improving	Medium	Low	Low
Education	June 15	Good/Fair	Robust	High	Very High
		Improving	Robust	High	Very High
Heritage	July 6	Good	Medium	High	High
		Improving	Medium	High	High
Sense of Place	June 15	Good/Fair		High	
		Improving		High	
Consumptive Recreation	July 7	Fair	Medium	High	High
		Undetermined	Limited	Medium	Low
	July 7	Good/Fair	Medium	Medium	Medium

Non-Consumptive Recreation		Mixed	Medium	Medium	Medium
Commercial Harvest	July 7	Good/Fair	Medium	Medium	Medium
		Mixed	Medium	High	High
Coastal Protection	July 5	Fair/Poor	Medium	Medium	Medium
		Undetermined	Limited	High	Medium

Appendix D: Additional State of the Resources Information

Additional Methods: Selection of Indicator Focal Species and Habitat Importance

Selection of Indicator Focal Species

Of the 1,140 species known to occur in GFNMS (ONMS, 2014), 92 are considered to be focal species in this report (i.e., species and taxa that require close attention from the perspective of sanctuary management and may be targeted for special protection; Table App.D.1). Of the 92 focal species of highest concern to sanctuary management, 16 taxa were selected as indicators of the status and trends of our focal species and taxa (Table S.LR.13.4, Table S.LR.13.5). The indicator species represent species or taxa that forage at different trophic levels, may be federally listed as Endangered or Threatened, are important prey species for birds and mammals, and/or are species that are highly dependent on the sanctuary for breeding, productivity, and foraging.

The following taxa were selected to indicate status and trend of focal species:

1. Brant
2. Brandt's cormorant
3. Common murre
4. White shark
5. California mussel
6. Cassin's auklet
7. Coralline algae taxa
8. Humpback whale
9. Juvenile rockfish taxa
10. Krill taxa
11. Olympia oyster
12. Red abalone
13. Sea palm
14. Shorebird taxa
15. Snowy plover
16. Willet

Definition of Habitat Importance

The GFNMS Management Plan (ONMS, 2014) categorizes the level of importance sanctuary resources are to the health and integrity for 92 of focal species and is called "Habitat Importance". Three categories are defined to describe the level of importance: 1) Extremely Important (EI), 2) Very Important (V), and 3) Somewhat Important (S). The table below indicates the level of importance sanctuary habitat and resources are important to the success of the listed taxa.

Sanctuary habitat is extremely important (EI) to the species when:

- A significant portion of the population occurs in the sanctuary year-round or is seasonally present,

- The species forages in the sanctuary during its breeding season or the sanctuary is a destination feeding ground, and
- The species or a distinct population segment is federally listed as Endangered, Threatened or Delisted or Critical Habitat within the sanctuary.

Sanctuary habitat is very important (V) to the species when:

- The species may be uncommon in sanctuary or this species is a foundation or keystone species.
- A significant portion of the population occurs in the sanctuary year-round or is seasonally present, and
- The species forages in the sanctuary during its breeding season or the sanctuary is a destination feeding ground, or is federally listed as Endangered or Threatened or has Critical Habitat within the sanctuary, or a significant portion of the population in the sanctuary and uses the sanctuary as a destination feeding ground.

Sanctuary habitat is somewhat important (S) to the species when:

- The species is common in sanctuary, and
- The species forages in the sanctuary during its breeding season or uses the sanctuary as a destination feeding ground.

Table App.D.1. List of focal species at GFNMS.

Common Name	Scientific Name	Category	Federal Status	Forage	Breeds in Sanctuary	Critical Habitat	Habitat Importance
Brant	*Branta bernicla*	Bird		x			S
Canada goose	*Branta canadensis*	Bird		x	x		S
Black-footed albatross	*Phoebastria nigripes*	Bird		x			V
Short-tailed albatross	*Phoebastria albatrus*	Bird	E	x			EI
Dark-rumped /Hawaiian petrel	*Pterodroma p.sandwichensis*	Bird	E	x			EI
Sooty shearwater	Ardenna griseus	Bird		x			S
Ashy storm-petrel	*Oceanodroma homochroa*	Bird		x	x		V
Brandt's cormorant	*Phalacrocorax penicillatus*	Bird		x	x		V
Brown pelican	*Pelecanus occidentalis*	Bird		x			S
Bald eagle	*Haliaeetus leucocephalus*	Bird	D	x	x		EI
Black oystercatcher	*Haematopus bachmani*	Bird		x	x		V

Snowy plover	*Charadrius alexandrinus*	Bird	T	x	x	x	EI
Willet	*Catoptrophorus semipalmatus*	Bird		x			S
Common murre	*Uria aalge californica*	Bird		x	x		V
Pigeon guillemot	*Cepphus columba*	Bird		x	x		V
Marbled murrelet	*Brachyramphus marmoratus*	Bird	T	x	x	x	EI
Cassin's auklet	*Ptychoramphus aleuticus*	Bird		x	x		V
Rhinoceros auklet	*Cerorhinca monocerata*	Bird		x	x		V
Peregrine falcon	*Falco peregrinus*	Bird	D	x	x		EI
Blue whale	*Balaenoptera musculus*	Mammal	E	x			EI
Fin whale	*Balaenoptera physalus*	Mammal	E	x			V
Sei whale	*Balaenoptera borealis*	Mammal	E	x			V
Minke whale	*Balaenoptera acutorostrata*	Mammal		x	x		S
Humpback whale, Mexico DPS	*Megaptera novaeangliae*	Mammal	T	x		x	EI
Humpback whale, Central America DPS	*Megaptera novaeangliae*	Mammal	E	x		x	EI
Gray whale, eastern population	*Eschrichtius robustus*	Mammal	E	x			V
Gray whale, western population	*Eschrichtius robustus*	Mammal	D				V
Right whale, North Pacific	*Eubalaena japonica*	Mammal	E	x			V
Harbor porpoise	*Phocoena phocoena*	Mammal		x	x		S
Pacific white-sided dolphin	*Lagenorhynchus obliquidens*	Mammal		x	x		S

Killer whale, southern resident stock	*Orcinus orca*	Mammal	E	x		x	EI
Killer whale, offshore stock	*Orcinus orca*	Mammal		x			S
Killer whale, transient stock	*Orcinus orca*	Mammal		x			S
Sperm whale	*Physeter macrocephalus*	Mammal	E	x			V
Steller sea lon, WA, OR, CA stock	*Eumetopius jubatus*	Mammal	D	x		x	EI
Northern fur seal	*Callorhinus ursinus*	Mammal		x	x		S
Guadalupe fur seal	*Arctocephalus townsendi*	Mammal	T	x			S
Northern elephant seal	*Mirounga angustirostris*	Mammal		x	x		S
Harbor seal	*Phoca vitulina richardii*	Mammal		x	x		S
Southern sea otter	*Enhydra lutris nereis*	Mammal	T	x			V
Southern green sturgeon	*Acipenser medirostris*	Fish	T	x	x	x	EI
White shark	*Carcharodon carcharias*	Fish		x			S
Pacific herring	*Clupea pallasii*	Fish		x	x		S
Northern anchovy	*Engraulis mordax*	Fish		x	x		V
Pacific halibut	*Hippoglossus stenolepis*	Fish		x	x		S
Tidewater goby	*Eucyclogobius newberryi*	Fish	E	x	x	x	EI
Chum salmon	*Oncorhynchus keta*	Fish	T	x			V
Coho salmon [silver salmon]	*Oncorhynchus kisutch*	Fish	E & T	x			V
Rainbow trout [steelhead]	*Oncorhynchus mykiss*	Fish		x			S
Chinook salmon	*Oncorhynchus tshawytscha*	Fish	E & T	x			V

Pacific sardine	*Sardinops sagax*	Fish		x	x		V
Starry rockfish	*Sebastes constellatus*	Fish		x	x		S
Widow rockfish	*Sebastes entomelas*	Fish		x	x		S
Yellowtail rockfish	*Sebastes flavidus*	Fish		x	x		S
Bocaccio	*Sebastes paucispinis*	Fish		x	x		S
Rosy rockfish	*Sebastes rosaceus*	Fish		x	x		S
Yelloweye rockfish	*Sebastes ruberrimus*	Fish	T	x	x		V
Cowcod	*Sebastes levis*	Fish		x	x		S
Petrale sole	*Eopsetta jordani*	Fish		x	x		S
Canary rockfish	*Sebastes pinniger*	Fish		x	x		S
Darkblotched rockfish	*Sebastes crameri*	Fish		x	x		S
Pacific ocean perch	*Sebastes alutus*	Fish		x	x		S
Blue rockfish	*Sebastes mystinus*	Fish		x	x		S
Cabezon (CA)	*Scorpaenichthys marmoratus*	Fish		x	x		S
Pacific whiting (hake)	*Merluccius productus*	Fish		x	x		S
Sablefish	*Anoplopoma fimbria*	Fish		x	x		S
Kelp greenling	*Hexagrammos decagrammus*	Fish		x	x		S
Starry flounder	*Platichthys stellatus*	Fish		x	x		S
Blackgill rockfish	*Sebastes melanostomus*	Fish		x	x		S
Black rockfish (OR/CA)	*Sebastes melanops*	Fish		x	x		S
Shortspine thornyhead	*Sebastolobus alascanus*	Fish		x	x		S
Dover sole	*Microstomus pacificus*	Fish		x	x		S

Longnose skate	*Raja rhina*	Fish		x	x		S
Splitnose Rockfish	*Sebastes diploproa*	Fish		x	x		S
Chilipepper	*Sebastes goodei*	Fish		x	x		S
Longspine thornyhead	*Sebastolobus altivelis*	Fish		x	x		S
Lingcod (CA)	*Ophiodon elongatus*	Fish		x	x		S
Arrowtooth flounder	*Atheresthes stomias*	Fish		x	x		S
Greenstriped rockfish	*Sebastes elongatus*	Fish		x	x		S
California scorpionfish	*Scorpaena guttata*	Fish		x	x		S
Gopher rockfish	*Sebastes carnatus*	Fish		x	x		S
English sole	*Parophrys vetulus*	Fish		x	x		S
Green sea turtle, East Pacific DPS	*Chelonia mydas*	Reptile	T	x			V
Loggerhead turtle, North Pacific DPS	*Caretta caretta*	Reptile	E	x			V
Leatherback turtle, East Pacific DPS	*Dermochelys coriacea*	Reptile	E	x		x	EI
Pacific (Olive) ridley, East Pacific DPS	*Lepidochelys olivacea*	Reptile	E	x			V
Black abalone	*Haliotis cracherodii*	Invertebrate	E	x	x	x	EI
Red abalone	*Haliotis rufescens*	Invertebrate		x	x		V
Eelgrass	*Zostera marina*	Plant/algae		x	x		V
Surf grass	*Phyllospadix scouleri*	Plant/algae		x	x		V
Bull kelp	*Nereocystis luetkeana*	Plant/algae		x	x		V
Sea palm	*Postelsia palmaeformis*	Plant/algae		x	x		S

(spare info if needed for future edits)

Literature Citation:

Habitat Importance

Office of National Marine Sanctuaries (ONMS). (2014). Gulf of the Farallones National Marine Sanctuary, Final Management Plan, Updated December 2014. San Francisco, CA. pps. 296.

Federally Listed Endangered and Threatened Species

U.S. Fish and Wildlife Service. (2023). *Find a species* [Data set]. U.S. Department of the Interior. https://www.fws.gov/species/search

and

NOAA Fisheries. (2023). *Species directory: ESA threatened and endangered* [Data set]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration. https://www.fisheries.noaa.gov/species-directory/threatened-endangered

Critical Habitat designation

Data Basin. (2023). *Maps* [Data set]. https://databasin.org/maps

and

National Marine Fisheries Service. (2021). *West Coast Region ESA critical habitat* [Data set]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration. https://www.webapps.nwfsc.noaa.gov/server7/rest/services/WCR/NMFS_WCR_ESA_Critical_Habitat/MapServer

And

https://www.arcgis.com/home/webmap/