CAMT Salmon Research Workshop

INTRODUCTION

On May 22, 2018, the Collaborative Adaptive Management Team (CAMT) hosted a one-day workshop focused on salmonid research activity in the Delta. The specific objectives of the workshop were to:

1. Provide an opportunity for researchers and managers to share their science needs, endeavors, and challenges.
2. Discuss how ongoing research efforts apply to key management needs, and what future research may be targeted to fill identified gaps in science for management purposes.

The workshop was attended by over 70 scientists and managers from academia, state and federal resource agencies, public water agencies and private firms. A list of workshop attendees in provided as Appendix A.

The workshop was organized according to a series of eight topic areas representing important management questions. Appendix B provides a listing of the topic areas and associated management questions. Workshop participants participated in facilitated, small group discussions focused on each topic. Participants rotated through the topic areas such that each participant had an opportunity to provide input on each topic.

The following provides a summary of the input received for each topic area. A detailed accounting of all comments recorded is provided in Appendix C.

The information presented here reflects the opinions of the various workshop participants. The information has not been verified and is not intended to reflect the current state of science. Rather the input reflects the knowledge, understanding and perspectives of the participants.

SUMMARY OF INPUT BY MANAGEMENT QUESTION

1. Condition, Behavior and Hydrodynamics

1.1 How is salmon condition and behavior (e.g. rearing, active swimming, lateral distribution within the channel, passive displacement, diel movements, energy expenditure, growth, timing of ocean entry, selective tidal stream transport, migration, routing) affected by hydrodynamics (tidal influence, inflows)?

1.2 What are the ways (e.g. habitat creation, landform changes, hydraulic residence time/water quality) that hydrodynamics in the Delta affect fish behavior?

<u>Summary</u>

Discussion focused on our lack of knowledge regarding how salmon condition and behavior are affected by hydrodynamics and mechanisms through which hydrodynamics may affect fish behavior. Lots of discussion was focused on studies that are needed to better understand the impacts that hydrodynamics have on fish condition and behavior. Comments on specific hydrodynamic effects on salmon condition and behavior from participants include:

- The flow actions/regimes on the Sacramento and San Joaquin River differ; what improves survival in the Sacramento does not translate to the same improvement in the San Joaquin River.
- Predators are a major factor not included in the list associated with this topic and have a tie in with hydrodynamics.
- Our understanding on this subject is based on bigger fish due to limitations of technology
- The relevant link is between depth and water velocity, big changes in water velocity based on depth/location in water column, tidal transport element of salmon behavior could be elucidated here.
- Behavior component of fish is their response to flow gradients across a channel.
- Rearing fish behave differently than fish migrating, interacting with hydrodynamics in a different way

<u>Concepts and Suggestions</u>

a. Fry and smolts have very different needs and behavioral responses to hydrodynamics.
b. We should be managing for both fry rearing and smolt migration, including providing habitat conditions conducive to rearing and migration guidance conducive to outmigration. Life history diversity is important for resilience (portfolio effect).
c. We should shift our thinking toward providing conditions to improve survival rather than focusing narrowly on the potential effects of project operations. Focus on factors that are most important to make an actual impact on salmon populations.
d. We should consider creating migration corridors that provide for both rearing and outmigration.

Knowledge Gaps

a. Fry use of the Delta and desired habitat characteristics for rearing in the Delta.
b. Vertical or lateral distribution of smolts in the water column, particularly in the tidally influenced areas of the Delta.

Suggested Studies

a. Couple biological and hydrodynamic monitoring to better understand behavioral responses to specific hydrodynamic condition.

2. Operations and Behavior

2.1 Where in the Delta are operations (see list below) changing hydrodynamics, and how are salmon behaviors changing given those changes?

a. DCC operations
b. OMR regulated operations
c. I:E regulations affecting hydrodynamics
d. Differential pumping at facilities – are there differences in hydrodynamics
e. Other operations

Summary

Discussion focused more on our lack of understanding about how hydrodynamics impact fish behavior than on where in the Delta operations change hydrodynamics. Participants identified the need to interface fish behavior and hydrodynamic models and focused on future studies needed. Comments on specific impacts of operations from participants included:

- Pump influence dissipates in the North Delta; operations down South have little influence on hydrodynamics at junctions in the North Delta. Hydrodynamics in the North Delta are dominated more by tides;
- DCC should be operated on tides rather than temporal windows;
- Radial gate operations should be considered;
- Need to consider operations both in and out of the Delta;
- Even if we fully develop a way to detect hydrodynamic changes in Delta we need to know what the available bookends are to existing hydrodynamics that can be changed;
- Should focus on survival rates, rather than salvage/entrainment.

Concepts and Suggestions

a. Regulatory constraints can hamper research (e.g. rigorous criteria associated with the BiOps make research and adaptive management difficult.
b. Existing monitoring programs need to be tweaked or completely re-designed to answer management questions.
c. Steelhead and salmon behaviors are very different so monitoring/trapping methods for one will probably not provide information on the other.
d. There is a lot of existing information that if synthesized, could provide insights (e.g. telemetry data)
e. Can we divert fish into Sutter and Steamboat Sloughs instead of keeping them out of Georgiana? Why do fish do better in Sutter and Steamboat Sloughs?

f. I:E and OMR are not good metrics to improve salmon survival
g. Exports are a better predictor of salvage than OMR
h. Salvage triggers not protective of fish
i. Differential pumping may be beneficial for fish survival

Knowledge Gaps

a. Understanding salmon behavior, particularly in tidal areas of the Delta. Lot to learn about how operations and tides effect behavioral ques and predators.
b. How would the Clifton Court Forebay radial gates be operated (e.g day/night cycle, tidal cycle)?

Suggested Studies

a. Focus on survival rates, rather than salvage/entrainment.
b. Evaluate how differential pumping affects fish survival;
c. Develop a better understanding the interaction between fish and predators
d. Examine how contaminants affect olfactory abilities.
e. Utilize data we already have?
f. How do hydrodynamics affect predators?

3. Condition, Behavior and Water Quality

3.1 How is salmon condition and behavior (e.g. rearing, active swimming, lateral distribution within the channel, passive displacement, diel movements, energy expenditure, growth, timing of ocean entry, selective tidal stream transport, migration, routing) affected by water quality drivers (i.e. Temp, DO, primary productivity, turbidity, salinity)?

3.2 How do operations affect water quality?

Summary

Participants discussed how water quality may influence salmon condition and behavior and had differing ideas how operations affect water quality. Lots of discussion was focused on research needed to fill knowledge gaps. Some specific comments included:

- Water quality is affecting fish activity and navigability
- Water quality influences olfactory cues
- Turbidity, salinity, contaminants, and temperature may influence routing of fish (DO may be less important factor)
- Water quality could influence the timing of when fish decide to migrate upstream or downstream
- Operations will affect temperature, residence time, primary production, and contaminants
- Operations aren’t affecting conventional WQ parameters much
- Turbidity restrictions may be controllable with operations, but how do we balance between Delta Smelt and salmon? Salinity and turbidity can be affected by operations
- Temperature is driven more by ambient air in the Delta
- It’s unknown if operations can really control sedimentation, especially for sediment augmentation or chlorophyll augmentation.

Concepts and Suggestions

a. Water quality is affecting fish activity and navigability.
b. Olfactory influences from hotspots of contaminants in urban areas during runoff periods may influence migration behavior and fitness (e.g. predator avoidance behavior).
c. Temperature and turbidity in the Delta cannot likely be controlled at a magnitude that would affect significant changes in salmon behavior (directly or indirectly) or stressors impacting fitness and survival (with the exception of localized benefits.
d. Water quality differences may influence lateral distribution and channel choice (outmigration choices).
e. Certain water quality constituents can affect the entire life history, especially if at a critical life stage.
f. Contaminants and temperature will affect out migrating smolts and gradients will help fish decide to go or stay so temperature would be very important.
g. Water quality could determine if fish go upstream or downstream, then a flood or ebb tide might push them a certain way because of their location.
h. Water temperature affects bioenergetics and DO.
i. Ground water recharge – instead of direct discharge of "hot" water from ag fields, urban surfaces, etc., groundwater that goes through constructed wetland, recharge, and other appropriate BMPs may reduce temperature and contaminant effects.
j. Contaminants are creating many pockets of hot spots spatially and temporally. The degree of contamination of SJR water vs SR water (Se issues and pesticides) is important.
k. Primary productivity influences condition probably more than behavior.
l. Rice fields drain then you get huge blooms with increased residence time.
m. Operations affect water quality parameters (primarily salinity and turbidity) directly and then salmonids indirectly. Operations can also affect residence time and temperature and could affect contaminants, possibly negatively affecting local conditions and creating places we don't want the fish to go into.
n. Operations affect what water mass dominates (SJR vs Sac) during different times, but not much work has been done on this to date.

Knowledge Gaps

a. Effect of olfactory ques and gradients on salmon behavior.
b. How salmon navigate the Delta. Don't know how fish determine where they want to be (where to get food, what they want/don't want). What water quality parameters tell a fish when it's done rearing and it's time to move on?
c. How water quality affects distribution as opposed to physical habitat or distribution across the channel when flow may take them in a particular direction.
d. Indirect effects and synergists effects are poorly understood.
e. Unclear if mortality (condition) is due to entering the Delta or their time in the ocean (there's a SAIL effort to count fish coming in and going out to help address this).
f. A lot of contaminant effects are unknown especially from nonpoint sources and how hydrodynamics effect contaminants.
g. Different, non-integrated program- or project-based monitoring efforts currently in place need to be evaluated in the context of questions related to salmon resiliency efforts (e.g., are their overlapping management questions among programs and projects that could be addressed with appropriate sampling and assessment designs?)
h. We know a lot about conventional water quality constituents, but the information has not been synthesized or put into context with biological data (abundance, biogeochemical,

telemetry data, as well as other water quality data including data from agencies generated for other purposes).

i. Lab studies are missing logistical field effects. We need to identify where there are more issues to see if the fish are getting particularly stressed in certain areas (can't skip the synergistic effects).
j. Need to know more about the Head of Old River Barrier operations and its effects on water quality (outside of salinity and DO).

<u>Suggested Studies</u>

a. Link field data to lab data (promote practical application of studies).
b. Conduct telemetry and caged fish experiments to examine the effect of olfactory ques and gradients on salmon behavior.
c. Need a better way of separating rearing vs conveyance areas of the Delta.
d. Mine existing data to examine when salmon lose their path.
e. Conduct a synthesis among topics (among synthesis efforts) to really get at our knowns and unknowns.
f. Tease apart linkages between different drivers (temperature, predation, bioenergetics, DO) with ex situ studies where you tweak the water quality with instream water coming in and out (decouple them and identify key factors with long-term trend analysis).
g. Mark recapture experiments.
h. Examine rearing vs conveyance.
i. Evaluate existing monitoring data.
j. Analysis and synthesis of existing data could provide inputs into behavioral models.
k. How does salinity affect fish behavior, physiological effects (ATPase work).
l. Synthesis of currently collected ancillary water quality constituents. Are they being collected in the right locations and times?
m. Habitat to occupancy models need more work so you can get at presence/absence as well as abundance.
n. Explore differences between the SJR and Sac River.
o. Look at how water quality leads to disease.
p. Use fingerprinting data to determine the proportion of each kind of water reaching the facilities (different source waters have different biogeochemical properties) and see how those affect primary productivity.

4. Flow Metrics and Thresholds

Several independent scientific investigations have found that average flows (or average velocities) in the tidal Delta lack a mechanistic basis for influencing the behavior of juvenile salmonids. For example, the SST concluded altered channel velocity and altered flow direction were the only two hydrodynamic mechanisms by which water project operations could affect juvenile salmonids.

4.1 Is there a channel velocity or flow direction threshold at which salmonids change their migration behavior or routing?

4.2 If so, what is it, how long must it be sustained, how frequently must it occur and would the change in behavior or routing be observable in an acoustic telemetry study?

<u>Summary</u>

Workshop participants noted that velocity and flow thresholds are dependent on a variety of factors and change depending on those factors, and therefore there is no one threshold value that can be applied uniformly. Factors noted that affect thresholds for movement include location and the physical characteristics of a junction, the size of the fish, water year type, tides, time of day, turbidity and fish life stage.

<u>Concepts and Suggestions</u>

a. Thresholds are dependent on tidal flux and inflow as well as junctions (would be interesting to have 4 graphs (stage [incoming or outgoing], inflow, and exports) for each region).
b. Thresholds in flow or velocities may change with water year types.
c. Thresholds are dependent on fish size given differences in orientation of fish (e.g. large fish tend to orient to the center of the cannel, they have interaction with habitat like rip-rap channels, exhibit zig-zagging behavior.
d. Movement is influenced by tides and diel cycle.
e. Threshold of turbidity could influence fish movement. If turbidity increases to a certain point, then fish might be more prone to be in the middle of channel.
f. Fish move given selective tidal stream transport – move on ebb tides so they move faster than the average velocities.
g. Thresholds are likely different spatially across the delta (no one threshold will do for all regions of delta) – need to divide Delta up.
h. A threshold could be when flow goes from being tidal to being reverse tidal. This is where you likely have maximum effect.
i. A velocity threshold could be dependent on the form of the junction geometry (the physical arrangement of each junction and tides)
j. Thresholds will be different depending on stage of fish (rearing vs migrating).
k. Thresholds are scale dependent.
l. Tributaries are more important to identify these thresholds – when water gets onto floodplains.
m. Shallow water habitat would improve conditions for fish on the right side of stream.

<u>Knowledge Gaps</u>

a. Need to understand how the cross channel distribution of fish changes. How does streak-line shift across channel. We could pick the most upstream channel that has the most mortality and investigate the cross channel distribution changes.
b. Are fish reacting to instantaneous stimuli to modify movement or is movement more driven by long term stress?
c. Are thresholds a function of directionality of flow – flood v ebb?
d. What small scale flow features are used for resting refuge areas?
e. What is the pattern of movement with diel cycle and with turbidity. If turbidity is increased is there less diel movement? This could inform when to pump.

<u>Suggested Studies</u>

a. Laboratory studies to control flow types at each junction followed up by a tagging study.
b. Change velocities in a flume to see the influence on movement behaviors (perhaps already done for salmonids?)

c. Upcoming study: Nearfield tagging study DWR and Cramer Fish Sciences – tagging spring run fish with VEMCO pdat tags and releasing them near the facilities and changing exports, tracking movement and how they move and their fate with SCHISM modeling.
d. Take advantage of tagging data to assess fish movement in different flow/velocities as well as junctions.
e. Post mortem of 2012 Stipulation study
f. Could use a simulation model to attempt to assess where thresholds might be (E. Gross did this for smelt – could do for salmonids).
g. Need to have fish releases 4/5 times a day over several weeks in spring over several years in different water years to look at influence of operations and other water properties together.
h. Need dense array of receivers around the facilities – predator detection here.
i. Need study to identify velocity threshold in other regions of the delta – OMR and Georgiana Slough studies look at covariates with movements. What is the breaking point of velocity that makes fish go a certain direction or not.
j. Russ could perhaps do a study looking at the role of the different flows on different movement/behaviors using change point analysis models? Could fit more complicated models with breakpoints and thresholds.
k. Could investigate one location such as Georgiana Slough and then scale up to whole system.
l. Look at tide stage and flow direction to determine routing in the 6 year study.
m. Routing studies need to be more fine scale and over multiple tidal cycles
n. Thermal limits of fish is being studied currently (UCD)
o. Pull together research looking at behavior in tidal systems – determine if fish exhibit selective tidal stream transport.
p. Hydrophone array at a junction – tag a bunch of fish see where they go. Couple with ADCPs to get good characterization of hydrodynamics in a particular junction (but which?).
q. Compare with studies on flow from the Columbia (McNatt, D. Bottom work with pit tags on islands on the Columbia.

5. Alternative Flow Metrics

5.1 To what extent can alternative flow metrics (identified in SST Question 5 as: Qwest; hydraulic residence time in south Delta; percentage of positive flow; proportion of CVP exports; and proportion of Sacramento River water at CVP/SWP) provide better management of south Delta water operations than existing metrics (OMR, I:E) intended to support behavior and migration that results in increased survival of salmonids?

<u>Summary</u>

There was mixed support from workshop participants on if the existing or alternative flow metrics support management of South Delta water operations intended to support behavior and migration that results in increased survival of salmonids. Comments from participants include:

- Alternative flow metrics should be based on biological goals that are meaningful (e.g. species, life stages, survival, habitat conditions for rearing, relative value of water) but also flexible. Physical metrics are not good measures of biological goals.

- The alternative flow metric used should be based on what management goal is (e.g. salmon survival, rearing habitat creation)
- Need to identify metrics that target/measure what fish are experiencing and to consider if there are lags between the metric and operations that need to be considered.
- The current metrics (OMR, I:E) and some of the proposed metrics are coarse in their spatial temporal resolution, unable to capture variability, and don't relay information of species effects.
- A number of the proposed metrics are very similar to one another (e.g. OMR and Qwest) and driven by San Joaquin inflow and some of the metrics would be difficult to measure or manage to. Some of the metrics (I:E and Qwest) can have the same number/value under drastically different conditions.
- Qwest does not capture how much distance the tides make fish move back and forth or how much exposure fish have to the tides; Qwest is difficult to manage because of the signal to noise ratio
- Proportion of CVP exports is useful for targeting salmonid survival; exports are a better predictor of salvage than OMR and easier to calculate
- OMR is based on salvage which contributes minimally to survival; OMR is a legacy metric for Delta entrainment of fish from the Sacramento River watershed and does not benefit fish from the San Joaquin watershed.
- Instead of the proportion of Sacramento River water at CVP/SWP should consider proportion of San Joaquin water at CVP/SWP as an alternative flow metric
- There should be a movement towards real time management and away from calendar based triggers, however it was recognized that moving away from calendar based triggers would take resources, time and effort.
- There are limitations (real or perceived) on the ability to experiment with alternative metrics and operations due to regulations, species status, and water demand. Outdated facilities and water demands limit or constrain the scientific questions that can be asked experimentally. The permitting process constrains or slows progress of studies.
- There was also discussion that management decisions are easier to justify if they are based on peer-reviewed published papers and consideration should be given to pay agency employees to publish their scientific research and studies. Participants discussed that more emphasis should be placed on learning and improving rather than monitoring for reporting obligations.

<u>Concepts and Suggestions</u>

a. Shorter hydraulic residence time increases fish survival and longer hydraulic residence time results in rearing opportunities and is important to habitat quality.
b. Different flow metrics support rearing in the Delta than migration through the Delta
c. There is a strong relationship between San Joaquin flows and survival

Knowledge Gaps

a. Are there possible metrics representative of what fish are experiencing? Would using acoustic telemetry provide a direct link to measure an observable relationship between conditions and fish survival?
b. How do fish behaviorally respond to the percentage of positive flow (in Old River or in another critical reach) or more positive velocities? How do fish behaviorally respond to the percentage of ebb/flood?
c. Is there a metric that can capture some of the influence of predation/mortality hot spots? What about hotspots that are not affected by operations (e.g. tidal San Joaquin River)?
d. Are the tools we have currently available to use adequate to utilize these metrics or fully understand them?
e. Management metrics need to consider their 'footprint', when a metric is applied what does it influence and how does it affect a fish?
f. How would managers manage to a channel velocity?
g. Should site specific metrics for management be considered, for example OMR is generalized and not specific to a location
h. Hydraulic residence time needs to be defined
i. Does fish life stage or where fish are within the South Delta modify how hydraulic residence time in south Delta influences fish?
j. It is difficult to determine what conditions are needed to get fish through the tidal region because there is a lack of good data in this area.
k. Should we consider metrics that are not based on the assumption that fish move with flow, e.g. metrics that target an amount of habitat?
l. Does the proposed proportion of CVP exports metric have other constraints to prioritizing CVP exports over SWP exports?
m. Goal of operations is to minimize salvage but is salvage a measure of fish survival (indirect vs direct mortality)?
n. Is a 4:1 I:E ratio too much, not enough, or too restrictive? Could there be more flex in I:E, for example during period of fish movement?
o. What are the effects of exports/operations in areas of concern such as the east San Joaquin?

Suggested Studies

a. Use acoustic telemetry techniques to validate assumptions in ePTM to understand if fish behavior is being captured in this model.
b. Studies to understand how fish behave at flow splits and at critical junctions.
c. Conduct fine scale reach specific survival experiments under different hydrodynamic conditions.
d. Effects of OMR on San Joaquin fish need to be tested.

6. Biological Response Metrics

The SST identified eight biological response metrics that would be useful for assessing the effectiveness of RPA actions. The metrics included:

a. Proportion of test fish at specific channel junctions that enter the Interior Delta;
b. Survival within specific reaches or to specific locations within the Delta;
c. survival through the Delta;
d. Condition of fish sampled above, within (at salvage facilities), and below the Delta;
e. Proportion of returning adults that display extended Delta rearing as fry based on otolith analysis;
f. Predicted risk that a juvenile salmonid would be entrained at the export facilities based on models;
g. Percentage of direct (salvage) mortality relative to estimated population abundance; and
h. Abundance of salmon populations leaving the Delta, or locations further downstream (e.g., Benicia or Golden Gate bridge).

Are any of the metrics listed above more effective than what is currently used to manage and assess the effects of water project operations on salmonids?

*letters in parentheses below refer to the metrics above.

Metrics

a. Some participants identified the proportional routing of test fish at specific channel junctions as a useful metric for assessing water operations, at least in terms of South Delta performance measures. Other participants felt this metric was detailed or “in the weeds” to be effectively applied to water project ops. Specific comments from participants include:
    - A few key junctions have disproportionate impact/influence on survival. North Delta junctions are more important than Central Delta where survival is poor regardless.
    - This metric is more operations centric than the other proposed survival metrics.
b. Survival within specific reaches was identified as a metric that could be implemented in the near term based on available information. Comments:
    - Reach specific survival would be a useful tool to inform restoration activities and assess the interaction between restored areas and project operations via influence on routing.
    - Reach specific survival may not be useful under the current operations management time interval due to potential in-reach variation and covariates.
c. Participants agreed that survival through the Delta is a major current management focal point. Comments:
    - Fry/other life stage specific survival data are deficient for salmon in the Delta. This limits understanding of the factors influencing through Delta survival.
d. There was consensus among participants that more condition data would be helpful in understanding the relationship between life stages.

- Collecting widespread condition/genetic data in conjunction with otolith analysis would provide important information linking survivorship to growth and rearing areas.
- Some participants suggested this metric was unnecessary in assessing or managing water project effects.

e. The majority of participants agreed that the proportion of returning adults displaying extended Delta rearing behavior would be useful information to have in management decision making and called for an expansion of otolith analysis to generate this information. Comments:
   - Understanding the connection between survival through the Delta (current management metric) and rearing strategy/location could aid in the identification of other avenues of improvement beyond the Delta.
   - Otoliths analysis is a cost effective and feasible approach to developing understanding of the impact of rearing behavior. It is possibly the best place to invest money at this time given our current knowledge.
   - There are existing models (WRLCM, hydrodynamic models) and telemetry (CWT) data sets that could be brought to bear in generating this information.

f. There was disagreement among participants on the appropriate approach for model-based prediction of export facility entrainment risk to juvenile salmonids as a metric, but many participants expressed an interest in a metric of this type (model based, predictive, addressing impact of operations) being implemented. Some participants felt models such as EPTM presented an opportunity for accurate modeling of this risk factor, while others felt this approach would be better off incorporating life-cycle components. Specific comments:
   - Use take related thresholds such as 2% of the JPI and/or change to a life-cycle relationship such as cohort replacement rate.
   - Predictive models have value for estimating entrainment into interior South Delta, but context is needed for determining the proportional impact and corresponding risk factor.
   - A raw entrainment based approach may not be the best indicator of operations impact on cohort.
   - Identify hotspots of especially low survival including within the footprint of the export facilities and at other management relevant locations. Apply EPTM to this metric.

g. There was disagreement among participants on the usefulness of percentage of direct (salvage) mortality relative to estimated population abundance as a metric for assessing RPA action effectiveness. Comments:
   - Multiple groups suggested the incorporation of a life cycle metric such as cohort replacement rate.
   - Participants suggested this metric could be measured through the use of existing models (SWFSC WRCLM and hydrodynamic models).
   - Similar to F, many believed there is high management value in a metric of this type that measures the impact of operations.

h. The abundance of salmon population leaving the Delta received less attention from the participants than other topics. More information/discussion is likely required to assess the usefulness of this metric. Comments:

- Abundance at Chipps can be a useful metric if detection methods are sound. There is disagreement within the scientific/monitoring community on the precision and reliability of this metric.

<u>Concepts and Suggestions</u>

a. Based on poor survival through the Delta, salvage and trucking increases the number of fish exiting the Delta (improves survival).
b. Size is correlated with survival through the Delta.
c. The scope of the RPAs (IE and OMR) is too limited to capture and sufficiently improve conditions in the Delta for fish.

<u>Knowledge Gaps</u>

a. Relationship between gage data, routing probability, and mechanistic fish response.
b. Interactions between restoration and operations: are there opportunities to use operations and restoration together in order to influence route specific survival?
c. Surrogates: Are hatchery fish acceptable surrogates for wild fish in outmigration/through Delta survival studies? Are Sacramento River fish/data acceptable surrogates for SJR?
d. Predator distribution, abundance, diet, and response to environmental covariates.

<u>Suggested Studies</u>

a. Proposed restoration metrics: lower trophic level health/abundance, reach specific survival, proportional habitat occupancy for rearing. Can use these to evaluate proposed activities such as farmland contributions to food web improvements.
b. Large scale PIT tagging and recapture in Delta to assess growth, add PIT tag arrays in Delta.
c. Test OMR RPA efficiency with marked fish under different flow regimes, test different operational scenarios. Target specifics/mechanism of flow-survival relationship, including predation.
d. Assess trawl/RST/sampling efficiency using paired acoustic/CWT estimates of abundance.

7. Monitoring and Decision Support Tools

Real- time monitoring and predictive modeling of juvenile salmon distribution in the South Delta could allow for more effective water project operations.

7.1 To better inform water project operations, what locations in the South Delta should be monitored/modeled, what metrics should be monitored/modeled, and what monitoring/modeling tools should we invest in?

7.2 How could these data be used to inform water project operations?

<u>Suggested Monitoring Locations</u>

- Georgiana Slough
- DCC
- SJR/Mokelumne confluence

- Pipe discharge at fish release sites (survival at point of release, and further downstream)
- Chipps Island
- Sutter and Steamboat Slough non-physical barriers (proportion of fish)
- Cavallo paper locations
- SJR at Vernallis
- Old and Middle Rivers, mouth of Old River
- Head of Old River (both sides of the diversion)
- Turner Cut
- Columbia Cut
- Clifton Court Forebay
- Franks Tract
- Increase monitoring of Steelhead on the SJR
- Disappointment Slough
- Jersey Point
- Verona

<u>Suggested Metrics</u>

- # of fish (route selection) by species
- Survival
- # of fish by species at Chips
- Fish proportion by route, abundance at specific locations
- Fish size and species
- WQ (salinity, temperature, turbidity at 5-15 min time scales) and hydrodynamics
- Abundance of fish entering South Delta via Old River
- Otolith chemistry
- Monitor predator population throughout all sites (abundance, type, etc.)
- Study the proportion of fish entering via HOR going to the pumps vs Chips Island
- Distribution of fish in the Delta
- Fish presence/absence
- Velocity profiles
- Hatchery vs wild
- Arrival times
- Movement
- Food
- Predation

<u>Suggested Tools</u>

- Russ Perry model
- Brandes Studies
- BDO South Delta Ag Barriers report
- Brad Cavallo Model
- DIDSON cameras to view fish release sites

- CVPIA SIT Model
- Is the Mid-water Trawl the best method to monitor? Is it giving actionable data? Should we look into new tools and new locations? Give better confidence in fish data
- Acoustic tags and telemetry arrays – properly located and consistent.
- PIT tags (can tag smaller fish) – PIT tag all hatchery fish
- Towed PIT tag antenna (fish swim through narrow capture, collect data without taking fish out of the water – Chips & Sacramento & Mossdale)
- Partial tracking model,
- Fish behavioral models,
- Agent based model
- eDNA
- ADCPs
- ePTM
- Trawls (November – April)
- Use genetic testing throughout the Delta to identify what type of fish is where (and when).
- ELAM
- Critical streakline analysis tools
- Modified eDSM for salmonids
- Hydraulic model coupled with fish behavior model

<u>How Data can Inform Operations</u>

- Provide more flexibility without increasing risk of fish mortality … can we set up a pilot study to test better flexibility?
- Help provide a better picture about how operations effect fish movements around the pumps.
- Adjust exports due to fish route selection
- Predict entrainment and timing
- Model potential outcomes of changes in operations
- ELAM could help evaluate alternative operation hypothesis with regard to how fish will react/entrain
- Help inform the RPAs
- Trigger opening and closing of the DCC
- Examine new ways to release salvaged fish (change release sites, timing, etc.)
- Better counts of fish can help regulate sport fishing
- eDNA can help us decide where the fish are, and where to put additional monitoring stations
- Use the models to show us the best locations to do specific types of monitoring
- Adaptively manage through iterations between collected data and modeled results
- Early detection can help avoid entrainment

8. Achieving Recovery

8.1 What are the optimal conditions in the Delta for salmon recovery?

a. In the near term (given existing upstream conditions and population size), and

b. Under proposed restored conditions in the upper watershed

8.2 What are the dominant conceptual models/ hypotheses describing 1) how salmon behave in the Delta now, and 2) how we anticipate salmon would behaving once populations targets are met and environmental/ habitat objectives in the upstream tributaries achieved?

a. What are the dominant conceptual models/ hypotheses related to desired conditions to support those behaviors?

b. What are the major areas of uncertainty around those conceptual models?

c. What are the most important actions or experiments that could be taken to resolve those areas of uncertainty?

8.3 How can operations, in combination with targeted restoration and other management actions, be optimized to achieve desired conditions for the range of salmon behaviors the delta will need to support in the near-term and the long-term?

a. How can we design operations to test key hypotheses and resolve core uncertainties?

b. What metrics should be used to measure the success of management actions that are used to achieve desired conditions (e.g. for rearing, migration, or both)?

1. Need a Common Vision and Understanding of

- Salmon use (behavior and survival) of the Delta
- The relationship of upstream habitat conditions and resulting fish condition, size, timing on a) behavior and survival in the Delta and it's sub-regions and b) survival to adulthood/ CRR

- **Conceptual models exist and/ or are under development:**
    - Habitat Opportunities, Conditions, Suitability criteria
        - Tidal wetlands work team
        - CAMT Salmon proposal
        - CVPIA SIT
        - CVSHP Implementation plan (still to be developed)
        - Historical Maps could be applied
        - Historic Delta Maps
            - Overlay current operations on historic habitat
            - Loss pf physical complexity may be bigger than water
            - Rearing corridors
            - Needs for shipping

- **Vision should be described in quantitative/ SMART objectives**
    - Need to define desired conditions (goals/objectives)
        - Delta
        - Upstream
        - Natural flow regime – especially upstream
        - SMART/quantitative/possible
    - Could become focus of regulatory structure (e.g. BiOps)
    - Many objectives already exist

      - CVFPP Cons. Strat
      - CVSHP
      - BDCP
      - Recovery Plan
      - SEP
    - Evaluate/characterize optimal conditions
      - Normal tolerance
      - For rearing and migrants
      - Include Carrying capacity
          - Prey
          - Density
          - Predators
    - What are key timings for habitat
      - Have we lost diversity by focusing on key times and losing the range of times?
      - Focus on particular life strategies
      - Life history pathway objectives

2. Link habitat restoration and operations to desired conditions via quantitative objectives

- **Restore habitat to achieve objectives**
  - What are the desired conditions?
    - Delta
    - Elsewhere
  - Where are they, what are the opportunities?
    - Upstream: Farming, rice
    - Delta: Islands that are already losing viability
  - Upstream habitat improvements
    - Low hanging fruit?
    - Should Accelerate
    - Will improve in river survival
        - Easier to improve in-river than Delta survival
  - How do we provide for fish and habitat needs without turning back clock?
    - Rebuild soils
    - Establish Long-term restoration plan
    - Fish needs centric habitat and Delta habitat parallel tracks? Integrated tracks?
  - Is it reasonable to expect fish to take advantage of habitat provided?
  - Habitat suitability for native and non-native species to overlay with restoration objectives and conceptual models
    - Natives as indicators for one another
  - Need studies investigating habitat restoration vs survival
    - Scale matters
    - WR model
    - Can model change in fish size from habitat change
    - What is most limiting?
      - Role of Delta may be less limiting then spawning/upstream habitat
    - Differences in length of corridor
  - Lifecycle perspective - how could upstream changes affect fish?
    - Use lifecycle model to probe future world
    - More healthy fish > better survival regardless

    - Could change what is limiting
    - More upstream habitat
        - Effects of upstream rearing
    - More Delta habitat
        - Is Delta rearing benefitting salmon?
        - How are they using the Delta now?
        - LHS of Delta Fish

- **Manage Operations throughout the system to advance/ achieve common vision and measurable objectives**
    - Dam releases, inflow and exports should be managed as a single system
        - In Delta - Exports inflows' and (+tides) need to be managed as one thing
            - Manage exports in combo with tides
                - Short time basis
                - Effects on velocities
                - Inundation
                - Experiment with modelling
                - Aim fish at restored habitat
    - Shift to operations designed to achieve conditions
        - More flexible
        - More dynamic - e.g. anadromy in steelhead
        - Develop quantitative goals/ targets that operations are managed to achieve
            - Multi-species
            - BDCP took this on CS5 – flow, function, life stage
            - CalSim – monthly not enough – need daily?
    - Real time operations
        - Improved monitoring
        - Real time tracking
        - Different triggers
    - Need to show benefits of operations modifications to incentivize changes
        - Develop operational scenarios to achieve objectives using models
            - Quantify benefits
            - Test hypothesis developed using models through operations experiments
            - Model recovery scenario – what will it take?
            - Model diversion effect (2300)
    - Explore different types of management actions
    - Manage flows to route fish through plumbing
        - Different strategies for SJR/Sac?
    - Managing for diversity and Resilience
    - Look at value of water and how many fish it can grow applied different ways/ times
    - Delta needs to be able to receive/support diversity
        - Flow/habitat
            - Populations
            - Life history
            - Specific types of resilience to manage for
        - Targeted scenario analysis – analysis relative to different risks, otolith analysis
        - Need to track fish through their migration (growth, timing. return success)
            - Spread risk
                - Genetics

        - Phenotypes
  - Manage flows for habitat extent duration
    - Reduce footprint of operations during migration
    - Need restoration to make flow a more effective knob
    - Flow not huge effect on habitat availability – change bathymetry to flow

3. Focus on actions to reduce uncertainty by testing hypotheses

- Bring tools/models to bear (SLCM, CVPIA, WRM, Delta DSM, etc.) on key questions
- Test hypotheses through actions that can produce a response vis a vis objectives
  - Consider what Knobs are available
    - I/E
    - OMR
    - Incidental take
    - Upstream flows
    - DELTA CROSS CHANNEL
    - Habitat alteration – setback levees
    - Pathways and conditions
    - Structural changes
    - Question about restoration under new conditions
    - Adaptive management and monitoring – ability to test hypotheses
    - Tough to explore options/test hypotheses because of all the constraints on management
    - Screens
    - Pumping screen operations
    - CVP, SWP
    - Barriers
    - Unscreened diversions
      - Could be a knob but isn't currently
  - Management Actions
  - Habitat Restoration
    - Need to run models to evaluate potential effect of restoration efforts
      - How does habitat restoration, lower down in the systems change fish, and flow?
    - Can we Leverage different parts of the system for different benefits/ life history stages/ species?
      - What can be achieved/ is possible in terms of Bay Restoration
      - How can refuges/ buffers be created?

- **Improve monitoring based on objectives**
  - To assess performance relative to hypotheses
  - To measure success and determine adaptive management
    - Tagging fish (all), recapture analysis
    - Sampling throughout the system
    - Acoustic tags
    - PIT tags - where can they work

- **Some of the key questions/ uncertainties/ areas of opportunity include:**
  - What are desired conditions/objectives for fish?
    - Is more rearing habitat good or bad?

        - Is predation the core condition?
            - How do we address it?
                - Make water colder?
                - Reduce predator habitat?
        - What is the growth vs survival trade off? How do we manage it?
    - Specific Pathways
        - What is optimal habitat
        - What is the desired outmigration pathway
            - Can we establish paths and keep fish there
            - Do different life stages need different pathways?
    - What does a functional delta ecosystem look like
        - Food production
        - Predation refuges
        - Turbidity (just right)
        - Flow regime that supports fish/habitat needs
        - Variable conditions – natural hydrograph

    - Might desired conditions be different now and later?
        - If habitat conditions upstream change?
        - If fish numbers increase of fish size/ timing changes?

    - How does habitat relate to fish recovery?
        - NMFS Lifecycle model could help resolve
        - CVPIA SIT model/ Delta DSM could be applied
        - Need to define recovery
            - AFRP/ CVPIA targets
            - Abundance
            - Survival – e.g. WR upstream to ocean survival
            - Positive CRR
        - How are fish using the Delta?
            - Conceptual model
                - Big fish coming down and leaving
                - Small fish arriving and rearing
                - More Upstream rearing => shorter Delta residence
        - Where/how are the fish using the channel?
            - Studies of fish at junctions
            - How many, when, where are they?
            - Is one pathway better than another? Under what circumstances?
            - How does upstream habitat relate to what is coming down?
            - Is Fry survival similar across habitats? Smolt?
            - Where do you end up smolting?
                - Central Delta => harder
                - Lower Sac => easier
            - What happens if things change (Upstream, in the Delta, in the ocean)?
        - What does survival target need to be?
        - What targets are appropriate/ critical to meet (e.g. diversity, timing, condition?)
            - Need to come together around key metrics
            - Size of fish and condition
            - Good abundance and diversity – size and timing

        - Better monitoring – decide who to manage for
        - More acoustic telemetry
    - Who is coming in and how are they doing?
    - Who is there now and how are they doing? Who could be there?
    - Need to understand what different LHS are doing
        - Specific rearing/migration pathways for specific fish
        - Can regions be parsed from otolith data?
- What are the key metrics?
    - For all species/ life-stages
    - Steelhead
        - Fry
        - What are the ideal metrics for fish condition?
            - Size
            - Fat
            - Disease

- What are barriers to action?
    - Turf
    - Leadership
    - Funding
    - New business models
    - Permitting

    } Direction we are all going

4. Other Important points/ concepts

- Looking at Delta as dynamic and linked with other parts of system
    - Opportunities to actively manage exist if we understood the system more
- Need to reduce/resolve proliferation of planning
- Need monitoring throughout system designed to inform key metrics
    - Some metrics may be difficult to monitor for
    - More photo metrics could be helpful
- Need to prevent harm while we plan
    - Identify short term actions that can be implemented now to prevent collapse/ extinction while we test hypotheses
- Exploit existing opportunities to advance recovery (e.g. Consultation)

APPENDIX A

Workshop Participants

NAME	AFFILIATION
Allison Collins	MWD
Amanda Bohl	DSC
Andrew Hein	NOAA
Arnold Ammann	NOAA/NMFS
Ben Geske	Delta Science Program
Bill McLaughlin	DWR
Bob Clarke	USFWS
Brad Cavallo	CFS
Brett Harvey	DWR
Brook Jacobs	CDFW
Carl Wilcox	CDFW
Caron Barcelo	NMFS
Cathy Marcinkevage	NMFS
Cyril Michel	UCSC/NMFS
Dan Kratville	CDFW
Deanna Sereno	CCWATER
Dick Pool	Golden Gate Salmon
Elizabeth Appy	Anchor QEA
Eric Chapman	ICF
Eric Danner	NOAA
Evan Sawyer	NOAA
Frances Brewster	SCVWD
Gabe Singer	UCD
Gardner Jones	DWR
Garwin Yip	NOAA
Griffin Hill	Anchor QEA
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James Newcomb	DWR
Jason Hassrick	ICF
Jason Pettier	CSD
Javier Miranda	DWR
Jennifer Pierre	SWC
JoAnna Lessard	Cramer Fish Sciences
Joe Heublein	NMFS
John Callaway	DSP
Josh Israel	USBR
Katrina Harrison	Reclamation

Kenneth Kundargi	CDFW
Kevin Clark	DWR
Kristen Towne	USFWS
Laura Valoppi	SFCWA
Lauren Hastings	DSC
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Lisa Hart	American Rivers
Maria Rea	NOAA
Mario Manzo	BOR
Matt Reeve	DWR
Michael George	Delta Watermaster
Michael MacWilliam	Anchor QEA
Mike Thomas	UCD
Noble Hendrix	QEDA
Pascale Goertler	DWR
Peter Dudley	UCSC/NMFS
Rachel Johnson	NMFS/UCD
Rainer Hoenicke	Delta Science Program
Rebecca Buchanan	U Washington
Rene C. Reyes	USBR
Rene Henery	TU
Ron Melcer	Delta Stewardship Council
Rusty Holleman	UC Davis
Sam Luoma	CAMT/UCD
Scott Brandl	PSP
Shaara Ainsley	FISHBIO
Sheila Greene	WWD
Steve Culberson	IEP
Steve Tsao	CDFW
Steve Zeug	CFS
Steven Hagerty	SFEI
Thomas Birmingham	Westlands Water District
Vamsi Sridharan	UCSC
Yumiko Henneberry	DSP

APPENDIX B

Management Questions Regarding Salmonid Behavior and Survival in the Delta

Topic 1: Condition, Behavior and Hydrodynamics

1.1 How is salmon condition and behavior (e.g. rearing, active swimming, lateral distribution within the channel, passive displacement, diel movements, energy expenditure, growth, timing of ocean entry, selective tidal stream transport, migration, routing) affected by hydrodynamics (tidal influence, inflows)?

1.2 What are the ways (e.g. habitat creation, landform changes, hydraulic residence time/water quality) that hydrodynamics in the Delta affect fish behavior?

Topic 2: Operations and Behavior

2.1 Where in the Delta are operations (see list below) changing hydrodynamics, and how are salmon behaviors changing given those changes?

a. DCC operations
b. OMR regulated operations
c. I:E regulations affecting hydrodynamics
d. Differential pumping at facilities – are there differences in hydrodynamics
e. Other operations

Topic 3: Condition, Behavior and Water Quality

3.1 How is salmon condition and behavior (e.g. rearing, active swimming, lateral distribution within the channel, passive displacement, diel movements, energy expenditure, growth, timing of ocean entry, selective tidal stream transport, migration, routing) affected by water quality drivers (i.e. Temp, DO, primary productivity, turbidity, salinity)?

3.2 How do operations affect water quality?

Topic 4: Flow Metrics and Thresholds

Several independent scientific investigations have found that average flows (or average velocities) in the tidal Delta lack a mechanistic basis for influencing the behavior of juvenile salmonids. For example, the SST concluded altered channel velocity and altered flow direction were the only two hydrodynamic mechanisms by which water project operations could affect juvenile salmonids.

4.1 Is there a channel velocity or flow direction threshold at which salmonids change their migration behavior or routing?

4.2 If so, what is it, how long must it be sustained, how frequently must it occur and would the change in behavior or routing be observable in an acoustic telemetry study?

Topic 5: Alternative Flow Metrics

5.1 To what extent can alternative flow metrics (identified in SST Question 5 as: Qwest; hydraulic residence time in south Delta; percentage of positive flow; proportion of CVP exports; and proportion of Sacramento River water at CVP/SWP) provide better management of south Delta water operations than existing metrics (OMR, I:E) intended to support behavior and migration that results in increased survival of salmonids?

Topic 6: Biological Response Metrics

The SST identified eight biological response metrics that would be useful for assessing the effectiveness of RPA actions. The metrics included:

a. Proportion of test fish at specific channel junctions that enter the Interior Delta;
b. Survival within specific reaches or to specific locations within the Delta;
c. survival through the Delta;
d. Condition of fish sampled above, within (at salvage facilities), and below the Delta;
e. Proportion of returning adults that display extended Delta rearing as fry based on otolith analysis;
f. Predicted risk that a juvenile salmonid would be entrained at the export facilities based on models;
g. Percentage of direct (salvage) mortality relative to estimated population abundance; and
h. Abundance of salmon populations leaving the Delta, or locations further downstream (e.g., Benicia or Golden Gate bridge).

6.1 Are any of the metrics listed above more effective than what is currently used to manage and assess the effects of water project operations on salmonids?

Topic 7: Monitoring and Decision Support Tools

Real- time monitoring and predictive modeling of juvenile salmon distribution in the South Delta could allow for more effective water project operations.

7.1 To better inform water project operations, what locations in the South Delta should be monitored/modeled, what metrics should be monitored/modeled, and what monitoring/modeling tools should we invest in?

7.2 How could these data be used to inform water project operations?

Topic 8: Achieving Recovery

8.1 What are the optimal conditions in the Delta for salmon recovery?

a) in the near term (given existing upstream conditions and population size), and

b) under proposed restored conditions in the upper watershed

8.2 What are the dominant conceptual models/ hypotheses describing 1) how salmon behave in the Delta now, and 2) how we anticipate salmon would behaving once populations targets are met and environmental/ habitat objectives in the upstream tributaries achieved?

a. What are the dominant conceptual models/ hypotheses related to desired conditions to support those behaviors?
b. What are the major areas of uncertainty around those conceptual models?
c. What are the most important actions or experiments that could be taken to resolve those areas of uncertainty?

8.3 How can operations, in combination with targeted restoration and other management actions, be optimized to achieve desired conditions for the range of salmon behaviors the delta will need to support in the near-term and the long-term?

a. How can we design operations to test key hypotheses and resolve core uncertainties?
b. What metrics should be used to measure the success of management actions that are used to achieve desired conditions (e.g. for rearing, migration, or both)?

APPENDIX C
Detailed Notes
May 22, 2018 CAMT Salmon Workshop

Table 1: Condition, Behavior and Hydrodynamics (Bruce and Griffin)

1.1 How is salmon condition and behavior (e.g. rearing, active swimming, lateral distribution within the channel, passive displacement, diel movements, energy expenditure, growth, timing of ocean entry, selective tidal stream transport, migration, routing) affected by hydrodynamics (tidal influence, inflows)?

1.2 What are the ways (e.g. habitat creation, landform changes, hydraulic residence time/water quality) that hydrodynamics in the Delta affect fish behavior?

<u>COMMON THEMES</u>

A) Do we want fish hanging out in the Delta? Role of Fry and related knowledge gaps.
B) Little is known about the local distribution of smolts in the water column. Research need = coupled biological and hydrodynamic monitoring.
C) Life history diversity is important for resilience. Portfolio effect.
D) Need habitat both for rearing fry and migrating smolts. Need for fish guidance systems and migration corridors.
E) We should shift our thinking toward providing conditions to improve survival rather than focusing narrowly on the potential effects of project operations.

=== Table 1: Group 1 ===

Eric Danner, Jason Peltier, Tom Birmingham, Steve Tsao, Steve Hagerty, Jennifer Pierre, Kevin Clark

- Unscreened diversions, conservation based management, other knobs to turn besides operations. What factors are most important to make an actual impact on salmon populations?
    - Narrowly focused workshop may be missing major factors affecting salmon survival through the Delta. The factors being focused on have been manipulated for years with no improvement, what else can be investigated/modified to try to improve conditions for salmon? Inconclusive impact of exports in the South Delta.
- Interactions between water operations and other factors in the Delta which have a combined impact on salmon. **Need better understanding of these interactions in order to better "turn the correct knobs," project ops a factor, but not the only factor.**
- Spending water at the right time and place, difficult to do without knowledge of other relevant factors
- All of these impacts go into lifecycle models to drive cumulative understanding of survival throughout lifecycle.
- DWR study involving release of fish below Stockton shows small impact of projects on routing, small "zone of influence" under multiple tidal scenarios and regulated project operations.

- Small amount of information from agencies put out in journals, most exists as gray literature, struggles to make its way to managers.
- Do we want fish to hang out in the Delta? Balancing desire to create beneficial habitat in Delta versus understanding that Delta is not good habitat and efforts should be put into preventing fish from encountering this habitat/moving fish through as fast as possible. Preventing contact vs. improving habitat.
  - Smolt vs. fry is an important differentiation here, salinity becomes a factor for fry, currently not as much a part of the conversation
  - Rearing habitat in Delta will not solve the problem because after rearing still exposed to poor Delta habitat on exit, this needs to be studied further.
  - Role of salvage/trucking – avoids Delta, high survival through this route for SJ fish (CVP). Trap and haul vs. salvage, success determined by survival past Chipps, would like to see impact on returning adult population.
- Sac vs. SJ act differently in terms of results from different flow actions/regimes. What improves survival in Sacramento does not translate to the same improvement in the SJR.
- Predators are a major factor not included in the list associated with this topic and have a tie in with hydrodynamics.
  - CDFW predator surveys are currently based on one time, small sample size, highly extrapolated, should be taken with a grain of salt.
  - Number thrown around is 95% mortality of smolts due to predators, regardless the group agreed it is a major factor. Disagreement over whether it was worth focusing on as THE major factor.
- Relationship between Delta survival and escapement: there is a connection based on lifecycle models, every year substantial portion of mortality is in the Delta
- **How are fish moving through the system?**
  - **Swimming at the surface vs. hunkering down at the bottom – ability to mitigate tidal influence, this is an area is uncertainty in terms of position in the water column.**
- Availability of research that has been done on the effect of the projects on salmon in the Delta, needs to be accessible to people working on the BiOps through ROC on LTO.
  - A lot of this information lies with DWR, working on getting it out there.
- Short versus long term focus
  - Looking forward to set a target that can't necessarily be based on a historic baseline due to fundamentally altered system.
- Research to be done now
  - Unscreened diversion impact, understanding lateral distribution of fish and role of that in potential impact.
  - Fry survival related to outflow – intensely pushed in waterfix conversations but no literature background, is there a relationship? What's the basis? Uncertainty definitely exists here. Fry survival in general poorly understood, do we want fry in the Delta? Probably not, but under population recovery scenarios habitat limitation will lead to more fry in the Delta.

  - Velocity refugia, restoration to provide refuge in tidally influenced environment, improve understanding of tidal/fluvial gradient zone and role in salmon migration.
  - Is South delta limiting survival of adults/population growth as a whole?

=== Table 1: Group 2 ===

Andrew Hein, Sam Luoma, Michael George, Lisa Hunt, Pascale Goertler, Maria Rea

- Question 2: more facilities centric, question 1: more conditions and behavior centric
- What information is out there in terms of **where in the channel are fish located?**
  - You can tell more about bigger fish due limitations of technology
  - Few existing monitoring technologies provide cross sectional information
  - Depth distribution of smolts not a lot of information available, hasn't been demand for this type of information. Tag for depth doesn't really exist, telemetry companies haven't developed it.
  - **Relevant link is between depth and water velocity, big changes in water velocity based on depth/location in water column, tidal transport element of salmon behavior could be elucidated here.**
  - Basic behavioral information important, but still relatively unknown. Day/night studies have been done, but not a lot published on tidal transport behaviors. In Oregon some PIT tag studies have been done on subadults and tidal transport behavior in estuarine systems (follow up with Pascale on these studies).
  - Availability of flow refugia less pronounced in this highly modified system.
- Predominant attitude is get fish out of Delta as fast as possible or they will get eaten.
- In other systems, the big idea is for fish to get bigger in the estuary and enter the ocean at a larger size, studies have shown bigger fish do better in the ocean. **Tradeoff between Delta mortality and increased ocean mortality due to smaller size at entry.**
  - **Ideally, there's a range of sizes based on different routes and rearing habitats. Channeling all fish through same route reduces this, may hurt survival, diversity, resilience.**
  - **Diversity is important for long term population survival**.
- Do we want fish to hang out in the Delta doesn't have to be an either or question, having different population segments moving differently could be a good thing. More habitat should provide more life history diversity
  - **Operations may push toward a narrower band of life histories, limit portfolio of life history strategies.**
  - Testing in Yolo Bypass: impacts of inundation timing and length on fish survival and size.
- Research to be done now
  - Distribution within the channel, basic lateral distribution behavior
  - **How fish interact with flows at a local scale, behavior component in response to flow gradients across a channel.**
  - What condition metrics are important in fish survival? Disease, length, weight, fat content.
  - Is there an important range of physical conditions that leads to survival? Portfolio of life history strategies, role of diversity, size and genetic diversity. Size is the most studied variable here, but still lots to do in terms of timing of growth and where growth occurs.

=== Table 1: Group 3 ===

Mario Manzo, Rebecca Buchanan, Garwin Yip, Peter Dudley, Rusty Holleman, Javier Miranda, Jason Hassrick, JD Wikert, Gardner Jones

- Hydrodynamics selecting for resident fish, water limited nature of system, link between operations limited hydrology and ecological selection.
- Steelhead specifically are encouraged to remain residents via compliance point temperature maintenance which reduces in river habitat variability. Delta canal entrainment also treacherous for migrating fish making residents more relatively successful.
    - More dynamic system is more favorable to anadromous fish.
    - Experiment with temperature compliance point could be done to determine extent of this impact, compare different systems Stan vs. Tuolomne vs. Merced. Shifting compliance point to favor different life history strategies, shift amount of available temperature habitat. Stable habitat hypothetically favors residents while variability will support anadromous.
    - Further experiments with variable treatments could be used to support native species, occasional salt water intrusion, return to more natural dynamism that native species evolved in. Certainly impacts on ag and water supply.
- Research to be done now
    - Flexibility with ops to test various conditions and associated hypotheses, take risks (ag, water supply reliability) in exploring edge case conditions.
    - Lab studies/modeling to look at how much salinity is required to have an appreciable impact on invasive species which could be extrapolated out to explore feasibility, economic impacts.
    - **Improve fry understanding, build life history diversity, what habitats are available at different flows, what rearing strategies do these habitats (quantity/quality/location) lend themselves to? Focus on fry and rearing, currently underrepresented in literature.**
- **Channel distribution and movement**
    - **Are we talking about fish that are migrating or rearing?** Can use otoliths to determine where rearing occurred and for how long, but micro scale behavior information not available through this data. Beach seines and increased sampling to determine use of different depths and habitat types.
        - Difficulty in permitting a lot of these efforts, associated take
    - Mobile telemetry surveys, can't do mobile 3D array, difficulty in differentiating tags on smolt vs. smolt consumed by predators, high degree of uncertainty. Hydroacoustic monitoring of channel could be applicable here. Difficulty in tagging wild fish (permits) and fry (size). PIT tagging could be applicable here.
- Bang for the buck: **water cost to # fish saved, operations are focused on actions timed with bulk of the run, less emphasis on saving fish at different points in the run for diversity or other purposes, not great for resiliency, susceptible to poor ocean conditions. What is best for overall survival is**

not always the determining factor, costs huge part of the formula. Can DOSS or another work group shape a seasonal or annual export budget to maximize fish survival under a given level of exports? Needs to be adaptive management with a survival target agreed on by managers rather than reactive management.

=== Table 1: Group 4 ===

Deanna Soreno, Dan Kratville, Eric Chapman, Ron Melser, Cyril Michelle, Cathy M., Bill McLaughlin

- Disaggregating CalSim outputs into a daily time step studying hydrodynamics, daily metrics
- **Need for lots of fine scale hydrodynamic experiments coupled with acoustic tag data, need lots of these paired biological-hydrodynamic studies in lots of different environments/locations. Emphasis on junctions. Needs to be done repeatedly over time to capture variation in system, within and between water years.**
- Within channel 3d distribution is another relevant layer of information on coupled bio-hydro studies. Fine vs. large scale behavior. Measuring aggregated response because finest scale (eddies and turbulence) is not measured**. Finding cutoff point where cost of measuring at a finer scale is not worth the amount of new information brought to bear.** Daily averages in tidal system not experienced by anything, 15 minute or other finer scale aggregation may sufficiently capture experience of fish.
    - Measure as fine as possible and look at whether hydrodynamics dictate behavior and if so to what extent.
    - Right level of resolution that balances cost with need to be done every year, as real time as possible to allow management based on the inflow of data.
    - **Routing possibility estimation is a desirable outcome.**
    - **Release tagged fish upstream of a critical junction repeatedly and measure response, routing decision under different hydro conditions.**
    - **Enhance existing arrays with paired hydro and bio/telemetry sensors, increase utility of each monitoring station**. For extra critical junctions a 2D array may be worthwhile.
- Baseline data before tunnels/restoration/climate change impacts? We may not have enough information currently to track changes adequately into the future.
- High degree of understanding of salmon behavior and reason behind behavior in clear upstream environments contrasted with **very low degree of understanding of salmon behavior/local distribution in Delta habitats**. "get to snorkel mask resolution" of understanding in at least some locations in the Delta.
- Most of the modeling is restricted to simple scenarios, lots of assumptions, especially in regards to climate change impacts. There are lots of modeling exercises that can be done with existing modeling tools to improve understanding of hydrodynamics at Delta junctions and the impacts on routing behavior. Get physics right, even if based on only a few locations, and then it can be applied more widely without huge concerns over regional mismatch, will need to be updated with new bathymetry information under climate change scenarios.

=== Table 1: Group 5 ===

Carl Wilcox, Michael MacWilliams, Mike Thomas, Arnold Ammann, Matt Reeve, Noble Hendrix, Joe

- How do we assess how hydrodynamics affect behavior and condition of salmon?
- How much data do we actually have on condition?
  - Otoliths used to get growth information and rearing habitat info. Otoliths are difficult in that they are energy intensive when it comes to processing. Backlog of otolith data in many places.
  - Ideally have at least fork length, weight info for sampled fish, other info includes otoliths, lipids, disease.
  - Seasonal growth information would be good to have, difficult to obtain. Comparing across years with ops manipulation, etc.
  - Role of restoration on condition, condition as a metric to assess restoration performance. How to link restoration to growth rate or overall size to survival improvement? Track faster/bigger growth as juveniles to escapement as adults, difficult.
- Research to be done now
  - Match up samples between juveniles and their adult returns via otoliths, looking at impact of rearing conditions on escapement.
  - Hatchery vs. wild behavior with respect to predators, wild better at avoiding, but by how much? Role in overall survival of hatchery vs. wild? Role of timing in survival? Many different factors having different impacts at different times.
    - Predator swamping has never been quantitatively validated in terms of hatchery releases overwhelming predators. Theorized but not well studied.
- Daily vs. longer term factors
  - **Tidal factors versus ocean conditions and water year type experiences. Learning about finer scale hydrodynamics through large fish tagging experiences, exploring tidal surfing mechanisms and flow responses.**
- Fish location in water column
  - **Agreement that there's not a lot known about this scale of distribution, would be advantageous to improve understanding here. Important ties to behavior and response to hydrodynamic conditions.**
  - Some work in this area has been done with Delta Smelt and reaction to tidal dynamics was observed, used bank habitat to avoid tidal sloshing.
  - Some lab experiments could be done in larger flumes to get some idea of general behavioral reactions to flow. Delta Smelt model not realistic for salmon based on numbers and sampling approaches. Inform how salmon are treated in models, likely not behaving like particles. Telemetry data could help with this. Need fish in hand for all these experiments which can be difficult at times.

- Habitat use, density dependence, flows all factors contributing to these behaviors, distribution at a variety of scales. How will fish distribute over habitat/utilize restored habitat as density dependence becomes more of a factor in increasing populations.
- **Life stage specific experiments, different behaviors by life stage.**

=== Table 1: Group 6 ===

Brad Cavallo, Steve Culberson, Russ Perry, Josh Israel, Joanna Lessard,

- Is condition affected by hydrodynamics?
- In tidal Delta fish can still go wherever they want, tidal velocities within their swimming ability. Tend to hold in flood and move out on ebb during outmigration.
    - Max velocities 1.5-1.7 ft./sec.
    - Historical Delta made up of much more low velocity habitat
    - **Rearing fish behave totally different than migrating; interact with hydrodynamics in a totally different way. Rearing fish much more bank associated.**
- Greater diversity of life history strategies than previously thought, **population does not respond as one body to changes in hydrodynamics/project ops, very difficult to observe or manage to.**
- Agree on subtle hydrologic role, shift focus to providing conditions to improve survival through restoration or other avenues. Tackle low hanging fruit and stop obsessing over how to adjust hydrological knobs just so because the impact is likely impossible to measure. **What can be done that has more potential than tweaking operations?** Agreement that the answer is a lot of things.
    - Bang for your buck: How to prioritize allocation of resources? **Likely not worth intensively monitoring in pursuit of detecting a very small change, instead pursue highly targeted actions/restoration. Use structured decision making to identify what tradeoffs need to be made to maximize benefit from resource investment.**
        - Trucking fish has had great short term success, what is role in long term recovery goals? Artificial solutions get results, are already being pursued, what is the limit?
- Some large scale actions such as levy breach or restoration have potential to fundamentally alter Delta hydrodynamics, influencing in ways to benefit fish. Greater potential than tweaking operations.
- We have life cycle models that can be applied to these questions to assess potential, degrees of confidence vary, much higher confidence for smolts than fry.
- **We want fry rearing in the Delta. In the interest of diversity and resilience, this rearing habitat needs to be maintained because there will be years when they are needed.** Focus this habitat away from influence of the facilities, outside of hydrodynamic zone of influence. Unless the goal is to salvage them and truck them.
    - **Rearing corridors – floodplain, intertidal**

=== Table 1: Group 7 ===

Steve Zeug, Dick Pool, Brett Harvey, Elizabeth Appy

- Distribution of fish within the channel
  - Highly modified channel makes it difficult to even hypothesize where fish, especially small fish, will orient and hang out. Undercut banks, side channels, rip rap, tules, tidally changing as waterline rises and falls. **Poorly understood how tide affects habitat selection.** Ongoing efforts to survey these edge habitats, difficult under current permits, capture differences in use over tidal cycle.
- Let fish categorize habitat, score based on fish presence, requires more sampling
  - Pursue fish presence first, then collect habitat data to see factors emerge as most important.
- In short to medium term, South Delta significant habitat improvement is unlikely to substantially alter habitat corridor**. Instead create very intentional corridors of high quality habitat that leads fish to best suited areas away from predation. This approach de-emphasizes hydro component, reliant on highly optimized habitat for both rearing and holding as well as migrating/moving. "Happy trail" for moving, marsh like habitat, more complex for holding in place and rearing/growing.**
  - Fish guidance system (focused around critical junctions)
    - Currently zig zag behavior across channel has been observed while migrating, could be searching for high quality habitat
    - Attractive: creating highly desirable habitat and habitat cues
    - Propulsive/avoidance: disco lights, water movement/jets
    - Coupled approach – at a junction combine desirable habitat with repulsion due to bad habitat or other measures
- Reduce fish in Delta via closing of channels to South Delta – problematic due to interference with senior water rights.

=== Table 1: Group 8 ===

Kristin Towne, Alison Collins, Shaara Ainsley, Gabe Singer, Vamsi Sridharan, Lauren Hastings

- Hydrodynamics influencing survival and route selection included in lots of conceptual models, swimming mechanism impacts less well understood.
  - **Distinct difference in behavior between riverine and tidal habitat in relative swimming speed and diel routine**. Tracking tides within tidal (holding through flood), after a certain point swimming downstream regardless of tide, cued into ocean – chronicled in the literature but small sample size and no recent studies.
- Cues that trigger changes in behavior throughout migration route are not well understood.
- Past studies in other systems have shown salmon moving into floodplain habitats on the flood tide to feed, coming out on the ebb. Target restoration area to these areas where food is being produced and predators are less of a threat, build off existing salmon behaviors.

- **Understanding fine scale hydrodynamics requires more data, more intensive longer term investigation. Is this information likely to affect management? If not, investment is unlikely. Could feed into hydrodynamic modeling efforts.**
- Manipulating exports in conjunction with other factors to better isolate impacts, conduct an investigation that **couples fish monitoring and continuous hydrodynamic modeling** focused on critical junctions (management consequences for routing).
- **Understand how hydrodynamic changes influence routing at critical intersections like head of Old River, from there can infer export actions that can benefit fish survival via optimal routing.**
    - What is the timescale for influencing hydrodynamics via modifying exports? How long does it take to make a change in exports? How long does it take for a change in exports to propagate out into system?
- **Impacts and behaviors of small fish/fry especially poorly understood.**

Table #2: Operations and Behavior (Amanda Bohl facilitator, Yumiko Henneberry note-taker)

Q: Where in the Delta are operations changing hydrodynamics, and how are salmon behaviors changing given those changes for:

- *DCC operations*
- *OMR Regulated operations*
- *I:E regulations affecting hydrodynamics*
- *Differential pumping at facilities – are these differences in hydrodynamics*
- *Other operations*

Genesis of this question-are I:E and OMR good metrics to use? If why not, why so? Been debate on these metrics. Are they the right operations metrics.

Bold text - management/science questions

Highlighted text - common themes

Shaded text – didn't quite catch

CAPS – WHEN ONE OF BULLET TOPICS DISCUSSED

Group A	Group B	Group C	Group D	Group E	Group F	Group G	Group H
Main points *Bottom line-we still know very little about salmon behavior. Hydrodynamic models are pretty advanced but fish behavior models still need work. Big gaps include fish movement with the tides. Discussion of more research on fish behavior including lab studies, 2D arrays, diel behavior, and studies related to these.* *There is a lot of existing information that if synthesized, could provide insights (e.g. results of telemetry studies)* *Some discussion on different operations including DCC, I:E. Other operations to consider are temporary/permanent, physical/non-physical barriers.* *Do we want salmon rearing in the Delta? Is the Delta a hospitable place? Recognition that we have smolt and fry but very little knowledge of fry use of the Delta.*	Main points *Discussion was centered around the rigorous criteria associated with the BiOps and operations, which made research and adaptive management difficult. Discussion on how pump influences dissipate in the North Delta and is more dominated by tide and how operations should take this more into account. E.g. DCC should be operated on tides, not strict temporal windows, issues with fish salvage calculations.* *Discussion that I:E is not a good metric and has not improved salmon survival.* *Need to evaluate how differential pumping affects fish survival highlighted as a needed study + interaction between fish & predators.* *Mention that steelhead and salmon behaviors are very different so monitoring/trapping methods for one will probably not provide information on the other.* *Lot more that we need to know. How ops effecting ques, hydrodynamics on predators, tides*	Main points *Participants noted the need to focus on survival rates, rather than salvage/entrainment.* *Potentially some discussion implying need to focus on fish-predator relationships.* *Again, discussion of how rigidity of criteria prevent good studies to be conducted (e.g., DCC).* *Again, members pointed out changes in hydrodynamics from pumps dissipates once in north Delta. Perhaps it's not fish behavior but where fish is located that matters more.* *Lots of discussion on radial gates to Clifton Court both in terms of managing for fish entry and differential pumping.* *Existing monitoring programs need to be tweaked or completely re-designed to answer management questions.* *Hot spots of contaminants information on how contaminants affect olfactory abilities.* *Lateral distribution and channel choice* DCC OPERATIONS	Main points *Discussion for need to focus on survival, not entrainment/salvage. And that perhaps more mortality occurring in north Delta and it's not south Delta…* *Again, issue with existing data that could provide a lot of information but currently unavailable or not synthesized.* *Again, management has to consider more than just fish (e.g., DCC)* *Discussed the need to consider other operations besides south Delta and central Delta (reservoirs) on hydrodynamics.* *Potential to look at fish behavior more near pumping facilities since hydrodynamics stronger there, also need smaller arrays, more test fish so there's more data points to work with.* *Issues associated with using hatchery fish to generalize outcomes.* We have the salvage data and OMR data. **But how do operations affect migration on other pathways?**	Main points *Discussion focused around whether hydrodynamics affected salmon behavior or if hydrodynamics were just providing the wrong cues that make fish think they're going in the right direction.* *Again, need to consider operations both in and out of Delta.* *A little related to Group D discussion—even if we had information we need, would it help determine management action that would help fish?* *Discussion that I:E and OMR not good metrics.* *Again, need to focus on radial gate operation, and that exports are a better predictor of salvage than OMR.* *Differential pumping may improve survival.* DCC AND I:E OPERATIONS Need to recognize both metrics are functions of SJR flows.	Main points *Again discussion on radial gates and should release fish more local to pumping to figure out effects of hydrodynamics, and the need for increased sample size.* *Again, influence of tides. Again, some discussion on Georgiana Slough barriers.* *Again, difficulties in assessing behavior but thoughts included that fish know what they're doing, so pumps just giving them wrong cues.* Consider tides, which are much bigger. Head of Old River junction tides going in one junction, out in one. Challenging scenario when tides going in opp direction to do a study. Easy to build hydrodynamic model to see what tide is doing. e.g. of tides swamping signal: If you go back in the 80s and 90s	Main points *Lots of discussion about using particle-tracking models and what these can tell us.* *Again, discussion of how salvage triggers are not great especially for CCF, how differential pumping may be beneficial for fish survival.* *Establishing acoustic telemetry network/array coupled with hydrodynamic modeling. PIT tag arrays for localized studies or tow a set of receivers. When are fish entering the Delta? Key locations I st & Mossdale. Modeling at key junctions (e.g turner cut, Columbia, head Old River, etc.). targeted releases of fish at these locations to improve studies. Co-locating habitat data with studies.* *Modeling – connect hydrodynamic models with fish behavior/PTMs.* DIFFERENTIAL PUMPING	Major points *Noted that we should focus on how hydrodynamics affect predators.* *Group felt operations have little effect on fish entering Delta and more important question should be looking at when where, and how many fish entering Delta and once in Delta, how hydrodynamics are affecting.* *Also noted importance of tides and that salmon were reacting to tidal cues. Also briefly talked about whether management would use the information.* Important efforts going to coupling hydrodynamics with behavior with PTM. What is not in there is effects on hydrodynamics on predators. Any efforts on operations and predicting how it impacts predators. We're always focusing on juves and how habitat attributes affect pred. Shift from striped bass to LMB. Lot associated with changes

Operations affecting hydrodynamics and local hydrodynamics - how much do we know about the hydrodynamics?
In Gaps analysis some information on hydrodynamics but there is interest in developing a next generation model, as current tools are not as accurate.

Hydrodynamic models not really an issue. The issue is that we need more interface with fish behavior and hydrodynamics.

How can we get more insight into fish behavior linked to hydrodynamics?
Targeted experiments that tie hydrodynamics and ONE fish does, will provide tools to model

How do fish know when tide going out?
Don't know. But evidence they move with tide.
Might be useful to have 2D arrays. Right now have single array, can look at arrival rate and can use as proxy for local fish movement. Can use that to get rough sense of when fish are arriving. But 2D array more powerful. There is data on that-Georgiana Slough and head of Old River, and small study on Sacramento River.

(Referring to spreadsheet of research studies provided) Nice table of studies that have been done. Can we use telemetry studies from these to figure out something about the interaction

Regulatory constraints and how they can hamper research opportunities. Focusing on data and modeling we have. How to utilize what we have.

Challenges with funding studies if they are not mandated.

What are the entrainment rates at the operations? How many go in and under what conditions?
unable to set up study where both facilities taking max amount of water and taking measurement of fish. Tried last year but difficult. Tried with VAMP but was not adaptive. Not any adaptive management.

Is there way to design where all we can rally behind?
OMR successful in being flexible. Need flexibility to study what these are doing. Currently at conservative level because of great uncertainty in trigger values. Current thought is that the few fish detected are the leading edge of what's coming.
What does four fish in the tank mean? Zero fish? Does zero really mean zero? By the time fish get down to salvage, too late. Zero is probably not zero.

Can eDNA be used to make decisions?

Are we taking right action when we detect the fish? Is right action turning water and letting fish die at that location (Clifton Court Forebay)?

How about increasing exports when detect fish?
Research shows we should do that.

We're not thinking outside the box enough - we're waiting until fish

DCC closed during Jan. Some interest in operating DCC to refresh system but need put in a barrier, potentially losing fish. But different flexibilities due to conditions. E.g., in 2015, DCC opened to let flow in because of drought.

Like idea diverting fish into Sutter and Steamboat instead of keeping out of Georgiana. Seems more feasible to move fish into channel rather than out. NMFS did adult tagging study found over 35% adult using Sutter & Steamboat.
Why do fish do better in Sutter & Steamboat? Both meet ship channel? Better habitat condition, shorter route, more direct than Sac R. Hydrodynamics of area. Tidal flux. Delta smelt do well in shipping channel. Maybe because of exports out of Cache and Liberty and bypass. Generally better place for fish.

Has anyone understand what we know about changes in hydrodynamics and fish wrt differential pumping?
No studies showing how this preferential pumping regime may affect fish. (Michael George)-90% of water goes to Grant line canal sucking into pumps. When you move water tank to CCFB change dynamics of this area. Dead water. Cut becomes giant suck. More you put at Fed pumps more hydrodynamic impact.
Study needs to be timing specific; can't do it when listed fish moving through.

Are decisions made based on time of Day?
No. Diel migration patterns of salmon populations. Signal attenuated in Delta compared to SJR but still some signal. Could think about in Delta is managing pumping to minimize fish intercepting. For salmon evidence during day will intercept less. But, diel movements

These are affected by many variables. When you look at scale of indirect effects, huge. Sphere of influence of operations is big.

Tracy fish facilities: not operating way designed (max exp at 4200 cfs to increase efficiency of louvers). But are you pulling more fish in as an indirect effect of that. More known what's going on at fish facilities but do not know what's going on outside.

Enormous amount of telemetry data but no organized. Not useable and available. Gold mine of information that uncapped.

Something we've overlooked: state and fed projects have upstream facilities and these affect Delta and tribs.

Moving forward thinking about how to consolidate and make it available.

DREAMS project is step in right direction. Hard infrastructure. **How do we bring all the studies that have done and how to bring into database so accessible?**
Biotelemetry PWT people can put in central location to access.

Acoustic telemetry lab—lot of good info for Georgiana Slough X channel. But (?) few fish got to south delta to inform management decisions.
For Georgiana Slough and DCC

SJR fish should inform OMR.

Can't really extract ops at facilities from ops as a whole in terms of reservoir releases, magnitude of inflows into Delta and hydrodynamics.

OTHER OPERATIONS
External operations important. Not really represented in this question**.**

We know and can determine hydrodynamics influenced by ops with exception of flow splits at junctions. Varies in space and time depending on hydrology.

Where in Delta are we are seeing hydrodynamic changes?
Even if we fully develop way to detect changes, what are available bookends to existing hydrodynamics that can be changed?
Lots of "possible" changes, but these may not help fish. We'll get more accurate info and predictions but is this within paradigm fish will see recovery? Things we'd like to do are probably not possible.

Where are ops NOT changing hydrodynamics? If we hold constant things coming into Delta, where are ops not making difference?
Hydrodynamics affected at Jersey point but we don't know mechanics of how it affects juvenile salmon. Need to go back to mechanism.

Fish are there because they're looking for places to rear. Will show up in S. Delta and so the more pumping, more salvage. But

when you see sturgeon down, ops were pulling
combined facility is 12k tidal flux is 100K a day. Even with max pumping, not creating signal in SJR. In 80s pumped like crazy in January and Feb.

Kevin Clark found tides mostly impacting fish behave.

Issue for north bay diversion was Georgiana and increasing frequency of reverse flows…is it a real thing or will they pick one way or the other if we put a barrier in.

Depending on what side of the channel you start on, determines which way you're going. What are the survival on each of decision points.

Other areas we need to know about? More specifics?
Old and Middle river corridor leading away from facilities seems really rough and high mortality. We know there is a project effect there. So let's look at their behavior there.

Fish know where they are going. They are actively swimming. Not getting "sucked" or "pushed".

Is there something we are not considering about the fish?
Are they smelling something as they are coming down Georgiana? Are there cues in Georgiana like Sac River water?

How are "minor" management actions at operations affecting hydrodynamics of nearby channels?
Many things they do at operations is ad hoc. E.g. manage screens, head height-these are not recorded and monitoring these may provide some answers. Very knowable question and should be addressed.

If install a non-physical barrier at CCFB entry, how would it change entrainment?
Looked at barrier at radial gates but super expensive.

Where do we need more information?
I:E ratio. Combined with fish data because I:E too correlated. Hard to de-couple. E.g. at 3:1 I:E. but don't have data on how this is supporting fish migration. Hard question to decouple. Metrics using to manage but don't have a lot of information. Thought is more flow to ocean, higher fish survival. So higher I more survival
DCC, OMR, I:E are BiOp related. I:E specifically targeted for steelhead juveniles. But all data based on salmon.

Recapture recirculation-how does it relate to inflow effect?
Is this being included in overall management scenario? Not sure if they're doing the R&R yet.
Could be exploratory area for modeling. Could put particles,

in habitat structure by SAV. But maybe there's something to do with hydrodynamics. Differences in food flux? Ultimately juvenile salmon only make up small fraction of pred diet.

Peter Moyle said why Sac perch disappeared from wild because life history thing-when juveniles recruiting and rearing a little bit later than black bass, so bass juveniles eating the perch juveniles.

Nobriga predators paper: found at juveniles recruitment stage where black bass getting leg up due to them being able to survive submerged aq veg.
Could do hydrodynamic model or investigate SAV. May need to do independently. Don't see a lot of SAV in locations where you have historical dendritic network of channels that cut through tule so banks lined by Tule. Where you do see SAV is open flooded island mudflats like Franks tract, liberty island.

Pred study in SJR showed roving bands of striped bass changed with hydrodynamics in relation to bathymetry. Speculation of why they were moving.

Lots of money in hydrodynamics and fish behavior—why aren't we doing same with predators?
Hydrodynamic interaction with fixed habitat that's creating vulnerability.

We know exactly where in Delta ops changing hydrodynamics.

between tidal cycle and fish behavior? Lots of information but probably need more synthesis. **Are there scientific studies that could answer how should we operate?** Looking at physical/non-physical barrier at head of Old River. Found scour hole at head of Old River was a predator picnic. NMFS looking at what happening at scouring hole. Physical barrier better, doesn't confuse fish. Also predators would congregate around non-physical barrier (bubbles) and scour hole. **Is there a way to deal with channel formation of junction and re-channelize junction of Old River with SJR?** One of challenges is fish will fly through and behavior will change. Trying to build predator filter in array to determine difference between predator and fish. 2015 started using predator filter. But hard to tell and really subjective, so been reporting both with and without predator filter. NMFS using machine learning filter to figure out natural variability in fish behavior. Steelhead have totally separate behaviors. Diel behavior and how that relates to operations: Jon Bureau studies on DCC. But seemed benefits were not large from salinity perspective. If we conceptualize this as a way to	getting to pumps before turning knob. The reality is though, people in upper management are considering whole system. So changing one part will require adjusting many other conditions. WaterFix-facilities can be adjusted better. DELTA CROSS CHANNEL DCC was not designed for constant adjusting **How can we re-design DCC to be more protective? What studies need to be done?** Need to acknowledge that Ops down south have little influence on hydrodynamics in North Delta. Should look at tidal oscillations. DCC gates should be operated based on tidal cycle and flow coming down river. Not necessarily because it's "salmon season". Same at Georgiana Slough. Risk to outmigrating salmon different depending on tide. Could be a place where we could make a difference. Utilize Yolo Bypass more. Provides a shorter and alternative migratory route. OTHER OPERATIONS Whether Old River Barrier should be installed or not or any barrier. Need technical workgroup on HORB to look at footprint of structure and operations and determine when steelhead are in the river. **What is an effective way of monitoring steelhead entering Delta?** State Water Contractors trying to contribute support to fund study to better track steelhead in S. Delta.	could change depending on pumping schedule **Across the system, what will benefit fish?** If ultimately more fish get past Chipps, it may not matter how many fish get into CCFB /or may not reduce the number of fish getting into CCFB.		no good data to say what is probability of entrain in neighborhood of ops.? Not saying changing behavior due to pumping. Local effect. Indirect effect. DIFFERENTIAL PUMPING Should be looking at CCFB gates operations. How doing that at tidal phase. Tides are so huge, reverse OMR does not make a difference Exports not affecting because tides so big. Exports do affect location in Delta where tidal change occurs. What fraction of the day is ebb or flood can be changed by ops. If you get in South, fish figuring out where ocean is. If they are sending they are going towards ocean they'll go that way. If net flow is such that they choose to go towards pumps. Getting mis-cued. Mechanism is tidally average flow. Salmon wants to go down stage. As long as ops mimicking downstage, going that way. If physical mechanism involved in when behavior switch occurs. (another person) Don't think tidal flows is the cause. Think it's other cues. More physiological. Salt—much saltier in south. Again, mis-cues. **How are we changing salmon cues and what false cues are we introducing through operations?** RPAs are all about hydrodynamic effects. Also, salmon not only trying to migrate out but also to spawn. They might actually trying to be in south Delta. Fish in SJR		play around with pumping regime, and see what's going on. Have behaviors in model right now as caveat, but good starting point. Something we can definitely do. DIFFERENTIAL PUMPING salvage and ops esp for SWP. Current op rules is RPA action. When salvage trigger reached we have lots of fish in CCFB they're stranded already, so does not seem this strategy is beneficial. Difficult to implement with model. RPA should be re-thought. Switch export and SWP and CVP during high density of juves in Delta. Potentially reduce from SWP and increase from CVP. So fewer fish get into CCFB. And more fish salvaged at CVP instead. Did not go through with CVP operations.	Operations have little effect on the number of salmon that enter delta. **Under current BiOps. Need to understand when fish are entering, why and where, and how many. Once in Delta, how do hydrodynamics affect entrainment predator loss, etc**. If hydro include velocity profiles around predator hotspots, could provide information. What you can change in terms of operations like channel cuts, how over connected Delta is historically. **Are we using this information in management?**

test operations that would minimize entrainment. Temporal aspect of migration. NMFS has couple studies. Any data sets from table can be used to answer. If you vary your operations to have more adverse effects during the day can you test. Establishing patterns of when fish move and how this varies across system would be helpful. Could probably mine that from existing data.	Johnathan Nelson may be doing some monitoring analysis in Sac River. **Any data on when steelhead from SJ tribs move into SJR?** Screw trap data at bottom of tribs. Might be effective way to capture steelhead. Behavior very different from Salmon and Steelhead. Can't use trawl and screw trap to catch both. **What is alternative method to detect steelhead and what do you do with that information in terms of operations?** HORB makes sense for steelhead because their survival different. Is timing different enough to operate HORB? I:E REGULATIONS **Any evidence I:E a real benefit? If it is, how much of a benefit?** Benefits low. Without HORB, not much of a relationship; if HORB in, positive relationship between I:E and survival for Fall Run Chinook. But survival still low. I;E range is not wide enough. DIFFERENTIAL PUMPING AT FACILITIES Not evaluated how to operate CCFB radial gates: day or night, tides. Conceptual model of predator-salmon interaction at these facilities good to know about.			have to out migrate through delta. Part of them might be distributed in South Delta. More fish that show up at facilities from SJR than Sac R. **How are operations affecting behaviors? What drives behavior?** DIFFERENCIAL PUMPING Lots of good evidence that diff pumping could increase survival. Rebecca's latest paper has CVP having highest survival. When pumping high, fish move around louvers.			

Table 3: Condition, Behavior and Water Quality – *Rainer/Stephanie*

3.1 How is salmon condition and behavior (e.g. rearing, active swimming, lateral distribution within the channel, passive displacement, diel movements, energy expenditure, growth, timing of ocean entry, selective tidal stream transport, migration, routing) affected by water quality drivers (i.e. Temp, DO, primary productivity, turbidity, salinity)?

3.2 How do operations affect water quality?

<u>Common Comments</u>

Agreed knowns:

- Temperature and turbidity in the Delta cannot likely be controlled at a magnitude that would prove significant changes in salmon behavior (directly or indirectly) or stressors impacting fitness and survival (with the exception of localized benefits outlined in the second bullet in the last category below)
- Different non-integrated program- or project-based monitoring efforts currently in place need to be evaluated in the context of questions related to salmon resiliency efforts (e.g., are their overlapping management questions among programs and projects that could be addressed with appropriate sampling and assessment designs?)

Question 1: **How is salmon condition and behavior affected by water quality drivers?**

- We know a lot about conventional WQ constituents, but they haven't yet been synthesized or put into context with biological data (abundance, biogeochemical, telemetry data, as well as other WQ data and data from agencies generating data for their own operational needs)
- Need to better link field to lab data (practical application of studies)
- Olfactory influences from hotspots of contaminants in the urban areas during runoff periods that influence migration behavior and fitness (e.g. predator avoidance behavior)
- Salmon behavior could be affected by olfactory ques and gradients (few if any data yet-telemetry and caged fish experiments)
- What WQ differences may influence lateral distribution, and how could they affect channel choice (outmigration choices)-not much data associated with that yet and activities vs navigation
- Certain WQ constituents can likely affect the entire life history, esp if at a critical life stage, but
- Need a better way of separating rearing vs conveyance areas of the Delta
- When do salmon lose their path?-opportunities to do data-mining

Question 2: **How do operations affect water quality?**

- Operations affect WQ parameters (primarily salinity and turbidity) directly and then salmonids indirectly
- Operations affect what water mass dominates (SJR vs Sac) during different times, but not much work has been done on this yet. Analysis and synthesis of existing data and inputs into behavioral models

New and different comments

Related to question 2:

- State Parks may be able to control effects-beyond DO sags and the SAV and FAV pesticides themselves
- Ground water recharge – instead of direct discharge of "hot" water from ag fields, urban surfaces, etc. Goes through constructed wetland, recharge, and other appropriate BMPs and may reduce temperature and contaminant effects before getting into system.

Table3: Group 1:

How is salmon condition and behavior affected by water quality drivers?

1. **Directionality** and them telling where they were going (not physical habitat and food). We don't know how they navigate the Delta once they get there.
2. How will WQ affect **distribution** as opposed to physical habitat or distribution across the channel when flow may take them a particular direction?
3. **Olfactory cues** – it takes 1 month for them to recover from Cu exposure, and contaminants can cause them not to respond to **alarm signals** (e.g., blood) after exposure. This is a major gap for basic research – linking it to route choices and successful outmigration. The need to know actual responses and effects of those responses is a gap so large that we can't synthesize anything.
4. Prioritizing integration of WQ effects with other stressors – not just synthesis by topic (which has been done), but synthesis among topics (among synthesis efforts) to really get at our knowns and unknows.
5. Need to keep conceptual models in mind and identify linkages.
6. **Routing** (assuming they have a choice and ability to "touch" both options then move to what they want – this only matters if there's a difference between different options) – turbidity (providing a feeling of comfort where they have adequate turbidity and it may be more/less important depending on life stage – more important to fry than smolt), salinity (less so because it affects their distribution more for depth than for lateral distribution), contaminants (depending on time of year). Contaminants and temperature will affect **out migrating smolts** and gradients will help fish decide to go or stay so temperature would be very important.
7. UCD study with low DO showing fish growing really well, so DO is less likely an important factor.
8. **When they decide to move** – WQ could determine if they go upstream or downstream, then a flood or ebb tide might push them a certain way because of their location (duality of choice selection and flow force acting on them).
9. What is the relative contribution of cues from water coming at them downstream? Choosing between salinity and other gradients (linked to 3).
10. If there's a WQ factor that affects **lateral distribution**, it would be important to know, but it's unknown how we could control the WQ to manage this (part of 2).
11. Need more monitoring and synthesis along with data mining to see where to go next.
12. Flood/ebb tides and strength of tides could affect WQ. The fish's familiarity with environmental cues may make them **continue with that pulse**, but if a water gradient is very different, the difference may scare them into a **holding position**. Also consider that up until then, they were trying to get *away* from what they know, so why would this make sense? If the gradient change is so great, it may be plausible.
13. Take home: **WQ is affecting their activity and navigability**.

How do operations affect water quality?

14. Operations will affect **temperature**.

15. Operations affect **residence time** and could affect contaminants. Possibly negatively affecting things in **localized areas**, creating places we don't want them to go.
16. Effects on **primary production**.

<u>Table 3: Group 2:</u>

How is salmon condition and behavior affected by water quality drivers?

1. Major gap – **olfactory effects**, connecting lab to field (how do we "see" fish responses in the field (are they dropping and hiding in the presence of negative cues?). Scaling up won't happen until we know what all the fish are doing.
2. We should pair telemetry studies with caged-fish studies to know what they're experiencing in real time and look at swimming behavior (what are the proportion of WQ effects on the salmon and predators?). What's **prompting** the fish to go one way vs another? Needs to be paired also with other disciplines. We need to do the in-between part better of connecting lab to field.
3. Linkages between the different drivers (temperature, predation, bioenergetics, DO) need to be teased apart with ex situ studies where you tweak the WQ with instream water coming in and out (decouple them and identify key factors with long-term trend analysis).
4. **Routing** – in order to really understand this, we need another capture route to study, and in many cases, there isn't a good comparison capture route at each end of a junction.
5. Temperature on **bioenergetics** and on DO.

How do operations affect water quality?

6. Temperature is driven more by ambient air in the Delta, so maybe managing temperature is not the best bang for the buck – even if holding (cold) spring water.
7. **Residence time** – faster moving is reasonable management according to models. Tidal overpowers riverine
8. A ton of work has been done on how operations affect WQ, so we need to identify and synthesize information on what we don't know (how does salinity affect fish behavior, physiological effects (ATPase work)).

<u>Table 3: Group 3:</u>

How is salmon condition and behavior affected by water quality drivers?

1. We need a synthesis of currently collected ancillary WQ constituents. Are they being collected in the right locations and times? Probably not because they can't be collected at the frequencies we need for fish. They're collected to answer regulatory questions, not understand effects on fish and their behavior/condition. Delta juvenile monitoring data isn't used enough. We should look into it more and link it to WQ data we already have. Start with beach seine data (rearing) and temperature and see if it's what the modelers are using. We don't even know if the proxies they're using are the ones we *should* use.
2. How can compliance monitoring be evolved to better answer management questions? Structured decision making should help this. As a community, we need to say these are the things we need to understand and see what we need to know to get that. Instead of fixed sites, can we just look for fish and go on from there (use more types of monitoring like in shallows)? Older sampling methods just aren't catching the fish anymore, so we need to look at other methods. There might be low-tech options that are better or worth exploring.
3. This is primarily a fish biology question, when we look at what or how to monitor, can we get at these questions?

4. Gap – Biologists don't know **how fish determine where they want to be** (where to get food, what they want/don't want). What WQ parameters tell a fish when it's **done rearing** and it's time to move on? It may be best to do this research concurrently with modifying compliance monitoring, but it doesn't make sense to change monitoring until some of the missing pieces of how the biology relates to those variables is addressed. We need to understand the preferred WQ of target spp, and also their predators (are we making the environment better for non-natives or predators over salmonids? What is the relative benefit, do they have opposing effects, etc?). We need empirical data for what they like.
5. Gap – Biologists don't know where the fish are, what they prefer for what (something during rearing may be less important at another time). Can we improve the arrays to better answer these types of questions? How do tagged hatchery Winter Run, Fall Run Chinook, and others move through the Delta? Is it too fast to matter? Should we spend time on understanding the older fish? It has been thought to be more worthwhile to study fry and smaller fish up until now.
6. How do we get fish to restored areas and then off when they're done?
7. Habitat to occupancy models need more work so you can get at presence/absence as well as abundance.
8. The differences between the SJR and Sac R should be explored. Proliferative Kidney Disease (caused by the parasite *Sphaerospora* in cultured and feral populations) on the SJR is worse at certain temperatures and can then give fish a secondary **infection** that kills them. This may be more of an issue on the Merced.

How do operations affect water quality?

9. Temperature can't be sustained by any water operations in the Delta.
10. **Turbidity** restrictions may be controllable with operations, but how do we balance between Delta Smelt and salmon?
11. It's unknown if operations can really control **sedimentation**, especially for sediment augmentation or chlorophyll augmentation.
12. **Salinity** and turbidity can be affected by operations.
13. What are the effects of DBW control efforts beyond possible DO sags and introducing contaminants?

<u>Table 3: Group 4:</u>

How is salmon condition and behavior affected by water quality drivers?

1. DO could have a big effect but doesn't in the Delta.
2. We don't want lab studies that can't be well connected to management in the field. The parameters listed aren't the ones we need. We need to know **why fish do/don't go in certain places** – integrating WQ with their behavior. If they're **impaired as larvae**, they are likely impaired for the rest of their lives. Maybe look at how WQ **leads to disease**.
3. Cloern and Lucas study showed that when the pumps are shut down, the difference between the SJR and SR dominance changes. We should study more of those types of rapid changes. We should be looking at major changes over the more typical or subtler changes. Tides already make things variable for fish, so they aren't likely following subtle cues.
4. Contaminants are creating many pockets of hot spots spatially and temporally. The degree of contamination of SJR water vs SR water (Se issues and pesticides) is important. The tunnels would cause a shift toward more SJR water to Delta.

5. Pumping schedule, productivity, and fish size all changed in the early 2000's. **Primary productivity influences condition** probably more than behavior. Is the Delta a conveyance place, rearing place, or other for salmon?
6. We should rank WQ drivers like temperature and turbidity to things like **rearing** and high **productivity** that affect behavior.
7. In 2017, as a high temperature and high flow year, there was a lot of food. Juveniles were the **slowest to move out** (almost twice as long as other yrs), so maybe there was something good keeping them there.

How do operations affect water quality?

8. What are the differences between the north Delta vs south? We should be test hypotheses with the Freemont Weir and how many fish go over it when it overtops (80% of fish that ended up there, came from the north – Pascale and Russ Perry for follow-up).
9. Operations aren't affecting conventional WQ parameters much.
10. Operations could affect WQ for **contaminants**. We could use fingerprinting data to determine the proportion of each kind of water reaching the facilities (different source waters have different biogeochemical properties) and see how those affect primary productivity. Primary productivity is related to **condition** more than behavior.
11. Operations could affect inundation potential and affect productivity differently in shallow water vs when it's deeper.
12. What are the biggest synthesis payoffs?
13. Routing water differently could affect **turbidity** and their behavior. This hasn't seemed to pan out as well as scientists have thought they would in past (2-gates). Turbidity is ecosystem driven and may be important at a scale larger than we can manage. The large picture is beyond what we can control.

<u>Table 3: Group 5:</u>

How is salmon condition and behavior affected by water quality drivers?

1. PAHs and Coho – **spawning impaired** in Pac Nor West study.
2. WQ affects them in small areas where there's a problem like Stockton DWSC.
3. With things like salinity, PPCPs, and MeHg, it's hard enough to determine their effects on fish condition, let alone single out the effects of individual constituents.
4. Lab studies are missing logistical field effects. We need to identify where there are more issues to see if the fish are getting particularly stressed in certain areas (can't skip the synergistic effects).
5. There are so many different inputs (storm water, etc that aren't part of operations) that have major effects on WQ.
6. **Indirect effects and synergists effects** are poorly understood.
7. Fry life history might be the most important to study because they spend the most time in Delta during that stage and we should focus on **food** studies then.
8. We should prioritize what's actionable.
9. We need telemetry data analysis across studies to look at WQ, and we'll need to smooth out data quality issues to do this. How do we link WQ to biological data?

How do operations affect water quality?

10. Do pumps **draw nutrients** from one area to another? Can we look at SAV to learn more?
11. Rice fields drain then you get huge **blooms** with increased residence time.

12. Temperature and reservoir releases – Stanislaus management can make it to the SJR even though it's very influenced by air temperature, but that's about it.
13. **Ground water recharge** – hot water from ag field, goes through and gets cleaned before getting into system to manage temperature and contaminants.
14. Retention basins – sand or plants can be used to **bind contaminants**.
15. When working with the current hydrograph, we need to consider how things change when going from shallow and wide to narrow and deep.
16. Can we mimic the natural riverine hydrograph to take care of **invasives** (esp if we don't stay so bound to X2, since so many invasives are lake spp that are doing well in the Delta now)? What are the salinity tolerance intervals for many of these spp? Can we get enough fiscal benefit that we can offset the farmers to allow for salinity to come in during the summers?
17. We need to know more about the Head of Old River Barrier operations and its effects on WQ (outside of salinity and DO).

<u>Table 3: Group 6:</u>

How is salmon condition and behavior affected by water quality drivers?

1. Stew _ and Corey Green from NMFS used beach seine data to look at things that co-vary. The timing of Delta arrival is affected by a group of conditions, and they stay longer (high flow = rear longer). Winter Run movements during drought showed they enter the Delta at smaller **sizes**, so there's a large-scale difference in WQ. We can't tell if the difference is due to older vs younger fish or due to other reasons. It isn't due to the arrays missing them at higher flows. In years where they enter at a smaller size, the adult returns are smaller (proportion of juveniles to adults is unknown). It's unclear if mortality (condition) is due to entering the Delta or their time in the ocean (there's a SAIL effort to count fish coming in and going out to help address this).
2. We should start looking at isotopic ratios more.
3. We need to start pairing real mark-recapture (not CWT or acoustic tags) data with WQ data and on a fine-grain scale.
4. A lot of contaminant effects are still **unknown** especially from nonpoint sources and how hydrodynamics effect contaminants.
5. **Queuing to move or do activities** can be affected by WQ. We need to decouple turbidity, temperature, and flow effects on fish.
6. The **components of salinity** are different for different water sources and may be important.

How do operations affect water quality?

7. Temperature is **residence time** driven. Mildred Is got even warmer with management, but Suisun has colder water plus a higher water level so if it's managed at night, it might work better. This wouldn't be as controllable in the Delta as in Bay though.
8. Habitat restoration – we should try to get high tide to be where it can make a **deeper** water column as a way to manage **temperature**.
9. Operations can affect salinity in the Delta, so we should see if changing **salinity gradients** affects how salmon queue/cue (change timing).

<u>Table 3: Group 7:</u>

How is salmon condition and behavior affected by water quality drivers?

1. Temperature is very important for the egg stage, then for juveniles temperature increases **metabolic demand**, so you really need to know about food availability. Is temperature an issue in Jan-Mar when it's most important for them to find food?

2. Olfactory cues for **routing**– what makes fish choose Georgiana Sl? Is where they are in the tidal cycle important? Do these make them choose one route over another? What about for fry Winter Run?
3. Turbidity as an advantage for **predator avoidance**. The enhanced particle tracking model needs more turbidity data and pairing with telemetry data to better inform this.
4. **Pathogen load** with increased temperature is always an issue but hasn't been identified in Delta yet (but the ones in river may already be dead).
5. We lack contaminant studies for salmon in this system, maybe because they're here for such a short time
6. DBW management effects are unknown. Their controls are primarily in the summer and fall, so they may not be during a time frame of issue.
7. Primary productivity at fry **rearing** habitat is unknown.
8. Salinity changes and X2 along with velocity and depth may be important for fry habitat modeling for rearing, which then touches on restoration goals (DSM2 qual – it's unknown where they got the salinity for the rearing model-Eric Danner for follow-up).
9. Salinity changes due to ag vs ocean may be important – we should use isotopes to differentiate them.
10. All WQ aspects are important for a functioning ecosystem, but how do you prioritize? There are some conceptual models that have been minimally tested and probably many mental conceptual models that haven't been supported by data yet.

How do operations affect water quality?

11. *(didn't get to this)*

<u>**Table 3: Group 8:**</u>

How is salmon condition and behavior affected by water quality drivers?

1. We should evaluate current stations for monitoring vs areas where we assume fish are.
2. Temperature tolerance isn't good with dewatering, with DO, flow, and turbidity.
3. We need pesticides and Delta-specific studies to understand **sublethal effects**, learn more about **olfactory cues** for navigation or imprinting, **food web**, and other binding issues.
4. Storm water effects to Coho study – we need to duplicate it for Steelhead (synergistic effects of mixtures), possibly important in Stockton and a bit in Sac. The Port of Stockton had a complete loss of tagged fish (**mortality** was not caused by low DO), but we don't know what really happened to them.
5. Turbidity on **predation** - the Delta is clearer now, but tolerance range is 1-20NTU. Refining this range would be helpful for different salmon populations and for other spp. Are types of turbidity important? We should look at big turbidity events.
6. **Sublethal** effects are a challenge to address due to their subtlety and diffuse sources.

How do operations affect water quality?

7. Instead of piecing out the chemical at fault, it may be better to just figure out how to retain them or hold them back.

Table 4: Flow Metrics and Thresholds – *Katrina/Caren*

Several independent scientific investigations have found that average flows (or average velocities) in the tidal Delta lack a mechanistic basis for influencing the behavior of juvenile salmonids. For example, the SST concluded altered channel velocity and altered flow direction were the only two hydrodynamic mechanisms by which water project operations could affect juvenile salmonids.

4.1 Is there a channel velocity or flow direction threshold at which salmonids change their migration behavior or routing?

4.2 If so, what is it, how long must it be sustained, how frequently must it occur and would the change in behavior or routing be observable in an acoustic telemetry study?

Table 4: Group 1: Joanna Lessard (CFS), Li Ming-He (USFWS), Eric Chapman (ICF), Bill (DWR), Sheila Green (Westlands WD), Cyril Michel (UCSC/NMFS)

Change in velocity of 0.1 would have a big effect or not? We don't know when change in velocity is an issue. What are the minimum thresholds. Georgiana slough, turner cut,

Flow not velocity is what is impacted. Not flow, it is velocity.

Survival – other variables that correlate with flow , but not so much if we're talking about movement.

If only one channel that we care about. Intertidal area along a long channel. Predator exposure in a tidal area. Tidally influenced zone and junctions. Downstream of the facilities and OMR. Anything that keeps flow from being close to zero or negative is a threshold. Issue with that Is that this area is tidal so they get influenced by tidal.

End goal is to go out to ocean, delta gets lost. Fish like to be in same velocity…so if velocity changes they try to follow.

If come in when there are lots of predators, they are holding out hiding. Has nothing to do with velocity – but lots of interactions!

Probably a threshold – dependent on tidal flux and inflow as well as junctions, it depends. Have at each junction, have stage (incoming and outgoing) and in flow, exports. Have 4 graphs for each junction.

To get at 4.1 – laboratory studies to control flow types at each junction. Then tag study.

How cross channel distribution of fish changes - critical streakline analysis – how that streak-line shifts across channel like USGS. Huge investment. Pick the most upstream channel that has the most mortality. And if the cross channel does affect. DWR.

Nearfield tagging study - tag fish and putting them near the facilities and changing exports, tracking movement and how they move and their fate with SCHISM modelling – Cramer and DWR prop 1. Vemco pdat tags, spring run

Ton of acoustic telemetry data that exists – take advantage of the existing data. Russ Perry – early 2000 – fish move into different channels.

Army corps has model that has decision framework for determining movements of fish in Fremont weir. And were able to predict behaviors that ere representative. ELAM model.

Yes there is a minimum threshold but it depends. Use a simulation model

Ed gross did 100s of runs for Delta Smelt– could we do this for salmonids.

Learn from each other – Delta Smelt – very important tidal surfing. During high tide they move into instream. Ebb tide they stay and don't go back- they have some mechanism to know this.
Try to understand in channel near facilities.
What is the proper scale of study that we need to understand. That can be scaled up with money and fish. Modeling is getting better – could understand ft/sec change per channel.
Percent change in velocity what the fish is actually encountering.
Understand coarse mechanism at reach level – identify hotspots – coming up on a stage.
Routing questions have to be more fine scale over tidal cycles, those studies are expensive. Releases – routing probabilities.
Fish releases 4/5 times a day over the week several weeks, in the spring, several years. In a big water year some of these thresholds might not matter as much.
We need to work with the facilities.

Table 4: Group 2: Nobel Hendrix (QEDA), Arnold Ammann (NMFS-SWFSC), Michael MacWilliams (Anchor QEA), Ken Kundargi (CDFW), Rene Reyes (USBR), Brett Harvey (DWR)

Fish size that are going to be orienting completely different. Smaller fish to be moving – depends on where they are in the stream. If they are on the edge or in the flow field. Larger fish tend to orient to the center of the channel – huge interaction with habitat – rip rap channels they go back to the other side – zig zagging behavior. Diel movement with tides – differently at night than during the day.
Difference between wild and hatchery – important to management.
Threshold effect on turbidity – could have effect on fish
If turbidity increases to a certain point then they are more prone to be in the middle of the channel.
Average flow – net metrics out of a huge flow. Fish might not be responding to that. Thresholds to average flow might not be useful.
Flow direction threshold – flood vs ebb.
Turner cut, Georgiana slough, dcc,
To find a threshold, then if exceed that, then can pump more. San Joaquin is less clear
Modelling could address that – DSM2 can do particle tracking.
Decision to make about flow in old and middle river – what is the flow velocity

- What would it take?
- What is the impact on operation – what is the mitigation to mitigate for these metrics.

If there was a clear diel pattern that we knew about it might help tailor flow impacts of moving water in an unfavorable conditions, pump during the day or pump during. Water turbidity increased – less diel movement. Paper on this
Decide when to pump, when to divert, day v night. Can at CVP but not SWP…
Flow threshold effect can be teased out with AT data?

> Not using AT data – RBDD outflow movement with flow events. – less clear in the delta. All the channelization due to ship traffic – tidal movements completely swamp inflow in the South Delta. Changed drastically from historically. Suisun it was attenuated historically. Forcing all the channels to have more tidal movement because of no marshes.

Is there a velocity threshold – don't have this evidence
Dense receivers around the facilities – Prop 1. Predator detection used here.
Changes in velocity, flow direction – previous OMR and Georgiana Slough studies –there is data on that.
Ask Russ – look at the role of the different flow on different covariates – change point analysis models?
Fitting a smooth relationship, but could fit more complicated models with breakpoints, thresholds.

Table 4: Group 3: Lauren Hastings (Delta Council), Josh Israel (USBR), Kristin Towne (USFWS), Russ Perry (USGS), Brad Cavallo (Cramer Fish Science), Steve Culbertson (IEP), Shara Ainsley (FISHBIO)

Dead end slough, different than in an flow through channel different behaviors
ePTM – fish are migrating slower in different riverine sections, but faster in the different tidal sections. Strong support for selective tidal stream – move on ebb tides, that is how they move faster than the average velocity. Estimating in that model what threshold they are beginning to hold at. Slightly positive velocity that they hold on ebb tides – the acoustic telemetry data. Selective tidal stream behavior. Holding on flood tides and moving on.
Riverine section where water is going water – when going to tidal setting change. When start diverting water from delta – 50/50 in delta – one way on the flood – potential to affect fish movement. How much more negative than half the time does it have to be. If always going towards the facilities. Where is the other end of that – if going the wrong way.
Facilities to take the water when the fish are expecting it to go that way. Don't have facilities that can change this –can we change operations at facilities? Tidal basis of facilities.
Where in the delta – main stem San Joaquin – 50/50 always. Further south.
Migration rate should be slower in tidal section –TIDAL regions but faster than the net water velocity. This is in migratory fish, what about rearing fish. What about other thresholds that are creating behaviors.
Threshold in the channel form – routing question solvable using physics. Every junction is different because driven by geometry at each junction and tides. Georgiana slough keep the tides from reversing because that is what drives entrainment.
Fish effects in a tidal environment – but almost impossible to observe – is it something to manage to?? Brad would argue that it isn't
At a certain junction – slack tide when velocities are zero. How long that occurs – radial gate, dcc, duration of slack tides at locations and how that affects behavior of fish. Velocity is zero go find some cover. Duration of that probability of fish changing behavior.
There is a change in AT data – swimming faster in change in behavior.
Is it related to duration of slack tide – amount of time between some thresholds – does it different across delta.
Delta smelt – 100s of scenarios what potential mechanism are affecting behaviors – changing temperature, turbidity, etc.
If you model them with any other cue besides that they are moving towards the ocean. Fish have navigational ability – they aren't at the mercy of the hydrodynamics.

Threshold – is when goes from tidal to reverse tidal, when it goes the wrong way. Maximum effect. Fish might think that upstream is downstream.

Table 4: Group 4: Elizabeth Appy (Anchor), Steve Zeug (Cramer Fish Science), Steve Tsao (CDFW), Jason Peltier (Sustainable Delta), Jennifer Pierre (SWC), Kevin Clark (DWR), Bob Clark (USFWS), Dick Pool (GSSA)

Changes in flow – DCC and Georgiana slough – Jon Burau and steam boat. – Jon coupled hydrodynamics
Survival and routing studies but are not coupled with hydrology
DSM2 data doesn't line up with gauge data – use actual measured data
Confined by biological opinions that we can't go out far enough to find a signal. Where can we see that there is an effect of water ops – water ops would have to be totally different?
Fish that ends of a steamboat might have lower probability of survival next year.
Release fish every day for 15 days to see where they go – this was powerful from Jon Burau study.
If can't measure the effect within the RPAs then why do we care? We don't know – not that flexibility around that. RPA is max limit – there must be some effect.
There isn't an effect under the RPAs. SJR fish – but what about Sacramento fish.
Fry are looking for somewhere to rear – looking for habitat to sit and grow so not necessarily moving with the flow. There are locations that there is a threshold. What do we do with that information – oh no – turn everything off. If catching fish at the facilities – turn exports up and salvage them – they have higher survival.
When exports are up you're not necessarily drawing more fish in – the projects aren't' affecting entrainment.
Where in the water column they are – panels at Georgiana slough assumed they were travelling at top of water column – that barrier was not very effective.
Don't make management decision that isn't physical data based.
Do we want fish to hang out in delta or not? Depends on which fish – Coleman fall run hanging out in delta. We need more data and what that habitat would be in the delta –inform restoration. Change the bathymetry in the delta.
What is the entrainment of fish at the facilities under different flow or velocities. Come up with threshold here.

Table 4: Group 5: Alison Collins (MWD), Pascale Geortler (DWR), Gabe Singer (UCD), Vamsi Sridharan (UCSC/NMFS SWFSC), Michael George (DWR)

Flow on the Columbia that looks at threshold – McNatt Astoria NMFS, Dan Bottom work pit tags on islands on the CR. Holding and then going back in a second time.
With ePTM – has been hypothesized but not necessarily
Elam model might be parameterized with reach specific survival through the Columbia.
Could alter velocities in an experiment - routing study. Fremont weir study.

Separation between scales – at small scale fish trying to avoid obstacles/feeding etc in flow. Large scale fish moving upstream and downstream, Need to bridge this gap.
Don't have ability to separate the movement of fish and hydrodynamics – decompose hydrodynamic flushing from actual swimming. – then you can start talking about true behavior.
Need finer scale studies and multiple releases that are diverse in release times. Release of fish within delta and track their movements within this.
Corey Phillis idea for a study - Hydrophone array at a junction tag a bunch of fish and see how where they go. Couple with ADCPs to get a good characterization of hydrodynamics at a particular junction – but what junction?
Cramer is developing an array on a boat …pit tagging gets expensive though.
Support PhD students to study these questions

Table 4: Group 6: Garwin Yip (NMFS WCR), Rusty Holleman (UCD), Mario Manzo (USBR), Jason Hasserick (ICF), JD Wilkert (USFWS), Eric Danner (NMFS SWFSC), Steve Hagerty (SFEI)

Ascending and descending flow spikes move these fish around – doesn't make sense to stay where you are. Depending on whether you're a smolt or a fry.
Conceptually intriguing idea – complicated by all those factors. Would have to divide the delta into regions to capture spatial variability? Flow threshold when you're in the tidally influenced area. Also need to consider predation presence or absence
What velocity influences routing of juveniles? Does it matter if it is faster or slower?
Create shallow water habitat on right side of stream.
Geometry of the junctions are important – very vulnerable to predators. Velocity threshold would change based on specific junction.
The fish aren't necessarily going down one way and then changing direction.
Is there a velocity that is going to encourage fish to go down stream vs encourage rearing?
We can change morphology – provide microhabitats so provide options.
Threshold in tributaries – to get water out onto floodplains – less important in Delta
Movement at night for juvenile fish analogy: It's like you're long distance driving and have no motel along the way so you keep driving… need resting areas one nights migration distance apart – resting areas, habitat rest stop, don't want rest stop overrun with predators or you would have to keep moving.

Table 4: Group 7: Frances Brewster (Santa Clara WD), Deana Sereno (Contra Costa WD), Maria Rea (NMFS WCR), Andrew Hein (NMFS SWFSC), Lisa Hunt (UC Berkeley), Dan Kratville (USFWS), Rachel Johnson (NMFS SWFSC)

Fish are reacting to the net flow – fish can tell what that is. Smolt - they think that is the direction they need to go
There isn't a magic flow velocity. Fish can't sense flow – OMR –they sense tidal flow over time. Test – pull together research looking at behavior in tidal systems.
Do they exhibit selective tidal stream transport?

Some vertical migration – what are the behavior criteria that determine whether they maintain position or go up or downstream.
Could do lab study in flume changing velocities to see influence on movement behaviors – has this been done? Delta smelt might have done this flume study
Need intensive tagging where they tracked lots of fish, vary exports, vary inflow
Influence of operations on other water properties (not going to have the same influence on water properties – not the same on different days). Varies seasonally and magnitude in different years.
Delta salinity is low – localized salinities in s delta are highly salty.
Focal group of fish are Sacramento fish that are trying to migrate out vs those that find themselves there. Couple lab and field - did they make one poor choice - what are the important junctions? Is it related to water ops or what other cues?
Where were they around the bend –they just need to not make that fatal turn.
Could do a post mortem of 2012 stipulation study – could get a lot out of this doing this again – but do it better (everyone hated it last time…).
Constraining the facilities is hard.
Slow velocities – shallow habitat. Rest refuge area. What small scale flow features do they use?
Outer junctions very small changes away from exports, get close to exports have more influence. Is it because of the velocity? What is the breaking point of velocity that they go a certain direction or not.

Table 4: Group 8: Peter Dudley (UCSC/NMFS), Javier Miranda (DWR), Mike Thomas (UCD), Carl Wilcox (CDFW), Rebecca Buchannan (UW), Matt Reeve (DWR)

Thresholds are scale dependent ….
Could look into Georgiana slough – then translate to system wide.
Predator removal study nodes that were a km apart tagged fish that went upstream and downstream.
Technology – closely spaced array near the facilities. DWR and Cramer fish study – Prop 1
In absence of predator tagging – have a trajectory have a baseline for smolt or for striper. Physical recaptures of these fish. Looked at behavioral differences to distinguish between predator and smolt.
Include tide stage and flow direction to determine routing in the 6 year study.
Assume that the fish just instantaneously feel something, but ignore that they accumulate long term stress.
Nann Fangue study looking at thermal limits

Table 5: Alternative Flow Metrics

5.1 To what extent can alternative flow metrics (identified in SST Question 5 as: Qwest; hydraulic residence time in south Delta; percentage of positive flow; proportion of CVP exports; and proportion of Sacramento River water at CVP/SWP) provide better management of south Delta water operations than existing metrics (OMR, I:E) intended to support behavior and migration that results in increased survival of salmonids?

Common Themes:

- Metrics depend on goals
  - Species, life stage, relative value of water, etc.
  - There is a desire to identify metrics that target/measure what fish are experiencing.
  - The physical metrics often time are not a good measure of a biological goal.
  - Move away from calendar based triggers and towards real time management (but this takes resources of time and effort)
- Fine scale modeling at specific junctions.
  - Current and some proposed metrics are fairly coarse in their resolution.
  - Some metrics I:E or Qwest can have the same number/value under drastically different conditions (issue of temporal and spatial scale?)
- Unclear what the effects of exports/operations are in areas of concern (east SJ area)
- There is limitation (real or perceived) on the ability to experiment with metrics and operations (due to regulations, species status and water demand)
- Improving our "learning mechanisms" by paying agency folks to publish.
  - Easier to justify policy decisions based on published research
- A number of the metrics being considered are similar (driven by San Joaquin inflow) and some are difficult to measure or manage to.

Group discussions – conversation highlights:

Themes to numbering system:

1. Biological basis
2. Scale and scope of metrics, fine scale, real time scale, season dependent
3. Proposed experiments (more fine-scale experiments, for example)
4. Experimental hurdles
5. Discussion of proposed metrics
6. High-level (management) considerations
7. Metrics depend on goals
9. In-delta rearing vs flush them through

Table 5: Group 1 (Noble Hendrix (QEDA), Arnold Ammann (SWFSC), Ken Kendargi (CDFW), Bob Clark (USFWS), Michael Macwilliams (anchor QEA), Mike Thomas (UCDAVIS), Carl Wilcox(CDFW), Mike Reeve (DWR))

1.Are there possible metrics representative of what fish are experiencing? A lot of times there is no observable relationship between conditions and survival. Acoustic telemetry can provide a direct link? ← can calculate survival from entry/exit.

2. Proposed Experiment: fine scale reach specific survivals under different flow conditions.

5. Tides are overwhelming (bigger influence/impact). But the tides have always been there for millennia.

6. Solution: Higher survival through the facilities. ← facilitator: "not a solution"

2. Exposure time is critical (hydro residence). Shorten the residence time to increase survival. Tides move fish back and forth but Qwest doesn't capture the effect of how much actual movement there is. Doesn't capture exposure? Need to address that question. Lots of variability within a "net" measurement.

3. Particle tracking model with added behavior. ePTM, or "agent based." Current PTM has a lot of assumptions → need to validate based on the telemetry, otherwise the model will "self-confirm" assumptions.

6. The challenge is also "how it can be used" what does this mean for water ops.? Can we experiment?

6. WIIN act "basically, can we modify OMR during storm events" – CDFW lot of fish based triggers. Also when is OMR controlling? When can you pump (during storm events)? CDFW (Ken Kundargi provided example) comparing some different measures (metrics) to determine when a flex is "ok" (based on the past). Goal minimize salvage but **is** salvage a measure of fish survival? (indirect mortality vs. direct mortality)

9. Different flow metrics for in-delta rearing (as opposed to rapids outmigration where you want to increase flow to "push" fish out).

2. Metrics need to consider season and temperature. Acoustic tag results in delta pretty consistent (for hatchery WR) ~30/32% → good season? Temperature (increases predation driven by biological demand)?

Table 5: Group 2 (James Newcomb DWR, Josh Israel BOR, Russ Perry USGS, Lee Ming-he FWS, Steve Culberson IEP, Brad Cavallo Cramer FS, Joanna Lessard Cramer FS, Shiela Green Westlands)

2. OMR I:E are very course on a spatial temporal scale.

2. OMR is a generalized metric not specific to a location (maybe we should consider site specific metrics? Or tie the metric to a desired result)

2. OMR is a legacy metric for delta entrainment of Sac fish. (doesn't really help SJ fish) Need to "test" but there is regulatory resistance to that test (uncertainty for the species).

5. The updated models show export is a better predictor of salvage than OMR. And export is easier to calculate.

5. OMR is based on salvage which is not related to survival (for salmon) (discussion: it does contribute but maybe only a little bit)

5. Qwest: measures same things but larger volumes of water.

5. Is there a metric that can capture some of the influence of predation/mortality hot spots? The problem is some of those spots are not really affected by operations (e.g. tidal SJR)

2, 5. Questions re: hydrodynamics in the tidal estuary low impact, or course metrics don't capture the complexity of the system.

2, 5. Consider operational/management "footprint" when a metric is applied what does it influence? How does that effect a fish.

4. Outdated facilities limit questions that can be asked. Also management (permitting) and water demand constraints.

5. Proportion of export between facilities, or proportion of Sac water (or flip it to proportion of SJ water since that's the driver)

Table 5: Group 3 (Rene Reyes CVP fish facility, Steve Zeus CFW, Brett Harvey DWR, Dick pool GGSA, Elizabeth Appy anchor QEA)

3. What about flow splits and critical junctions? Until habitat is better really just trying to "push" fish through. → mainstem SJ (for SJ fish).

5. Percentage time of positive Old River (or another critical reach). More positive velocity. Need to look at behavioral response. Percentage of ebb/flood.

5. Percentage of Sacramento River at facilities: questionable at this point dependent of water quality effects on migration. Need baseline understanding.

Table 5: Group 4 (Gabe Singer UCD, Kristen Towns USFWS, Lauren Hastings DSC, Vamsi Sar SWFSC, Alison Collins Metropolitan, Shaara Ainsley FishBio)

5. Percentage of positive flow, pumping during the ebb creates larger footprint.

2. Residence time in the south delta, but need finer scale. Location specific. "what is meant by south delta" "great promise" but how do you study this? Validate? Less time better survival but… more time might be rearing. → very different results/uses depending on life strategy and "where"

5. Tools we have may not be adequate to utilize these metrics, or even understand them?

5, 9. All metrics are trying to achieve the same things and are based on the assumption that fish move with flow. Should we consider something else. E.g. metrics that target an amount of habitat?

5. Proportional exports from CVP are there other constraints to prioritizing CVP exports over SWP?

Table 5: Group 5 (Kevin Clark DWR, Steve Hagerty SF estuary, Jennifer Pierre SWC, Eric Danner SWFSC, Steve Tsao CDFW, Lenny Grimaldo ICF, Jason Peltier, Coalition for a Sustainable Delta)

1, 5. Percent positive flow: Too rigid, what is a positive flow for? → needs to be behavior based.

1. There is a biological basis but it is pretty crude (coarse) so not very management appropriate → RTO and monitoring.

2. If they're not manageable in real time they're not useful. (daily, weekly → mgmt. perspective)

6, 5, 2.Problem: operational lag → any metric needs to acknowledge the delay

1. Link any metric to biological significance

1. Targeting a desired condition as a management metric

1.Alternative metrics (not listed) are resource (time and money) intensive

6. Lack of learning mechanism → pay agency folks to publish in peer reviewed?

6. Easier to justify management decisions on publish lit.

6. Learning is more important than report for obligation only.

6. Needs to be more emphasis on learning and improving, or one should lead to the others.

Table 5: Group 6 (Maria Rea NMFS, Pascale Goertler DWR, Lisa Hunt American rivers, Michael George delta water master, Andrew Hein)

2. Coarse scale metrics that don't relay information about species effects. Doesn't capture the variability.

1. Difficult to identify the use without understanding the linkage to the biological impact

9. Strong relationship with SJ flows and survival

5. How would you manage to channel velocity?

Table 5: Group 7 (Jassen Hasrick, ICF, Garwin Yip NMFS, Javier Miranda DWR, JD Wikert FWS, Peter Dudley SWFSC, Rebeca Bucchanen UW, Rusty Holleman UCD, Mario Manzo BoR)

5. Proportion of CVP is useful for "targeting" salmonid survival

9. What metric you use depends on want your goal is: salmon survival, rearing habitat creation (availability).

4. Not a lot of good data for the tidal region, so difficult to determine what conditions are needed to get fish through that region.

6. I:E 4:1 is that too much? Not enough, too restrictive? Could there be more flex in I:E? Maybe ramp down during periods of fish movement.

6. All regulatory decisions should be made in the context of experimentation

1. Metrics need to be more biologically meaningful but also flexible

Table 5: Group 8 (Cath Marcinkevage, NMFS, Dan Kratville, Eric chapman ICF, Ron Melcer, DSC, Bill Mc… DWR, Cyril Michel SWFSC)

5. Qwest difficult to manage to because signal to noise. → "I thought we were moving to a mechanistic metric"

5. Looking directly at exports?

6. SJ flows are ignored because "they can't be controlled"

5. Hydraulic residence time: need to define residence time → same as net flow also not as feasible

5, 9. Residence time matters because of habitat quality.

Table 6: Biological Response Metrics – *John/Joe*

The SST identified eight biological response metrics that would be useful for assessing the effectiveness of RPA actions. The metrics included:

a. *Proportion of test fish at specific channel junctions that enter the Interior Delta;*
b. *Survival within specific reaches or to specific locations within the Delta;*
c. *survival through the Delta;*
d. *Condition of fish sampled above, within (at salvage facilities), and below the Delta;*
e. *Proportion of returning adults that display extended Delta rearing as fry based on otolith analysis;*
f. *Predicted risk that a juvenile salmonid would be entrained at the export facilities based on models;*
g. *Percentage of direct (salvage) mortality relative to estimated population abundance; and*
h. *Abundance of salmon populations leaving the Delta, or locations further downstream (e.g., Benicia or Golden Gate bridge).*

6.1 Are any of the metrics listed above more effective than what is currently used to manage and assess the effects of water project operations on salmonids?

<u>Table 6: Group 1</u>

The focus of this question is on Delta

Survival metric within reach and overall covered- need specific to lifestage, travel time, migration rate, and residence time

Is this useful? Possible linkages to predator exposure, unknown relation to grand metric (through-Delta survival and abundance)

Having larger fish leave the delta objective? Individual response vs population response

Delta too constrained for overall model

B-E all good

F and G- entrainment based- the effect of operations may not be indicated by entrainment/salvage. i.e., high salvage, entrainment during low effect of operations on cohort (high abundance/salvage efficiencies)

Delta operations are linked to reservoir releases- which may have a contradictory effect on salmon (reservoir releases improve survival but may be related to more pumping and salvage)

Currently operating for episodic cohorts, not diversity portfolio

Can recreate condition during success with otolith analysis

Growth important metric- challenging to collect

Large scale PIT tagging and recapture to assess growth. Add PIT tag arrays in Delta?

G- managing for lower entrainment may be a poor metric for operational success

H- abundance-

Abundance at Salvage and Chipps- disagreement amongst group on precision. Good metric if methods are good.

Reservoir releases not tide to export during ‘excess’ conditions

A- few key junctions that influence survival
poor survival regardless of central delta junctions, n. delta junctions more important
SJR routing not heavily influenced by operations
Performance metric should be associated with retaining fish in n. delta routes

Biological metrics- through delta survival by life stage is a priority
Experimental designs to test different operational scenarios
There is a need for hypotheses for RPA objectives- measure effect of management action
OMR requirement- is there a better way to accomplish this objective?
Test OMR RPA with marked fish/flow experiment. Different run experiments
What is estimated abundance associated with G? Missing population metrics (entering and leaving Delta). Historic CWT models for salvage vs abundance
G- change to through facility mortality estimate
Priorities ?s- How many fish get to Delta? how many get to Chipps? how many go to salvage?
Overall survival or reach survival? GG most important, different actions necessary depending on flow condition
Relate reach specific survival to gage data, mechanistic fish response, routing probabilities
Individual condition vs overall survival- important/feasible? Permitting issues? Size has a big effect on survival, but not necessarily predictive for hatchery fish. Trawling efficient enough at catching fish?
Entire Delta survival hotspot? Develop survival in non-hotspots. Specific survival at CVP and SWP?
Delta rearing piece absent- understanding life history of fish collected at Chipps- Ototliths and CWT potentials
Condition vs survival/population- possible mitigation of upstream operations (on survival, abundance, condition) for Delta effects. Uncertain on effectiveness

<u>Table 6: Group 3</u>
Monitoring to assess efficacy of RPA actions- What would you monitor and why?
-identifying hotspots within the footprint of operations important.
-size and genetic variability, life history diversity targets for monitoring and operations
-monitoring framework to assess diversity and the effect of operations
-reach-specific survival rates, junctions- velocity impacts on survival and routing
-Big picture- overall delta survival of salmonids, hard to estimate with existing monitoring infrastructure
-proportional survival and routing
-A-H focused on south delta RPA performance measures
-upstream abundance may lower impact of low delta survival, life-cycle/cvpia models
-metric useful for restoration management- reach specific or proportional rearing, occupancy
-relevance to SWFSC life-cycle and hydrodynamic models- decision support metric easy to measure (E,F and G), measuring individual (A,B, D) and population (C and H) metrics more challenging but necessary
-value of individual condition metrics? Mitigating value of upriver condition? Fast out-migration related to survival so this is a challenging metric because fish that grow large have high ocean survival and fast outmigrants may be small. Yolo Bypass inundation also slows migration.

F- what is an acceptable level of salvage and loss. Looking at population metrics associated with acceptable levels of salvage, i.e. cohort replacement rate. Possibly overlay EPTM to evaluate the proportional impact.
-Predictive models for risk in salvage in inform operations
Lower trophic levels not included, should be metric for habitat restoration, possibly influence survival. Evaluate farmland opportunities for food web improvements

Table 6: Group 4
B- reach specific survival important. Study reach specific behavioral responses. Use this to inform restoration. Use this to assess if water operations can influence opportunities to change route specific survival. Study interaction of restoration and operations
Identify poor survival reaches, transit times, trade-offs- growth, residence
Investigative Goldylocks acoustic array- optimal level of coverage to answer questions but still feasible
D and E- link survivorship to growth to rearing areas (otolith)
E- ototliths cost effective and feasible, possible #1 place to invest money (winners-based understanding)
Brett Priorities- BD and E
High value in otolith analysis for montiring temperature and habitat profiles- carcass surveys should collect all otoliths for current analysis and archive samples for future techniques
F and G- value of predictive models for entrainment into interior south Delta, need context for proportional levels. EPTM?

Table 6: Group 5
Linked metrics to RPA objectives or conceptual models
OMR goal/biological rational- change units for relevance to RPA or management
Need long time-series for reach specific survival estimates with multiple management scenarios, tides, etc. Compare to some baseline condition
Testing hatchery fish- available but relation to wild surrogates? Examples- 2012 study. Cramer proposal.
Tracer/Flex fish (WIIN idea)
Develop South delta survival route selection model similar to north delta model
E- rearing portfolio- link back to rearing conditions and delta occupancy, long time series on data
F,G- take related- 2% of JPI. Change to life-cycle relationship e.g. cohort replacement rate.
B- is important for overall issues, A is more operations specific

Table 6: Group 6
Flip side of G- contribution of salvaged fish to the population (salvage improves survival). These are response metrics not actions.
Population effect of exports- how are operations related to other factors? Mortality effects of non-operations? Test- tagging studies under a variety of conditions/operational scenarios
A-E in the weeds/unnecessary except entrainment, F and G
Develop through Delta survival and abundance estimates?
Understand tradeoffs of different routes/low reach survival/high cumulative survival
E- analysis all otoliths

Conduct full genetic analysis (all handled fish)
Specifics/mechanism of flow survival relationship in Sac R and riverine SJR- testing relative predation may elucidate presumed flow/survival mechanisms
B- reach specific survival not necessarily useful under current time interval due to potential in-reach variation and co-variates
Mortality effects of non-project factors? contaminants, habitat, etc.
Salmon fry monitoring is deficient
Need to measure ecosystem metrics at management relevant locations
Assess overall value of acoustic tagging studies

Table 6: Group 7

C- survival through the Delta is the focal point for management
IE and OMR- focus of RPAs too narrow
Measuring B includes A and C
Reach specific survival needs to be collected over variable conditions and years
Tagging hatchery fish, deciding on release time is highly biased. Need to investigate surrogacy, variable timing and location of release
Limitations in funding to have good sample size on AT, limitations on upriver release sights, i.e., few survive to survey reach so must release closer to delta
Combining otoliths and telemetry, possibly CWT/AT tag group to relate to otolith collection in adults
Comparing otoliths and delta rearing over long time series to evaluate delta restoration activities.
Archived otoliths for future techniques and retrospective analyses
G- high management value, measures impact of operation
Population abundance estimates lacking, add RBDD JPI to all runs including steelhead
Need to collect condition metrics across all life stages
Study predator population- how do predators respond to environmental covariates, abundance, diet?

Table 6: Group 8

Expand sampling of juvenile otoliths, refinement of beach seine location throughout delta habitats. Use results to inform restoration site selection
Bated minnow traps could be cost effective method to sample juveniles in a broad range of habitats, could salmon roe as bait
USGS delta acoustic tagging/flow gage study (DREAMS)- reach specific survival and route selection model in real-time
Fry survival data need, could be deduced from abundance data.
Adding collection of condition in existing sampling, run-specific, genetics. Morphometric and full pathology. How do hydrodynamics effect condition?
Direct vs indirect mortality. 2% of JPI from pumps, don't know habitat effect of water operations and infrastructure. Possible to model effect?
F,G- Need to compare baseline overall and reach specific survival with effect of operations
G- population estimate to estimate proportional loss to salvage, need pop estimates for other runs

Paired acoustic tag/CWT abundance estimates for sampling efficiency and abundance- requires a high trawl effort, staffing, etc. Similar opportunities at Knight's landing RST, SJR tribs, etc. trap/trawl efficiencies and abundance
EPTM- opportunities for calculating F

Table 7 – Monitoring and Decision Support Tools – Laura/*Ben*

Real- time monitoring and predictive modeling of juvenile salmon distribution in the South Delta could allow for more effective water project operations.

7.1 To better inform water project operations, what locations in the South Delta should be monitored/modeled, what metrics should be monitored/modeled, and what monitoring/modeling tools should we invest in?
7.2 How could these data be used to inform water project operations?

<u>Table 7: Group 1</u>
7.1
Locations: Georgiana Slough, DCC, SJQ Mokulumne confluence, pipe discharge at fish release sites (survival at point of release, and further downstream), Chipps Island
Metrics: # of fish (route selection) by species, survival, # of fish by species at Chips
Tools: Russ Perry model, Brandes Studies, BDO South Delta Ag Barriers report, Brad Cavallo Model, DIDSON cameras to view fish release sites, CVPIA SIT Model

- Suggestion to somehow disconnect OMR from pumps (siphon, etc.)
- Real-time fish array (constant release of tagged fish)?
- Is the Mid-water Trawl the best method to monitor? Is it giving actionable data? Should we look into new tools and new locations? Give better confidence in fish data

7.2

- Open or close DCC
- Adjust exports due to fish route selection
- Examine new ways to release salvaged fish (change release sites, timing, etc.)
- Better counts of fish can help regulate sport fishing

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<u>Table 7: Group 2</u>
7.1
Locations: Sutter and Steamboat Slough non-physical barriers (proportion of fish), Cavallo paper locations, SJQ by Vernallis, Old and Middle Rivers

Metrics: fish proportion by route, fish size, WQ and hydrodynamics, salinity, temp turbidity (5min to 15min time scale), To get to the "Why" fish choose different routes

Tools: acoustic tags, PIT tags, partial tracking model, fish behavioral models, agent based model, Perry survival model, E-DNA

7.2 Potential Management action question:

- Increase monitoring of Stealhead on the SJQ
- Is monitoring fish release sites a cost effective exercise (what percent of population is being trucked?) You would need to tag the salvage fish.
- Non-physical barriers for Sutter and steamboat
- Abundance of fish entering South Delta via Old River to advise South delta pump operations

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<u>Table 7: Group 3</u>

7.1

Locations: Head of Old River, Turner   Cut, Columbia Cut, Clifton Court Forebay, Franks Tract

Metrics: hydrodynamics, vorticity, WQ (salinity, temp, etc.), genetic monitoring, otolith chemistry

Tools: ADCP, ePTM, telemetry, trawls, nets,

7.2

- Observe biological behavior and layer on top of hydrodynamic models
- Proportion of fish into HOR vs SJQ
- Use this info to advise export rates
- Use the models to show us the best locations to do specific types of monitoring.
- Abundance numbers coming into the legal Delta (timing, survival,
- Genetic information at sites throughout the delta. Knowing what type of fish is where (and when) will help inform.
- Don’t limit to endangered species
- Monitor predator population throughout all sites (abundance, type, etc) … bio-energetics model
- Study the proportion of fish entering via HOR going to the pumps vs Chips Island
- These ideas will help inform the RPAs
- Management wants to how to better monitor to give operators more flexibility without increasing risk of fish mortality … can we set up a pilot study to test better flexibility

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<u>Table 7: Group 4</u>

7.1 Locations: HOR, Turner Cut, Columbia, The Mouth of Old River, somewhere in the interior delta as well, Georgiana Slough

Metrics: how many fish are entering compared to hydrodynamics, size of fish, abundance, distribution of fish in the Delta

Tools: ADCPs, tags and telemetry arrays, ELAM, eDNA (maybe auto sampling), ePTM, critical streakline analysis tools, modify eDSM,

7.2 Potential Management action question:

- Real-time operations can better inform the flexibility of pumping – where are the best locations to do this, and what are the metrics and tools to achieve this.
- We need to invest in a fish behavioral model (ELAM, etc) to help evaluate alternative operation hypothesis with regard to how fish will react/entrain.
- eDNA can help us decide where the fish are, and where to put additional monitoring stations

- More intense/regular sampling
- Timing of sampling is important to maybe give us more flexibility in operations
- Use multiple models (ELAM, ePTM, behavioral models, etc.) and compare results
- Can any Delta Smelt studies inform the Salmon questions
- More intensive sampling at particular time of year (eDSM) … modify eDSM for Salmonids

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Table 7: Group 5

7.1

Locations: key junctions/locations in the (Delta) South Delta, Mossdale, Chips Island, Turner Cut, Head of Middle River, CVP and SWP area, Old river and Middle river, Disappointment Slough, Columbia Cut, Mouth of Old River, Clifton Court Forebay, Georgiana Slough, DCC, Steamboat and Sutter Slough, Jersey Point

Metrics: abundance estimates, flow splits, survival, mark recapture, velocity profiles

Tools: hydraulic model coupled with fish behavior model, ePTM, Cavallo model, ADCPs

7.2 Potential Management action question:

- Modeling flows splits at junctions, and combine fish behavior models … this will help provide a better picture about how operations effect fish movements around the pumps.
- This could predict entrainment and timing (would take a lot of computing power)
- Monitoring fish metrics at those same key junctions
- Adaptively manage through iterations between collected data and modeled results.
- Standard acoustic array that everybody can use
- Targeted releases of fish at the junctions to inform the fish behavior models
- This could model potential outcomes of changes in operations

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Table 7: Group 6

7.1

Locations: HOR & SJQ on both sides of the diversion, Turner and Columbia Cut,

Metrics: species, size, hatchery v wild, abundance, arrival times, movement

Tools: trawls (November – April), fish tagging and receivers, PIT tags, towed PIT tag antenna (fish swim through narrow capture, collect data without taking fish out of the water – Chips & Sacramento & Mossdale)

7.2

- Better fish sampling (trawls) on both sides of the HOR and SJQ diversion
- This would inform operations (I:E ratio) – revised, readjusted, inform future implementation
- Real-time telemetry and/or trawl in the South Delta might not give operators enough time
- This could inform future management of operations
- Put acoustic arrays at all of the same location , this would help link the route selection, regional survival

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Table 7: Group 7

7.1

Locations: Entry points into the Delta, Verona, Turner and Columbia Cut, Georgiana Slough, Middle river, Old River,
Metrics: abundance at specific locations, presence/absence, survival, food, temp
Tools: PIT tags, acoustic tags,

7.2

- When are fish entering the Delta (way before south Delta), need to know early.
- Standardized array around Old Town Sac, SJQ, and Delta.
- Acoustically tagged fish may not represent wild fish for real-time monitoring…better than nothing?
- PIT tags are more useful because you can tag smaller fish.
- Tell management with hatchery fish have entered the Delta
- Trawl and screw-traps for including the arrival time of wild fish
- Sacramento (I Street) is important for current measurements of Delta arrival timing
- Every single hatchery salmonid should have a PIT tag in it
- We need to measure for habitat conditions (DO, food, aquatic weed, temp, etc) – maybe synthesis the data we are collecting to explain our habitat conditions
- We need studies on fry (abundance, survival, movement … electrofishing … Knights landing, Yolo bypass, San Pablo Bay, Turner Colombia area … what are the habitat conditions when you find them WQ, food, DO)
- We need studies on Steelhead coming out of the SJQ
- Steelhead monitoring … somewhere around Vernalis … use a fish count weir

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<u>Table 7: Group 8</u>

7.1

- Locations – DCC, GS, Steamboat, Sutter, Jersey Point
- Metrics – proportions of fish entering the South Delta (and from where? North, South, West)
- Predation needs to be monitored – tools TBD – same location as above

- Properly located acoustic and environmental monitoring network. The metrics should be consistent across the entire system/network.
- Where matters a great deal. Triggers in real-time might not get us to where we need to be.
- Discussion about how to decide what percent/proportion of distribution (use observed fish data, and statistical tools) … presence/absence, occupancy, probability of true presence
- We need to know about Steelhead entering Delta from SJQ (when and how many) – trapping somehow to count upstream passed tidal influence
- Tag striped bass to help follow the predators

Table 8: Achieving Recovery – *Rene/Brooke*

8.1 *What are the optimal conditions in the Delta for salmon recovery?*
a) in the near term (given existing upstream conditions and population size), and
b) under proposed restored conditions in the upper watershed

8.2 *What are the dominant conceptual models/ hypotheses describing 1) how salmon behave in the Delta now, and 2) how we anticipate salmon would behaving once populations targets are met and environmental/ habitat objectives in the upstream tributaries achieved?*

a. *What are the dominant conceptual models/ hypotheses related to desired conditions to support those behaviors?*
b. *What are the major areas of uncertainty around those conceptual models?*
c. *What are the most important actions or experiments that could be taken to resolve those areas of uncertainty?*

8.3 *How can operations, in combination with targeted restoration and other management actions, be optimized to achieve desired conditions for the range of salmon behaviors the delta will need to support in the near-term and the long-term?*

a. *How can we design operations to test key hypotheses and resolve core uncertainties?*
b. *What metrics should be used to measure the success of management actions that are used to achieve desired conditions (e.g. for rearing, migration, or both)?*

Table 8: Group 1: Sam Luoma, Alison Collins, Gabe Singer, Michael George (Delta Water Master), Vamsi Sridharan, Pascale Goertler

Conceptual models:
Tidal wetlands project work team (PWT) has a conceptual model for salmon in the Delta that might apply here

- PWT focuses on conditions metrics instead of growth and foodwebs
  - Food web
- PWT focuses on opportunity metrics (access, complexity and connectivity)
  - Access (temperature, depth, physical accessibility)
- No consideration of carrying capacity like in the life cycle models – focused instead on how to monitor tidal wetlands for habitat conditions using fish specific metrics
- It would be easier to measure proxy metrics as opposed to fish specifically
- Now their efforts are focused on gear comparisons testing
- No current consideration of metric relationship with recovery – this is something the life cycle model should and will do
- What is the survival through the Delta now? –> Can we use the LCM to back track from the Delta to give us a starting point –> What should Delta survival be to set trajectory towards recovery? We can't ask the model for a number but we can adjust things in the model to glean an understanding

of what survival in Delta should be (play with key parameters to look at response) for salmon recovery.

- Taking a view of Delta as a dynamical system helps – we can look at that and understand where our efforts to improve conditions towards recovery within that broad and complex system.
- Is it possible to achieve the survival we need for recovery in the Delta?
- No good understanding of how many fish use Delta as migration corridor vs rearing habitat.

Survival is an OK metric, however a much better metric is cohort replacement rate.
Question #1: How does one understand what is going on in the system with a simple model to explain system with certain parameters – some of which are measured and some not?
Question #2: How could one use science to develop parameters that would be incorporated key parameters in the model?

- Conceptual model is going through this process now to identify which factors you can manipulate and which you can't.

Need better monitoring to inform parameters in the conceptual and quantitative models.

- Number of fish entering (abundance)
    - Knights Landing could use some help with efficiency problems
    - Trawls are also working to improve abundance estimates
    - Knights landing misses the Feather River
    - Trawls miss the yolo bypass

        -> Need more distributed monitoring tools to capture all components needed for monitoring
- Condition of fish entering the Delta (diversity of size and timing of Delta entry)
    - Underwater cameras could help but only target larger fish that use the Delta as migratory route
- Better monitoring needed to understand potential benefits of targeted efforts then track over the longer term
- Then, combine improved monitoring with overall population metric to understand how changes in the system influence baseline population.
- If you do 10,000 acres habitat restoration, for example, you should start to see bigger fish leaving the Delta as restored habitat generates rearing habitat.
- We need a target for restoration efforts and a way to understand the response of actions.
- We need to be clear about the metrics we will use at key places in the Delta and inputs.
- San Joaquin side - Mossdale trawls provide good information in an area that is easier to monitor and capture. However, steelhead monitoring is currently insufficient.
    - Then migration gets complicated when fish hit Middle and Old Rivers which diminishes the value of the data understanding how fish move out of the Delta.
- Is it that we cant understand what is coming in to the Delta? Or, that we aren't courageous enough to ask for the number of stations we really need to get that estimate?
- There are things that could be done to improve efficiency at existing stations (knights landing efficiency is around 1% depending on operations of diversions)

What about factors occurring at upstream areas?

- Are we agnostic of actions occurring upstream (eg Yolo Bypass) and only focus on the processes in the Delta?
- Or, are we interested in integrating with many upstream models and then using that to inform actions in the Delta?
    - Upstream temperature is a big issue and driven by climate change and the dams – what can we do about that?
    - We should run upstream models to see what they tell us to look at population level responses.
    - Actions can create temperature refuges which can be helpful. Interesting to look at temp refuges in the face of climate change moving forward. Refuges could be gravel augmentation associated with riparian restoration.
    - Has there been an evaluation of rearing habitat in the upper reaches?
        - Yes, there is a modeling team that evaluates habitat in the upper river and throughout the system. Most well developed for the upper river on a monthly time scale (based on HEC RAS: riparian vegetation, flow parameters, WQ, depth, temperature). Effort needed to build better models. CVPIA model also does something similar (based on approximations of inundation duration and timing). Inundation duration is a proxy for food production. Other suitability factors like temp, depth, cover, and velocity. (Developed for the Flood Protection Plan)
        - TNC just redid the model to evaluate habitat needs based on fish territory sizes and life cycle model to achieve CPVIA salmon targets.

Metrics: The obvious ones are suitable and informative to understand the system - Diversity of life stages, cohort replacement rate, survival, condition
Other new metrics: Disease? Lipid content? Condition index as an integrated measure of multiple components?

- Disease can be very important metric – also pathogen loading vs mortality
- Impact of disease is context dependent – in ideal years disease doesn't limit emigration and survival. However in drought years all diseased fish die.
- Traps available in the restoration areas – disease could be measured there.
- Richard Condon is conducting disease measurements and research with results coming soon.
- Trawl data – is it possible to get weight metrics? Not easy to bring scales on the boats. Photographs could be an easy way to collect and store data – girth could be a condition proxy. Could only do this on a subset of the fish caught. Technology is available to glean a lot of information from pictures. Need to understand what is the necessary sample size to be informative.

How does this discussion so far relate to operations? If we had all the information we have been discussing how would we manage differently?

Upstream: Could use flow pulses to inundate key areas at certain times of the year.

- Interesting relationship between export effects and tides. Changing exports during flood tides doesn't influence the system as much as manipulating exports during an ebb tide.

- If you have restored habitat in one area and want fish to access it time the exports to enable hydrology to allow fish to access at key times.
- They already do this with DCC operations when salmon are migrating through. Could use Yolo Bypass operations in the same way as lower predation habitat to selectively route migrating salmon.
- Openness from water operators to understanding these relationships to give more flexibility in operations.
- These could be investigated with modeling ahead of time to make informed choices about operations experiments.
- Feather River has tested application of pulse flows as well as upper San Joaquin and the Stan.
- How does habitat restoration lower down change flows in the lower Sacramento? Can restoration sites be chosen to minimize impacts of hydrodynamics?
- San Joaquin fish survival cant be manipulated to avoid export mortality as a result of hydrodynamics. -> Can we shift the focus for San Joaquin fish on upstream rearing instead of Delta rearing to make them more able to survive as migrants through the Delta?
- Could install barriers and capture most of the fish at a given point. However, truck and haul is dangerous because it could influence diversity if only a subset of the population is caught. Salvage survivors are biased towards larger fish.
- DS and FLS restoration actions in Suisun could be leveraged to benefit rearing salmon.
- How is "restoration in the Bay" potentially beneficial to salmon? There is a lot of effort and $ for restoration there but possibly no focus on benefitting salmon needs. -> Better conceptual models of how these species use specific habitats would be very helpful. Need to understand entire fish migration pathway options and consequences. "Choose your own adventure" conceptual models for different migratory pathways.
- Acoustic tagging studies have very low sample sizes when they reach the Bay so low sample sizes from ta may not be entirely informative.

Table 8: Group 2: Eric Danner, JD Wickert, Mario Manzo, Jason Hassick, Garwin Yip, Steve Haggerty, and Rusty Holleman

Factors outside the Delta influence the number and conditions of fish entering the Delta. If this is done how do we need to manipulate the Delta to target recovery?
Very different questions for smolts and fry. Also determined by origin of smolts and fry.
Habitat conditions upstream generate more fry that are pushed into the Delta.
Optimal in the Delta would be actually having a Delta, not just a series of conveyance canals bordered by agricultural water diversions. Need some portion of that to look like a Delta gain. (Functional ecosystem). Need food production, shallow predation refugia, thermal and flow regimes that interface with the geography to create those conditions. Turbidity – some is good but too much is bad – find that sweet spot. Function of what fish use the system and how. If they use it as a migratory route turbidity can hide them form predators.

- We need variability – static conditions that arise from management are not idea for species that evolve in highly variable environments.

- We know 95% of the tidal habitat is gone. What can we do with what we have now? Can we provide all those needs with riprap in place?
- Yes, below sea level islands need to be made into at sea level islands as marshes.
    - o Dump soil in to ag pits and plant to reverse subsidence – also benefits bird habitat
    - o Fill below sea level landscape with green waste and dredge spoils to speed up subsidence reversal. However all of these options take very long time scales and continued efforts.
    - o When we start producing more fish in tribs they need somewhere to go.
    - o Variable conditions – allowing for a variable hydrograph with some saltwater instruction in the summer (would take care of Egeria and other aquatic weeds)

Two points – habitat centric and fish centric (if conditions upstream it could change the way fish use the Delta) – How do these two pathways relate to one and other?

- It needs to be a parallel tract
    - o In good precip years with spring pulse flows we get a lot of fry sized fish migrating in to the Delta (surplus production beyond carrying capacity in tribs)
    - o In low precip years we don't have many fry sides fish moving out

Do people have a sense of whether there are multiple paths – is it viable to restore habitat along only one path and hope fish will find it? Or should we do less and cover all migratory paths?

- Roadside rest stop ideas: Fish migrate at night and need shallow water refugia with food. Restoration triage is to provide small refugia for migrating fish at some spacing no wider than distance covered during a typical night of travel.
- Better than creating one golden migratory road? This is a good idea over the long term but the rest stops are good in triage mode (now).
- However, we have one idea of how habitat restoration influences survival. There is no empirical data here and it is needed to justify continued work. How do you get enough fish down there is effectively evaluate impact of restoration?
- Habitat restoration might actually decrease in river survival in the area in the river because they get misdirected – but ocean survival may increase with increasing condition of fish that do make it though.
- WR LCM can computationally model these efforts but it is data limited (need field data to aprameterize0. Ex. Increase growth in one habitat and resulting size of fish at ocean entry – then can model that benefit across the entire life cycle.
- When thinking of winter run – nothing in the Delta matters if they don't have spawning habitat. How do you get around the Shasta Dam issue?
    - o It still matters – through Delta survival is still important but not limiter.
- 1993 Crit hab for WR – Mainstem Sac not including Delta past the DCC
    - o One of the key lines of evidence demonstrating how messed up the Delta is – early efforts were to keep fish in the mainstem and out of the Delta entirely.
- How many miles before Shasta and Keswick were built were available for rearing and growth Maybe 150 miles? Even if the Delta was functional – or improved – the size of fish coming down now are in

a fundamentally different condition than before. We have also selected for different fish that can handle more limited migratory routes.

- We also focus in the Delta in preserving greatest periods of abundance at the expense of periods of lower abundance – at the expense of lifecycle diversity.
- Same problem for VAMP efforts. Ultimately this selects for smolt size outmigrants. Fry sized fish are more vulnerable to predation. Smolt sized fish enter the Delta during higher temp times and vulnerable to low quality abiotic conditions. Need to conduct operations to protect all life history strategies and build habitat to support all those strategies.

Operations: What does the paradigm shift look like?

Compare value of fish vs value of water – it is fundamentally lopsided?

We cant value fish in the same way that almonds and crops are valued. This puts us continually in the place of operating to bare bones to avoid jeopardy.

We are all in jeopardy now given that many of the RPAs have not achieved the goals set out for them. Operations need to be more flexible and we need a more dynamic hydrograph than we do now. Humans like stability but the fish didn't evolve in these conditions. We need some intermediate disturbance regime to facilitate fish that need to outmigrate. Also problem of competition with resident fish that don't outmigrate.

Dynamic regime combined with reducing hazards along the migratory corridor could contribute towards recovery.

Paradigm shift on operations to achieve some suite of conditions defined by the needs of the fish anticipated to show up there.

Operations – Delta and exports or overall including releases on tribs?

Need to include operations on all tribs in combination with the Delta.

Fish evolved under flood and drought cycles. Resident fish do well some years and outmigrants do well in other years.

Operators work with given clear restrictions – we can modify operations but if there is no habitat there then why would be modify operations in the Delta? We need to be shown a clear tangible benefit to motivate giving up water supply.

Could a model be used to develop a scenario to improve conditions under different operational conditions? Yes, that would be more compelling.

Others at the table felt that the relationship between flow and SR survival is well documented. Especially on the San Joaquin.

Table 8: Group 3: Maria Rea, Lisa Hunt, Deanna Serreno, Dan Kratville, Ron Melcer, Andrew Hein

These are extremely broad questions

What are the proposed restored conditions? Is there a set goal? That makes a big difference?

Central Valley Flood Protection Plan and Conservation Strategy with species needs and objectives – cover the Delta but not tribs

You currently see fish in the Delta at a certain life stage. In the future when we restore tribs we expect to see fish at a different life stage. How does this change their use of the Delta, timing, and needs?

There are objectives that have been developed that describe what the habitat looks like – how much rearing habitat do we need to meet CVPIA targets?

> If we restore all the CVPIA habitat targets then more fry and smolts coming into the Delta? Or, fewer fry and more smolts? What does this mean for how we manage the Delta?

Currently do we see a lot of very young fish entering the Delta?

> Depends on the water year – when the river is high fish get washed into the Delta at young stages. Because the Delta is a bad place they are lost there. This is the dominate model.
>
> However we don't have good data on this – we don't really understand what fry use in the Delta is. We could use trawl data better to build our understanding of fry use of the Delta.

Optimal conditions suggest a desire to focus in on goals and objectives.

> BDCP has good goals and objectives.
>
> CV plan has good goals and objectives
>
> Recovery plan has goals and objectives for salmonids (not as many objectives – actions for the Delta but not as specific as upstream areas. Focuses on a need for diversity of populations, to spread life stages and sizes entering the Delta)
>
> Individual trib populations and life histories within these populations need to be the focus of objectives

What are the sources of resilience to manage for?

> Diversity, larger population sizes
>
> Manage for temperature

We need a targeted scenario analysis to understand the response of a network (life cycle) to particular forms of disturbance.

What is needed for resilience to specific types of events?

> No one gets into this level of detail – general assumption that improved diversity creates the best buffer for the species as a whole in the face of varied stressors and impacts. Needs to be made more like a natural system where evolution spreads the risk across a broad range of life history types and phenotypes. The Delta landscape has to be able to accept this diversity over a range of times. Needs to look like and function as a natural eco system which can create physical attributes (flow, physical habitat and their interaction).

We need more information about juvenile life history survival and strategies – otoliths have provided some new information but not all the needed data. Need to also sample fish to figure out their run, where they came from, and track them through adult hood. This is the data we need to understand how to best manipulate the system.

Note: Otolith microchemistry can be related to size at given time points. However, otoliths can't be used to inform growth rates in different reaches along migratory pathways. The only way to do this is to capture fish, tag them and track them.

We need full life cycle monitoring to fully answer the questions we have about what to manipulate to promote recovery and resilience. These big sampling efforts require a lot of money and need to be sustained over long time frames to provide meaningful data. These are feasible given sufficient motivation.

Example, when fish are sampled at screw traps they could be tagged and used to glean valuable data. They need to be recaptured or tracked to give the type of information we need throughout their migratory path.

Could we tag all fish sampled that aren't already tagged? Yes, this would be possible. This would be done outside the Delta then allows us to follow them through the Delta.

Would you improve monitoring programs using pit tag arrays?

Acoustic tags data could be accomplished with pit tag arrays.

It is very difficult to motivate the need for an acoustic array at a high level and then implement.

There is a tradeoff between cost per tag and sample size. Pit tags are cheaper and can be put in smaller fish. AT are more expensive and larger.

How does this discussion fit in with managing operations?

We currently manage to avoid jeopardy. Can we manage for recovery?

Cannot separate the operation of the pumps form the structure of the system from the operation of Shasta and the operation to put water in to the system on the tribs. You have to operate as an integrated unit.

Looking only at pumping gives you only a partial picture of the system.

Is the solution to have goals or set points that can be achieved in a variety of different ways?

Goal is to restore the populations to make the losses to exports irrelevant?

On other side: Cant restore the species without controlling operations.

We would develop scenarios and conditions that operations would be managed to meet? IN a modeling context to figure out how close we can get to those operations scenarios. We did this for the BDCP at one point. (CS5 with a CAL SIM run). Different to set up flows that meet the needs for lifestages at each point. There may be more work being done on this as a part of the voluntary settlement efforts.

Develop flow schedules that meet multispecies objectives no the tribs – then layer those into the whole system to see what the benefits are.

Other groups suggested using the CVPIA or R LCM to develop different scenarios. These operate at different time steps than CAL SIM which is on a monthly time step. Dayflow could be used to disaggregate monthly time step. This was done in BDCP but didn't work in the context of operations.

Connectivity – we are always trying to manage things with reservoirs

Below the reservoir connectivity – 80% of the spawning habitat is inaccessible because it is above dams.

Table 8: Group 4: Rebecca Buchanan, Gardner Jones, Javier Miranda, Peter Dudley, Carl Wilcox, Rachel Johnson, Mike Thomas, Matt Reeve

If one were to start to evaluate optimal conditions – thermal tolerance should be a first priority. Optimal conditions for migrants and rearing fish – need to focus on both when considering how to define "optimal".

Curious about they prey relationship availability to migrating smolt. How available are their prey – what are they eating, how much of the prey is there, is there density dependence? What is the effect of primary production? In other species – ex shad – if conditions benefit those other species then they are likely to also benefit salmonids.
Salmon that use the Delta as fry – informed by trawls – then there is a big lag per Chipps Island trawls. What is the fate of the tiny fish? DO they rear in the Delta and leave as big fish? Or, do they just die and the only fish that make it out are those that enter the Delta at large sizes?
Fall run use estuaries as rearing ground – known in other tribs but not in the Delta.
Floodplain habitat is an important component.
Do otolith studies provide information on rearing tin the Delta vs upstream?

> NOAA is working on a project to address this question. What is the life history strategies of fish collected in the Delta? DO some rear there or is the Delta a strong selective factor for fish entering the Delta? Is the Delta a place for successful rearing? Who is there now and how are they doing?

Juvenile work indicates that they move preferentially to the Bay, not back to the Delta. This is also consistent for sturgeon. Fish in the Decker Island and Rio Vista down to Jersey Point area don't move east – they move quickly out to the Bay. Fish have consistent rearing pathways. However, we need to better understand what the different life history strategies are doing. It is likely to be very different.
If green sturgeon cant living in the Delta at certain times of years then not much else can. This is also true of many other native fish species.
How much information is there from otolith studies to parse out different regions of the Delta? Cache vs mainstem vs Central Delta Mokolumne?

> Only a coarse ability to parse this out now. We aren't currently looking into ways to better refine the spatial scale of in Delta rearing using otoliths.

Looking ahead: If we implemented all upstream habitat improvement projects and change the distribution and timing and size of fish arriving in the Del what is optimal in the Delta?

> If cold water were moving across the Yolo Bypass more continuously as pseudo floodplain habitat.
>
> > This would create foodweb benefits if done in the summer. This could be done with ag drainage. What else/?
>
> Summer water temperatures in the Delta cant be controlled.
>
> If we do so many project upstream the only fish that encounter the Delta re the ones that are actively migrating to the Delta? If this were true does it change how we manage the system?
>
> > We need the whole lifecycle understanding to understand how changes upstream influence how fish use the Delta. It is a nonlinear relationship. Hope is that upstream restoration reduces water project impacts. More fish coming in will moderate the effect of water operations in the Delta on a population level.
> >
> > Depends on where the bottlenecks are over time: If you produce many fish and survival in freshwater goes way up but then you could become restricted at the point of transition from adult to fry. Improving conditions upstream could make the Delta more of a population level bottleneck.

The LCM could be used to ask and answer these questions. We could use this to think about what we need in the Delta to promote recovery over the long term.

Optimal conditions: Look at the diversity of the habitat available to different life stages. This will promote genetic and biological diversity. On the fli side – we are torn between conservation approaches and providing hatchery fishes to support ocean sport fisheries.

How does the operations piece fit in? What do we need to do to support the conditions the fish need in the Delta if the LCM indicates that this could have a pop level effect?

The problem is that we don't have the option to turn multiple knobs.

What are the nobs we can turn in the Delta and upstream? I:E (San Joaquin side), OMR, incidental take limit, E:I (Sac side), habitat restoration on channel margins in the Delta (although scale of setback levees in the Delta is small)

Delta is more interconnected and very different than it used to be. Many more –laces for Salmon to go through the Delta and unfavorable habitat. Ex. Franks Tract cold help change the interconnected nature of the Delta. Make False River a False River again to reduce the nozzle effect.

Salmon used to use the Delta in its dendritic form. With the new fish community what does this mean in the context of the new predatory fish community? We don't really know.

Data indicates that most dendritic habitat preferentially supports native species while predators sit at the mouth of dendritic channels.

Overlay habitat suitability for predators with habitat suitability for native fishes that are the target for restoration.

Decker Island is a terrible example of tidal habitat restoration – it created striper and SAV habitat because it was designed wrong from the beginning.

Vegetation is an important aspect of habitat – are there things we can do to tip the favor towards native species?

Is it true that conditions that favor other natives will also benefit salmon? Ex. Little Holland Tract isn't being designed for salmon specifically? Would it look different if salmon were the focus? Will it still provide meaningful benefits for salmon?

First – you design to suitability criteria for individual species. The first thing is to establish habitat suitability criteria – then use those to design.

Of the nobs available to turn which could actually be adaptively turned?

Operators have tight windows on when nobs can be turned – when things could be changed. Exploring new I:E ratios, for example, is very difficult.

There isn't a lot of precision on the biological side to understand responses to fine magnitude changes in operations.

Operators need a suite of hypotheses about responses along a range of operations scenarios. Stipulation Study from 2012 had that goal but ended up with a very narrow range of scenarios to test. Didn't truly explore the extreme ends of OMR.

To be salmon centric is not totally appropriate. For example, changing reliance on I:E ratio and OMR have cascading effects on other species in the Delta (Ex. LFS and DS). These cascading impacts need to be considered when contemplating changes to operations. Changing the I:E doesn't necessarily create more water because that water is needed to support other species. If the I:E wasn't in place we wouldn't see the outflow we have been getting to support salmon post-BiOp.

If you want to help salmon habitat in the Delta screen all in-Delta diversions.

There are 2,300 diversions in the Delta, most of which have no effect on anything other than silversides. Also – you cant screen larval life stages of DS and LFS.

From operations and biological standpoints – are there any tools that we don't have that we could use to turn the nobs we want to turn?

Time machine to see the former Delta?

Money and sediment.

Fish screens.

Table 8: Group 5: Cathy Marcinkevage, Eric Chapman, Johanna Lesser?, Cyril Michel, Bill McLauren, Lee He USFWS

This is an important and huge question. When we talk about recovery of salmon (WR, SR and Steelhead) we have to consider upstream and the Delta together – connected.
In terms of recovery the idea behind recovery targets ex. Use as number of fish or survival rates for each run on Sac River to the ocean. My thinking is that survival rates are a better indicator for recovery. For example, WR have only 10% survival from upstream to the ocean, however in the South Delta survival rates are only 2% over a much shorter distance. The strategy here should be to focus on upstream survival rates in the Sac River and the size of fish in the Sacramento River.

Agree. Unfortunately because a lot of pumping and operations occur in the Delta and a lot of fish die in the Delta a lot of recovery efforts are focused on the Delta. We cant forget that survival and conditions upstream are terrible. When fish arrive at Freeport or Mossdale we are already behind the game. Delta stakeholders need to be convinced to invest in the upper river wherever possible. There is more to be gained upstream where habitat is less altered than the Delta.

Invest in habitat upstream so they can reproduce naturally? This question is focused on wild fish. How feasible is that?

If we start each year with a larger number upstream it gives us more flexibility as they move through the Delta.

More resources need to be allocated to the upstream component. In contrast lots of resources have been allocated to the Delta and that may not be the best way to spend that money.

What has been spent upstream? Clear Creek?

The spending is definitely smaller.

Also remember that a single fish life in the Delta is more valuable because it represents cumulative impacts. However, water is also better valued in the Delta than upstream. Therefor lots of money is spent avoiding effects in the Delta. Ex. Screening fish facilities in the Delta is $$$ but could provide a significant benefit over the long term. Tackle obvious solutions that may cost a lot upfront but have significant benefits long term. Same logic applies upstream.

Salmon Resiliency Strategy looks to improvements upstream. A lot of work is being directed in that direction.

However, the species are in such a bad condition that we need to approach all possible solutions throughout the system. Again, a fish that makes it to the Delta is disproportionately valuable.
When fish do get to the Delta where are they spending their time? How long?

Restoration upstream could reduce survival upstream but in the long run increase cohort replacement rate because when the fish do make it to the ocean they are in better condition.

How do we figure out what it is supposed to look like when the system is "fixed"?

It looks more natural? It needs less intervention? System allows more volitional behavior for fish?

I wanted to talk about the idea of the Delta as rearing habitat. Contentious. Most of what we talk about is how to get the salmon out f the Delta as fast as possible. However, there is a need to think about how fry moving in the Delta and we don't know anything about this. It is not easily measured. DO we invest resources and $ into restoring the fry in the Delta life history component or do we give up because the Delta has changed so much?

What does "letting it go" mean? There are fry rearing in the Delta now, regardless.

We need to think hard about restoring hard about restoring parts of the Delta and what kind of fish community will live there. We don't want to restore habitat and have it turn into good bass habitat. We need ot be smart about where and how we spend restoration $$$ in the Delta.

CAMT salmon subcommittee put together a proposal to the Conservancy to get at salmon rearing habitat in the Delta. 1) DO we know what conditions rearing salmon need? 2) Analyses of in Delta locations to see if the conditions they need could be recreated at all? -> Do this work before we start setting back levees.

What about reducing farming in the Delta? There are a lot of unscreened local diversions in the Delta. By taking out ag and removing these diversions it would benefit salmon substantially.

We had a sidebar conversation about the need to acknowledge and work side by side with Delta landowners and agriculture. Both are essential components to implementing conservation in the Delta.

What are nobs we can turn to achieve optimal conditions?

UOne nob: Upstream operations I'd like to see more discussion of returning the hydrograph to more natural conditions. Increase spring pulse to mimic what the river was doing historically in response to snowmelt.
SR is rearing in tributaries and don't start to migrate until there is a pulse flow. Then they out migrate and hit a Sacramento River with low flows because it doesn't respond to pulse flows in tributaries. The system needs ot be hydrologically linked as it used to be in terms of pulse flows from tribs on down the Sac to the Delta.

Winter run come up in December and January at a very small size. If smolt (?) fish can stay in a better area (Sac River for ex.) they will higher survival rates and they will do better than smaller fish. (???)

In general fish need good rearing options at all sections along a migratory route down to improve condition and avoid predation.

In the Stan (or Tuolumne?) if there isn't a spring flow pulse the fry life history doesn't leave. They either stay long term and turn into smolts or die via predation.

Another knob: Operations in the Delta

Pumping operations and screens create a hydrologic draw into the south Delta

Ag barriers

Unscreened diversions (not really a nob – we cant tell them to stop pumping but we can find screens). We need to combine funding and enforcement to motivate screening program.

- ➔ More comprehensive model linking the effect of diversions on impacts to the species to motivate and inform legislation to give agencies more control to regulate

Better monitoring to understand where the fish are relative to diversions

Where are the fish in a channel cross section depending on the time of day (2D models)

There are studies conducted by John Bureau that show how salmonids are distributed across the channel (this is focused on Georgiana Slough and at other junctions around bends)

How could you influence management to compensate for impacts of unscreened diversions?

Need to understand where to install screens. For example, where is a diversion relative to the proposed location of fish screens for California WaterFix?

If we understand distribution based on time of day we could restrict pumping at particular times of day when fish are migrating. We could ask farmers to pump only during the day to minimize impacts on migrating fish. They could do this if they had retention basins to hold one days worth of water to allow them to pump only during the day.

The loss of hatchery fish could be investigated and used as a model to explain low survival for wild fish.

What is the problem with the hatchery fish? Can it be fixed?

Table 8: Group 6: Michael MacWilliams, Ken Kundargi, Arnold Ammann, Noble Hendrix, and Brett Harvey

Question: What are the optimal conditions for salmon recovery in the Delta? Is our conceptual model that increasing rearing habitat for salmon tine the Delta good or bad? Does habitat increase predation in the Delta?

Optimal conditions for salmon recovery would be fewer nonnative predators.

Optimal conditions would be to restore rearing habitat only if it doesn't include predators.
Why is more rearing habitat bad? -> If predation is main stressor in the Delta, spending more time in the delta rearing will increase predation and decrease survival.

It is important to consider the growth – survival tradeoff. Delta historically was a place of elevated growth relative to the river channel. Due to temp and food or some combo of the two. What about the role of rearing habitat in the Delta to improve growth? Ex. Scott creek estuary paper showed highest adult returns with improved rearing despite low survival.

What are the objectives for fish?

Higher growth conditions, bigger fish

We have areas where we are targeting restoration: Confluence, and Suisun marsh

What about the south delta corridor where no restoration is being proposed?

Instead of just pushing fish through the Delta we need ot push them through the Delta TO a place where we want them to go.

What is the targeted corridor on the San Joaquin? How to we get fish on that corridor and help the fish there survive and rear until they get to the confluence?

Are there restoration opportunities on the San Joaquin where we won't have an increase in predation? We need ot think about the condition of fish before they even get to the Delta.

Fish that enter the Delta are valued at the intersection of numbers, size and condition. The Delta is a broker for what fish are delivered to the ocean. What are the optimal conditions in the Delta?

Improving upriver habitat is just as important as improving conditions in the Delta. Many fish die due to poor conditions in the Sacramento River, increased temperature and increased predators which are adapted to warmer water. How do we decrease temp in the river? Cant use chillers. Historically summer temperatures were very high with low flows.

We currently never allow salinity fluctuations that were seen historically. We do this for DS and human needs in the Delta.

If they build the tunnels and divert a lot of water there isn't as much incentive to maintain low salinity in the Delta for south Delta pumps. D 1641 and local residents are motivators for mainlining low salinity Delta.

1) What is optimal Delta habitat?

- Higher salinity (maybe? This resembles historic habitat but may not be best for salmon)
    - Look at beach seine data to determine what optimal habitat is.

2) What are the guidance systems attracting fish to one or the other side of flow splits?

We need good habitat distributed throughout the system.
I disagree. We need a corridor of habitat through the South Delta and give up on the rest.

Previous group was focused on the need to restore habitat upstream. If we do that is restoration meaningful in the Delta?

If you restore a lot of upstream habitat there will be less fish in the Delta but they will be bigger.

What is the limiting factor? Predation or rearing habitat in the Delta?

> Rearing fish in the Delta wont be the biggest fish.
> Most of the fish coming down the system are hatchery fish that have a greater survival rate through the Delta.

Need to look at otoliths for returning adults. Some rear upstream and some rear in the Delta. Varies across years.

> Wet years give you the highest component for Delta rearers and returns. The fish in the upper river get washed out and pushed into the Delta.

LCM takes a simplistic view of fry distribution. Fry survival rates are assumed to be equivalent across habitats. SMolt survival rates vary. Those that originate from lower Sac do OK, but those that originate from the Central Delta fare worse. The model therefor emphasizes the location of smoltification and subsequent outmigration.

Frys that smoltify in the Central Delta have a lower survival rate than fry that smoltify in the Sacramento River because they have a simpler path out to the ocean.

Based on EPTM model fit to late fall run acoustic model dataset.

Let me understand: If you drop fish in different places right before they smolt their survival is determined by the location where they smolt.

As a clump of fish moves down the river it will have different objectives based on its life history stage at different places in the system.

Some places in the system are better for big fish vs. small fish. It's not all about moving fish to the confluence as fast as possible.

Is it an acclimation issue and a need for more time to acclimate to conditions at each stage of migration?

What is our conceptual model of how salmon behave in the Delta?

Flow splits

What would we do differently relative to operations if we were to manage to the survival topics we just discussed?

Simulate more natural hydrograph

Move pumping facilities to northern delta

Encourage more fish on yolo bypass

Maintain flows to put more habitat in lower Sac

(managing flow for survival through the Delta – pump less more flow – however this manages for hatchery smolts and not wild fish and is also problematic.)

Table 8: Group 7: Lauren Hastings, Brad Cavallo, Steven Culberson, Kristen Town, Josh Israel, Shara Ainsley, Russ Perry

Has everyone seen the Historic Delta maps that have been made by SFEI?

If you overlaid our current water operations over historic habitat the Delta would be a good place for salmon. They physical environment would be there to provide low velocity habitat for rearing of salmonids. It is the loss of physical structure and complexity that is a bigger determinant for salmon than water operations. Would rather have historic habitat with modern flow than historic flow with modern habitat.

This gets to the idea of restoring corridors to help fish stay in place and rear.

Yes, but some of these corridors have to remain shipping channels. Stockton is very complicated. Sacramento DW ship channel is disconnected and more simple.

Survival is poor because of all the connected features, not channel depth.
Yes, also fish communities in the deep water ship channel.
Agree, we see bad survival in the network of connected channels.

If we restored a lot upstream would we still feel the same way about flow and habitat in the Delta?

> Yes. We have done a lot upstream already and the poor condition remains in the Delta. SO, we need to focus on the Delta and improving conditions there.
> Do we need rearing habitat in the Delta is we have mostly smolts coming into the Delta?
> Yes, because in some years fry will wash down and need to rear in the Delta. Need a board life history portfolio.
> To improve the Delta is it more important to change geometry or physical habitat conditions?
>
> > We don't know what salmon habitat in the Delta and estuary is – need more studies here.
>
> Upstream restoration is valuable, but at the same time smolts moving into the Delta at the head of old river still have very poor survival. Something would need to change in the Delta regardless.
>
> At the last table we talked about the interaction between restoration and operations to benefit smolts and fry -> targeted restoration at specific locations would buffer tidal energy and improve routing to benefit both fry and smolt life stages.
>
> RMA is looking at the link between locations of restoration projects and tidal influence and hydrology. If you do restoration downstream you rob the system of tidal energy and keep it from moving up into the system. This is more complicated when you layer on the complication of where restoration with willing sellers is actually possible and available. We will really only be able to implement patchwork small parcels. We have dramatically oversold what we can get done on the ground and it is unlikely restoration will move forward ot the extent that it would influence tidal influence at the level that the RMA model predicts.
>
> We need to be frank about what we are really doing and what to expect from it. We have a history of overselling what we can achieve on the ground.
>
> Our ability to get things done is a matter of motivation and concerted effort. Motivating the entire state of CA infrastructure to get restoration done is much more effective than pointing only to the CVP to manipulate conditions in the Delta.
>
> If someone modeled recovery of salmonids, how would the Delta function in those recover scenarios?

Carrying capacity would absorb fish moving into the Delta and support migration. The problem is that we don't know what those numbers are and how they translate into habitat.

We know the numbers but they are orders of magnitude higher than what we are willing to invest in.
For example: Entrainment exercise looking at reductions in entrainment to have a measurable impact on population overall – it would take a 200% improvement in entrainment to influence overall population size.

Maybe it is possible to increase rearing habitat in some tributaries by orders of magnitude which could then have a dramatic population level effect.

It is likely that salmonids – allowing for adaptation and selection without hatchery introgression – will home to a rearing habitat that is productive for them. Its not a random process. If we create spots of excellent rearing habitat they will find it generation after generation. Build it and they will come.
I disagree – it is a matter of encountering the habitat and staying, not seeking out and locating high quality rearing habitat. They are tracking cues (ex temp differentials) to encounter high quality rearing habitat.
If these cues and the propensity to respond is genetic it could be a combination of both.

Question: If we knew what migratory corridor we want fish to move down, and we had built more habitat along that corridor, what do we do with operations in the Delta to further improve conditions?

Isnt that essentially altering the notch on the Yolo Bypass to focus fish into rearing habitat?
Directing fish to the good habitat at the right time.

➔ Upstream Manage flows for habitat extent and duration.
➔ In the Delta we need to reduce the footprint of operations when fish want to migrate. Not much we can do when fish are rearing, they stick to a particular location. (Others disagreed with this idea – there is a need to look at the footprint and operate to the size of the footprint).

What are some approaches to achieve desired conditions through operations?
Create rearing corridors instead of migratory corridors to allow fish to rear in locations away from the footprint of the project. DO restoration to make flow a more effective nob to benefit rearing.
The amount of flow doesn't have a dramatic effect on habitat under current conditions and the overall extent of intertidal habitat. Instead change they bathymetry to suit the flow.

What about nonnatives?

> Changes in bathymetry may influence native and nonnatives. Important to conduct restoration in a way that benefits natives.
> What about Liberty Island? It has never been taken over by aquatic macrophytes. It is being taken over now.

Real time telemetry will become an important management tool. If you have the right detection as fish move downstream you can selectively manage to reduce impacts and entrainment when fish are present and reduce restrictions when they are not present.

Sherman Island – beautiful flats and tules are teeming with striped bass and western pondweed. Does restoration create habitat for predators and juvenile salmon?

The attractive idea is to maximize upstream productivity to allow the species to persist despite multiple impacts throughout the rest of the lifestages.

Table 8: Group 8: Kevin Clark, Frances Brewster, Jason Peltier, Jennifer Pierre, Elizabeth Appy, Steve Zeug, Dick Pool, Steve ??? CDFW

One of the things we have to start thinking about is what we want the Delta to be in the future. We need to know this to figure out how we want to manage moving forward. We need a feasible shared vision. This is when we can answer questions about what is optimal and what species and objectives we will manage to.

Could this work the other way? Can we figure out what is optimal and base the vision on that?

Yes, as long as the optimal number of fish is feasible. We cant manage the Delta or the system in a way that tries to return to pre-settlement CA. If we cant do that what will it really look like? Many of the current objectives are based on historic conditions not the future with climate change and the built system we have.

How many planning efforts have we had on this subject on how to help the salmon? How many have sat on the shelf and been ignored? Look at the Conservation Framework being worked on by DFW – there is a great slide that says that the DCF will be integrated into the following planning efforts (then lists 12 previous efforts). Need to figure out a way to stop planning and just get started doing things!

Two points being made – pull all planning efforts together so they aren't running in parallel?

Take a pause on planning and start implementing.

To that point – what are the optimal conditions for salmon recovery in the Delta in the near term – we cant do a lot for recovery in one year so focus on trap and haul in the next year or two to keep populations going while we are moving forward with longer term efforts like restoration. Even if these near term actions are not "natural" they are sufficient to produce a response until we can get other longer term actions implemented.

There are a number of projects that have emerged from diverse planning efforts – there is no concerted effort to implement. That is the good thing about the resiliency strategy – motivation to get things done. We need the same motivation to get started and move forward with projects.

Do we have a goal of what recovery is for salmon? Is the goal increase 5% survival to 10% or to 50%? Is it the doubling goal for juveniles or returning adults?

As far as I am concerned the optimal conditions for salmon recovery in the Delta is to keep them out of the Delta. Keep them out of Georgiana Slough and the DCC. Find a way to put barriers in up above and keep them in the ir migration channel. Block Georgiana Slough and Cross Channel Gates and put screens in up above and run pipes down. This would keep salmon out of the Delta and along their corridor.

Other stakeholders want rearing habitat in the Delta and don't want to focus on moving them through. What about fry that do rear in the Delta.

OK – we want them to rear in their traditional channel on the Sac River and not rear in the Central Delta.

What if we do habitat projects upstream? How does that influence this discussion?

Bigger sized and more fish will move to the Delta. Improve habitat conditions upstream in both rivers.

Riverine systems are simpler with already identified projects that are being implemented and could have more benefit.

In low water years we lose more fish in the Sac River than in the Delta. Up river is a big opportunity.

Looking at the San Joaquin river – they have finally gotten started implementing. They got good outmigration but no returns (critical bottlenecks remain). SJRRP is focused upriver. But Stanislaus River is producing fall run. Other rivers have successful programs other than the Sac and San Joaquin.

I think the answer to 8.3 is real time operations with improved monitoring tools and as yet undiscovered monitoring tools.
Real time tracking with different triggers would be better. The triggers we have right now suck. What do they actually mean ecologically? No biological relevance. They just chose triggers at salvage because it is an easy place to count and observe fish. Habitat metrics are better. For example, in light of reduced fish pops we should be focusing on functions and measuring things that indicate response of ecosystem functions. We need objectives and metrics to support recovery. We need to know what recovery looks like form an ecosystem perspective.

Exploit reconsultation opportunity for taking recovery activities.

If we have 20 plans what is preventing us from taking action? It’s not money. People don’t know here to start and there is no leadership. The people in charge change and want to improve upon previous plans over and over again.

Funding is abundant but getting approval to spend money is incredibly difficult. Internal red tape stalls or stops spending within agencies. Also all about a problem of lack of leadership and turf.

That is the brilliance of the resiliency strategy because it provides and agreed upon direction forward – the leader ship we need to move forward.

The salmon resiliency strategy doesn’t accomplish this.

The previous 20 plans have such vaguely defined objectives that any pet project could be fit into any of them and reduces focus on actual recovery.

What about the last question – what does management of operations with common vision and objectives to implement?

Need quantitative links between operations and ecosystem functions we are interested in – instead of hypotheses. If no quantitative relationship demonstrated then we need to agree to give up.
This is why I said that “triggers suck”. 15 years of studies show that triggers are meaningless.
These comments apply to both inflows and exports.

What about removing weeds in Franks Tract? This would generate X acres of rearing habitat and have X impact.

This common quantitative story needs to be linked to achieving recovery.

Another barrier to action is permitting. Not only permitting but current BiOps preclude actions. BiOps don’t allow exceeding flow targets to run flow experiments. BiOps should be described in the terms of the common vision for recovery and allow for flexibility in operations and implementation to achieve the common vision.