Collaborative Adaptive Management Team (CAMT)

Examining Adult Delta Smelt Behaviors that Best Explain Entrainment and Statistical Evaluation of Adult Behavior Models to Estimate Proportional Entrainment Losses

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CAMT Presentation

Original salvage/entrainment model

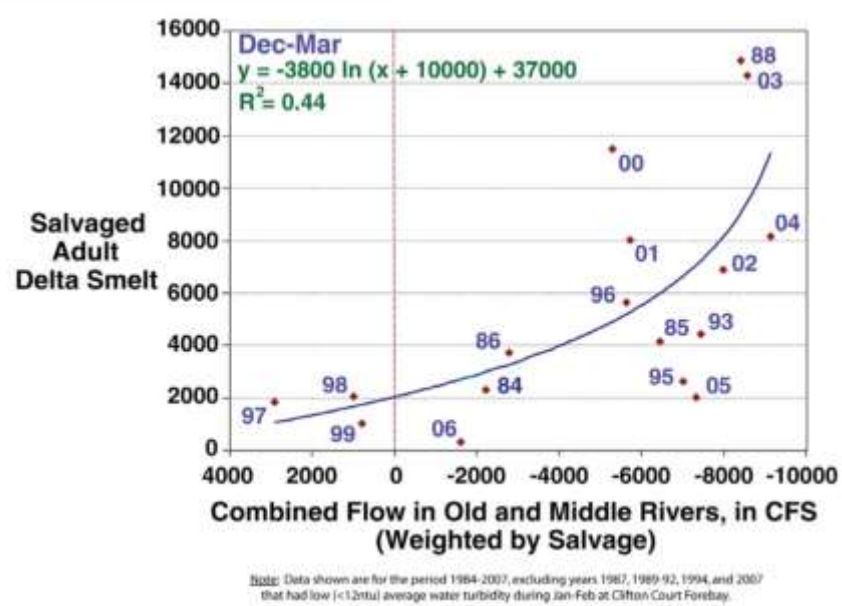
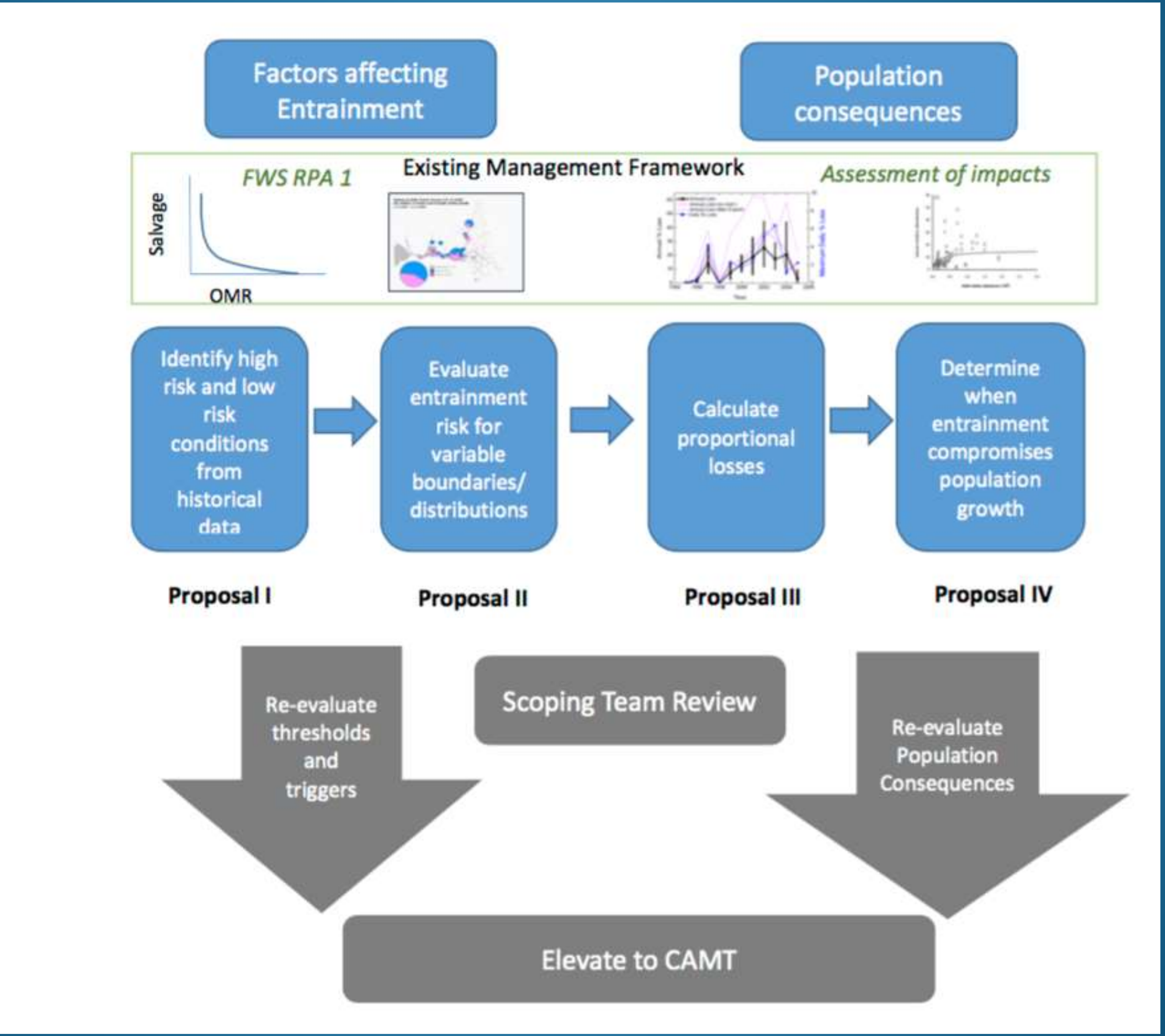


Figure B-13. OMR-Salvage relationship for adult delta smelt. (source, P. Smith). Data from this figure were the raw data used in the piecewise polynomial regression analysis.

2008 USFWS Biological Opinion

Previous research did not consider:

1. Finer-scale variability (i.e., what drives salvage during first flush periods)
2. Other potentially important predictor variables (e.g., predators, water temperature, etc.)
3. Fish behavior during first flush events
4. Population-level impacts (i.e., salvage scaled to previous FMWT abundance)


Factors affecting Entrainment
Population consequences
FWS RPA 1
Existing Management Framework
Assessment of impacts
Salvage
OMR
Identify high risk and low risk conditions from historical data
Evaluate entrainment risk for variable boundaries/ distributions
Calculate proportional losses
Determine when entrainment compromises population growth
Proposal I
Proposal II
Proposal III
Proposal IV
Re-evaluate thresholds and triggers
Scoping Team Review
Re-evaluate Population Consequences
Elevate to CAMT

Status of Delta Smelt DSST reports

- SWC recently funded investigators to publish behavior and fitting reports into a peer-reviewed journal
- Studies 1 and 2 will be submitted together to SFEWS (target September)
- Study 2 manuscripts will be sent to the DSST one final time for review
- Study 3 needs to be revised and include a discussion section

Stated Research Questions of Task

- What are the environmental conditions that “trigger” spawning migration of delta smelt?
- How does the distribution of adult delta smelt vary at time scales not resolved by surveys? In particular how does the distribution evolve during the spawning migration?
- Which environmental conditions lead to adults entering the south Delta?
- Which environmental conditions lead to adult delta smelt exiting the central and south Delta to regions with lower entrainment risk?
- To what degree has implementation of the U.S. Fish and Wildlife Service (FWS) Biological Opinion, Reasonable and Prudent Alternatives (RPA) reduced adult delta smelt entrainment?
- What are the salvage efficiencies of the SWP and CVP water export facilities?

Goals of Swimming Behavior Modeling

- Much of the previous work on delta smelt assumed passive transport, in some cases using particle-tracking models
- Contrast distribution predictions from passive particle tracking with multiple active swimming behaviors
- Evaluate which swimming behaviors give distributions most consistent with SKT and salvage observations
- Evaluate whether conclusions of the swimming evaluation depended on details of model grid and numerics by contrasting conclusions from 2D and 3D modeling
- Perform evaluation for multiple water years
- Use particle tracking results to estimate entrainment losses
- Evaluate the effectiveness of the RPA in reducing entrainment losses

Additional Assumptions to Modeling

- Constant in time and uniform in space natural mortality

- Solicit advice on delta smelt behavior and implement a number of swimming behavior rules
  - Implemented in 2 different codes (2D and 3D)

- Swimming behaviors could be driven by a combination of
  - Hydrodynamics
  - Depth
  - Distance to shore
  - Salinity
  - Turbidity

- Key limitations
  - Limited number of environmental stimuli considered
  - Behavior rules do not vary between individuals or with time (life stage)
  - Limited complexity of rules
  - Limited resolution of nearshore velocity and other environmental conditions

Swimming Behavior Conclusions

- Predicted distributions varied dramatically with behavior
- A small set of behaviors were most consistent with the SKT both with 3D modeling tools and 2D modeling tools and across years
  - However the top ranked behavior varied among years
- Passive particles and a simple implementation of “turbidity seeking” did not retain particles and were therefore not consistent with the SKT data
- Continuous tidal migration behavior typically lead to shifting distribution further landward than realistic
- The behaviors which produced distributions most consistent with the SKT were largely driven by intermittent tidal migration in the presence of brackish water or perceived increases in salinity
- Additional aspects such as holding behavior in turbid water could lead to small increases in likelihood (slightly more consistent with SKT)

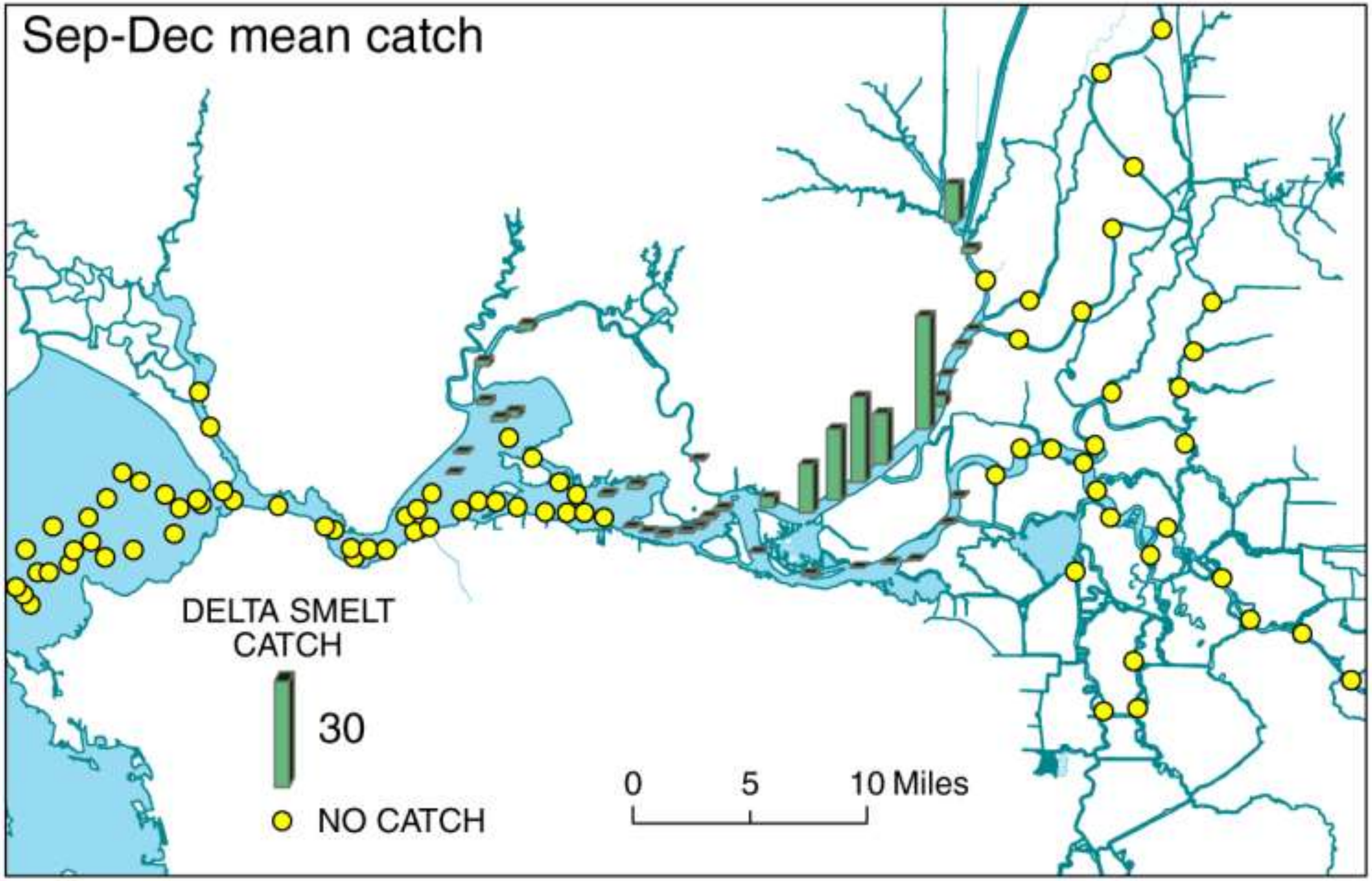
Key Conclusions Related to Research Questions

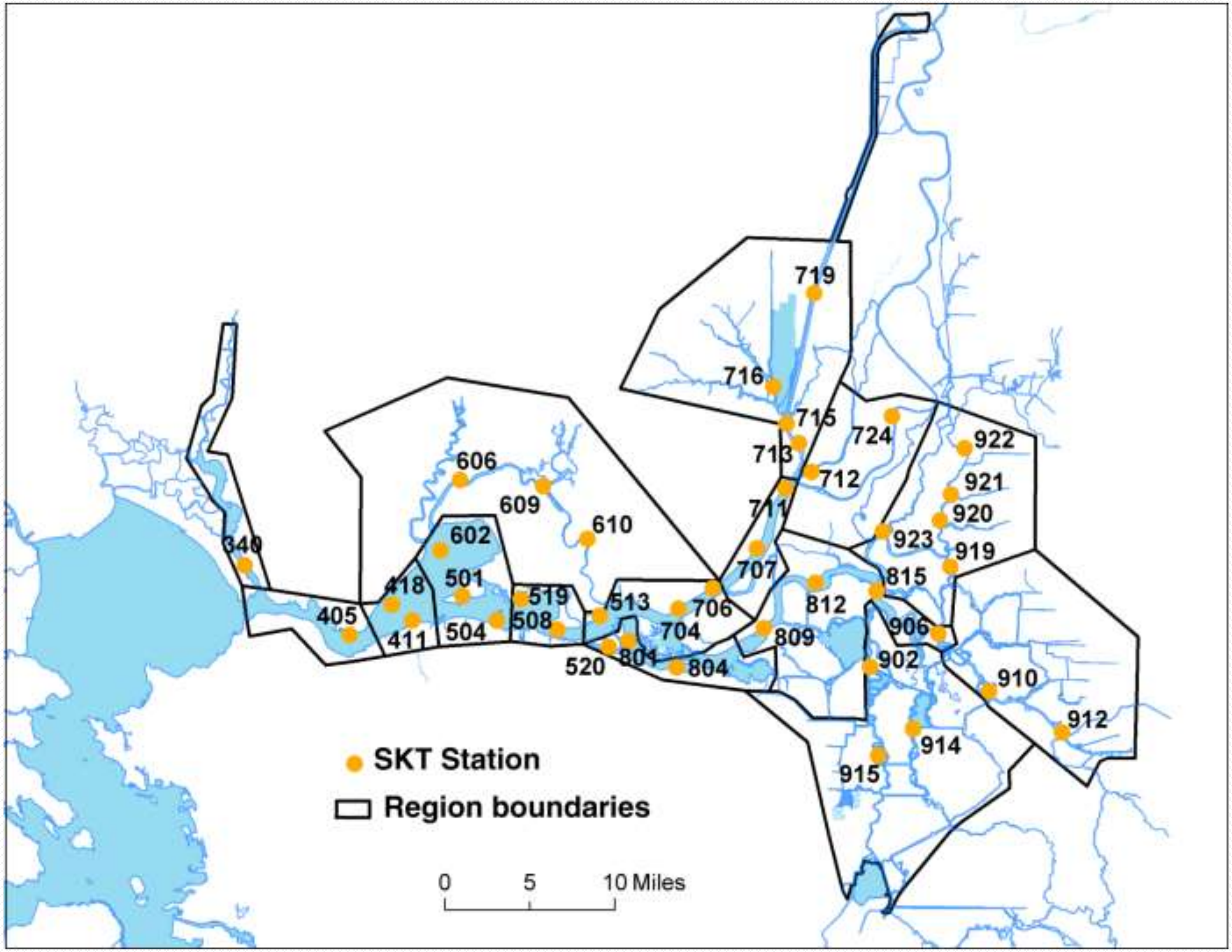
- Which environmental conditions lead to adults entering the south Delta?
  - Net flows toward South Delta
  - Salt intrusion into the western Delta
  - Possible influence of substantial turbidity

- To what degree has implementation of the U.S. Fish and Wildlife Service (FWS) Biological Opinion, Reasonable and Prudent Alternatives (RPA) reduced adult delta smelt entrainment?
  - Substantial to large drops in entrainment estimated (up to 60% decrease using a conditional tidal migration behavior)

- What are the salvage efficiencies of the SWP and CVP water export facilities?
  - Uncertain and possibly related to turbidity or other abiotic or biotic conditions

2001 Fall Mid-Water Trawl




719
716
715
713
724
712
922
921
920
711
923
919
606
609
610
602
340
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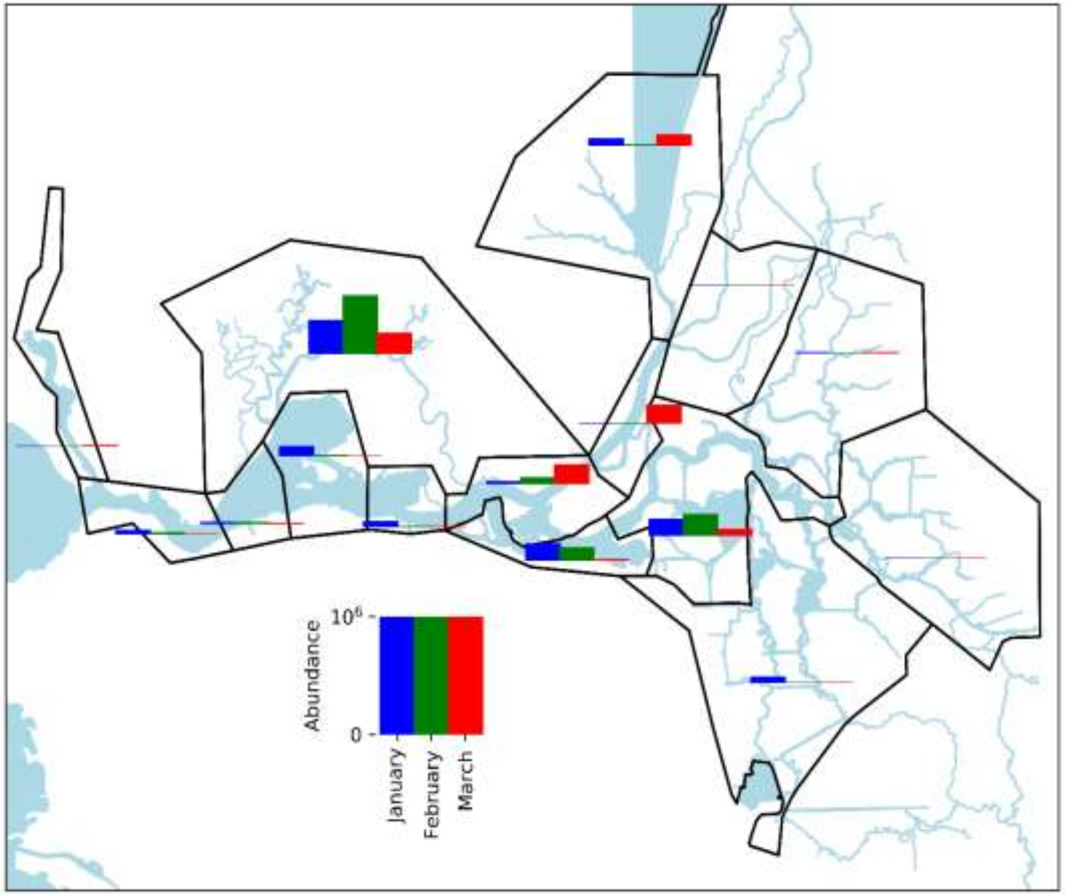
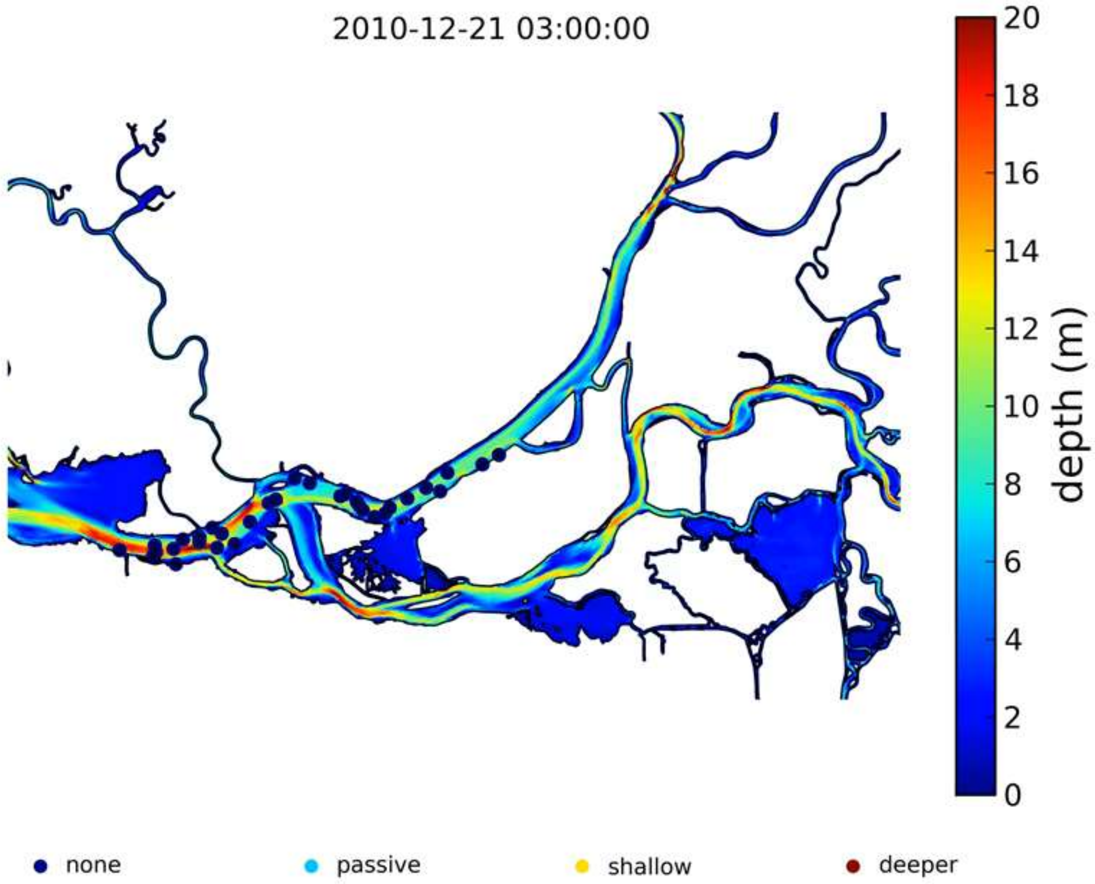
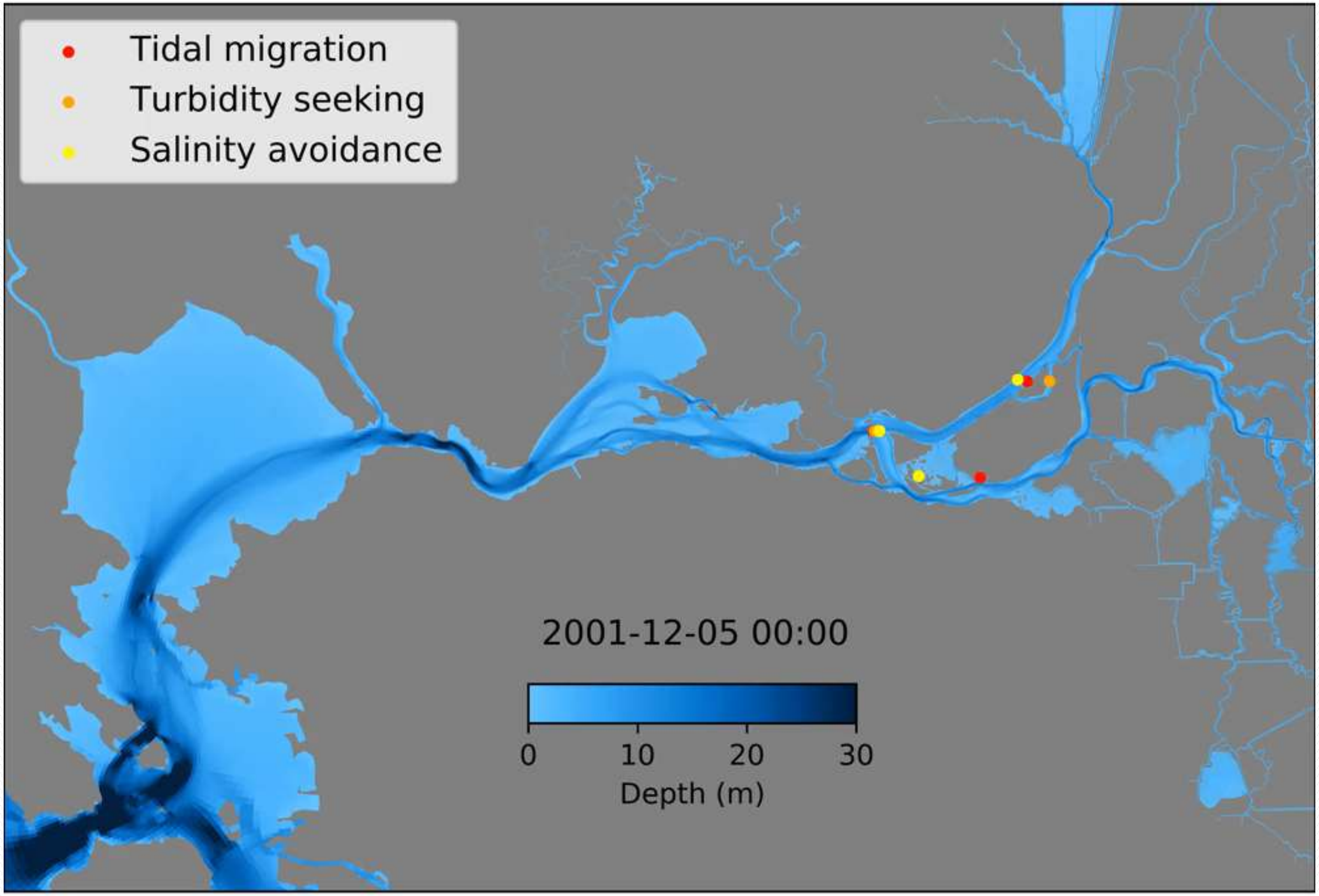
501
519
513
706
707
815
812
405
411
504
508
704
809
906
520
801
804
902
910
912
914
915
SKT Station
Region boundaries
0
5
10 Miles

SKT Regional Abundance Estimates, 2002

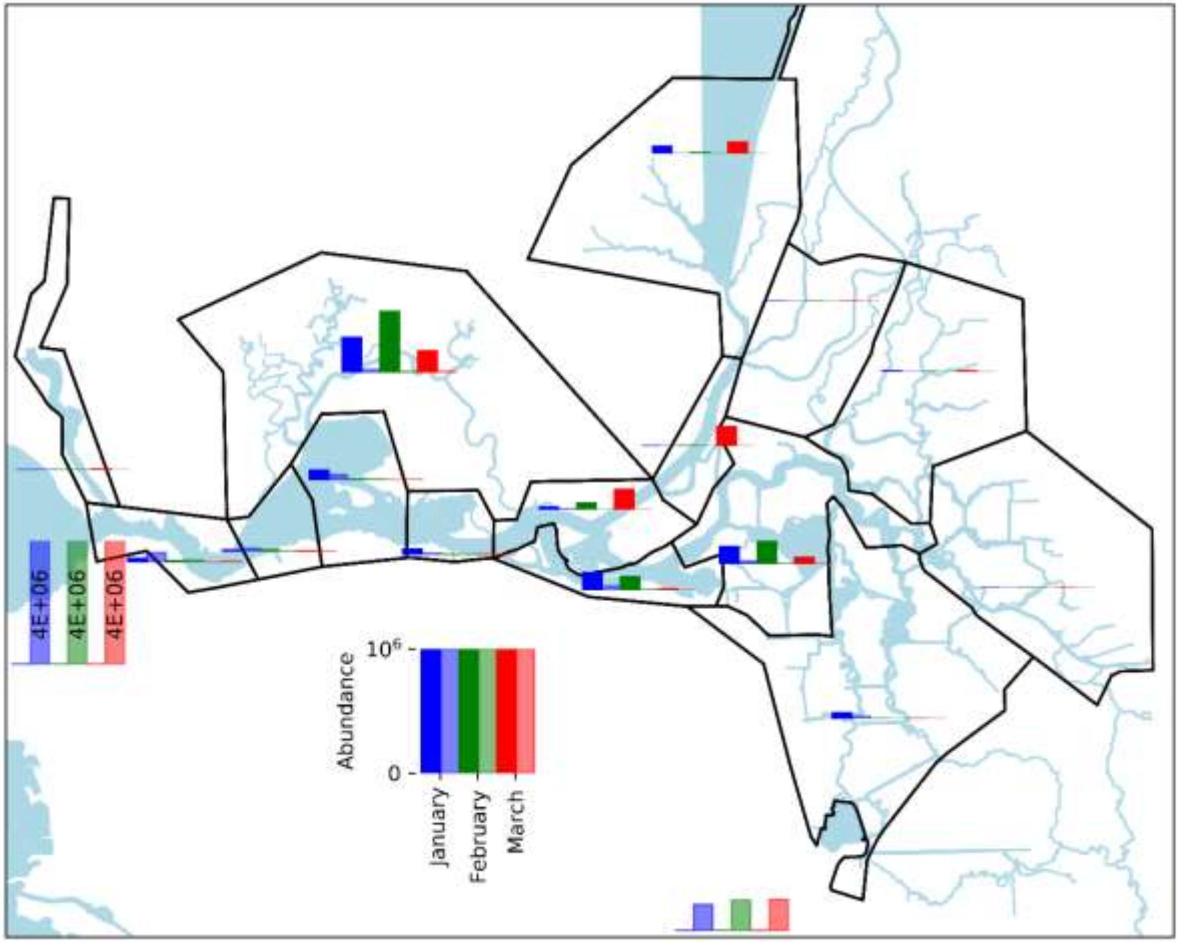



2010-12-21 03:00:00
20
18
16
14
12
10
8
6
4
2
0
depth (m)
none
passive
shallow
deeper

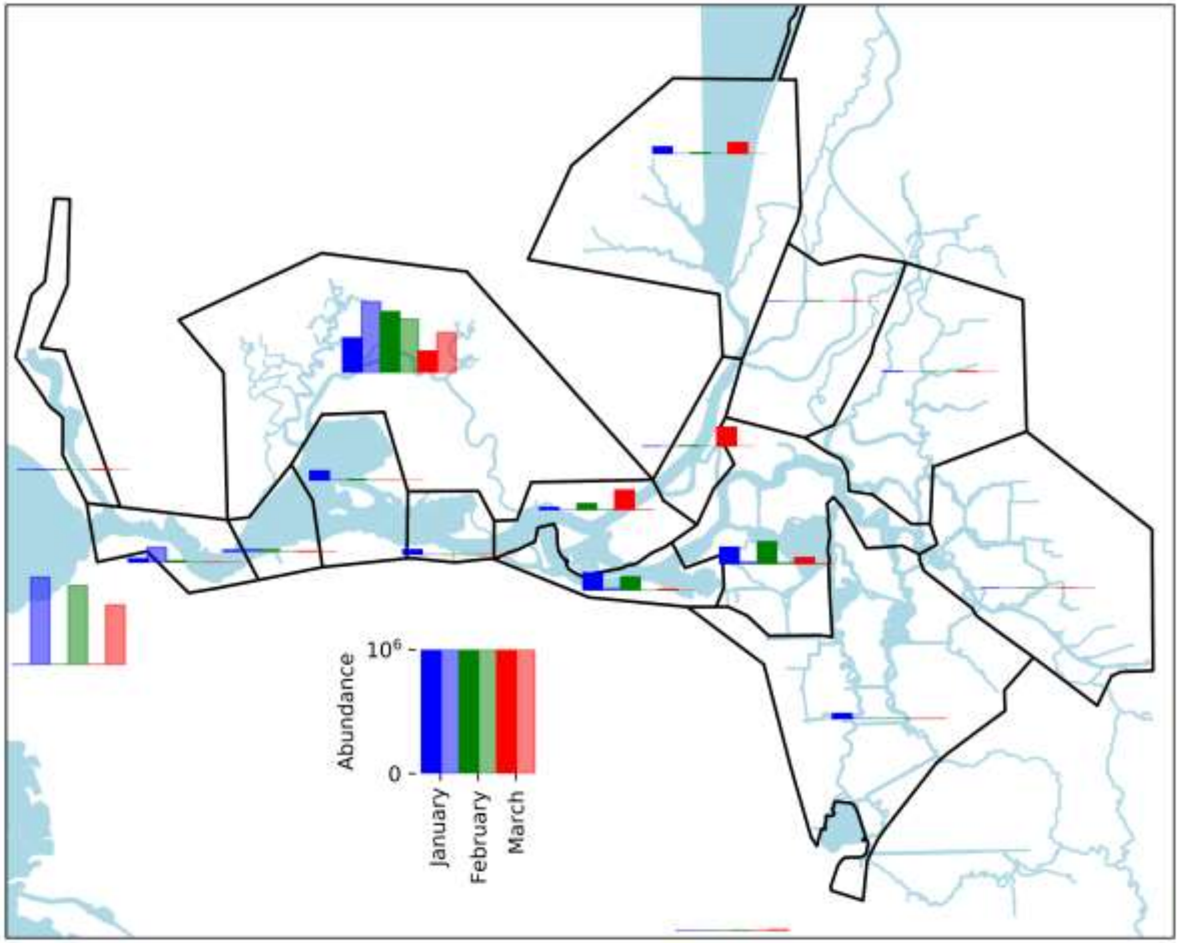


Tidal migration
Turbidity seeking
Salinity avoidance
2001-12-05 00:00
0
10
20
30
Depth (m)

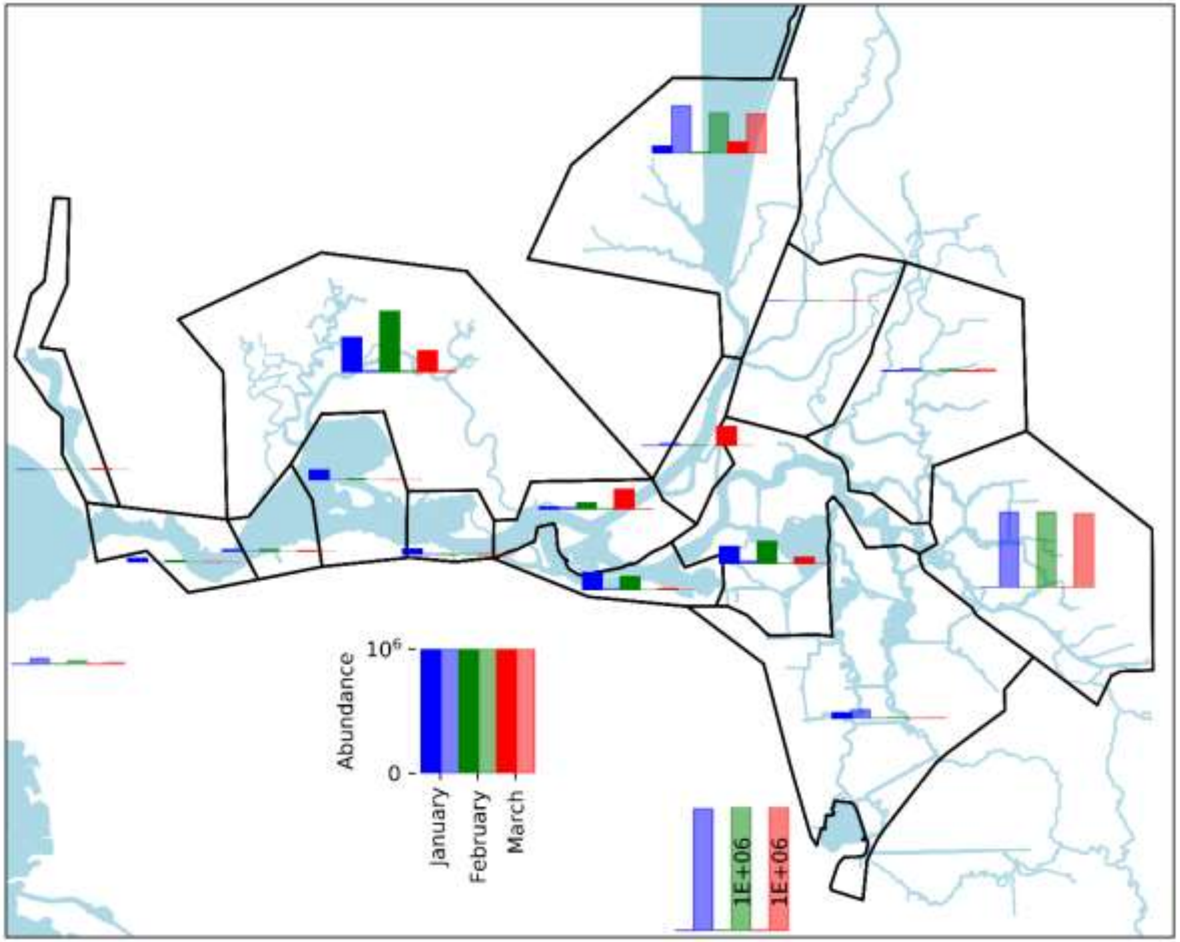
Passive



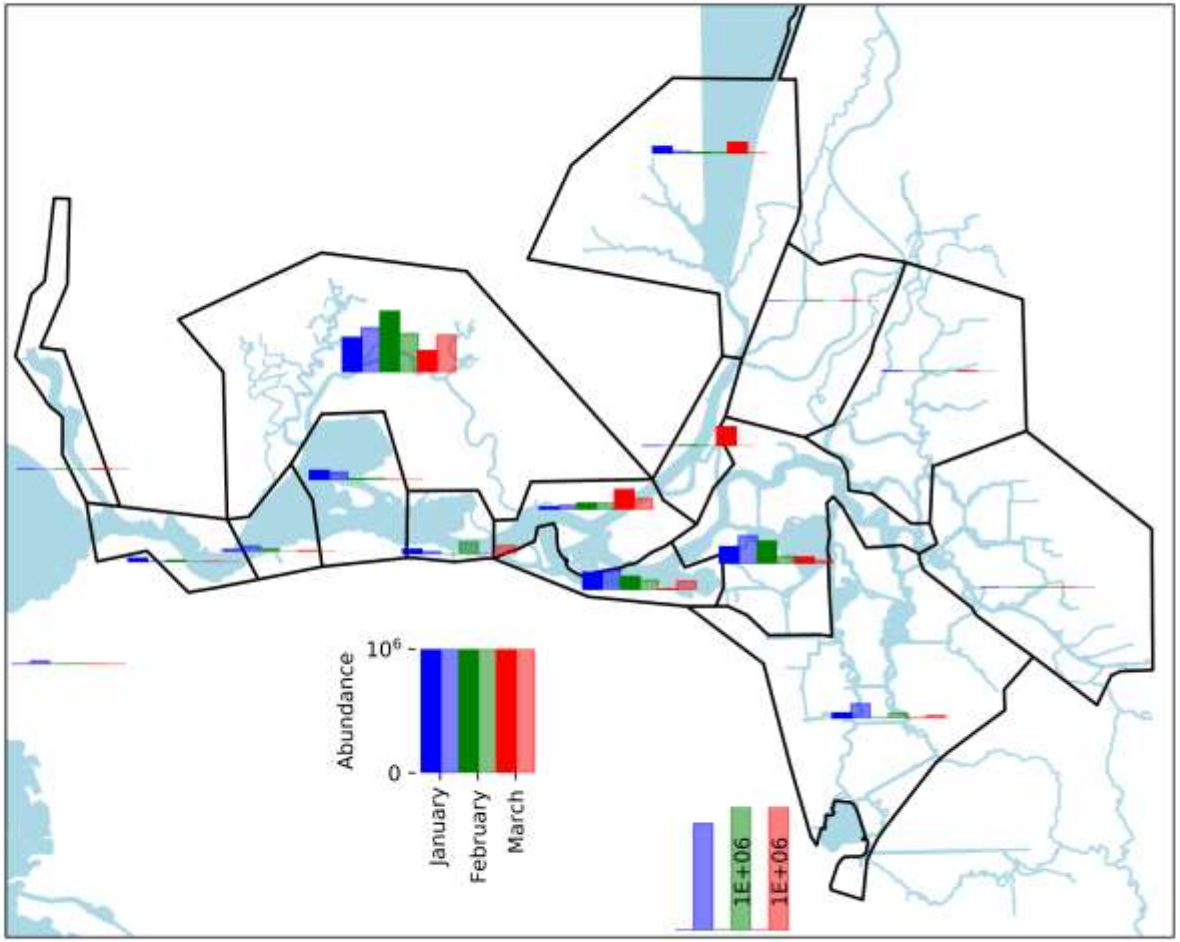
Turbidity Seeking

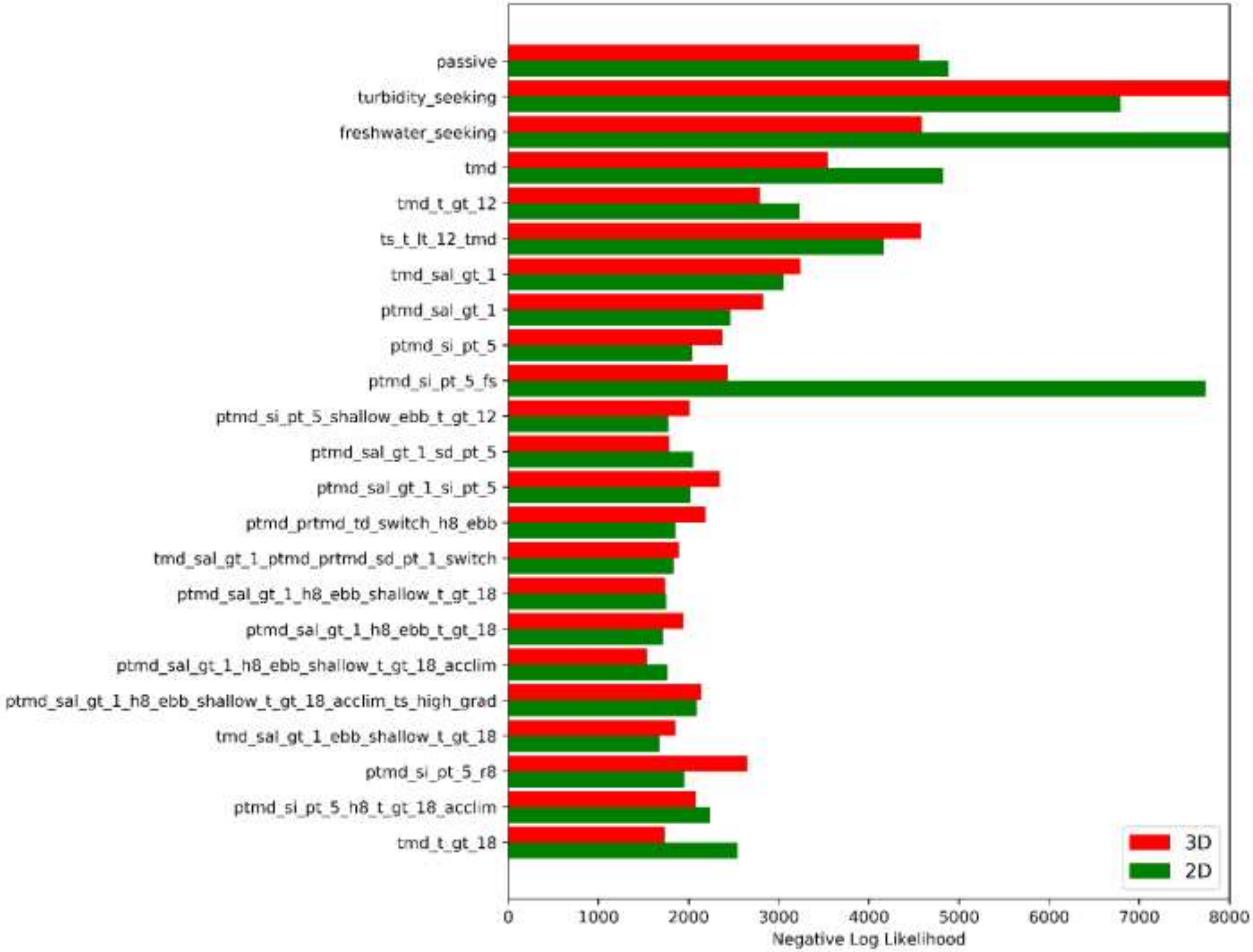


Tidal Migration



Tidal Migration for Salinity Increasing, Holding for Turbidity > 18 NTU




passive
turbidity_seeking
freshwater_seeking
tmd
tmd_t_gt_12
ts_t_lt_12_tmd
tmd_sal_gt_1
ptmd_sal_gt_1
ptmd_si_pt_5
ptmd_si_pt_5_fs
ptmd_si_pt_5_shallow_ebb_t_gt_12
ptmd_sal_gt_1_sd_pt_5
ptmd_sal_gt_1_si_pt_5
ptmd_prtmd_td_switch_h8_ebb
tmd_sal_gt_1_ptmd_prtmd_sd_pt_1_switch
ptmd_sal_gt_1_h8_ebb_shallow_t_gt_18
ptmd_sal_gt_1_h8_ebb_t_gt_18
ptmd_sal_gt_1_h8_ebb_shallow_t_gt_18_acclim
ptmd_sal_gt_1_h8_ebb_shallow_t_gt_18_acclim_ts_high_grad
tmd_sal_gt_1_ebb_shallow_t_gt_18
ptmd_si_pt_5_r8
ptmd_si_pt_5_h8_t_gt_18_acclim
tmd_t_gt_18
3D
2D
0
1000
2000
3000
4000
5000
6000
7000
8000
Negative Log Likelihood

Key Conclusions Related to Research Questions

- Which environmental conditions lead to adults entering the south Delta?
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- To what degree has implementation of the U.S. Fish and Wildlife Service (FWS) Biological Opinion, Reasonable and Prudent Alternatives (RPA) reduced adult delta smelt entrainment?
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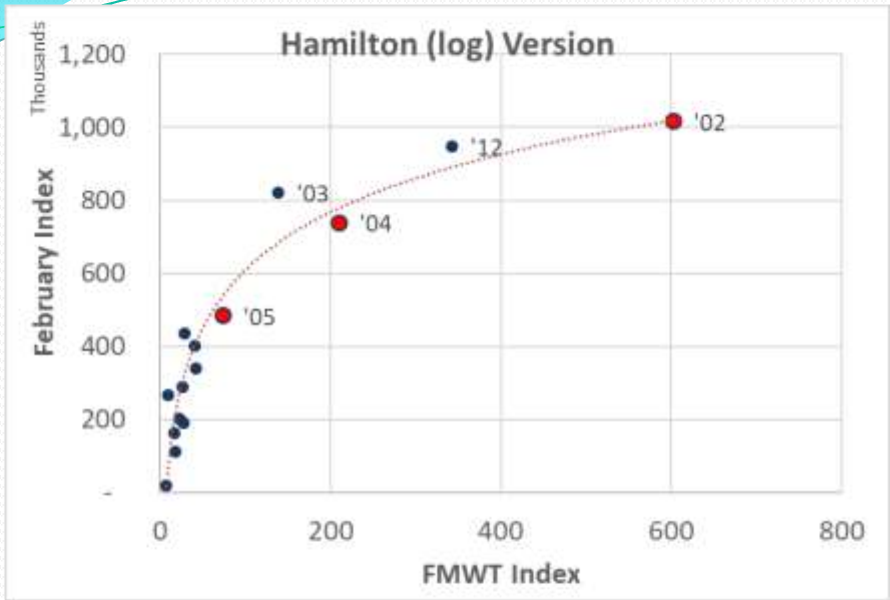
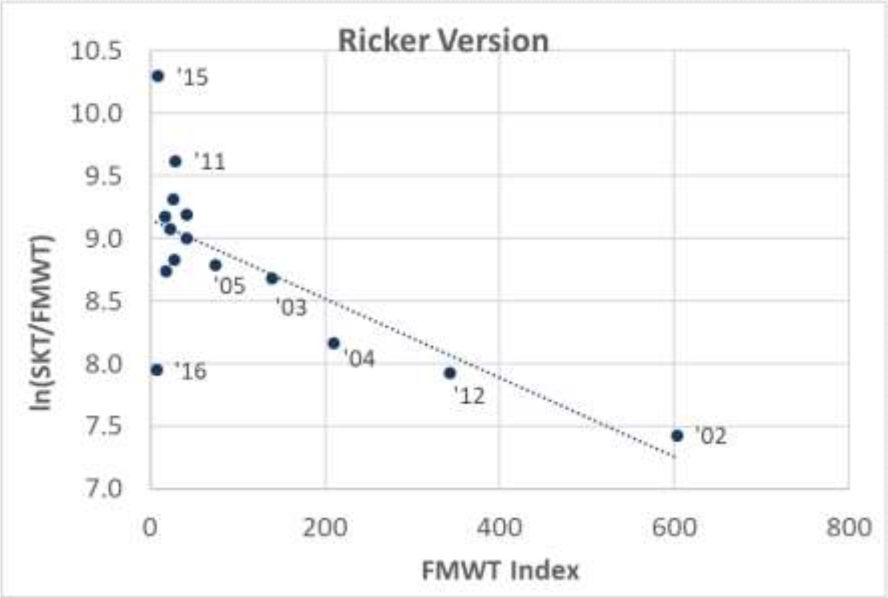
Key Conclusions from Statistical PEL Model

- Different behavioral assumptions led to very different estimates of PEL.
- More complex behavioral models fit the FMWT, SKT, and salvage data better than simpler models.
- PEL estimates from best fit behavioral models were 35% (2002), 50% (2004), 15% (2005), and 3% (2011). Fits to salvage data with turbidity-driven time-varying salvage expansion were very good, and fits to SKT data were generally good.
- PEL estimates from 2002-2005 were more than 2-fold higher than Kimmerer 2008!
- Lots of uncertainty in PEL estimates driven mostly by no data on expansion factors for SKT to translate catch to abundance, and very limited data on expansion factors for translate salvage data to entrainment.

FMWT-SKT Relationship





- Two interpretations:
  - PEL is not variable among years and lower SKT/FMWT ratio in '02-'05 and '12 is due to lower survival rate due to higher FMWT density. Thus, predicted high interannual variation in PEL is wrong.
  - There is no or very limited density-dependence in survival, and low SKT/FMWT ratio in '02-'05 and '12 is due to other factors like PEL. Higher and variable PEL might be OK.
  - Density and PEL effects are confounded because we selected high abundance years to model.

Reliability of PEL Estimates to Address Management Questions (e.g., has PEL Been Relatively Low Since 2006?)

- There is large uncertainty in estimates of proportional entrainment loss due to uncertainties in both θ_S and θ_{SKT}.

$$\text{PEL} = \frac{C_{sal} \cdot \theta_s}{C_{SKT} \cdot \theta_{SKT}} \quad \begin{array}{l} \longleftarrow \text{entrainment} \\ \longleftarrow \text{abundance} \end{array}$$

- Error in the **<u>ratio</u>** of θ_S to θ_{SKT} will lead to error in PEL estimates.

- It is not feasible to directly estimate θ_{SKT} for Delta Smelt based on mark-recapture. All PEL estimates therefore rely on this highly uncertain assumption.

- Direct estimation of θ_S via additional field-based salvage expansion studies using cultured Delta Smelt (like Castillo et al. 2012) should reduce uncertainty in the numerator of PEL.

Sources of Uncertainty in θ_{SKT}

- The gorilla assumption

$$\theta_{SKT_i} = \frac{V_i}{v_i} \qquad \frac{\text{habitat volume in region i}}{\text{tow volume in region i}}$$

- Use of ratio of habitat volume/sampled volume is not an accepted approach for estimating capture probability ($1/\theta_{SKT}$).

- We should expect large variation in capture probability not accounted for by V/v due to:
  - Differences in morphology among regions, leading to potential biases in relative differences in V's among regions, leading to biases in spatial distribution (and hence % of population vulnerable to entrainment).
  - If population spatially contracts at lower abundance, spatial bias could lead to bias in temporal trends.
  - Variation in V over time within a region, due to trends in factors like turbidity, predators, SAV, and Delta Smelt abundance, could lead to temporal bias even if there is no spatial bias.

- Non-random selection of survey sites.
  - If high quality sites were selected, there could expect a hyper-stable relationship between abundance and catch (e.g. decreases in catch underestimate the decrease in population size).

Bottom-Lines for Decision-Makers

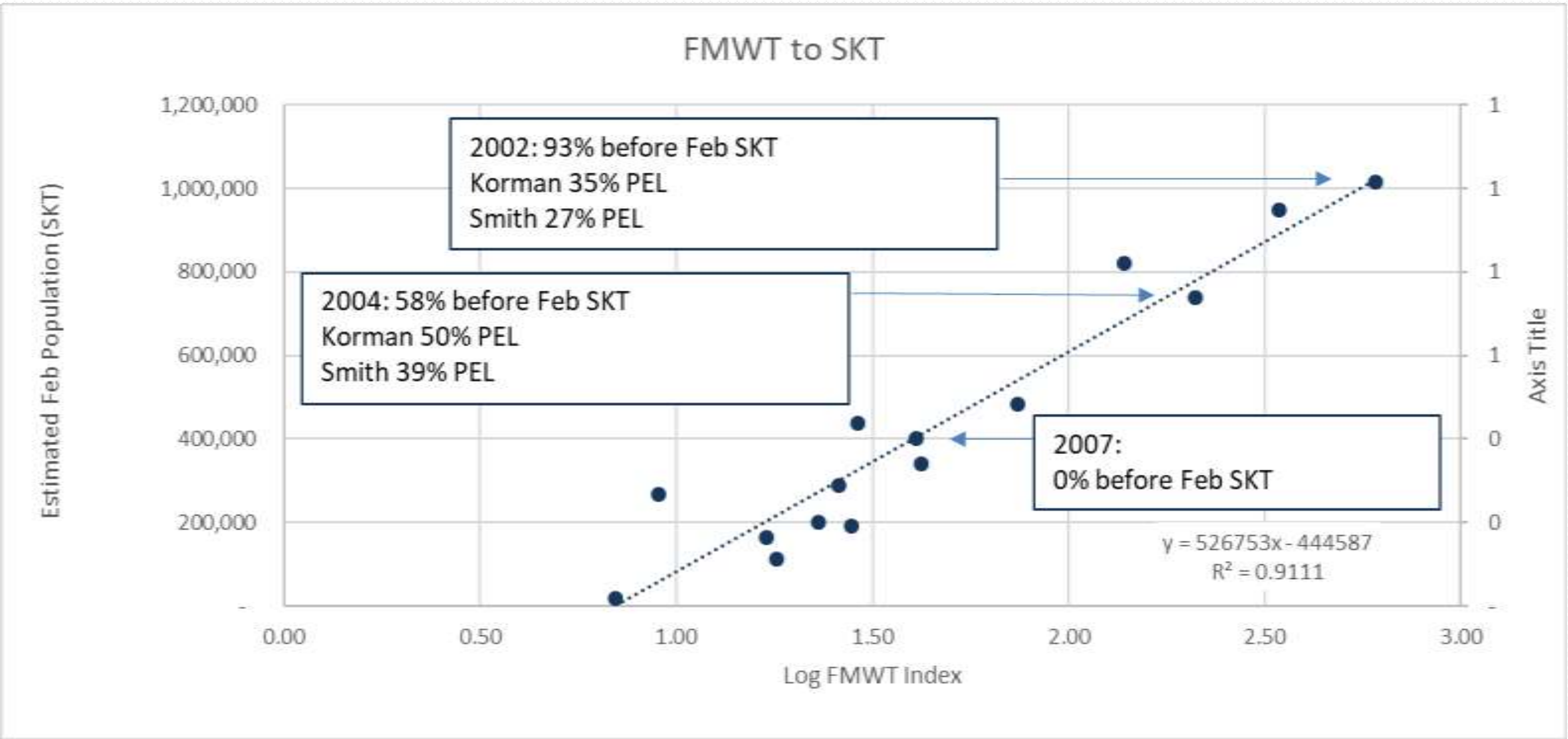
- Too many unsupported assumptions to make definitive statements about recent trends in PEL.
  - Don't have reliable estimates of q_s or q_{SKT}.
  - Thus, we can't reliably determine if the q_s/q_{SKT} ratio has been changing over time.
  - Hence, the time trend in PEL, which assumes a stationary q_s/q_{SKT} ratio, is uncertain.

- These uncertainties also apply to the interpretation of the strong relationship between log(FMWT) and SKT abundance indices.
  - Additional uncertainty resulting from V/v assumption needed to create FMWT index. Thus analysis is not informative re. reliability of PELs.
  - If we trust all q's and assume SKT/FMWT ratio is low in '02-'05 and '12 due to density-dependence, then relationship indicates that PEL is not variable among years, which contradicts modelled estimates of PEL.
  - If we trust all q's and assume the ratio of SKT/FMWT is not density dependent, then relationship does not contradict modelled PEL estimates.

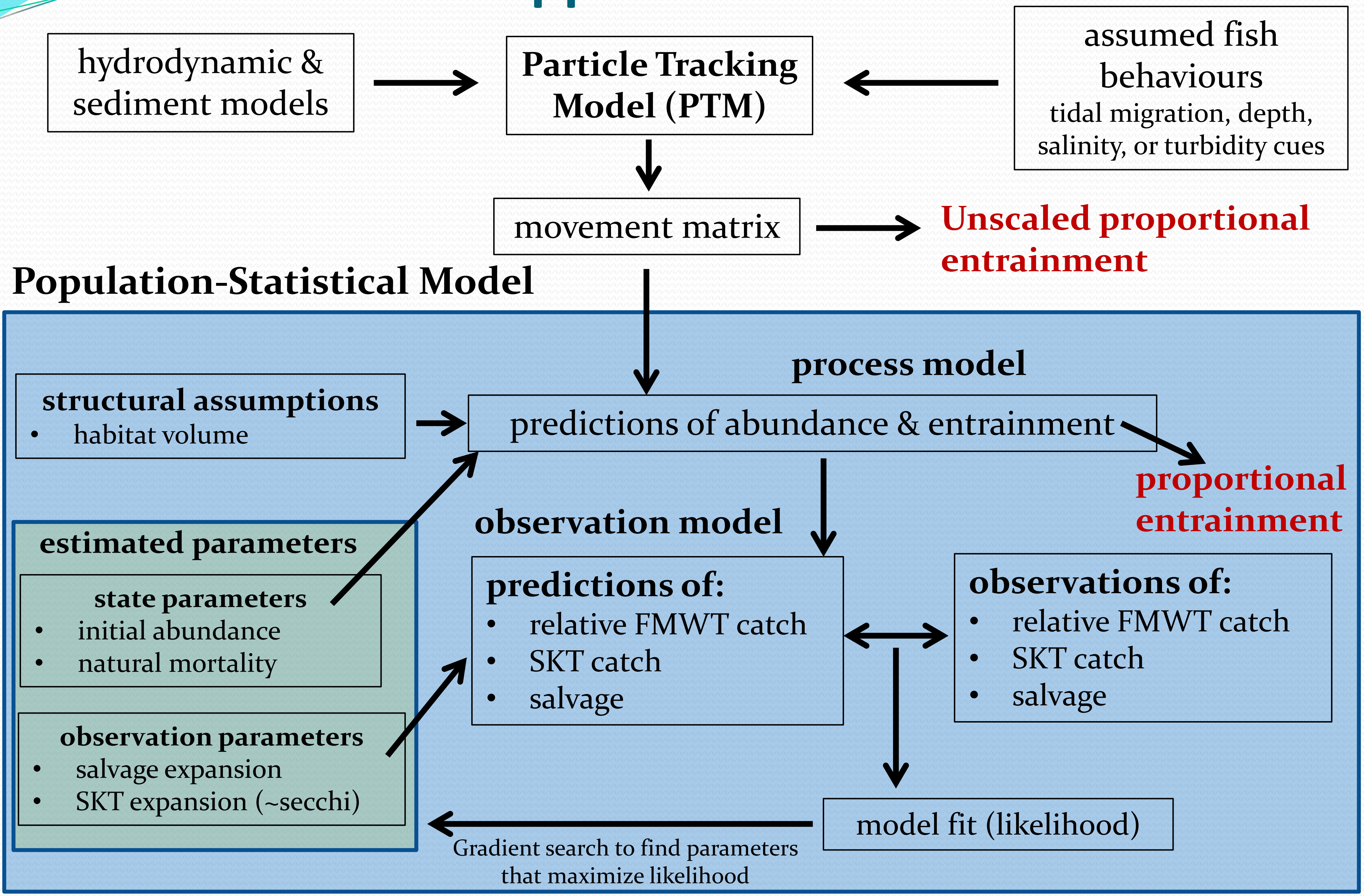
- Recommend repeating Pete Smith's analysis but with integration of data from FMWT-SKT relationship. May reduce inter-annual variation or magnitude of PEL estimates as determined by information in FMWT-SKT data vs. SKT data (all trips) vs. salvage data.

Extra Slides

Hamilton 2019



Overview of Approach



CAMT Regional Boundaries

15 or 16 CAMT regions + additional ghost regions + domain loss to San Francisco Bay
2 entrainment locations (CVP, SWP)