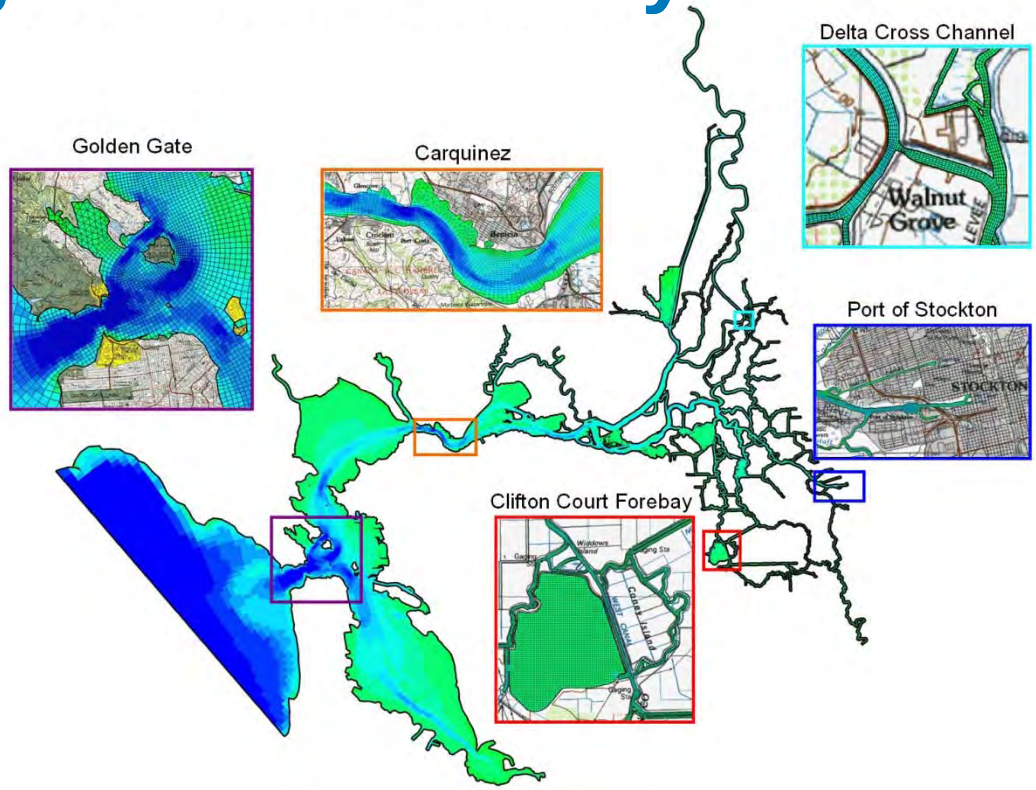
EPA Technical Workshop on Estuarine Habitat in the Bay Delta Estuary

Modeling Estuarine Habitat using the UnTRIM Bay-Delta Model



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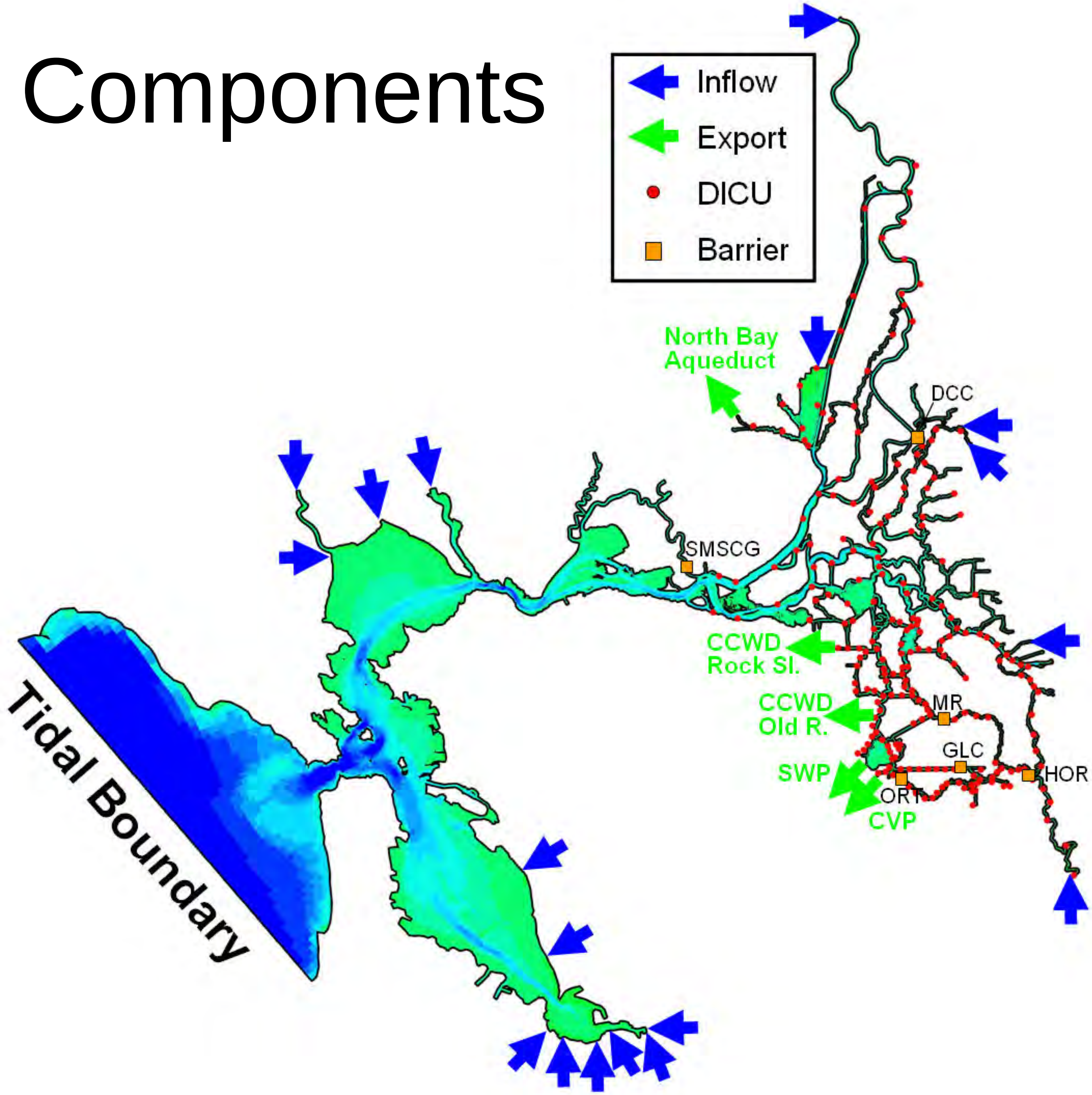
March 27, 2012

DELTA MODELING ASSOCIATES

Outline

- Tools
  - UnTRIM Bay-Delta Model
- How is X2 Calculated?
  - Assumptions of Common Calculation Approaches
- Habitat Analysis Approaches
  - Modeling X2
  - Low Salinity Zone
- Conclusions

Model Components



TRIM-UnTRIM Literature

Numerical Model Verification

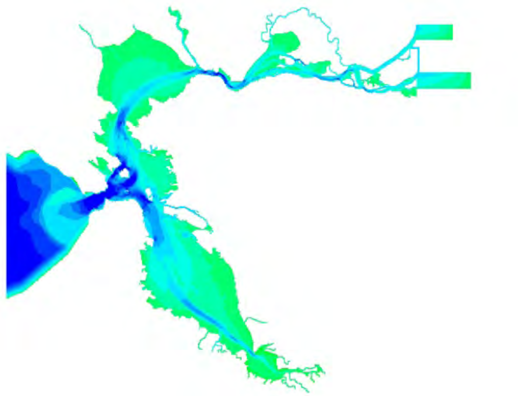
- **TRIM3D**
  - Casulli (1990)
  - Casulli and Cheng (1992)
  - Casulli and Cattani (1994)
  - Gross et al. (1998)
  - Gross et al. (2002)
- **UnTRIM**
  - Casulli (1998)
  - Casulli (1999)
  - Casulli and Walters (2000)
  - Casulli and Zanolli (2002)
  - Casulli and Zanolli (2005)
  - Brugnano and Casulli (2007)
  - Casulli (2009)
  - Casulli and Stelling (2010)

SF Bay-Delta Validation

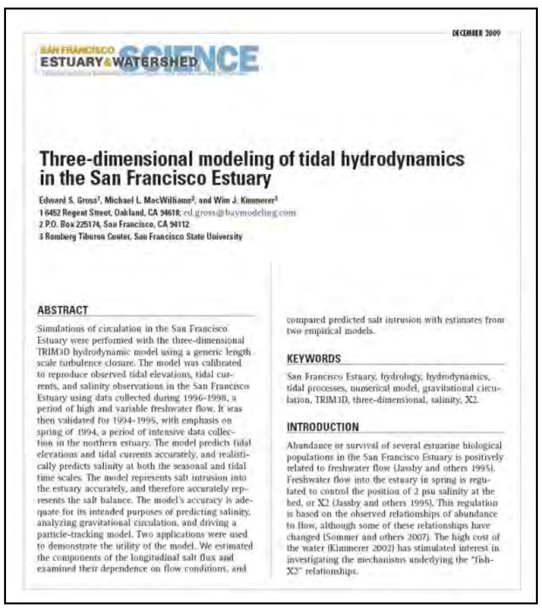
- **TRIM2D/3D**
  - Casulli and Cheng (1992)
  - Cheng et al. (1993)
  - Cheng and Casulli (1996)
  - SFPORTS: Cheng and Smith (1998)
  - Gross (1998)
  - Gross et al. (1999)
  - 2-D Delta: Monsen (2000)
  - Cargill: Gross & Schaaf & Wheeler (2003)
  - ECM: Gross et al. (2006)
  - Fish-X2: Gross, MacWilliams & Kimmerer (2009)
- **UnTRIM**
  - Cheng and Casulli (2002)
  - Hamilton ATF: MacWilliams & Cheng (2005)
  - ICHE: MacWilliams and Cheng (2006)
  - DRMS: MacWilliams et al. (2007a)
  - IAHR: MacWilliams et al. (2007b)
  - POD: MacWilliams et al. (2008)
  - USACE: MacWilliams et al. (2009)
  - BDCP: MacWilliams & Gross(2010)

Entrapment Zone Salinity Comparisons

- TRIM3D Fish-X2: 2004-2005



Gross, MacWilliams and Kimmerer, 2009



DECEMBER 2009

SAN FRANCISCO ESTUARY & WATERSHED SCIENCE

Three-dimensional modeling of tidal hydrodynamics in the San Francisco Estuary

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1 6452 Regent Street, Oakland, CA 94618; ed.gross@baymodeling.com
2 P.O. Box 225174, San Francisco, CA 94112
3 Romberg Tiburon Center, San Francisco State University

ABSTRACT

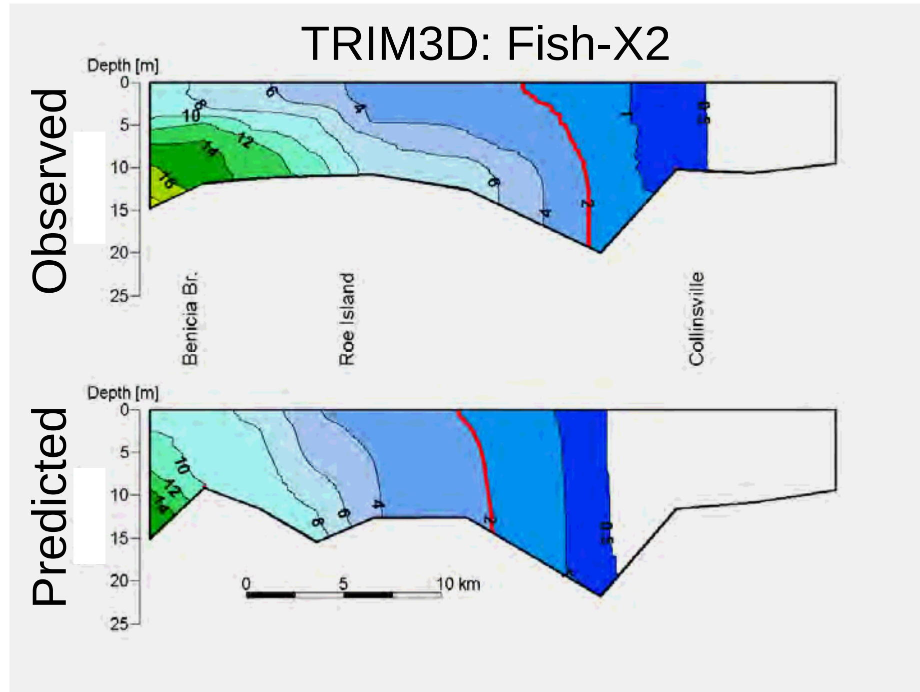
Simulations of circulation in the San Francisco Estuary were performed with the three-dimensional TRIM3D hydrodynamic model using a generic length scale turbulence closure. The model was calibrated to reproduce observed tidal elevations, tidal currents, and salinity observations in the San Francisco Estuary using data collected during 1996-1998, a period of high and variable freshwater flow. It was then validated for 1994-1995, with emphasis on spring of 1994, a period of intensive data collection in the northern estuary. The model predicts tidal elevations and tidal currents accurately, and realistically predicts salinity at both the seasonal and tidal time scales. The model represents salt intrusion into the estuary accurately, and therefore accurately represents the salt balance. The model's accuracy is adequate for its intended purposes of predicting salinity, analyzing gravitational circulation, and driving a particle-tracking model. Two applications were used to demonstrate the utility of the model. We estimated the components of the longitudinal salt flux and examined their dependence on flow conditions, and compared predicted salt intrusion with estimates from two empirical models.

KEYWORDS

San Francisco Estuary, hydrology, hydrodynamics, tidal processes, numerical model, gravitational circulation, TRIM3D, three-dimensional, salinity, X2.

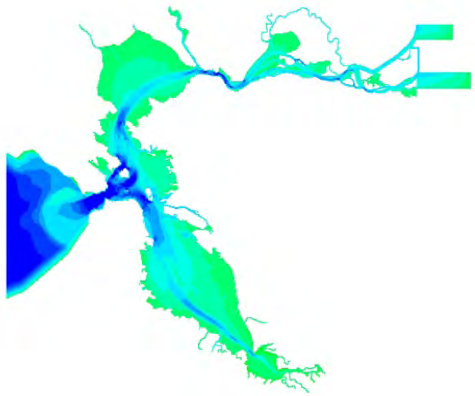
INTRODUCTION

Abundance or survival of several estuarine biological populations in the San Francisco Estuary is positively related to freshwater flow (Jassby and others 1995). Freshwater flow into the estuary in spring is regulated to control the position of 2 psu salinity at the bed, or X2 (Jassby and others 1995). This regulation is based on the observed relationships of abundance to flow, although some of these relationships have changed (Sommer and others 2007). The high cost of the water (Kimmerer 2002) has stimulated interest in investigating the mechanisms underlying the "fish-X2" relationships.

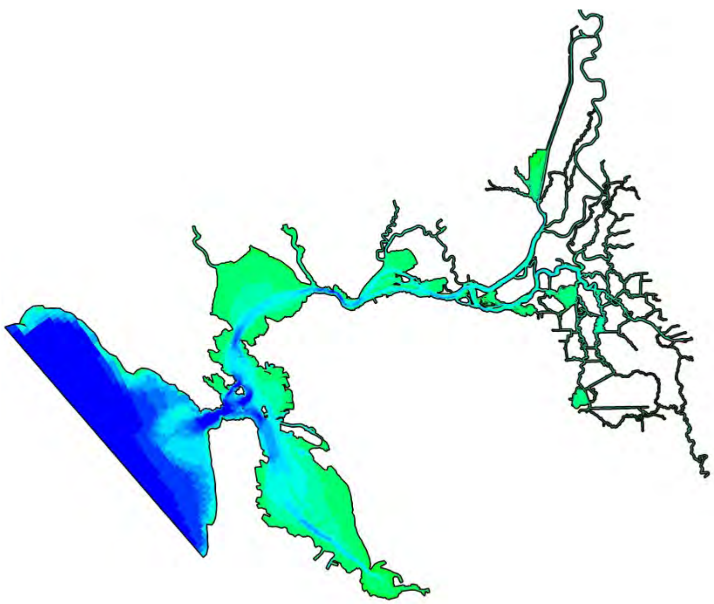


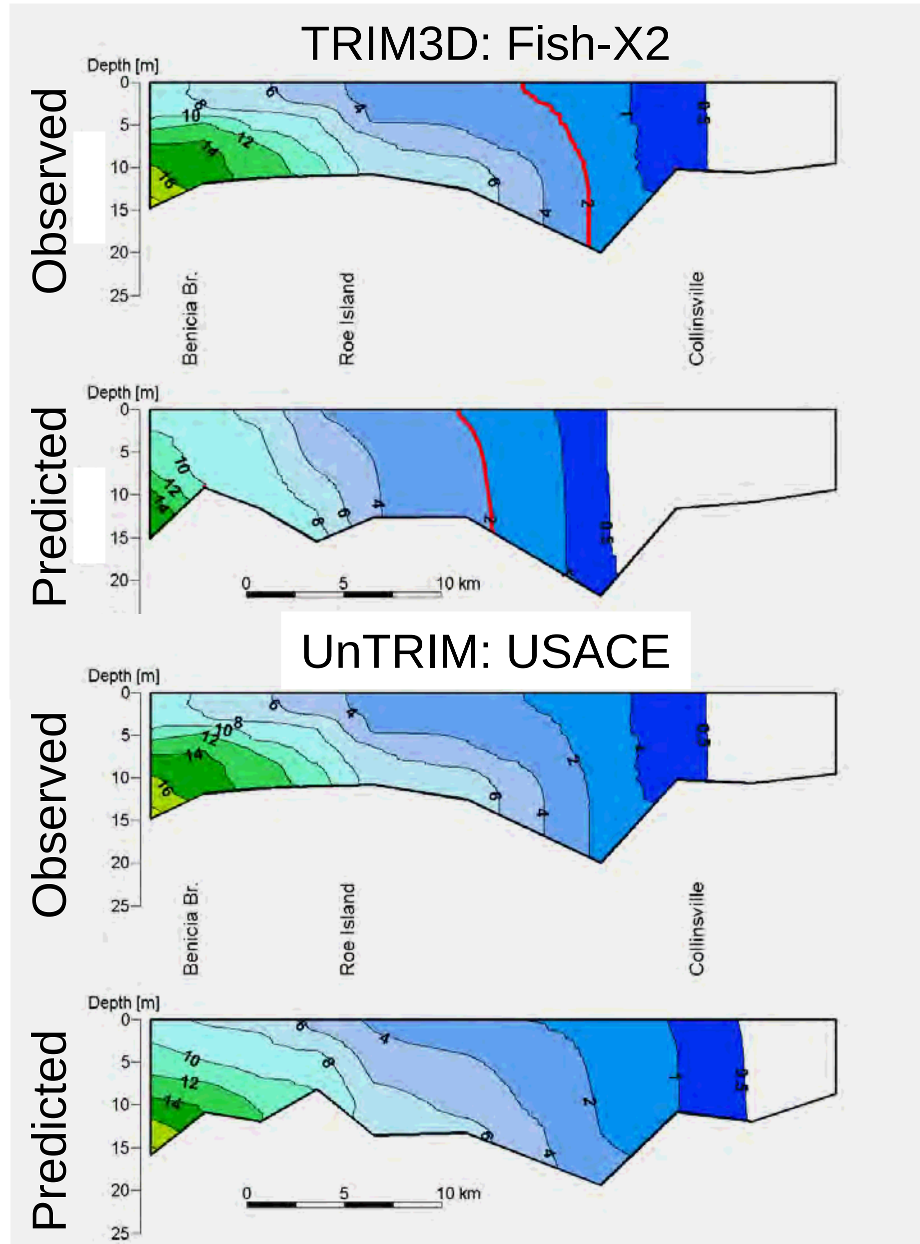
Entrapment Zone Salinity Comparisons

- TRIM3D Fish-X2: 2004-2005



- UnTRIM USACE: 2009-2010





Entrapment Zone Salinity Comparisons

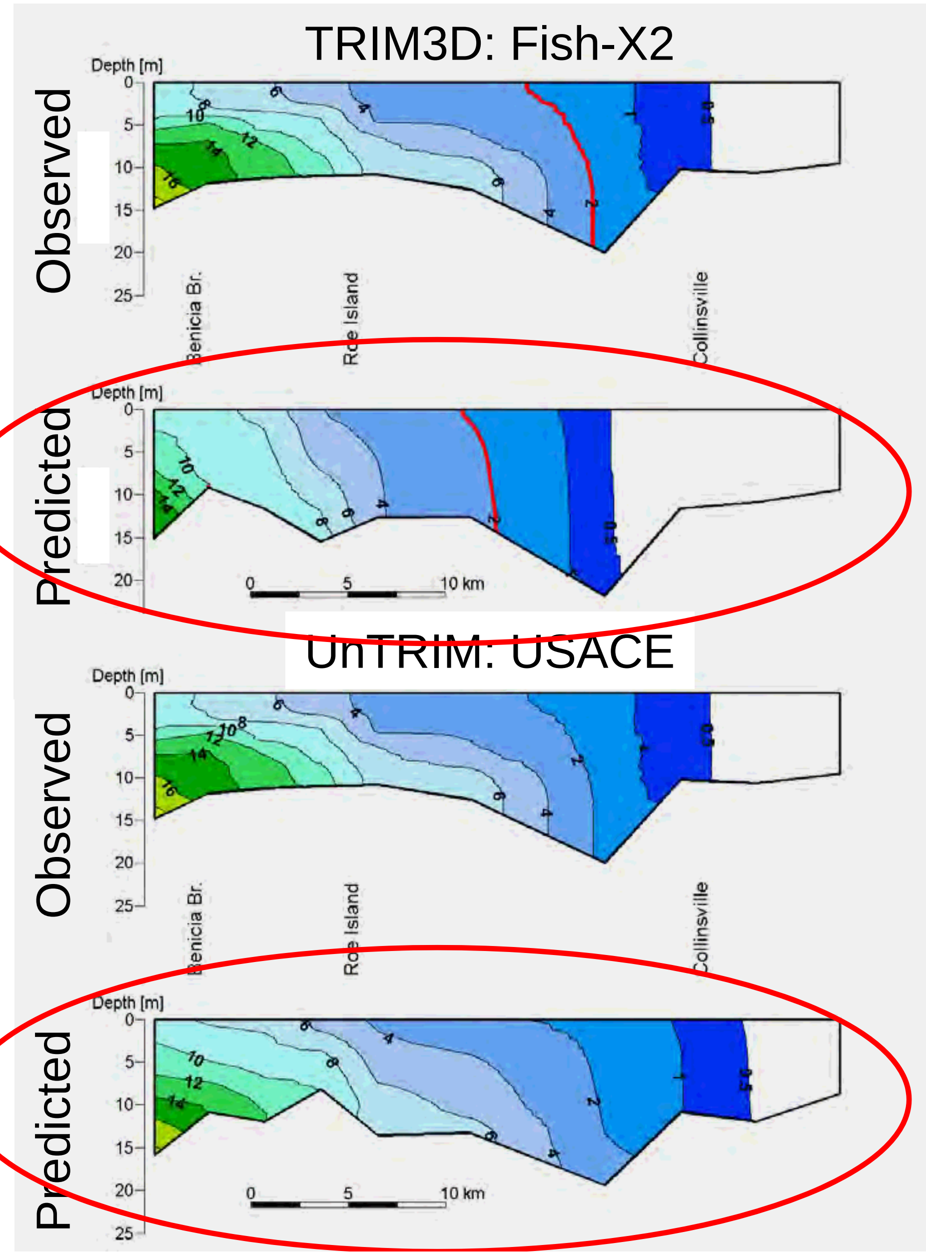
Date and Time	Average Error (psu)	Standard Error (psu)
4/27/1994 6:18	-1.63	0.82
4/27/1994 9:44	-1.48	0.98
4/27/1994 14:03	-1.58	0.92
4/27/1994 17:28	-0.64	0.63
4/27/1994 22:47	-1.55	1.07
4/28/1994 3:46	-1.54	0.84
4/28/1994 8:26	-1.78	0.97
4/28/1994 12:44	-1.48	1.09
5/17/1994 6:46	-0.70	1.33
5/17/1994 9:41	-1.25	1.52
5/17/1994 12:30	-0.76	0.58
5/17/1994 17:53	-0.97	1.02
5/17/1994 19:24	-0.50	0.71
5/17/1994 23:44	-0.73	0.68
5/18/1994 3:27	-1.59	1.66
5/18/1994 8:05	-1.15	1.44
5/18/1994 11:14	-1.26	1.33

FISH-X2: MEAN ERROR SPRING: -1.46
MEAN ERROR NEAP: -0.99 PSU

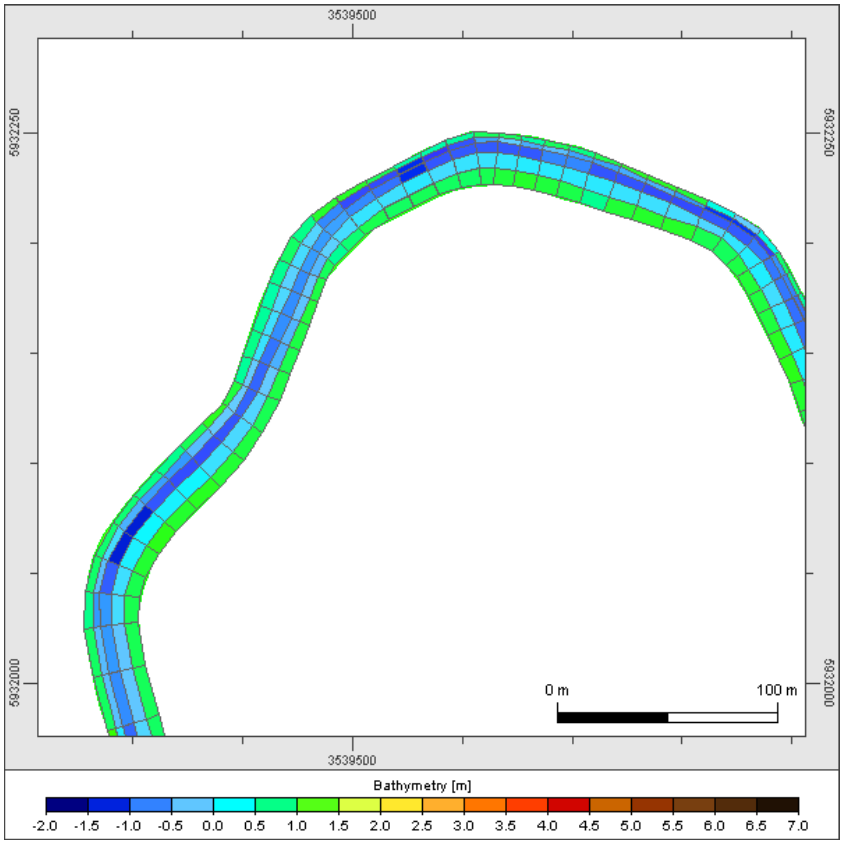
USACE. Average error and standard error for each Entrapment Zone Study synoptic salinity sampling cruise.

Date and Time	Average Error (psu)	Standard Error (psu)
4/27/1994 6:18	0.19	0.67
4/27/1994 9:44	-0.07	0.32
4/27/1994 14:03	-0.68	0.46
4/27/1994 17:28	-0.38	0.96
4/27/1994 22:47	0.52	0.66
4/28/1994 3:46	0.05	0.96
4/28/1994 8:26	0.03	0.36
4/28/1994 12:44	-0.27	0.39
5/17/1994 6:46	0.67	1.11
5/17/1994 9:41	0.17	0.80
5/17/1994 12:30	0.17	0.35
5/17/1994 17:53	-0.36	0.65
5/17/1994 19:24	-0.51	0.70
5/17/1994 23:44	0.31	0.87
5/18/1994 3:27	0.24	0.75
5/18/1994 8:05	0.13	0.91
5/18/1994 11:14	-0.04	0.79

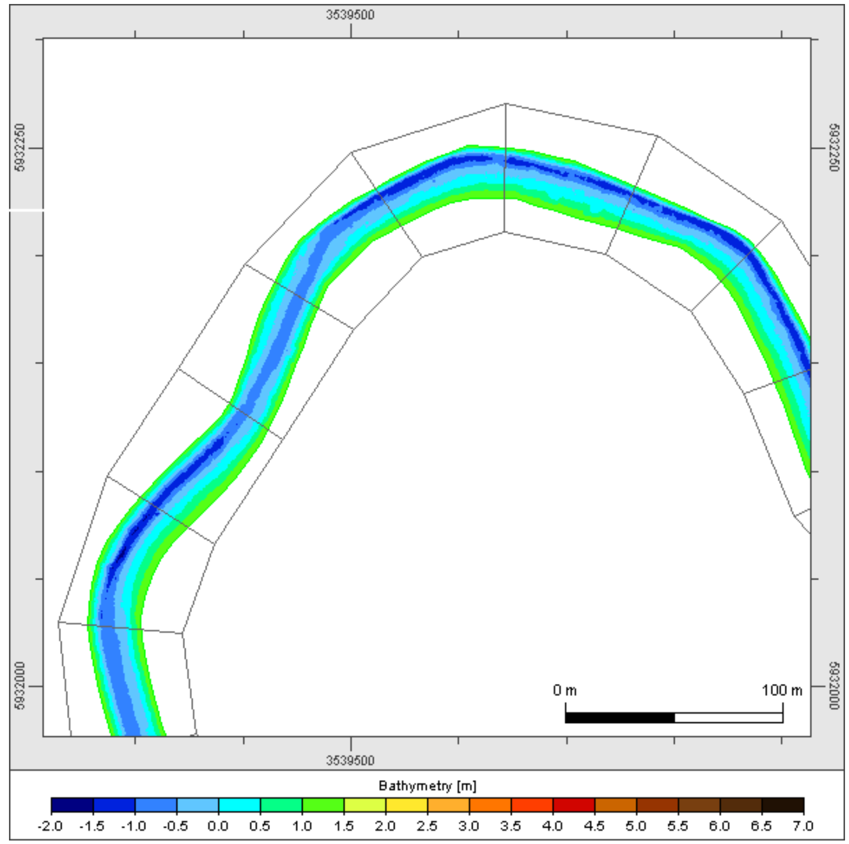
USACE: MEAN ERROR SPRING: -0.08
MEAN ERROR NEAP: = -0.09 PSU



UnTRIM^2 2009 Sub-Grid Bathymetry



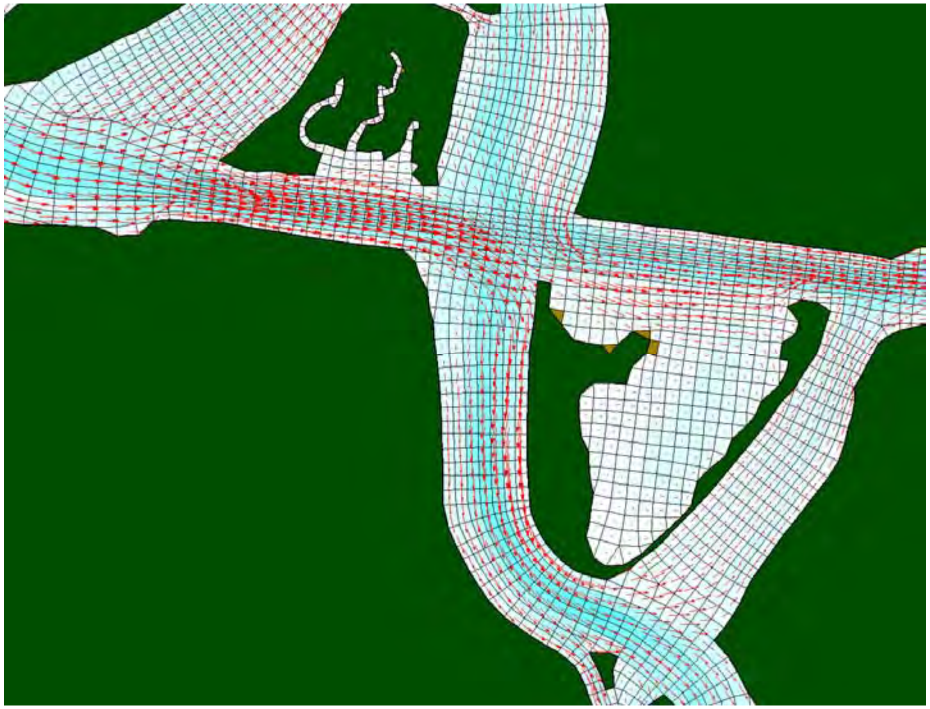
UnTRIM2004 river stretch with 5 cells across channel cross-section



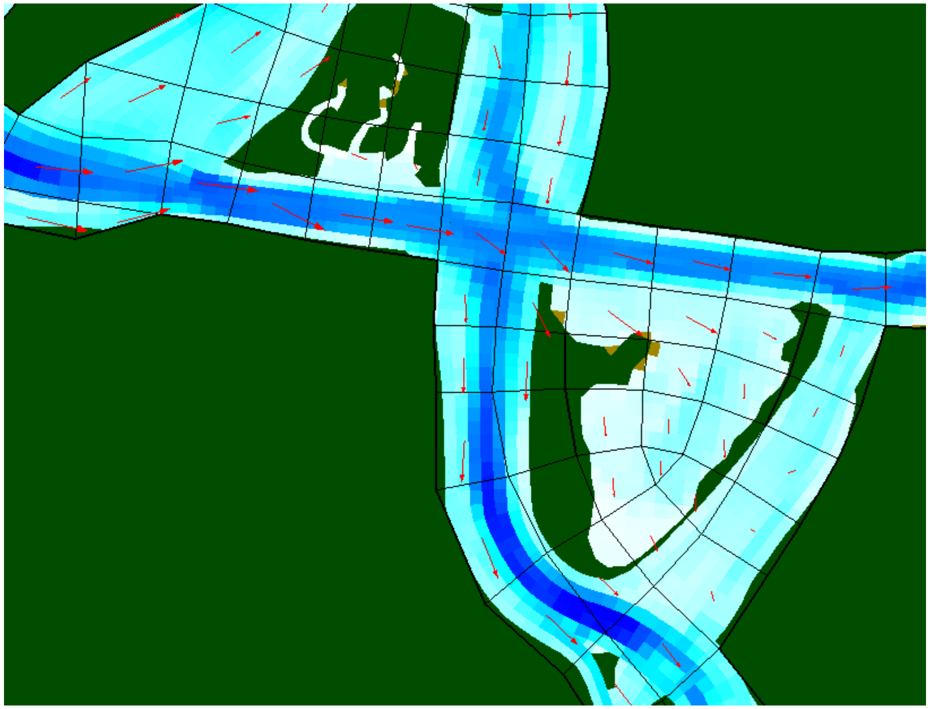
UnTRIM2009 1D river stretch with terraced topography sub-grid

(From Lippert, 2009)

UnTRIM Bay-Delta Model



UnTRIM Subgrid Bay-Delta



UnTRIM Bay-Delta Model

Full Bay-Delta Model Domain

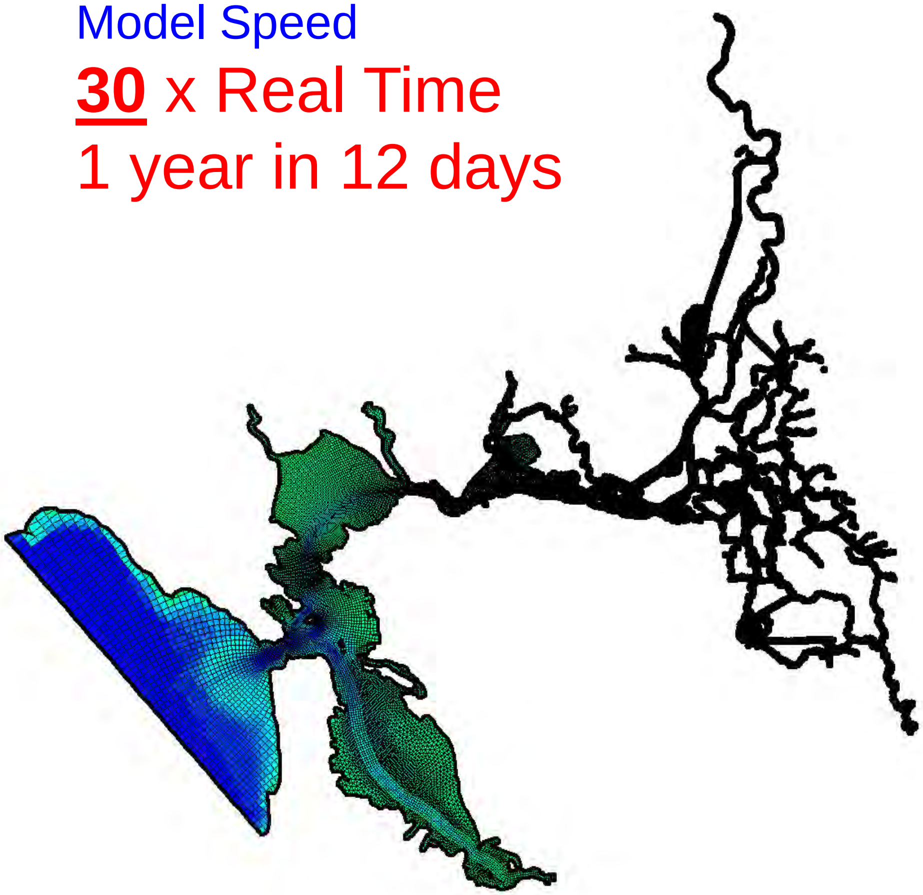
129,949 2D cells (1.2M 3D cells)

dt = 90 s, dz = 1m

Model Speed

<u>30</u> x Real Time

1 year in 12 days



UnTRIM Subgrid Bay-Delta

Full Bay-Delta Model Domain

8,902 2D cells (87,000 3D cells)

dt = 300 s, dz = 1m

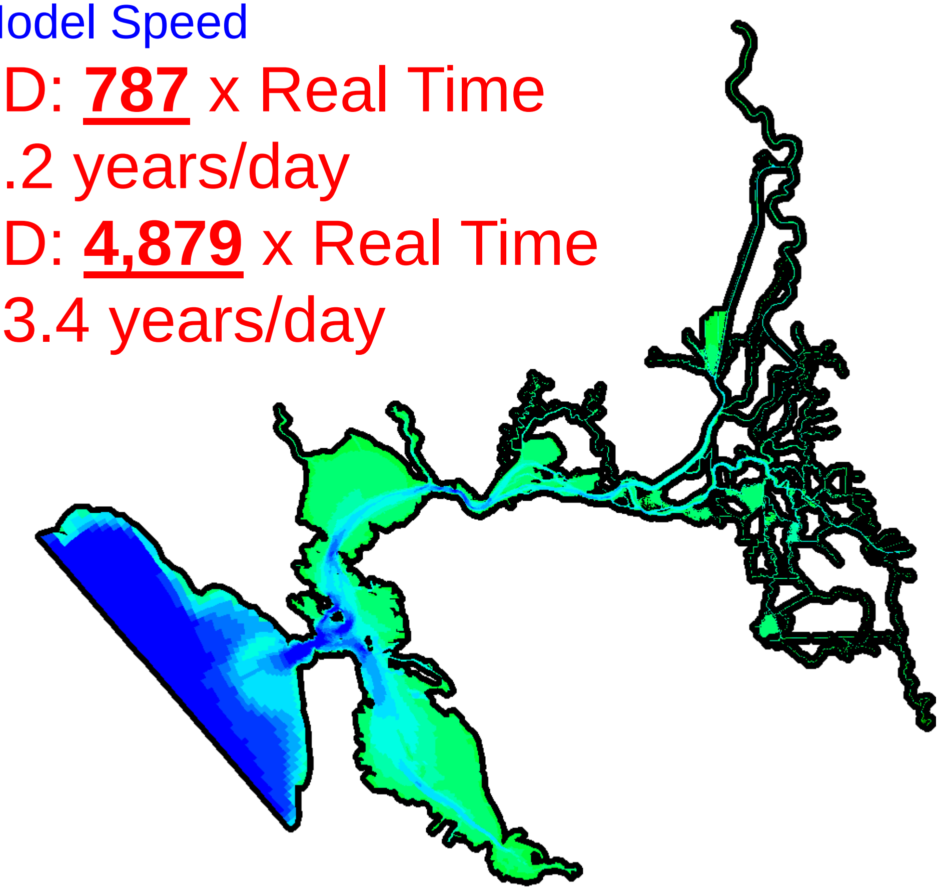
Model Speed

3D: **<u>787</u>** x Real Time

2.2 years/day

2D: **<u>4,879</u>** x Real Time

13.4 years/day



Benchmarks on Dell Precision T7500 Workstation

- 2 Xeon W5580 3.20 GHz Nehalem Processors
- 4.0 GB of RAM, Windows XP Professional x64

UnTRIM Bay-Delta Model

Full Bay-Delta Model Domain

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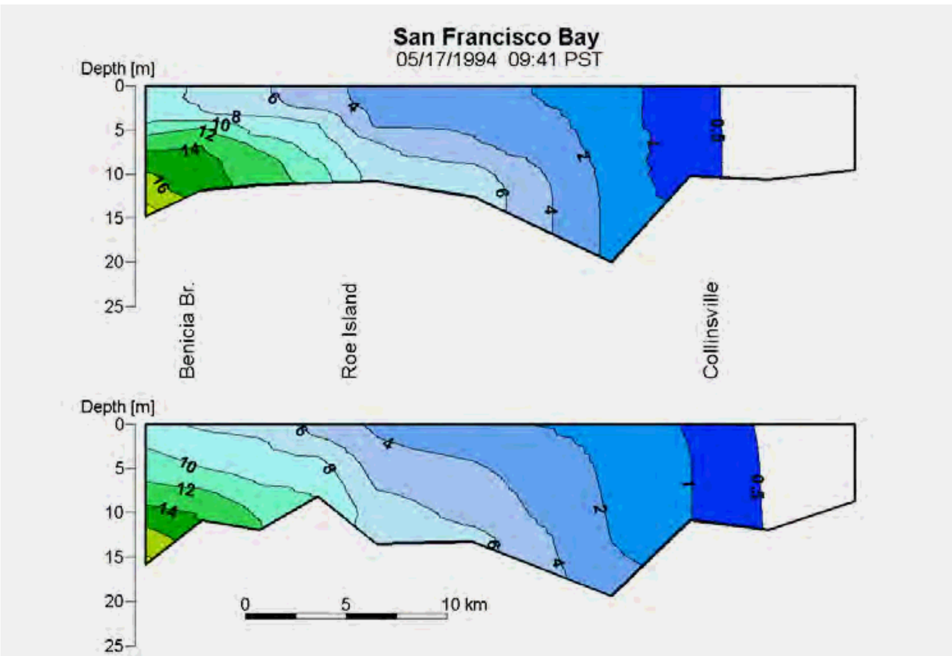

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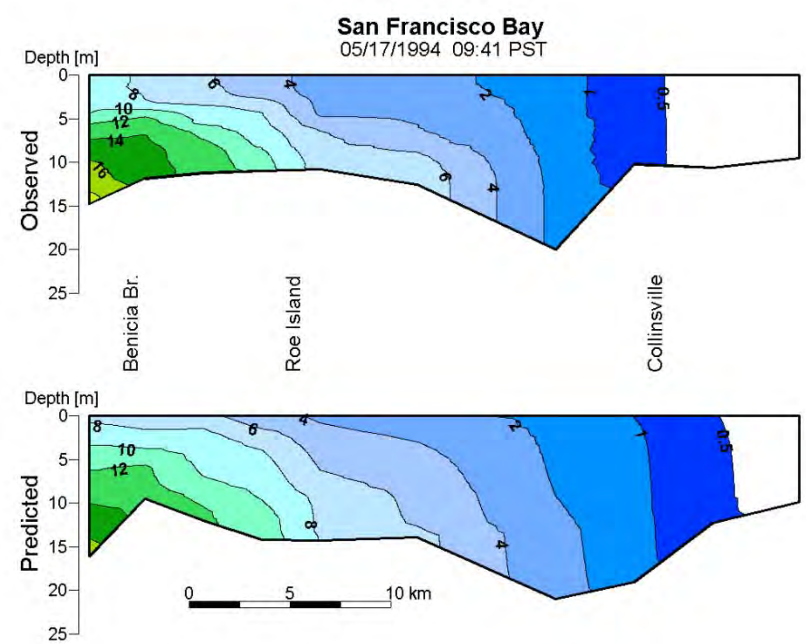

Outline

- Tools
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- How is X2 Calculated?
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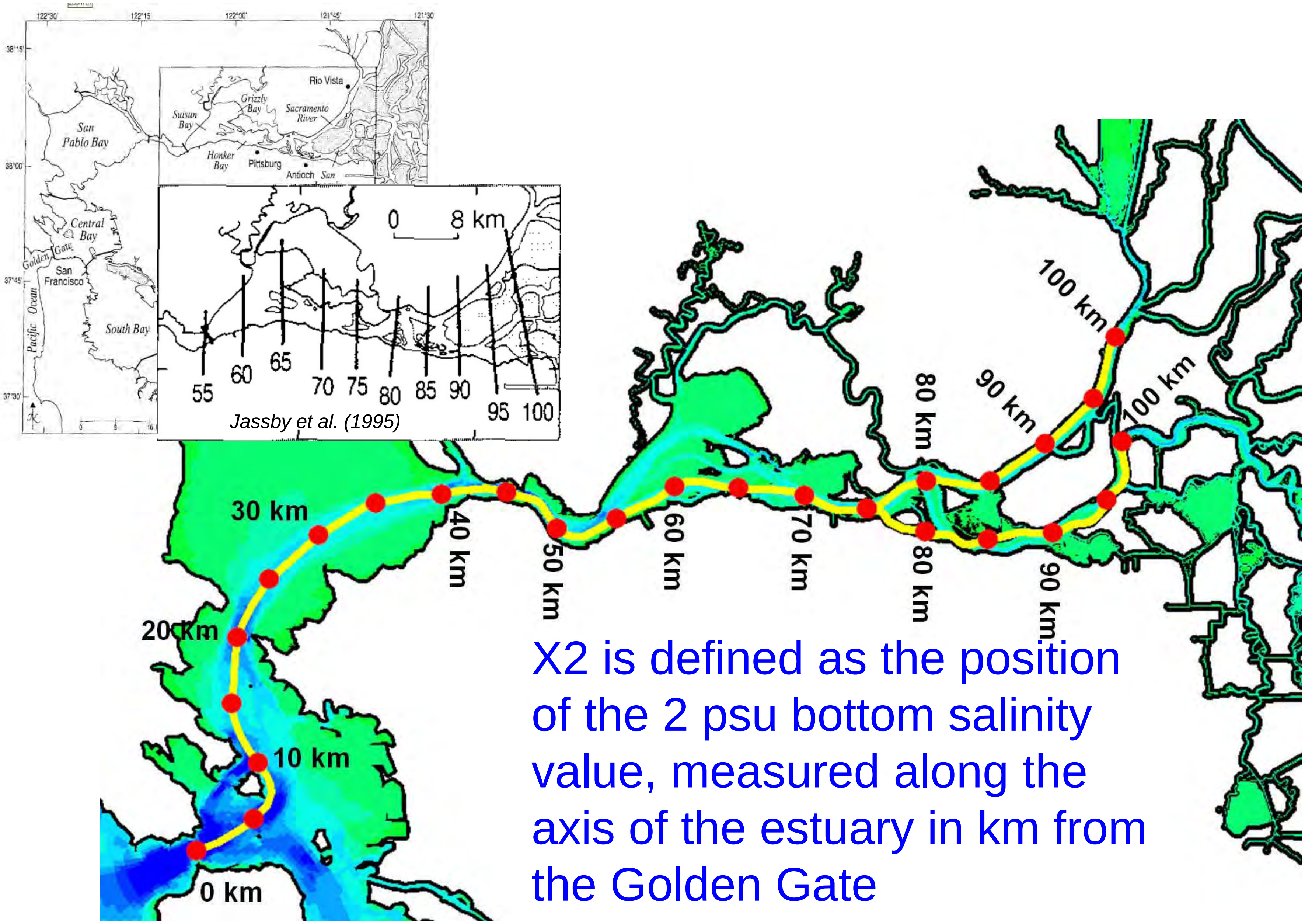
- Habitat Analysis Approaches
  - Modeling X2
  - Low Salinity Zone
- Conclusions

What is X2?



X2 is defined as the position of the 2 psu bottom salinity value, measured along the axis of the estuary in km from the Golden Gate

Surface Salinity vs. Bed Salinity

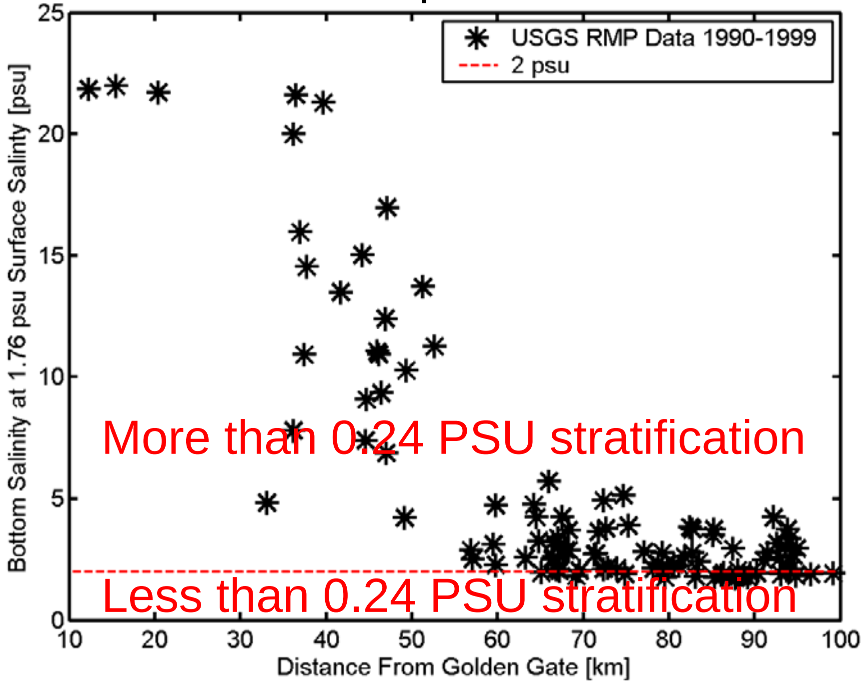
- Operationally X2 (CX2) is calculated from observed surface EC at Martinez, Port Chicago, Mallard Island and Collinsville using the equation (Applies only for 56<X2<81):

$$X2 = wkm + \frac{2.64 - wEC}{wEC - eEC}(wkm - ekm)$$

  - *wEC* is the daily-average EC in mmhos/cm of the westerly station
  - *eEC* is the daily-average EC in mmhos/cm of the easterly station
  - *wkm* is the km from the Golden Gate of the westerly station
  - *ekm* is the km from the Golden Gate of the easterly station
- Assumes bed salinity is 2 psu (3.80 mmhos/cm) when surface EC is 2.64 mmhos/cm (1.36 psu).
  - Assumes 0.64 psu stratification
- Jassby et al., 1995 and Monismith et al., 2002 assumed that the bed salinity was 2.0 psu when the surface salinity was equal to 1.76 psu (3.36 mmhos/cm)
  - Assumes 0.24 psu stratification

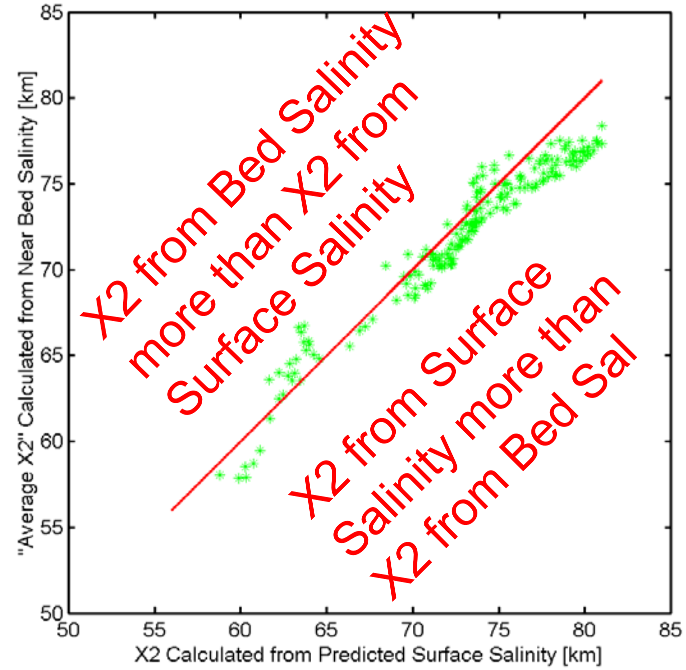
Surface Salinity vs. Bed Salinity

Analysis of Jassby Stratification Assumptions from Observations:
Assumes 0.24 psu stratification



Assumption of 0.24 psu stratification (3.37 mmhos/cm surface EC) tends to under predict X2 relative to X2 calculated from <u>OBSERVED</u> bed salinity

Analysis of CX2 Stratification Assumptions from Predicted:
Assumes 0.64 psu stratification



Assumption of 0.64 psu stratification (2.64 mmhos/cm surface EC) tends to over predict X2 relative to X2 calculated from <u>PREDICTED</u> bed salinity

From MacWilliams, Gross and Kimmerer (2005)

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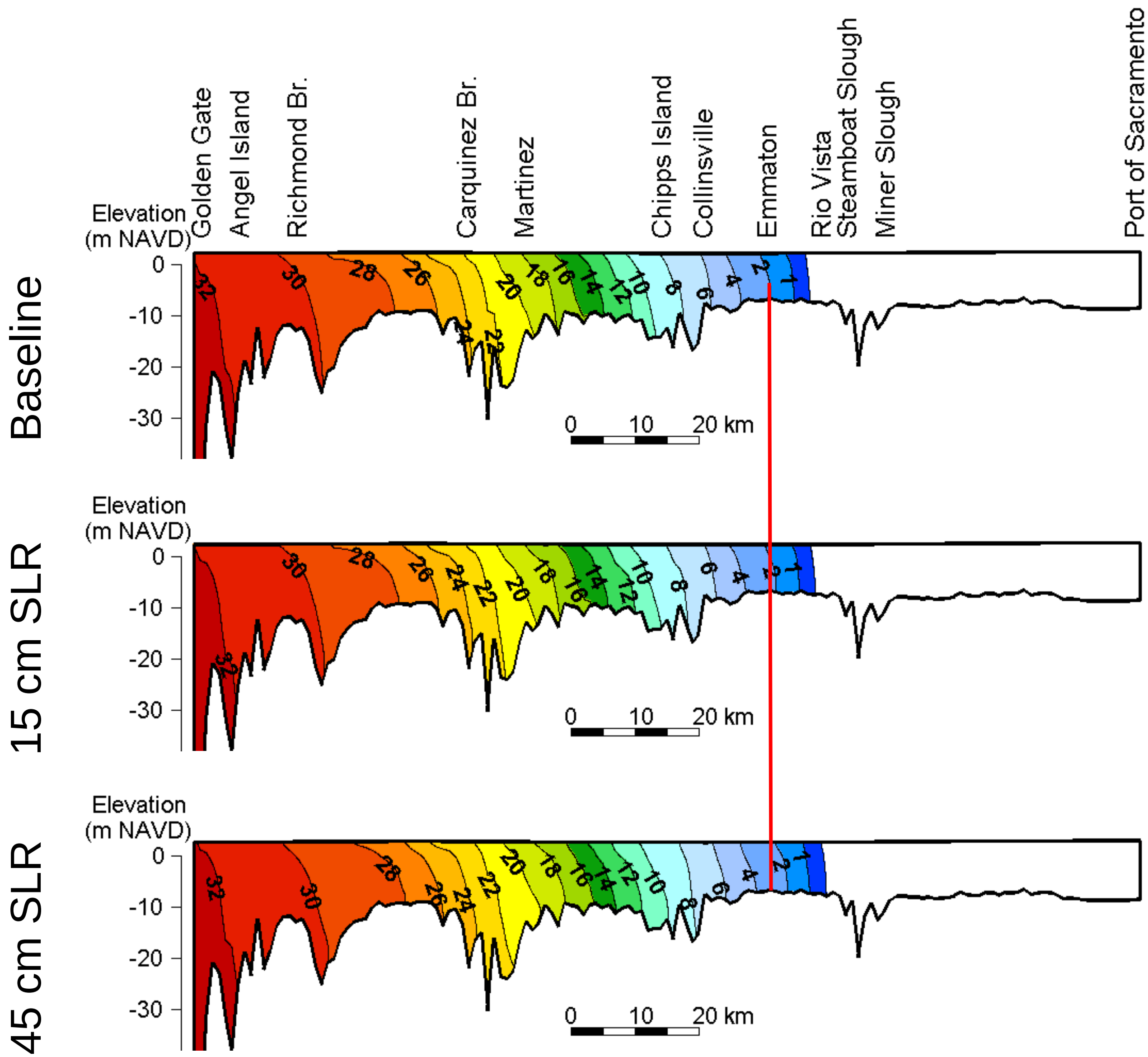
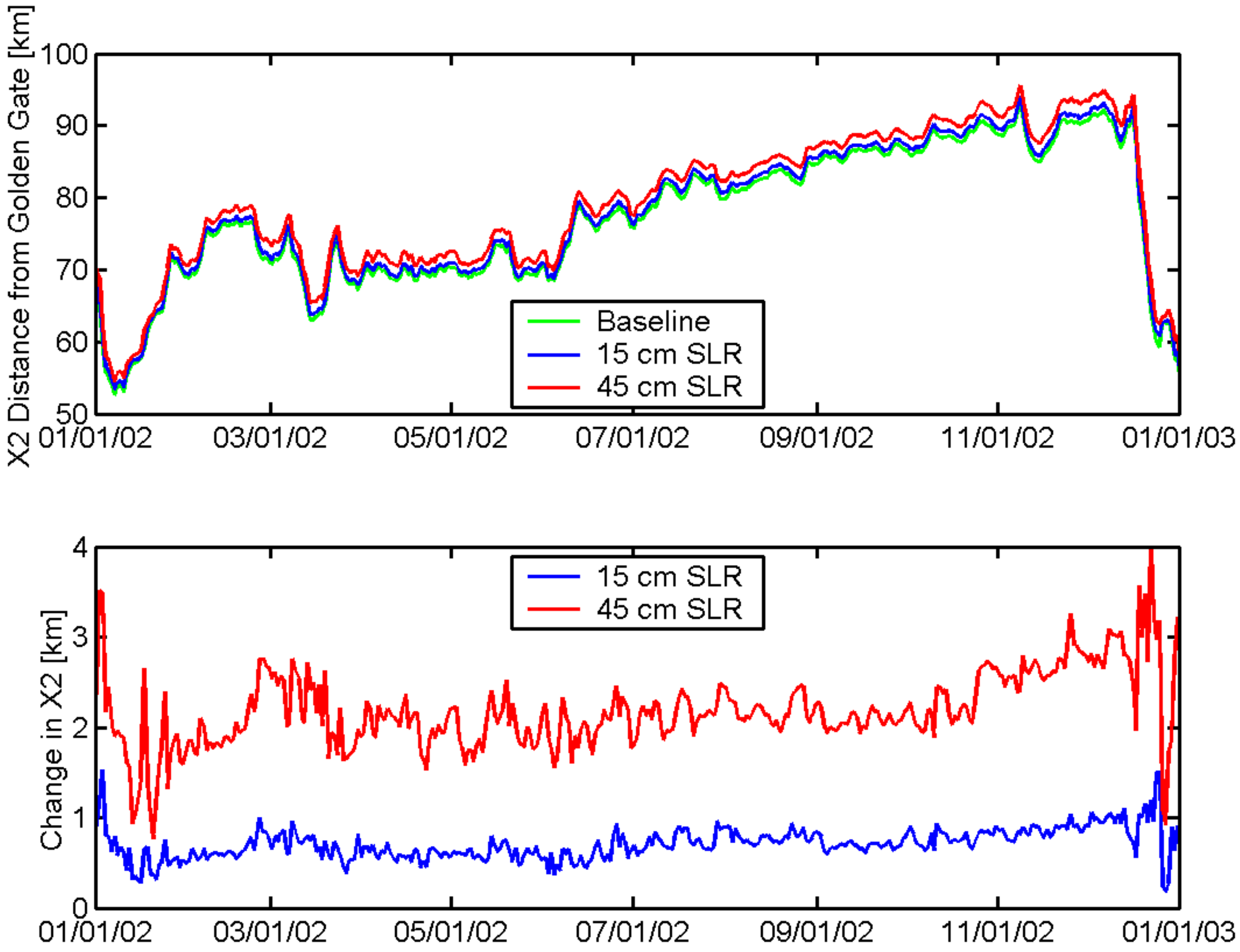
Modeling X2



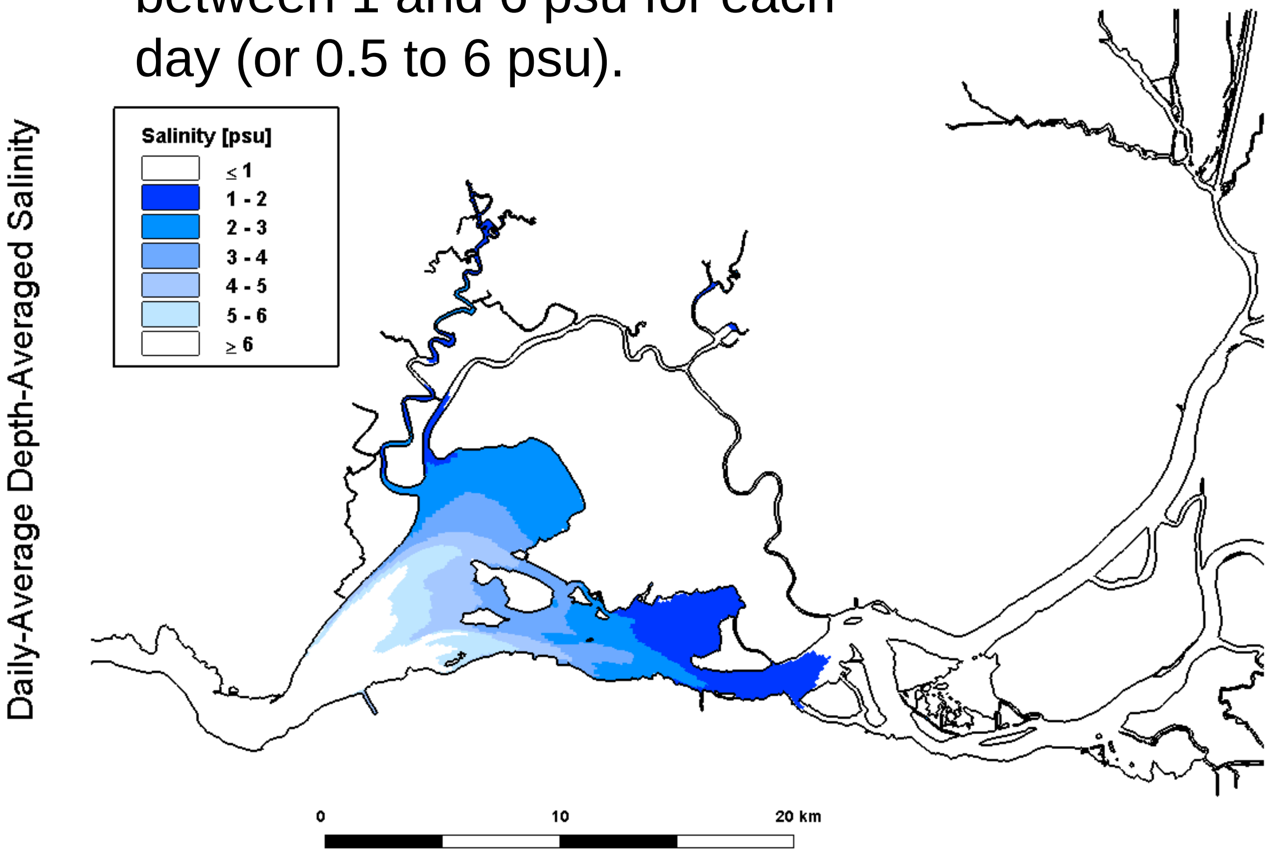
Golden Gate
Angel Island
Richmond Br.
Carquinez Br.
Martinez
Chipps Island
Collinsville
Emmaton
Rio Vista
Steamboat Slough
Miner Slough
Port of Sacramento
Baseline
15 cm SLR
45 cm SLR
Elevation (m NAVD)
0
-10
-20
-30
0 10 20 km

Effect of Sea Level Rise on X2



Low Salinity Zone (LSZ) Habitat Area

- Calculated from predicted daily-average depth-averaged salinity in each grid cell.
- Total area of habitat for salinity between 1 and 6 psu for each day (or 0.5 to 6 psu).



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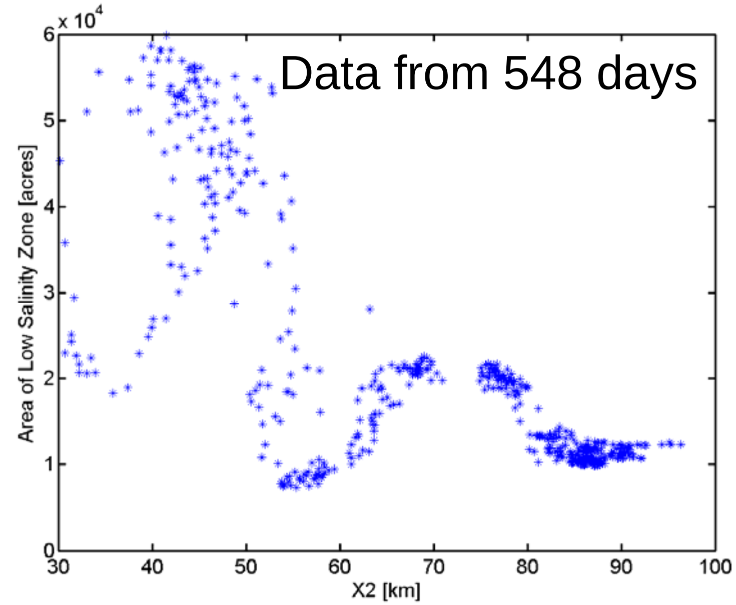

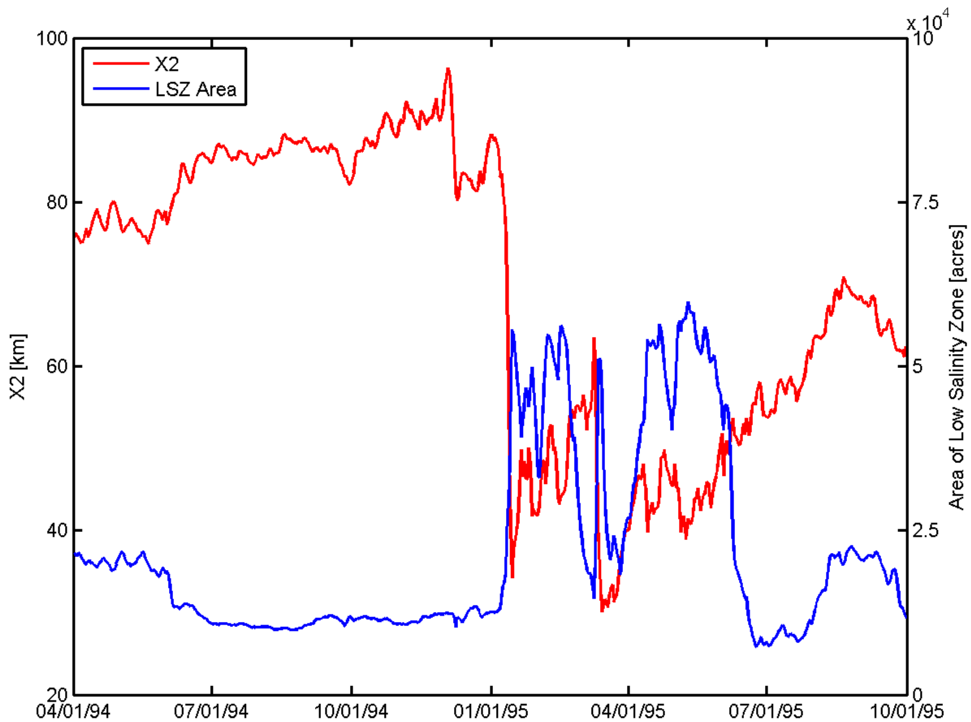

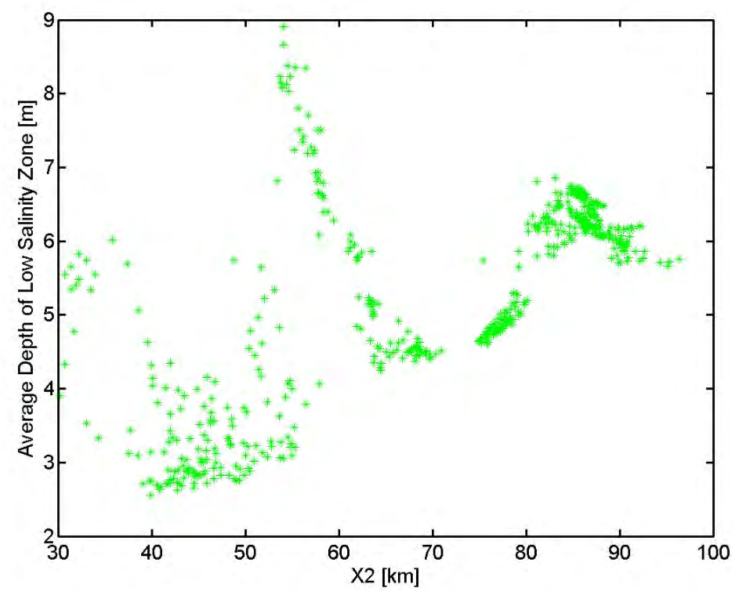

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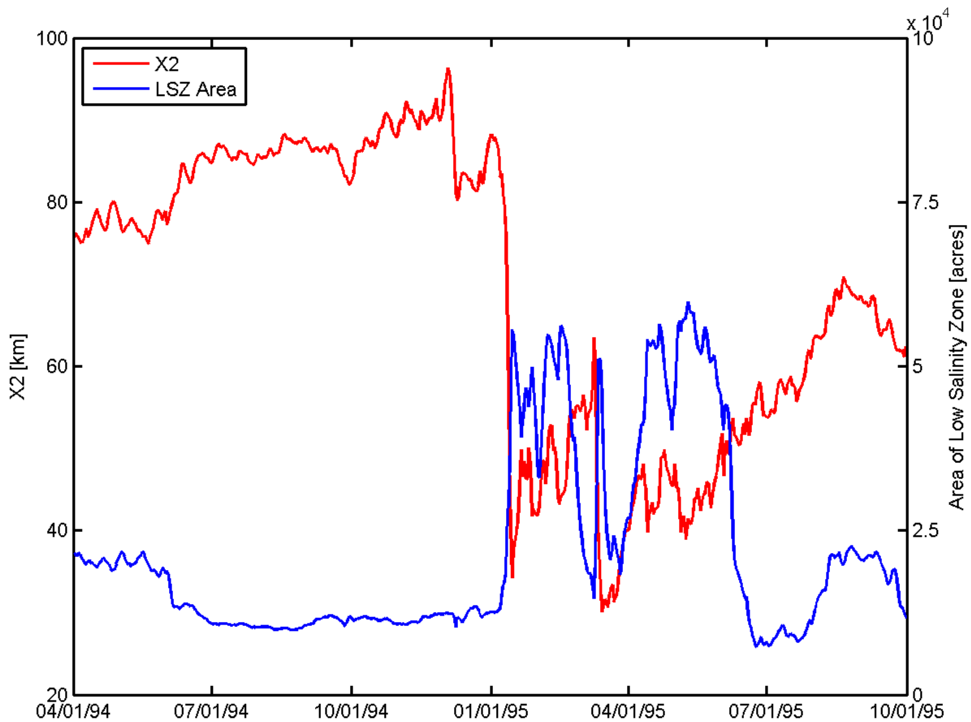
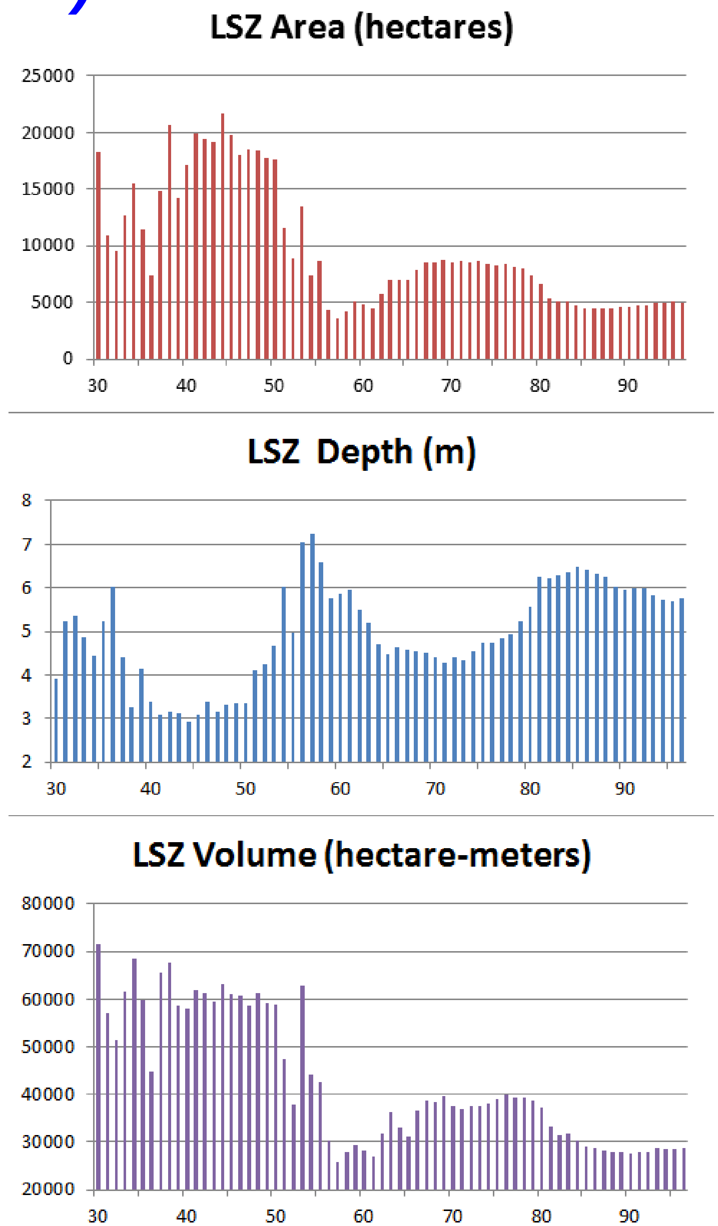
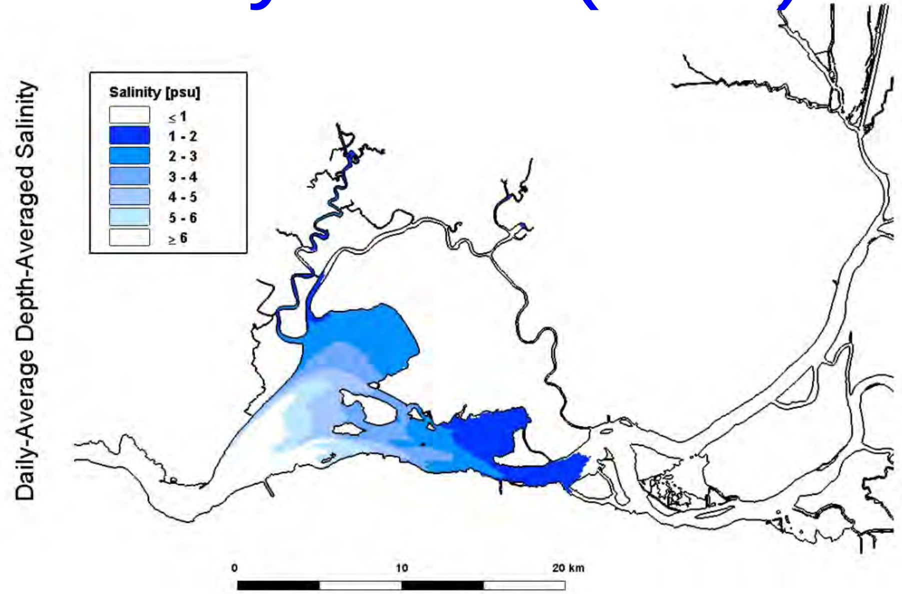
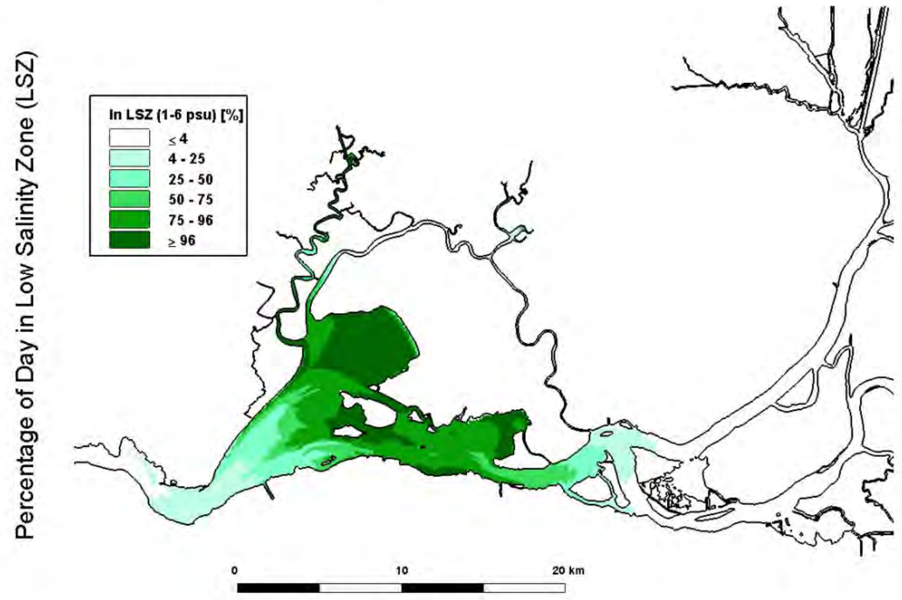




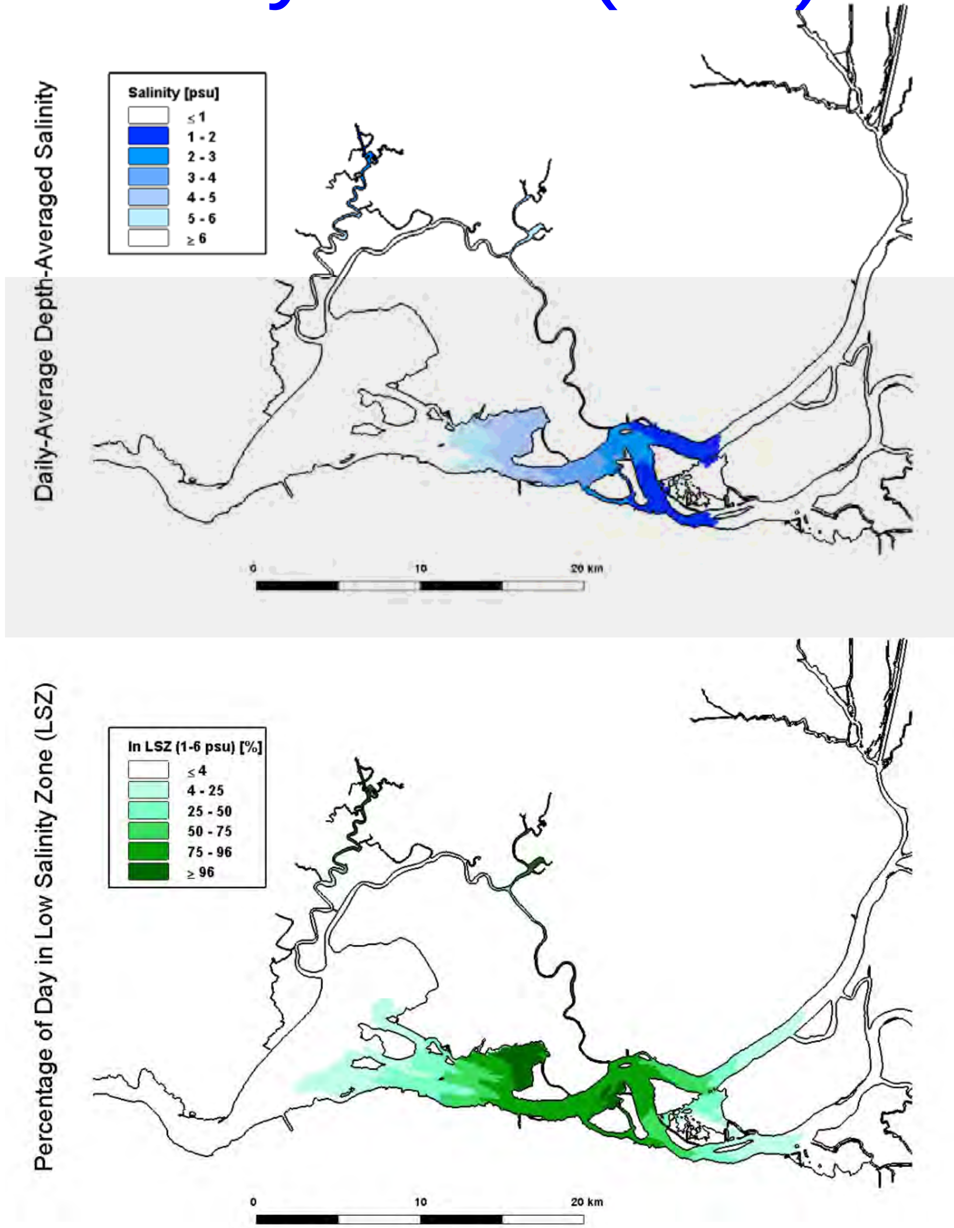
Figures from Herbold (2012)

Low Salinity Zone (LSZ): **X2=74**

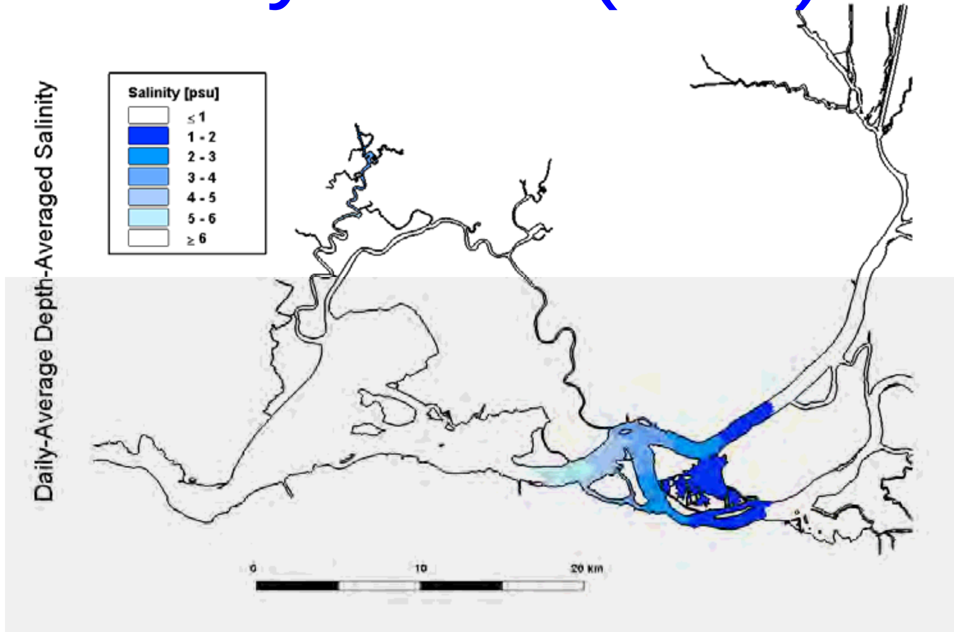


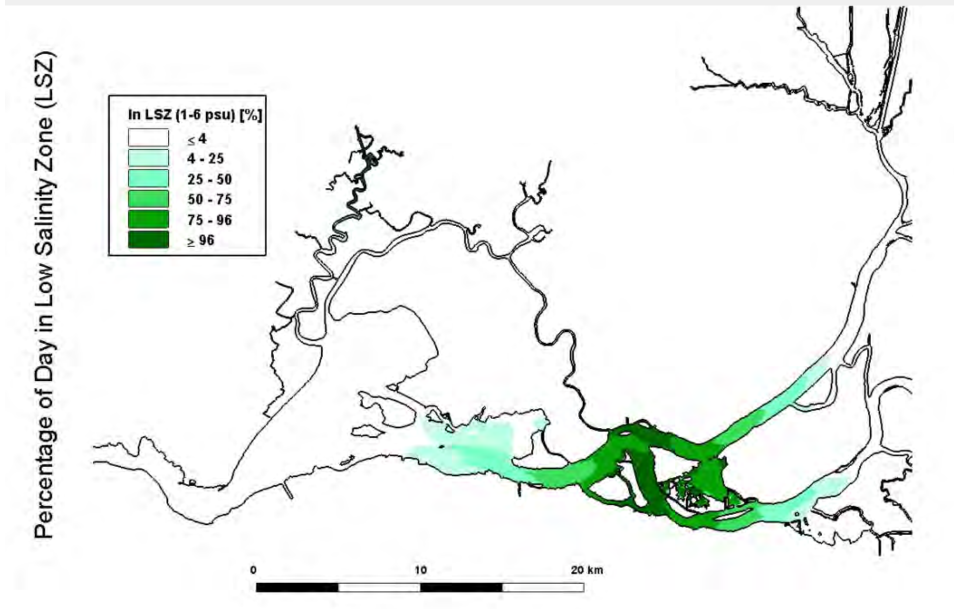


Low Salinity Zone (LSZ): **X2=81**

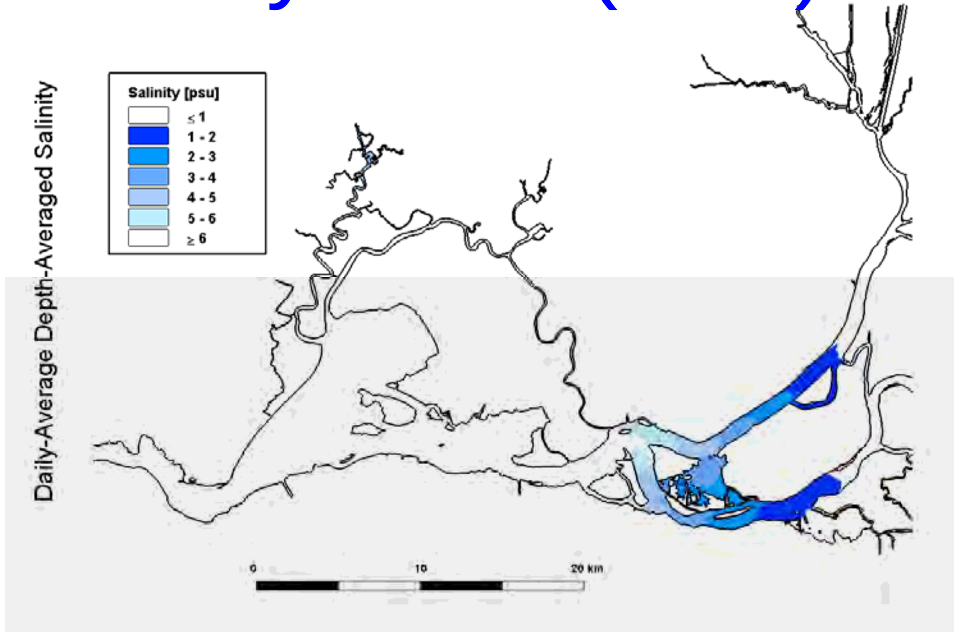


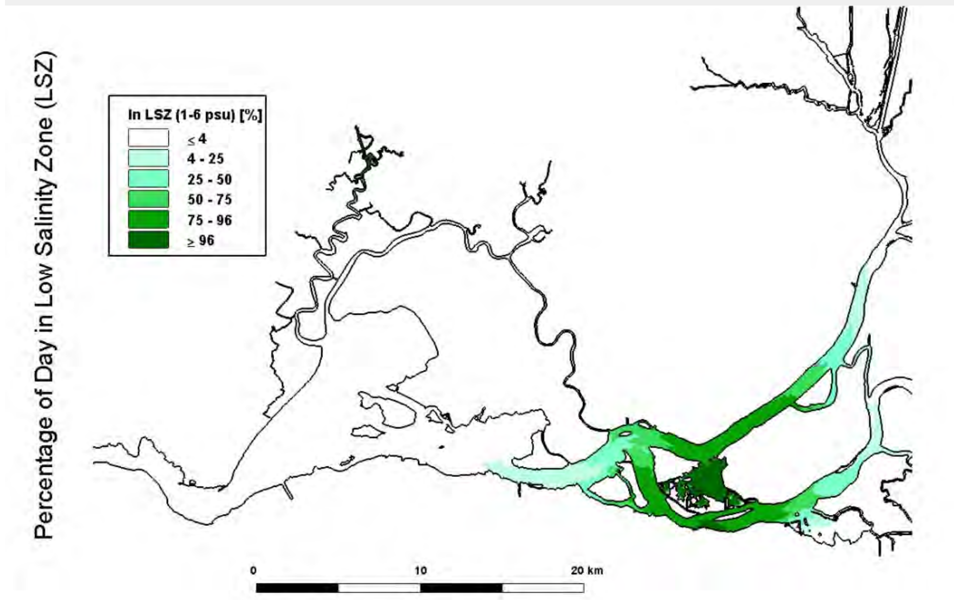
Low Salinity Zone (LSZ): **X2=85**





Low Salinity Zone (LSZ): **X2=90**





Modeling Estuarine Habitat

- X2 is a useful “operational” metric because it can easily be estimated based on either outflow or observed surface salinity.
  - Uncertainty inherent in estimating X2
- Models can be used to:
  - Evaluate potential impacts of management decisions on habitat quality and quantity.
  - Forecast or hindcast habitat conditions (LSZ, X2) under future (SLR, Marsh restoration scenarios, levee failure) or historic (pre-POD, pre-SWP/CVP) conditions.
  - Quantify linkages between X2 or LSZ and ecologically significant indicators.
  - Help design monitoring or data collection programs.
  - guide decision making in real-time.

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Conclusions

- 3-D Bay-Delta Models are significantly faster and more accurate than those available only a few years ago.
  - High-resolution: 1 year 3-D simulations ~12-14 days
  - Coarser Resolution with Subgrid: 1 year 3-D simulations < 12 hours!
- High resolution and coarser resolution 3-D models allow for choice between detailed hydrodynamics or speed.
  - Accurate 3-D simulations of 10-30 year periods now feasible.
- Approaches available for evaluation of estuarine habitat:
  - Hindcasting and Forecasting (could be implemented for real time)
  - X2 Calculation
    - From bed salinity and/or surface salinity
  - Low Salinity Zone Analysis
    - Area, Depth, Bed Salinity, Daily Range, Area/Depth Slices, Marsh Connectivity
    - Can evaluate how specific management actions affect LSZ (rather than X2)
    - Use LSZ modeling to design sampling programs, or to help interpret trawl data
  - Temperature, Sediment, Particle Tracking Models