Review of the 1995 Water Quality Control Plan For the San Francisco Bay/ Sacramento San Joaquin Delta Estuary

(X2 Standard)

Development of the X2 standard

New scientific understanding

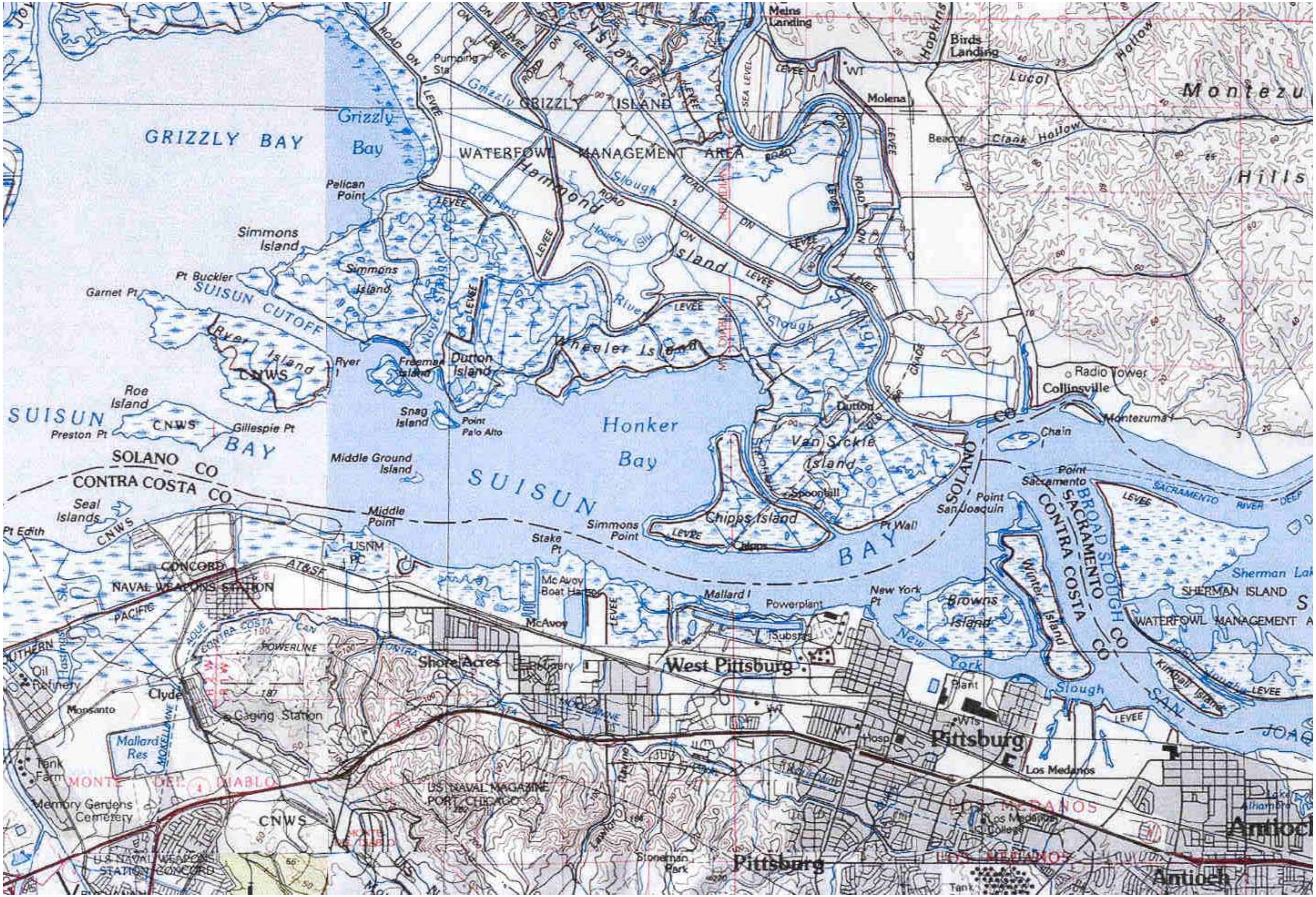
Management options

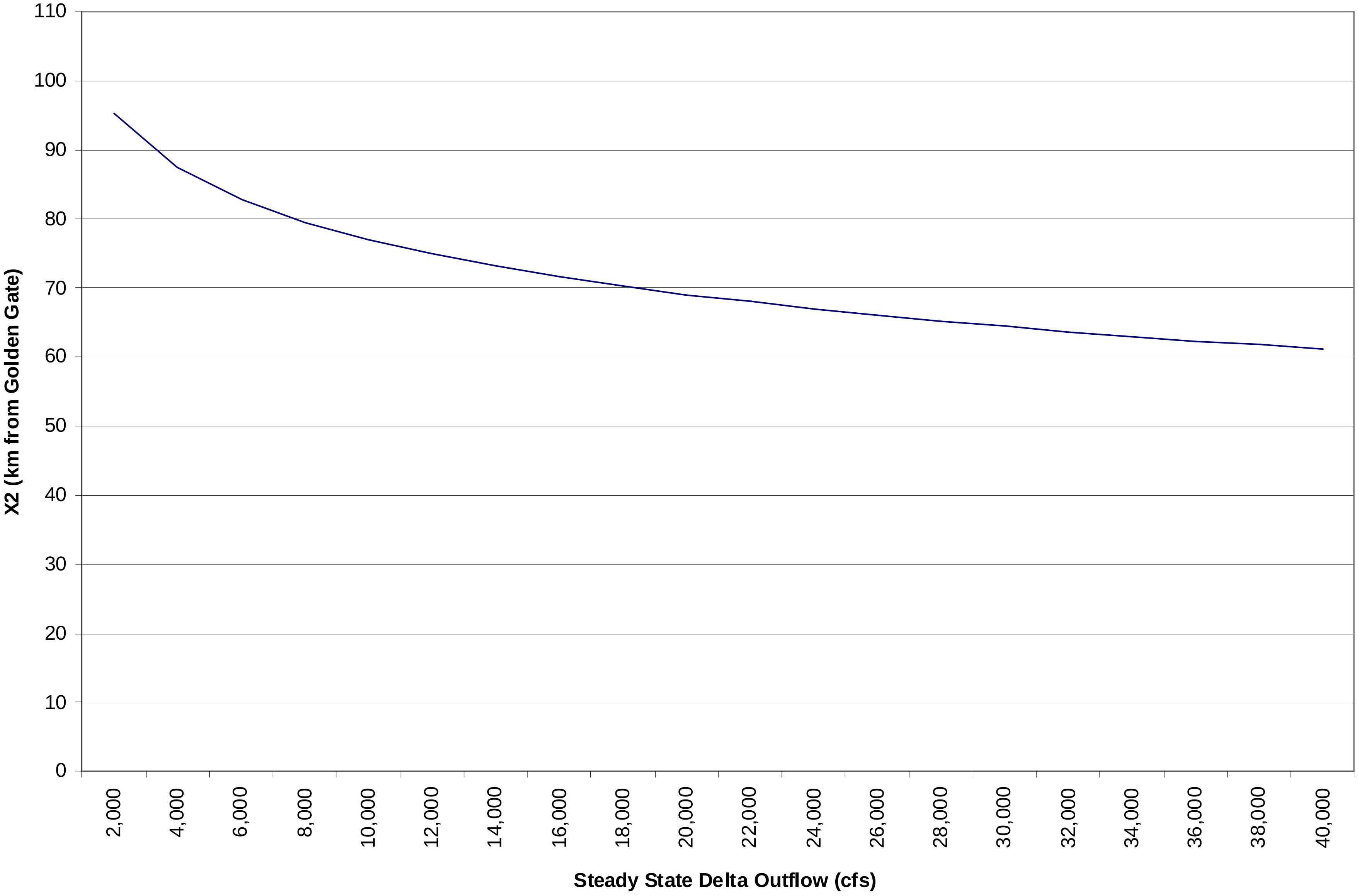
Biological Basis for X2 Relationships

- Prior to 1995, estuarine habitat managed by delta Outflow standards
- 1992 San Francisco Estuary – USEPA workshop
- Location of a low-salinity (2 ppt) zone reflects a biologically significant estuarine habitat
- X2 position hypothesized to define location of an “entrapment” zone within Suisun Bay
- Flows associated with X2 deliver nutrients to shallow water habitats in Suisun Bay
- X2 productivity at various trophic levels
- Correlations between fish abundance and X2 location

X2 – Location of 2 ppt Salinity

- Average position of X2 during February – June
- Two positions - Chipps Island and Port Chicago/Roe Island
- Location and duration based on hydrology
- About 11,500 cfs for Chipps Island
- About 30,000 cfs for Port Chicago/Roe Island


GRIZZLY BAY
Grizzly Bay
GRIZZLY ISLAND
WATERFOWL MANAGEMENT AREA
Pumping Sta
Pelican Point
Simmons Island
Pt Buckler
Garnet Pt
SUISUN CUTOFF
Ryer Island
CNWS
Roe Island
SUISUN BAY
Preston Pt
Gillespie Pt
SOLANO CO
CONTRA COSTA CO
Seal Islands
Pt Edith
Middle Ground Island
Middle Point
Freeman Island
Dutton Island
Snag Island
Point Palo Alto
Wheeler Island
Honker Bay
Van Sickle Island
Chipps Island
Spoonbill
Simmons Point
Stake Pt
USNM PC
Pt Wall
Meins Landing
Birds Landing
Molena
Beacon
Montezuma Hills
Radio Tower
Collinsville
Montezuma
Chain Island
Point Sacramento
Point San Joaquin
SACRAMENTO RIVER
BROAD SLOUGH
Winter Island
Browns Island
New York Pt
Powerplant
Mallard I
SHERMAN ISLAND
WATERFOWL MANAGEMENT AREA
Kimball Island
New York Slough
CONCORD NAVAL WEAPONS STATION
McAvoy Boat Harbor
McAvoy
Shore Acres
West Pittsburg
Oil Refinery
Clyde
Monsanto
Mallard Res
Tank Farm
Memory Gardens Cemetery
MONTE DEL DIABLO
US NAVAL MAGAZINE PORT CHICAGO
CNWS
Pittsburg
Los Medanos
LOS MEDANOS
Stoneman Park
Antioch
U.S. NAVAL WEAPONS STATION CONCORD



X2 (km from Golden Gate)
0
10
20
30
40
50
60
70
80
90
100
110
2,000
4,000
6,000
8,000
10,000
12,000
14,000
16,000
18,000
20,000
22,000
24,000
26,000
28,000
30,000
32,000
34,000
36,000
38,000
40,000
Steady State Delta Outflow (cfs)

Conceptual Model – 1995 Understanding

- X2 defines position of the estuarine salinity field
- X2 reflects freshwater outflow through the estuary
- Salinity determines the location of the estuarine turbidity maxima, entrapment or null zones
- Freshwater flow and entrapment effect nutrient and organic loading
- Residence time of plankton and detrital particles
- Salinity reflects habitat conditions for estuarine biota
- Temporal variability in X2 reflects changing habitat conditions
- X2 location corresponds to maximum zooplankton abundance
- X2 is an index of both outflow and estuarine salinity gradients

Summary of X2 Relationships

from Jassby *et al* (1995)

VARIABLE	X2 AVERAGING PERIOD	YEARS	SIGNIFICANT RELATIONSHIP (P <0.01)?	CORRELATION COEFFICIENT (R)
Particulate organic carbon	Jan-Dec	1975-89	YES	0.85
Eurytemora affinis	Mar-Nov	1972-82; 1984-90	NO	NA
Neomysis mercedis	Mar-Nov	1972-82; 1984-90	YES	0.79
Crangon franciscorum	Mar-May	1980-1990	YES	0.93
Delta smelt, *Hypomesus transpicificus*	Apr-Jul	1968-73; 1975-78; 1980-82; 1984-91	NO	NA
Longfin smelt, *Spirinchus thaleichthys*	Jan-Jun	1968-73; 1975-78; 1980-82; 1984-91	YES	0.89
Striped bass, *Marone saxatilis* (38 mm survival)	Apr-Jul	1969-82; 1984-91	YES	0.59
Striped bass, *Marone saxatilis* (MWT index)	Jul-Nov	1968-73; 1975-78; 1980-91	YES	0.85
Molluscs	3-year mean Jan-Dec	1981-1990	YES	0.80
Starry flounder, *Platichthys stellatus*	Previous year Mat-Jun	1980-91	YES	0.76

Hypothesized Mechanisms for Biological Benefits - 1995

- Phytoplankton concentrate in the estuarine turbidity maximum zone
- Phytoplankton growth is favored by an X2 position in shallow habitat in Suisun Bay
- Deep, vegetation-limited flood control channels of the Delta are less productive
- Low flows allow colonization of Suisun Bay by introduced clams
- Consumption by clams increase losses of phytoplankton
- Low flows reduce phytoplankton input from upstream
- Production of the estuarine biota depends on
  - Nutrient input
  - Available shallow water habitat
  - Residence time of nutrients over shallow-water habitat
- X2 is a useful indicator of estuarine salinity

Hypothesized Mechanisms for Biological Benefits (continued)

- X2 from February to June reflects overall outflow
- Short-term changes in hydrology are biologically meaningful

OUTFLOW CHARACTERISTICS	1971	1973
Location of February-May X2, River km	66	66
Days of flow > 100,000 cfs	3	37
Days of flow 50,000 cfs to 99,999 cfs	34	37
Last day of flow > 50,000 cfs	April 6	March 27
Days of flow > 25,000 cfs	104	86
Days of Yolo Bypass Inundation	14	62
Days of Yolo Bypass flow > 40,000 cfs	0	15

Changes in scientific understanding since 1995

- X2 determines the primary mixing zone location – this hypothesis has been withdrawn and replaced by the concept of a low salinity zone
- Location varies based on tidal cycle - westerly during spring tides, easterly during neap tides

- Nutrient input is related to floodplain flow
- X2 is an indicator of total nutrient input from the Yolo Bypass
- High productivity is linked to riverine nutrient input
- Nutrient residence time within the shallow-water zone of the estuary affect productivity
- Phytoplankton and zooplankton declined over 1975-1995
- Decline after 1986 potentially related to the introduction of *Potamocorbula amurensis*
- Spring flow and riverine nutrient input to the estuary is important

Changes in scientific understanding (continued)

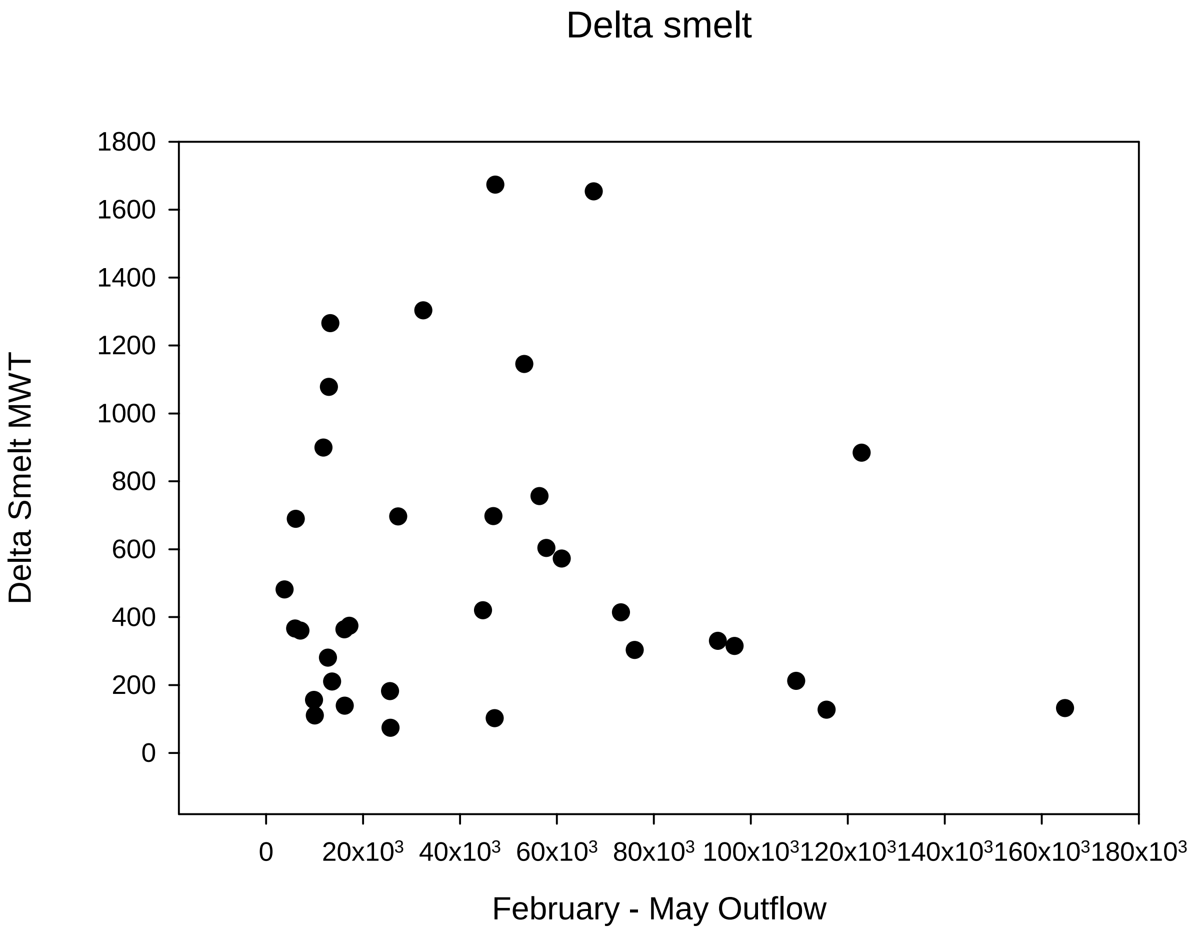
- Bulk nutrient accounting is inadequate
- Phytoplankton are a significant source of bioavailable organic matter
- Bioavailable organic matter has high nutrient quality
- Deep-river channel habitats contribute total nutrients, but low levels of phytoplankton
- Nutrient supplies in the delta are in excess of phytoplankton needs
- Decreasing sediment transport results from:
  – sediment trapping behind dams
  – depletion of in-channel sediments
  – armoring of river banks
- Phytoplankton are most abundant in shallow water
- Long residence times enhance phytoplankton growth
- Relationships exist between lower trophic level productivity and fish abundance
- The Asian clam has probably reduced phytoplankton in Suisun Bay

X2/Abundance pre and post introduction of *Potamocorbula amurensis*

RELATIONSHIP (X2 VS SPECIES)	MILLER CONCLUSIONS	KIMMERER CONCLUSIONS
Crangon franciscorum	No change	No significant change post 1987
Eurytemora affinis	Not addressed	Stronger relationship post 1987
Neomysis mercedes	Not addressed	Change in shape of relationship curve
Longfin smelt	Not as strong	Weakened post 1988
Delta smelt	No X2 relationship	No X2 relationship
Splittail	Remains strong	Remains strong
Striped bass (38mm index)	No relationship exists	Same as pre- 1986
Striped bass (Year 3)	No relationship	Not analyzed
Striped bass (MWT index)	Weaker post 1986	Weakened post 1988
Pacific herring	Not analyzed	Weaker since 1990
Starry flounder	Not analyzed	Weaker since 1988
American shad	Not analyzed	Weaker since 1988

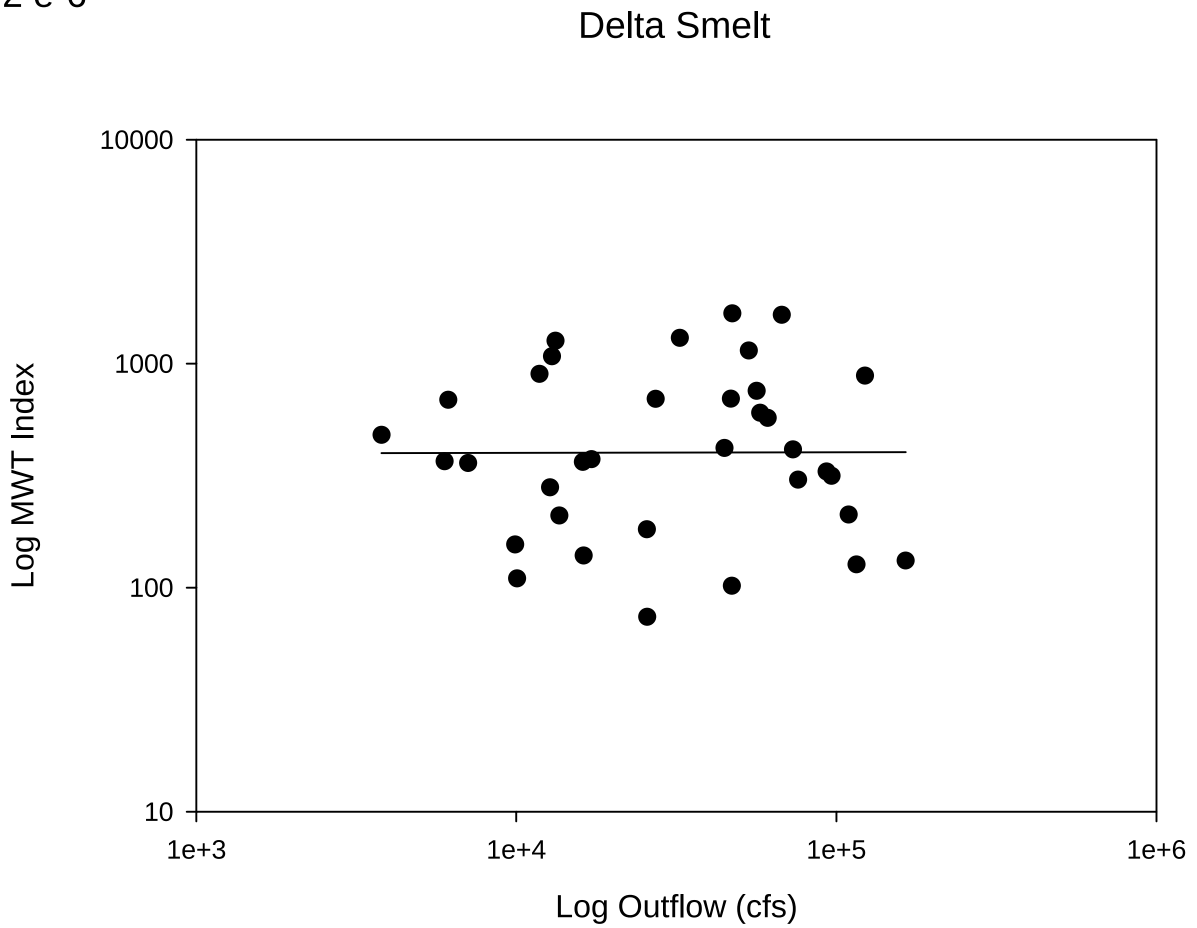
X2/Trophic Dynamics

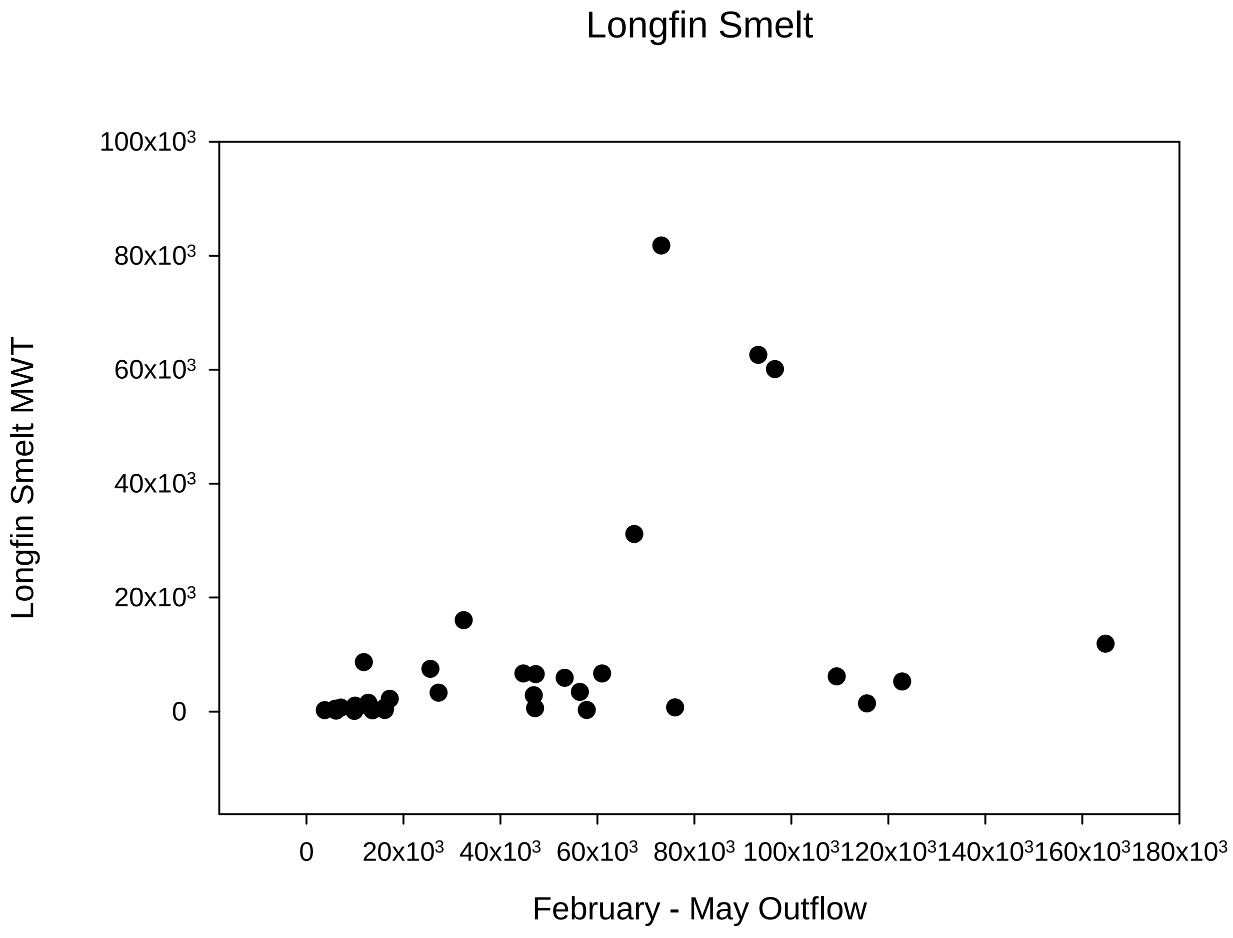
- Phytoplankton fuel the Delta food web
- Suisun Bay is dominated by Delta inputs of phytoplankton
- Yolo Bypass appears to be a major source of organic matter/phytoplankton
- The contribution of benthic microalgae is not known
- Bacterial production is high; its importance is not known
- Benthic suspension feeders remove phytoplankton
- Sediment chemistry is linked to the cycling of organic matter
- Delta diversions may affect total nutrient loading, particularly when X2 is upstream of Chipps Island.
- Nutrient losses due to diversions combined with benthic grazers reduce total system productivity
- X2 reflects low salinity zone where bacteria, zooplankton, and juvenile fishes interact
- Relationships between X2 and habitat are difficult to model statistically and remain obscure
- A variety of factors affect species
- Estuary is seasonally and spatially dynamic
- Average conditions may mask important processes
- Statistical correlations exist between X2 and abundance of some aquatic organisms



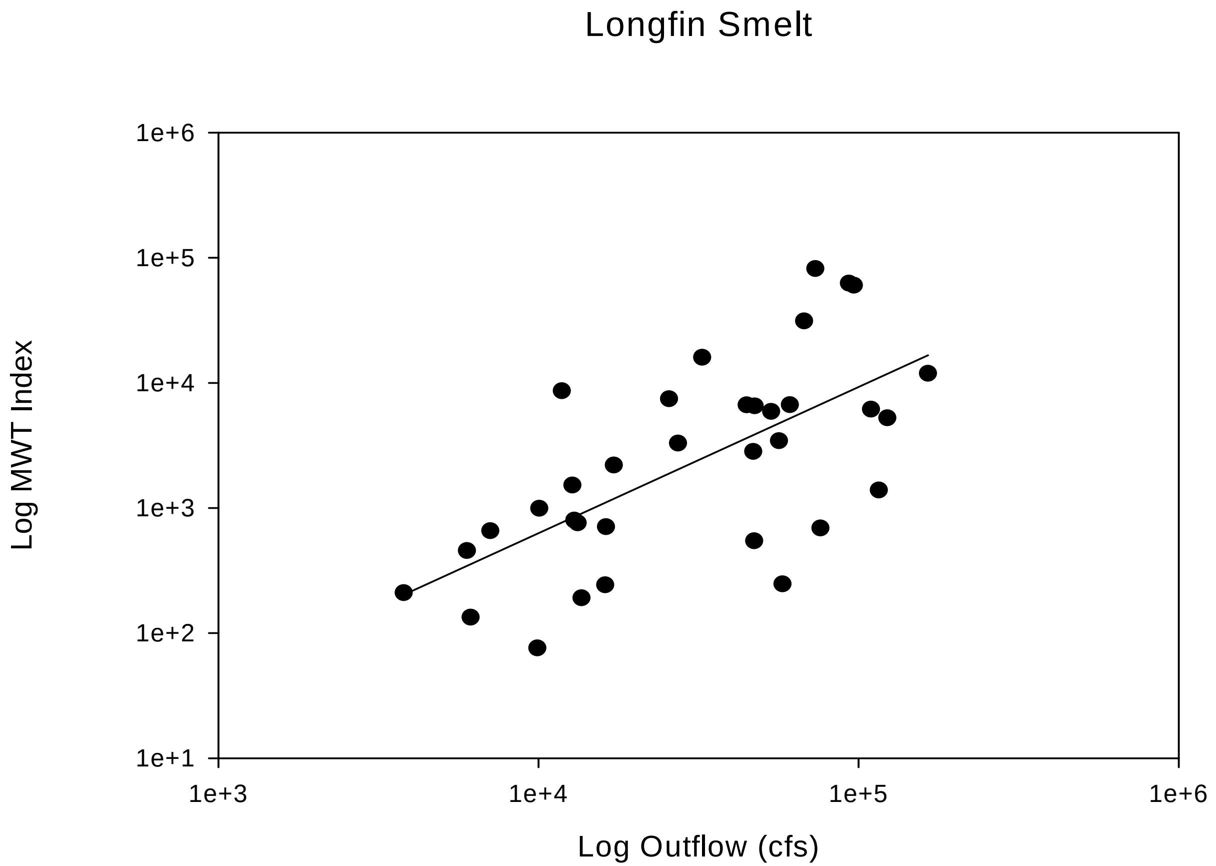
Delta smelt
Delta Smelt MWT
1800
1600
1400
1200
1000
800
600
400
200
0
0
20x10³
40x10³
60x10³
80x10³
100x10³
120x10³
140x10³
160x10³
180x10³
February - May Outflow

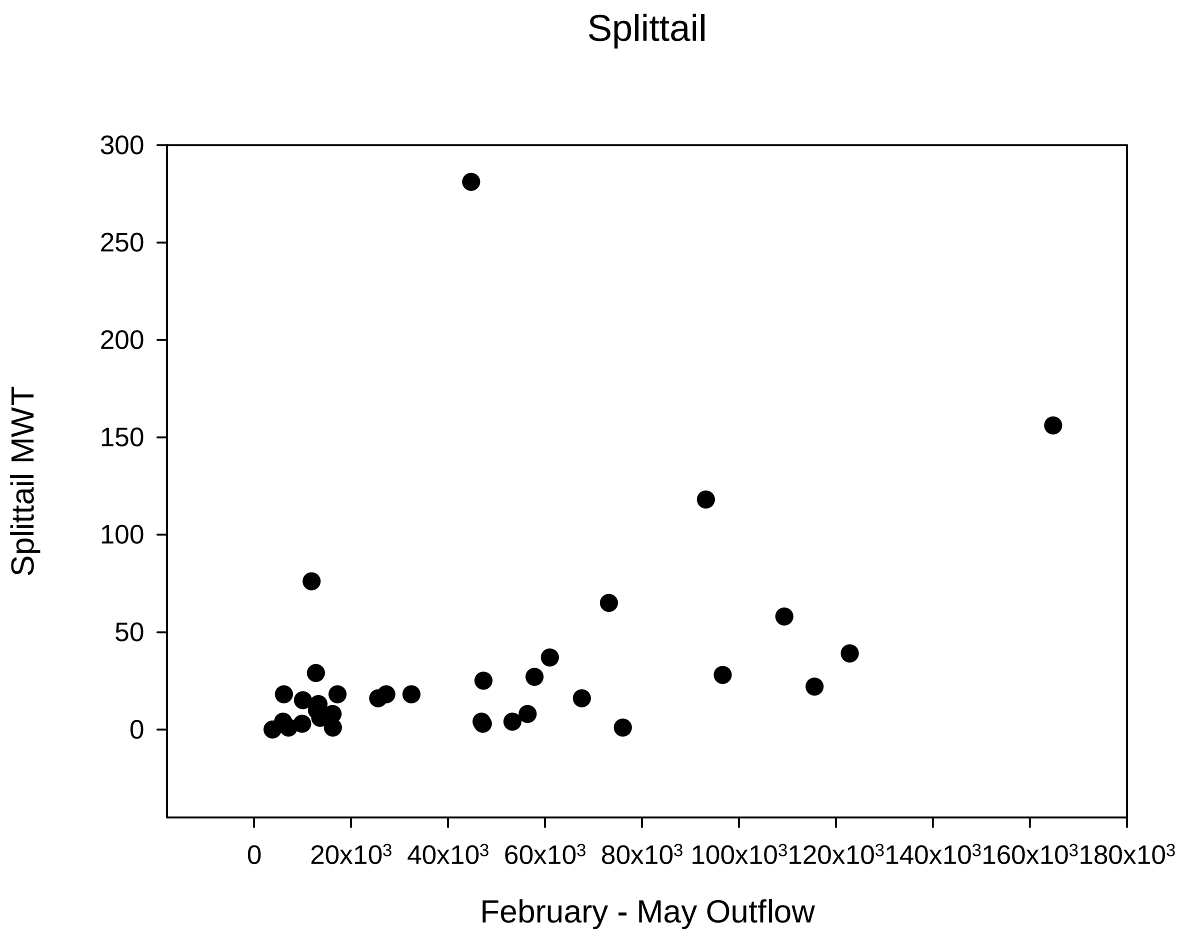
$b[0] = 2.59$
$b[1] = 2.38\text{ e-}3$
$r^2 = 7.92\text{ e-}6$




Longfin Smelt
Longfin Smelt MWT
100x10^3
80x10^3
60x10^3
40x10^3
20x10^3
0
0
20x10^3
40x10^3
60x10^3
80x10^3
100x10^3
120x10^3
140x10^3
160x10^3
180x10^3
February - May Outflow

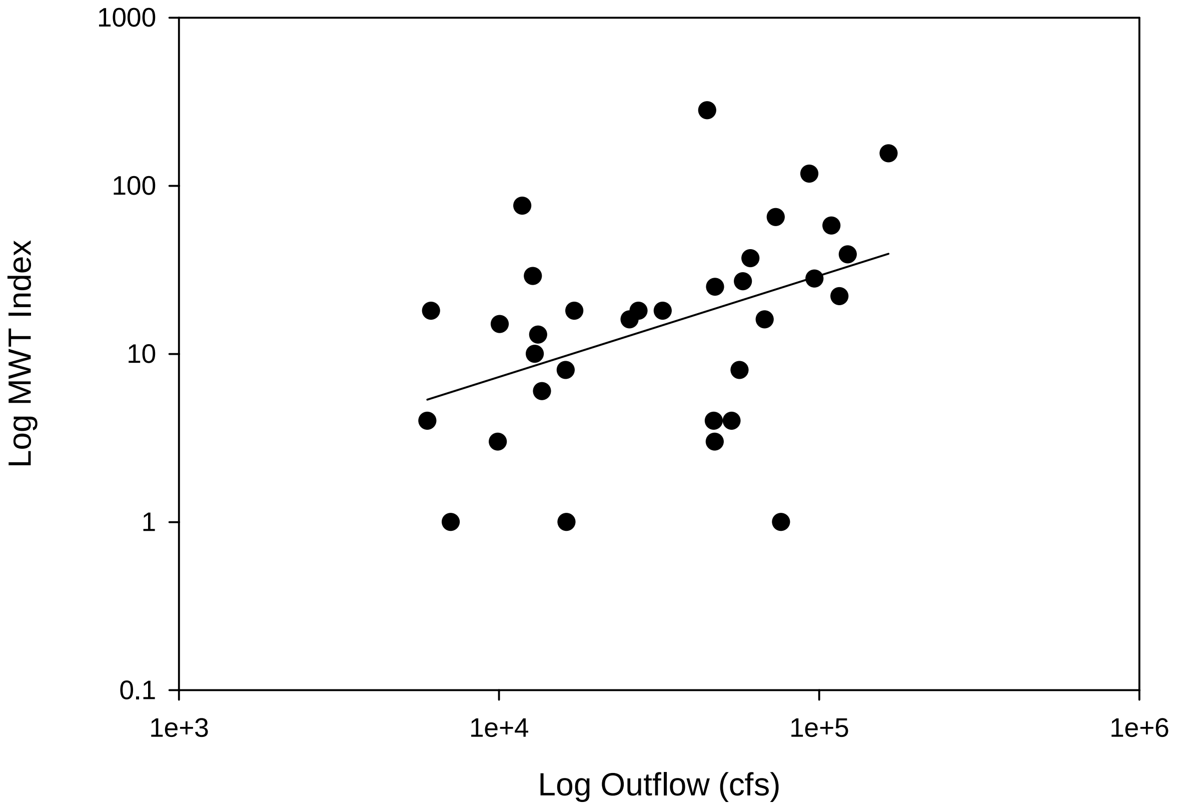
b[0] = -1.88
b[1] = 1.17
$r^2 = 0.42$




Splittail
300
250
200
150
100
50
0
Splittail MWT
0
20x10³
40x10³
60x10³
80x10³
100x10³
120x10³
140x10³
160x10³
180x10³
February - May Outflow

b[0] = -1.55
b[1] = 0.60
$r^2 = 0.17$

Splittail



Potential Revisions to the Conceptual Model/Biological Basis for Benefits

- A well-mixed zone of low salinity functions as habitat for phytoplankton, zooplankton, and juvenile fish
- The location of this zone is (on average) related to the magnitude of outflow
- Tidal action creates daily variation
- Productivity of the estuary varies with riverine inflow
- Location of X2 is influenced by inflow from the watershed, outflow, tides, and bathymetry
- High degree of variability in the response of the estuary

February-June outflow varies in numerous ways

- Magnitude in peak outflow (variation of several orders of magnitude)
- Total volume of outflow (variation of several orders of magnitude)
- Seasonal timing of flow (the distribution of flow during February-June)
- "Flow does not produce fish”
  - Flow may influence productivity depending on:
  - floodplain inundation
  - extent, duration, and pattern of floodplain inundation
  - timing of floodplain inundation

February-June X2 Standard/ outflow varies in numerous ways (continued)

- Air and water temperatures
- Net residence time over shallow-water habitat
- Seasonal relationship between nutrient dynamics and flow
- Flows in February-March, when light availability and temperatures are low, would not have the same effect on productivity as flows in April-May, when days are longer and air temperature begins to rise
- Steady state flow may not have the same effects as variable flow
- Floodplain inundation may increase productivity benefits

February-June X2 does not account for:

- In-Delta entrainment of egg, larval, juvenile (and some adult) fish
- Effects of invasive species adaptable to a wide range of salinities
- Effects of sediment re-suspension in Delta channels due to recreational boating
- Lack of vegetative habitat in mainstem rivers due to channelization and riprapping
- Effects of pesticides, herbicides, and other toxins
- Effects of reservoirs on mobilization and transport of sediments
- Loss of nutrient loading in reservoirs over time
- Increased urban development
- Long-term climate change
- Long-term sea level rise
- Harvest of salmon and loss of salmon-derived nutrients from the watershed
- Other factors not related to outflow and the interaction of tides and river flow

February-June X2 does not account for (continued):

- Continued uncertainty about the mechanisms for:
  - sediment and nutrient recruitment
  - loading, transport, dispersal, and conversion
- The estuary may benefit most from management of flows that enhance productivity
- Releases to meet X2 may flood upstream spawning gravels and dewater redds when releases are reduced

Options for modifying the X2 releases

- Vary releases to vary the position of X2 in Suisun Bay
  - hydrologic conditions
  - biological conditions
  - alterative priorities for resource allocation
- Vary the timing of releases to enhance productivity and/or phytoplankton transport
- No change in the "Chipps Island" portion of the X2 standard
- Allow for changes in the timing and flow rate used to meet the Port Chicago X2
- X2 standard is a relatively simple tool designed to manage a relatively complicated and dynamic function
- Current scientific information supports flexibility in the implementation of the X2 standard, particularly in the Roe Island/Port Chicago Standard

Hypothetical Example

	Initial Condition	Change	Final Condition	Difference	Percentage Change
Outflow	**30,000 cfs**	**24,000 cfs 14 days**	**29,444 cfs**	**-166,320 AF**	**1.9**
X2	**64.4 km**	**67 km for 14 days**	**64.45 km**	**+0.05 km**	**0.08**
Delta Smelt Index	**399**		**399**	**0**	**0**
Longfin Smelt Index	**2281**		**2232**	**-49**	**2.2**
Splittail Index	**13.7**		**13.5**	**-0.2**	**1.5**

Possible adaptive management strategies

- Flexibility in the position of X2
  - Maintaining X2 at a precise location is not necessary. New data suggest that X2 may be maintained as a continuum
- Flexibility in the timing of compliance
  - There is no apparent benefit to compliance tied directly to the triggering date of the Roe Island/Port Chicago Standard
- Flexibility in the location and timing of compliance could result in greater benefit to the estuary