Conceptual Model of Selenium in North San Francisco Bay

Technical Memorandum 4

Prepared by Tetra Tech

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Presentation to

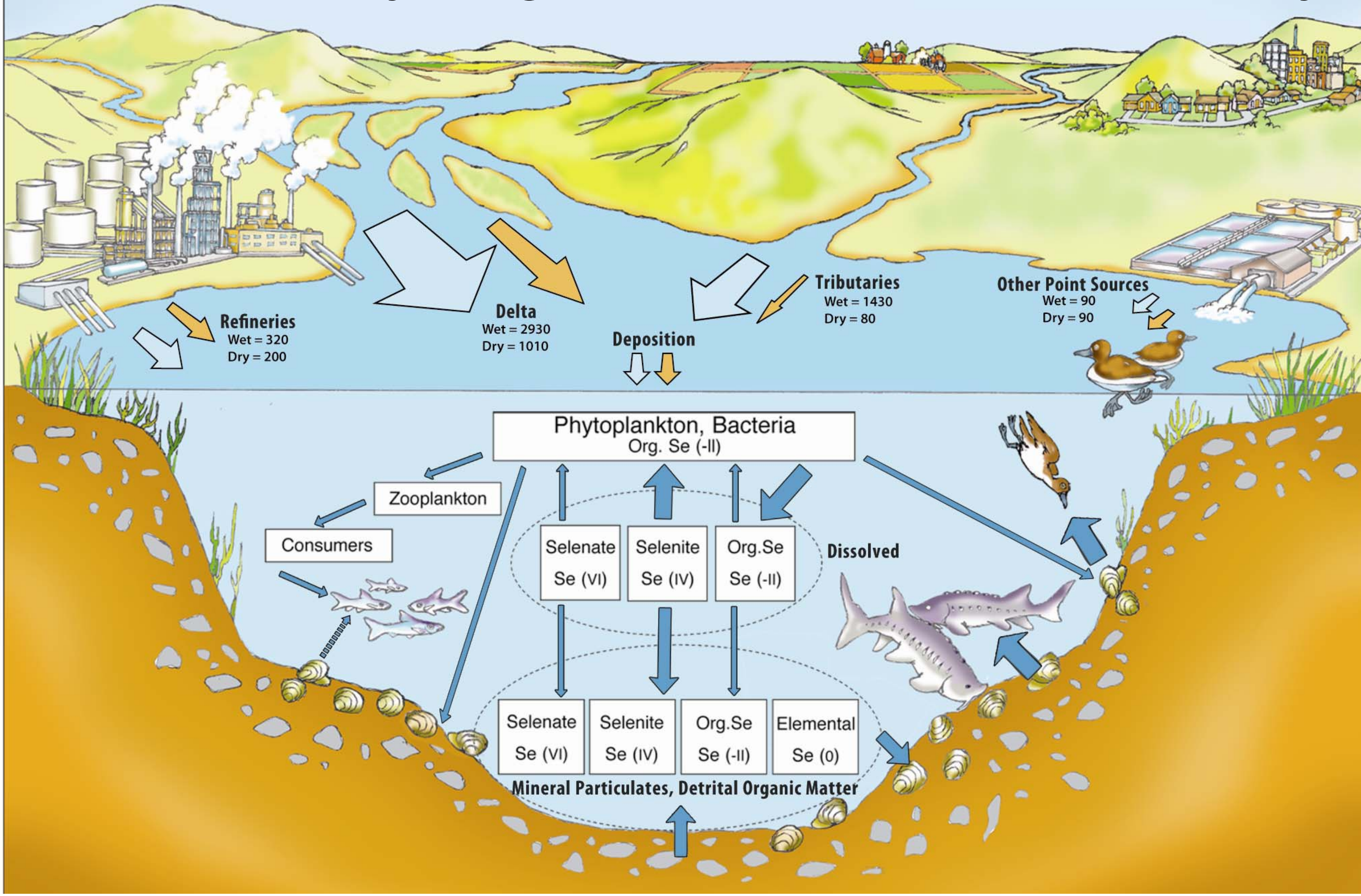
Advisory Committee

April 1, 2008

Objectives

- Explain important selenium-related processes to stakeholders, and to lay out broad areas of agreement in the scientific literature.
- Summarize spatial and temporal trends in selenium data, with a focus on concentrations in bivalves, waterfowl and fish, so that they can be compared against toxicological and health-based guidelines.
- Highlight data gaps and uncertainties of relevance to the TMDL.
- Guide the development of a numerical model that is proposed to be used to link selenium sources quantified in TM-2 to biota

Selenium Cycling in North San Francisco Bay



Overview of Presentation

- Summary of processes in
  - Water column
  - Sediments
  - Phytoplankton/bacteria
  - Fish and birds
- Recent data from NSFB
- Next steps in analysis and data collection

Water Column Selenium

- **Selenium (+VI) (selenate):** Present in very oxidizing environments, and does not adsorb strongly to particulates
- **Selenium (+IV) (selenite):** This form of selenium is common in oxygenated estuarine waters and can be taken up microbes and algae more readily than selenate.
- **Selenium-II (selenide):** Selenides can form through the uptake of oxidized selenium by plankton or microbes, where the selenium is biologically reduced and incorporated into organic compounds.

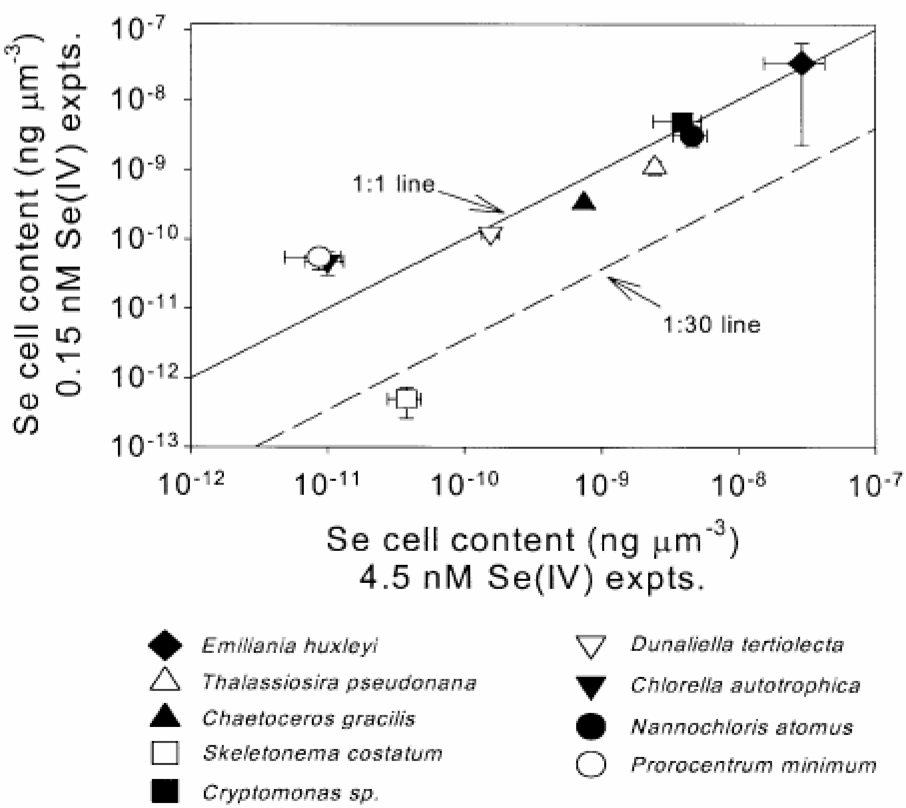
Particulate Selenium

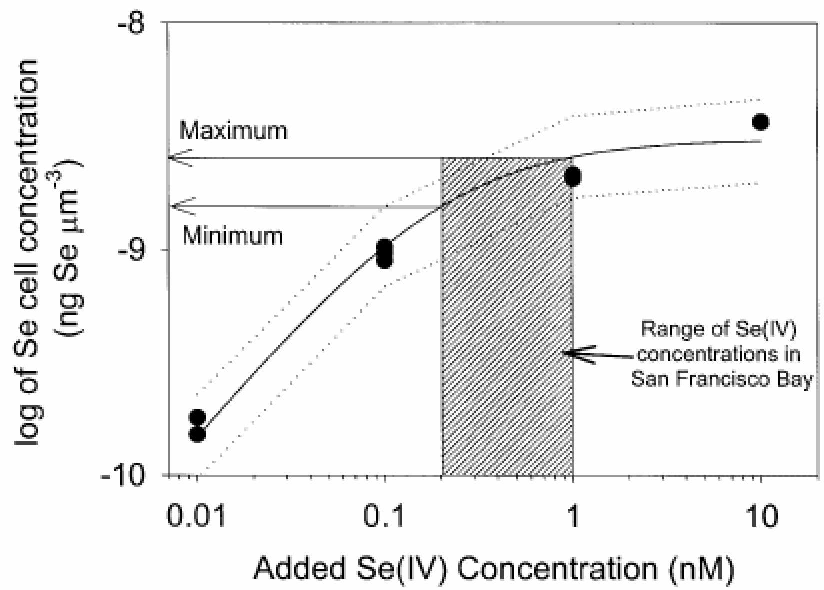
- **Mineral-particulate selenium:** Selenium can be adsorbed onto these particles as selenate, selenite, or organic selenide. Exchange between the water and sediments may be important source of mineral sediment-associated selenium. Riverine inputs from the Delta or from tributaries are also an important source.
- **Elemental selenium in zero oxidation state**: This form is stable in mildly reducing conditions, is very insoluble, and can be present in sediments or in suspended particulates.
- **Algal or bacterial associated selenium:** Selenium species, particularly selenite, can be taken up into the cytoplasm of these unicellular organisms as be converted into various organic forms such as seleno-methionine.
- **Selenium associated with organic detritus:** Selenium may be associated with non-living particulate organic carbon, which is likely to have originated in biologically associated selenium

Bioaccumulation

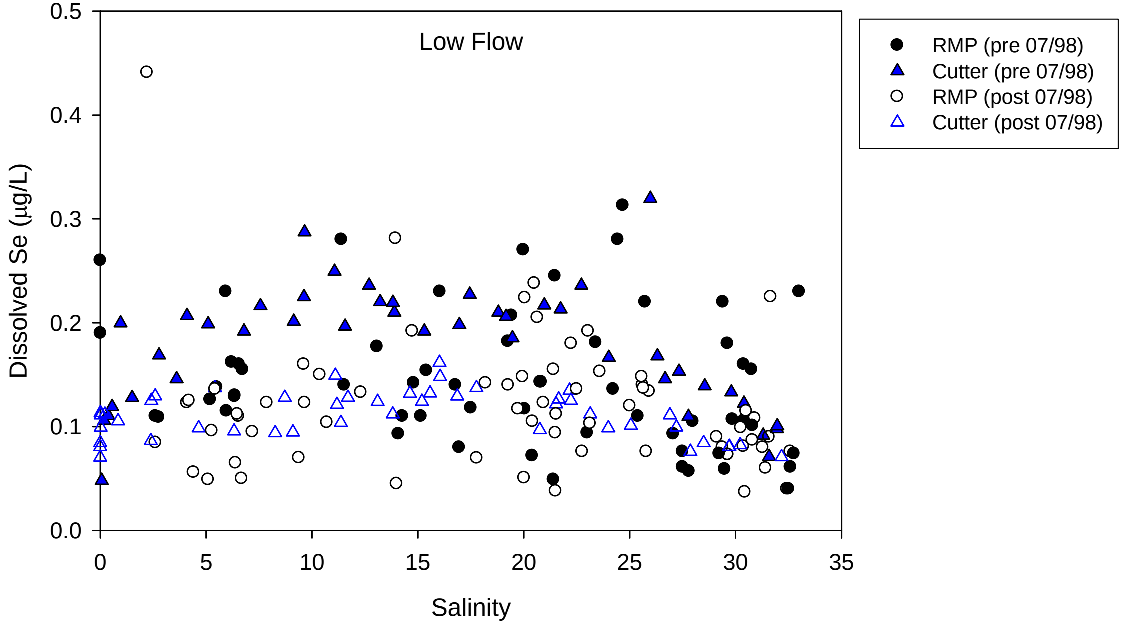
- Little direct uptake from the dissolved phase for most species
- Uptake occurs through particulates and higher particulate selenium concentrations should result in greater bioaccumulation

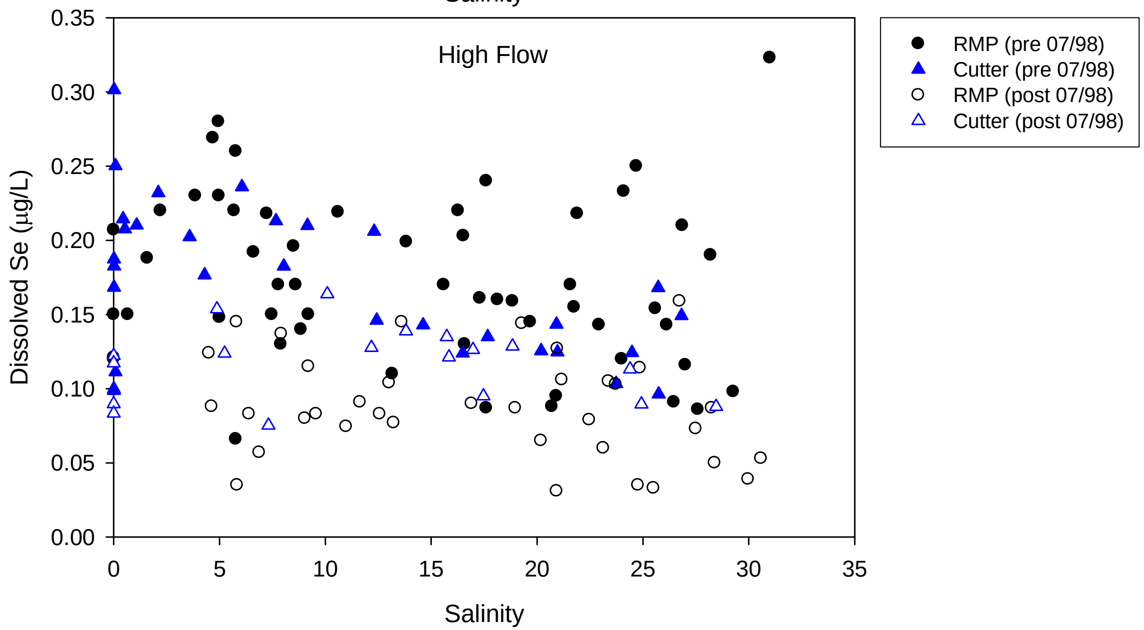
Algal Uptake can be Non-Linear to Ambient Concentrations



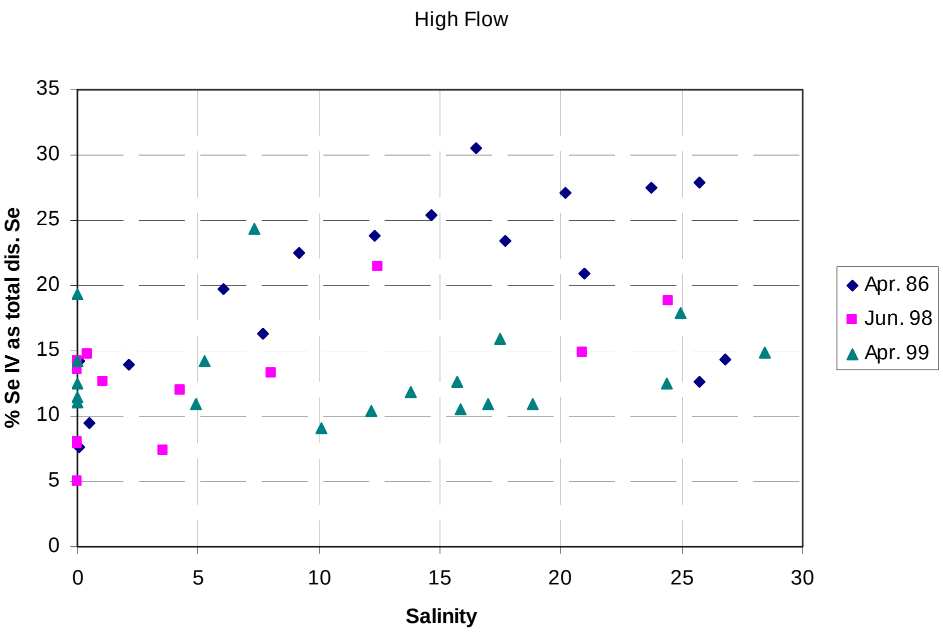


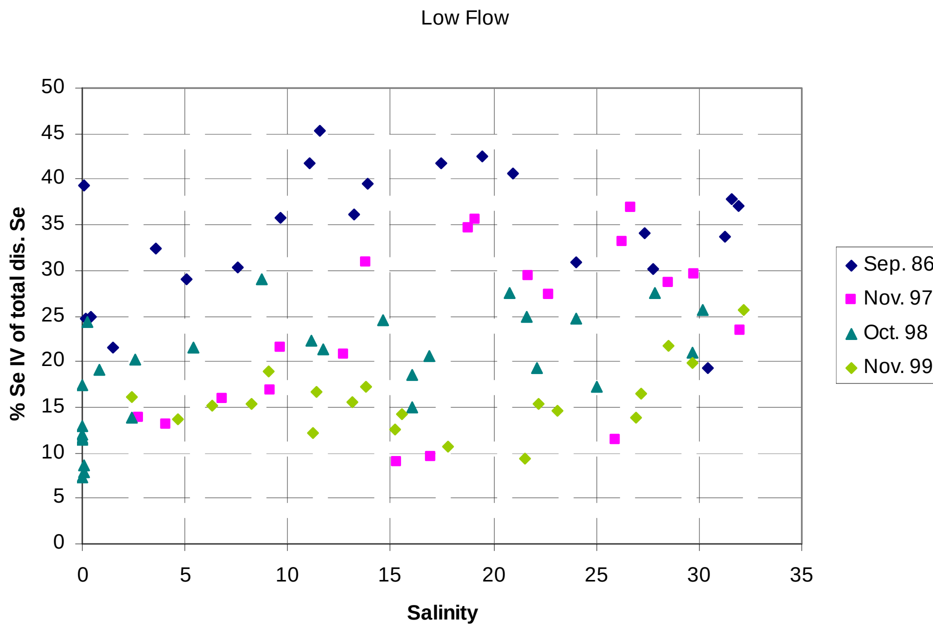
Dissolved Selenium Concentrations





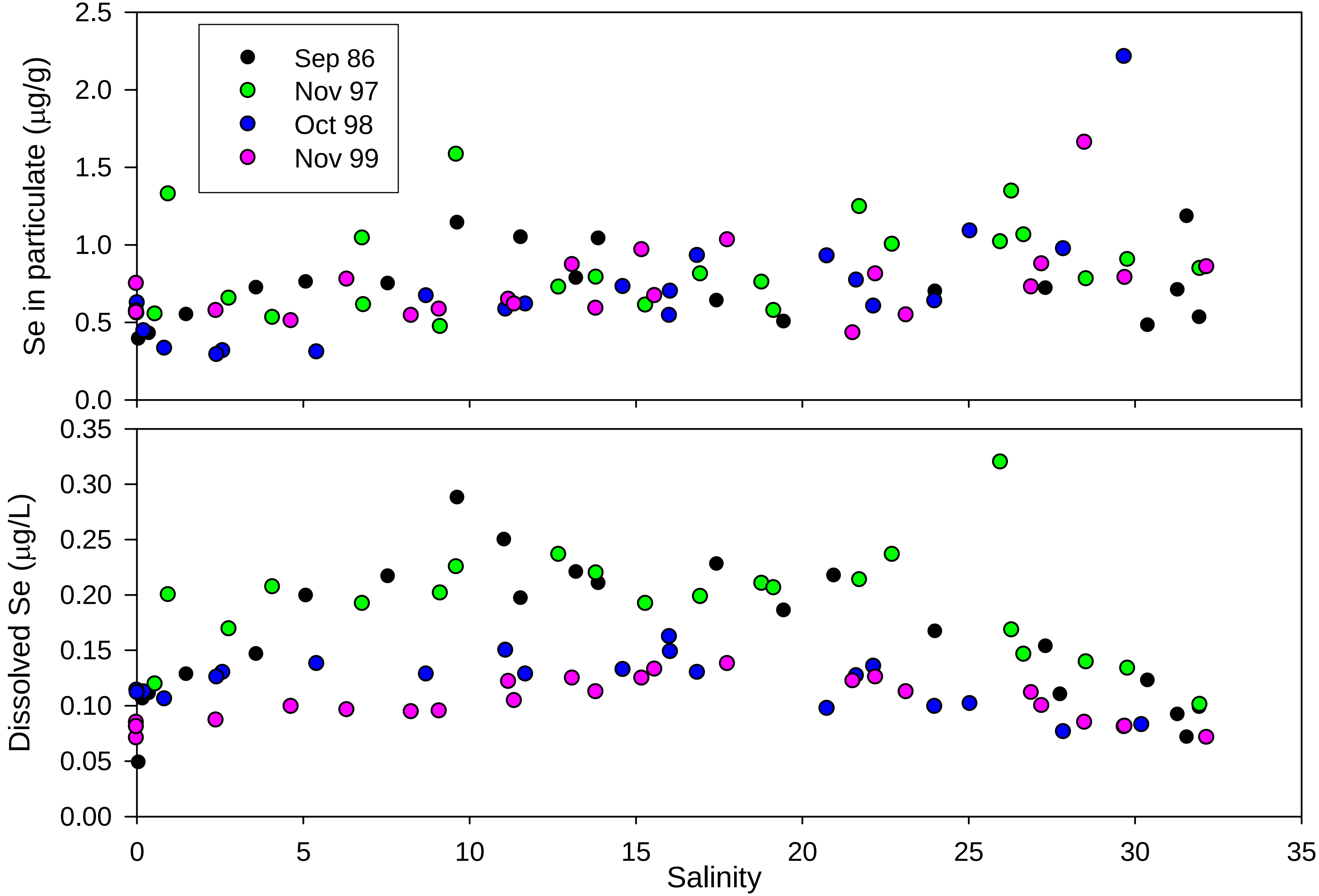
Selenite Concentrations



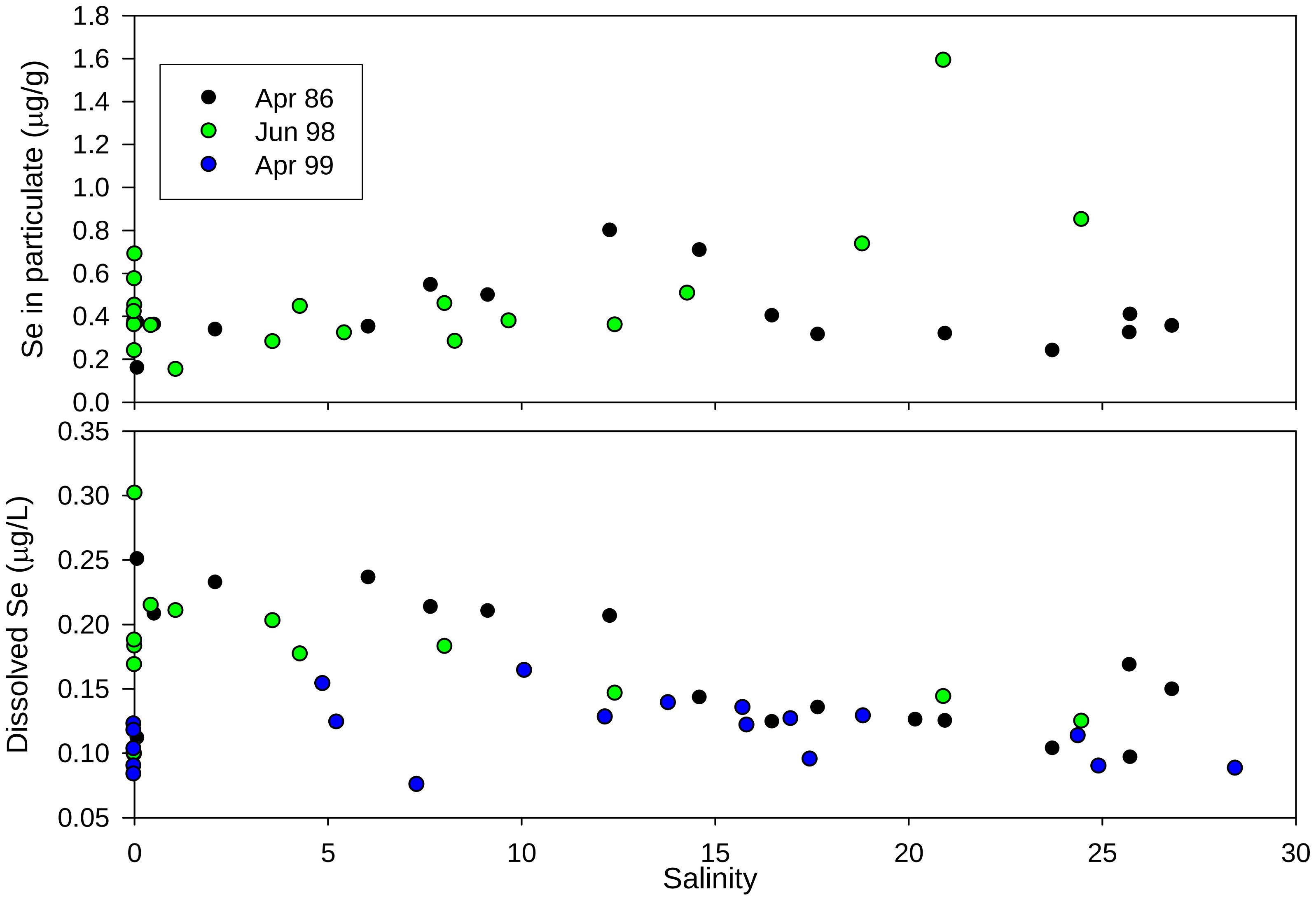


Particulate and Dissolved Se: Low Flow

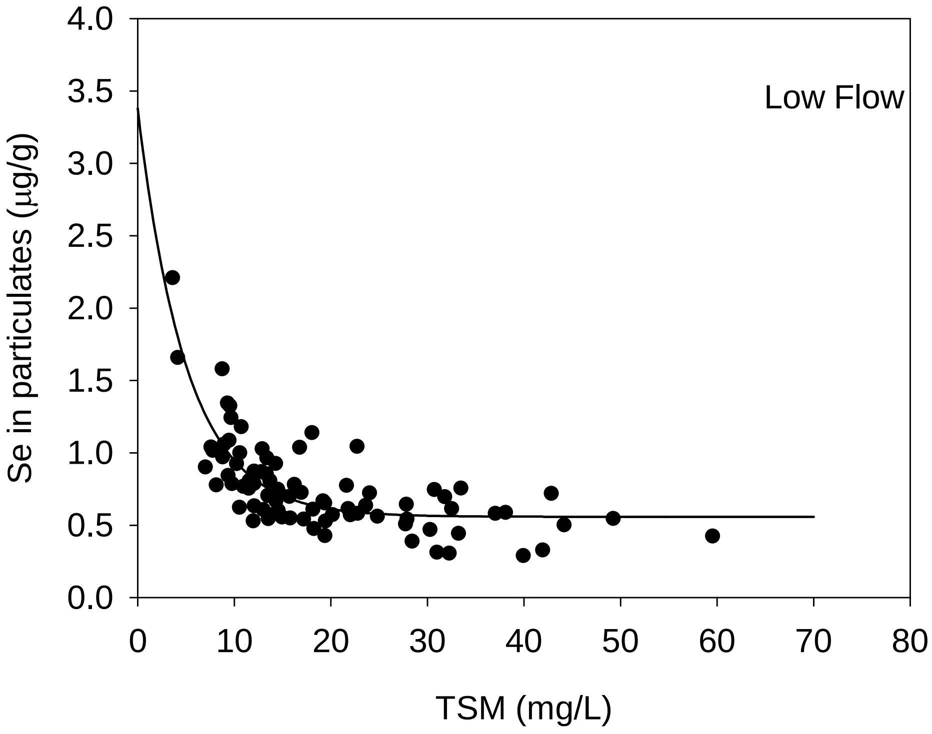
(Source: Cutter Research Group papers)

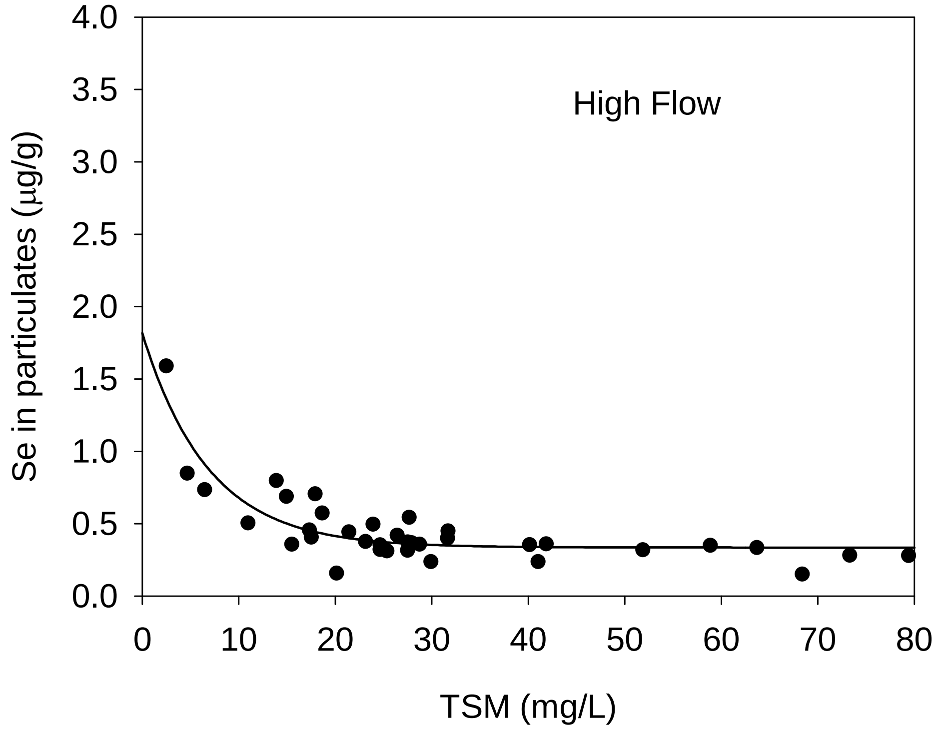


Particulate and Dissolved Se: High Flow
(Source: Cutter Research Group papers)

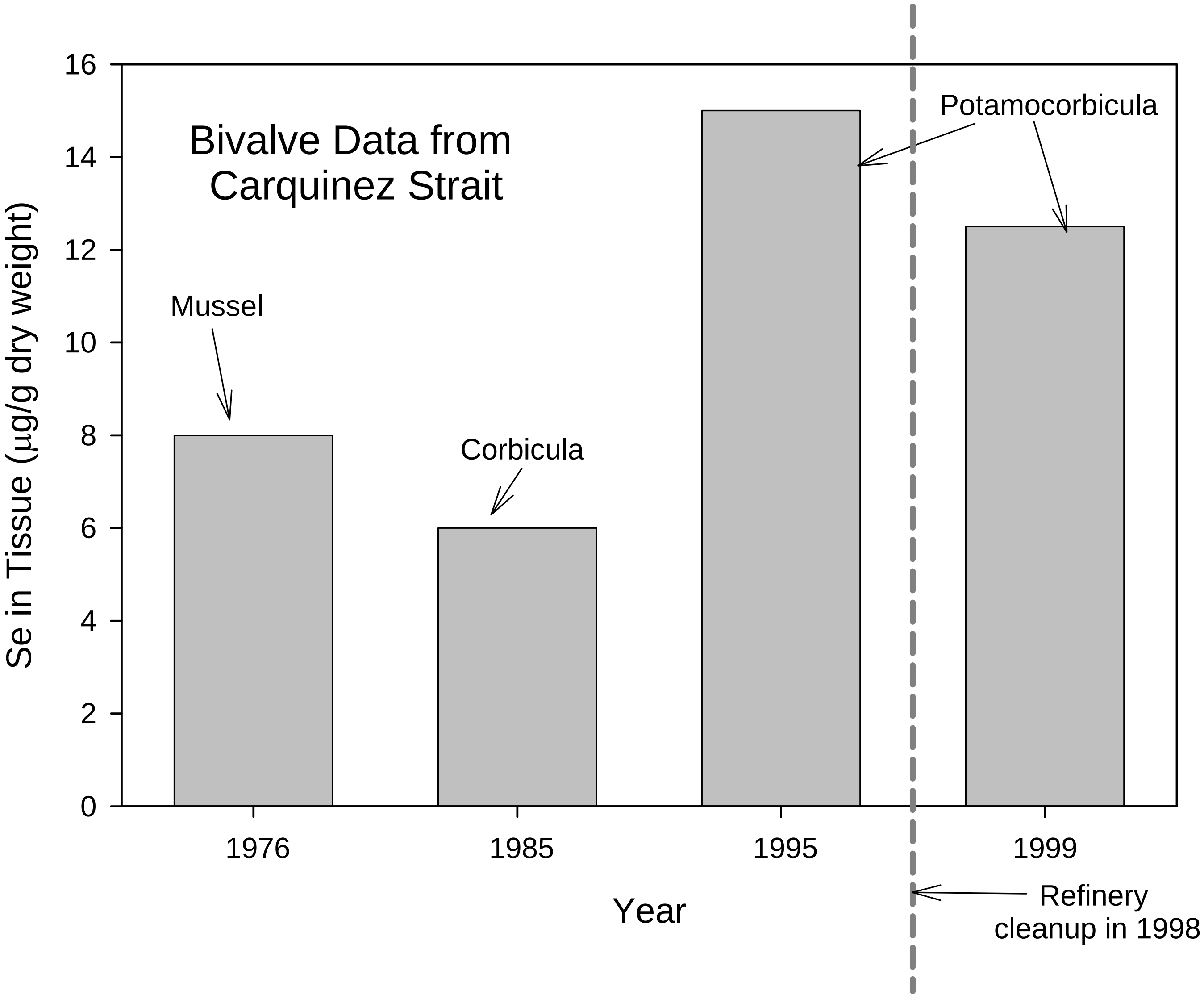


Particulate Se As a Function of TSM
(Source: Cutter Research Group papers)

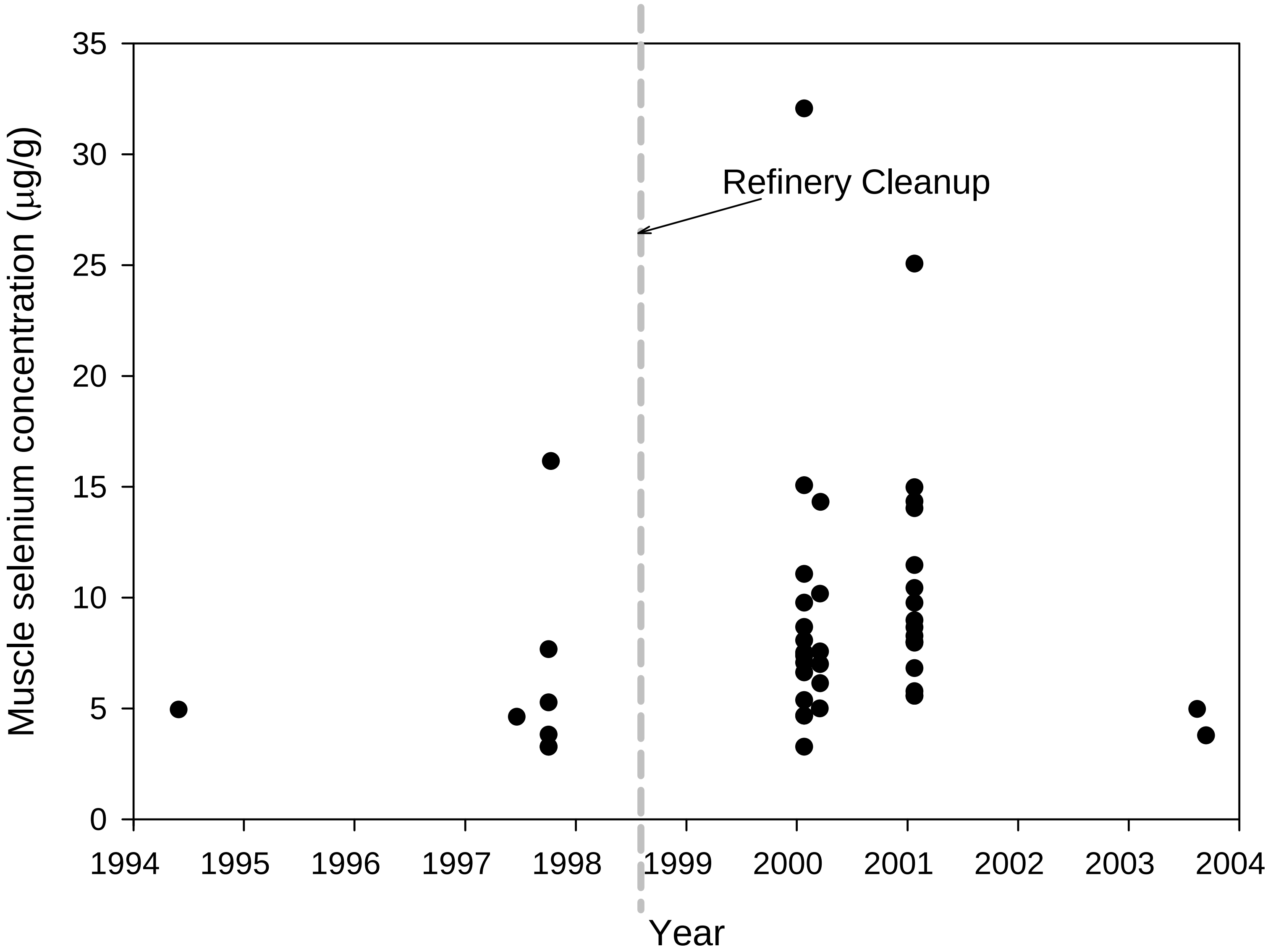




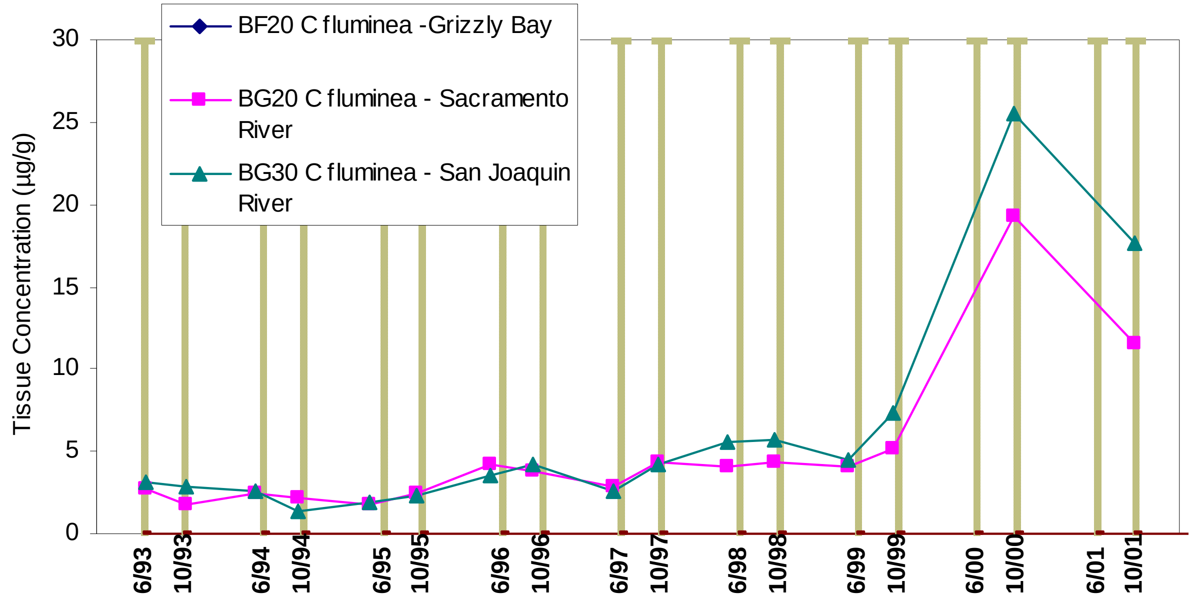
Resident Bivalve Data (USGS)

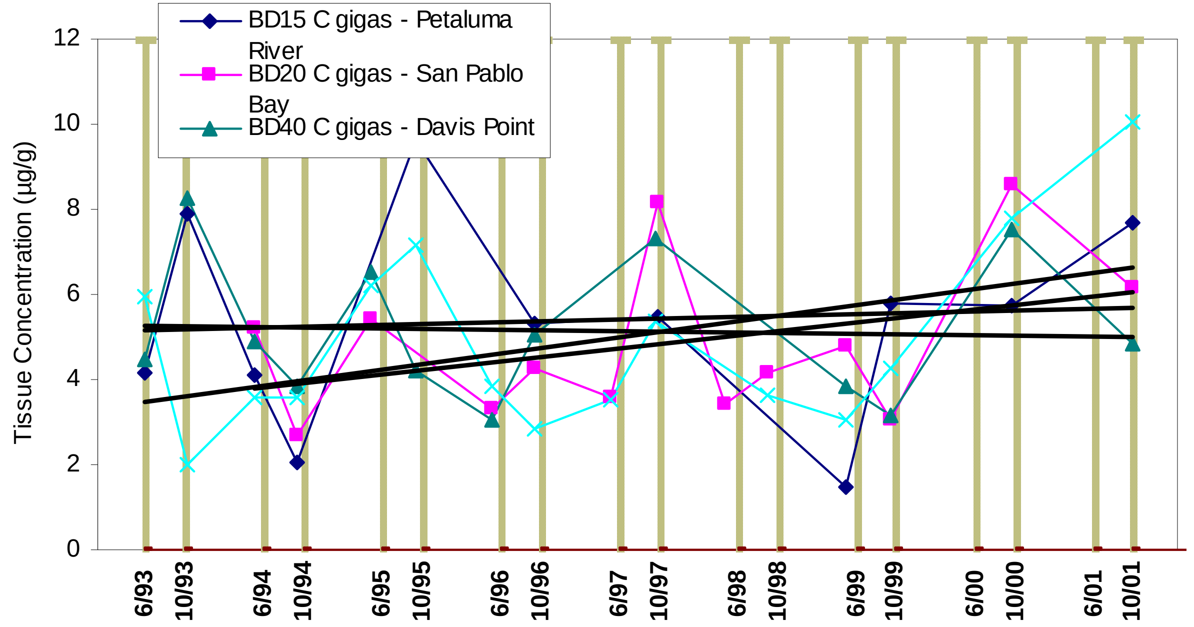


White Sturgeon Muscle Tissue Data

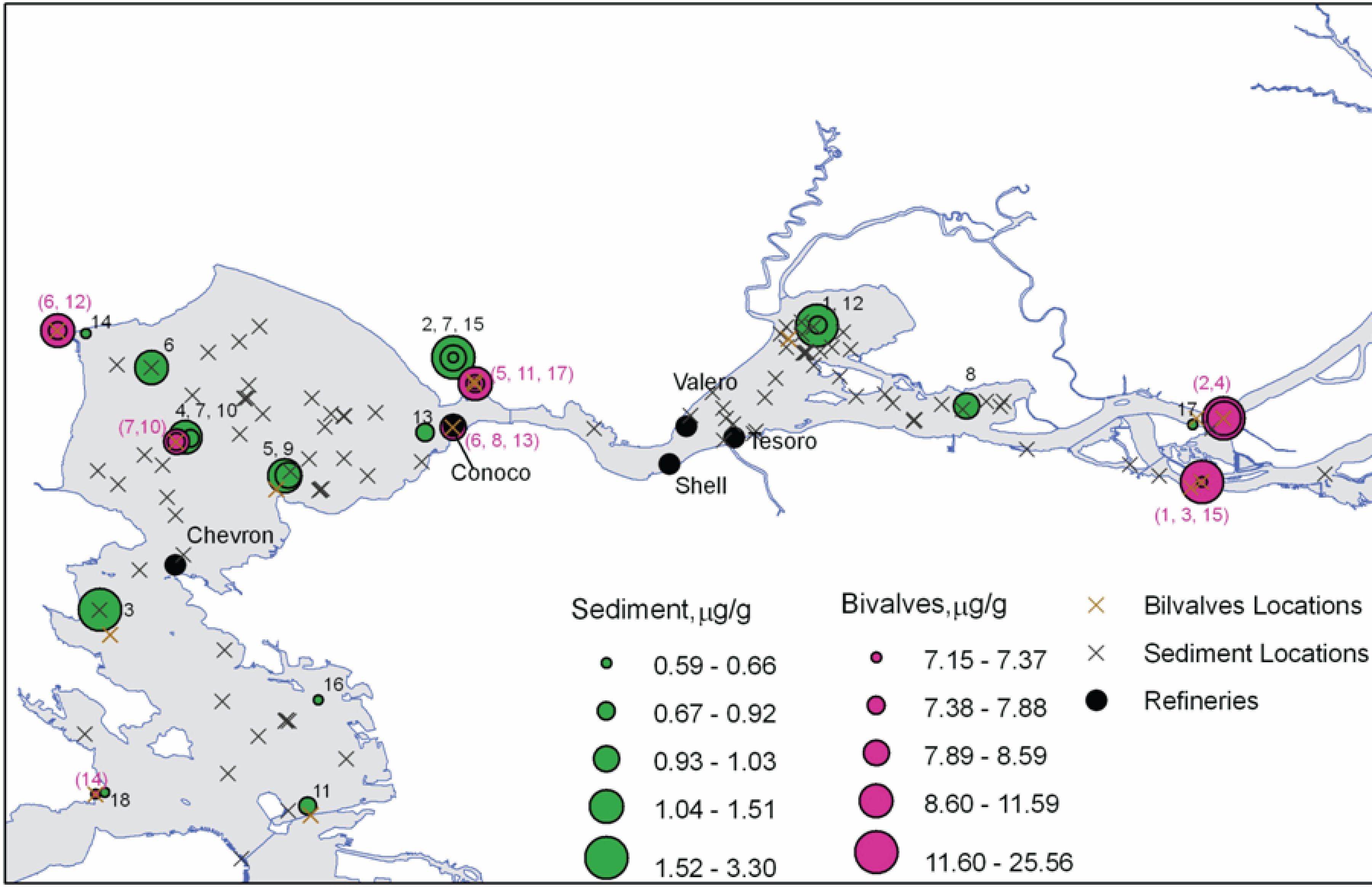


Transplanted Bivalve Data (RMP)

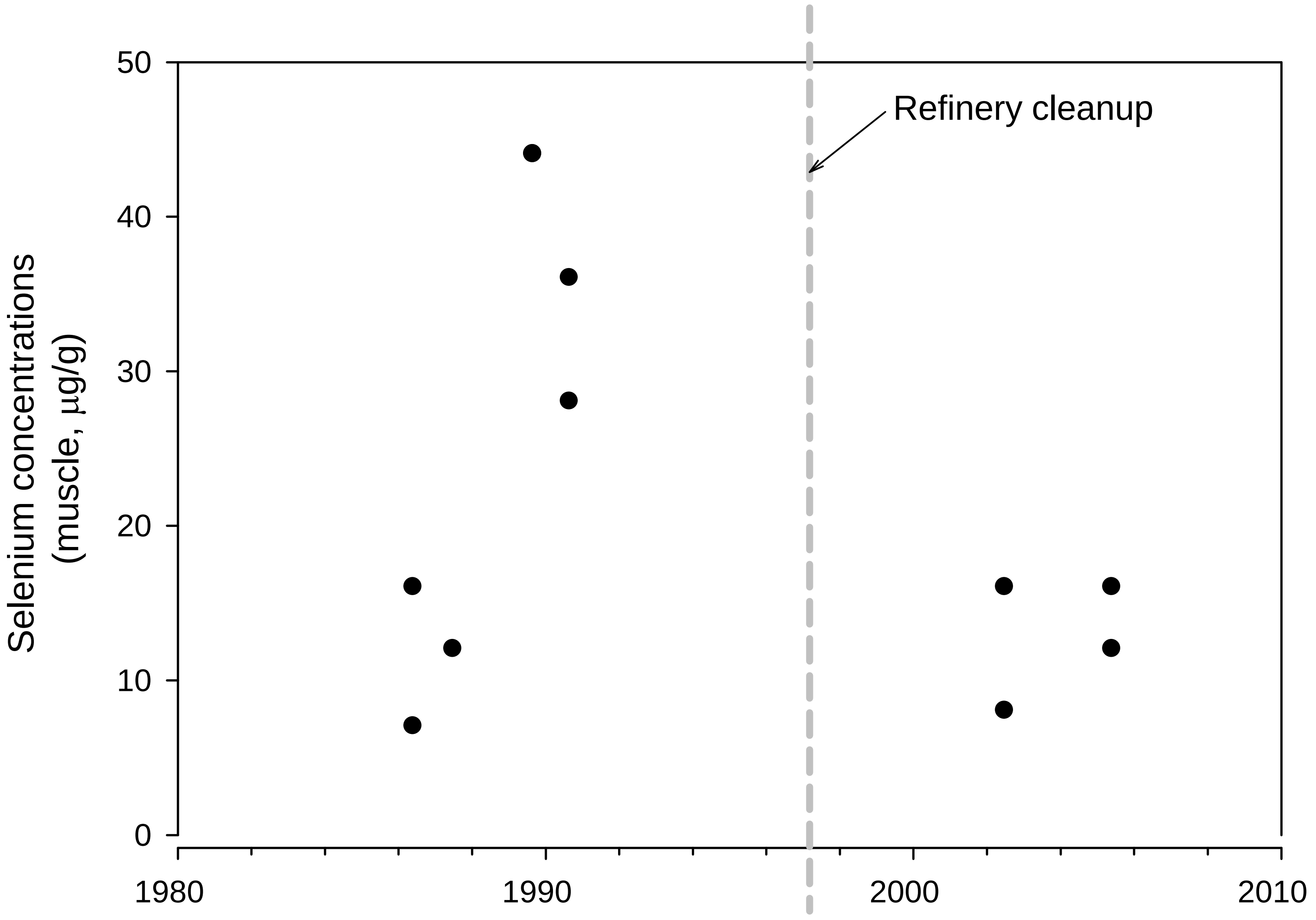




Bivalves and Sediment Concentrations

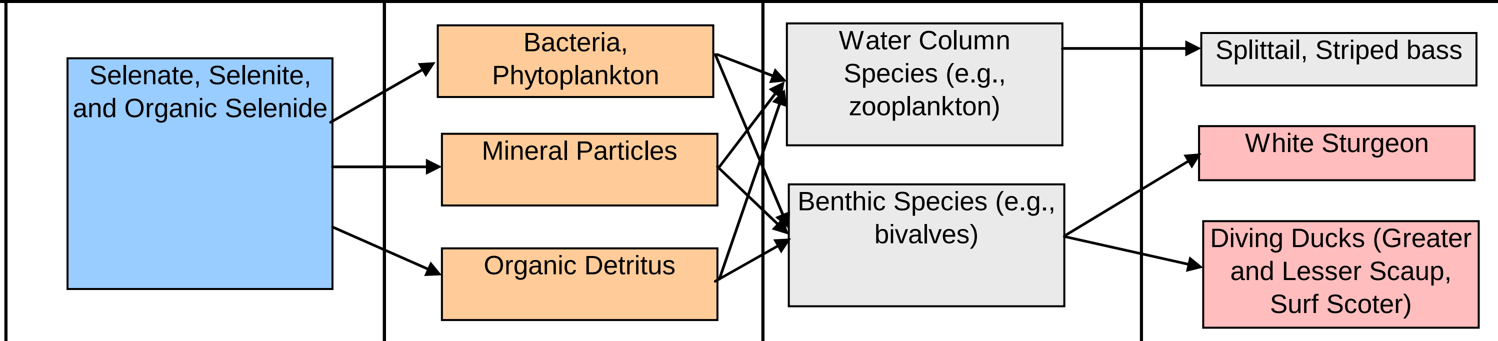


Concentrations in Diving Ducks



Uncertainty in Predicting Bioaccumulation

Selenium in Different Compartments



	Dissolved	Particulate	Prey Items	Predators
Key Drivers of Uncertainty	Conversion to particulate form, and thus bioavailability, varies by selenium speciation. Concentrations and speciation change with season and with the volume of rainfall during the wet season. However, selenium speciation data (i.e., whether in selenite, selenate, or organic selenide form) are available for limited times in the bay.	Algal selenium uptake varies significantly depending on algal species, and may respond only weakly to changes in dissolved selenium concentrations. Recent changes in phytoplankton concentrations may have unknown impacts on bioaccumulation. Bacterial uptake may also occur and result in higher cellular concentrations although data are limited.	Although uptake in prey items can be represented by a simple function, there are several variables, especially feeding rate, assimiliative efficiency, and loss rate, that make a significant difference to the prey tissue concentrations. These variables are a function of the species of interest and of the particulate form of selenium. Published bivalve data show some spatial patterns, but there are differences in behavior among resident and transplanted species. For data from transplanted species, different species are used in different salinities in the bay. In recent years, bivalve populations may have changed because of predation. Zooplankton data in the bay are limited although they do not show significant spatial variations.	Based on a limited amount of data, much of it from the 1980s, predator selenium concentrations are generally presented as a linear function of selenium concentration in prey items. There is limited recent data to evaluate changes in response to changes in water column and prey concentrations. There is little direct information on the assimilative efficiency of selenium from different prey items.
Data Sources	Cutter and Cutter, 2004; Doblin et al., 2006; Regional Monitoring Program in San Francisco Bay	Baines and Fisher, 2001; Hogue et al., 2001; Cloern et al., 1992; Cloern et al., 2007	Regional Monitoring Program in San Francisco Bay; Linville et al., 2002; Stewart et al., 2004; Luoma and Rainbow, 2005; Luoma et al., 1992; Schlekat et al., 2002	White et al., 1987, 1988, 1989; Luoma and Presser, 2006; SFEI 2006

Key Findings and Next Steps-1

- **For key biological indicators, data beyond 2001 were not available in the public domain.**
- **In addition to the load changes, there have been recent changes in the ecology of the bay, primarily an increase in phytoplankton productivity to levels seen prior to the *P. amurensis* invasion.**
- **There is no information now on what the *P. amurensis* populations are, and whether a decline in its numbers may reduce the levels of bioaccumulation in the future.**
- **Laboratory data show the dramatic effect of algal species on selenium uptake, although this information is not collected in the field.**
- **Field data show minimal change in particulate selenium concentrations (expressed as μg/g) despite substantial changes in dissolved concentrations in the late 1990's.**

Key Findings and Next Steps-2

- **Although 1999-2001 particulate, bivalve, and white sturgeon selenium data do not show decreases from prior periods, the very small amount of bird muscle data does indicate a decrease**
- **The role of particulates in the uptake of selenium implies that the modeling of the freshwater residence time and uptake in the bay is critical to understanding potential risk.**
- **From the sediment coring performed to date, there is limited knowledge of the historical signal of selenium in the bay, especially conditions that were prevalent prior to large scale irrigation in the San Joaquin Valley.**