Sacramento-San Joaquin Delta
Regional Ecosystem Restoration Implementation Plan

EXCERPT FROM

Ecosystem Conceptual Model

Selenium

Prepared by: Theresa S. Presser, U.S. Geological Survey, Menlo Park, California
tpresser@usgs.gov

and
Samuel N. Luoma, U.S. Geological Survey, Menlo Park
Susan E. Wainwright-De La Cruz, U.S. Geological Survey, Vallejo
Regina G. Linville, CA State Water Resources Control Board, Sacramento
William N. Beckon, U.S. Fish and Wildlife Service, Sacramento
Steve Detwiler, U.S. Fish and Wildlife Service, Sacramento

Date of this excerpt: January 24, 2008

For further inquiries on the DRERIP conceptual models, please contact Brad Burkholder at BBURKHOLDER@dfg.ca.gov or Steve Detwiler at Steven_Detwiler@fws.gov
.

PREFACE

This Conceptual Model is part of a suite of conceptual models which collectively articulate the current scientific understanding of important aspects of the Sacramento-San Joaquin River Delta ecosystem. The conceptual models are designed to aid in the identification and evaluation of ecosystem restoration actions in the Delta. These models are designed to structure scientific information such that it can be used to inform sound public policy.

The Delta Conceptual Models include both ecosystem element models (including process, habitat, and stressor models); and species life history models. The models were prepared by teams of experts using common guidance documents developed to promote consistency in the format and terminology of the models
http://www.delta.dfg.ca.gov/erpdeltaplan/science_process.asp .

The Delta Conceptual Models are qualitative models which describe current understanding of how the system works. They are designed and intended to be used by experts to identify and evaluate potential restoration actions. They are not quantitative, numeric computer models that can be "run" to determine the effects of actions. Rather they are designed to facilitate informed discussions regarding expected outcomes resulting from restoration actions and the scientific basis for those expectations. The structure of many of the Delta Conceptual Models can serve as the basis for future development of quantitative models.

Each of the Delta Conceptual Models has been, or is currently being subject to a rigorous scientific peer review process. The peer review status of each model is indicated on the title page of the model.

The Delta Conceptual models will be updated and refined over time as new information is developed, and/or as the models are used and the need for further refinements or clarifications are identified.

Table of Contents

DRERIP Selenium Conceptual Model

Summary

Understanding the biotransfer of selenium through the Bay-Delta estuary is essential for evaluating the effects of selenium on ecosystem resources. The linked approach used here considers progressive modeling of selenium through water-column loads, concentrations, and speciation; particulate matter transformation and bioavailability; the biodynamics of bioaccumulation in prey; and trophic transfer to predators. This approach can conceptualize and model selenium through site-specific Bay-Delta foodwebs and determine the vulnerability of predators important in the Bay-Delta ecosystem. This approach can be used to generate forecasts of how selenium moves through the estuary based on selected management and regulatory options.

Sources of selenium to the estuary are 1) oil refinery effluents from five refineries in the North Bay; 2) agricultural drainage discharged through the San Joaquin River; 3) direct discharge of agricultural drainage through a proposed extension of the San Luis Drain; and 4) effluents from municipal wastewater treatment plant. The Sacramento River inflow establishes a baseline flow and selenium concentration entering the estuary, with selenium loads increasing with volume of inflow and selenium concentration relatively constant. Selenium sources are modeled based on detailed historical or current loading (selenium concentration and flow) data.

The volume of water flowing into the Bay-Delta is determined by climate and water management. On a broad scale, the Bay-Delta watershed is characterized by a distinct seasonal cycle of high inflows from the Sacramento and San Joaquin Rivers in January through June (high flow season), followed by lower inflows through the last six months of the calendar year (low flow season). Riverine influences also depend on water year type (wet year or dry year). Volumes of water flowing into the Bay-Delta are modeled on various time steps (low or high flow season; monthly; weekly) and climatic regimes based on current flow data.

The majority of selenium that enters the Bay-Delta is as dissolved load. Selenium dispersion is modeled based on salinity as a composite freshwater point source of selenium is discharged into the estuary and diluted by the volume of the rivers. Concentrations of selenium can be calculated for hypothetical locations throughout the estuary (e.g., at the head of the estuary in the North Bay and a point midway in the North Bay at Carquinez Strait) based on additional considerations of hydrodynamics. Factors such as residence time and exchanges within the Bay and Delta are important in smaller-scale modeling.

Uptake of dissolved selenium and recycling of selenium in the Bay-Delta results in efficient partitioning in particulate material (i.e., phytoplankton, detritus and sediment). The distribution coefficient (K_d) is the ratio of selenium per unit mass particulate material to selenium per unit volume water in equivalent units. Speciation of dissolved selenium and transformation reactions of dissolved selenium to particulate selenium have a combined influence on the distribution of selenium.

Enhanced biogeochemical transformations to bioavailable particulate selenium and efficient bioaccumulation by bivalves characterize the Bay-Delta ecosystem. Selenium bioaccumulates in foodwebs principally through dietary exposure, with tissue selenium attributable to dissolved exposure making up only a small percentage of overall selenium. Biodynamics (kinetic bioaccumulation models) best represents how selenium is processed through food webs (Stewart et al., 2004; Schelkat et al., 2004; Luoma and Rainbow, 2005). Biodynamic modeling is based on the physiology of invertebrates ingesting particulate matter. Factors for modeling are derived from laboratory experiments that determine assimilation efficiency (AE), ingestion rate (IR), growth (g), and efflux rate (ke). The model is specific for each food web based on the bioavailability of particulate matter to copepods, mysids, clams, and amphipods.

Predators are more at risk from selenium contamination than their prey, with invertebrate toxicity an insensitive response to selenium contamination. Predators ingest selenium through choice of diet. Traditional dietary and energetic models are used in modeling, along with migration and resident timing of exposure and feeding. Sensitive endpoints include those for reproduction (hatchability and teratogenicity), growth, and body condition. Species-specific diets and reference doses can be calculated to determine allowable concentrations in food (wildlife value) that can be compared to available food in the ecosystem. Alternatively, 1) regression models between food and tissue selenium concentrations; or 2) trophic transfer factors can be developed.

Food-web specific and species-specific models considered are:
  Bivalve:
  - to diving ducks (white-winged, black and surf scoter; greater and lesser scaup)
  - to sturgeon (green and white)
  - to California clapper rail
  - to Sacramento splittail
  - to Dungeness crab
  Copepod to Delta smelt
  Copepod to mysid
  - to striped bass
  - to Chinook salmon (adult and juvenile)
  Amphipod to starry flounder
  Siberian shrimp, insect, worm, midge, fish larvae, bivalve
  - to steelhead
  - to Chinook salmon(adults and juveniles)

FIGURE 1

Ecosystem-Scale Selenium Model

Figure 1.

Se Loads: SJR   Sacramento R.   Refineries

River inflows, Season

Concentration in estuary

Dissolved species   Transformation **(Kd)**   **Phytoplankton, suspended particulates & sediment**

prey — **clams**   **zooplankton**   **amphipods**

predators — **sturgeon splittail diving ducks**   **striped bass**   **splittail flounder**

effects — **Impaired reproduction, teratogenesis**