SALTON SEA ECOSYSTEM RESTORATION PLAN

Tools for Predicting Selenium Concentrations and Effects in the Salton Sea

June 2005

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TOOLS FOR PREDICTING SELENIUM CONCENTRATIONS AND EFFECTS IN THE SALTON SEA

INTRODUCTION AND PURPOSE

A number of restoration alternatives for the Salton Sea will be evaluated in the Programmatic Environmental Impact Report (PEIR). One of the factors that will be considered in the evaluation is the anticipated impact of each alternative on the distribution and bioavailability of selenium in the ecosystem. Selenium is important to the Salton Sea ecosystem because it is known to occur at elevated levels and because it has the potential to bioaccumulate within the food web (Setmire et al. 1993). Selenium also represents a potential human health risk from consumption of fish and waterfowl from the Salton Sea.

In order to provide a consistent means to assess the future selenium impacts of each alternative, a computer model will be used to predict the anticipated distribution of selenium and to allow a comparison of the relative risks from selenium under various alternatives. A model for predicting selenium distribution in water, sediment, and biota has been developed for the San Francisco Bay (Luoma and Presser 2000); this model will be adapted to the Salton Sea using site-specific data and selenium transfer factors. The model will be used to evaluate selenium distribution under different salinity conditions (2, 20, and 35 parts-per-thousand [ppt], as well as the current baseline). The purpose of this report is to describe the required inputs for the computer model and the availability and suitability of data from the Salton Sea.

A description of the food-chain transfer pathways for various Salton Sea habitats (e.g., deep water, near-shore, estuaries and drains, and freshwater wetlands) was previously presented in a separate memorandum (CH2M HILL 2005). That memorandum showed graphical representations of the food webs and selenium pathways for the different aquatic and terrestrial habitats that would likely be altered or created under different restoration alternatives. While the overall purpose of the food web diagrams were to support the upcoming evaluation of the ecological risks associated with selenium in the Salton Sea ecosystem, they also serve as a basis for understanding the potential selenium food-chain transfer pathways and how they relate to the model.

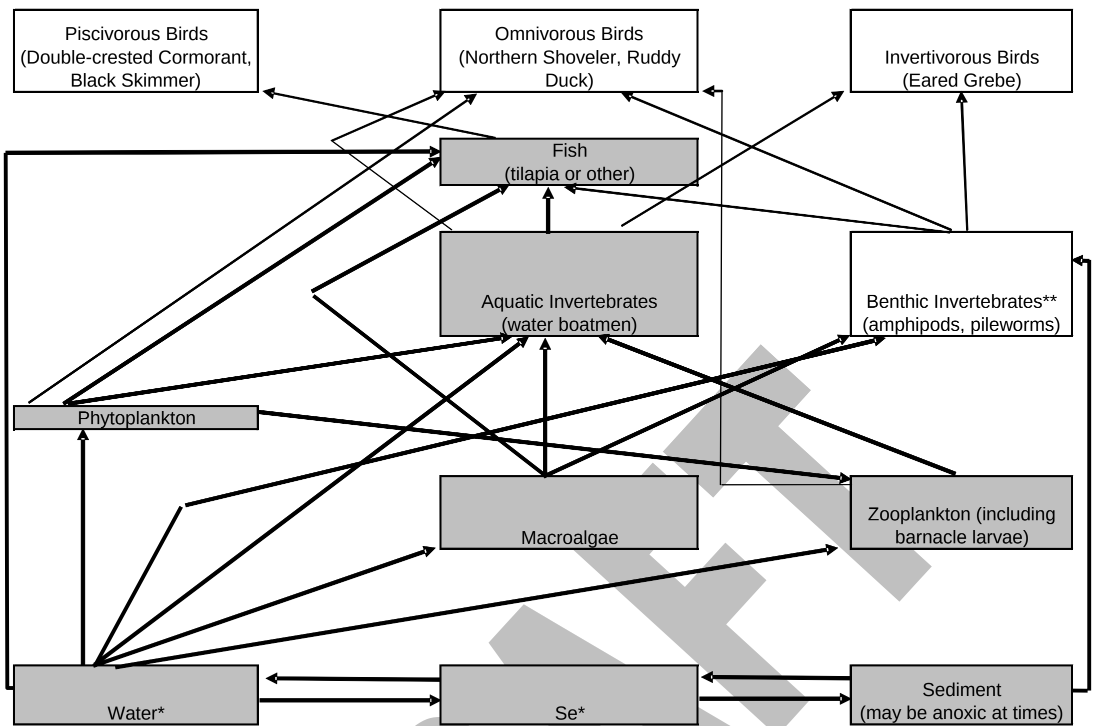
MODEL DESCRIPTION

Model Source

The model developed to forecast selenium discharges to the San Francisco Bay estuary and subsequent biological effects (i.e., Luoma and Presser 2000) provides an excellent framework and thorough literature review for the Salton Sea modeling needs. The Bay model is based on projecting alternatives in load, concentration, and speciation of selenium to the Bay and follows the concentrations in water and sediment up through the food web. Similar projections of variable loads and concentrations to the Salton Sea will be available as part of this project through the Salton Sea hydrologic and salt loading model, now under development. The Bay-specific biotic effects must be modified for application to the Salton Sea, but the basic conceptual model and structure of the estimating techniques are broadly applicable to the Salton Sea needs.

The conceptual model for important components of the food web and transfers between compartments are shown in Figure 1 for the main body of the Salton Sea. Highlighted boxes and arrows show which components of the model are reasonably well described (ambient concentrations or experimental results) versus those components that will be estimated using literature or Bay model values.

Figure 1
Exposure Pathways and Food-web Relationships for Deep (.0.5 ft. [0.15m]) Open Water Habitat



* Water-borne selenium
** Characterized primarily
Shaded boxes = Measured selenium concentrations from the field
Bold lines = Relationship characterized by field-derived bioaccumulation factor.
Thin lines = Unquantified bioaccumulation relationship (but dietary exposure can be calculated).

Similarities/Differences between SF Bay and Salton Sea Models

The Bay model and the current Salton Sea adaptation both focus on projected loads and concentrations of selenium as well as selenium speciation as the basis for evaluating subsequent biological effects. The models are similar, except for the infinite hydrologic residence time of the Salton Sea (terminal lake versus the throughput of selenium experienced in San Francisco Bay) and the differences between the biological communities. Nevertheless, the models are similar in their ability to project future tissue concentrations based on changes in ambient, water-column concentrations and sediment concentrations as may occur under various project scenarios.

The main difference in the models is the aquatic food webs of the two systems. Both include uptake by plankton and attached algae, transfer to invertebrate consumers, and on to small fish, larger fish, and birds (which may also feed on the invertebrates). In the Bay system, uptake occurs mostly through benthic bivalves, with higher-order consumers being exposed by feeding on the bivalves. In the Salton Sea there are important exposure pathways through the plankton directly to one species of fish (tilapia) and through benthic worms and amphipods to various other species of fish as well as omnivorous and invertivorous birds. In both systems, the fish then serve as diet for piscivorous birds.

Unlike the Bay model, the Salton Sea model will be used to evaluate effects under widely differing salinity regimes, from current conditions at 44 ppt salinity down to 35 ppt, 20 ppt, and 2 ppt to simulate future remediation alternatives including the creation of new freshwater marsh habitat.

Required Inputs to the Salton Sea Model

- Concentrations of total and dissolved selenium in water, along with a knowledge of dissolved selenium speciation, to estimate bioaccumulation.
- Total selenium concentrations in bulk sediment are needed to set baseline conditions for the model and to establish relationships with sediment-associated biota.
- Tissue selenium concentrations in benthic invertebrates are required to set the baseline conditions in the model and to establish sediment-invertebrate relationship and estimate bioaccumulation in invertebrate tissue. Selenium concentrations in the tissue of water-column invertebrates also will be an important factor in the Salton Sea model because of their relative abundance and importance in the Salton Sea food web (exposure to fish and some birds).
- Fish tissue selenium concentrations are needed as a measure of exposure to birds and humans and to establish a relationship between fish and existing water column and benthic food items.
- Bird or egg tissue selenium concentrations will be used to set baseline conditions in the Salton Sea model.
- Transfer factors for all important pathways as shown in Figure 1 are needed.

AVAILABILITY AND SUITABILITY OF SALTON SEA DATA INPUTS

Water

Influent water concentrations of total selenium and concentrations of total, particulate, dissolved, and dissolved species of selenium in the Salton Sea will be reasonably well characterized by the results of the spring 2005 sampling effort (Task Order SS0405-3575-0013). The results will be compared to past sampling efforts to understand the importance of seasonality and/or long-term changes over time. A best-case understanding of current, baseline conditions will be produced as a summary of 2005 results.

Potential changes in water-column concentrations of selenium that may result from changing environmental conditions and project salinity alternatives have been investigated as part of an experiment using intact-core sediment and overlying water (Task Order SS0405-3575-0023). The relatively undisturbed Salton Sea sediment cores with intact overlying water were subjected to either anaerobic or aerobic conditions using the three project alternative test salinities of 2, 20, and 35 ppt. The resulting flux of total selenium and various dissolved selenium species are being compared among test conditions as a general measure of potential changes in water-column selenium and selenium bioavailability that may result from changes in salinity and water quality (using anaerobic overlying water as a surrogate for the effects of nutrient over-enrichment). The results of the intact-core experiments will be used to help select the degree of bioavailability and concentrations of water-column selenium that may be expected under future project alternatives.

Sediment

Surface sediment concentrations of selenium were well characterized as part of the results of the spring 2005 sampling effort (Task Orders SS0405-3575-0013 and SS0405-3575-0020) and from other several recent sampling efforts (Setmire and Schroeder 1998 plus the 2005 reanalysis). The results include values for all water depths and areas of the lake for surface sediment (top 6 inches). The body of historical results will be examined for evidence of change over time as compared to 2003-2005 results and for the production of a current, best summary of the spatial variability in surface sediment concentrations to be used as the baseline case in the model.

Sediment quality was measured from each of the intact sediment cores at the beginning and end of the intact-core experiments (Task Order SS0405-3575-0023). The degree of selenium leaching and loss from the sediment to overlying water observed during the intact-core experiments will be used as evidence for potential changes in sediment quality that may be expected under different project alternatives. In addition, the bioaccumulation experiments that are currently underway will serve as a second measure of longer term conditioning and leaching in response to the alternative target salinities; selenium content of the bioaccumulation sediments will be measured before and after the experiments at all three target salinities.

Benthic Invertebrates

Benthic invertebrate tissue selenium concentrations are much less well known for the Salton Sea than for the Bay. Extensive sampling during the spring of 2005 yielded less than five samples of benthic invertebrates (Task Order SS0405-3575-0013). Apparently, recent poor water quality conditions (spring 2005) in the lake have contributed to an unusually severe die-off of benthic species, particularly the pileworm and gammarid amphipods. The pileworm, in particular, has historically been a very important base of the lake's food web, supporting both birds and fish. Older Salton Sea and general toxicological literature will be searched to develop a direct relationship for selenium concentrations between field-collected benthic invertebrates and co-located sediment samples (e.g. Setmire et al. 1993, Setmire and Schroeder 1998). The resulting biota-sediment accumulation factor (BSAF) for selenium will be a simple, predictive relationship to allow the estimation of pileworm concentrations (poorly known) from current sediment concentrations (well known). The few samples collected during 2005 will then be compared to co-collected (2005) sediment quality and older sediment/invertebrate samples (Setmire et al. 1993) to verify the applicability of the sediment/tissue BSAF relationship. In addition to a few benthic invertebrates, samples of benthic macroalgae were collected in 2005 and can be used as evidence for uptake from the water column (Task Order SS0405-3575-0013).

Bioaccumulation experiments that are currently underway (under Task Order SS0405-3575-0023) also will be used to develop a BSAF relationship between sediment and invertebrate tissue selenium concentrations. The experiments are being conducted under three different over-lying water salinities to estimate selenium bioaccumulation from Salton Sea sediments to polychaetes (similar to pileworms, using 35 ppt and 20 ppt salinity) and a freshwater annelid (2 ppt salinity) as part of a test of project alternatives. The results will provide direct, comparative bioaccumulation values and sediment/tissue BSAF relationships that can be used as a general, predictive tool and as a comparison to BSAF values developed from field-collected samples. BSAF values used to provide the linkage between sediment and benthic invertebrates will be chosen based on the combination of laboratory and field results.

Water-Column Invertebrates

Water-column invertebrates were fairly well sampled during the spring 2005 sampling events in some parts of the lake (Task Order SS0405-3575-0013). Near-shore corixids (water boatmen) and mid-water plankton (mixed assemblages of algae, zooplankton, and all particles by size class) will provide good characterizations of current tissue selenium concentrations for these portions of the food web. The water-column invertebrates of the Salton Sea provide a different food web pathway than was used for the Bay model, but are important for the Salton Sea and will be used as a tool in predicting fish and bird exposures. Corixids and plankton can be compared to water-column concentrations of selenium to produce bioaccumulation factors (BAF) values to be used in the model.

Fish

The fish community at the Salton Sea has changed dramatically in the last few years with the probable disappearance of the marine sport fish (Corvina, Bairdiella, Sargo) that historically formed the basis of the recreational sportfishery and much of the diets of piscivorous birds at the lake. The tilapia have persisted, however, and were extensively sampled as part of the spring, 2005 sampling effort (Task Orders SS0405-3575-0013 and SS0405-3575-0020). Various size classes of tilapia were sampled as composites of smaller fish and a few larger fish (for assessing bird dietary exposure) and as fillets from the larger fish (for human health exposure). A single composite sailfin molly sample was collected. These fish sampling results will be used to characterize baseline model conditions and will be compared to recent, historical tissue concentration results for evidence of changes over time. The fish concentrations will be compared to water and sediment concentrations to develop BAFs and BASFs.

Birds

Bird and egg tissue selenium concentrations were characterized as part of historical sampling efforts at the Salton Sea, with some egg samples collected as recently as 2004 (Chuck Henny, unpub. data). They will be used as summary tissue concentrations by species to describe the baseline condition for the model.

Transfer Factors

The relationships between waterborne and particulate selenium (Kd) can be estimated based on our field measurements of co-collected raw water and dissolved fractions and/or by literature and Bay model estimates based on the measured Salton Sea selenium speciation.

Measured relationships between sediment and organisms (BSAF) and water and organisms (BAF) will come directly from the 2005 data set as described above, with the possible exception of benthic invertebrates (pileworms and freshwater worms), which may be estimated from the bioaccumulation experiments and/or historical data, instead. Where a variety of co-collected values are available, a BSAF or BAF regression relationship will be developed (e.g., pileworms in the bioaccumulation experiment). Where lake-wide values are available (e.g., water, fish, plankton), lake-wide bioaccumulation factor ratios will be used as a predictive tool.

CONCLUSIONS

The body of information collected in 2005 and compiled from recent studies of the Salton Sea will provide an adequate characterization of baseline selenium concentrations for all essential media at the Salton Sea and, for most media, an estimate of changing conditions over the last few years. Combined with the ability to characterize transfer factors and to estimate conditions for varying project salinities, the Salton Sea bioaccumulation model should be an effective tool to assist in the evaluation of project alternatives.

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