MANAGING FRESHWATER DISCHARGE TO THE SAN FRANCISCO BAY DELTA-ESTUARY: THE SCIENTIFIC BASIS FOR AN ESTUARINE STANDARD

Conclusions and Recommendations of Members of the San Francisco Bay-Delta Estuarine Scientific, Policy, and Management Communities

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Affiliations and areas of expertise of these individuals and a full listing of all participants in one, or more, of the workshops appears in Appendix A

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PREFACE
A PERSONAL OBSERVATION

As a result of diversions of fresh water from the Sacramento-San Joaquin River system for agriculture and for urban use, the river discharge into the San Francisco Bay-Delta Estuary is significantly lower than natural levels. According to some estimates, river inflow to the estuary is only 50 to 70% of what it was in 1800. Among the primary responses of the estuary to this decrease in freshwater inflow have been an upstream (landward) displacement of the low salinity transition zone between the estuary proper and the tidal reaches of the river, and a compression of low salinity habitat.

It is well established scientifically that the extent -- the area and volume -- of low salinity habitat in estuaries is important to the success of a number of species, such as anadromous and semi-anadromous fishes, and to the success of other estuarine ecosystem components such as salt marshes. The contribution of each of the different processes and properties characteristic of low salinity zones of estuaries, and the contributions of different combinations of these processes and properties, to the success of different ecosystems components, are complex and have not been successfully evaluated for any estuary.

I know of no other estuary that has as complicated a situation in the low salinity transition zone as does the San Francisco Bay-Delta Estuary. The complex system in the Delta region for withdrawing and diverting freshwater away from the estuary acts like a giant predator, particularly for ichthyoplankton and young-of-the-year fish. This confounding leads to debate and disagreement over the relative importance of the benefits of low salinity habitat and therefore of flow, on the one hand, and of the liabilities of the physical diversion of a portion of that flow and the associated processes of entrainment of organisms, on the other. The debate and the demands for scientific certainty are intensified because of the economic importance of water, particularly for agriculture. Are total flow and the extent of low salinity habitat the most important factors for a healthy estuarine ecosystem? Or, are the places, times and mechanisms by which a fraction of that flow is diverted the most important factors? Could stresses on the estuarine ecosystem related to water use be reduced sufficiently by changing the timing and mechanisms of withdrawal without reducing the total amount of water diverted? If so, what specific water management strategies would be most effective? What would the associated biological benefits be? Until these questions can be answered with a degree of scientific certainty acceptable to the State Water Resources Control Board, estuarine standards are needed to protect the estuarine ecosystem against further degradation.

This complex situation argues strongly for the development of estuarine standards as part of a set of management tools for protecting the San Francisco Bay estuarine ecosystem. The vast majority of the workshop participants, and virtually all of the participating scientists, believe that one set of estuarine standards should be salinity standards which can be used to position the low salinity zone relative to the "predator." Different standards should be developed for different seasons to reflect the presence and vulnerability of "prey" that are particularly sensitive to the actions of this "predator." One appropriate index proposed by these workshops for the development of salinity standards is the upstream limit of the near bottom 2‰ isohaline. The salinity standards based upon this index should be expressed as specific upstream limits -- one for each of several periods (seasons) of the year and averaged over that period. The locations, the standards, would be selected to attain an appropriate level of ecosystem protection; to achieve an appropriate environmental goal.

Given the present state of knowledge, the principal method of selecting salinity standards for the San Francisco Bay estuary will be through the use of statistical relationships. A number of these relationships were developed during these workshops to evaluate the responses of estuarine organisms at different trophic levels to seasonal changes in the position of the 2‰ isohaline. This approach "lumps together" a number of factors including the ecological effects of low salinity habitat and the physical effects of entrainment losses.[1] Research efforts should be enhanced to provide the knowledge needed to disaggregate the cause-effect relationships between biological success and salinity, flow, diversion, and a variety of other environmental factors. Until that understanding is developed, salinity standards can provide a valuable tool for protecting the ecosystem because they integrate the effects of all these processes and phenomena upstream from the specified location of the 2‰ isohaline.

While the confounding of the effects of habitat by entrainment provides value-added to the proposed salinity standard which integrates the effects of both, it also raises a caution flag. Any proposed changes to the water withdrawal and distribution system, or in the way in which this system is operated--particularly within the Delta region--should trigger a re-evaluation of the standards. And, if any changes are actually made to that system, or to its operation, the biological responses to those changes should be monitored carefully to produce the data needed to formulate new salinity standards; standards to achieve the desired level of environmental protection.

Depending upon the nature of the changes made to the "plumbing system" or to its operation, and the resulting changes in "predation rates," the upstream limit of the 2‰ isohaline (the salinity standard) might have to be moved farther downstream by providing more fresh water or might be allowed to migrate farther upstream and still maintain a level of environmental protection equivalent to that before the changes were made. The proposed method of setting salinity standards provide for such adjustments.

Each conclusion and recommendation in this report was reviewed and voted upon in the final workshop. In no case did the final number of dissenting votes exceed three and in only a few cases did the number exceed two. In spite of this endorsement, a number of participants subsequently requested

[1]This issue is explored in the technical papers that accompany this report.

those requests. I thank each participant for his or her hard work and creativity in a search for solutions to a complex problem, a problem with a variety of dimensions: environmental, economic and socio-political.

J. R. Schubel
Stony Brook, NY
26 October 1992

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I thank Maureen Flynn for her patient and careful typing of the many drafts of this final report as well as the other reports. She never lost her good humor. I thank Liz Blair for making the necessary preparations for each of the workshops. Her attention to detail contributed to productive workshops. I thank Susan Schubel for assisting in the facilitation of the first workshop.

Finally, I thank Tim Vendlinski for his overall project support and management. He did a superb job and was largely responsible for maintaining an even keel even in some troubled seas.

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INTRODUCTION

Aquatic resources of the Sacramento-San Joaquin Delta and upper portions of San Francisco Bay have undergone significant declines over the past several decades. Species characteristic of the Delta and rivers, such as striped bass and salmon, began to decline during the late 1970s. Prolonged drought, large diversions of fresh water, and dramatic increases in populations of introduced aquatic species during the 1980s and 1990s brought a number of indigenous species to extremely low levels. Species that spend more of their lives downstream of the Delta, including Delta smelt, longfin smelt, and many zooplankton, maintained large populations through the 1970s, but declined sharply after the mid-1980s. Declines in aquatic resources have led to curtailed fishing seasons, to petitions for endangered species status, and general concern about the health of the estuarine ecosystem.

Concern over the impacts of increased salinity produced from the combination of drought and high diversion rates is not limited to aquatic communities. Remaining fragments of brackish and freshwater tidal marshlands are particularly vulnerable to increased salinity or to reduced variability in salinity. Such tidal marsh communities are unable to relocate upstream because of the absence of suitable areas. Tidal marshes provide important habitat for a number of plants and animals of special concern.

Large demands for water by the agricultural community and by the burgeoning human population in urban areas make it difficult to allocate additional freshwater for the protection of dwindling aquatic resources of the estuary. Management of the State's water resources necessitates a delicate balancing of needs, given the intense and growing competition for water. If the freshwater needs of the estuary are to be considered seriously they must be based on sensitive, straight-forward, and diagnostic indicators of the responses of the estuarine ecosystem to patterns of freshwater inflow.

An extensive body of scientific evidence indicates that flows into, within, and through the estuary are extremely important to organisms that depend on the estuary for at least a portion of their life cycles. However, the mechanisms by which flows affect different elements of the ecosystem are not well understood. In the San Francisco Bay-Delta Estuary, many chemical and physical properties and processes are tightly linked to flow, including proportion of water diverted, salinity at a given point, the longitudinal position of a particular salinity range, and alteration of the effects of toxicants through dilutions. Any of these phenomena could be controlling a particular species, but each will also vary with the other variables that are closely correlated with flow.

At present, the complex configuration of the Delta and the estuary, combined with the complex withdrawal and diversion network, preclude any simple, directly monitored measure of freshwater discharge to the estuary. Effective protection and management of the estuary requires an index of the estuary's response to freshwater inflow that (1) can be measured accurately, easily and inexpensively; (2) has ecological significance; and (3) has meaning for nonspecialists. Net Delta outflow, which is calculated from various measures and estimates of water inflow and use, has been a useful tool but it does not satisfy all of these requirements. Because of the high correlations among the flow-related variables, the choice of a suitable index does not need to be based on any presumed mechanism.

The San Francisco Estuary Project convened a series of workshops to evaluate the responses of estuarine biota and habitats to various conditions of salinity and flow. The workshops involved approximately 30 scientists and policy makers with expertise in estuarine oceanography and ecology, and in water and living resource management. The group focused its attention on Suisun Bay, the portion of the estuary downstream of the confluence of the Sacramento and San Joaquin Rivers and upstream of Carquinez Strait. Internal delta issues (such as gate closures, water exports, and internal flows) or problems of downstream portions of San Francisco Bay (such as urban and industrial discharges) were not directly addressed by the group. No attempt was made to incorporate all management actions that might benefit biological communities, nor to identify what level of environmental restoration and protection should be set based on salinity and flow.

Identification of freshwater needs of aquatic resources has caused conflict for a variety of reasons. Debate of scientific issues is fundamentally different from other kinds of debate in that it should yield to scientific investigation. Participants developed issue papers that delineated areas of scientific agreement. Several issue papers showed that conditions in Suisun Bay largely reflected the abundance, recruitment, or survival not only of species in Suisun Bay, but also of habitat conditions for species upstream and downstream. A primary result of the issue papers produced for this group was that almost all species studied increased in abundance as a simple function of increased outflow and decreased salinity. The absence of a plateau or peak in the relationship of species abundances and outflow conditions means that science alone cannot identify an optimal outflow. Furthermore, the similar response of species at all ecological (trophic) levels argues strongly that the estuary should be managed using an ecosystem approach rather than on a species by species basis.

The series of workshops concentrated on developing the scientific rationale for an estuarine index to measure the estuary's response to different levels and patterns of freshwater input. Participants recognized that economic and socio-political considerations should be accounted for at other points in the deliberations. The needs of society, as well as the needs of the environment, should be considered in determining appropriate allocations of fresh water. However, the premise of the workshops was that one should start with the best scientific and technical judgements possible.

Many large-scale changes in the structure of the Delta have been proposed to facilitate water use and to reduce impacts of water withdrawal on aquatic resources. There was general recognition by the group that the present Delta withdrawal and distribution system is a major contributor to the declines of important species. The conclusions and recommendations of the workshops are based upon the present water withdrawal and distribution system and would need to be re-evaluated if any significant alterations to that system are considered.

The conclusions and recommendations in this report were developed by the estuarine scientists and managers who participated in one or more of the workshops. The complete list of participants and their affiliations are listed in Appendix A. All conclusions and recommendations in this report were reviewed, voted on, and endorsed by a consensus of the estuarine scientists and managers who participated in the fourth and final workshop in the series (26 August 1992). The term consensus is used to represent group solidarity on an issue; a judgement arrived at by most of the scientists and managers present. In all cases, the consensus was unanimous or nearly unanimous. The conclusions and recommendations are arranged in a sequence that "tracks" the evolution of thinking of the participants. The conclusions and recommendations reached by the group reflect the participants' best scientific and technical judgements, not necessarily the positions of their affiliated agencies or organizations.

The following conclusions and recommendations are intended to provide guidance and information on how estuarine standards could be developed and how different levels of protection of estuarine resources could be selected.

The full justifications to these conclusions and recommendations are contained in earlier workshop reports and in other documents prepared for the San Francisco Estuary Project. (Appendix B).

IMPORTANT CONCLUSIONS AND RECOMMENDATIONS

(1) Conclusion

Because of the complex nature of the San Francisco Bay-Delta Estuary's freshwater delivery and distribution system, there is at present no single, simple, accurate measure of freshwater input to the estuary that conveys information important to resource managers and to the public, and that is meaningful to those with special concerns about how fluctuations in freshwater inflow to the estuary affect habitat and the condition of the estuarine ecosystem.

Recommendation

Estuarine standards should be developed to be used in conjunction with flow standards. One set of standards should be based upon an index of the physical response of the estuary to fluctuations in the input of fresh water. These standards should have diagnostic value in providing, throughout the year, a level of protection to the estuary and to important ecosystem values and functions consistent with environmental goals and objectives for the San Francisco Bay-Delta Estuary.

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(2) Conclusion

Estuarine standards to be used in conjunction with flow standards should be based upon an index that is simple and inexpensive to measure accurately, that has ecological significance, that integrates a number of important estuarine properties and processes, and that is meaningful to a large number of constituencies.

Recommendation

Salinity should be used as an index for the development of some estuarine standards.

Scientific Justification

In the first workshop (August 1991), participants identified and assessed a number of indices of the estuary's responses to flow to use in managing freshwater discharge to the estuary. The preliminary, pre-workshop, choice was the position of the entrapment zone. This index was abandoned quickly, however. The entrapment zone is important to estuarine ecosystem processes and functions, but at present there is no single, straight-forward "entrapment zone index" suitable for monitoring the position or strength of the entrapment zone as a function of freshwater input.

Salinity was selected as the most appropriate index because (1) the salinity distribution is of direct ecological importance to many species; (2) the salinity distribution is a result of the interplay of freshwater input, geometry of the estuarine basin, diversion of fresh water in the Delta, and the tidal regime; and (3) salinity measurements can be made accurately, directly, easily, and economically. Moreover, since most of the major concerns about reductions in the freshwater input to the estuary are associated either directly or indirectly with the loss or alteration of low salinity habitat, salinity is an ideal index for keeping track of the extent -- both area and volume -- of low salinity habitat. The salinity distribution represents the response of the estuary to different combinations of river discharge, diversions and withdrawals, tidal regime, and basin geometry.

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(3) Conclusion

Salinity measured at about 1m above the bottom* is an index upon which estuarine standards should be developed. The index is a practical way of tracking changes in habitat.

*Because the difference between surface and near-bottom salinities is small and because the relationship between them is reasonably well known, surface salinity could also be used. Near-bottom salinity is recommended, however, because it is a more stable indicator.

Recommendation

Standards should be developed using an index that establishes an upstream limit of the position of the 2‰ near-bottom isohaline, averaged over different periods of the year.

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(4) Conclusion

Analysis of the available historical data indicates that, throughout the year, the farther downstream the 2‰ near-bottom isohaline is displaced, the greater the abundance or survival of most species examined.

Recommendation

The downstream position of the 2‰ isohaline should be unconstrained.

Justification

From the environmental perspective -- an important perspective, but not the only one -- scientific uncertainty dictates taking an environmentally conservative approach, i.e. providing enough Delta outflow to the estuary to push the 2‰ isohaline farther downstream than might be required with greater scientific certainty. It is anticipated, and preliminary analysis supports it, that the salinity standard -- the upstream limit of the 2‰ near-bottom isohaline -- will vary from season to season to provide the desired level of protection.

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(5) Conclusion

Estuarine systems are characterized not only by short-term responses to the mean salinity at any given location, but also by responses to longer-term seasonal, annual and interannual variability in salinity and other properties.

Recent advances in scientific understanding indicate that this dynamic character of healthy estuarine ecosystems is particularly true for the distribution and abundance of wetland vegetation, but also holds for other aquatic organisms.

Recommendation

The potential importance of variations in salinity on different time scales to the structure and dynamics of estuarine ecosystems should be considered in developing salinity standards. Deviations from the patterns of salinity variability in the historical data set could increase the risk of not achieving environmental goals and objectives even if mean positions of the 2‰ near-bottom isohaline were matched with the historical data sets.

Justification

There is strong biological evidence from a number of estuaries throughout the world that variability in flow, in circulation and mixing, in the salinity distribution, and in the distribution of other important properties and processes is important in maintaining a healthy estuarine ecosystem. Therefore, variability in flow above the threshold needed to meet the seasonal salinity standard is encouraged.

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(6) Conclusions

Empirical statistical relationships were developed between a variety of estuarine properties and resources, and the position of the near-bottom 2‰ isohaline and other flow-related variables. The relationships developed are statistical relationships. They are not proof of cause-effect. The relationships indicate clearly, however, that the position of the near-bottom 2‰ isohaline can serve as a powerful diagnostic indicator of the condition of biological "units" (communities, populations) across a range of different trophic levels.

With the information these relationships can provide, water managers will be in a far better position to regulate freshwater discharge to the estuarine system to produce, on the average*, predictable and desirable ecological

*Over a period of several years.

responses of the estuary consistent with goals selected for the estuarine ecosystem. If this strategy is followed, the probability of the desired ecological response will be enhanced and the chances of undesirable ecological surprises in the estuary will be reduced.

Because the statistical relationship between net Delta outflow and the position of the near-bottom 2‰ isohaline is strong, the position of the near-bottom 2‰ isohaline is an excellent surrogate for net Delta outflow in managing freshwater input to the estuary. The relationship may be improved further through routine direct monitoring of the position of the 2‰ isohaline and a suite of biological responses.

Recommendations

The salinity distribution should be monitored continuously at a series of at least six stations spaced approximately five kilometers apart and located along the channel between about Emmaton and Carquinez Bridge. Measurements should be made at least near the surface and near the bottom at each station. The data should be telemetered to a convenient location for timely analysis and interpretation. These continuous monitoring data should be supplemented with detailed surveys to map the distribution of salinity in three dimensions. The data should be readily available in a timely way to all interested parties.

An appropriate biological monitoring program should determine responses of a variety of organisms to changes in position of the 2‰ isohaline.

Justification

During the second and third workshops, and during intersessions between workshops, a systematic search was made to select the most powerful tools of analysis to describe how diagnostic biological indicators respond to changes in position of the near-bottom 2‰ isohaline. When data were rich enough, other variables were included in the analyses.

The first task was to specify the most diagnostic resource variables -- the responses of indicators that would convey the maximum amount of environmental/ecological information. In every case, the objective was to demonstrate how these diagnostic environmental/ecological indicators responded to changes in the position of the near-bottom 2‰ isohaline and to a variety of other flow measures. In every case, experts on the particular biological response were consulted in selecting the appropriate averaging time for the position of the 2‰ isohaline.

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(7) Conclusion

The position of the near-bottom 2‰ salinity isohaline is an index of habitat conditions for estuarine resources at all trophic levels, including the supply of organic matter to the food web of Suisun Bay, an important nursery area. In other words, well-behaved statistical relationships exist between the near-bottom 2‰ isohaline and many estuarine resources for which sufficient data exist to make appropriate analyses. Moreover, at least a rudimentary understanding exists for the causal mechanisms underlying many of these relationships. The location of the near-bottom 2‰ isohaline is important either because it is a direct causal factor or because it is highly correlated with a direct causal factor (e.g. diversions).

Preliminary analyses show that errors in prediction using models which incorporate only the position of the 2‰ isohaline are comparable to the errors using more complex models which incorporate additional flow-related variables. In other words, given the present data sets, predictive models using only the position of the near-bottom 2‰ isohaline perform as well as more complex models that incorporate other variables. However, some of these other variables may be very important in affecting habitat and the condition of biological resources of the estuary.

Recommendations

At this time, the most appropriate basis for setting salinity standards for the portion of the estuary on which this report concentrates is the position of the near-bottom 2‰ isohaline alone, unless it can be shown either that another variable is the controlling variable or that incorporation of additional variables improves the predictive capability.

Further research should be conducted to improve prediction of the responses of important estuarine resources to variations in the position of the near-bottom 2‰ isohaline. That research should incorporate other variables where they can be shown to contribute significantly.

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(8) Conclusion

A number of key species are subject not only to the biological effects of the location of the near-bottom 2‰ isohaline, and therefore the effects of freshwater inflow to the estuary, but also to the physical effects of entrainment and diversion by the various water projects.

Recommendations

Salinity standards should be keyed to the existing city, county, regional, state, and federal water diversion and distribution system. Proposed changes to that system should trigger a re-evaluation of the salinity standards to ensure that they will continue to provide the desired level of environmental protection while retaining as much flexibility as possible in meeting the state's other needs for water.

Since a broad class of models can be constructed, including mechanistic and statistical models that incorporate both biological and physical parameters and other factors such as diversions, exports, and antecedent conditions, efforts should be enhanced to ensure a consistent, long-term accurate measurement program to enhance these models and to decrease the uncertainties in their application. The ultimate goal is to have a predictive model that incorporates the position of the 2‰ isohaline and other appropriate physical and biological variables.

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(9) Conclusion

Salinity standards should be based upon the best scientific and technical knowledge. A method is needed to summarize and to advance the state of scientific and technical knowledge of the complex relationships between variations in the position of the near-bottom 2‰ isohaline during different periods of the year (and associated Delta outflow) and a variety of diagnostic ecosystem responses.

Recommendations

Estuarine response matrices should be developed for different biologically important periods of the year. The matrices should summarize the existing state of knowledge of the responses of a rich variety of estuarine organisms and communities as well as estuarine properties and processes, to the location of the near-bottom 2‰ isohaline and associated freshwater discharge to the estuary. The estuarine properties and biological responses initially identified for inclusion in these matrices are summarized in Exhibit A.

A Matrix Manager should be appointed to oversee the development of the summary matrices and to ensure quality control. The Matrix Manager should orchestrate the analyses of relevant data and ensure that the results of the analyses are cast into forms appropriate for the intended uses.

Because estuarine habitat suitability and, therefore, estuarine ecosystem health are not simply a function of the instantaneous salinity distribution, the entry in each response cell of the matrix, whenever possible, should be based upon the development of functional relationships of estuarine properties to isohaline positions (and freshwater input to the estuary) that incorporate lagged terms, seasonal variability, and other water management variables. Ideally, the input to each matrix cell would include a directory of the appropriate model, or models, that could be used for prediction.

The proposed matrices are shorthand methods for keeping track of advances in the state of scientific knowledge and for ensuring that the most up-to-date scientific knowledge is used in decision-making. They are not intended to be used as isolated regulatory tools. They are a summary of the state of development of those tools, a guide to which tools to use during different times of the year, and an index of where to find them. The responsibility for development of the matrices and for periodically updating them should be *institutionalized. One appropriate agency might be the Interagency Ecological Studies Program.*

Justification

The proposed matrices are an effective shorthand way of summarizing in a convenient format the status of a large amount of data and information relating the responses of the estuary to fluctuations in freshwater inflow to the estuary and to other water management variables. The matrices are a useful vehicle for summarizing the biological benefits -- using a broad array of response indicators -- of positioning the near-bottom 2‰ salinity isohaline at various distances upstream (inland) from the Golden Gate Bridge during different periods of the year. The proposed matrices would provide the first quantitative and comprehensive summary of how the San Francisco Bay-Delta-Estuary ecosystem responds to fluctuations in freshwater inflow to the estuary (Delta outflow) and to the estuary's changing salinity regime. The matrices have further advantages. They will provide managers, policy-makers and the public with (1) a clear statement by the scientific community of the current status of understanding of the effects of different freshwater discharge-diversion scenarios on the estuarine ecosystem; (2) an identification of critical gaps in scientific knowledge that can be used to guide future research and monitoring activities; and (3) a summary that is easily updated on a cell-by-cell basis as new knowledge is developed.

The models upon which the matrices are based can serve as tools for regulatory agencies to use in incorporating the environmental needs of the estuary into a set of management prescriptions for storing and releasing water and diverting water from the estuary for consumptive uses. Selection of the level or degree of biological response to be achieved -- the level of environmental protection -- is the responsibility of regulatory bodies acting in response to society's priorities.

EXHIBIT A

A PRELIMINARY LIST OF DIAGNOSTIC ESTUARINE PROPERTIES AND COMMUNITIES TO BE INCLUDED IN THE FLOW-RESPONSE MATRICES FOR DIFFERENT BIOLOGICALLY-IMPORTANT PERIODS OF THE YEAR

Estuarine Property/Community

I. Water Quality for Human Use
   - A. taste & odor
   - B. THM content
   - C. salinity

II. Bathymetry Changes

III. Hydrodynamic Processes
   - A. transport/circulation
   - B. structure
   - C. bay-ocean exchange
   - D. residence times

IV. Habitat Area and Volume

V. Suspended Sediment Dynamics

VI. Water Properties
   - A. light availability
   - B. temperature
   - C. salinity distribution
   - D. nutrient distributions

VII. Fates & Effects of Toxins

VIII. Algal Biomass, Primary Productivity, Species
   - A. bay
   - B. Delta

IX. Nuisance Blooms
   - A. macroalgal
   - B. microalgal

X Organic Carbon as Food

XI. Planktonic/Neritic Crustaceans: Copepods & Mysids

XII. Fish Abundance
   - A. estuarine residents
   - B. estuarine spawners
   - C. euryhaline estuarine species
   - D. anadromous species
   - E. euryhaline marine species

XIII. Benthic Faunal Abundance

XIV. Invasion Likelihood, Success

XV. Marsh Structure & Function

XVI. Waterfowl Abundance

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(10) Conclusion

The actual setting of salinity standards -- specifying the upstream locations of the near-bottom 2‰ isohaline for different periods of the year -- should be keyed to environmental goals: to achieving and sustaining some desired biological response level specified in terms of habitat protection or abundance and survival rates of important and diagnostic estuarine and wetland species.

Recommendation

Goals should be expressed in terms of desired conditions for some future time. Progress toward those goals should be monitored and reported widely. Environmental goals for the estuary will be most effective if they are expressed in terms of restoring conditions to those that existed at specific historical times such as those summarized in Exhibit B.

EXHIBIT B

SOME ALTERNATIVE LEVELS OF BIOLOGICAL RESPONSE (i.e. MAINTENANCE, ENHANCEMENT, RESTORATION) THAT COULD BE USED IN FORMULATING GOALS FOR THE ESTUARY

Of the possible alternative biological goals, five could be expressed in terms of average historical levels of abundance or survival rates of key species during the following periods:

1984-89: In selecting this period, the goal would be to maintain key species at current levels and to prevent further declines. This period encompasses wet and dry years, including the first three years of the recent extended drought, during which full export demands for water were met.

1970-75: In selecting this period, the goal would be to restore key species to levels that existed during a series of years that encompass 1975, the benchmark year for the anti-degradation standard for water quality parameters under the federal Clean Water Act. There were no critically dry years in this sequence period.

1973-77: In selecting this period, the goal would be to restore key species to levels that existed during a representative period of years encompassing 1975, the benchmark year for the federal anti-degradation standard. This period includes two critically dry years (1976 and 1977).

1956-68: In selecting this period, the goal would be to restore estuarine populations and habitat conditions to those that existed before large impacts of the State Water Project. This period covers a broad range of hydrologic and hydrodynamic conditions and provides a reasonable estimate of impacts of the state operated project that should be subject to the state's anti-degradation

EXHIBIT B CONTINUED

policy. (1968 is taken as the marker year for the California non-degradation standard.) Resource agencies have identified the probable habitat conditions of the Delta for salmon through this period, and factors that controlled populations of striped bass are reasonably well understood.

1922-44: In selecting this period, the goal would be to restore key species to levels that existed before the federal and state water projects were constructed and operated. Selection of this period reflects the EPA policy in its bio-criteria guidance paper which suggests restoring biological parameters in impaired water bodies to levels that existed under reasonably unimpaired conditions.

Environmental goals could also be formulated directly in terms of the position of the near-bottom 2‰ isohaline. Using this approach, two alternative goals would be to restore the movement of the near-bottom 2‰ isohaline to average pre-project conditions and to maintain the movement of the near-bottom 2‰ isohaline to average conditions forecasted to include demands to 1995.

- Pre-project conditions: the goal would be to restore variation in the position of the near-bottom 2‰ isohaline (and/or Delta outflow) to conditions that would exist today without operation of the state and federal projects. The rationale for this alternative is that the Central Valley Project (CVP) and State Water Project (SWP) have a mitigation obligation which, if enforced, would require restoration to these conditions.

- Forecasted level of diversions: the goal would be to maintain the position of the near-bottom 2‰ isohaline (and/or Delta outflow) at conditions that would probably exist if the levels of demand for exports via the project pumps and in-Delta diversions continue as projected to 1995. This alternative would illustrate the response of biological resources if the regulatory agencies take no action.

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(11) Conclusions

At prevailing patterns of the position of the near-bottom 2‰ isohaline, the biological resources of the low salinity portion of the estuary, including the Delta, have been seriously depleted. Data from the Interagency Ecological Studies Program and the University of California at Davis indicate clearly that species at every trophic level are now at, or near, record low levels in the Delta and in Suisun Bay. This is not surprising considering the recent drought, the introduction of exotic species, and the increased diversion of water.

Analyses of the data indicate that the abundance or survival of a number of important species at a variety of life history stages and from a variety of trophic levels is related to the position of the near-bottom 2‰ isohaline. Of the organisms whose response to salinity has been analyzed, the farther downstream the 2‰ isohaline is, the higher their abundance or survival.

Almost all of the components of the estuarine community analyzed for the workshops show a strong, coherent, and negative monotonic response to increased penetration (upstream movement) of the near-bottom 2‰ isohaline. There is no well-defined break point in the composite relationship of position of the 2‰ isohaline to abundance or survival that can be reliably identified statistically. In other words, the biological benefits of downstream displacement of the 2‰ continue to increase over the range of positions of the 2‰ near-bottom isohaline reflected in the historical data set.

If one selects a certain level of restoration as a goal, then one can develop statistical relationships to prescribe the appropriate range of the position of the near-bottom 2‰ isohaline and the amounts of water necessary to achieve these salinity distributions during different periods of the year. **While such action will not guarantee achieving a desired level of resource recovery or protection, it would increase the probability of attaining these goals.**

Recommendations

A range of environmental/ecosystem restoration goals should be selected and analyses should be made to determine the distribution of the 2‰ near-bottom isohaline throughout the year consistent with those goals. Historical flow and salinity data should be examined to determine how frequently these conditions would have been met before construction of the Central Valley Project; the State Water Project (SWP); and a variety of city, county, and regional projects that divert water. The results of these analyses would provide a valuable context within which to evaluate the amounts of water needed to achieve a range of ecological goals.

SUMMARY

Estuarine scientists and managers of the Sacramento-San Joaquin Delta and San Francisco Bay area recommend development of salinity standards for different periods of the year to be used in conjunction with flow standards. An appropriate index upon which to base salinity standards is an upstream position of the near-bottom 2‰ isohaline, averaged over the period of interest, to provide a prescribed level of environmental protection. Selection of the appropriate average upstream positions -- the salinity standards -- should be based upon environmental goals and the development of predictive models that relate diagnostic responses of organisms and processes to the position of the near-bottom 2‰ isohaline, and associated Delta outflow.

When appropriate, other flow-related variables should be incorporated into the models. Existing data and information are adequate to make a first cut at defining upstream limits of the 2‰ isohaline consistent with a range of environmental goals. The downstream limit of the near-bottom 2‰ isohaline should not be controlled; variability in flow and, therefore, in salinity response should be encouraged. While such policies and practices can not guarantee recovery and maintenance of important living resources, they will increase the probability of restoring and sustaining populations of a number of the San Francisco Bay-Delta Estuary's important estuarine species.

APPENDIX A

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APPENDIX B

SOME KEY DOCUMENTS WHICH PROVIDE THE SCIENTIFIC RATIONALE FOR THE CONCLUSIONS AND RECOMMENDATIONS OF THIS REPORT

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