CALFED
BAY-DELTA
PROGRAM

SCIENCE CONFERENCE

2000

October 3–5, 2000
Sacramento, California

SUMMARY

Conference Planning
Technical Highlights
Plenary, Oral, and Poster Presentations

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2000 CALFED Science Conference: A Summary

Introduction

More than 800 scientists, managers, and policy makers attended the first CALFED Science Conference, held at the Sacramento Convention Center from October 3 through 5, 2000. The conference, first recommended by CALFED's 1997 Ecosystem Restoration Program Scientific Review Panel, was designed as a forum for presenting scientific information and ideas relevant to CALFED's goals and objectives in the San Francisco Bay, Delta, and watershed, particularly pertaining to ecosystem restoration, levee system integrity, and water quality. The intent of the conference was to foster communication among scientists and managers and to provide an update of new information (results, models, syntheses) concerning CALFED-related science issues.

This report includes a review of the conference planning, budget, and recommendations; summaries of overall highlights of the conference; and brief summaries of the plenary session, oral presentations, and poster presentations that were pertinent to the technical sessions. A list of the session chairs and notetakers is provided in Appendix A (see page 44). A list of acronyms used in this report can be found in Appendix B (see page 46).

Interested readers can find additional information about the conference, such as copies of the abstracts submitted to the conference, detailed notes taken during each of the oral presentations, a summary of the number of attendees by organization, and a downloadable copy of this report at the conference website: http://www.iep.water.ca.gov/calfed/sciconf/

This summary is based on abstracts submitted, the oral presentations, and detailed notes taken during each technical session. It should be understood, however, that the summary reflects the impressions and interpretations of its authors who are ultimately responsible for its contents. The summary is being made available solely to provide a brief synopsis of presentations made at the conference. Findings reported in this summary should not be cited without consulting appropriate lead authors.

Conference Organization

Pre-conference Planning

The March 1999 report to CALFED by the Comprehensive Monitoring, Assessment and Research Program (CMARP) recommended annual science conferences as a means of helping communicate science findings and directions among CALFED program participants. Fred Nichols (USGS) and Randy Brown (DWR) agreed to serve as conference co-chairs of the first such conference, and subsequently established a Conference Steering Committee to provide guidance and review as the program developed. Bill Bennett (UC Davis) and Larry Brown (USGS) served as program co-chairs and assembled the scientific program from the abstracts submitted. Peggy Lehman (DWR) and Bruce Thompson (SFEI) organized the poster session. Finally Joan Patton and Marcia Brockbank of the San Francisco Estuary Project provided logistic support through the Association of Bay Area Governments (ABAG). Other Steering Committee members included academic and agency scientists and CALFED staff members.

Active planning began in November 1999, and the Steering Committee selected the Sacramento site in December. The Committee announced the conference in the *IEP Newsletter* and other appropriate newsletters, and mailed an initial flier and "call for abstracts" to about 2000 potential attendees in March 2000. About 4,500 copies of the final program were mailed in August 2000. With the help of DWR technical staff, the Committee established a website, accessible through the CALFED homepage, to provide general information and to handle web-based abstract submittal and registration. The Estuarine Research Federation provided the software to handle electronic abstract submittal.

Conference Statistics

Presentations

The conference included oral and poster presentations and a half-day plenary session. The technical sessions included 137 oral presentations in three concurrent sessions over the 3-day conference in 12 topical areas: organic carbon and lower trophic level processes, levee system integrity, species of special concern, climate variability, salmonids, drinking water quality, effects of contaminants and other chemical stressors, fluvial processes, effects of non-native invasive species, hydrodynamics, fish facilities and fish screening, and tidal wetland processes.

The poster session, an important component of all scientific conferences, included 96 posters displayed for viewing and discussion during the entire conference. In addition, the organizers scheduled a formal 3-hour poster session and reception during the late afternoon of the second day during which the authors were available to discuss their work while conference attendees enjoyed food and beverages. There were no oral presentations during this period.

Attendance

The 800+ attendees represented an impressive variety of interests and organizations. As expected, representatives of CALFED and its member agencies dominated the attendance list with about 450 registrants. There were 115 registrants from universities and colleges. Although most of the academic scientists came from California, other states represented included Oregon, Washington, Nevada, Utah, Arkansas, Louisiana, Georgia, New York, and Virginia. Three scientists came from outside the United States—two from Canada (British Columbia) and one from England. Stakeholder presence consisted of 12 representatives of water, agricultural, and environmental interests. The remainder of the attendees came from local governments (city, county, reclamation districts, etc.) and consulting firms. Overall, the attendees represented a good cross section of CALFED's constituency, although stakeholders were somewhat under represented.

Budget

The overall cost of the science conference was about $115,000. The approximate breakdown is:

Staff, printing, mailing, consultants and other direct and indirect costs..... $44,000

Catering $48,000

Site rental and audio and visual..... $23,000

The costs are being recovered as follows:

Paid registrations $67,000

CMARP funds to ABAG (from original CMARP contract with DWR) $25,000

DWR funds for site rental.....$11,000

CALFED funds contained in 2000 research budget..... $12,000

Conference Evaluations

Comments from attendees, both verbal and through conference evaluation forms, were quite positive. Copies of the evaluations will be retained for use by the steering committees of subsequent CALFED science conferences. As an example, a post conference comment about the lack of media coverage needs to be considered in upcoming science conferences.

Recommendations

After the conference, the Steering Committee members met to consider the evaluations and their personal observations, and made the following general recommendations.

- CALFED should hold science conferences every second year. The State of the Estuary Conference would be held in the intervening years. Because the next State of the Estuary Conference is scheduled for October 2001, the second CALFED Science Conference should be held in the fall of 2002.

- A CALFED science staff representative should be a member of the State of Estuary Conference Steering Committee. This representation would help assure that CALFED's communication needs are met in those years when there is not a CALFED science conference.

- In the fall of 2001 (just after the State of the Estuary Conference) the CALFED Science Leader should appoint a conference steering committee for the 2002 Science Conference.

- By the fall of 2001, CALFED and its member agencies should establish a fund of $50,000 to cover such initial conference costs as site rental, the preparation, printing and mailing of brochures, and other pre-conference administrative costs. This fund would alleviate cash flow problems that were encountered during the organization of the first conference.

- The next conference should be held in the Sacramento Convention Center. The Center provided excellent facilities and is readily accessible to the majority of potential attendees.

Conference Highlights

The first CALFED Science Conference consisted of a plenary session and more than 200 oral and poster presentations organized as eight concurrent technical sessions and a poster session. In the "Session Summaries" section beginning on page 7, we provide a condensed report of significant information presented by the speakers and in the posters. Here, we present a brief assessment of some of the overarching "take-home" messages of the conference, i.e., general conclusions that we have drawn regarding the contributions of the conference to the support of CALFED Bay-Delta Program science.

Quantity, Quality and Breadth of Science in the Bay-Delta and Its Watershed

The conference presentations clearly demonstrated the wide range and impressive technical accomplishment of the many ongoing research and monitoring studies that are being conducted by agency, academic and consulting scientists, and engineers. The presentations, addressing key issues of the San Francisco Bay, Delta, and watershed, provided numerous examples of important linkages between scientific advances and the achievement of CALFED's goals and objectives. The presenters made attendees aware of what we know and what we do not know about technical issues critical to successful implementation of CALFED's ambitious program. Most of the results presented are relevant to CALFED implementation issues, including the design of management actions and the evaluation of consequences.

It is obvious, however, that the 200 or so presentations only began to provide the information and understanding required to answer some of the key questions regarding the restoration and management of the San Francisco Bay estuary, Delta, and watershed. Important research and monitoring questions remain to be answered before we can be confident that restoration actions will achieve the desired outcomes. Future science conferences should provide a forum for an even broader array of topics and participants, presentation of new information and syntheses and, at the same time, a sharpened focus on resolving the uncertainties about key scientific issues.

The challenges of describing the status and trends of key species, understanding key ecological processes, and successfully employing active adaptive management require that CALFED make a concerted, coordinated and long-term commitment to a strong science program. Appointing the Ecosystem Restoration Program (ERP) Science Board, the Lead Scientist, and funding science projects through an annual proposal solicitation process are appropriate initial steps in ensuring that science is an integral element of the CALFED Bay-Delta Program.

Coordination of Research and Monitoring Activities

It was clear that the degree of coordination among scientists in each topical area varies widely. On one hand, CALFED-funded studies of some of the major areas of interest (for example, mercury, organic carbon and lower trophic level processes, Cosumnes River floodplain studies, and breached levee and wetland restoration) are well coordinated by principal investigators, and at least a portion of these sessions brought study collaborators together for an organized presentation of multiple, interconnected sub-studies. On the other hand, the salmonid session consisted of papers about a common theme, but without an apparent common conceptual model or coordinated leadership.

While there is room for both approaches in meeting CALFED's science needs, a greater degree of coordination among researchers working on the main technical issues would make for more

effective data collection, analysis, and information dissemination. The Interagency Ecological Program (IEP) may provide an example of how such coordination can be achieved, although even in this program there is little use of common conceptual models to guide its research and monitoring.

Another model for coordination now being considered by CALFED—a proposed Bay-Delta Science Consortium—would consist of a formal understanding between several agency and academic research groups now working in the estuary. The current focus of discussions about the Consortium is on the information needs of the Ecosystem Restoration Program, but the scope could be expanded.

Transfer of Technical Information to CALFED Scientists, Managers, and Policy Makers

Despite the presentation of important findings in critical areas, the breadth and technical complexity of many of the issues addressed in the science conference continue to present challenges in achieving effective translation and communication of information needed by other interested scientists, managers, and policy makers. Establishing a biennial CALFED science conference within the existing Bay-Delta meeting framework (the annual IEP workshop, the annual Regional Monitoring Program Workshop, the biennial State of the Estuary Conference and numerous technical workshops) is a positive step in information sharing.

CALFED should consider preparing an annual written technical summary for managers and other interested parties. This summary could be along the lines of the annual status and trends report in the spring issue of the *IEP Newsletter* but expanded to cover CALFED's broader scope. All conference participants are encouraged to make the results of their efforts available promptly in the open literature and/or peer reviewed reports and technical memoranda. Other means for achieving wide dissemination of information are described on pages 108-110 in the March 1999 CMARP report.

Use of Technical Findings in an Adaptive Management Framework

Although many of the speakers described how their results could help CALFED address its goals and objectives and reduce uncertainties, few examples were provided that demonstrated the use of the presented information as part of an overall adaptive management strategy. In fact one speaker, in specifically describing salmonid studies funded by CALFED, concluded that he was unable to determine if the studies included sufficient monitoring and tracking to allow managers to assess their contribution to recovery and restoration. Successful adaptive management must be a true partnership between management and science, and such partnerships require time to develop.

Significant Conference Findings, Emerging Themes, and Implications

- Global and regional climate changes will affect CALFED's ability to realize some of its key goals and objectives; understanding climate change and its impacts should receive increased program emphasis.

- Hydrodynamic monitoring, data assessment and modeling are the subject of considerable study in the Bay-Delta system. It may be time for CALFED to sponsor a series of workshops to synthesize the information and to lay out a strategy for future field and analytical work.

- Long-term (for example, 30-year) solutions to levee instability will probably require more than physical strengthening of existing levees. If selectively reducing seismic vulnerability is infeasible, restoring subsided land to sea level may be preferable to continuing land subsidence and increasingly expensive maintenance of weak levees.

- Organic carbon in Delta waters is simultaneously an important food source for estuarine food webs and a drinking water contaminant. Restoration plans that would intentionally or unintentionally alter organic carbon sources, fates, or chemical quality must consider the consequences both for the food web and for drinking water.

- Although much is being learned about the distributions of environmental contaminants in the CALFED "solution area," effects of such pollutants as mercury, selenium, and pesticides on populations of threatened and endangered species generally remain poorly understood.

- There is emerging recognition of the role of natural geomorphic processes of floodplains in supporting a variety of sensitive fish species and supporting food webs. As with hydrodynamics, it is appropriate that CALFED sponsor technical workshops that aim to share information and develop research programs on the physics, chemistry, and ecology of floodplains.

- Introduced invasive plants and animals are responsible for continuing dramatic changes in the Bay-Delta ecosystem, changes that may affect CALFED's ability to achieve its restoration goals.

- As aptly demonstrated by the BREACH study and other comparative investigations, tidal wetlands are extremely complex systems, and the outcome (in terms of achieving stated goals) of any particular wetland restoration effort is difficult to predict. The likelihood that invasive species will successfully exploit restored wetlands is a major concern.

- Significant differences in chinook salmon and steelhead life histories and environmental requirements clearly demonstrate that their research and management need to be addressed by distinct but complementary field and analytical efforts.

- Salmonid studies and conceptual models should be integrated to consider the animals' use of widely varying habitats, from the upper rivers through the Delta and into the ocean and back to the rivers.

- A combination of extensive monitoring, laboratory examination of collected animals, and data analysis is beginning to shed light on factors that may be controlling the distribution and abundance of delta smelt. It appears, for example, that density dependence, the number of 2-year olds, late winter entrainment, contaminants, changes in preferred prey populations, and incidence of parasite infestation may be important components of a conceptual delta smelt life history model.

- Although real-time monitoring provides important biological data, it does not provide a consistent early warning of take at water project export facilities in the South Delta.

Session Summaries

The following summaries of the oral presentations, for both plenary and technical sessions, are intended to provide managers, stakeholders, and other interested parties with brief synopses of talks given at the conference. The summaries of the technical sessions, arranged by topical area with reference to relevant posters, are intended to provide easy access to the material presented during the conference. Although these brief summaries were created using the abstracts and the session notes and reviewed by the session chairs and members of the conference steering committee, they largely represent what the authors of this summary found important. We take full responsibility for any misinterpretation of what was presented at the conference. It is expected that readers may wish to seek additional information on particular subjects by reading the full abstracts and the session notes that are provided at the Science Conference website.

While there were commonly several authors for individual presentations, we show (in bold) only the name of the author making the oral presentation or the lead author on the poster. The names of authors and co-authors, with email addresses and institutional affiliations, can be found in the abstracts at the conference website.

The names and affiliations of the technical-session chairs and the note takers are found in Appendix A (see page 44).

Plenary Session

Welcome

Dr. William Bennett (UC Davis and Conference Program Co-Chair) welcomed participants to the conference and introduced the plenary session speakers. He noted that while CALFED has been identified as one of the world's largest water management efforts, many scientists are confused or frustrated and view CALFED as a political morass. Yet, a growing number of scientists is funded by CALFED, and as members of society scientists share an obligation to support this effort. Therefore, the plenary session strives to clarify the role of scientists in CALFED and, in particular, to identify the caliber of scientific knowledge required to ensure CALFED actions are science-based.

The Role of Science in CALFED

Mr. Steven Ritchie (Acting CALFED Executive Director) emphasized the critical role that science must and will play in all CALFED program elements. Uncertainty is a given, but a strong science program, including frequent review by external researchers, will help increase our understanding of difficult technical issues so that informed debate moves forward. To achieve CALFED goals, scientists and managers need a shared vision and open and active lines of communication. Two-way communication is an essential component of effective adaptive management. Scientists develop and conduct research and monitoring programs that are necessary to inform managers as to the effectiveness of their actions. Built-in feedback loops promote an iterative learning process. The communications pathway will help scientists and managers cope with inevitable surprises. Scientists and managers will be working together to implement an environmental restoration and ecosystem management program of almost unprecedented complexity. Working together not only means a shared vision but also shared responsibility to help ensure the success of CALFED actions.

Why CALFED needs Ecological Detectives

Professor Marc Mangel (UC Santa Cruz), referring to a book that he published with Ray Hilborn, *The Ecological Detective* (Princeton University Press, 1997) described a process for comparing theories about environmental problems for which there are typically multiple potential causes and poor data. Rather than using an individual model approach (for example, testing whether the probability is less than 0.05 that a given outcome occurred by chance), Professor Mangel favors examination of several alternative models to determine which one best explains the data at hand relative to the others. Using the example of the relationship between river outflow and striped bass production, he compared three models—linear, curvilinear, and parabolic—by testing them simultaneously using the principle of maximum likelihood which asks: "Given the data at hand, how likely is it that model X is true?" One of Mangel's key points is that this is an iterative process: a model can be refined and updated with additional data, and then compared with alternative models. Professor Mangel concluded by explaining in non-technical terms how one can use prior information to "weight" the likelihood that a particular model may be the best one. Through this Bayesian approach, if prior weightings can be unambiguously assigned, the modeling process can evolve more efficiently. This is a promising approach to solving ecological problems in a world in which we have to base decisions on inadequate data.

CALFED Interim Science Board: A Balance Between Independent Review and Hands-on Participation in Adaptive Management

Professor Robert Twiss (UC Berkeley and Co-Chair of the CALFED Interim Science Board) described the composition, role, and recent work of the Ecosystem Restoration Program's Interim Science Board (ISB). Board members are attempting to balance independent science review with hands-on participation in developing and implementing CALFED's adaptive management program. The Board, established in 1999, meets with CALFED staff and the public every four to six weeks and was extensively involved in providing the scientific underpinnings for the 2001 Proposal Solicitation Process. Along with promoting science and adaptive management in the ERP, Board members are helping integrate science across several CALFED components including levees, water quality and water supply reliability. Over the next several months the Board will be working to design an over-arching conceptual model of the Central Valley and Bay-Delta system that can be used to help in establishing priorities for restoration efforts and adaptive management interventions. The Board's Draft Terms of Reference, list of members and meeting summaries can be found on line at: http://www.calfed.water.ca.gov/ecosystem/board/index.html

Adaptive Management: Models, Monitoring, and Management

Professor Michael Healey (University of British Columbia and ISB member) outlined new approaches to the conservation and management of environmental resources through ecosystem and adaptive management. CALFED is faced with numerous scientific uncertainties, such as the value of interceptor habitat in the Delta, which are suitable for the application of adaptive management. As an approach to resource management, adaptive management can be compared to the process used in medicine to incorporate new therapies into the human health care tool kit. Candidate remedies are first tested in model systems (laboratory rats, for example), and promising ones move to carefully controlled clinical trials with humans—trials which are designed to ensure that patients are not subject to unacceptable risk. Even after successful therapies are folded into day-to-day medicine, they may be critically reexamined in periodic case studies. Given the inherent uncertainties in resource management, this approach ensures a rigorous and efficient reassessment of management actions.

Adaptive management is an iterative process (shown diagrammatically in Appendix C on page 48), consisting of a series of steps to define the problem, establish goals and objectives, develop conceptual models, and implement restoration actions accompanied by monitoring and data synthesis and communications with managers. As scientists and managers learn more, they may revise their conceptual models, refine goals and objectives, and modify restoration and data collection activities. A key to successful adaptive management is to recognize that resource systems are dynamic and subject to unanticipated changes. Thus, managers must be flexible and able to evolve with changes in the resource.

Ecosystem-based management, also integral to CALFED, approaches resource management through maintenance of ecological processes that enhance system productivity. Ecosystem-based management is better suited to maintenance of productivity in complex multi-species systems than the more traditional species approach. However, an ecosystem-based approach also demands a more flexible and evaluative management methodology such as adaptive management.

Science and Water Management in California

Dr. Samuel Luoma (USGS, CALFED Lead Scientist) described the unique opportunities and responsibilities associated with the world class science program mandated in the 2000 CALFED Framework Agreement. He emphasized that the CALFED Science Program must be unbiased, authoritative, relevant, and effectively communicated. Unbiased science requires that projects be designed to advance knowledge, without pre-selection of expected outcomes, and that are balanced in their interpretations. Authoritative science is that which meets the highest standards of quality and objectivity. Traditional approaches based on a transparent and peer-reviewed project selection process can be used to ensure that CALFED science is both unbiased and authoritative. Relevant science has public, agency, and stakeholder involvement, but again a transparent peer reviewed process is required to help ensure CALFED addresses the most important questions. Relevance must also be defined broadly enough to include projects with long-term potential and to anticipate surprises and unexpected linkages. Communication includes communication among scientists through publication in peer reviewed outlets, communication with managers, stakeholders, and politicians in newsletters, websites and to the interested public through websites, fact sheets, workshops, and press releases. Adaptive management, as called for in the Framework Agreement, means, where feasible, CALFED actions are designed as experiments with monitoring and feedback to managers. In adaptive management, process understanding must advance continually and some actions will be initiated as pilot programs before full-scale implementation. Through white papers and workshops, neutral experts can help resolve debates about controversial topics. Short-term investigations will be needed to quickly and directly address high priority management questions. CALFED must recognize that there is always time to inject science into policy and that policy without science will progress slowly, if at all.

Technical Sessions

Climate Variability

Climate provides a dynamic background for CALFED planning and implementation that has not yet received sufficient attention. Observed past variations in climate on shorter (150 years) and longer (several hundred years) time scales, and ongoing climatic changes provide clear evidence, however, that climate variability has important CALFED policy implications. Climate variability is the biggest single natural environmental driver of the Bay-Delta system. The flow of fresh water into and through the Delta determines much of the non-tidal variability of salinity and other physical and biological resources. During droughts and wet periods, effects of climate variability on Bay-Delta natural resources can overwhelm any counterbalancing influences of human management. Finally, there is strong evidence for climate-induced changes in Sierra Nevada runoff. Whether or not these changes are long-term trends or part of longer-term climatic oscillations is not yet known. Distinguishing climatic effects from other natural and human effects on natural resources is necessary if the CALFED Science Program and CALFED are to achieve success.

Kelley **Redmond** (Desert Research Institute; abstract #100) described the need for a physical monitoring program to collect climatic data. The program would include meteorological and hydrological data from the crest of the Sierra Nevada to the coastal ocean. Detecting subtle climatic shifts may require nearly continuous records for decades. He noted that although much of the necessary data is already being collected, there is no data delivery system that makes most of the diverse data sets readily available to scientists or managers.

Frank **Gehrke** (DWR; abstract #44) noted that snow accumulation in the Sierra Nevada is an important climatic variable because it is a large part of California's water supply. DWR's surveys include more than 300 human-observed snow courses, some of which go back to 1929, and since 1980 include over 100 automated recording snow sensors. Snow accumulation in the high Sierra usually peaks during late March or early April, but timing of the peak varies by weeks from year to year, and the maximum accumulation often varies from its long-term average by 50%. Global climate change is likely to produce a marked decrease in the natural storage that snowpack provides because a substantial fraction of the watershed's snow-covered area lies in a moderate elevation zone that is vulnerable to air temperature increases.

Daniel **Cayan** (USGS and UC San Diego/SIO; abstract #17) described floods and droughts of the Sacramento and San Joaquin drainage basins. Larger scale Pacific basin atmospheric circulation systems are always involved but, unfortunately, there is no single unique pattern that causes floods and, especially, droughts. For instance, the 1987-1992 drought was marked by several different large-scale climate conditions, including both El Niño and La Niña. Magnitudes of large floods have increased in the last three to four decades in some of the major Sierra Nevada streams. Under climate change, larger winter floods could result from more rainfall runoff and rapid snowmelt, increasing the length and intensity of the subsequent dry season because spring flows would recede more quickly.

Michael **Dettinger** (USGS; abstract #30) mentioned that Maury Roos of DWR first noticed that snowmelt runoff has declined as a fraction of annual streamflow by about 10% since the 1950s in both the northern and south-central Sierra Nevada. Dettinger noted that warming of winter and

spring temperatures in the Sierra Nevada since the 1940s has been large enough to explain this streamflow-timing trend. In turn, a persistent northward change in storm tracks and corresponding north Pacific sea-surface temperature (SST) trends have been statistically sufficient to explain the observed warming in California. Some of this long-term streamflow-timing trend now appears to have been masked in recent decades by a variation of North Pacific climate called the Pacific Decadal Oscillation (PDO). This climate oscillation may be a large part of these atmospheric-circulation and SST trends. Said another way, what have been called trends may be reversible.

Noah **Knowles** (UC San Diego/SIO; abstract #64) introduced a combined estuarine/ hydrological model, which was used to diagnose effects of climate variability in the Bay-Delta estuary and watershed. Changes in magnitude of annual Delta flows were due to disproportionately large changes of snowmelt versus rainfall. Changes in timing of annual inflows resulted from precipitation timing shifts in the Sacramento basin and increased snowpack in the San Joaquin basin. Climate-driven changes in the north-south distribution of precipitation contributed to changes in the timing of Delta flow.

Franklin **Schwing** (NOAA/NMFS; abstract #105) described how coastal currents, upwelling, and ocean temperatures along the coast of California are strongly influenced by the behavior of the overlying atmosphere. These affect ocean and estuarine conditions experienced by ocean dwelling and anadromous fish. Timing of the spring transition, strength of the subtropical high, alongshore winds patterns, and fog patterns affect aquatic life and show long-term variations during this century.

William **Bennett** (UC Davis; abstract #8) described how effects of climate change on fish populations could be difficult to distinguish from human interventions within the San Francisco Estuary. He presented analyses suggesting that the decline in striped bass is related to a period of frequent El Niños and a concurrent shift in the PDO beginning in 1976-1977. Previously analyses have attributed the decline of striped bass to effects of spring outflows and Delta withdrawals on larval and juvenile fish, and recently to density dependence during the pre-adult stage. An alternative hypothesis is older striped bass (age 6+ years) migrated more frequently to the warmer Pacific Ocean during multiple El Niño events and the PDO shift and were vulnerable to an effective ocean fishery.

David **Stahle** (U. Arkansas; abstract #111) discussed a strong correlation that he discovered between blue oak (*Quercus douglasii*) tree-ring chronologies from California and salinity in San Francisco Bay. A blue oak reconstruction of salinity at the Golden Gate from 1922-1952 (Fort Point) indicates that the salinity extremes witnessed in San Francisco Bay after 1952 have been unprecedented over the past 400 years, particularly during the record California droughts of 1976-1977 and 1987-1992. These recent extremes and an increase in average salinity between January and July measured at Fort Point from 1953-1994 appear to reflect export of Sacramento-San Joaquin streamflow.

Hydrodynamics

Delta flows determine the transport of dissolved and particulate matter and exert a strong influence on weak swimmers such as small fish. Thus, understanding and estimating flow and transport in the Delta and San Francisco Bay are a necessary part of assessing effects of a variety of environmental influences on aquatic ecosystems and their habitats. Such knowledge is also

needed to design habitat and levee restorations, and to assess drinking water source quality issues. This session included studies of flow and transport of salt and sediment.

Modeling and analysis of field data are complementary approaches to understanding river and Delta flows and transport. A combination of these approaches is needed to resolve the many issues important to CALFED. The first four presentations focused mainly on model results, and the remainder focused primarily on analysis of data.

Noah **Knowles** (UC San Diego/SIO; abstract #65) described a long-term, precipitation-runoff model for the entire Bay-Delta watershed, and analysis of a long time series (1930-1998) of bay salinities. The data indicate a trend toward earlier runoff during the period 1930-1970 that abated thereafter. Before 1970 both management actions and natural climate effects contributed to the trend in the whole watershed. After 1970, management actions stopped contributing to early runoff. The magnitude of the timing shift in the annual runoff cycle is about two or three weeks, and is not explained by climatic shifts of the North Pacific Oscillation.

Levent **Kavvas** (UC Davis; abstract #57) applied a physically based rainfall-runoff model to the 162 km^2 Camp Creek Watershed, tributary to the North Fork of the Cosumnes River. Although the model presently does not incorporate snowmelt, it uses hillslope topography from digital elevation models and model infiltration and subsurface flow parameters from soil maps.

Numerical models will be used to evaluate effects of many proposed CALFED actions because they can simulate consequences of physical modifications of the estuary. Calibrating and validating models to reduce and quantify their error bounds is a critical part of the evaluation process. Parviz **Nader** (DWR, for Christopher **Enright**; abstract #36) summarized an interagency and stakeholder effort to calibrate a one-dimensional hydrodynamic model of the Delta, called DSM2, using recent bathymetry data and several years of continuous flow data from about a dozen sites in the Delta. Accuracy of the model has improved, and model limitations are better understood. Additional calibration and a validation are anticipated.

Using results from a two-dimensional simulation, Nancy **Monsen** (Stanford U.; abstract #86) estimated cross-sectional fluxes of both water and a conservative tracer (such as salinity) at selected locations in the Delta. She separated the fluxes into a mean advective component, due to the tidally averaged flow, and a dispersive component, due to tidal fluctuations, about the mean flow. In the western Delta estimates of the dispersive flux were larger than advective flux estimates. For example, in Threemile Slough significant transport of salt through the slough can occur when the net flow is small because of tidal mixing between the Sacramento and San Joaquin rivers. These results demonstrate that transport depends on tidal fluctuations as well as net flows.

Knowledge of lateral variations of currents and concentrations helps qualify interpretations of hydrodynamic field measurements made at a single location in a channel cross-section, and helps bound the applicability of one-dimensional models. Jessica **Lacy** (Stanford U.; abstract #68) analyzed repeated transects across Suisun Cutoff and Snag Channel in Suisun Bay during a 12.5-hour tidal cycle to study the lateral variability of currents, salinity, temperature, and suspended solids concentrations. Lateral variability is large in both channels studied, and lateral density gradients are large enough to force two-layer transverse flows. Secondary circulation, involving transverse and vertical velocities, occurs in both channels and changes through the phases of the tide.

Susan **Paulsen** (Flow Science Inc.; abstract #96) estimated mixing in the Delta of water from the Sacramento River, the San Joaquin River, and San Francisco Bay using naturally occurring elemental tracers and the Fischer Delta Model. She estimated that 40% to 90% of the water at Clifton Court originates from the Sacramento River; the remainder originates mostly from the San Joaquin River, with only a small fraction originating from San Francisco Bay. Opening the Delta Cross Channel increases the amount of Sacramento River water that reaches the south Delta. Flow barriers in the south Delta strongly affect the distribution and amount of San Joaquin River water in the south Delta.

David **Schoellhamer** (USGS; abstract #104) analyzed long-term records of measured daily suspended-sediment concentration (SSC) in the Sacramento River at Freeport and in the San Joaquin River near Vernalis, and continuous measurements of SSC at five within-Delta sites during the water year 1999. He found that the Sacramento River provides ten times more suspended sediment load to the Delta than the San Joaquin River. A general trend of decreasing SSC occurred from 1955 to 2000. Overall, suspended sediment supplies to the Delta do not appear to be large enough to support creation of new large areas of shallow water habitat.

Bedload transport is ordinarily ten times smaller than suspended-sediment transport, but is the major mechanism by which sand particles move in the Delta. Randal **Dinehart** (USGS; abstract #32) periodically surveyed bedforms at the south end of Threemile Slough since 1998. He found sand dunes exceeding 3 meters in height in the surveyed reach, indicating high rates of bedload transport and large flow resistance. Although bedform movement can be bi-directional during lower flows, bedforms were all observed to move from the Sacramento River to the San Joaquin River during high flows of February 2000. This resulted in a bedform transport rate of 100 metric tons per day for February 18-25, 2000.

Matthew **Brennan** (Stanford U.; abstract #12) measured near-bed water velocity, suspended-sediment concentration, and turbulent sediment flux continuously for an 8-day period in October 1999 at a site in Suisun Cutoff. Bed sediments at the study site eroded more easily during the first two hours of the flood tide. Tidal currents and estimated bed shear stress at the study site were found to be flood dominated. Over the 8-day study period Brennan estimated that the bed sediment flux was landward. Taken together, increased near-bed shear stress and more easily erodible sediments during flood tide could explain increased turbidities near X2, the distance in kilometers of the tidally averaged 2 psu isohaline from Golden Gate Bridge.

Poster Presentation

Cathy **Ruhl** and David Schoellhamer (abstract #195) presented an analysis of time series of suspended-sediment concentration (SSC) at several sites in Honker Bay. They showed that Honker Bay acted as a temporary storage zone for flood-derived sediments during the winter rainy season with extended periods of elevated SSC in the shallow-water areas relative to the neighboring channels. Wind waves in the early spring re-suspended the unconsolidated fine sediments. During the summer, even though wind-waves persisted, SSC was lower because the supply of erodible sediments was exhausted.

Fluvial Processes

Streams of the Central Valley watershed have naturally co-evolved with geologic features to produce the familiar landforms of the CALFED solution area. Local ecosystems have, in turn, evolved partly in response to these geomorphological processes and the habitats created

thereby. Since about 1850, the large-scale disturbances of hydraulic mining, levee and reservoir and bridge construction, floodway maintenance, and aggregate mining have altered streamflows and sediment transport and isolated larger streams from their natural floodplains. These changes have undoubtedly been partly responsible for irreversible ecosystem changes. Finding ways to restore some of the natural geomorphic processes in this highly altered system is a major challenge of the ERP and other CALFED programs.

Mathias **Kondolf** (UC Berkeley; abstract #67) showed that reservoirs have trapped about 83% of the bedload sediment supply that historically reached the lower reaches of Central Valley streams. The sediment deficit in these reaches is exacerbated by extraction of sand and gravel for construction aggregate. Reductions in high flows, dams and gravel extraction have dramatically altered dynamic channel processes that create and maintain habitats. CALFED must consider overall stream dynamics when considering funding small-scale restoration projects involving gravel replenishment and other streambed alterations.

Jennifer **Vick** (Stillwater Sciences; abstract #122) described recent CALFED-funded work on the Merced River to identify and design appropriate restoration projects. This effort includes extensive public outreach and technical studies designed to lead to a comprehensive restoration plan for the river. The objectives of the scientific investigations are to quantify relationships between flow, sediment transport, channel morphology, and the distribution and quality of in-channel and floodplain habitats.

Gregory **Pasternack** (UC Davis; abstract #95) and his colleagues used a two-dimensional hydraulic model to assess reach-scale salmonid spawning ground rehabilitation in the lower Mokelumne River. In fall 1999, 3200 cubic yards of gravel, woody debris, and boulders were used to rehabilitate a 90-m stream reach below Comanche Dam. The model and field measurements indicated that the project increased water surface slope and increased habitat complexity by increasing the coefficient of variation of depth and velocity.

Steven **Greco** (UC Davis; abstract #46) conducted an analysis of Sacramento River flows at Vina to quantify 1952 to 1997 interannual flow variation. The annual hydrograph was used to calculate a flow magnitude index score based on flow duration (number of days) and frequency (recurrence interval). Years with the highest scores had large flow events and were considered to contribute to channel migration. Historic channel alignment (from aerial photographs) was digitized and animated to show channel migration over the 40+ years.

Laurel **Collins** (SFEI; abstract #22) performed a watershed assessment of Wildcat Creek, located on the east side of the Berkeley Hills, to determine historical changes in supply and distribution of water and sediment. The 8.7-square mile drainage area varies from open spaces in the upper area to a highly urbanized middle section and a short tidal slough. The assessment is being used to determine the watershed's restoration potential, particularly in the context of reducing accelerated erosion rates and increased runoff.

Joan **Florsheim** (UC Davis; abstract #39) and Jeffrey **Mount** (UC Davis; abstract #88) described results of geomorphic studies in the Cosumnes River floodplain, comparing an intentional levee breach by the Corps of Engineers in 1997 with an accidental breach just downstream in 1995. Although the Cosumnes River is the last major free-flowing tributary of the Delta, levees now separate it from its floodplain, which now is primarily flat agricultural land. After a 3-year flood, documented patterns of deposition and erosion in the floodplain adjacent to the intentional breach show that the floodplain has begun a first phase of geomorphological evolution. Pre-

breach grading of the area appears to be altering natural geomorphic processes at least temporarily. Based on a conceptual model, they speculated about necessary ingredients for Cosumnes breaches to be successful: (1) a natural flood hydrograph; (2) breaches at downstream ends of the outside of meander bends; (3) an aquatic link to the river until the floodplain drains completely.

Edwin **Grosholz** (UC Davis; abstract #49) presented evidence of large variations in zooplankton abundance and biomass as a result of small-scale physical gradients of velocity and temperature across floodplain areas near the intentional Cosumnes River breach. Residence time of water on the floodplain, and the occurrence of secondary flood pulses, appear to be important in promoting zooplankton production, and help explain a 100-fold variation in zooplankton biomass within the area.

Patrick **Crain** (UC Davis; abstract #26) and Peter **Moyle** (UC Davis; abstract #90) presented evidence of Cosumnes River floodplain habitat use by adult and juvenile fishes. Adults of native species used primarily shallow floodplain areas whereas adults of alien species occupied deeper sloughs and ponds within the floodplain. Moyle showed differences in habitat use between juvenile species with data collected over 3 years from the lower Cosumnes River floodplain. Adults of native and alien species showed differences in habitat use, mainly in the arrival and departure time from the floodplain. Year-to-year differences in abundance of splittail are believed to result from reduced flood levels, which have led to higher water temperatures.

Gerrit **Platenkamp** (Jones & Stokes Associates; abstract #97) described a modeling project that is examining the extent and depth of inundation of San Joaquin River floodplain areas in the event of a levee breach. None of five scenarios considered predicted a significant reduction in flood stage downstream. However, biological effects were predicted to be favorable with the restoration of native plant communities.

Kaylene **Keller** (UC Davis; abstract #60) described a GIS model designed to select appropriate sites for riparian restoration projects based on a set of geographically varying criteria. Physical factors included a wetness index, soil drainage classes, and flood frequency, and the area was divided into 3 elevation classes: <10 m, 10 to 30 m, and >30 m. The model had a high validation rate (about 73%) when compared to existing riparian sites along the lower Cosumnes River.

Poster Presentations

Dylan **Ahearn** and R. Dahlgren (abstract #129) used biweekly water samples collected for 2 years from up to 28 sites and daily during storm events from 7 sites to show how the majority of the nutrients (nitrogen and phosphorus) and suspended sediments originates from the lower portion of the Cosumnes watershed. A few point and non-point sources strongly affect nutrient loadings in the lower watershed, and the highest nutrient concentrations occur during fall and winter with decreasing concentrations during the spring and summer.

Stephen **Blake** and S. Schladow (abstract #136) constructed a one-dimensional dynamic model of the north Delta and Cosumnes-Mokelumne floodplain area to describe interactions between channels, floodplains, floodplain restrictions, and potential hydraulic effects of floodplain modifications and restoration strategies. Using flow records from the last five flood seasons, the model predicted flood statistics in the vicinity of the Cosumnes River Preserve.

Chris **Bowles** (abstract #138) described construction of a one-dimensional flow and sediment transport model of the Napa River from just upstream of the City of Napa, through the city, to approximately 11 km downstream. By including lateral variations in sediment transport, Bowles used the model to identify areas of excessive deposition and erosion.

Jan **Fleckenstein** et al. (abstract #151) presented preliminary numerical model simulations of groundwater-surface water interactions suggesting that a 50% reduction in regional groundwater pumping would reconnect the Cosumnes River with the regional aquifer, and reduce channel seepage losses sufficiently for salmon to migrate and spawn in September and October. The pumping reduction, however, would create average annual water shortages of 36% in the model area unless artificial recharge is implemented.

Eriko **Suzuki** et al. (abstract #202) determined that seepage losses in the summer months and over-appropriation of the stream were the major factors contributing to a lack of fall streamflow in the Cosumnes River. Although the regional groundwater level is substantially lower than the streambed, previous seepage meter measurements have indicated upward seepage following the wet winter season, suggesting contributions from perched aquifers.

Wendy **Trowbridge** et al. (abstract #205) evaluated how levee breaches along the Cosumnes River that reconnect the river with its floodplain influences establishment, survival, and growth rate of cottonwoods (*Populus fremontii*) and willows (*Salix* sp.). Within two years, patches of these trees sprouted on new floodplain created by Cosumnes levee breaches, and patch density and growth rate are positively correlated with the depth of the surrounding sand deposit.

Jeffrey **Hart** (abstract #163), evaluated how various configurations of plants and fabric affect erosional and depositional processes on a revetment site along the Lower American River. He showed after three months of being flooded, experimental sites ranged from 84% rock exposure at control sites to 1% exposure at sites with full treatments.

Keith **Whitener** and B. Waegell (abstract #208) described the progress being made by The Nature Conservancy in restoring riparian and floodplain habitat. The Conservancy has reconnected about 600 acres of previously farmed land to its floodplain. To date, 5 properties totaling approximately 2,550 acres have been purchased and one 300-acre property has been optioned using CALFED funding.

Lester **McKee** (abstract #182) presented a preliminary analysis of local suspended sediment data sets that support the hypothesis that sediment load entering San Pablo Bay from local watersheds is likely to vary by a magnitude that is similar to or greater than that observed in systems elsewhere in the world due to higher discharge variability.

Delta Levees

Although the original function of Delta levees was to separate wetlands from river channels so that the land could be drained for cultivation, the levees now confine the channels of a critical portion of California's north-to-south, water delivery system. By isolating more than one-half million acres from tidal fluctuations, levees also reduce the Delta's tidal prism (the amount of water entering the Delta between low and high tides), and thereby reduce landward mixing of ocean salt into the Delta. The CALFED Delta levees program seeks to maintain these functions by

reducing risks and consequences of levee failures while the CALFED ecosystem restoration program seeks to create shallow water and riparian habitat and wetlands.

Kevin **Tillis** (Hultgren-Tillis Engineers; abstract #118) described a typical levee as 5 to 15 feet of fill material on top of peat soils underlain by sand with a landside slope of between 3:1 and 5:1 (horizontal:vertical) and a waterside slope of about 2:1. Construction of these levees has evolved from the late 19th century as fill materials have shifted from local soils and channel sediments to imported mineral fill and riprap. Unlike floodplain levees, Delta levees are under year-round pressure from wind waves and boat wakes. Landside berms are often preferable to higher levee crowns for strengthening levees because excessive overburden can compress peat soils to the point of structural failure.

Increased seepage through levee foundations increases the potential for structural failure. Edwin **Hultgren** (Hultgren-Tillis Engineers; abstract #55) characterized water seepage through levee foundations by modeling changes in groundwater levels beneath a levee that might result from various conditions. The water level beneath the interior toe of the levee was calculated to be –16 ft (relative to the water surface elevation in the channel) for a base condition, –14 ft during flood stage, –12 ft when a neighboring island is flooded, and –10 feet when the channel is dredged. Numbers closer to 0 reflect larger rates of seepage, and the last 2 numbers reflect the model assumption that permeable sands lie beneath adjacent islands and the channel that separates them. Proposed measures to counteract seepage include landside berms with 7:1 to 10:1 slopes and pumping relief wells.

Despite such extensive engineering attention, Delta levees remain vulnerable to failure because of instability, seepage, overtopping, erosion, land subsidence, and earthquakes. Leslie **Harder** (DWR, for N. **Abrahamson**; abstract #1) described an assessment of the probabilities of earthquake-induced failures for 600 miles of Delta levees, where failure depends on seismicity and levee fragility. Hypothesized seismic accelerations with a 100-year return interval are estimated to be between 10 and 20% of gravity. Levee fragility was defined in terms of a number of catastrophic failures in each of 4 geographic zones in the Delta, failures being derived from estimated probabilities of soil liquefaction or dynamic structural deformation. Up to 20 failures might result from a magnitude 6 earthquake on a hypothesized Coast Range Central Valley fault. Thus far the highest recorded accelerations are 5% to 8% of gravity, and no earthquake-induced levee failures have been recorded. Most of the island subsidence, however, has taken place since the last great earthquake in 1906. Planned levee improvements are not expected to reduce probabilities of earthquake-induced failures, and Harder judged that reducing these probabilities significantly would be prohibitively expensive.

Steven **Deverel** (HydroFocus, Inc.; abstract #31) pointed out that reducing or reversing subsidence is an alternative means for improving levee stability because levee and island subsidence are root causes of Delta levee instability. Continuing subsidence increases levee instability by increasing seepage onto islands and by exacerbating levee failure consequences (increasing island volumes flooded and resultant seawater intrusion). Soil consolidation and microbial oxidation of peat to CO_2 account for most of the historical subsidence of 0.5 to 4 inches per year, with peat oxidation accounting for over 70% of present-day subsidence, which he estimates to be a maximum of 1 to 2 inches per year. Highest priority areas for subsidence mitigation comprise about 23,000 acres in the central and western Delta, where historic subsidence rates exceeded 1.5 inches per year and where large volumes of unoxidized peat remain. Mitigation involves

flooding soils, thereby reducing oxidation and accumulating residual plant matter, and probably accreting soils more quickly than natural rates of just less than 0.1 inches per year.

Robin **Miller** (USGS; abstract #85) measured carbon balances for 2 adjacent experimental wetlands on Twitchell Island. Flooding reduced previous CO_2 emissions while increasing CH_4 emissions by a smaller amount. In addition, the primary carbon source of the emissions shifted from peat to new plant material, thereby reducing soil loss. These effects combined with plant mass accumulation have resulted in a net gain of carbon at the sites over a 2-year period.

Levee setbacks and biotechnical improvement of channel banks provide ways to simultaneously replace or improve existing levees and increase shallow water habitat in the Delta, a major goal of the many agencies participating in California's AB 360 program (James **Martin**, DWR; abstract #77; and Gilbert Cosio, MBK Engineers; abstract #24). Christopher **Neudeck** (Kjeldsen, Sinnock, and Neudeck, Inc.; abstract #91) described a levee setback project on the south side of Twitchell Island in which phased levee construction avoided failure of the underlying peat foundation by controlling the rate and extent of peat compression. The remnant levee was modified to create shallow water and riparian habitat. Jeffrey **Hart** (Habitat Assessment and Restoration Team, Inc.; abstract #51) described CALFED-funded tests at 50 sites along channel banks in Georgiana Slough designed to assess the ability of "coir biologs" (biotechnical structures made of coconut fiber), brush boxes, and ballast buckets to dampen waves and retain deposited sediments. Two-thirds of the sites were modified and the remaining one-third were used as control sites. All sites retained sediments during winter, but only the control sites lost their accumulated sediment during the subsequent boating season.

Christopher **Enright** (DWR; abstract #35) presented hydrodynamic modeling results that suggest that breaching levees in the Suisun Marsh area can alter mean salinities in the Delta. The magnitude and sign of the salinity changes appear to be sensitive to the location and configuration of the breach. Breaches adjacent to channels with high salinity gradients, and that fill and empty relatively rapidly appear to increase landward mixing of salt. Conversely, breaches near low salinity gradient channels or that fill and empty at about the same rate as the rest of the Delta appear not to affect landward areas significantly. The results suggest that carefully designed wetland rehabilitations may simultaneously reduce Delta salinities.

Poster Presentations

Edwin **Hultgren** and R. Tillis (abstract #171) showed how groundwater conditions beneath Delta levees vary based on data derived from an eight-year study of groundwater beneath levees on 17 islands in the deep peat areas of the Delta.

Callie **Harrison** et al. (abstract #162), using a one-dimensional modeling evaluation of salinity effects of levee breaches for the Sherman Lake, Big Break, and Franks Tract areas, showed that some Sherman Lake alternatives provide marginal salinity reduction, while Big Break and Franks Tract alternatives show potential for significant central and south Delta salinity reduction.

Tidal Wetland Processes

A primary goal of the CALFED Ecosystem Restoration Program is to "Protect and/or restore functional habitat types in the Bay-Delta estuary and its watershed for ecological … values such as supporting species and biotic communities, [and] ecological processes...." However, there are many unanswered questions regarding habitat restoration. For example, what are the key rela-

tionships between tidal wetland habitats and threatened and endangered species populations; which types of habitat are most critically needed; what are the best approaches for creating natural habitat out of leveed and subsided island farm lands; and what have been the trajectories of past reclamations of Delta islands (by either human or natural intervention) with respect to repopulation by native and exotic species? The presentations in this session provided some answers to these questions.

Breaching Levees

Charles **Simenstad** (U. Washington; abstract #106) described the findings from a CALFED-funded study (BREACH) in which breached-levee wetlands of different ages were examined to determine how long it takes for a site to become a functioning wetland and whether the eventual breached-levee wetland attains functionality equivalent to natural wetlands. Answers to these questions seem to depend on: (1) extent of subsidence since levee construction; (2) historical modifications to watershed and tidal hydrology and sediment sources; (3) extent to which invasive species have modified the adjacent ecosystem; and (4) design approaches used in breaching levees and restoring tidal inundation. Successful restoration projects may require the achievement of interim states with an adaptive management approach necessary to achieving the final goals. An overall conclusion was that the prognosis for any breached-levee restoration is uncertain.

Philip **Williams** (P. Williams & Associates; abstract #126), in reporting findings from field studies at 6 breached sites and 4 natural reference sites, described a conceptual model of tidal wetland morphology incorporating open-water sedimentation rates, rates and patterns of emergent marsh expansion, substrate elevation controls on emergent vegetation establishment, rates of marsh plain elevation change following vegetation establishment, and channel formation. Acknowledging that the Delta, as a result of alteration of the sediment regime by dams and levees, bears no resemblance to the historic conditions, the study highlighted the importance of understanding the relationship between sediment accumulation rate and desired marsh elevation at a given site in projecting success of a breached-levee restoration project.

Denise **Reed** (U. New Orleans; abstract #101) used information from the study of breached-levee sites of different ages to develop a conceptual model of tidal wetland development. The model shows how substrate elevation controls colonization by emergent versus submerged plants; how river discharge, sediment supply, and tidal action modulate changes in substrate elevation; and which fishes are associated with certain biotic and morphological site characteristics.

Lenny **Grimaldo** (DWR; abstract #47), reporting on fish and invertebrate usage of the same sites described above, found that the age of a restored wetland is probably not a reliable indicator of whether certain fish assemblages (for example, native fishes) will eventually re-colonize a restored wetland. Physical attributes of the flooded island are apparently better indicators. Moreover, introduced species (fish and invertebrates) were the dominant organisms collected at most study sites, and may inhibit the restoration of natural ecosystem functions and native fish populations.

Jeremy **Lowe** (U. Newcastle; abstract #74), drawing on experience gained in British estuaries, pointed out the importance of considering individual restoration projects in the context of larger-scale effects such as increases in tidal prism, tidal velocities, and channel erosion near the site and the longer-term demand for sediment in the context of rising sea levels, that result from opening areas to tidal action.

Poster Presentations

Laura **Hanson** et al. (abstract #160) conducted a study of vegetation changes that occurred following restoration of a Suisun Bay marsh to tidal action after 80 years behind a dike, showing that brackish tidal marsh plants, particularly cattail, replaced species common to hypersaline, tidally-muted marshes such as pickleweed. The process was enhanced by the occurrence of a wet year following restoration.

Michelle **Orr** and P. Williams (abstract #186) developed a conceptual model of tidal wetlands evolution at restored sites based on evolutionary history of 21 sites in the Delta and San Pablo Bay that were flooded by levee breaches. When deposition, erosion, sea level rise, and vegetation accumulations are accounted for, most Delta sites in the study reveal slow sedimentation rates and high wind wave action that appear to limit deposition to an elevation below which vegetation can establish.

Anitra **Pawley** (abstract #187) reviewed literature on tidal marsh restoration and mitigation projects to develop a list of indicators of functional tidal marshes. The list of common indicators includes hydrologic and geomorphic processes, habitat structure, biotic community response, and composite measures proposed to synthesize these processes.

Anitra **Pawley** (abstract #188) described the process by which a CALFED team developed and recommended a set of performance indicators for the CALFED Ecosystem Restoration Program. The proposed program-wide performance indicators are intended to help scientists and managers assess and review the extent to which CALFED's goals and objectives have been achieved over both short (1 to 7 years) and longer timescales (more than 7 years).

Valerie **Calegari** and K. Whitener (abstract #142) described how The Nature Conservancy used CALFED funding to purchase the McCormick–Williamson Tract, 1,634 acres of farmland and 8.6 levee miles of riparian habitats to restore the land to tidal marsh under guidance of ongoing modeling and research efforts. Short-term plans include a 200-acre pilot tidal wetland project, exotic tree removal, wildlife friendly levee restoration, and cooperation in the long-term North Delta flood abatement planning process.

Distributions of Native Versus Exotic Fish in Tidal Wetlands

Kathryn **Hieb** (DFG; abstract #53) presented the results of a 5-year study of fishes, shrimps, and crabs in tidal marsh and river habitats in the lower Petaluma River and northern Napa-Sonoma Marsh. She found that resident native species generally dominated catches in the marsh plain channels, with a gradation to transient species (many introduced), as sampling approached deeper water habitats. The high degree of variability in the occurrence of sensitive native species in these habitats over space and time (exacerbated by the need to use different sampling gear in different types of habitat) illustrated the importance of carefully designed multi-year studies when determining the use of tidal marsh habitats by native species.

Poster Presentations

Christopher **Kitting** et al. (abstract #173) described a study of the relative use of restored versus historic marsh sites near Suisun Bay (three each) by native and exotic fish species. Study results revealed that fish or invertebrates made little use of historic marshes while abundant populations were found in a decade-old restored marsh, including a larger number of introduced species than native species.

Deborah **Rudnick** et al. (abstract #194) demonstrated through monitoring of the Chinese mitten crab in South San Francisco Bay that this species is widespread in the tributaries and open water in South Bay, with high burrow densities along steep, vegetated, tidally influenced banks.

Animal-Plant Interaction in a Saltmarsh

Steven **Obrebski** (SFSU Romberg Tiburon Center; abstract #92) used experimental field manipulations to show that release of nitrogen by amphipods during feeding and burrowing in a salt marsh enhanced the production of pickleweed, an example of the kind of important functional relationships that need to be reestablished in marsh restoration projects.

Monitoring in Tidal Wetlands

Gretchen **Coffman** (UC Los Angeles; abstract #21) demonstrated the utility of seed occurrence and germination success as a monitoring tool through an evaluation of the accumulation of seeds in marsh soils ("soil seed banks") in 10 natural and restored salt marshes of coastal California. Seed densities increased with distance from the mouths of tidal channels, with highest densities of seeds typically found at the marsh wrack line (that point in a marsh where floating material accumulates). Densities were low in newly created marshes, reached a peak in older restored marshes, and leveled off again in natural marshes, suggesting a general trajectory that might be used as a performance curve for salt marsh restoration planning and monitoring throughout California.

Giselle **Downard** (USGS; abstract #34), in describing two restoration projects (the Cullinan Ranch and Tolay Creek sites adjacent to San Pablo Bay), showed how monitoring before, during, and after a project can provide critical information for adaptive management of the sites. Monitoring at Cullinan Ranch tracked the transition from a subsided oat-hay field to a diverse seasonal wetland community with increases a number of desirable species while that at Tolay Creek showed how a degraded wetland strip with limited tidal exchange was transformed into an area in which previously dominant weedy plants were inundated and to which birds were quickly attracted.

Poster Presentations

Todd **Hopkins** (abstract #168) described a multi-institution partnership (NOAA, Romberg Tiburon Center, California State Parks, Solano County Farmlands and Open Space Foundation, and East Bay Regional Park District) that has proposed a San Francisco Bay National Estuarine Research Reserve (NERR). The NERR would incorporate continuous weather and water quality monitoring and study at three historically unchanged sites—China Camp State Park, Rush Ranch Open Space Preserve, and Brown's Island Regional Shoreline.

Theodore **Foin** et al. (abstract #152) expanded an existing vegetation-hydrology model to characterize the most important determinants (for example, tidal hydrology and salinity) of tidal marsh vegetation productivity, diversity, and structure.

Edwin **Grosholz** and K. Forshay (abstract #158) quantified the responses (changes in abundance and biomass) of invertebrate species to both event-driven flooding cycles and longer-term seasonal changes in the Cosumnes River flood plain, demonstrating that large declines in dominant zooplankton after inundation may reflect fish predation.

Organic Carbon and Lower Trophic Level Processes

Long term monitoring of plankton and young fishes by State and federal agencies has shown that a number of biological populations in the Sacramento-San Joaquin Delta are smaller now than they were only three decades ago. Nonetheless, we know little about the causes of these population declines and the degree to which they are linked to impairment of ecosystem functions necessary to support fish production. Developing a better understanding of the causes of these changes is critical to the proper design of restoration strategies that will be the foundation of the CALFED Ecosystem Restoration Program. This session included presentations about field and laboratory studies, using a variety of approaches, that addressed questions about the origin, quantity, quality, availability and use of organic matter as a food resource for the primary-consumer biota, particularly zooplankton.

Sources and Quality of Food in the Delta

James **Cloern** (USGS; abstract #20) introduced the first six presentations on the sources and quality or organic matter that fuels biological production at the base of the food web in the Delta by arguing that a combination of historical analysis, hydrodynamic modeling, field experiments, and laboratory experiments will be required to yield insight into Delta food web processes. He pointed out that, because of past emphasis on largely independent and isolated scientific investigations, such insight has not yet been successfully achieved. Cloern argued that bringing together a suite of investigative tools and strategies will greatly improve our chances of understanding the changes that have been observed.

Anke **Mueller-Solger** (UC Davis; abstract #84) used laboratory feeding experiments to show that zooplankton in the Delta have higher growth rates when fed particulate matter from shallow, slower-moving water environments such as floodplains and tidal marshes (containing more phytoplankton) than when fed particulate matter from deeper habitats such as tidal rivers (containing more non-living organic material).

Alan **Jassby** (UC Davis; abstract #56) summarized 30 years of information on sources of food for plankton species in the Delta. He concluded that, while river water is the largest source of organic carbon, phytoplankton transported both from upstream and produced within the Delta is a much more important source of food for Delta food webs because it is used more efficiently. Unfortunately, the data show that phytoplankton production in the Delta has been declining over the long term.

Nancy **Monsen** (Stanford U.; abstract #87) presented the results of a multi-dimensional modeling study that allowed her to determine the relative sources of water at any given location in the Delta and Suisun Bay and any water flow conditions. Among the key findings were (1) temporary barriers installed in the Delta can have an extremely large effect on circulation and source fractions and (2) Yolo Bypass water, flowing primarily through the Sacramento ship channel into Honker Bay and Suisun Bay, is not a source of food for organisms in the Central Delta.

Lisa **Lucas** (USGS; abstract #75) used carefully designed field experiments, including high-resolution spatial mapping of water quality and biological constituents, to show that flooded Delta islands do not behave similarly with respect to phytoplankton production. Depending on water depth, local hydrology, and presence and absence of benthic organisms within a flooded island, the island will or will not be a significant source of food for zooplankton and small fish.

Elizabeth **Canuel** (Virginia Institute of Marine Science; abstract #16) described the use of biomarkers and stable isotopes to further identify the sources of particulate organic matter in sub-environments characteristic of the Delta, with the goal of identifying the types of habitats most likely to best support the Delta food web. Initial results showed that sources of carbon derived from various primary producers differ in their potential usefulness to zooplankton and higher organisms. In other words, success in restoration projects may depend not only on the quantity of food available at particular locations, but also the composition of that food.

William **Sobczak** (USGS; abstract #110), reporting on a bioassay study of the availability of both dissolved and particulate organic carbon to consumers, showed that water from the Sacramento River appears to deliver less bioavailable organic matter (when normalized to volume) than water from the San Joaquin River because the latter contains higher algal biomass. Water from marsh sites (including sloughs draining Suisun Marsh) contains more bioavailable organic matter (for example, chlorophyll *a*) than channel water, suggesting that the historic Delta supported a higher level of phytoplankton production than at present.

Ramunas **Stepanauskas** (U. Georgia, for T. **Hollibaugh**; abstract #54) described preliminary results of a study of microbial decomposition of dissolved organic matter in Delta waters—the largest component of total organic matter present in the water—that showed that less than 10% of the dissolved organic matter present is in a form that is available to microbial consumers, a percentage that is substantially lower than the average in river systems elsewhere in the world.

Poster Presentations

Marisa **Cox** et al. (abstract #147) described how concentrations of dissolved organic carbon, a source of energy for organisms, in the Yolo Bypass decreased during the flooding period, but increased again when flow decreased, thus enhancing the food supply both within and downstream of the Bypass.

Laurence **Schemel** et al. (abstract #197), in an investigation of nutrient and particulate carbon concentrations in the Yolo Bypass, demonstrated the effects in the Yolo Bypass of the cycle of rising and falling flood water levels, and the sources of the water, on biological productivity within the floodplain.

Ted **Sommer** et al. (abstract #200) showed that chlorophyll in Yolo Bypass water is an important source of phytoplankton (food for zooplankton and small fish) during the drainage period following flooding.

Vicki **Pilon** et al. (abstract #189) used lipid biomarker compounds to track temporal variations in both sources and relative lability of organic matter for three shallow-water habitats in the Delta (Mildred Island, Franks Tract, Little Holland Tract). The results indicate that although shallow-water habitats may produce more labile organic matter than open water habitat, this production is not homogeneously distributed throughout each shallow water system.

Geographic and Temporal Comparisons of Plankton Dynamics

Francis **Wilkerson** (SFSU Romberg Tiburon Center; abstract #125) described a new long-term program of monthly water column sampling (conductivity, temperature and depth, light penetration, plant nutrients, phytoplankton) between Suisun Bay and Central San Francisco Bay, with an emphasis on evaluating environmental change as may occur following unexpected biological

invasions, changes in nutrient or hydrologic regimes, or changes following Delta or estuary restoration decisions. The authors illustrated the value of such a program by documenting an unexpected phytoplankton bloom in Suisun Bay and the need for more frequent sampling in spring to detect blooms.

Peggy **Lehman** (DWR; abstract #70) described how environmental and biological data collected in the northern San Francisco Estuary between 1975 and 1993 can be used to develop a conceptual model of the interaction between lower food web production and natural changes in environmental conditions. Of particular note was the apparent effect of varying climatic conditions on water transparency, wind velocity, water temperature and precipitation that, in turn, influenced total organic phytoplankton and zooplankton carbon. An appreciation of the long-term context of these interactions is critical to developing and evaluating rehabilitation projects within the estuary and Delta.

Poster Presentations

Brian **Cole** and James Cloern (abstract #146) summarized the results from a long-term, bay-wide sampling program that showed large geographic variations in primary production (highest in South Bay and lowest in North Bay) as a result of differences in nutrient, light, temperature, and possibly, pollutant regimes. Low production in North Bay, relative to that seen in other estuaries, is caused by high rates of grazing by benthic animals and high water turbidity.

Darren **Gewant** et al. (abstract #156), in a new study of zooplankton in San Francisco Bay using samples collected both in daytime and nighttime, have found heretofore unreported large differences between day and night in abundances of macrozooplankton and micronekton such as bay shrimp. This finding has important implications regarding the interpretation of past plankton data.

Gretchen **Rollwagen-Bollens** and Deborah Penry (abstract #193), in a study of the copepod genus *Acartia*, one of the dominant members of San Francisco Bay zooplankton, showed how El Niño-related high river flows can have a positive influence on zooplankton food supplies.

Species of Special Concern

This session included talks on avian and fish species, listed pursuant to the federal and State endangered species acts, that have particular ecological importance, or whose populations are in decline. Many of these species and their supporting physical and biological environments will benefit from CALFED's ecological restoration activities.

Birds

Nadav **Nur** (Point Reyes Bird Observatory, for Stacy **Small**; abstract #108) described the results of long-term monitoring initiated to compare bird species abundance and diversity in riparian forests and restoration sites in the Central Valley. He and his colleagues found that bird diversity increases with the age of the restoration site. They also found poor nesting success for two-thirds of the target species, with predation and parasitism being the likely causes of poor reproduction. They concluded that birds are attracted to restoration sites.

David **Gilmer** (USGS; abstract #45) reported that in 1999 he and his colleagues used field surveys on the Sacramento, Kern, and lower Colorado rivers to assess the status of the yellow-billed cuckoo, listed as endangered under the State endangered species act. This bird nests in

riparian habitat, and Sacramento River habitat appears to be increasing in relative importance statewide. Any effort to increase populations of this neo-tropical migrant should focus on increasing riparian habitat and monitoring abundance in existing and restored habitat.

Over the past three years, Joseph **Fleskes** (USGS; abstract #38) and his coworkers have been studying waterfowl distribution, movement, habitat use, and survival throughout the Central Valley that provides critical habitat for about one-fourth of North American waterfowl. Preliminary results indicate ecology of waterfowl wintering in the Central Valley has changed over the past decade. These changes, partly due to increased wetlands and rice farming, may require the Central Valley Habitat Joint Venture to modify its habitat goals.

John **Takekawa** (USGS; abstract #115) described the importance of about 30,000 acres of existing artificial salt evaporation ponds to waterbirds. He and his colleagues found 66 species of waterbirds representing 6 feeding guilds using the evaporation ponds. These birds make extensive use of the macroalgal and macroinvertebrate communities found in the ponds. Converting these ponds to tidal wetlands may increase the abundance of some species while decreasing the abundance of others.

Fish

White and Green Sturgeon

Although not listed, the white sturgeon sports fishery in the upper estuary is economically important. Ray **Schaffter** (DFG; abstract #103) noted that white sturgeon year-class strength is highly variable and related to water years. Recruitment was low during the 1987-1992 drought but rebounded in some of the recent high flow years. The present high population of legal sized sturgeon (due to strong 1982-1984 year classes) is beginning to decline and a resurgence will not occur until the good 1990s year classes begin to enter the fishery in about 2006.

Green sturgeon are present in the Sacramento-San Joaquin system but are much more rare than white sturgeon, and is a CALFED species of special concern. Ryan **Mayfield** (UC Davis; abstract #78) described the results of CALFED-funded laboratory studies to learn more about how this animal uses its food supply at different temperatures. The studies indicated that food consumption, growth and food conversion increased with temperature in the range of 11 to 24 °C. These and other data will be used by resource managers to manage this species.

Poster Presentation

Scott **Lankford** and Joe Cech (abstract #176) used laboratory studies to demonstrate that juvenile green sturgeon are capable of responding to a stress event as early as 8 days after hatching. Young-of-the-year sturgeon were shown to have a higher stress response in the dark as compared to light. The information can help develop green sturgeon management strategies.

Longfin Smelt

Randy **Baxter** (DFG; abstract #7) used the results of IEP studies to describe the life history of this important local member of the smelt family and a fish of special concern. Annual abundance of longfin smelt is correlated with winter and spring flows and fell to record low levels during the 1987-1992 drought. Longfin smelt use the entire estuary and nearshore ocean during their life cycle. The adults are winter spawners, spawning mostly as two-year olds in the lower Sacramento and San Joaquin rivers. Their entire life history is tied to flow, and in the wet years the fish

are larger at any given age than in dry years. Recent wet years have seen the population rebound; however, overall abundance continues to be below pre-drought levels.

Delta Smelt

Delta smelt is listed as threatened under both the federal and State endangered species acts. Bradd **Baskerville-Bridges** (UC Davis; abstract #6) and his colleagues conducted laboratory and outdoor studies to culture delta smelt. The culture work, funded by CALFED and DWR, has two objectives: to learn more about the animal's basic biology and to provide test animals for other researchers. They have successfully grown larvae from natural spawns in the culture tanks to the juvenile stage. Delta smelt have a long and vulnerable larval stage and will only begin feeding when the water is turbid.

Michael **Dege** (DFG; abstract #29) described how DFG biologists, as part of IEP's Real Time Monitoring Program (see Urquhart below), have been tracking the abundance of larval delta smelt and the small animals (zooplankton) that may be their first prey. Initial results indicate that the abundance of an important native food organism peaks earlier that an introduced invasive species that appears to be replacing it. Changes in important prey items may help explain annual variations in delta smelt abundance.

Recent analyses by William **Bennett** (UC Davis; abstract #9) are providing new directions for research and management of this enigmatic species. His examination of data from culture studies (see Baskerville-Bridges above) and IEP historical information indicates that delta smelt spawning and hatching are tied to tidal cues, and that population dynamics and year-class strength are affected by density dependence, the numbers of 2-year-old spawners, predation by an introduced fish, and entrainment into federal and State water exports.

Kevin **Urquhart** (DFG; abstract #121) reviewed IEP's 6-year-old Real-Time Monitoring Program. The program is conducted each spring to help biologists and water project operators manage the projects for fish protection and to help ensure water supply reliability. Key program elements have been weekly or bi-weekly surveys of the abundance and distribution of small (less than about 3/4 inch) delta smelt. Although the program provides important biological data, it does not provide a consistent early warning of take at the project export facilities.

For over one year Christopher **Kitting** (CSU Hayward; abstract #63) sampled 4 pairs of restored and reference tidal marshes in the medium to low salinity habitat of San Pablo and Suisun bays. The monthly ichthyoplankton (small fish) tows did not collect many fish until March 2000 when delta smelt and splittail were collected at sites in north San Pablo Bay and just outside restored and reference sites in Suisun Marsh. Several years of data collected over a variety of water years are essential to assessing the value of tidal wetland restoration to the increased abundance of native fish.

Poster Presentations

William **Bennett** et al. (abstract #135) described a study by a multi-disciplinary team of UC Davis scientists examining a suite of physiological, genetic, and morphological characteristics of delta smelt collected by IEP monitoring programs. They have found some apparent liver abnormalities and DNA strand breakage. "Healthy" smelt grew at a faster rate than "impaired" specimens. This integrative approach looks promising in evaluating factors regulating delta smelt abundance.

James **Hobbs** et al. (abstract #165), using measurements of daily increments on delta smelt ear bones (otoliths), determined that smelt spawn in distinct pulses. The study also showed that smelt growth rates vary with age—slow for the first 15 days of life, relatively fast for the next 75 days and slowing again after day 90—with the slow growth coinciding with the transition to the adult stage.

James **Hobbs** et al. (abstract #166) examined delta smelt for nematodes, finding that overall infestation was low, about 4%; however, the infestation rate of fish one year and older was 62%. Data analysis indicated that smelt with high nematode infestation may have delayed egg maturation and spawning - factors which could disrupt recruitment dynamics and affect overall population strength.

Cosumnes River

The Cosumnes River is largest undammed river in the Sierra Nevada and has a relatively natural flow regime and a functional floodplain. Peter **Moyle** (UC Davis; abstract #89) and his colleagues sampled the floodplain from January through May in 1998, 1999, and 2000. Juvenile salmon entered the floodplains soon after inundation and achieved high growth rates by feeding on abundant zooplankton and insects. In 1998 and 2000 adult splittail spawned on the floodplain with most of the juveniles emigrating as the waters receded. Both salmon and splittail are highly adapted to use floodplain habitats.

Patrick **Crain** (UC Davis; abstract #25) and colleagues examined fish assemblages throughout the basin. Native fish dominated the upper and upper middle portions of the basin with the lower middle portion containing both native and introduced species. The lower basin fish assemblage consisted almost entirely of non-native invaders. Water temperature, elevation, stream gradient and turbidity can be used to predict the fish assemblage in any given reach. Information from similar baseline monitoring programs can help CALFED and others develop and evaluate watershed management actions.

Other Fish Poster Presentations

D. **Deng** et al. (abstract #149) determined with laboratory studies that growth rate, total length, and condition factor of larval splittail were affected by water temperature. Water temperatures in the range of 22 to 26 °C were optimal for larval splittail.

David **Fullerton** et al. (abstract #154), while not specifically addressing special status species, suggested that CALFED's Environmental Water Account, in concert with CVPIA, CALFED Ecosystem Restoration Program actions and the 1995 Water Quality Control Plan, offer hope for such native fishes as chinook salmon, steelhead, delta smelt, and splittail.

William **Harrell** et al. (abstract #161) suggest that flow pulses in the Yolo Bypass apparently triggered upstream migration of several adult native fish including Sacramento blackfish, splittail, suckers, and pike minnow, with at least the splittail successfully spawning in the bypass. Other adult fish (for example, chinook salmon, white sturgeon, and striped bass) moved into the bypass even during low flow periods and were likely trapped behind the flood control levee. The floodplain provides excellent habitat, but better fish passage is needed.

Lisa **Lynch** et al. (abstract #178) emphasized the need for accurate identification of fish larvae collected in IEP and other field studies. Identification of the larvae of many species is difficult, and the researchers are using a variety of morphological diagnostic characteristics and DNA to

develop a taxonomic key available to all biologists. A voucher collection of larvae of known origin is being assembled to verify the diagnostic characters used in the key.

Chinook Salmon and Steelhead

All four Central Valley chinook salmon races and steelhead qualify as special status species. The winter run is listed as endangered and the spring run as threatened by the federal and State endangered species acts. The fall run and late-fall run are candidate species pursuant to the federal Endangered Species Act. The federal government has listed steelhead as threatened. In addition to being special status species, these salmonids are excellent indicator species in that their complex life cycle includes residence or passage in valley and mountain streams, the estuary, and the ocean. While in these habitats the juveniles and adults are subject to numerous natural and human induced stressors such as droughts, recreational and commercial fishing, low stream flows, blockage from historical habitat, high water temperatures, exposure to diversions, and contaminants and changing ocean conditions. The complex multi-year life cycle also increases the difficulty of identifying which of the multiple factors may have caused observed changes in abundance. The salmonid session speakers presented information on management, restoration, and information needs of these important species.

Chinook Salmon

To simplify the discussion, the chinook salmon talk summaries are divided into life history identification, restoration, and modeling.

Life History Identification

Dennis **Hedgecock** (UC Davis Bodega Marine Laboratory; abstract #52) and his colleagues used molecular genetic techniques to type about 2600 fish from 41 nominal Central Valley chinook salmon populations. They concluded that there are distinctive genetic lineages worth preserving; genetic markers can be used to identify these lineages; hybridization has occurred in production hatcheries; and the winter run is most divergent followed by spring run, with Butte Creek springs being different from those in Mill and Deer creeks.

Michael **Banks** (UC Davis Bodega Marine Laboratory; abstract #5) presented a new computer program, WHICHLOCI, which uses information from genetic markers described above to assign individual chinook by race, with an error rate of less than 0.5%. The number of loci (markers) needed to assure this degree of reliability varies with the degree of genetic separation. For example, the number of markers is least for winter run.

Peter **Weber** (UC Berkeley; abstract #123) described techniques using variations in the microchemistry of salmon ear bones (otoliths) to help determine where they have resided. Salmon ear bones lay down a daily growth increment, the composition of which may be in part due to the chemistry of the surrounding water. Thus, it may be possible to chemically analyze these increments as well as stream water to determine rearing location. Preliminary work has shown that while there is statistically significant variation in one potential chemical marker—the ratios of natural and radioactive strontium in Central Valley streams and salmon otoliths—the results are not yet adequate to determine where the salmon have lived. Hatchery feed, which contains adult salmon carcasses, thereby contributing a significant amount of ocean derived strontium, is a confounding factor. Weber and his colleagues at UC Berkeley and Lawrence Livermore National Laboratory (LLNL) are working to identify other chemical markers.

Patricia **Brandes** (USFWS, for R. **Burmester**; abstract #14) and staff used DFG's length-at-age criteria to estimate when the different races of juvenile salmon enter and leave the lower Sacramento River and Delta. Preliminary results indicate that late-fall run rapidly move through the lower system in one peak, and that fall run arrive in two peaks. The first fall run peak consists of fry moving (or washed) out in early storms, and their survival may be poor. The next step will be to look at the genetic information provided by the Bodega Marine Laboratory to confirm that the juvenile salmon are being correctly assigned to race. Information of this type is critical to management of these runs as they reside in and migrate through the Delta.

Restoration

Edward **Cheslak** (Jones & Stokes Associates; abstract #19) described an evaluation of CALFED salmonid restoration projects. Of 268 restoration projects to date, 138 are salmonid (mostly salmon) related with habitat restoration and fish passage and screening activities receiving about 90% of the total allocated funds. It is presently difficult to track projects accurately, and their benefits are poorly documented. Explicit conceptual models of salmon life histories in the Sacramento-San Joaquin systems are proposed as a way to facilitate project selection and evaluation through identification of specific habitat requirements and accompanying performance measures. Additional data will be needed to develop, verify, and modify these conceptual models.

Carl **Mesick** (Carl Mesick Consultants; abstract #81) summarized spawning gravel restoration studies that he conducted on the Stanislaus River. The general conclusions were that gravel restoration projects should use smooth native rock; the rock worked best when graded ¼ inch to 5 inches; and the gravel works best when placed in areas upstream of hydraulic controls where currents assist in redeposition. When done correctly, chinook salmon will spawn in restored riffles.

Modeling

Steven **Lindley** (NMFS; abstract #72) discussed a new tool, the population viability assessment (PVA) model that will be used to help develop regional recovery plans for listed salmonids. (The Central Valley is considered by NMFS to be a region.) The models will also be used to assess recovery goals. As with all models, good time series data are essential. Even with good data, the confidence intervals surrounding the output, for example probability of extinction, will be large. Using a simple PVA model, Lindley found that the Sacramento River winter run has an almost 100% probability of going extinct in the next 100 years.

Wim **Kimmerer** (SFSU Romberg Tiburon Center; abstract #62) presented the design and preliminary results of a Sacramento River chinook salmon population model. The model, which is being developed to support analyses of CVPIA actions, can encompass all four runs, but initial efforts focus on fall run. After presenting results of three model scenarios, Kimmerer emphasized that we need more information on all salmon related process—from how flow affects the redds to predation and mortality rates and carrying capacity of riverine reaches. We must move salmonid monitoring and research beyond enumerating their abundance at specific life stages to mechanistic studies.

Poster Presentations

Peter **Adams** et al. (abstract #128) showed that in the Gulf of Farallones chinook salmon feed on anchovy, herring, shrimp, and juvenile rockfish in a predictable seasonal cycle. This cycle is dis-

rupted by El Niño events when the prey concentrations do not form and, as a result, salmon condition factor declines.

Noel **Bush** and T. Horner (abstract #140) used physical measurements (hydraulic head, temperature, pH, dissolved oxygen, turbidity and specific conductance) in overlying and subsurface flow in an American River gravel bar to investigate salmon spawning site selection. None of the individual parameters correlated with salmon spawning sites.

Thomas **Cannon** and Warren Shaul (abstract #144), in examining the problem of stranding of juvenile salmon and steelhead on floodplains, reported that stranding does occur in wet years. However, the problem may be more serious in drier years when year class strength is more likely to be poor. Potential improvements in floodplain habitat can improve survival, production, and subsequent escapement.

Thomas **Cannon** (abstract #143) described how high flows in the Sacramento River (40,000 to 60,000 cfs) and the San Joaquin River (20,000 to 40,000 cfs) bring salmon fry to the estuary. Young salmon can remain in Central and North bays year-round but are rare in the Delta after water temperatures exceed 70 °F.

Sheila **Greene** (abstract #157) showed how genetic tools have enabled fish biologists to determine the numbers of juvenile winter-run chinook salmon salvaged at the Delta water intakes. These data also indicate that juvenile winter run can be present in the Delta from late fall through the end of April.

Paula **Landis** et al. (abstract #175) described how CALFED, CVPIA, and DWR funding is being used to restore ecological functionality to a 4.5-mile reach of the Merced River. The first phase involved isolating a 43-acre pond from the river by a berm and improving stream and floodplain dynamics. Post project monitoring is an essential project feature.

Tom **Taylor** et al. (abstract #203) demonstrated that chinook salmon fry on the Mokelumne River showed a peak mid-February migration in 2000, with juvenile salmon captured by a variety of gear from mid-February through early April. It appeared that juvenile salmon continue to migrate and grow during this period, although their fate after leaving the river is not well known.

Steelhead

Dennis **McEwan** (DFG; abstract #79) emphasized the need to rethink not only how steelhead populations are identified but also how they are managed. The traditional time of migration and related characteristics are not adequate to separate resident rainbow trout from the extremely adaptable steelhead. To date much of the salmonid information needs have been met through chinook salmon monitoring and research, and steelhead management has been a by-product of salmon management. This indirect management strategy will not be effective. From restoration management standpoint, we must explicitly recognize that juvenile steelhead spend one or more years in freshwater thus have more demanding stream environmental requirements than do chinook salmon in which most of the juveniles leave the streams after a few weeks or months.

Joe **Merz** (EBMUD; abstract #80) confirmed that, in the Mokelumne River, juvenile steelhead feed primarily on small organisms drifting downstream with the current. These organisms fall from adjacent riparian vegetation; thus, this habitat type is required for restoration and mainte-

nance of steelhead populations. Although large quantities of algal detritus were often found in their stomachs, it is not clear that the algae provide nutritional value.

Fish Facilities and Fish Screening

There are more than 2,500 mostly unscreened water diversions in the Sacramento-San Joaquin system ranging in size from a few cfs to more than 10,000 cfs. Some of these diversions are screened to limit the numbers of fish entering canals and ditches and onto farmland and wetlands. Many others are either being screened or screening is being considered. Fish facilities, including the screens and ancillary fish collecting and hauling devices at some installations, are inherently expensive and imperfect. The work described in the following presentation summaries will help CALFED better understand the limitations of the present fish protection facilities and how to design and build them more effectively.

Salvage at Federal, State, and Contra Costa Water District facilities in the South Delta

The South Delta intakes have a combined diversion capability of about 15,000 cfs with each intake equipped with fish collection and transport facilities. The effects of fish losses through and near the screens and minimizing these losses are important CALFED considerations.

William **Miller** (Consulting Engineer; abstract #82) used fish survival or fish abundance relationships with flow, X2, or amount of water diverted to estimate the water supply effects of a 1% increase in fish population survival. Miller also described physical modifications (for example, a barrier at the head of Old River) that could be used to reduce fish losses. The estimates and physical modifications are examples of the kind of information CALFED should consider when balancing fish and water supply benefits.

Thomas **Cannon** (Foster-Wheeler Environmental Corp.; abstract #15) described results of analyses of the 1980-1997 State and federal fish facilities salvage database. These analyses, conducted as part of CALFED's Diversion Effects Team, were intended to lead to ways to minimize fish losses. A combination of seasonally decreasing outflow and increasing exports explains many of the high fish entrainment/fish loss events in the 1980s and early 1990s. Recent actions by CALFED and CVPIA and spring export reductions as part of the Vernalis Adaptive Management Plan have reduced losses. Additional ERP and CVPIA actions, as well as operation of the Environmental Water Account (EWA), will further reduce fish mortality at the existing facilities. His analyses of factors affecting entrainment of several individual species will assist biologists and managers in operating and evaluating the EWA.

Robert **Fujimura** (DFG; abstract #42) examined 1979-1999 trends in fish salvage at the State and federal fish facilities. The two facilities are located in close proximity and have the same basic behavioral barrier (louver) fish screening system. The facilities do differ significantly in that the federal intake is directly on the river and diverts essentially around the clock, whereas the State periodically diverts to a small regulatory reservoir during the daily tidal cycle. In spite of the short distance between the two intakes, the annual and seasonal salvage patterns at the two facilities are often quite different. Comparison of salvage indices between the two facilities showed no or poor correlation and did not demonstrate consistent increasing or decreasing trends at either facility. The results of these analyses will help engineers and biologists design new south Delta intakes.

Jerry **Morinaka** (DFG; abstract #83) described the results of two years of fish monitoring conducted behind CCWD's newly installed positive barrier screen on Old River. DFG used a large sieve net to determine if chinook salmon, steelhead, and delta smelt were being entrained (taken) at the diversion. The net captured 19 species (3 native and 16 non-native) with only one delta smelt and no salmon found in the samples. The results demonstrate that a properly designed and operated screen can reduce entrainment losses.

Innovative Screening Technologies

Most new fish screens on California water intakes are positive barriers with small holes in the screen allowing the water to flow through but preventing most fish from being entrained. To prevent fish from being impinged, water velocities in front of the screens are about a few tenths of a foot per second. The following talks described alternative screening technologies.

Kevan **Urquhart** (DFG; abstract #120) summarized the results of 1993 through 1996 IEP studies testing the ability of acoustic signals to prevent a portion of the downstream migrating juvenile salmon from entering the interior Delta via Georgiana Slough. The hypothesis tested was that acoustic signals could be used to elicit an avoidance response in juvenile salmon and they would stay in the mainstem Sacramento River where mortality would be lower. The studies provided mixed results in that the 1993 and 1994 results indicated some success (up to 57% guidance efficiency) but with no apparent guidance in 1996. The results show the importance of properly designed and adequately funded studies conducted over period of at least a few years and the need for extensive data analysis.

James **Buell** (Buell and Associates; abstract #13) tested two unconventional screening configurations (COANDA and horizontal flat plate) in Oregon, both using high sweeping velocities to help move the fish and debris past the screen. Results from these tests on moderate size diversions (127 and 75 cfs) demonstrated that the screens protected target fish species (chinook salmon and steelhead fry and steelhead smolts) and were self-cleaning.

Steven **Gallo** (Southern Energy California; abstract #43) is proposing to install an aquatic filter fiber curtain (Gunderboom Inc. Marine/Aquatic Life Exclusion System) to limit the numbers of fish entrained into the cooling water intake to the Contra Costa Power Plant. The 1,700-ft barrier, suspended from the surface and anchored on the bottom, consists of two layers of polypropylene and polyethylene fibers and will have 3/32-inch holes. The screen would be periodically cleaned with air bursts. The test screen, which has also been evaluated on New York's Hudson River, would be in place in 2001.

Kent **Zammit** (Electric Power Research Institute, for Edward **Taft**; abstract #116) described a new screen type, the modular inclined screen that has been designed to provide fish protection at almost all intakes. The screen itself is angled upwards to the flow at 10 to 20 degrees and operates at water approach velocities of about 10 fps, as opposed to 0.2 to 0.33 fps in typical California positive barrier screen installations. The increased approach velocity results in a more compact and less expensive screen. Pilot scale tests with a variety of fish, including chinook salmon and rainbow trout, showed diversion effectiveness of almost 100% with little or no latent mortality. The screen is periodically cleaned by tilting to horizontal and backflushing.

Fish Passage Tests at the Red Bluff Diversion Dam

To protect salmon, the gates at the Red Bluff Diversion Dam are now raised for most of the year, and the option of removing the dam completely is being considered. The USBR is testing two systems to determine if water can be lifted from the Sacramento River into the Tehama-Colusa Canal without harming fish. These systems are also being considered for use in new fish protection facilities at the federal and State Delta project intakes.

Charles **Liston** (USBR; abstract #73) and Sandra **Borthwick** (USBR; abstract #11) described the results of their studies to evaluate fish passage effects of two water lift systems—a helical pump and an Archimedes lift—and the use of pulsing flows to move fish through screens and bypass systems at the RBDD. The helical pumps showed a slightly higher pump-passage effect on direct mortality, but did not cause significantly different 96-hour mortality or non-lethal injuries. (Both lift systems appear to be fish friendly and do not cause significant mortality or non-lethal injuries.) There was no significant difference in fish condition factor between fish passing through the two systems. Pulse flows were not effective at moving fish through the screening facilities but did increase movement through the bypasses.

University of California Davis Fish Swimming Tests

Screen water approach velocity is one of the key fish screen design criteria. An approach velocity of 0.2 fps is required by USFWS (DFG and NMFS) to protect delta smelt and 0.33 fps for juvenile chinook salmon. DWR, USBR, and CALFED have funded the construction and operation of a "fish treadmill" at UC Davis to determine the long-term (several hour) swimming abilities of several fish species in front of a simulated screen.

In separate presentations Zhiquang **Chen** (UC Davis, for Levent **Kavvas**; abstract #58), Joe **Cech**, UC Davis; abstract #18) and Christina **Swanson** (UC Davis; abstract #114) described the above apparatus and representative test results. The treadmill itself is a circular flume with a fixed inner screen and a rotatable outer screen with a 2-ft wide test channel between the screens. The system can be operated with various combinations of approach and sweeping velocities. Splittail, delta smelt, juvenile chinook salmon, and steelhead are among the species tested. Preliminary results indicate that screen contact rates (which can lead to mortality) were a function of approach and sweeping velocities and the amount of light. Screen contacts, and resultant injuries, were higher at night than during the day. There were significant differences in the frequencies and effects of impingement among the species tested. These data will be used in designing more fish friendly screens.

Poster Presentations

James **Haefner** and M. Bowen (abstract #159) simulated fish movement and hydrodynamics in a model to determine fish collection efficiency in a louver screen system. Predicted screen efficiencies at the Tracy facility varied from a low of 66% for delta smelt to a high of 81% for chinook salmon.

Louis **Helfrich** et al. (abstract #164) demonstrated that an internal helical pump tested at the USBR's Tracy facility could lift a variety of fish with little mortality and low incidence of scale loss on such fish as juvenile splittail. Pumps are being considered for the modernization of fish protection facilities at the federal and State Delta project intakes.

Lisa **Holm** and D. Briggs (abstract #167) showed how field data collection at the new screened intake to Los Vaqueros Reservoir indicates that the new design—a screen located at the side of

a channel with high sweeping velocities—has proved successful at minimizing the pumping plant damage to fish.

Cathy **Karp** et al. (abstract #172) used an experimental flume to evaluate the ability of various louver angles and slat spacing to separate larger fish from smaller fish. Preliminary data suggest that a 30-degree angle with slats spaced 2 inches apart achieved the highest degree of fish sorting. Since the larger fish prey on the smaller ones, separating the fish is important because it may increase salvage efficiency.

Steven **Foss** (abstract #153) compared salvage trends of native and non-native fish at the State and federal fish protection facilities. He also looked at factors that might influence salvage such as season, time of day, water temperature, and percent of Delta outflow being diverted.

Robert **White** (abstract #207) evaluated screen technology to exclude mitten crabs from the Tracy fish facility. A vertical traveling fish screen appeared to exclude about 90% of the crabs with no effect on fish passage.

Paciencia **Young** (abstract #210) used the fish treadmill to evaluate the stress responses of juvenile splittail exposed to a simulated screen. The tests indicated that a 2-hour exposure may have stressed the test fish, with the physiological responses returning to normal after 24 to 48 hours. There was greater stress at higher temperatures.

Introduced Species

Over the past 150 or so years accidental and purposeful introductions of plants and animals from around the United States and the world have dramatically changed the basic food webs in the San Francisco Estuary. In fact, the estuary has been described as the most invaded water body in the world. These invasions, which continue today, are of particular importance to the CALFED Bay-Delta Program in that some of the introduced organisms may affect the outcome of restoration actions. For example, such introduced fish as largemouth black bass and carp may colonize restored shallow water habitat to the detriment of the native Sacramento splittail and chinook salmon.

New Introductions and Their Effects

James **Orsi** (DFG; abstract #94) described the results of about 30 years of zooplankton distribution and abundance monitoring in the upper estuary. During that period at least 12 new zooplankters have become established, with some remaining abundant while the numbers of others fluctuate. Although the data are preliminary, new species appear to be more apt to become established after droughts. In general the native copepods are decreasing in abundance while the introduced ones are increasing, and the new copepods are more likely to be predators on other zooplankton.

Wim **Kimmerer** (SFSU Romberg Tiburon Center; abstract #61) used laboratory experiments to evaluate the effects of the introduced Asian clam, *Potamocorbula amurensis*, in the abundance of a native zooplankter, *Acartia* sp. He and his colleagues found that the small animal can easily escape being entrained by the clam and that the observed decline in the species was more likely due to the clam's effect on food supply than due to direct predation by the clam.

Frederick **Feyrer** (DWR; abstract #37) examined the food contents in the guts of five fish species using Suisun Marsh (3 native fish and 2 introduced) during 1998-1999. He compared his results with those of a similar study conducted before the Asian clam became established in the estuary during the mid 1980s. He found that the diets were similar during both periods but that there was a 6-fold decline in the numbers of a key small shrimp (*Neomysis*) between the pre- and post-clam-invasion periods. Although the fish appeared to be able to use other food sources (some of which were introduced species), in some fish there was an apparent decrease in average size and number of eggs from the early 1980s to the 1990s. The differences may cause population effects.

Edwin **Grosholtz** (UC Davis; abstract #48) presented results on the effects of the European green crab (*Carcinus maenas*, introduced to the estuary in 1989-1990) on the benthic community. His studies, conducted in Bodega Bay, show that the crab can decimate local populations of clams and other invertebrates and can indirectly affect fish and shorebirds. He called for CALFED to move away from managing individual introduced species to a broad program funding education, outreach, and prevention of species introductions.

Debra **Ayres** (UC Davis; abstract #2) has been looking at the biology, spread, and effects of a saltmarsh grass, the tall eastern cordgrass *Spartina alterniflora*, introduced purposefully to the estuary about 25 years ago. She and others have found that the new cordgrass colonizes open mud flats, thus decreasing the amount and quality of this important shorebird habitat. She also used genetic techniques to determine that the new species is hybridizing with its shorter native cousin, *Spartina foliosa*, and the hybrid potentially may cause more ecological problems than the original introduction.

Introduced Species and Shallow Water Habitat Restoration

James **Toft** (U. Washington; abstract #119) described some results of a CALFED-funded study examining the wetlands behind a set of levees that had been breached over a period of years. He and his colleagues looked at the fish and invertebrate communities associated with the introduced water hyacinth and the native pennywort. Although there was extensive intersite variation, it appeared that non-native invertebrates were most abundant in the introduced plant whereas native invertebrates were more common on the pennywort. The non-native invertebrates were smaller and had lower fish food value. The investigators also identified three new non-native invertebrates.

Laura **Hanson** (Contra Costa Mosquito and Vector Control District; abstract #50) and her colleagues have been monitoring the abundance of a non-native shrub in a wetland south of Suisun Bay restored in 1991. During the dry years, they noted an increase in abundance and distribution of this introduced plant. In this project, restoration increased abundance of one non-native plant but not another. She emphasized that restoration projects need to be monitored over a range of climate conditions to determine if they are achieving the original ecological objectives.

Poster Presentations

Carri **Benefield** and C. Gallagher (abstract #134) described how purple loosestrife, an ornamental plant that escaped from homes and gardens around the country, has become common in California. It is now found in small, scattered populations in the Delta and its watershed. An extensive collaborative effort of State and federal agencies and watershed groups is attempting to develop outreach and management strategies to limit the spread of this noxious weed.

Deborah **Rudnick** et al. (abstract #194) described results from a study of the ecology, and distribution, and effects of the introduced Chinese mitten crab showing that the animal is widely distributed in the Bay-Delta and its tributary streams. Field and laboratory studies indicate that the crab may affect widespread ecological changes in the system.

Robert **White** et al. (abstract #207) presented results from another study of the Chinese mitten crab that was initiated to determine if a traveling vertical fish screen could exclude adult crabs from the intake to the USBR Delta-Mendota Canal. Preliminary results indicated that about 90% of the crabs were removed with no apparent effects on fish during the mid-September through mid-October study period.

Effects of Contaminants and Other Chemical Stressors

Since the passage of the national Clean Water Act much has been accomplished to reduce the levels of contamination in the State's waterways and to measure the distribution of individual contaminants in these waterways and adjacent lands. However, many uncertainties remain with regard to the effects of contaminants on habitats and biota. Mercury from mines and other sources, selenium from the western San Joaquin Valley and local refineries, and contaminants in runoff from agricultural land and urban areas, particularly pesticides, all have the potential to harm fish and wildlife species and impede progress in CALFED programs for restoring healthy species populations. Speakers in this session addressed several of the most important topical questions from a variety of perspectives.

Mercury

Wetland habitats in general, and flooded wetlands in particular, are susceptible to elevated levels of toxic methyl mercury as a result of historic sources and uses of elemental mercury (mine runoff and hydraulic mining debris). Thus, restoration projects involving the intentional breaching of existing levees may have the potential to increase levels of toxic methyl mercury in the Bay-Delta ecosystem.

Thomas **Suchanek** (UC Davis; abstract #113) reported on a study of mercury contamination in a series of islands and agricultural tracts that have been flooded by levee breaches that occurred from 3 to 67 years ago. In a companion study, Darrel **Slotton** (UC Davis; abstract #107) examined mercury exposure in biota (crayfish, *Corbicula* clams, and inland silversides) at over 60 sites throughout the Delta and used laboratory experiments with sediment cores to determine the conditions under which methylation occurs. Peaking after only several days, methylation was greatest in organic-rich wetland areas. These two studies showed that while flooded tracts in the Central Delta exhibited the highest potential for mercury methylation, accumulation by biota was highest in proximity to mining sources and in the Western Delta near the fresh/saltwater mixing zone.

Jay **Davis** (SFEI; abstract #28), using results from three monitoring programs, reported that nearly two thirds of largemouth bass and white catfish sampled in the Delta, Sacramento River and San Joaquin River contained high mercury levels, with highest concentrations in the lower watersheds of the rivers, and lower concentrations in the central and southern Delta.

Janis **Cooke** (CVRWQCB; abstract #23) described the process being used by the Regional Water Quality Control Board to develop a safe mercury level for human consumption of fish - determined to be 0.1 micrograms of mercury per gram of fish, wet weight. The process will lead

to the establishment of a total maximum daily load that, if implemented, should reduce contaminant levels to the point where consumption of fish by human and wildlife predators would be considered safe.

Poster Presentations

Robin **Bouse** et al. (abstract #137) described how the combined use of isotope markers and mineralogical characteristics of sediments in cores and historical bathymetric data has provided a tool for determining the distribution and amounts of mercury in mining debris throughout the watershed.

Jay **Davis** et al. (abstract #148) defended the need for mercury monitoring in areas proposed for wetland restoration because of concerns about the conversion of elemental mercury to its toxic form, methyl mercury, in the sediments throughout the estuary and watershed.

Jason **May** et al. (abstract #181) described results from a study of mercury contamination of fish in the Bear and South Yuba watersheds that showed 65% of the bass contained greater than 0.5 ppm total mercury, concentrations that may pose a health risk to animals that feed on these fish.

Dissolved Oxygen in the Stockton Ship Channel

For at least the past 30 years each autumn, concentrations of dissolved oxygen in the deep-water ship channel near Stockton have fallen to below 5 to 6 mg/L, a level below the EPA and Regional Water Quality Control Board standards for aquatic health. The presence of low oxygen water in the ship channel appears to act as a barrier to the migration of fall-run chinook salmon.

Peggy **Lehman** (DWR; abstract #71) described an ongoing sampling program designed to documenting water quality conditions at a number of sites along the channel. Study results suggest that growth and decay of phytoplankton produced locally in the channel was sometimes a greater contributor to the dissolved oxygen problem than phytoplankton delivered from upstream.

Hari **Rajbhandari** (DWR; abstract #99) described how a one-dimensional hydrodynamics and water quality model, DSM2, is being used to simulate the dynamics of dissolved oxygen, algal growth, and nutrients in the ship channel. The goal is to develop the model as a predictive tool in developing total maximum daily load standards.

G. Fred **Lee** (Lee & Associates; abstract #69) presented an overview of the dissolved oxygen problem in the ship channel, suggesting that a substantial part of the oxygen demand is due to the discharge of nitrogen and phosphorous into the San Joaquin River and tributaries, that, when transported with other oxygen demanding materials to the slower moving, deeper water of the ship channel, contribute to enhanced algal production, decay, and oxygen consumption. Water diversions, contributing to longer hydraulic residence times in the lower rivers and ship channel, aggravate the problem. He elaborated on the need for reducing upstream oxygen-demanding loads. In the meantime, aeration of the water column in the ship channel may be necessary to alleviate the immediate problem for migrating salmon.

Selenium

Selenium, in high concentrations a well-known hazard for wildlife, exists in multiple chemical states, and its bioavailability depends on the chemical state found at any location in the environment.

Gregory **Cutter** (Old Dominion U.; abstract #27) showed that recent values of total dissolved selenium concentrations in the San Francisco Bay are nearly unchanged from values observed in a mid-1980s study. While the abundance of selenite, with a mid-estuary oil refinery effluent source, has decreased during this period, suspended particulate selenium is still high, and phytoplankton and zooplankton are enriched in selenium relative to inorganic particles. Further, greater than 75% of the selenium in suspended particulate matter is the bioavailable form, organic selenide that can be incorporated in the food chain at toxic concentrations.

Stephen **Baines** (SUNY Stony Brook; abstract #3) reported on laboratory experiments with radiolabeled selenium-75 designed to determine the relative rates of uptake of selenite, selenate, and organic selenides by phytoplankton. He found that uptake by phytoplankton represented a major pathway for transfer of selenium up the food chain, particularly organic selenides. However, the relative rate of transfer to consumers would be dependent on the species of phytoplankton consumed.

Robin **Stewart** (USGS; abstract #112) used stable isotopes of carbon, nitrogen, and sulfur to examine the pathways of selenium movement through the food web. She found that higher selenium concentrations were found in a bivalve-based food web than a crustacean-based food web, in part because clams have a slower rate of excreting selenium from their tissues. As a result, fish and birds that feed on clams have higher body burdens of selenium.

Nicholas **Fisher** (SUNY Stony Brook, for Nicholas **Baines**; abstract #4) examined uptake of selenium by larval striped bass in the laboratory, finding that assimilation of selenium was at a rate more rapid than that observed for the assimilation of the metals silver, cadmium, and zinc. Highest concentrations of selenium were found in the larval fish livers. The rapid uptake of selenium explains the high selenium concentrations found in fish feeding on selenium-enriched food.

Poster Presentations

Erin **Amweg** and Donald Weston (abstract #130) showed that the use of a prototype Algal-Bacterial Selenium Removal System in the Panoche District was effective in removing 40% of total selenium from agricultural drain water. However, field and laboratory tests of the uptake of selenium by organisms in the effluent revealed that the remaining selenium is converted to a more bioavailable form.

Byeong-Gweon **Lee** and Samuel Luoma (abstract #177) showed a difference in the bioaccumulation of selenium in two species of clam (*Corbicula* and *Potamocorbula*) in laboratory studies. The difference seemed to be dependent on the optimal salinity regime preferred by each of the species (fresh and saline respectively).

David **Purkerson** et al. (abstract #190) conducted a field study of selenium in zooplankton in San Francisco Bay and demonstrated that while there were no significant spatial patterns, higher concentrations were found in smaller organisms and during low flow seasons.

Christian **Schlekat** et al. (abstract #198) described results from a laboratory study that showed that selenium transfer to wildlife feeding on bivalves is more efficient because bivalves assimilate most of the selenium they ingest and lose the element slowly. In contrast, wildlife feeding on planktonic organisms, for example, zooplankton and mysids, are not similarly exposed because the zooplankton prey lose their assimilated selenium rapidly.

Pesticides

The wide use of pesticides in commercial agriculture and domestic gardens represents a threat to aquatic biota because the residues are commonly transported to waterways during rainfall and runoff events at concentrations that are known to be toxic to some organisms.

Scott **Ogle** (Pacific EcoRisk; abstract #93), reporting on bioassay and benthic community composition results from the San Francisco Estuary Institute Regional Monitoring Program for Trace Substances, showed that there do not appear to be consistent, widespread toxicity problems within the San Francisco Bay's waters. Nonetheless, significant events of toxicity have occurred, particularly in the region between just upstream of the confluence of the Sacramento and San Joaquin rivers and the mouth of the Napa River following major storm events, possibly the result of organophosphate pesticides in storm water runoff.

Kathy **Kuivila** (USGS; abstract #66) identified four major seasonal patterns of source inputs (pesticide applications on orchards in winter; alfalfa and rice in spring; and irrigation return flows in summer) that have potential environmental effects. While usage of organophosphate pesticides is declining, usage of pyrethroids (more toxic to fish) is increasing. Studies of the effects of pesticides are hampered because more than 150 pesticides are applied annually in the Delta watershed yet only a small fraction of these is analyzed in monitoring studies, making it difficult to pinpoint which pesticides may be causing problems. Part of the solution to this problem may be in focusing on species-specific questions, that is, effects during vulnerable life stages.

Kathleen **Russick** (Russick Environmental Consulting; abstract #102) reported that organophosphate pesticides in Sacramento urban creeks were found at toxic concentrations 40% of the time, that is, during periods of rainfall and runoff. Increased monitoring and public education are underway to evaluate the extent of the problem and to get the public to better appreciate their role in reducing it.

Frank **Zalom** (UC Davis; abstract #127) described an experimental study of the movement of organophosphate pesticides through an orchard with differing orchard floor vegetation cover by measuring the toxicity of the runoff that passed through each type of cover. A goal of the project is the development of best management practices (BMPs) for pesticide usage and control in both orchard and urban settings.

Nicholas **Poletika** (Dow Agrosciences; abstract #98), using the example of stressors on native taxa in Orestimba Creek, suggested that the use of conceptual modeling and cumulative risk assessment is necessary to discriminate among multiple stressors, that is, between the effects of pesticides and invasive species.

Poster Presentations

Susan **Anderson** et al. (abstract #131) conducted field and laboratory studies of the effects of organophosphate pesticide on the California sucker, revealing high genetic damage in the San Joaquin River, although other contaminants could also be contributors.

Till **Angermann** et al. (abstract #132) developed a new method to show how pesticide concentrations in runoff from an orchard are influenced by the type of vegetation cover.

Jody **Edmunds** et al. (abstract #150) found that pesticide concentrations in the Delta do not appear to limit phytoplankton primary production on a system-wide scale. However, localized occurrences of elevated herbicide concentrations exist and may inhibit primary production at local scales.

Jacqueline **Houston** et al. (abstract #169), using pesticide data from 40 sites in the Delta, showed that there are four major seasonal patterns of distribution identified by usage and transport mechanism. Several pesticides, despite being applied in large amounts, are rarely if ever detected, probably because of their chemical properties.

Edward **Moon** et al. (abstract #183),studied the exposure of delta smelt to dissolved pesticides during its vulnerable larval and juvenile stages life stages and found that while concentrations were well below toxicity values for the individual pesticides, the combination of multiple pesticides could potentially have sublethal effects.

Carl **Orazio** et al. (abstract #184) described a study that is underway to develop broad-based analytical screening methods for detecting agrochemicals in clams.

James **Orlando** and Kathryn Kuivila (abstract #185) suggested that trends in diazinon and methidathion loads in the Sacramento and San Joaquin rivers are not explained by pesticide application data alone. A more direct relationship exists between concentrations in the rivers and a combination of application; timing, amount, and location of rainfall; soil types; and the hydrologic connection between the orchards and the rivers.

Swee **Teh** et al. (abstract #204) examined the effects of the pesticides esfenvalerate and diazinon on Sacramento splittail with 96-hour laboratory exposure tests using field water samples and recording cumulative mortality, fish weight, and biochemical and histopathological indicators of sublethal effects.

Inge **Werner** et al. (abstract #206) used acute toxicity tests of fathead minnows to evaluate best management practices for controlling organophosphorous pesticide runoff through a prune orchard.

Frank **Zalom** et al. (abstract #211) developed a method to identify potential costs associated with viable options to the dormant spray using a number of variables such as monitoring cost, number of applications and cost of alternative pesticide(s), and number of in-season sprays in excess of those normally applied.

Endocrine Disruptors

Mark **Snyder** (UC Davis; abstract #109) described a new study being designed to examine the effects of endocrine disruptors (EDCs) on an estuarine shrimp species that is widely distributed within the Sacramento-San Joaquin Delta and associated tributaries. Combining studies of embryonic development, larval feeding and swimming behaviors, and biochemical markers, the study participants are determining the relative risks that EDCs may have on the life cycle of important estuarine invertebrates.

Contaminant Assessment Strategies

Bruce **Thompson** (SFEI; abstract #117) reported on a sediment quality assessment using the triad of sediment contamination (the "Effects-Range Median" index of trace contaminants), sediment toxicity (bioassays), and benthic community composition. While the results from the three methods similarly revealed "hot spots" of contamination, they were not always correlated, suggesting other sources of toxicity or other stress.

Donald **Weston** (UC Berkeley; abstract #124) described a method of extracting contaminants from sediments using the digestive fluid of aquatic organisms, a method that may allow for predicting the potential for bioaccumulation of contaminants by organisms exposed to the contaminated material in the those sediments.

Poster Presentation

Clifford **Hui** and W. Beyer (abstract #170) described an effort to develop a means of estimating bird contaminant exposure from bill morphology and feeding behavior, but obtained results that were contrary to expectations.

Other Contaminant-related Poster Presentations

Cynthia **Brown** et al. (abstract #139) described a decade-long study of contaminants in the Asian clam in northern San Francisco Bay that has shown that the amounts of particular metals and their biological effects are determined by an array of factors including river flow variations, different sources of the metals, and different seasonal dynamics among the metals.

Daniel **Cain** et al. (abstract #141) measured concentrations of metals in an insect in the upper Sacramento River between Redding and Tehama (for example, at least 120 km downstream of the mine sources), and found cadmium concentrations comparable to concentrations in the same organism from the Clark Fork River in Montana, where metal exposure has been associated with effects on benthic invertebrates and resident trout.

Drinking Water

Delta withdrawals provide drinking water to more than 22 million people in California as well as being a major water supply for irrigated agriculture. Treating Delta water to meet drinking water standards requires, among other things, simultaneous disinfection for pathogens and minimization of disinfection byproducts (DBPs) such at trihalomethane (THM), many of which are suspected health risks. Disinfection byproducts result when chlorine or ozone react with organic carbon and bromide, both of which are present in significant concentrations in Delta waters. Although present treatment plants meet or exceed EPA's DBP standards using Delta source water, EPA's regulatory process may lower DBP standards and raise pathogen inactivation requirements. Unless levels of pathogens, organic carbon, and bromide can be reduced in Delta withdrawals, meeting anticipated future drinking water standards will require some combination of substantial investments in treatment facilities, new treatment technologies, and higher quality water sources to blend with Delta supplies.

Reducing the quantity of seawater mixed into Delta withdrawals is the mechanism for lowering bromide concentrations because seawater is the dominant source of bromide. Mechanisms are less clear, however, for controlling organic carbon in Delta withdrawals, particularly for controlling those fractions that form DBPs. The problem is further complicated because Delta organic car-

bon is also a major food source for the bay's ecosystems. The organic carbon session focused on ecosystem issues; this session focuses on drinking water issues.

Brian **Bergamaschi** (USGS; abstract #10) showed that concentrations of dissolved organic carbon (DOC) in Delta waters and in the Sacramento and San Joaquin rivers vary annually from about 2 to 12 mg/L, but that the changes do not appear to result from inputs from a single source or class of sources. Analysis of a decade of data produced little evidence that addition of island drainage to Delta channel waters is the major cause of a persistent elevation of DOC concentrations above river concentrations. An intensive study of the chemistry of a small number of Delta samples also suggests: (1) DOC in Delta channel water samples had greater THM formation potential (on a per carbon basis) than peat island drain water; (2) DOC in Delta channel waters was not a simple mixture of peat-island-derived carbon and river-borne carbon; and (3) processes such as primary production and microbial degradation appear to affect significantly both the quality and concentration of DOC in Delta channel waters as they transit the Delta.

Miranda **Fram** (USGS; abstract #40) described how studies of sources and quality of dissolved organic carbon (DOC) could help improve source water quality in San Diego's Sweetwater Reservoir. Sweetwater Reservoir and Delta withdrawals both have elevated concentrations of bromide and DOC and receive DOC from rivers, wetlands, and algal and microbial production. The findings from the mass-balance study suggest that changes in reservoir management could result in a 10% to 40% reduction in THM formation potential (THMFP). First flushing of the river channel above Sweetwater Reservoir, grass in a seasonally flooded zone of the reservoir, and algal production in the reservoir contributed more DOC than local wetlands. The grass and algae also had showed the highest THMFP, and the first flush of the river contained elevated levels of bromide.

Roger **Fujii** (USGS; abstract #41) evaluated changes in DOC and THMFP that resulted from experimental wetland restorations in a managed open-water wetland, a shallow-flooded wetland, and an agricultural field on Twitchell Island. The shallow-flooded wetland had higher concentrations of DOC, THMFP, and THMFP per unit carbon than drainage from the agricultural field. Although THMFP per unit carbon increased even more in an open-water wetland, its DOC and THMFP concentrations were lowest among the three cases. All of these concentrations were higher than those in channel waters nearby. The results indicate that DBP characteristics of DOC differ among DOC sources - peat soils, wetland plants, and crops—and that loads of DOC and THM precursors must be calculated to evaluate relative effects of these land uses on the quality of Delta withdrawals.

Acknowledgments

The authors appreciate the efforts of the individuals who assisted in the planning, organization, and running of the very successful first CALFED Science Conference. In particular, we would like to acknowledge the other members of the organizing committee who helped make the conference the success that it was: Bill Bennett, Marcia Brockbank, Larry Brown, Dick Daniel, Tim Hollibaugh, Wim Kimmerer, Peggy Lehman, Joan Patton, Bruce Thompson, and Jo Turner. We also want to acknowledge the efforts of the session chairs who organized and led the technical sessions, and the notetakers who provided very informative synopses of each oral presentation. The session notes can be found at the conference website. Finally, we want to thank those people who worked behind the scenes to make our website such an attractive and effective tool for conference publicity, abstract submittal and registration: Karl Jacobs created and maintained the website; Erin Johansen designed the CALFED Science Conference logo; Jim Hagy of the Estuarine Research Federation provided the software for abstract submittal; conference announcements were designed by Marcie Adams and Nina Lisowski; and the Association of Bay Area Governments provided the software for registration and handled the conference accounting.

Appendix A:
Session Titles, Session Chairs, and Notetakers

Climate Variability and CALFED

Session Chair..... Michael Dettinger, USGS

Session Notes.....Daniel Cayan, USGS

Hydrodynamics

Session Chair.....Jon Burau, USGS

Session Notes..... Peter Smith, USGS

Fluvial Processes

Session Co-Chairs..... G. Mathias Kondolf, UC Berkeley, and Jeffrey Mount, UC Davis

Session Notes.... Laura Rempel, University of British Columbia, and Elizabeth Vonckx, UC Davis

Levee System Integrity

Session Chair.....Lauren Hastings, CALFED

Session Notes..... Gwen Knittweis, CALFED

Tidal Wetlands Processes

Session Chair.....Larry Brown, USGS

Session Notes.....Michael Chotkowski, USBR

Organic Carbon and Lower Trophic Level Processes

Session Chair.....Wim Kimmerer, SFSU, for Tim Hollibaugh, University of Georgia

Session Notes.....William Sobczak, USGS

Species of Special Concern

Session Chairs..... William Bennett, UC Davis, and Peter Stine, USGS

Session Notes..... James Hobbs, UC Davis

Salmonids

Session Chair..... Randall Brown, DWR

Session Notes..... Kenneth Lentz, USBR

Fish Facilities and Fish Screening

Session Chairs.....John Andrew, DWR, and Dan Odenweller, DFG

Session Notes.....Marianne Kirkland, DWR

Effects of Nonnative Invasive Species

Session Chair.....Kim Webb, USFWS

Session Notes..... Deborah Rudnick, UC Berkeley

Effects of Contaminants and Other Chemical Stressors

Session Chairs.....Valerie Connor, CVRWQCB, and Victor DeVlaming, SWRCB

Session Notes.....Kelly Briggs, Robert Holmes, and Karen Larsen, CVRWQCB

Drinking Water Quality

Session Chair..... Elaine Archibald, Consultant

Session Notes.....Erica Kalve, USGS

Poster Session

Session Chairs..... Peggy Lehman, DWR, and Bruce Thompson, SFEI

Appendix B:
List of Acronyms

ABAG ..... Association of Bay-Area Governments

BMP ..... best management practices

cfs ..... cubic feet per second

CMARP ..... CALFED Comprehensive Monitoring, Assessment, and Research Program

CVPIA ..... Central Valley Project Improvement Act

CVRWQCB ..... Central Valley Regional Water Quality Control Board

DBP ..... disinfection byproduct

DOC ..... dissolved organic carbon

DFG ..... California Department of Fish and Game

DWR ..... California Department of Water Resources

EBMUD ..... East Bay Municipal Utility District

EPA ..... U.S. Environmental Protection Agency

ERP ..... CALFED Ecosystem Restoration Program

ESA ..... Endangered Species Act

EWA ..... Environmental Water Account

IEP ..... Interagency Ecological Program

ISB ..... CALFED ERP Interim Science Board

LLNL ..... Lawrence Livermore National Laboratory

NERR ..... San Francisco Bay National Estuarine Research Reserve

NMFS ..... National Marine Fisheries Service

NOAA ..... National Oceanic and Atmospheric Administration

PDO ..... Pacific decadal oscillation

RBDD ..... Red Bluff Diversion Dam

SFEI ..... San Francisco Estuary Institute

SFSU ..... San Francisco State University

SIO ..... Scripps Institution of Oceanography

SSC ..... suspended sediment concentration

SST ..... sea surface temperature

SUNY ..... State University of New York

SWRCB ..... State Water Resources Control Board

THM ..... trihalomethane

THMFP ..... trihalomethane formation potential

UC ..... University of California

USBR ..... U.S. Bureau of Reclamation

USFWS ..... U.S. Fish and Wildlife Service

USGS ..... U.S. Geological Survey

Appendix C:
The Adaptive Management Process