Interagency Ecological Program for the Sacramento-San Joaquin Estuary

Newsletter

Autumn 1994

Readers are encouraged to submit brief articles or ideas for articles. Correspondence, including requests for changes in the mailing list, should be addressed to Randy Brown, California Department of Water Resources, 3251 S Street, Sacramento, CA 95816-7017.

Comments on a Peripheral Canal

H.K. Chadwick

My comments are in response to an article on a peripheral canal[1] published in the *Interagency Newsletter* a year ago.

First, my comments pertain to the concept of moving all CVP/SWP southern delta diversions to the Sacramento River rather than to a specific physical structure. Thus, my comments largely ignore important issues associated with the specific physical structure, which would affect the biological consequences substantially. This concept reflects my bias that if one builds a large conveyance facility to the Sacramento River, it is probably unwise biologically to continue diverting the relatively small remaining flows in the San Joaquin River.

I agree with the basic point in Wim's discussion that the well-being of some aquatic resources depends primarily on factors associated with outflow and that those resources would receive no benefit from a peripheral canal. Strong evidence suggests that longfin smelt, starry flounder, and *Crangon franciscorum* are in this category. One wonders how many aquatic resources have such flow-dependent effects. A particular need is to explore evidence as to whether primary and secondary productivity in the lower estuary are related to flow.

In any event, certain resources in the estuary clearly depend on adequate outflow, regardless of the physical system used to divert water.

I also agree that a peripheral canal offers benefits only for species adversely affected by entrainment. Wim's description, however, might be interpreted as defining entrainment as only including organisms actually entering the CVP/SWP intakes. Entrainment must be defined to include any organisms diverted from natural migration paths or habitat by hydrodynamic changes caused by diversions or structures built to accommodate the diversions. The latter caveat is important primarily to include effects of the Delta Cross Channel.

Fish adversely affected by entrainment include striped bass, delta smelt, all races of salmon, white catfish, American shad, and splittail. Some of these, particularly striped bass and delta smelt, almost certainly receive important intrinsic benefits both from outflow and by avoiding entrainment. Statistical models are inherently weak in quantifying the relative benefits of outflow and avoiding entrainment, particularly for any new physical configuration of the delta. Hence, considerable uncertainty is probably inevitable in assessing the benefits of a peripheral canal or any other water diversion facility.

Incidentally, regarding the conclusion that entrainment losses are negligible for *Neomysis*, the fact that *Neomysis* move farther off the bottom during flood tide than during ebb tide seems like an important mechanism for maintaining the location of the population in the estuary. Might that not make the population vulnerable to

1 Wim Kimmerer, BioSystems Analysis Inc. "The Peripheral Canal: What We Need to Do Before We Start Building". *Interagency Newsletter*. Autumn 1993.

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reverse flows, causing significant increases in mortality due to upstream transport from optimum habitat, even if only a small fraction were actually entrained at the export pumps?

I was left with the impression that the article inaccurately stated the case relative to the group of resources affected by entrainment. For one thing, the article states: "The idea that entrainment of fish is the sole important issue in the delta has become an article of faith ...." I don't think I know any biologist who believes that. Most biologists who supported a peripheral canal did so with the caveat that it be "properly operated". Maintenance of adequate outflow is a key aspect of proper operation.

Also, the article tends to diminish the group of fish affected by entrainment by saying: "Emphasis for protection of estuarine species has shifted away from striped bass toward special-status species such as delta smelt and winter-run Chinook salmon." That is true, but the group adversely affected by entrainment includes both special-status species and species that support most recreational and commercial fishing dependent on the estuary. Hence, restoration of aquatic resources clearly requires measures to alleviate adverse effects from both flow and entrainment, as well as measures to deal with other aspects of habitat degradation.

Returning to issues associated directly with moving the CVP/SWP diversion point to the Sacramento River, a strong case can be made for benefits to each of the species adversely affected by entrainment, with the possible exception of races of salmon originating in the Sacramento River. The benefits still can't be defined quantitatively, but there is good reason to believe they are substantial.

The possible exception of races of salmon originating in the Sacramento River is important. Briefly, entrainment harms those salmon significantly now, primarily by higher mortality in the delta rather than actual losses at the CVP/SWP intakes, but installing a fish screen effective enough to create a net benefit will be a major challenge. (I agree with Wim's point about the importance of measures upstream from the estuary for salmon restoration.)

The point about a need for certain studies is well taken, but I don't think results achievable in the next 3 to 5 years will be nearly as definitive as the article infers. That is not to say appropriate studies should not be pursued; they should.

Some of the questions posed are directly related to benefits achievable through flow augmentation and other measures, so a logical extension of the argument for doing nothing until we know more is a moratorium on all management measures. Of course, that is not Wim's intent, and I certainly wouldn't advocate it.

We will not have the technical capability to quantify changes that would result from many potential management strategies. Hence, the alternative to continued degradation is to implement measures based on best available evidence, evaluate them, and expect to make adjustments. As Wim infers, that is particularly risky when expensive, physical structures are involved, and it can bring blame on those whose recommendations proved faulty.

One needs to honestly recognize the uncertainties in describing management alternatives. That is the only answer I have to the dilemma Wim poses in his conclusions. It is an imperfect answer, because uncertainties will be exploited by opponents to stop implementation and ignored by those wanting to assess blame.

Program Manager

On May 15, Pat Coulston (DFG Bay-Delta Division) formally took over Interagency Program Study Manager responsibilities from Perry Herrgesell. (Since we removed "studies" from the program title, it may be appropriate to call Pat the Program Manager.) Pat came to DFG in 1985 from the private sector (EA Engineering, Science, and Technology). Pat's first assignment at DFG was as a biologist on the San Francisco Bay/Delta Outflow Study; he later did staff work for the "Article VII" negotiations. Before assuming the role of Program Manager, Pat led the Fish Facilities Unit at Bay-Delta and was chair of the "old" Interagency Program Fish Facilities Technical Committee. Pat is actually doing "double duty" these days while DFG tries to fill the fish facilities position. We hope DFG can fill the position soon so Pat can concentrate on keeping the Interagency Program on track.

Data Management

The Metropolitan Water District of Southern California recently hired Tom Cannon as a consultant to work with Interagency Program staff and management to organize our data. Tom indicated that his role is to provide assistance in such areas as data entry and programming, with the general goal of making our datasets available to anyone who wants to better understand the estuary. Tom will be working closely with the Program Manager, the data committee, management committee, and project staff.

Spread and Control of Alien Smooth Cordgrass in San Francisco Bay

Donald R. Strong and Curtis C. Daehler, Bodega Marine Laboratory

Open intertidal mud without vegetation is one of the most striking features of Pacific estuaries. This contrasts with estuaries of the Atlantic and Gulf coasts, where dense tall *Spartina* cordgrasses dominate. The very character of Pacific estuarine ecology is defined by its open mud. Shore birds, some marine mammals, fish, and invertebrates, as well as flood control, recreation, and general navigation, depend on the openness of the habitat. *Spartina alterniflora*, smooth cordgrass, introduced to San Francisco Bay in the mid-1970s, is among the most aggressive, dominant, and persistent cordgrasses worldwide. This plant grows into dense, tall thickets that block the beach, cement the substrate, and exclude animals. Densely packed *S. alterniflora* stems alter marsh hydrology by hindering tidal flow and drainage. Suspended sediments precipitate, and the plants' dense root mats trap and hold sediments, rapidly raising the level of the invaded marsh. Introduced initially at New Alameda Creek in the southeast corner of the bay, the plant has spread south to San Francisco Bay National Wildlife Refuge and north along the Hayward and Alameda shores. In the west bay, *S. alterniflora* is rapidly invading mudflats north and south of the San Francisco Airport. The most recent known colonization is at Redwood Shores, near Palo Alto.

Smooth cordgrass invading San Francisco Bay grows clonally, forming large, discrete, circular patches. These circular patches show every indication of being genetic clones, each formed from a single seed or vegetative fragment (Daehler and Strong 1994). There appears to be great variation among clones in ecological characters like flowering phenology, stem size, and rate of vegetative growth. We are now developing high resolution genotypic RAPD[1] markers to distinguish individual genetic clones and trace their spread. These markers will also be useful in identifying possible hybrids between *S. alterniflora* and our native cordgrass, *Spartina foliosa*. The native *S. foliosa* is endemic to California estuaries, growing only at the upper edge of intertidal mud. Introgression and competition with introduced *S. alterniflora* are major threats to the native *S. foliosa* in San Francisco Bay.

Our research has concentrated on understanding the biology of both introduced and native *Spartina* of the Pacific coast, with emphasis on protecting the native and controlling aliens. *S. alterniflora* experiences little in the way of interspecific competitors in Pacific marshes, so it is lacking a powerful ecological constraint upon spread. The potential for natural biological control of the alien is great in San Francisco Bay. A major insect herbivore of cordgrasses in the Atlantic, the aphid-like plant hopper *Prokelisia marginata* (Homoptera, Delphacidae; Strong *et al* 1984), occurs in San Francisco Bay, with our native *S. foliosa* its host (Daehler and Strong 1994). It feeds from the cordgrass' vascular system, through a proboscis or stylet, imbibing phloem fluid that carries carbohydrates and amides. While only modest population densities are attained by the plant hopper on the native California cordgrass, densities commonly climb to several hundred per stem and many thousands per plant on the alien *S. alterniflora* by mid-July (Daehler and Strong, in rev). The plant hopper also attains extraordinarily high densities on flowers of *S. alterniflora*. Numbers between 200 and 300 per inflorescence are not uncommon from July to October. In addition, we have discovered a new alien insect herbivore species, *Trigonotylus uhleri* (Homoptera, Miridae), which grows to densities of about 10 per stem and hundreds per plant in some locations on *S. alterniflora*; it is as yet rare on the native *S. foliosa*. *T. uhleri* feeds on the sap of *S. alterniflora*, leaving distinct chlorotic patches on the leaves. There is no information about how *T. uhleri*, native to the Atlantic seaboard, reached California, but its appearance demonstrates that the traffic of introduced species to San Francisco Bay is not limited to organisms carried in ballast water.

Cordgrass inflorescences are composed of hundreds of spikelets, each of which can make a single seed. Seeds float, greatly augmenting spread of the plant, and we hypothesized that insect herbivory decreases seed set and could thereby depress spread of the weed. We found, however, that this herbivory probably does not have much depressive effect because most *S. alterniflora* clones in Pacific marshes set relatively little viable seed, even in the absence of herbivory. Substantial variation exists among clones, with a small minority of clones accounting for the lion's share of viable seed. We surmise that ovule and embryo abortion may be occurring due to inbreeding depression in this primarily out-crossing plant. We are working on pollination experiments that should allow us to establish more definitively the reason for low seed viability in most clones. We compared the viability of field-collected seed from Willapa Bay, Washington, where the plant has also been introduced, with seeds from San Francisco Bay (Figure 1). No insect herbivores of *S. alterniflora* have reached Willapa Bay, yet there was no difference in viable seed set between plants there and plants in San Francisco Bay. We have found a similar lack of direct effect of the high densities of *P. marginata* on the vegetative growth of *S. alterniflora*. We excluded most plant hoppers from selected patches in the field for 14 consecutive weeks. There was no increase in the rate of vegetative growth of these patches (Daehler and Strong, submitted). Greenhouse experiments with seedlings, however, demonstrate variation among clones in ability to tolerate feeding by the plant hopper.

Our most recent project is to understand an extensive die-off of *S. alterniflora* at New Alameda Creek. Several acres of the plant failed to produce new shoots in 1994, and the plants are apparently dead. With the dry winter of 1993-94, New Alameda Creek had

1 Randomly amplified polymorphic DNA.

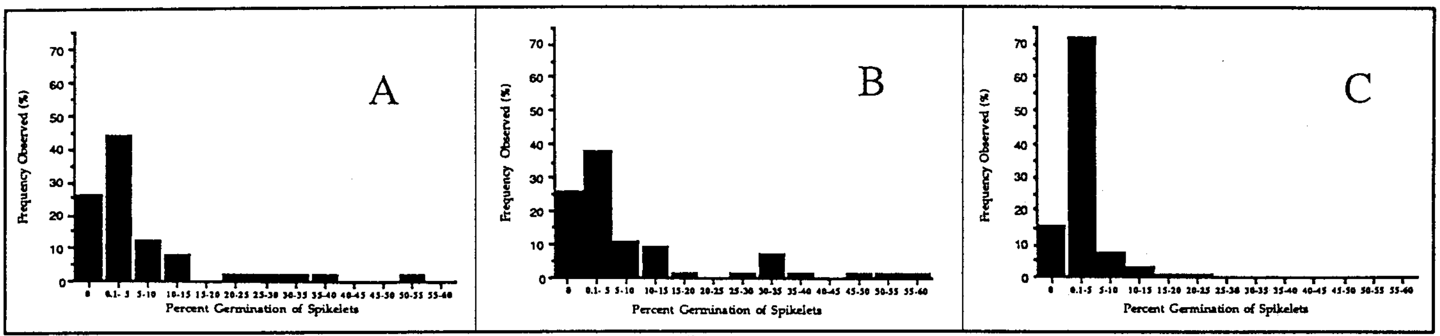

Figure 1
Frequency Distribution of Percent Spikelet Germination

A = Clones sampled from Willapa Bay, Washington, grown in the absence of herbivores (N=50).

B, C = Clones sampled from San Francisco Bay, California, herbivory by P. marginata. [B=Coyote Hills Slough, N=72; C=San Bruno, N=97.]

Germination distributions do not differ significantly between Willapa and San Francisco bays (Kolmogorov-Smirnov 2-sample test, P>0.2.) (From Daehler and Strong 1994)

little flow, and the stems of the previous year's growth remained *in situ* to form a thick layer of wrack. Our hypothesis is that the young shoots died due to an indirect effect of the wrack, which can foster high densities of the plant hopper. The tide sweeps away many plant hoppers in wrack-free environments, protecting young shoots and seedlings. Although invading *S. alterniflora* can tolerate high levels of herbivory under good conditions, herbivores could be a potent controlling factor under more stressful conditions.

Literature Cited

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Strong, DR, JA Lawton, TRE Southwood. 1984. *Insects on Plants*. Blackwell (Europe), Harvard Univ. Press (North America). 313 pp.

Editor's Note: This project is being funded by the Interagency Research Enhancement Program.

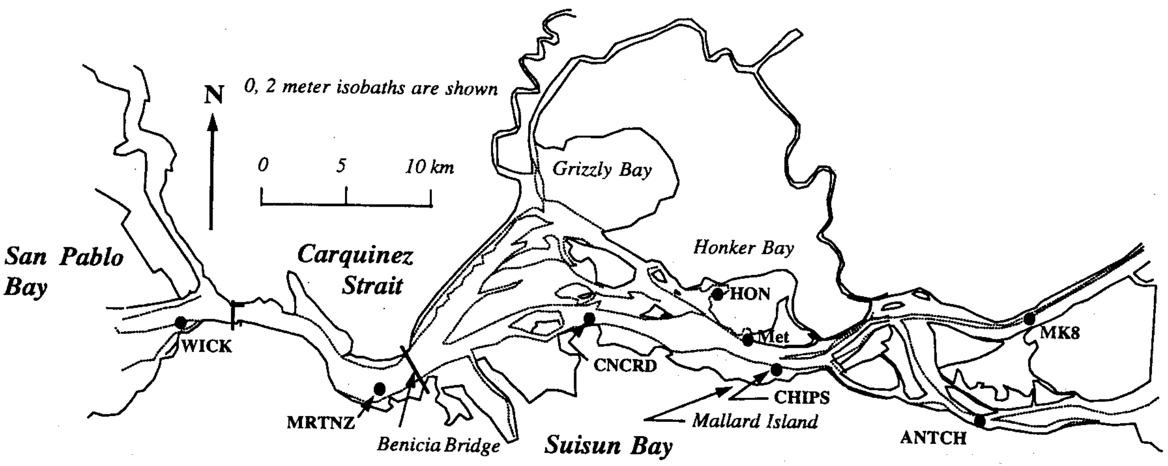
Summary of the Hydrodynamic Element of the Entrapment Zone Study

Jon R. Burau, USGS

Last spring the USGS hydrodynamics group, in collaboration with DWR, DFG, USBR, the USGS national research program, Tiburon Center for Environmental Studies, and Stanford University, conducted an interdisciplinary investigation of the western delta and Suisun Bay. This effort involved 2-month deployments of *in situ* hydrodynamic instrumentation during which three 30-hour synoptic investigations were conducted. The overall goal was to better understand linkages between low-salinity hydrodynamics, suspended sediment, and biology.

Specific objectives of the hydrodynamic element were to assess the relative contribution from vertical processes (*eg*, gravitational circulation, strain-induced stratification, *etc*) on the overall salinity budget. In addition, we hoped to determine net movement, spatial extent, and interrelationships between the turbidity maximum, the null zone, and X2. This article gives an overview of the hydrodynamic data collection effort. Work is underway on a report that describes details of the experimental design, provides plots of raw and low-pass filtered (tides removed) data, and discusses preliminary results.

The hydrodynamic element involved two complementary yet distinct components. The most important component, from an analysis perspective, involved deployment of five Acoustic Doppler Current Profilers and seven self-contained submersible Conductivity-Temperature-Depth packages along the axis of the estuary extending from Carquinez Strait to about Decker Island on the Sacramento River, as shown on the map (page 5). The equipment was deployed for about 50 days (April 11 to June 20) to capture several spring/neap cycles. In addition, the USGS toxics group (Kathy Kuivila) collected top/mid-depth Optical Back Scatter data at Mallard Island and Martinez. OBS data can be calibrated with grab samples to measure suspended solids concentration. Because time series analysis techniques can be used to "remove" the tides, the *in situ* data can be used to detect the presence or absence of gravitational circulation, the null zone, and sustained high turbidity.



In–Situ Instrument Legend

WICK: $CT_{(top–mid)}D$
MRTNZ: BBADCP, $CT_{(top–mid–bot)}D$, $OBS_{(mid–bot)}$
CNCRD: BBADCP, $CT_{(top–mid–bot)}D$
CHIPS: BBADCP, $CT_{(top–mid–bot)}D$, $OBS_{(mid–bot)}$
HON: EG&G V/TD/OBS
Met: Met Station, Wind Vel,, Atmos. press.
ANTCH: NBADCP, $CT_{(top–mid–bot)}D$
MK8: NBADCP, $CT_{(top–bot)}$

Notes

C – Conductivity, T – Temperature,
D – Pressure (sea level), V – Velocity (point),
OBS – Optical Backscatter (turbidity)
BBADCP – Broad Band Acoustic Doppler Current Profiler
NBADCP – Narrow Band Acoustic Doppler Current Profiler
top – Surface sensor
mid – Mid–depth sensor (relative to channel)
bot – Bottom Sensor (relative to channel)

FIXED-SITE SAMPLING LOCATIONS

The second component of the hydrodynamic effort involved three 30-hour synoptic datasets designed to fill in spatial gaps between the *in situ* instrumentation and to provide an overall picture of the salinity, turbidity, and velocity fields for analysis of the Lagrangian-based biological data. The synoptic work was timed to coincide with peaks in the spring/neap cycle. The 30-hour studies were concurrent with biological sampling on the neap tide of April 19, the spring tide of April 27, and the neap tide of May 17.

Two research vessels were used. The *Compliance* was engaged in taking longitudinal profiles of salinity, OBS (using a Seabird 911), and velocity (vessel-mounted narrow-band ADCP) at 10 stations along the axis of Suisun Bay from Carquinez Strait to Decker Island. About eight complete longitudinal profiles were taken in the course of each 30-hour study. The *Turning Tide* was anchored over the ADCP at Mallard Island taking CTD-turbidity profiles every 15 minutes to look at strain-induced stratification (among other things).

It is difficult, if not impossible, to "remove" the tides from synoptically collected data. Yet much of our present understanding of the null zone, entrapment zone, and turbidity maximum is derived from scattered profile data collected without regard to the phase of the tidal currents or the phase of the spring/neap cycle. The OBS data collected in this experiment show that suspended solids concentrations vary significantly with the tidal currents and the spring/neap cycle. For example, the synoptically collected OBS data show that elevated suspended solids concentrations are highly correlated with the peak ebb and flood currents. Distinct minima in suspended solids concentration occur near slack water. Therefore, large quantities of material (presumably clay and silt) are eroded and suspended in direct response to peak tidal currents, and rapid settling and sedimentation occur during periods of slack water. Furthermore, OBS data collected at Mallard Island show a fortnightly (spring/neap period) variation in suspended solids concentration. When the tides change from spring to neap, peak currents decrease, which increases the ratio of sedimentation to erosion over the tidal cycle. This process results in a decline in mean suspended solids concentration on neap tides. The converse occurs when the tides change from neap to spring, and we see increasing mean suspended solids concentrations during spring tides. In marotidal estuaries like Suisun Bay, suspended solids appear to be controlled — like almost everything else — by the tides.

Given the tidal cycle and fortnightly variations in suspended sediment concentration, determination of the mean or tidally-averaged position of the turbidity maximum from synoptically collected information without regard to the strength of the tidal currents or the spring-neap cycle is a tenuous proposition at best. With about 2 months of continuous hydrodynamic time series data collected during this experiment, for the first time we can critically test the hydrodynamic underpinnings of the null zone and turbidity maximum hypotheses.

SFEI Update

Margaret Johnston, Aquatic Habitat Institute

On September 23, the San Francisco Estuary Institute was launched at a day-long conference and celebration at Treasure Island. Sam Luoma of the USGS and a member of SFEI's new Committee of Science Advisors, gave the keynote address. Felecia Marcus (Administrator of EPA Region IX), James Burroughs (Deputy Secretary of The Resources Agency), and Jack Pandol (Undersecretary of the California Environmental Protection Agency) spoke to support the founding of the new institute and to commit to serve as part of its Board of Directors.

Built on the foundation of the Aquatic Habitat Institute, SFEI has a new mandate, a new Board of Directors, and two new advisory committees. The Committee of Science Advisors has been appointed with nine members, and most appointments have been made for the Committee of Policy Advisors, including agency, user group, and environmental/public interest representatives. The committees are expected to be instrumental in setting the SFEI agenda. The committees plan to meet in early December.

Meanwhile, work that started during the transition from AHI to SFEI is continuing. The first year of the regional monitoring program for trace substances was completed in December 1993. The draft of the first annual report was circulated in May 1994. The final report will be completed by October 31. Significant findings include:

- Few Exceedences of Basin Plan water quality objectives for metals were found, but lead, mercury, nickel, chromium, and copper exceeded objectives at one or more stations on one or more occasions. Total concentrations of arsenic, cadmium, cyanide, selenium, silver, and zinc were never above water quality objectives.
- Total PCBs exceeded the EPA objective for protection of human health at all stations, but the objective is based on a different way of calculating total PCBs than was measured in the Regional Monitoring Program.
- Significant sediment toxicity was measured at each of eight stations tested.
- No water column toxicity was detected.

Since no sediment quality objectives have been adopted for San Francisco Bay or the delta, median effects ranges (ER-M) developed by NOAA were used to give some biological perspective to the level of sediment contaminants found. Only nickel was found to exceed these levels throughout the estuary, and nickel concentrations are known to be naturally elevated throughout the estuary and adjacent ocean. PAHs, PCBs, and total pesticides were measured and detected at all stations, but never in excess of ER-M levels.

Given the number of confounding factors that may affect bioaccumulation measurements, few conclusions can be drawn from the 1993 data. As with sediment, no objectives have been adopted for tissue concentration. Bioaccumulation of trace metals exceeded Median International Standards for human consumption or the California State Mussel Watch statewide 85th percentile during one or the other sampling period. None of the bivalves for which data were available exceeded FDA guidelines for trace organic contaminants.

For the 1994 program, two of three sampling cruises have been completed. An intercalibration exercise has begun with SFEI contractor labs, sponsoring agency labs, and several private labs participating. The Sacramento Comprehensive Monitoring Program, Regional Board 5, USGS, USBR, DWR, and the Regional Monitoring Program are coordinating a separate intercalibration exercise on river water. The 1995 Regional Monitoring Program implementation plan has been drafted and is undergoing final review.

SFEI's wetlands program began 18 months ago. A draft Wetlands Monitoring Plan will be available after October 18. The Wetlands Habitat Restoration Goals project is nearing completion of its data gathering phase. Information on historical and present tidal and seasonal wetlands, their use by avian resources, climate patterns, and infrastructure barriers to restoration are available in SFEI's *GIS Baylands Atlas*. Workshops are being scheduled for early next year to develop a scientific basis for goals on "how much of what kind of wetlands we want where" in the bay area.

SFEI's education program is continuing to expand. Seven *Kids in Creeks* workshops have been conducted this year, and more are planned for this fall. Nearly 300 teachers have participated in the program. The fifth annual Educators Conference, *Teaching About Wetlands* will be held November 5; the 1995 conference, *Teaching about Monitoring* is being planned. Information on freshwater flows has been added to the interactive educational software *Exploring the Estuary*, and conversion of this program for use on IBM PC (in addition to Macintosh) is nearly complete.

To obtain the 1993 RMP Annual Report or for information on other SFEI programs, call 510/231-9539.

Quantifying Salinity Habitat of Estuarine Species

Philip A. Unger, Jones & Stokes Associates, Inc.

Abundance of numerous fish and invertebrate species of the Sacramento-San Joaquin estuary is correlated with delta outflow. Many have suggested that outflow affects species abundance through its effects on estuarine habitat (Moyle *et al* 1992), but attempts to quantify the effects of outflow on estuarine habitat have been limited.

Salinity is an important habitat factor and is strongly affected by outflow, so estuarine habitat often is defined in terms of a salinity range (Hieb and Baxter 1993). All estuarine species are assumed to have optimal salinity ranges, and life stages within a species often differ in salinity preference. Species survival may be determined partly by the amount of habitat available within their optimal salinity ranges. Because survival during an early life stage often determines the size of the year class, which in turn affects the size of the adult population, the optimal salinity habitat of this limiting life stage may be particularly important.

This article describes methods for quantifying salinity habitat of 10 fish and shrimp species in the estuary. To quantify the available salinity habitat of a species or life stage, it is necessary to determine the optimal salinity range, estimate the upstream and downstream limits of this range, and calculate the surface area or volume of water between these estuarine locations.

Optimal Salinity Range

Limits of optimal salinity ranges of fish and shrimp species investigated were defined as the 10th and 90th percentile of salinity distribution of all sampled larvae or young juveniles (or both) of the species. DFG provided the 10th and 90th percentile of salinity distributions for species other than striped bass and delta smelt. The 10th and 90th percentile for striped bass and delta smelt were computed using data from DFG's striped bass egg and larval survey. Table 1 lists estimated optimal salinity range for each of the selected species.

Location of Optimal Salinity Habitat

Upstream and downstream limits of the optimal salinity habitat were computed from monthly average outflow and the optimal salinity range of each species. Delta outflow was used to estimate X_2, the in-channel distance upstream of the Golden Gate Bridge, in kilometers, where the near-bottom salinity is 2 ppt. The distances (X) upstream from the Golden Gate Bridge of salinities representing the upper and lower limits of the optimal salinity range were computed from X_2 using a logistic equation derived from longitudinal salinity profiles presented by Monismith (1993).

Monthly (end-of-month) X2 was computed using Kimmerer and Monismith's (1992) regression equation for monthly data:

$$X_2(t) = 122.2 + 0.3278X_2(t-1) - 7.65LOG[Q_{OUT}(t)]$$

where $X_2(t)$ and $X_2(t-1)$ are the average 2-ppt positions for the current and previous months, respectively, and $LOG[Q_{OUT}(t)]$ is the $\log_{10}$ of the average outflow for the current month. Kimmerer and Monismith's (1992) equation for daily X_2 could have been used to provide daily estimates of estuarine habitat locations.

Monismith (1993) showed that when X_2 is known, the average position (X) in the estuary of other salinities can be estimated with little error. For a given ratio of X/X_2, mean salinity is nearly constant regardless of the value of X_2 (Figure 1). To derive an equation for estimating X, a logistic model was fitted to Monismith's data using nonlinear regression (SAS 1990).

Parameters of the regression model were modified slightly to im-

Table 1
OPTIMAL SALINITY RANGES AND MONTHLY WEIGHTING FACTORS FOR SELECTED ESTUARINE SPECIES

		Salinity Range		Monthly Weighting Factors											
Species	Life Stage	Upper Limit (ppt)	Lower Limit (ppt)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Striped Bass (a)	Larvae (5-9 mm)	0.1	2.5	.00	.00	.00	.12	.52	.34	.02	.00	.00	.00	.00	.00
Delta Smelt (b)	Larvae and early juveniles	0.3	1.8	.00	.05	.10	.20	.30	.20	.10	.05	.00	.00	.00	.00
Longfin Smelt (c)	Larvae & early juveniles (< 50 mm)	1.1	18.5	.04	.44	.42	.09	.01	.00	.00	.00	.00	.00	.00	.00
Starry Flounder (c)	YOY (< 70 mm)	0.1	19.7	.00	.00	.04	.00	.03	.37	.24	.26	.05	.01	.00	.00
English Sole (c)	YOY (15-80 mm)	18.8	32.8	.00	.02	.04	.09	.20	.18	.15	.11	.07	.08	.03	.03
White Croaker (c)	YOY	18.1	32.4	.00	.00	.06	.04	.18	.24	.13	.10	.09	.17	.05	.00
Northern Anchovy (c)	YOY	21.3	32.1	.00	.00	.01	.04	.05	.17	.22	.11	.20	.13	.07	.00
Pacific Herring (c)	YOY	12.5	25.9	.26	.57	.12	.02	.00	.00	.00	.00	.00	.00	.00	.03
Crangon franciscorum (c)	Juveniles (< 26 mm)	1.6	21.6	.02	.01	.00	.02	.10	.24	.23	.16	.12	.05	.03	.02
Crangon nigricauda (c)	Juveniles (< 20 mm)	18.1	32.0	.09	.06	.03	.05	.14	.17	.09	.12	.07	.06	.05	.07

(a) Salinity range estimated by Jones & Stokes Associates from 16 years of DFG's Egg and Larval Survey data.
(b) Salinity range estimated by Jones & Stokes Associates from 2 years of DFG's Egg and Larval Survey data.
(c) Salinity range estimated by DFG from IEP Delta Outflow/San Francisco Bay Study Program data.

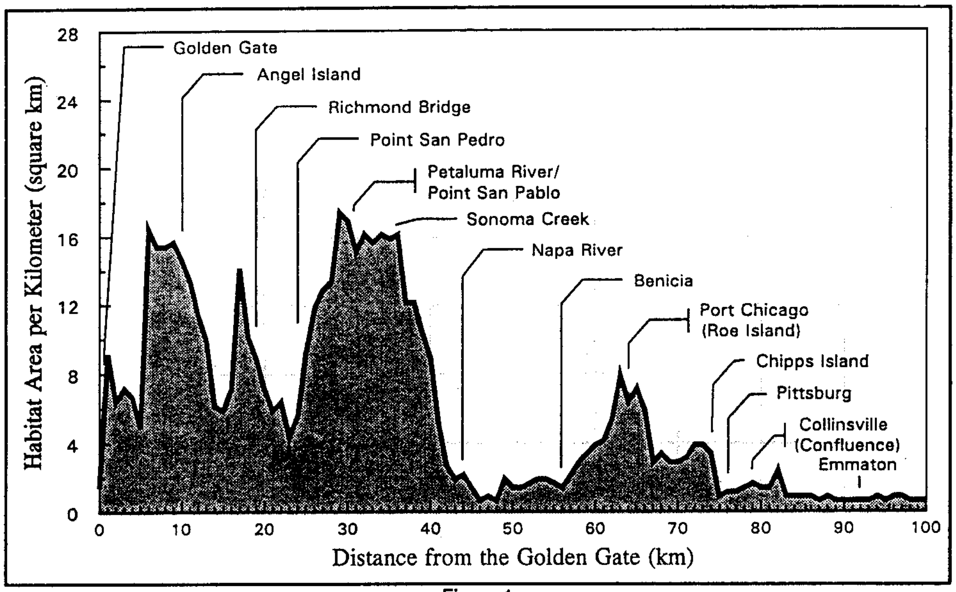


Figure 1
ESTUARINE HABITAT AREA UPSTREAM OF THE GOLDEN GATE

prove the fit in the low-salinity region of the curve with X/X_2 equal to about 1, because this region represents important habitat for many estuarine species. The logistic equation was solved for X so that the positions of the upstream and downstream limits of the optimal salinity habitat could be computed:

$$X = -X_2(\ln((31-S)/(515.67*S))/-7) - 1.5$$

where S equals mean (depth-averaged) salinity in practical salinity units (psu) of the upper or lower limit of the optimal salinity range. For the range of salinities found in the estuary, practical salinity units are nearly identical to parts per thousand (Monismith 1993).

Surface Area of Optimal Salinity Habitat

The Sacramento-San Joaquin estuary has a complex shape, so the area or volume of optimal salinity habitat varies greatly with its location. The surface area at different locations was estimated using tracings of nautical charts (prepared by USBR) to measure the shore-to-shore width perpendicular to the main shipping channel at each kilometer of distance along the channel upstream from the Golden Gate Bridge (Figure 2). Shorelines on the nautical charts represent mean lower-low tide position. Total surface area of optimal salinity habitat was computed by summing all the widths within the upstream and downstream limits of the habitat. South Bay was not included in the analyses.

Surface area rather than volume was used to quantify optimal salinity habitat, because habitat surface area was believed to affect most of the selected species more directly than habitat volume, and surface area is calculated more easily with available information.

Results of Historical Comparisons

Mean monthly outflow for 1922-1993 from the DWR (1994) DAYFLOW database were used to estimate optimal salinity habitat area for different species under a variety of outflow conditions (1922-1929 data were estimated by Jones & Stokes Associates). The database included many outflows greatly exceeding those that would produce the minimum X_2 value (X_2=58

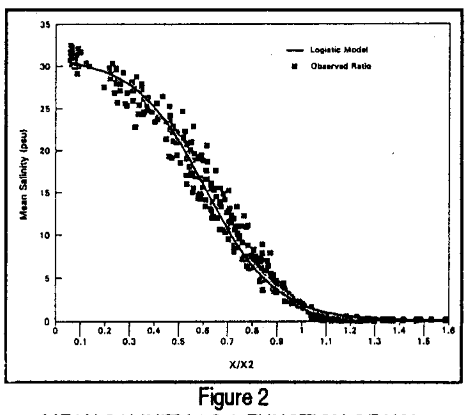


Figure 2
MEAN SALINITY AS A FUNCTION OF X/X_2

km) included in the data Monismith (1993) used to investigate the relationship between X/X_2 and salinity, but it was assumed that the relationship between X/X_2 and salinity was unchanged at low X_2 (*ie*, higher outflows).

Computed optimal salinity habitat area for delta smelt, longfin smelt, striped bass, and the shrimp *Crangon franciscorum* are plotted against outflow in Figure 3 and against X_2 in Figure 4 (both on page 9). The species show important differences in response of computed habitat area to changes in outflow or X_2. For example, computed habitat areas for striped bass and delta smelt increased rapidly as X_2 moved downstream of 100 km, but the habitat area for longfin smelt and *C. franciscorum* changed little until X_2 was below 80 or 90 km. At X_2 below about 60 km, habitat areas for striped bass and delta smelt leveled off or declined, while those for longfin smelt and *C. franciscorum* increased continuously.

If surface area of optimal salinity habitat is an important contributor to survival in estuarine species and if the method described above for estimating this area is reliable, then variation in computed habitat area of the limiting life stage should explain a significant portion of the observed variation in annual abundance indices for these species. The relationship between abundance and habitat area was examined for the ten species by linear regression analysis of annual indices of abundance on annual indices of optimal monthly salinity habitat area. Annual indices of optimal monthly salinity habitat area were computed by weighting monthly habitat areas by the average proportion of the limiting life stage present in each month (Table 1). Thus, the annual habitat area indices give weight to habitat area according to the presumed relative importance to the species of the month in which the habitat area was present. The proportions of the limiting life stage present in each month were computed from DFG survey data (Baxter, Hieb, Mecum, Sweetnam, pers comm).

Regressions were significant ($p<0.05$) for all the species whose limiting life stages inhabit relatively fresh

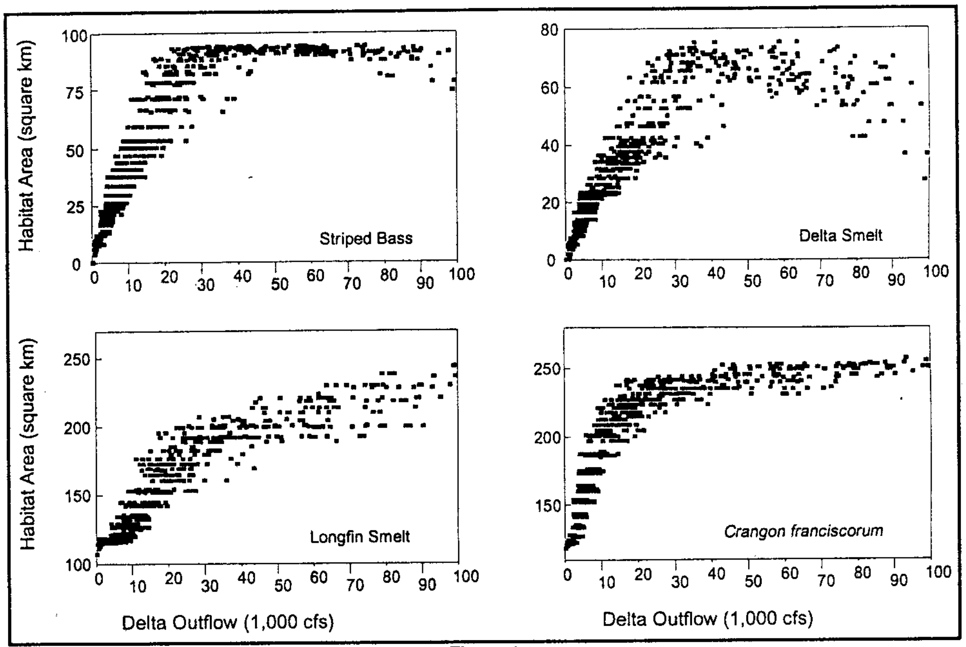


Figure 3
OPTIMAL SALINITY HABITAT AREA AS A FUNCTION OF DELTA OUTFLOW

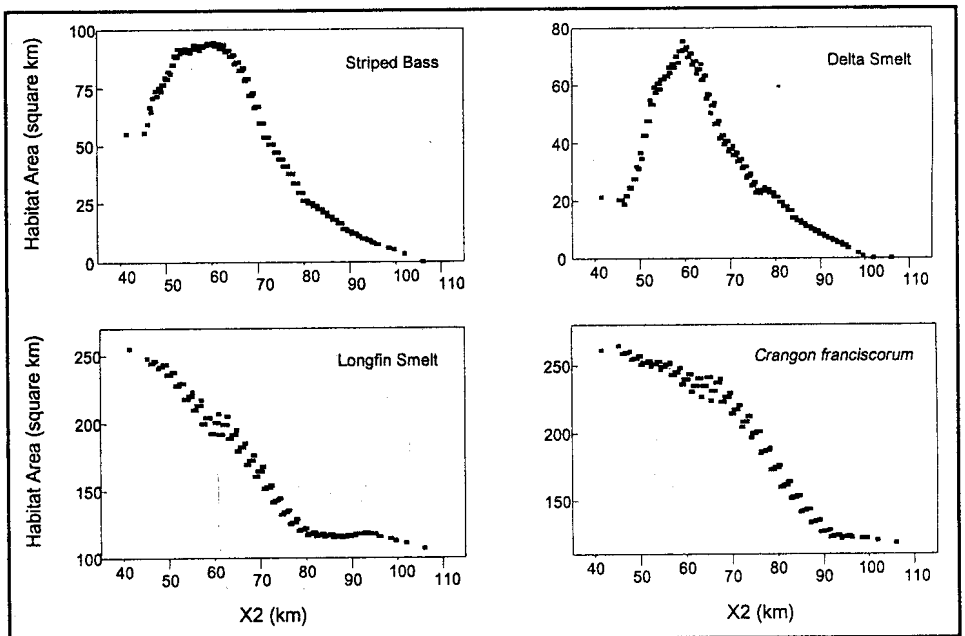


Figure 4
OPTIMAL SALINITY HABITAT AREA AS A FUNCTION OF X_2

or brackish water, except delta smelt (Table 2). The regression for delta smelt gave a p-value of 0.08, which is close to the significance level. Regressions were not significant for all the more marine species, presumably because abundance of these species is determined largely by habitat conditions in the ocean (Baxter, Hieb, pers comm).

Table 2
COEFFICIENTS OF DETERMINATION AND REGRESSION EQUATIONS FOR SELECTED SPECIES

Species	r2	Regression Equation*
Striped bass	0.43	Y = 1.189 + 0.784 (OSHA)
Delta smelt	0.13	Y = 2.377 + 0.008 (OSHA)
Longfin smelt	0.70	Y = 0.393 + 0.016 (OSHA)
Starry flounder	0.57	Y = -1855.737+ 15.435 (OSHA)
C. franciscorum	0.75	Y = -272.923+2.304 (OSHA)

* OSHA = Optimal Salinity Habitat Area
For striped bass, Y = 38-mm index.
For delta and longfin smelt, y = Log10(MWT index).
For starry flounder, Y = Log10(following year's bay survey yearling index.
For *C. franciscorum*, Y = Bay survey juvenile index.

Conclusions

The method described for quantifying optimal salinity habitat surface area should be useful for predicting optimal salinity habitat area available at a given flow and for evaluating salinity habitat conditions of any estuarine species whose optimal salinity range is known. Hieb and Baxter (1993) presented results of analyses relating abundance of three estuarine species to estimated optimal salinity habitat area. They estimated habitat area by extrapolating from measured salinities. The method presented here relies on general relationships between outflow and salinity and, therefore, can be used to predict habitat area from outflow.

Statistically significant relationships have been demonstrated between abundance indices of the species listed in Table 2 and outflow or X_2 (*eg*, see Jassby 1992). Optimal salinity habitat area of these species also generally increases with increased outflow (*ie*, reduced X_2) (Figures 3 and 4). The effect of habitat area on species abundance is difficult to separate from effects of other factors related to outflow, such as residence time, nutrient input, sediment transport, transport of eggs and larvae, entrainment in diversions, and dilution of toxins. Nevertheless, the ability to quantify habitat area separately from other factors makes possible more refined analyses of the effects of outflow on estuarine species.

I thank Chuck Armor, Randy Baxter, Kathy Hieb, Lee Mecum, and Dale Sweetnam of the Department of Fish and Game and the Interagency Ecological Program and Russ Brown of Jones & Stokes Associates for their important contributions to this study.

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Decline of the Opossum Shrimp, *Neomysis mercedis*

James J. Orsi and Lee W. Mecum, DFG

Neomysis mercedis is an estuarine and freshwater shrimp native to the Pacific Coast from Alaska to below Santa Barbara. In the Sacramento-San Joaquin estuary, it is most abundant in the entrapment zone but ranges from fresh water to near-oceanic salinity. *Neomysis* is eaten by the bay shrimp *Crangon franciscorum*, the oriental shrimp *Palaemon macrodactylus*, and many fish species including striped bass and delta smelt. Because of its importance to fish, DFG has monitored *Neomysis* abundance since June 1968. Abundance has declined greatly over the years, especially during the 1987-1992 drought (Figure 1). Abundance is now so low that *Neomysis* is unlikely to be a significant food resource for striped bass or any other fish or invertebrate species.

Several factors can explain the decline, but food limitation caused by reduced phytoplankton concentrations is the most probable. Correlations between abundance and chlorophyll *a* are significant and curvilinear in all seasons for the 1968-1993 period (Figure 2), providing statistical evidence for food limitation. R-square analyses for each season for 1972-1993 using chlorophyll *a*, outflow, outflow squared, temperature, and logs of rotifers and copepods showed that only chlorophyll *a* explained a significant amount of the variance in abundance (Table 1).

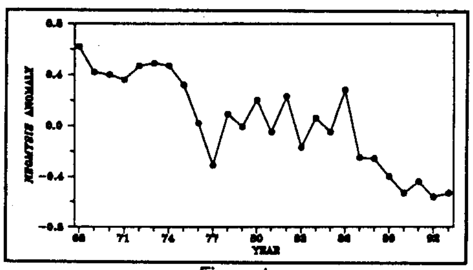

Figure 1
NEOMYSIS ABUNDANCE ANOMALIES, MARCH-NOVEMBER, 1968-1993

Abundance anomalies are logs of numbers/m^3 corrected for salinity and month.

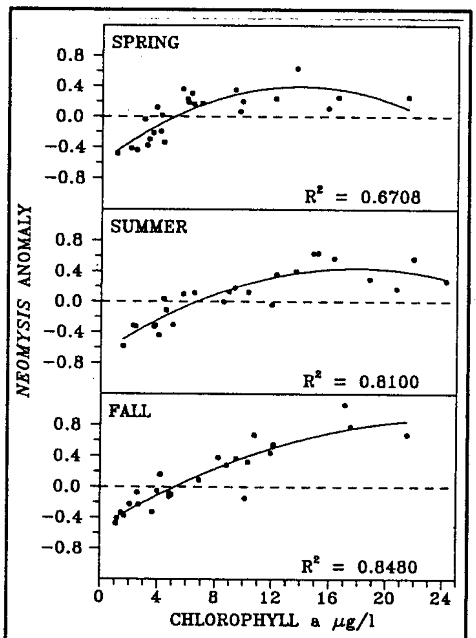

Figure 2
ABUNDANCE ANOMALIES VERSUS CHLOROPHYLL a, 1968-1993

If low phytoplankton concentrations are limiting *Neomysis*, this limitation would probably cause lower juvenile growth rates. This would result in smaller adults and, because brood size depends on female size, egg production would be lower. Adults may also be directly affected by food limitation because one of their food sources, rotifers, has declined over the years. The other food source, copepods, has remained high due to the introduction of exotic copepods.

In support of the food limitation hypothesis, adult females were smaller in July and August during 1989-1993, years of very low chlorophyll *a* concentrations (Figure 3). This indicates juvenile growth rates were lower, but brood size of females was not lower in these years when effects of length on brood size was corrected for. This indicates adults were not food limited. Since small mysids are more dependent on phytoplankton than adults are, the results are reasonable. Birth rates, as measured by neonate (newly released young) abundance, were lower from 1987-1993 as compared to earlier periods. The birth rates were particularly reduced in fall the variance in abundance (Figure 4).

Other factors that could have caused the abundance decline are high temperature, rice herbicides, and export pumping. Mortality from high temperature would be expected only in summer and early fall, when temperatures are highest and above the 22°C level found to cause sharply increase mortality in mysids held in the laboratory (Hair 1971). However, in the San Joaquin River at Stockton, where temperature ranges up to 28°C, no relationship between abundance and temperature was found and temperatures >22°C were not associated with lower abundance.

Rice herbicides applied to rice fields and draining into the Sacramento River above Sacramento did not appear to be a significant mortality factor. The most heavily applied herbicide, molinate, was not significantly correlated with mysid abundance during April-June, when the rice fields are drained. In addition, DFG criteria for molinate were exceeded in the Sacramento River only in 1983 (Harrington *et al* 1989) when the mysid population was located far downstream, in western Suisun Bay and Carquinez Strait.

To test for the impact of export pumping on the mysid population, daily loss rates to the southern delta pumps were calculated for 1972-1988 and were almost always too low to have had a significant impact on abundance (Kimmerer, unpub).

Mysid abundance is also significantly correlated with outflow at Chipps Island but not as highly as with chlorophyll *a*. Mysid abundance did not rise in 1993, the first high outflow year after the 1987-1992 drought. Outflow could affect abundance by weakening the 2-layered flow pattern that may concentrate mysids in the entrapment zone. Hydrodynamic data to evaluate the possible seaward loss of mysids are still lacking.

In 1992, a new mysid species of the genus *Acanthomysis* was accidentally introduced to the estuary from Asia. It is now present at the same salinities as *Neomysis* and is much more abundant than *Neomysis*. The two species may be competing for the small phytoplankton resource, and *Neomysis* appears to be losing. If phytoplankton concentrations increase, we cannot predict what will happen to *Neomysis*, because the competition pressure from *Acanthomysis* has created a new situation.

Table 1
R-SQUARE ANALYSIS RESULTS FOR MYSIDS ≥4 MM, APRIL-JUNE 1973-1992

Variables in Model	R-Square Values
chlorophyll *a*	0.776
chlorophyll *a*, copepods	0.788
outflow, outflow squared, chlorophyll *a*	0.877
outflow, outflow squared, chlorophyll *a*, copepods	0.888
molinate, outflow, outflow squared, chlorophyll *a*, copepods	0.891
molinate, outflow, outflow squared, temperature, chlorophyll *a*, copepods	0.893
all	0.894

Single Variables	R-Square Values
chlorophyll *a*	0.776
rotifers	0.363
molinate	0.100
copepods	0.041
outflow	0.018
temperature	0.002
outflow squared	0.002

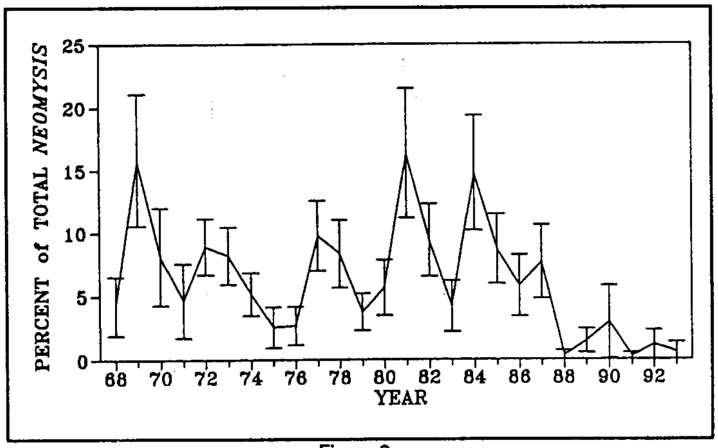

Figure 3
PERCENTAGE OF ADULTS >11 MM LONG IN AUGUST

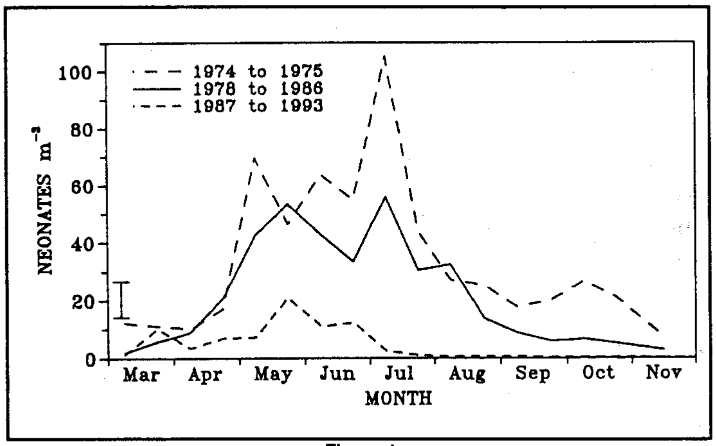

Figure 4
NEONATE ABUNDANCE IN THREE TIME PERIODS

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Bay/Delta THM Formation Potential: Data Collection and Mathematical Modeling

Paul Hutton, DWR

The San Francisco Bay and delta are important sources of drinking water for 20 million Californians. DWR monitors the water for constituents harmful to human health, including the formation potential of a group of chlorine disinfection byproducts known as trihalomethanes or THMs. THMs can cause cancer in animals and are suspected human carcinogens.

Under authority of the Safe Drinking Water Act, EPA will soon be promulgating more stringent standards on THMs and other disinfection byproducts. Tighter regulations will likely require modifications in drinking water treatment processes, in delta pumping operations, or both (DWR 1989). Water purveyors are concerned about the technical feasibility, reliability, and cost of meeting the new standards.

DWR has developed a computer model to study proposed solutions to drinking water problems. Objectives for using the model are to:

- Study impacts of existing THM precursor sources on drinking water quality.
- Evaluate potential benefits realized by employing different management strategies.
- Provide guidance in setting data collection priorities.

Data Collection

DWR first studied THM precursors in the bay/delta in 1981. Water from the Sacramento River upstream of the delta was found to contain fewer THM precursors than water pumped from the southern delta. In 1982, DWR commissioned a panel of independent scientists to evaluate human health aspects of bay/delta water supplies. The panel identified THM precursors as parameters of concern and recommended a program of data collection and analysis. In response, DWR created the Interagency Delta Health Aspects Monitoring Program in 1983. Since then, the program has collected data from a variety of sites and under a wide range of hydrologic conditions. A related study, the Delta Island Drainage Investigation, began in 1987 to measure the influence of agricultural activities on drinking water quality (DWR 1990). In 1990, the programs were merged into the Municipal Water Quality Investigations program.

Mathematical Modeling

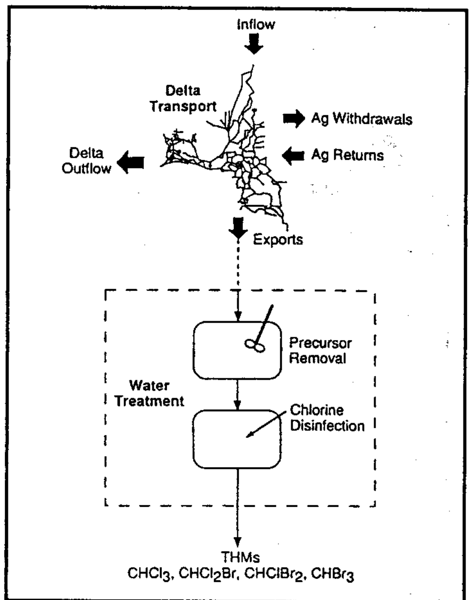
A two-component model framework was designed to meet planning objectives, using data collected under the MWQI program. The model framework is illustrated in the figure.

The first component is an existing numerical transport model, DWRDSM, which simulates the complex hydrology of the estuary and can predict THM precursor transport from source to export location. Transport of organic and inorganic precursors (*eg*, bromide) is modeled as a conservative process. (DWR is developing a new model to replace DWRDSM (DWR 1994). The new model, DSM2, will have the capability to simulate several biologically-significant variables, including temperature, dissolved oxygen, nitrogen and phosphorus species, and algae.) The second component uses output from DWRDSM and input on assumed water treatment conditions to simulate the chemistry of THM formation. Estimates of THM formation potential and speciation are provided by this second component — the THM formation model.

Original work on developing this model framework, published by Hutton and Chung (1992), demonstrates the model's validity under steady-state conditions. Subsequent articles describe model refinements (Hutton and Chung 1994a,b).

The model is being evaluated under dynamic conditions (DWR 1994) and will be used to evaluate management alternatives for the South Delta EIR. The model may also be used in conjunction with a water treatment plant simulation program developed for EPA (Malcolm Pirnie Inc. 1992) to define water treatment costs and benefits associated with management alternatives.

For further information, contact Paul Hutton at 916/653-5666.



DELTA THM COMPUTER MODEL FRAMEWORK

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Entrapment Zone Study Update

Wim Kimmerer, Romberg Tiburon Center, San Francisco State University

Interagency and university scientists collaborated in spring 1994 on a study of the interaction of biology and physics of the entrapment zone. The study was designed to take advantage of knowledge gained by the USGS study, led by Jon Burau (page 4, this issue), of circulation patterns in the upper estuary.

The field portion of the project was a joint effort of Tiburon Center for Environmental Studies, UC-Davis, DFG, USBR, and DWR. Key scientists on the biological study were Jim Arthur, Bill Bennett, Peggy Lehman, and Tim Hollibaugh.

Background

Studies of entrapment processes in the estuary began with the work of Jim Arthur and Doug Ball in the early 1970s. The conceptual model prevailing at that time describes the entrapment zone as a region, near the upstream limit of 2-layer flow or null zone, where particles are trapped through the interaction of their sinking and the net upstream bottom current. This model was extended by Jim Cloern and USGS/USBR colleagues to include the effects of shoals on growth of phytoplankton. Zooplankton can maintain position in this region of the estuary through vertical migratory patterns, as shown by Jim Orsi.

Estuarine circulation turns out to be considerably more complicated than suggested by the simple conceptual model of an entrapment zone. Upstream flow at the bottom occurs only for very brief periods during neap tides. Tidal and lateral processes may be more important than gravitational circulation in producing maxima in turbidity and organisms. Yet, maxima in turbidity and in abundance peaks of zooplankton and larval fish persist under most conditions of tide and freshwater inflow. How do these maxima persist, and what are the implications for population regulation in the estuary? Revisions in the conceptual model of the physics of the entrapment zone seem to demand parallel revisions for biology.

Study Objectives

The main objective was to determine the relationship between vertical and longitudinal positions of common entrapment zone species and the velocity field under various conditions of tide and outflow. Entrapment zone species examined included phytoplankton, bacteria, microzooplankton, *Eurytemora, Neomysis*, and larval fish that are sufficiently abundant in the entrapment zone, including delta and longfin smelt and gobies.

Secondary objectives were:

- To determine the importance of losses from populations through exchange and advection relative to *in situ* mortality.
- To obtain information on small-scale spatial (particularly vertical) distribution of larval fish and zooplankton.

Study Design

We sampled on two neap tides and one spring tide in April and May from R/V *San Carlos*. Stations were tied to salinity (1, 3, and 6 mS/cm surface specific conductance) to approximate the entrapment zone and locations upstream and downstream of it. We sampled for *Neomysis* with Bongo nets and used a high-volume pump sampler for smaller zooplankton and phytoplankton.

These kinds of samples have been taken before, but not in such large numbers nor with such a large volume sampled. Taking large samples improves the statistical utility of the data, and should make it easier to discern patterns in the data.

The biggest improvement over previous such sampling was the ancillary data: precise locations from a GPS receiver, profiles of temperature, salinity, and turbidity from Sea-Bird CTDs, and profiles of velocity and acoustic backscatter from an on-board acoustic doppler current profiler (ADCP). This instrument enabled us to "see" layers of *Neomysis*, amphipods, and fish, and observe directly their vertical migration.

Expected Results

Larval fish analysis to date indicates that gobies were most abundant. Smelt larvae were abundant as well, mainly on the surface at night; most of these were longfin, with a few delta smelt. Longfin smelt were most abundant at the surface; those caught at mid-depth and near the bottom tended to be larger than those at the surface. Some striped bass larvae and a few other taxa were found, but no splittail.

Only a small proportion of the samples have been analyzed for zooplankton. *Eurytemora affinis* was still quite abundant at the time we sampled, and much more abundant on the bottom than at the surface. *Neomysis* was also abundant, especially at night. Amphipods were very abundant at night; this taxonomic and functional group of organisms has heretofore been overlooked by Interagency Program sampling.

We expect to be able to combine the results of sample analysis with those from the ADCP backscattering intensity to obtain a clearer picture of the vertical and longitudinal movement of these organisms and the role of these movements in population maintenance and retention in the estuary.

We anticipate learning:

- Vertical and longitudinal distributions of the biota sampled.
- The nutritional environment of all heterotrophs (bacteria through fish larvae) in and adjacent to the entrapment zone.
- The degree of food limitation in fish larvae and zooplankton, based on their food environment. Conditions of some fish larvae in areas of low food concentration may be examined for morphological evidence of food limitation.
- The importance of hydrodynamic forcing and vertical positioning behavior in maintaining populations within the entrapment zone.

Preliminary Results of a Summer Gill-Net Survey for Sacramento Splittail

Randall Baxter, DFG

In early August, an extensive gill-net survey was conducted at night, targeting Sacramento splittail in the lower Sacramento and San Joaquin rivers, the delta, Suisun Marsh, and Suisun Bay. Use of gill-nets at night was intended to improve catchability of splittail and, thereby, strengthen distribution and relative abundance results. This survey was a cooperative effort involving DWR, USBR, PG&E, Beak Consulting, Chuck Hanson Environmental, Bailey Environmental, Buell and Associates, UC-Davis, FWS, and DFG. The survey was developed through the Interagency Program's Special Status Project work team.

Primary objectives were to determine the summer distribution and relative abundance of splittail within this range and to gather data on their habitat use. Of particular interest was whether juvenile or adult Sacramento splittail remained in either the Sacramento or San Joaquin river during summer. If so, in-delta trawl sampling would not sample the entire population and could produce trend data that did not follow trends of the whole population. Relatively few splittail are caught during the DFG trawl surveys in the delta, yet gill-net sampling by PG&E and DFG has produced good catches with overnight or shorter sets.

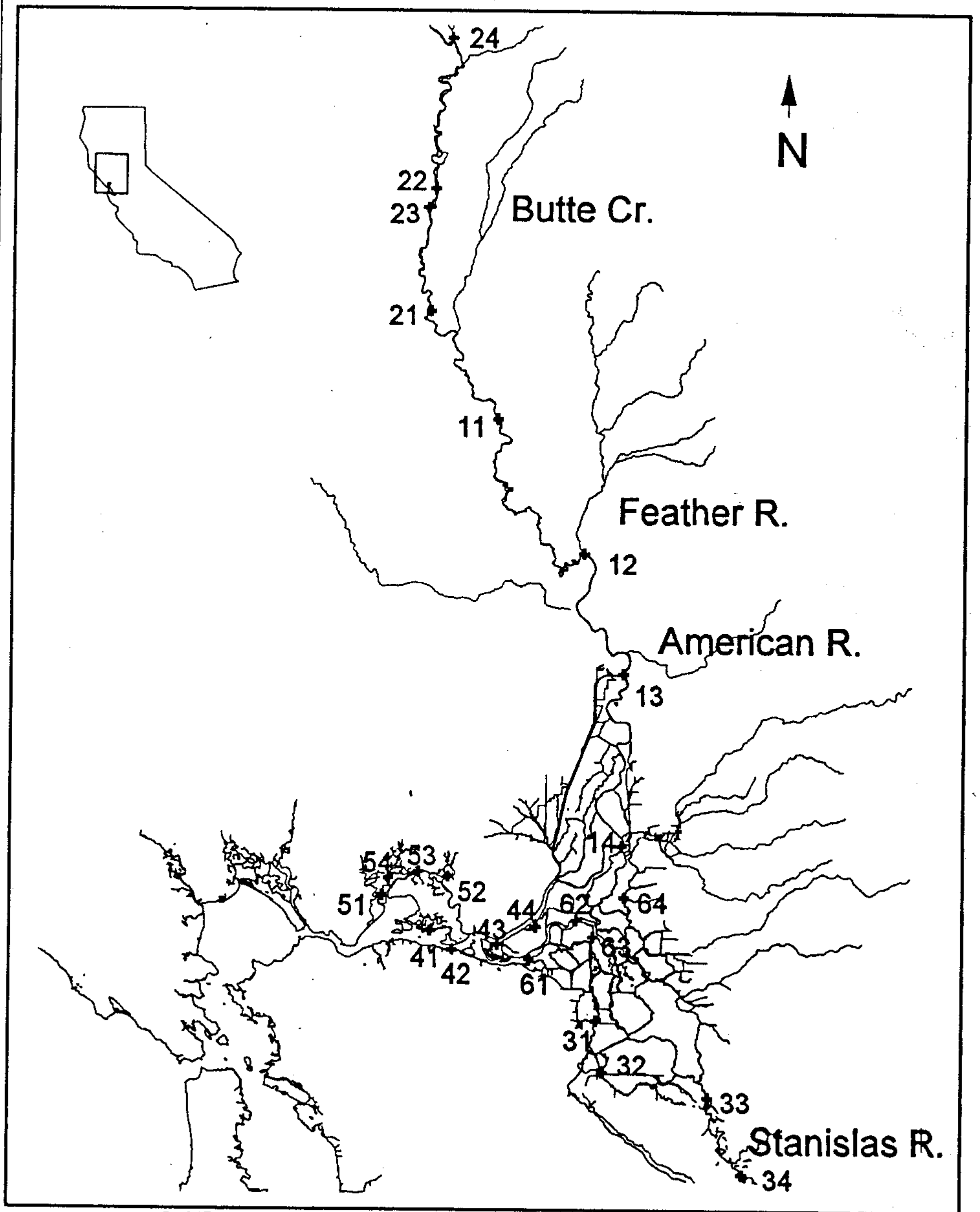
The map at right shows the 24 sampling sites selected from six areas encompassing the recent range of splittail based on 1992-1994 FWS beach seine sampling and UC-Davis and DFG trawl sampling. Each site was sampled one night a week during August 1-12. Each of six crews set three 100- by 8-foot variable-mesh gill-nets at a site and fished them between the hours of 1830 and 0630. Nets were checked at intervals from 0.5 to 3 hours, based on expected catch. Sampling effort was measured as the total hours each net was fished during each night. Net sets were rated as good or bad, based on whether the net held in place, maintained a spread between the cork and lead lines, and was not excessively damaged by fish or debris.

All fish caught were identified, measured to the nearest millimeter fork length, then released. (A subsample of threadfin shad and white catfish were measured and the rest were counted.) Length was used to assign splittail to age groups based on DFG Bay Study splittail length-frequency analyses. Catch-per-unit-effort was calculated in two ways:

- The average catch per hour of splittail by net for each night — used in analysis of variance.
- The average of the six nightly CPUE for each site (*ie*, 3 nets/night times 2 nights) — used to show relative abundance by site.

Analyses were duplicated using all CPUE data, then using only data from "good" sets. Some results from good set analyses are presented here.

In about 1,370 hours of fishing, 274 splittail were brought to the boat and measured. No splittail were collected upstream of the delta (Table 1), and no young-of-the-year splittail were collected. Of splittail collected, only 28 (10%) were age-1 fish (1993 year class). Splittail were collected at all Suisun Marsh, Suisun Bay, and western delta sites. Tukey multiple comparisons, following a significant difference between sites in the split-plot ANOVA ($p<0.05$), indicated Nurse Slough (in Suisun Marsh) had significantly higher CPUE than other sites except



SAMPLING SITES, 1994 SACRAMENTO SPLITTAIL GILL-NET SURVEY

Sherman Lake and Big Break; Sherman Lake and Big Break were significantly different from zero-catch sites, but generally not from non-zero-càtch sites. Other non-zero and zero-catch sites were not significantly different from one another.

Although this distribution probably does not describe the exact summer range of the species because of the distance between sites and the possibility of isolated habitats not sampled, it is a good indication that most of the large juvenile (age-1) and adult population resides in the central and western delta, Suisun Bay, and Suisun Marsh during the summer. Thus, for age-1 and older fish at least, trend analyses based on in-delta sampling are probably not affected by a significant number of fish residing outside the sampling area.

It is unclear whether young-of-the-year were absent from this sampling because of low numbers due to poor recruitment in a drought year, because the net meshes were too large, because their habitat was not sampled effectively, or because of some combination of reasons. The lack of YOY in the catch leaves unanswered the question of whether any remain in the rivers during summer. It is very possible some were in the rivers but were missed. It may be necessary to sample during a wet year, when presumably more YOY would be present, or with other equipment (electrofishing gear) to document the summer/fall YOY distribution.

Older juveniles and adults were collected in highest numbers from sites with extensive shallows and well-vegetated margins (Nurse Slough, Sherman Lake, and Big Break), supporting the contention that such areas are important to splittail. Shallow vegetated areas still exist, but they were more extensive before the delta was reclaimed for agriculture. Protection and re-creation of such areas are important for maintaining or increasing splittail numbers.

SIGNIFICANT DIFFERENCES (P<0.05) IN LOCATION BASED ON
CATCH-PER-UNIT-EFFORT FROM TUKEY MULTIPLE COMPARISONS OF A SIGNIFICANT ANOVA

Locations are arranged in descending order of average CPUE (all ages) from "good" sets; Std. Dev. = one standard deviation.
Stations not listed by Location Number line had no Sacramento splittail catch. Lines extend under sites that were not significantly different.
The tens place in Loc_code indicates the general area:
30s - South Delta/San Joaquin River; 40s - Honker Bay/Lower Sacramento River; 50s - Suisun Marsh; 60s - Central Delta/Lower Mokelumne River.

Location	Nurse Sl.	Sherman Lk	Big Break	Suisun Sl.1	Montezuma Sl.	S.J.River1	Mallard Sl.	Suisun Sl.2	Honker Bay	S.J.R./Old R.	Horseshoe Bend	Old R./Indian Sl.	
Location Number	52	43	61	54	53	62	42	51	41	63	44	31	others
Avg. CPUE	1.46	1.04	0.92	0.41	0.36	0.32	0.29	0.26	0.22	0.18	0.15	0.02	0.0
Std. Dev.	1.04	1.05	0.61	0.41	0.27	0.56	0.21	0.46	0.31	0.17	0.14	0.04	0.0

Management Advisory Committee

The new Interagency Program organization calls for an advisory committee consisting of representatives of participating agencies not actively involved in the program, water contractors, environmental organizations, and the academic community. This committee is to help ensure that the Interagency Program is developing answers to important management questions facing decision-makers. The coordinators have asked Steve Ford (DWR) to head up this important committee, and Steve has prepared a list of about 20 possible members. The goal is to have the first committee meeting sometime this winter — between the time the project work teams draft work plans next year and the time we present these plans to the Agency Directors for approval.

Interagency Ecological Program
Newsletter
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Interagency Ecological Program for the Sacramento-San Joaquin Estuary

Newsletter

Pat Coulston, Department of Fish and Game, Program Manager
Randy Brown, Department of Water Resources, Managing Editor
Vera Tharp, Department of Water Resources, Editor

The Interagency Ecological Program is a
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U.S. Army Corps of Engineers
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U.S. Fish and Wildlife Service
U.S. Geological Survey
U.S. Environmental Protection Agency

Net Comparison Studies

In September, Interagency Program staff and a consultant conducted the first in a series of tests designed specifically to evaluate the relative efficiency of three types of nets for capturing juvenile and adult delta smelt. The three nets, a conventional fall midwater trawl, the FWS Chipps Island trawl, and the Kodiak trawl were towed side by side at the surface. Preliminary results indicated that the Kodiak trawl was by far the most effective at capturing delta smelt, but it did not capture striped bass. The conventional midwater trawl was the least effective for delta smelt, but it did capture a larger variety of fish than the Kodiak, including striped bass. The Chipps Island trawl was about in the middle. Tests will continue for the next few months, including test of different net deployment methods (*eg*, oblique versus surface tows). Early results suggest that program managers should include similar gear evaluations when studies focus on individual species. The gear chosen for a study should also reflect the questions being asked. The gear evaluation data, along with considerations of the eventual use of the data, will help in selecting the most appropriate gear.

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