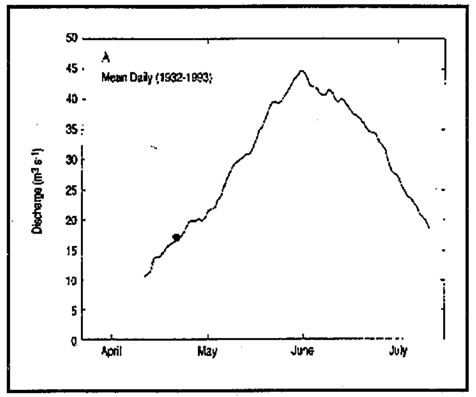

Figure 4
MEAN DAILY DISCHARGE, 1932-1993, DURING AND FOLLOWING THE MEDIAN DAY OF SNOWMELT "PULSE" (April 19) UP TO ONSET OF THE SUMMER TRANSITION

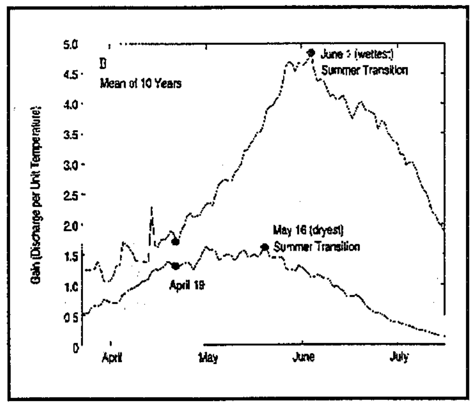

Figure 5
AVERAGE DAY OF THE SUM OF DAILY RESPONSE COEFFICIENTS, bi, BEFORE THE SUMMER TRANSITION IN A WET AND DRY 10-YEAR COMPOSITE

Our last example is an initial attempt to use these methods in a prediction mode. At some point only predicted (rather than observed) air temperatures will be included in the modeling scheme. To keep this simple, we are assuming the observed air temperature values are predicted values. Therefore, the results are better than can be expected using true predictions of air temperature. This assumption is of minor significance here, because assessment of prediction error in air temperature (which is very small) is a different issue. Here we are attempting to predict discharge solely on the basis of air temperature and past estimates of discharge to advance the predictions one day at a time.

When the time series are extended to an 8-day forecast, these initial results appear to be reasonable (Figure 6). Beyond day 3 the parameters (b_i) continue to change but are based solely on predicted values of temperature (assumed) and discharge.

If the parameter changes were small over the 8-day window of forecasting, a constant parameter model might be an adequate method of approximation (*ie,* Figure 3). But we would only know that after the fact (*ie,* hindcasting).

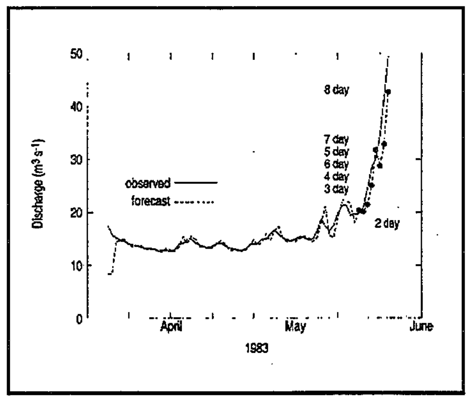

Figure 6
FORECAST OF MERCED RIVER DISCHARGE AT HAPPY ISLES, WITH 1-DAY FORECAST DAY 225, 2-DAY ON 226, 3-DAY ON 227, ETC.
Note divergence around the 5-day forecast between observed and forecasted.

Discussion

The basic evolution of a spring snowmelt cycle in the West seems to start with a change in atmospheric circulation. A low pressure (winter) pattern is replaced (within days) by a strong and expanding high pressure pattern, accompanied by high air temperature and a persistent surge in snowmelt-driven discharge (Cayan, this issue). This, at least for purposes of discussion, might be called a hydroclimatic spring transition (Figure 4). This transition may or may not show a relationship to the presumably more fickle oceanographic/atmospheric spring transition. (Strub *et al* (1985) discuss the oceanographic spring and fall transition.)

Following the typical strong surge in discharge, the temperature response coefficients (b_i) in the equation largely track the rise in discharge as temperature increases its control over the snowmelt process. At some point the system is saturated (the rise in coefficients tends to flatten out). This phase is followed by a steady decline. This point of the decline, where the sum of the coefficients (or gain) decreases, might be a summer transition (Figure 5). We are not aware of an oceanographic counterpart summer transition.

The initial stages of forecasting spring snowmelt discharge using statistical/dynamical time series are encouraging. These methods provide some insight into the response characteristics of the system, but we need to test further the forecasting power in our data-derived coefficients (Dettinger, this issue). We know the coefficients vary from year-to-year and tend to be higher in wet than in dry years. The alternating use of a Kalman filter with the difference equation appears to extend forecasts beyond low-risk 1-day forecasts, which use only observed discharge values. Also, multi-parameter models such as input of the daily variations in high-elevation snowpack as well as air temperature, may better constrain predictions, but such records are short. As the model complexity increases, it makes more sense to use physically based models (Jeton and Smith 1993; Jeton *et al* 1996). In closing, we have only scratched the surface, and there are many options.

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Sampling for Zooplankton in the Lower Estuary

Wim Kimmerer

This report describes results to date of the zooplankton pilot study begun in spring 1997. The objectives of this study are to answer these questions:

- What changes have occurred in the zooplankton of the lower estuary since the previous survey, conducted in 1978-1981?
- What sampling design would represent the zooplankton of the lower estuary most cost-effectively in a long-term monitoring program?
- What species (or larger taxonomic groupings) are important in the lower estuary, and what is their distribution in space and time?

The study design calls for initial sampling to determine the best sampling strategy to account for vertical and lateral variability in abundance. At present we are finishing this initial phase. A large part of the work in this phase has been in training assistants to identify the species occurring in this area. Because plankton can freely enter the bay from the coastal ocean, the potential species diversity is much higher than in the regions of the upper estuary now being sampled frequently. This diversity suggests caution in assigning names to specimens until the counters gain familiarity with the whole suite of species likely to be encountered.

The USGS sampled for zooplankton in 1978-1991 (Ambler *et al* 1985). Part of the rationale for this study is to detect changes since the USGS sampling that result from introductions of zooplankton and possibly from grazing by *Potamocorbula amurensis.* Other current sampling efforts will provide additional information: Dr. Steve Bollens (RTC) has been sampling on monthly cruises of R/V *Polaris,* and we may analyze some of those samples to supplement samples we will begin taking on the Bay Study surveys. His assistant, Jeff Cordell of the University of Washington, has provided an initial list of species from the Gulf of the Farallones, which will prove useful in analyzing samples, particularly from the Central Bay. NMFS is taking samples with a 500 μm mesh net in Central Bay, and identifications resulting from these samples (by Tony Chess) will be useful as well.

We have conducted two sampling cruises on R/V *Questuary* and two on an outboard boat. On the *Questuary* cruises (April and May) we sampled along transects across the bay (South, Central, and San Pablo, the latter omitted in April because of a vessel breakdown). On each transect we took both vertical and surface tows at stations deeper than about 3 meters and oblique tows at other stations. In the third cruise (June) we took several samples for identification, eight replicate vertical tows for examination of sampling variability, and samples for analyzing size classes of copepods. The fourth cruise, from which analysis is incomplete, was for further sampling for identification and to conduct a transect into shallow water in San Pablo Bay to determine whether zooplankton in this region is depauperate (as has been found in other shallow areas).

Abundant Species

Species identifications so far are tentative. In general, results to date are similar to those presented by Ambler *et al* (1985) except for two introduced species, the copepods *Tortanus dextrilobatus* and *Pseudodiaptomus marinus.* It is too early to tell if abundance of common species such as copepods of the genus *Acartia* is lower than before; not only do we need more data to determine this, but in areas sampled by the Interagency Program, *Acartia* species are still abundant in spring and typically become uncommon only in summer. This may be because the community grazing rate of *P. amurensis* does not become a major factor in the dynamics of these populations until late spring and summer (Kimmerer and Orsi 1996).

Acartia spp. have been by far the most abundant taxon in the samples we have taken, even in samples taken in the Golden Gate near the end of a flood tide. This is somewhat surprising: neritic species (from the coastal ocean) were fairly common in previous sampling in San Francisco Bay (Ambler *et al* 1985) and Tomales Bay (Kimmerer 1993) but have not yet been common in our samples. Most of the *Acartia* were of the subgenus *Acartiura*, identified by Ambler *et al* (1985) as *A. clausi*, but in nearby Tomales Bay there were two species of this subgenus, *A. hudsonica* and *A. omorii* (Kimmerer 1993). Species of this subgenus are notoriously difficult to distinguish. The summer dominant (*A. californiensis*) has not yet appeared in our samples.

The second most common copepod genus was *Tortanus*, represented by the common introduced *T. dextrilobatus* (Orsi 1995) and the rarer, neritic *T. discaudatus*. Also common were the introduced *Pseudodiaptomus marinus* (*P. forbesi* is the summer numeric dominant just landward of the entrapment zone) and the large copepod *Epilabidocera longipedata*. We have identified several other common neritic species previously listed by Ambler *et al* (1985), although none has been common in our samples.

Several taxa common in the 1997 samples were not listed by Ambler *et al* (1985), presumably because that report focused on copepods and microzooplankton. These include the cladoceran *Podon polyphemoides* and the larvacean *Oikopleura dioica*. Both of these species are moderately abundant; *O. dioica* in particular could play an important role in bay food webs because larvaceans of this genus can grow very rapidly. Meroplanktonic taxa were dominated by barnacle nauplii.

Gelatinous zooplankton were represented by a few chaetognaths (arrow worms; genus *Sagitta*) and occasional medusae, but they do not appear to be as abundant as they can be in other estuaries. During sampling in April, we collected large numbers of worms identified as nemerteans, which will need to be confirmed by an expert on that group.

Distribution

Data so far do not allow much interpretation regarding patterns. The major influence on distribution appeared to be salinity and depth: *Acartia* species were less abundant and *T. dextrilobatus* more abundant at low salinity than at high salinity (Table 1). In the April cruise *Acartia* adults were significantly ($p < 0.05$, t test) less abundant in surface tows than in vertical tows, but not in May. Juvenile abundance was not different between the two sample types on either cruise. This contrasts somewhat with the results of Ambler *et al* (1985), who found adults to be more abundant below the surface and juveniles more abundant at the surface.

There was little consistent difference in abundance of common taxa among transects or between stations on transects except as explained by salinity and depth. This may reflect the generally vigorous circulation patterns in the estuary.

Table 1
ABUNDANCE RELATIONSHIPS OF *ACARTIA* spp. AND *TORTANUS DEXTRILOBATUS* TO SALINITY
Determined by robust regression on salinity over a range of 14.9-30.7 psu.

Species	Slope ± SE	P value
Acartia spp.	0.093 ± 0.016	<0.0001
Tortanus dextrilobatus	-0.091 ± 0.017	<0.0001

Next Steps

We will scale up to the Bay Study cruises in August or September after some additional work to identify species and to sample for larger organisms such as mysids. In addition, we will develop and test a pump system for sampling microzooplankton. We will also explore day/night differences in abundance to determine their importance in biasing results of day-only sampling.

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Status of Delta Smelt Culture Project

Joan Lindberg, Randy Mager, Brent Bridges, and Serge Doroshov

In recent years the Interagency Program has supported two research projects on breeding and culture of delta smelt aimed at creating a supply of this threatened species for research. This year we are combining efforts into a single project to capitalize on expertise and site-specific advantages. The work is being performed at two sites: the SWP fish facility near Tracy, and the Institute of Ecology at UC-Davis. The project is designed to take advantage of each site's strengths in rearing particular life stages. Most broodstock are spawned and the post-larvae reared to juveniles at the SWP site, where the use of delta water provides the advantages of natural temperature fluctuations and a supply of natural zooplankton for the post-larval stage. The eggs are incubated and the larvae reared to age 30 days after hatching at the UC-Davis site, where the clean well water and temperature-controlled recirculation system promotes success with these early developmental stages. Further, the well water allows the rearing, in monoculture, of unicellular algae and rotifers required for feeding the early larval stage of smelt.

Immature smelt were collected from the delta in the fall, and by January 1 the SWP site had 278 and UC-Davis had 220 future brood fish. These fish were reared in tanks and matured over the winter, with little mortality (7-8%). Brood fish at the SWP site were maintained in a flow-through system with delta water supply; the UC-Davis fish were maintained in recirculating systems, with controlled temperature and photoperiod.

Natural spawning in tanks began in late March as water temperatures rose above 14°C, peaked in April, and continued through May (Figure 1). Spawning success rate was significantly higher than our previous trial at the SWP site: 27,000 eggs were obtained compared to 5,000 in 1995 (Lindberg 1996). As previously observed, natural spawning occurred at night, and the adhesive eggs were removed from tanks to incubators in the morning. The collected embryos were usually at the morula stage. At the UC-Davis site, only few spawns occurred naturally in the tanks (about 2,000 eggs were collected). The majority of fertile eggs (4,500) at UC-Davis were obtained by stripping the brood fish and *in vitro* insemination.

In the beginning of June, the captive populations at both sites were surveyed for any remaining ripe females. Nine gravid females were stripped and their eggs fertilized *in vitro*, resulting in another 7,600 inseminated eggs. From both sites, 40,500 eggs were collected, yielding 18,000 developing embryos and 10,700 hatched larvae. Early in the season, fungal infestation accounted for 30% of the embryo losses; later, the prophylactic treatment with 250 ppm formaldehyde (1-hour bath) prevented further occurrence.

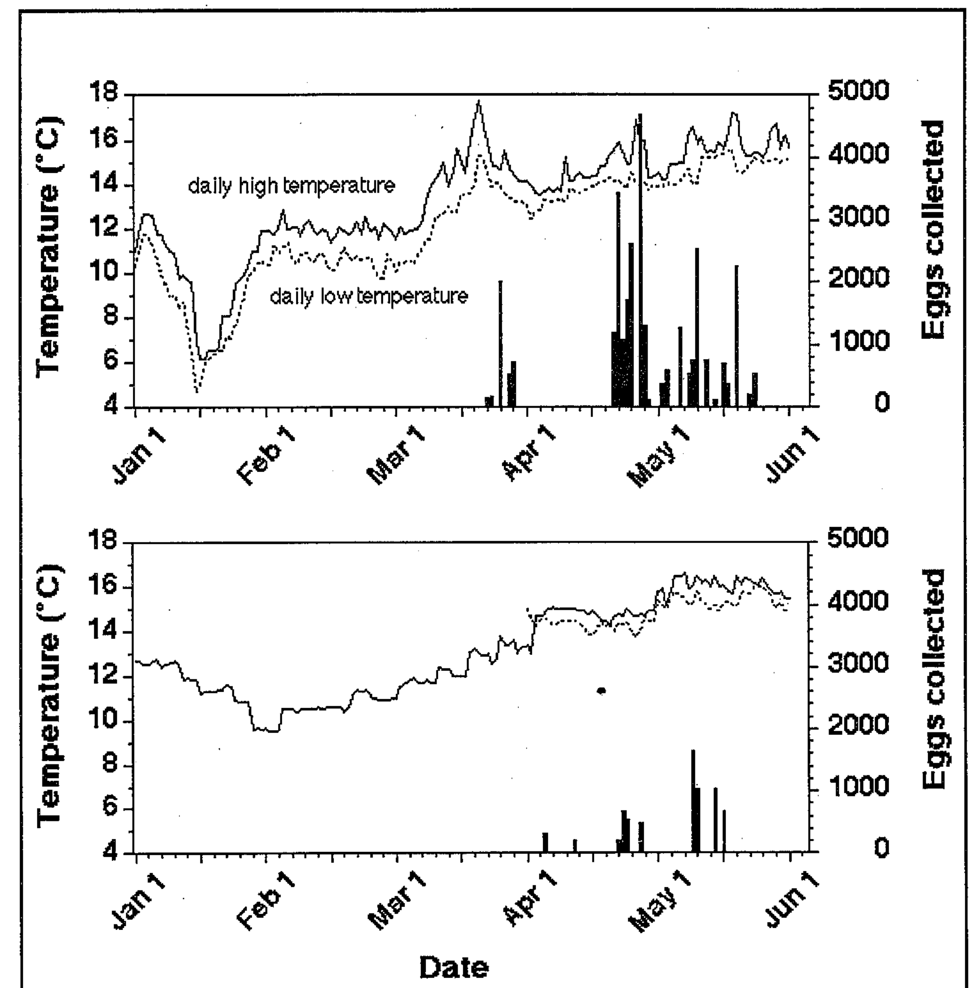

Figure 1
DAILY WATER TEMPERATURE AND DELTA SMELT EGGS COLLECTED DURING SPRING 1997
Temperatures are daily minimum and maximum at SWP site (top) and at 7 a.m. and 7 p.m. at UC-Davis site (bottom. The adhesiver eggs were collected from tanks, except for eggs stripped from fresh mortalities and fertilized in vitro at the UC-Davis site in May.