

# Phytoplankton Species and Their Possible Effect on Copepod Food Availability in the Low Salinity Zone of San Francisco Bay Estuary

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The following summary contains information selected from a phytoplankton study (IEP technical report in press) conducted in the low salinity zone (LSZ) between 1 and 4 ppt (formerly known as the entrapment zone) during 1994 that addresses the questions of how phytoplankton species composition, biomass, density and cell diameter vary across the low salinity zone and how this might influence the quantity and quality of phytoplankton food available for copepods.

## Methods

Phytoplankton and zooplankton were collected at 1, 5, and 10-meter depths for a full tidal cycle (30 hr) during

a strong spring tide on April 27-28, 1994, and a strong neap tide on May 17-18, 1994. Water samples for phytoplankton and zooplankton were collected at each tide using a submersible pump as the sampling boat moved from 0.6 to 2 and then to 4 ppt (hereafter stations 1, 3, and 6) and back again.

## Results and Discussion

*Phytoplankton biomass, biovolume, cell dimensions and species composition.* Median phytoplankton biomass, estimated by chlorophyll *a* concentration, significantly decreased seaward from 4.5-9 ug/l at station 1 to 2 ug/l at station 6 in both April and May (Figure 1); stations 3 and 6 were not significantly different.

The seaward decrease in chlorophyll *a* concentration was accompanied by a decrease in phytoplankton cell diameter. In April, median cell diameter was highest ( $p < 0.05$ ) at station 1, which contained 40% of the microplankton ( $> 20 \mu\text{m}$  diameter) and 80% of the microplankton plus nanoplankton ( $< 5-20 \mu\text{m}$  diameter) in the LSZ (Figure 2). Median cell diameter was smallest ( $p < 0.05$ ) at station 6, where 40% of the ultraplankton ( $< 5 \mu\text{m}$  diameter) and 80% of the ultraplankton plus nanoplankton occurred. In May, median cell diameter was also significantly higher ( $p < 0.05$ ) at station 1, which contained 50% of the microplankton in the LSZ and decreased seaward ( $p < 0.05$ ). Densities were not significantly different among stations for ultraplankton in May and nanoplankton in April or May.

The high abundance of ultraplankton in the LSZ was not expected. Previous species identification at high magnification (1000X), indicated the salinity zone contained large diameter ( $> 20 \mu\text{m}$ ) marine diatoms in the 1970s and 1980s (Wong and Cloern 1981). The abundance of ultraplankton in this study may be the result of grazing by the clam *P. amurensis*, which has poor retention of  $< 5 \mu\text{m}$  diameter cells (Werner and Hollibaugh 1993).

Changes in cell diameter across the LSZ was caused by a shift in phytoplankton species composition. In April, diatoms were most abundant ( $p < 0.01$ ) at station 1, where they comprised 70% of the density and 97% of the biovolume (Figure 3). In contrast, the density and biovolume of the green alga *Nannochloris* spp. was highest ( $p < 0.01$ ) at station 6 where it comprised 93% of the density and up to 30% of the biovolume. Diatoms were common at the center of the zone and comprised 40% of the density and 95% of the biovolume.

In May, the chain-forming diatom *Aulacoseira granulata* was most abundant at station 1, where it comprised 30% of the density and 95% of the biovolume, and significantly decreased seaward ( $p < 0.01$ ; Figure 3). Ultraplankton comprised of the green alga *Nannochloris* spp. and the bluegreen alga *Synechococcus* spp. were abundant throughout the LSZ and together comprised at least 70% of the density at all stations. However, they comprised only a few percent of the biovolume at station 1 compared with 15% of the biovolume at stations 3 and 6.

*The quality and quantity of phytoplankton food available for copepods* - The co-occurrence of maximum copepod and phytoplankton biomass at station 1 suggested most of the copepods had access to the phytoplankton food available in the low salinity zone; phytoplankton and copepod biomass were significantly correlated ( $p < 0.01$ ; Figure 4).

Phytoplankton biomass was probably not limiting to copepods at the landward edge of the LSZ, but may have been sufficiently low at the center and seaward edge of

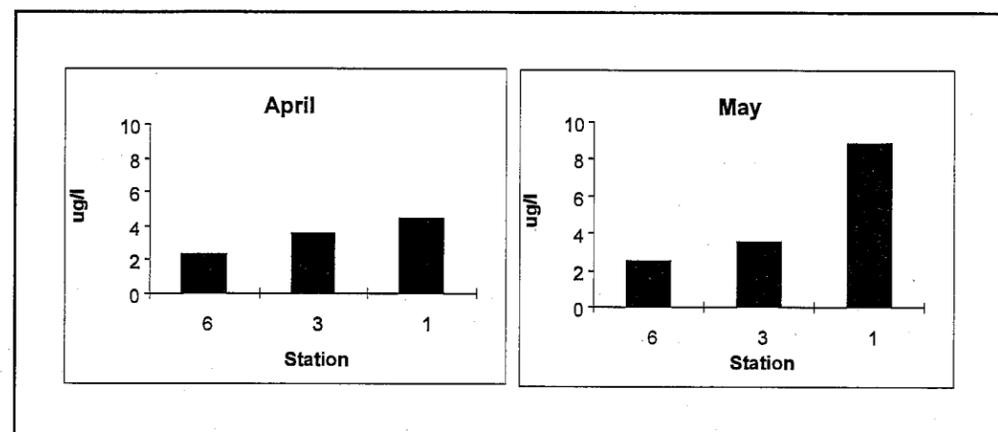


Figure 1  
Median chlorophyll *a* concentration at 0.6, 2, and 4 ppt.

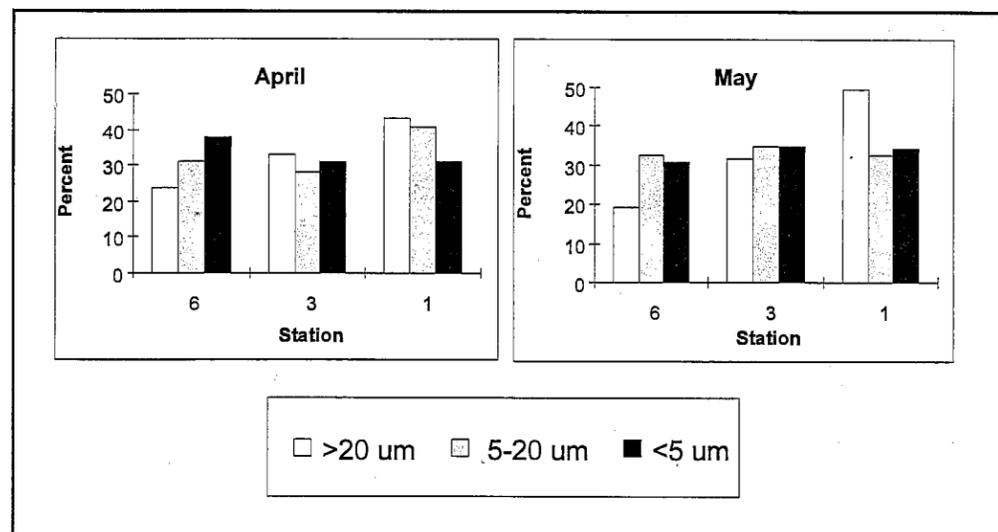


Figure 2  
Number of phytoplankton cells  $> 20 \mu\text{m}$ ,  $5-20 \mu\text{m}$ , or  $< 5 \mu\text{m}$  in diameter at each station.

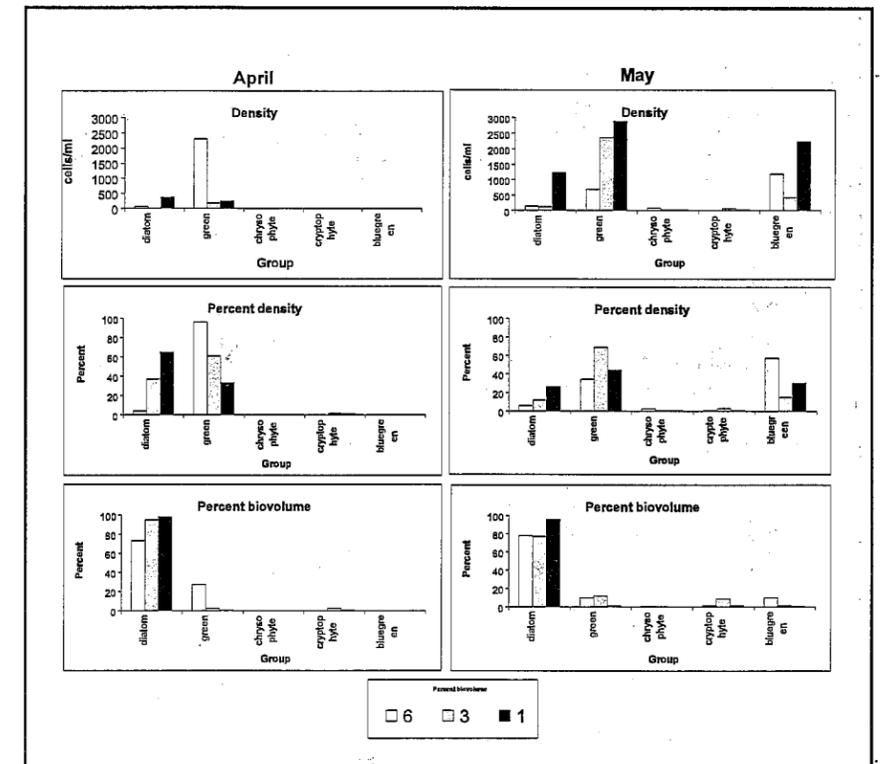


Figure 3  
Density, percent density, and percent volume for five groups of phytoplankton within the low salinity zone at stations 6, 3, and 1.

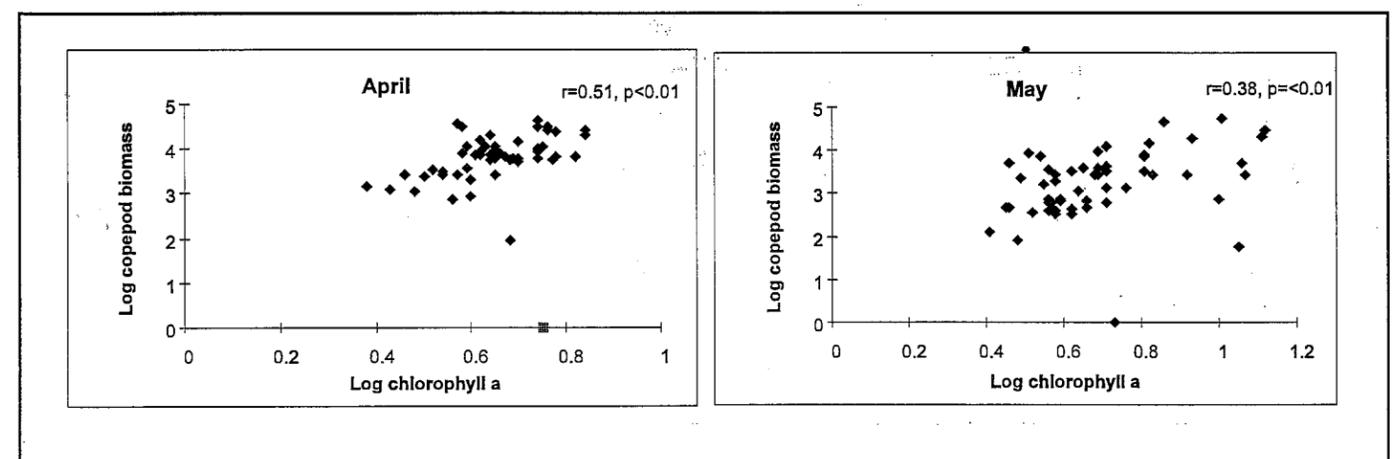


Figure 4  
Log chlorophyll *a* concentration and copepod biomass within the low salinity zone.

the zone to affect copepod egg production, egg viability or growth rate. Median chlorophyll *a* concentrations of 4.5-8.9  $\mu\text{g/l}$  (range 3.2-12.3  $\mu\text{g/l}$ ) at the landward edge of the low salinity zone were above threshold values of 0.5-2.5  $\mu\text{g/l}$  that limit copepod growth or egg production (Peterson et al. 1991). In contrast, the median (2.4-2.5  $\mu\text{g/l}$ ) and range (1.45-3.6  $\mu\text{g/l}$ ) of chlorophyll *a* concen-

trations at the seaward edge of the low salinity zone fell below or near these threshold values.

Chlorophyll *a* concentration, however, was probably not the best indicator of phytoplankton food availability in the LSZ. Copepods are size selective feeders and optimum predator to prey ratios calculated from the ratio of estimated spherical diameters (ESD) range from 9:1 to 33:1 for adults and copepodids (Hansen et al. 1994). For copepods in this study, optimum predator/prey ratios require phytoplankton ESD values in the range of 10.5-43.0  $\mu\text{m}$  for adults and 10-29  $\mu\text{m}$  for copepodids.

Many phytoplankton cells fell within the preferred ESD size range for adults and copepodids at station 1, where at least 45% of the cells were  $>10 \mu\text{m}$  (ESD) (Figure 5) and contrasted with station 6, where most of the ESD of most of the cells were  $<10 \mu\text{m}$ . Station 3 had some cells with the optimum ESD size in April, but few in May. These ESD values were reflected in the me-

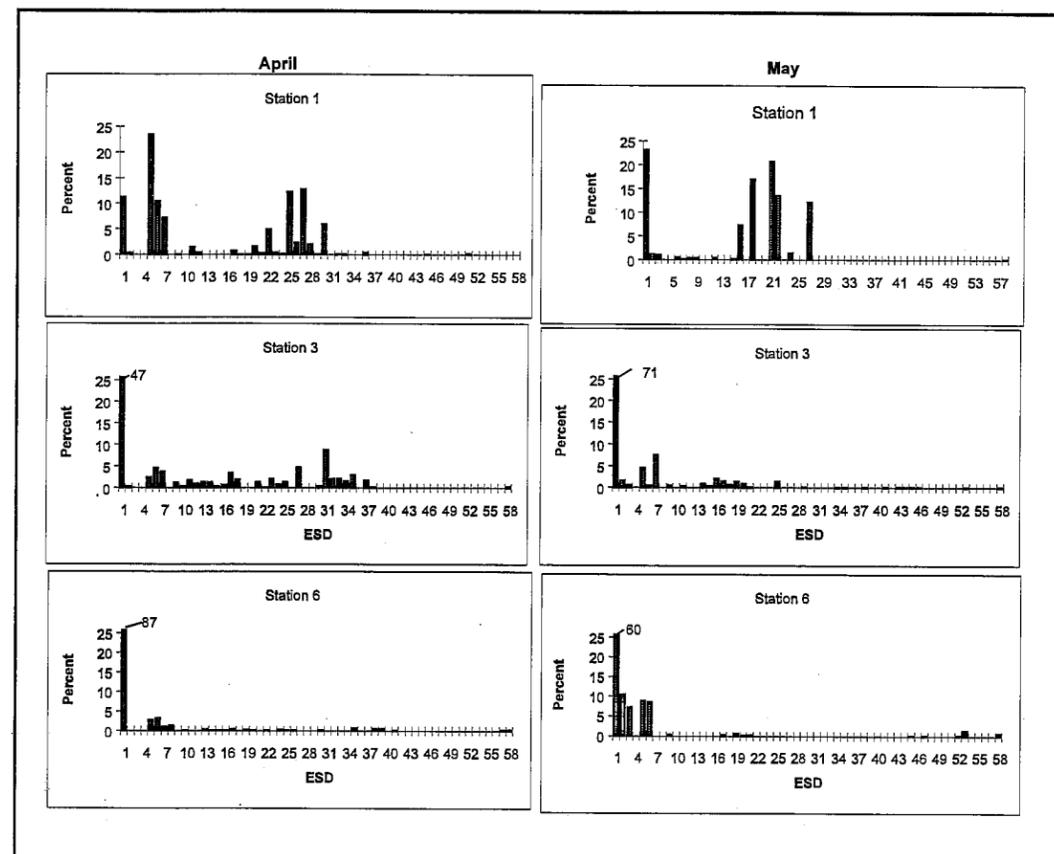


Figure 5

Percent of phytoplankton cells at different estimated spherical diameters (ESD). Optimum ESD for copepods in this study was 10-43  $\mu\text{m}$ .

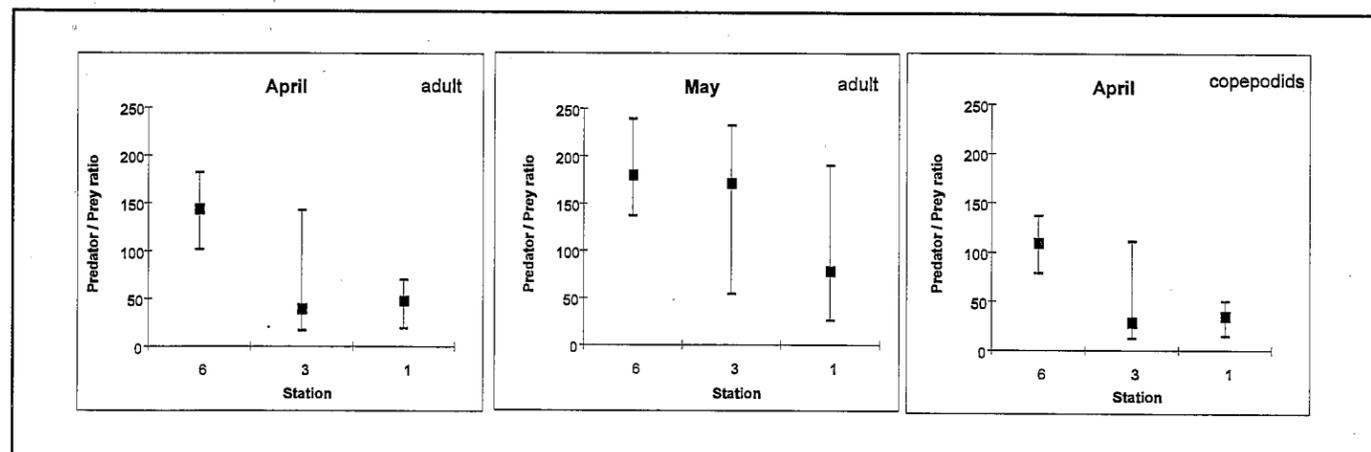


Figure 6

Median and 95th and 5th percentiles of predator/prey ratios at stations within the low salinity zone. Optimum ratios for copepods in this study were 9-33:1.

dian predator/prey ratios which suggested adult and juvenile copepods had food available within the optimum size range at stations 1 and 3 in April (Figure 6). In May, only 10-25% of the ratios fell within the optimum size range at station 1.

## Summary

Abundant, large-diameter diatom cells and high biomass characterized the landward edge of the zone and contrasted with the seaward edge of the zone where ultraplankton composed of green and bluegreen algae were abundant and phytoplankton biomass was low. The center of the zone was more similar to the landward edge of the zone in April and the seaward edge of the zone in May. Although we do not know the actual copepod diet,

## Growth of Largemouth Bass in the Sacramento-San Joaquin Delta

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### Introduction

Largemouth bass (*Micropterus salmoides*) were first introduced into California and the Sacramento-San Joaquin drainage in 1895 at Clear Lake and distributed to Sisson Hatchery (now inundated by Shasta Lake) (Dill and Cordone 1997). They were not noted in an extensive 1888-1889 survey of the Central Valley (Rutter 1907), but were sufficiently abundant to support a local "hook and line" commercial fishery in the Colusa area by 1908 (Dill and Cordone 1997). In the last 30 years, interest in largemouth bass fishing has increased rapidly, and they are now one of the most sought after fish in the Delta.

Original introductions of largemouth bass were of the northern subspecies (*M. s. salmoides*), but between 1979 and 1983 the faster growing Florida subspecies (*M. s. floridanus*) was introduced into Clear and Folsom lakes, Lake Amador, and New Hogan Reservoir, all on delta tributaries. In all these lakes and reservoirs, genetic markers of the Florida strain largemouth bass had introgressed into the northern populations from relatively small introductions (Pelzman 1980), presumably because the Florida strain is faster growing and less vulnerable to angling. Sampling of largemouth bass in east delta dead-end sloughs in 1993 indicated that 21% of the 1992 year class and 30% of the 1993 year class contained Florida-strain alleles (unpublished data, CDFG).

This article reports largemouth bass lengths-at-age in the delta of fish collected during 1980-1984, before large-scale introgression of Florida strain alleles, and compares this growth with that of other largemouth bass in California. I also compare length at the end of the growing

the quality and quantity of phytoplankton food was probably good at the landward edge of the low salinity zone in both April and May and at the middle of the zone in April.

### Literature Cited

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season in 1980-1984 with length in 1995 and 1997, after Florida-strain largemouth bass genes entered the delta population.

### Methods

Largemouth bass for the 1980-1984 growth analysis were collected by electrofishing during three related surveys: (1) a delta-wide stratified random resident fish survey from May 1980 to April 1983, (2) a delta-wide monthly resident fish survey at 10 locations during 1984, (3) and a dedicated tagging survey during June and July of each year 1980 through 1984 which concentrated on east and central delta locations where largemouth bass were most abundant. Only largemouth bass  $>200 \text{ mm}$  fork length (FL) were tagged, so only fish in that size range were aged from the dedicated tagging. Fish  $\leq 199 \text{ mm}$  FL were subsampled for aging from the two resident fish surveys.

During 1995 and 1997, largemouth bass were collected in February and March during a resident fish monitoring study at 20 Delta locations. Largemouth bass  $\leq 199 \text{ mm}$  were available for aging only from 1997 sampling.

Length-at-age during the 1980s was estimated by back-calculating from annular growth marks and scale radii using the Frazier-Lee method (Carlander 1982). During the 1995 and 1997 sampling, length-at-age was determined by adding 1 to the scale age of fish captured at the end of the growing season. A similarly treated subset of the 1980s data (fish collected from October to March) was used for growth comparisons between the 2