**CALFED SCIENCE FELLOWS PROGRAM**

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# Protistan Microzooplankton in the Suisun Bay Food Web: Source or Sink?

Gretchen Rollwagen-Bollens
Washington State University

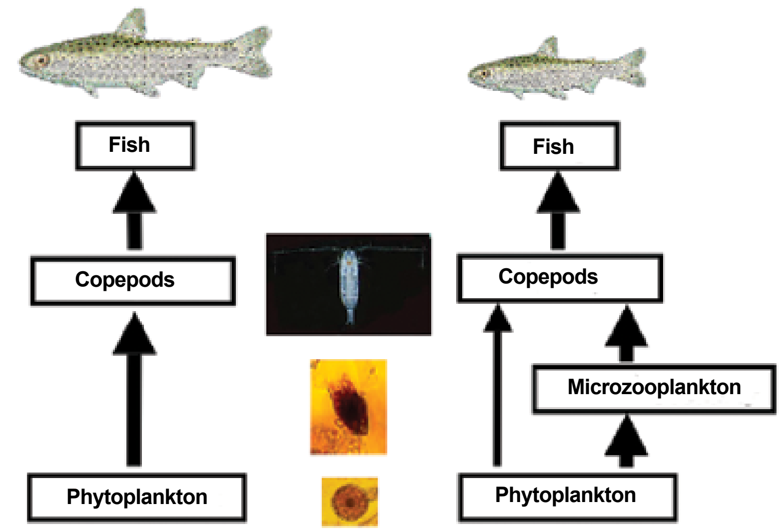
## Background

Water pollution, habitat loss and freshwater diversion—all these are possible reasons for declines in some fish species in the San Francisco Bay-Delta. Another less investigated cause for the declines may relate to feeding dynamics among protists—single-celled organisms that include photosynthetic algae and animal-like zooplankton.

## Project

Gretchen Rollwagen-Bollens was awarded a CALFED Science Fellowship in 2003 to study protists in Suisun Bay in the San Francisco Estuary, their feeding behaviors and feeding rates—who eats whom, how much and how fast. In particular, she examined dietary habitats of a group of larger zooplankton (mesozooplankton) known as copepods and of smaller zooplankton (microzooplankton) called ciliates.

In the classical model of estuarine food web dynamics, copepods are assumed to eat a whole lot of algae. As such, they are placed in the trophic level above algae, the base of the food chain. Perhaps the most significant discovery of this research has been that copepods in Suisun Bay do not follow this pattern. They seem to be "meat lovers," feeding more heavily on ciliates, as compared to algae of the same size or smaller. In turn, ciliates not copepods are the ones feasting on algae. To the extent that Suisun Bay is representative, the classical model of the estuarine food chain has been missing a trophic level, namely that between algae and copepods, represented by ciliates and other microzooplankton.




**Scenario #1**
Microzooplankton are not a significant component of copepod diet and fish production is therefore dependent primarily on the abundance of copepods and in turn phytoplankton.

**Scenario #2**
Copepods consume much more microzooplankton than phytoplankton, effectively adding a trophic level, which substantially lowers fish production. Microzooplankton are a food web "sink."

Illustration credit: Gretchen Rollwagen-Bollens

## Field Studies and Feeding Experiments

The scientist's research conclusions are based on counts of algae and zooplankton in water samples collected monthly and bimonthly (depending on the season) from various parts of Suisun Bay in 2004–05.

Bottle incubation experiments were also conducted to measure feeding rates of various mesozooplankton: a cladoceran (*Daphnia* sp.), calanoid copepod (*Acartia* spp.) and two cyclopoid copepods (*Oithona davisae* and *Limnoithona tetraspina*) on plankton less than 200 µm in diameter. Microzooplankton feeding rates on chlorophyll-containing algae were also measured.

## Results

Nanoplankton (organisms 2 to 15 µm in size) were 10 to 100 times more abundant than microplankton (15 to 200 µm).

Nonetheless, in every experiment, mesozooplankton (200 to 2000 µm) were found to ingest ciliate carbon at the highest rates (3 to 29 nanograms of carbon per hour).

In 2004 the most common microzooplankton (the source of ciliate carbon) were aloricate ciliates (*Strombidium*, *Strobilidium*). Aloricate and tintinnid ciliates (*Tintinnopsis*, *Stenosemella*) were most common in 2005.

Both years, populations of ciliates peaked in late spring when phytoplankton (as measured by chlorophyll concentration) was also at an annual maximum. In some cases, grazing rates of ciliates exceeded phytoplankton growth in a 3 to 10 ratio, which means that ciliates can "over graze" the base of the food chain.

## Implications

"Our results indicate that protists are the dominant grazers of phytoplankton chlorophyll and in turn the dominant prey for copepods and cladocerans in Suisun Bay," said Rollwagen-Bollens, who is now an assistant professor of biology at Washington State University, Vancouver. Moreover, she said, the relative abundance of aloricate ciliates versus tintinnids may affect the overall grazing impact of microzooplankton and the prey selectivity of mesozooplankton predators. This confirms the need to assess both protist diversity and community grazing activity in studies of planktonic food webs.

The discovery of an "extra" trophic level above the base of the food chain means that carbon flows from phytoplankton to ciliates to copepods, not from phytoplankton straight to copepods, as long assumed.

Since energy (i.e., available carbon) is lost through each trophic level, everything else being equal, animals at higher trophic levels may have less carbon available to them than previously thought. In this sense, microzooplankton may be a "sink" for carbon otherwise available for larger animals. Alternatively, microzooplankton may be consuming relatively large amounts of very small bacteria or other nutritious material normally inaccessible to copepods. If this is true, the addition of carbon from nonalgal sources could exceed energy losses, meaning that microzooplankton could actually be a "source" of carbon.

Rollwagen-Bollens plans to continue to investigate whether microzooplankton are adding to or subtracting from the carbon budget. In either case, microzooplankton, especially ciliates, appear to be an important component of the upper San Francisco Estuary food web. Their dynamics, she said, need to be incorporated into biological models that are used, among other things, to estimate fish stock sizes.


## Collaborations

All field collections and experiments were conducted using the facilities (including the RV *Questuary*) of the Romberg Tiburon Center for Environmental Studies, San Francisco State University.


## Mentors

**Research**: Stephen M. Bollens, Washington State University, Vancouver

**Community**: Anke Mueller-Solger, Department of Water Resources, Sacramento

## Presentations


Rollwagen Bollens, G., S.M. Gifford, and S.M. Bollens. Protist Diversity and Trophic Role in a Large Temperate Estuary. Gordon Research Conference on Marine Microbes, July 2006, Biddeford, ME.

Rollwagen Bollens, G., et al. Protists in a Temperate Estuary: Diversity, Grazing and Consumption by Metazoans. Joint Ocean Sciences Meeting of the American Society of Limnology and Oceanography (ASLO) and the American Geophysical Union, February 2006, Honolulu, Hawaii.

Rollwagen Bollens, G., et al. Protists in a Temperate Estuary: Diversity, Grazing and Consumption by Metazoans. Pacific Estuarine Research Society Annual Meeting, February 2006, Friday Harbor, WA.


Gretchen Rollwagen-Bollens (personal collectilon).


Rollwagen Bollens, G., et al. Microzooplankton in the Northern San Francisco Estuary: Important Food Resources but Minimal Phytoplankton Grazers. ASLO Aquatic Sciences Meeting, February 2005, Salt Lake City, UT.

Rollwagen Bollens, G. The Role of Microzooplankton in the San Francisco Estuary. DIALOG VI Symposium, cosponsored by ASLO and the Estuarine Research Federation, November 2004, Dauphin Island Marine Laboratory, Mobile, AL.

Rollwagen Bollens, G. Microzooplankton in the Suisun Bay Food Web: Source or Sink? Third California Bay-Delta Science Conference, October 4–6, 2004, Sacramento, CA.



**For more information:**
Gretchen Rollwagen-Bollens
School of Biological Sciences
Washington State University
Vancouver, WA 98686
Tel.: (360) 546-9115
Fax: (360) 546-9064
Email: rollboll@vancouver.wsu.edu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**CALIFORNIA SEA GRANT COLLEGE PROGRAM**
**Russell A. Moll, Director • Paul Olin, Extension Director • Marsha Gear, Communications Director**
**University of California, San Diego, 9500 Gilman Drive, La Jolla, CA 92093-0232**
**Phone: (858) 534-4440 Fax: (858) 453-2948 Web site: http://www.csgc.ucsd.edu**