Estuarine microbial food webs

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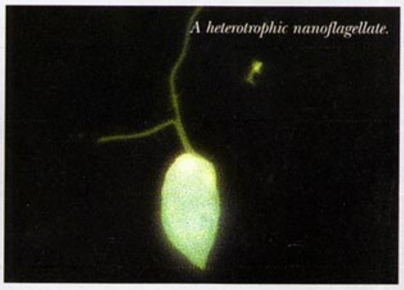
Interactions among the tiny organisms in estuaries can play a major role in maintaining water quality.

GRAZING OF PHYTOPLANKTON and the prevention of phytoplankton blooms in the estuarine environment are traditionally attributed to shellfish and zooplankton populations. It has even been suggested that the shellfish present in some estuaries could filter the entire volume of water present in just a few days.

Both shellfish and zooplankton, however, are often inefficient grazers of small phytoplankton and bacteria as these groups are too small to be consumed directly. In these circumstances small prey may have to pass though additional links in the food chain. In other words, they are "repackaged" via grazing by small organisms into a size which will make them available to the larger grazers.

The microbial food web

In the 1970s the classical model of the marine food web was revised as it became recognised that micro-organisms less than 200 μm across were often as important as larger zooplankton in terms of biomass and energy flows. The term "microbial food web" was introduced in order to describe the complex interactions between organisms within the <200-μm size class.

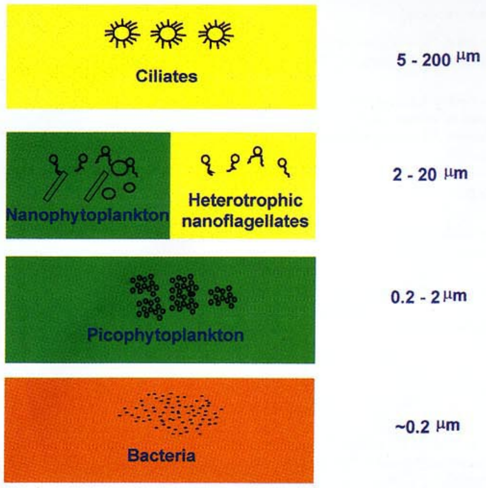


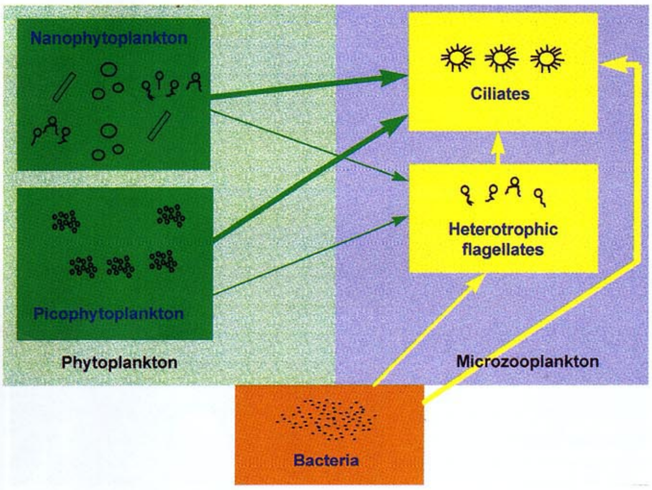
A heterotrophic nanoflagellate.

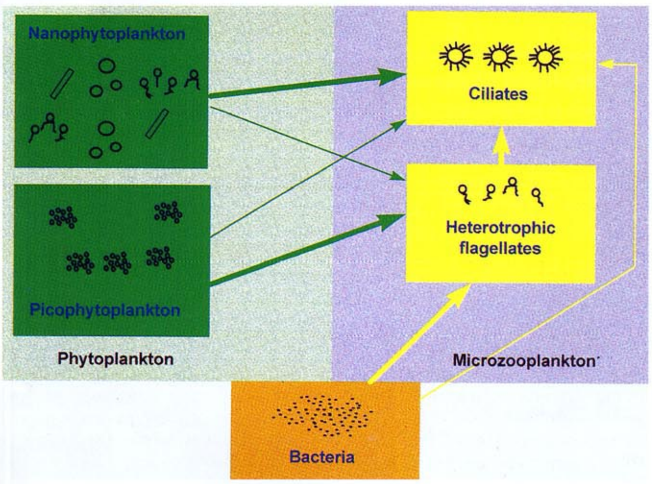
Recent evidence suggests that the microbial food web is a fundamental feature in both coastal and marine waters. It is still largely unexplored in the estuarine environment.

Organisms within the microbial food web can be broken down into groups based on size class and function (see illustrations). The organisms responsible for predation are collectively referred to as the microzooplankton. Microzooplankton have maximum growth rates similar to those of their prey and this can enable them to control assemblages of bacterioplankton and smaller phytoplankton.

It is now recognised that, within the microbial food web, heterotrophic nanoflagellates (see photograph) are the primary grazers of bacteria and picophytoplankton (algae 0.2–2.0 μm in diameter). These protozoa are in turn the prey of large ciliates and dinoflagellates.







The role of microzooplankton in Manukau Harbour

The north-east region of Manukau Harbour represents a eutrophic estuarine environment in which late-summer phytoplankton blooms occur. These blooms consist predominantly of the large diatom *Odontella sinensis*. Despite its large biomass during its blooms, this diatom has no significant nuisance effects.

Collaborative studies involving NIWA scientists have indicated that microzooplankton grazing may be largely responsible for the prevention of bloom formation by the smaller phytoplankton during summer. These studies also found that ciliate abundance in the study area was substantially higher than could be supported by the biomass of the smaller phytoplankton. One explanation for this may be that organic waste has stimulated the growth of natural bacteria already present in the study area. This natural bacterial growth and any introduced bacteria associated with detrital material may have increased food availability and hence enhanced the ciliate abundance.

Activity within the microbial food web in Manukau Harbour.

Studies which focused on phytoplankton biomass (measured by chlorophyll *a*) in Manukau Harbour could not explain the high microzooplankton numbers, nor could they identify which groups of microzooplankton were responsible for the control of the smaller phytoplankton.

In order to answer these questions, experiments were carried out to look at the key predator and prey populations involved in the microbial food web. These studies investigated grazing on phytoplankton prey (represented by chlorophyll *a*) but also investigated grazing on heterotrophic prey within the food web by microzooplankton. Using size-fractionated grazing experiments, we have been able to assess separately the grazing impacts of the two primary predators – ciliates and heterotrophic nanoflagellates.

top:

The different size ranges of organisms found in the microbial food web. This diagram shows that nanoplankton (2–20 µm) consists of two distinct groups the nanophytoplankton and the heterotrophic nanoflagellates.

centre:

A diagrammatic representation of the microbial food web. This figure shows the key members of the microbial (<200 µm) food web with the arrows indicating the pathways of energy and carbon flow.

bottom:

A diagrammatic representation of the microbial food web food observed in Manukau Harbour. This shows that in Manukau Harbour the role of ciliates is less complex than expected with no significant grazing occurring on bacteria or picophytoplankton.

Foodweb terminology

bacteria : microscopic singe-celled organisms that utilise organic matter as an energy source.

chlorophyll *a* : the pigment which plants require for photosynthesis; its concentration is commonly used as a measure of amount of plant material.

ciliates : a group of the protozoa characterised by possessing many fine hairs (cilia).

flagellates : a group of the protozoa characterised by possessing one or more long flagellae (tails) which are used for movement.

dinoflagellates : rigid cells with two flagellae: one passes horizontally around the body usually in a grove; the other often trailing behind the cell. Has photosynthesthic and heterotrophic (see below) representatives.

heterotrophic nanoflagellates : in the size class 2–20 μm; graze to gain energy.

heterotrophs : organisms that obtain energy from organic material.

phytoplankton : single celled organisms that photosynthesise.

picophytoplankton : in the size class 0.2–2 μm.

nanophytoplankton : in the size class 2–20 μm.

protozoa : the scientific name for single-celled grazing organisms; some are also capable of photosynthesis.

zooplankton : tiny animal-like organisms that graze (consume other organisms, including plants).

microzooplankton : zooplankton less than 200 μm in diameter.

The results of the studies were surprising. Instead of ciliates grazing directly on bacterial populations the results indicated that heterotrophic nanoflagellate grazing removed almost all the bacterial growth. Hence, heterotrophic nanoflagellates were the primary factor controlling bacterial populations. This evidence suggests that bacteria naturally present in the harbour, as well as any introduced bacteria, are controlled by grazing. Heterotrophic nanoflagellates were also capable of consuming ~95% of the picophytoplankton and ~80% of phytoplankton production in the <5-μm size class and therefore also contributed significantly to grazing on the smaller phytoplankton.

Ciliate populations were found to graze scarcely at all on bacteria and picophytoplankton and not heavily on phytoplankton in the <5-μm size class. They appeared instead to be grazing primarily on heterotrophic nanoflagellates and nanophytoplankton populations (<20 μm). The high ciliate numbers in the north-east of Manukau Harbour, therefore, appear to be sustained at least partially by the rapid turnover of the heterotrophic nanoflagellate population.

This population was previously unaccounted for in chlorophyll *a*-based experiments which only measured phytoplankton biomass (see centre diagram, page 18).

These findings have, by revealing the complex grazing relationships of the smaller grazers, lead us to a revision of our understanding of the predominant pathways in the microbial food web within the north-east corner of Manukau Harbour.

Conclusions

These results indicate that the microbial food web plays an important role in the prevention of blooms by populations of the smaller phytoplankton in Manukau Harbour. A significant amount of this grazing can be attributed to the heterotrophic nanoflagellate population. This group is responsible for the rapid repackaging of bacteria and picophytoplankton biomass. In turn, ciliate grazing on heterotrophic nanoflagellates and nanophytoplankton provides a pathway for biomass to be made available to grazers from higher trophic levels such as zooplankton and shellfish. This study has also revealed that high ciliate populations are sustained in Manukau Harbour at least partly by the consumption of heterotrophic prey within the microbial food web. Ciliate populations appear to be enhanced through direct consumption of heterotrophic nanoflagellates and indirect consumption of bacterial biomass.

Implications for the role of the microbial food web

In estuarine and other coastal environments, algal blooms from a variety of size-classes can cause problems including fish kills, contamination of shellfish, oxygen depletion caused by the decay of large amounts of phytoplankton, the production of surface scums and poor water clarity. The current investigations into the role of the microbial food web have shown that in the north-east corner of Manukau Harbour blooms by smaller and possibly more problematic nuisance algae may be prevented by the grazing activity of microzooplankton. In addition to nuisance phytoplankton blooms, problems may arise from the introduction of harmful pathogens including bacteria associated with organic waste inputs. These can cause contamination of shellfish and have detrimental effects on human health. The results of the current study indicate that in Manukau Harbour heterotrophic nanoflagellates may be rapidly consuming any introduced bacteria, reducing detrimental effects that these organisms may cause. Overall these studies indicate that the microbial food web plays an important role in the maintenance of water quality. ■

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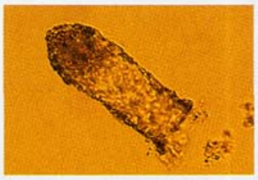

A loricate ciliate isolated from Manukau Harbour.

Further reading

James, M. 1994. Microzooplankton and their role in marine food webs. *Water & Atmosphere 2*(3): 25-26.

Hall, J. 1994. Microbial food webs: the importance of algae that raze. *Water & Atmosphere 2*(3): 26-27.