

VIRAL MORTALITY OF PHYTOPLANKTON

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Viruses are the most abundant ‘forms of life’ in the ocean. These pathogens potentially infect all marine organisms, but bacteria and phytoplankton are numerically their major hosts. Marine viruses strongly affect the nutrient cycling and they can contribute substantially to the demise of algal blooms. Our study shows that viruses infecting phytoplankton can harbour high diversity and play a relevant role for the regulation of phytoplankton in contrasted marine environments.

Microbial communities (phytoplankton, bacteria, archaea, heterotrophic protozoa and viruses) comprise the majority of the biomass in the oceans and drive the nutrient and energy cycling. Photosynthetic unicellular algae (phytoplankton) form the basis of the marine food web. Traditionally, grazing by zooplankton and sinking have been considered to be important sources of phytoplankton mortality. The past decades, however, evidence has accumulated showing the existence of other sources of phytoplankton cell death, amongst which virally mediated lysis. Most of the existing classes of phytoplankton have been reported as hosts for virus-like particles. Viruses can have a strong effect on the abundance of the phytoplankton population they infect, and particularly for bloom-forming algal species. Because viruses are typically host-specific pathogens and regularly exhibit a high degree of strain* specificity, viral infection impacts specific phytoplankton populations and thus enhances interspecies, and even intraspecies, diversity.

In the southern North Sea, the phytoplankter *Phaeocystis globosa* is well known for its high biomass spring blooms. *P. globosa* has a polymorphic life cycle with flagellated unicellular and non-motile cells that are embedded in colonies (Fig. 1). The collapse of *P. globosa* blooms can be sudden and generate large amounts of foam that can be washed onshore (Fig. 2). During the bloom demise, cell lysis was found to be a major source of mortality. A recent mesocosm experiment carried out at the Royal NIOZ revealed that viruses were the responsible factor for cell lysis of *P. globosa* single cells during the bloom. The characterization of these viruses and the estimation

of their influence in the field still had to be explored.

The ecological role of algal viruses in the field has long remained elusive because of the lack of appropriate methods. Very recently, a dilution approach that directly estimates viral lysis and microzooplankton grazing rates was developed. An adapted version of this assay was applied during two consecutive *P. globosa* spring blooms in the coastal southern North Sea. Viral lysis accounted for 5 to 66% of the loss of *P. globosa* single cells. Towards the end of the bloom, viral lysis rates could be even higher than microzooplankton grazing rates (Fig. 3). Thus viruses contributed

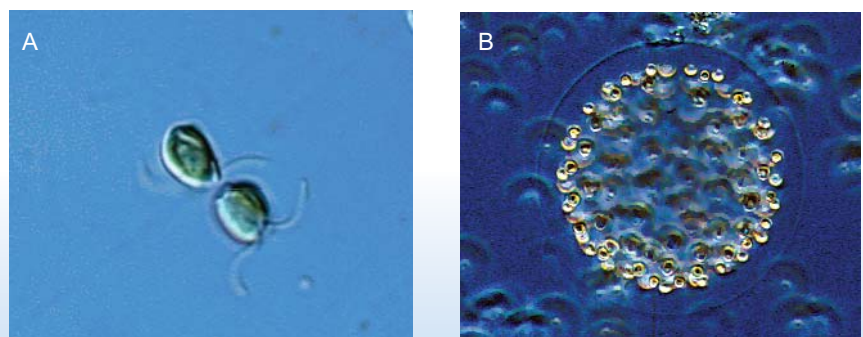


Fig 1. *Phaeocystis globosa* (A) single cells (5-8 μm in diameter), and (B) colonies up to 1 mm in diameter containing up to 20,000 cells. Photos taken by Anna Noordeloos.

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Fig. 2. Foam washing ashore at the end of a *Phaeocystis globosa* spring bloom. Courtesy of Marcel Veldhuis.

groups, e.g. cyanobacteria, grazing was the main loss factor.

These results imply that viruses infecting phytoplankton are diverse and cause a significant amount of marine phytoplankton mortality, collectively with grazers, in contrasted marine environments. This finding is important since phytoplankton losses caused by viral lysis and grazing influence the flow of nutrient and energy in different ways. The release of cell con-

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actively to the demise of the *P. globosa* bloom. The isolation and the characterization of twelve *P. globosa* viruses furthermore revealed that they harbour a high level of diversity, based on phenotypic criteria such as their particle size, their genome size and the way these viruses interact with their host (Fig. 4).

In more oligotrophic systems (e.g. the open ocean), the phytoplankton community is composed of several groups of phytoplankton of very small size (typically $<3 \mu\text{m}$). In these environments, the impact of viruses differed across the groups forming the phytoplankton community. While viral lysis was the main source of mortality for some eukaryotic algae, for other

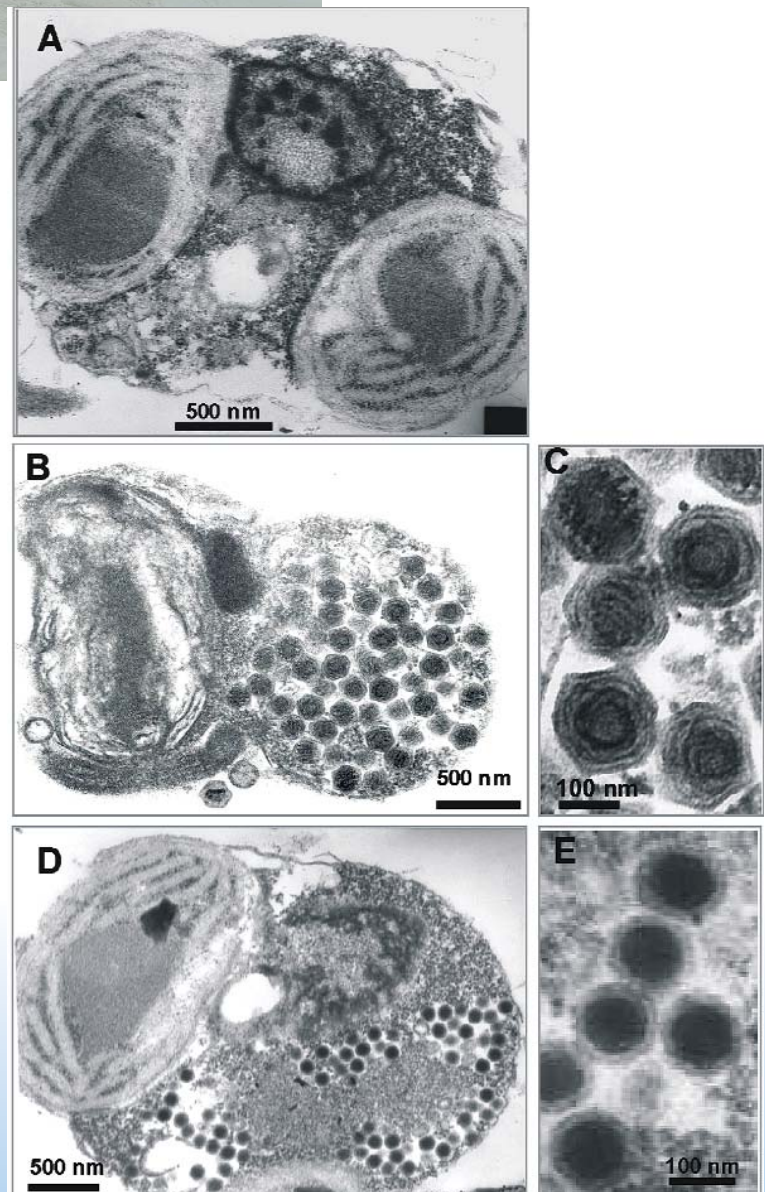


Fig. 3. Transmission electron micrographs of *Phaeocystis globosa* noninfected (A) and infected by two different virus (B, C and D, E).

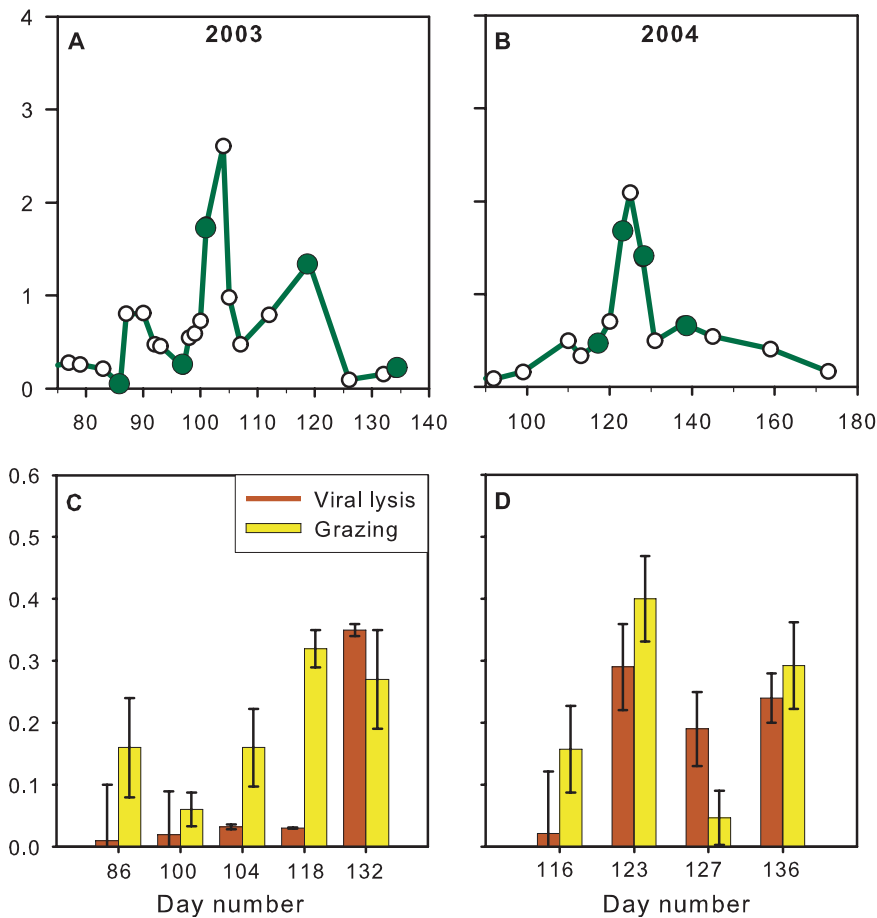


Fig. 4. Abundance of *Phaeocystis globosa* single cells during the spring blooms in 2003 (A) and 2004 (B), with estimates of viral lysis and microzooplankton grazing by the dilution assay on selected dates (green dots) of 2003 (C) and 2004 (D).

stituents upon lysis has a direct impact on the flux of organic carbon and the recycling of nutrients whereas grazing channels phytoplankton biomass to the higher trophic levels. Future research should aim on gaining more insight into the genetic diversity and clonal variation of the algal virus and its host, the regulatory factors underlying successful viral infection, and last but not least should study the impact climate change has on virus-host interactions.

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