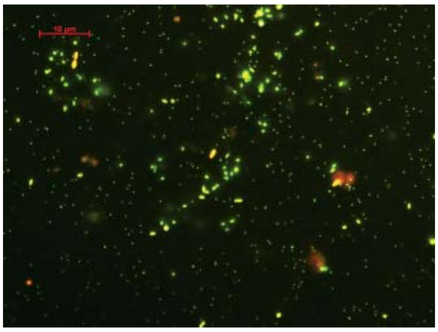
Theme 5: Biodiversity and Ecosystem Functioning

Introduction

At present, about 230,000 species of marine plants and animals and a few thousand prokaryotes have been scientifically described. The known biodiversity, however, only represents a small fraction of the number of species existing. Exploration of the marine environment constantly yields new species and will continue to do so for decades if not centuries to come. These species occupy a wide variety of niches and trophic levels in the food web. Through their activities, especially of the unseen majority of microbes, they also exert a major influence and control on the major biogeochemical cycles. However, even basic knowledge does not exist on the relationship between the specific characteristics of species, their genetic make-up, biochemistry, physiology, and behaviour and ecosystem structure and especially functioning for the vast majority of species.

Mixed bed of Japanese oysters, blue mussels and periwinkles in the Wadden Sea. The Japanese oyster escaped from aquaculture experiments in the early eighties of the last century. Its population in the Wadden Sea has been rapidly expanding ever since. Is this purely negative of is there a positive side too? Photo: Bert Aggenbach (NIOZ).

Moreover, the conceptual and theoretical framework describing the relationship between biodiversity and ecosystem functioning, stability and resilience is almost entirely based on observations and experiments on land. Only a few studies exist for the marine environment and they are restricted to intertidal, easily accessible areas. Simple experiments in which species were added to or removed from artificially assembled or defaunated natural communities have shown that species number and composition have an impact on the rate of ecosystem processes. However, the fundamental question whether all species or only a subset of species is required to maintain ecosystem health and functioning has not been answered yet. Solving this question will have important consequences for protection, preservation and management of biodiversity and ecosystems as a whole.



Epifluorescence microscopy picture of bacteria (large dots of about 1 micrometer) and algal virusses (small dots of about 0.1 micrometer). The nucleic acids of the micro-organisms have been coloured with the dye Sybr Green I. Photo: Govert van Noort (NIOZ).

If the relationship between biodiversity and ecosystem functioning is poorly known for macro-organisms, the challenge is even more daunting for microbes. Major discoveries during the last decade have come from the use of molecular methods both to elucidate microbial biodiversity itself and to link it to ecosystem functioning. Examples are the discovery of the widespread occurrence of archaea and their role in nitrification, and the discovery of bacteria able to oxidize ammonium anaerobically and thought to be responsible for at least half of the denitrification in the ocean.

Unravelling the Diversity of the Microbial World

Research on microbial diversity and function encompasses prokaryotes, viruses and protists, thus essentially covering all members of the microbial food web. Major progress has been made in elucidating the carbon and matter flux through microbial communities in marine systems over the past three decades using largely a 'black box' approach. The composition, particularly of prokaryotic communities, has only been addressed efficiently since the advent of molecular biology approaches in microbial ecology. Since their introduction, our knowledge on prokaryotic phylogenetic and functional diversity has increased exponentially. Applying fingerprinting techniques, it became apparent that the prokaryotic community composition changes in a predictable manner in coastal temperate waters over seasonal cycles similar to the phytoplankton successions.

Recently, high-throughput sequencing approaches have revealed an enormous diversity of prokaryotic species. We do know now that the prokaryotic community composition is highly stratified in the water column and hence, apparently well adapted to the composition of the substrate and in delicate balance with its main predators, the protists and viruses. Remarkably, it appears that changes in prokaryotic community composition do not result in changes in the major ecosystem functions such as remineralization of organic matter. Apparently the rich microbial biodiversity allows multiple food-web structures for a given environment.

Testing ecological concepts, such as the diversity – stability relation, the area – species relation, and even the neutral theory, which is hard to test with macrobial members of ecosystems, is possible in microbial communities. The great advantage is that microbial populations react quickly to changing conditions and change their genetic inventory within a few thousand generations, hence within months. In an evolutionary context, the occurrence of ecotypes and the role of viruses in evolutionary sweeps of ecotypes are tractable in microbial systems.

NIOZ will apply the tools that are now available to integrate microbial ecology into the general science of ecology, as the microbial food web provides unique opportunities to identify ecological patterns and processes common to all forms of life. To arrive at a mechanistic understanding of microbial diversity and its impact on major ecosystem functions, metabolic rate measurements and phylogenetic analyses of the bulk prokaryotic community with single cell techniques will be combined.

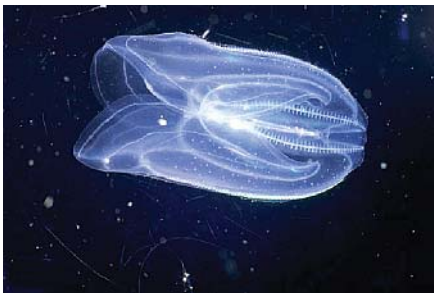
The slightly curved American jacknife *Ensis americanus* which came to Dutch waters in the nineteen seventies with ships' ballast water has virtually outcompeted the original and completely straight species *Ensis siliqua*. Meanwhile eider ducks (*Somateria mollissima*) have learned to feed on the juveniles. Photo: Bert Aggenbach (NIOZ).

Invasive Species

On a global scale, and certainly also in the marine environment, the number of non-indigenous species is increasing exponentially. Because the appearance of invasive species is often accompanied by economic damage, alteration of the local biodiversity, or even threats to human health, this topic has been subject of intensive studies.

Biodiversity can influence the ability of exotic species to invade communities through either the influence of traits of resident species or some cumulative effect of species richness. Early theoretical models and observations of invasions on islands indicate that species-poor communities are more vulnerable to invasion because they offer more empty niches. However, studies of intact ecosystems find both negative and positive correlations between species richness and successful invasion events.

Invading species will be monitored by NIOZ through the long-term sustained observation series of NIOZ in the Wadden Sea. The ecological consequences of invasions and range extensions such as by the Japanese oyster and several fish species in the Wadden Sea will be studied experimentally and by using ecosystem models.



Another ballast water intruder from America is the comb jelly-fish *Mnemiopsis leidyi*. This species had a severe impact on the Black Sea ecosystem. In recent years, it has also been found along the Dutch coast. Will it cause similarly dramatic changes here or will it merge gently with the existing ecosystem?

Changes in the distribution of species may be the result of large-scale climatic events or changes in anthropogenic pressures. However, ships are one of the main vectors responsible for the introduction of invasive species. With increasing tonnage, number and speed of vessels, it is likely that this vector will increase in importance in the future. To halt the transport of non-indigenous organisms by ship's ballast water, the International Maritime Organization (IMO) has recently adopted a convention. This states that from the year 2012 onwards, ships must treat their ballast water in such a manner that it is free of living organisms at discharge. This challenges not only industry to develop whole new concepts of cleaning ballast but also research on the efficient mitigation of invasive organisms transported by ships.

NIOZ is one of the five leading institutes worldwide which can meet the international standards for testing clean ballast water treatment technologies for final certification. The Institute also has the capacity to assess how the chemicals used impact the receiving ecosystem at discharge, from viruses to macroplankton.