Annual Report 2011

NIOZ Royal Netherlands Institute for Sea Research

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Texel, June 2012
NIOZ Royal Netherlands Institute for Sea Research

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Content

Introduction

Living with a warming ocean, the central theme of the EU Framework 7 project 'European Research and Public Perception of Climate Change Impacts in the Marine Environment' (CLAMER) in which Royal NIOZ has participated, echoes many of our research topics. Gaining fundamental insights in the combined effects of e.g., climatic warming, ocean acidification, stratification, biodiversity loss, pollution and many other anthropogenic factors, in terms of changing marine ecosystems and environments is vital for modern society and future directions. Royal NIOZ activities, our mission, our multidisciplinary research, and modern facilities, including ships, were and are dedicated to this task, also in 2011. Moreover, NIOZ continued its support of academic marine research in the Netherlands and Europe, and in 2011 further strengthened its role as the national oceanographic institute, also in international perspective.

Indeed, 2011 saw the outcome of an external scientific peer review for NIOZ over the years 2005-2010 by an international committee of outstanding marine scientists. The review committee concluded that '*all the NIOZ departments have improved their scientific output over the evaluation period*'. The committee found a number of them to have become really world-class, like the organic biogeochemistry department, with many publications in high-ranking journals. '*..The impressive list of all NIOZ publications testifies directly to the outstanding academic reputation of NIOZ scientists, who are active in international organisations, participate in scientific networks, and in many cases act as part-time or guest professors at one or the other of the Dutch universities...*' They also judged NIOZ technical support and facilities to be at a very high level, with (in some cases) unique and world-leading technologies. Overall, the performance of the institute as a whole was classified as 'excellent', with high societal relevance. No doubt, the outcome of the peer review is a positive boost to the entire organisation, and here, we thank all NIOZers for their excellent contribution to the institute over the past years.

2011 was not only a year of review, it was also a year of transition. Preparations and activities concerning the merger between NWO-NIOZ and the Centre for Estuarine and Coastal Ecology of the Netherlands Institute of Ecology (NIOO-CEME) peaked in 2011. This merger is seen by all parties as essential to maintain a viable fundamental marine research community in the Netherlands, and was finally clinched to start January 1, 2012.

Another transition involved the retiring of Prof Dr Carlo Heip as general director NIOZ per December 1, 2011. Carlo's outstanding achievements as a scientist and as NIOZ general director were celebrated through a dedicated international symposium held at the Royal Academy in Amsterdam in December. Fortunately, he will remain active for NIOZ as senior advisor, with particular attention for European affairs. His successor, Prof Dr Henk Brinkhuis, a biogeologist from Utrecht University started the 1st of October, 2011. Henk will continue his chair in Utrecht part time.

The overall budget of NIOZ approached 32 M€ in 2011, of which 34% was obtained through external grants. This marks an important increase of close to 30% over the last two years. The number of people employed by NIOZ is now close to 300 (equalling 228 fte; 142 tenured and 86 temporary), of which only 34 are tenured scientists.

This low ratio permanent/temporary staff remains (too) low, an aspect also the peer review committee highlighted in their report to NWO. The system of tenure track was continued and NIOZ now has 5 young scientists on tenure-track positions.

A total of 16 new projects were granted. Especially the intertidal work in international consortia appeared to be very successful. A challenging project aims to identify core metabolisms of benthic microorganisms in the Wadden Sea using compound specific hydrogen isotopes. Our participation in Antarctic research is further esta-blished with a new study on the lower pelagic food web and the seasonality in trace metal availability and plankton dynamics. An 'NWO-Middelgroot' grant was received to further the non-destructive scanning of sedimentary and coral climate archives.

Like in 2010, the NIOZ production of articles in peer reviewed journals passed the 200 publications mark in 2011, with a total of 203 papers. Eight articles appeared in the top journals Nature, Science, Nature Reviews Microbiology, Nature Geosciences and PNAS. Major papers of 2011 dealt with the role of the Agulhas system as a climate trigger or feedback system for global warming, with the microbial carbon pump, with the bioavailability of iron in the Southern Ocean, with mega-droughts during Pleistocene interglacials, with African precipitation patterns over the past 23,000 years, with the link between the end-Triassic mass extinction and atmospheric carbon injection, and with a reconstruction of the climate variability in East Africa during the last ice age.

NIOZ is a respected partner in many EU and ESF projects and has close collaborations with major institutes and scientists in Europe and worldwide. Over eighty PhD students and post-docs are an important part of the NIOZ community. This year, 9 PhD students received their degree after a successful defence of their thesis, some of who made a special contribution to this annual report.

NIOZ hosted 2 international symposia. In collaboration with IMARES and DELTARES the International Symposium on the Ecology of the Wadden Sea was organised (10-14 October). This year's focus was on the importance of scale and connectivity in the functioning of the Wadden Sea ecosystem. Dr. C. Brussaard organized the 6th International Aquatic Virus Workshop (AVW6), held from 30 October-3 November. This workshop aims to establish a forum where the most recent results in the field are presented, ideas are exchanged, new methods and developments are discussed, and future collaboration is encouraged. AVW6 was timely and has attracted many new participants (86 participants in total). The high quality of the science presented, has made it an outstanding environment for allowing graduate students and other junior scholars to mingle with the leaders in aquatic-virus research.

Besides being under threat from multiple angles, the oceans also remain a frontier area for economy and exploration. Technological advances now allow penetration of the twilight zones of the oceans and even deeper, and the exploration and exploitation of the deep sea is no longer science fiction. 'Deep Sea Mining', a consequence of the ever-increasing need for resources, has become a major theme this year. NIOZ considers that the increasing use of the marine environment requires new national and international legislation and governance, and that the scientific knowledge that is required to regulate operations is not yet available. To accommodate both fundamental as well as applied deep marine research, NIOZ launched its '*Netherlands Deep Sea Science & Technology Centre*' in the fall of 2011, bringing together researchers from various scientific disciplines and technical departments. The centre combines fundamental knowledge of potentially threatened deep sea ecosystems with the technological expertise to reliably sample and monitor these extreme environments. With this centre, NIOZ can respond even better to solving questions and problems related to the deep sea.

After its mid-life overhaul in 2010 the R.V. Pelagia was in full flow in terms of expeditions in 2011. R.V. Pelagia sailed for 301 operational days on a total of 18 cruises ranging from North Atlantic waters to the Libyan Gulf of Sidra in the Mediterranean. Not less than eight of these cruises addressed both fundamental and applied research in the North Sea. A full list of cruises is available from the section on Marine Research Facilities.

The renovation of the NIOZ buildings steadily continued, with good progress of the high tech chemical labs in the C-00/D-00 blocks. It is anticipated that this phase will be completed successful, within budget and on time around mid-March 2012.

Building on the success of the increased usage of the NIOZ harbour for e.g. certification trials of ballast water treatment installations and cultivation experiments with algae, seaweeds, shellfish and fish, renovation plans of the harbour were formulated. In close concert and cooperation with the Texel council and the Province of Noord Holland, sufficient funding was obtained for these investments.

NIOZ harbour with the ballast water installations. Photo: Pieter de Vries

Ronald de Koster, system developer and database administrator for the NIOZ Data Management Group, was the 2011 Laureate in the category 'Environment' of the 23rd Honors Program of the leading ICT magazine Computerworld. This program aims to recognise those, whose visionary applications of information technology promote positive social, economic and educational change in the world today. Ronald de Koster was awarded for his contribution to improve the exchange of complex multidisciplinary oceanographic data through global standardization protocols and the design of a distributed environment for data management.

2011 was a year of excellent productivity, growth and change, including the finalizing of the merger with NIOO-CEME, and new directorship. Overall, another very successful year for our institute and we look forward to 2012, with one NIOZ at two locations, TX and YE.

Henk Brinkhuis
Herman Ridderinkhof

Carlo Heip retires as director of NIOZ

Peter Herman

On 1 December, we honored Carlo Heip with a scientific symposium at the Royal Academy of Sciences in Amsterdam, at the occasion of his retirement as NIOZ director. This celebration almost coincided with the fusion between the Yerseke and Texel centres into the new NIOZ, as of 1 January 2012. The fusion is one of Carlo Heip's major achievements.

Carlo Heip studied biology at Ghent University (Belgium), where he obtained his Master's and Ph.D. degrees with studies on meiobenthos in a small brackish-water pond (Dievengat) in the polders near the Belgian coast. In Ghent, Carlo pursued his career at the prestigious National Fund for Scientific Research. He founded a successful group of marine biologists that gradually expanded its research area to the Belgian coastal sea, the Dutch Delta and even to the Mediterranean and the deep sea. Research was focused on benthos, mostly meiobenthos, aiming at quantifying the functional role of meiobenthos in the marine system under variable levels of human stress.

Following his research contacts with the Delta Institute for Hydrobiological Research in Yerseke, he was asked to become director of this institute in 1987. In Yerseke he managed three important reorientations. The scientific programme of the institute was reoriented from the description of the consequences of the Delta Works, towards fundamental ecological research in estuaries and seas around the world. The organization of the institute was fundamentally changed when it became part of the Netherlands Institute of Ecology in 1992. At that time he became the Centre Director of Yerseke, which he remained until 2009.

Finally, in the latest years of his centre directorship he initiated the transition of the Centre for Estuarine and Marine Ecology of NIOO to become part of NIOZ.

As a scientist and group leader, Carlo Heip contributed to the strong development of biogeochemistry and modeling in the institute, and later concentrated mainly on linking these aspects of ecosystem functioning to marine biodiversity. He promoted interdisciplinary research, as well as blending theoretical and field-based approaches. He successfully linked the institute's scientific research to the European framework, thereby securing financial means but mainly international visibility of the institute. Much of this culminated in his leading role in marine biodiversity research.

Carlo Heip became director of NIOZ in 2006. Until 2009, he combined this function with the centre directorship at Yerseke. At NIOZ he consolidated and strengthened the organization of the institute. The recent peer review of the institute recognized excellent management and organization, and described it as one of the factors that had contributed significantly to the excellence of the scientific research in the institute.

Having started his scientific career with small organisms in a small pond, his appointment as a director of an oceanographic institute with a worldwide orientation was a deserving expression of his ever-widening scope and ambition. He became an important member of global organizations promoting the study and conservation of

marine biodiversity, such as the Census of Marine Life. He actively stimulated global-oriented oceanographic research at NIOZ, but also kept a strong link to coastal and estuarine research. His involvement with Dutch national funding for Wadden Sea research was instrumental in the current upheaval of this research.
When Carlo Heip became director in Yerseke in 1987, a possible fusion with NIOZ was one of the first issues that he had to handle. Although endorsed by the scientists and directors, the fusion failed for organizational reasons at the time. CEME in Yerseke became part of NIOO, but despite this move continued to collaborate with NIOZ, resulting in more joint projects and publications with NIOZ than with the other NIOO centres. Following the concentration movements in Dutch marine research, with the formation of two large institutes for applied research, a concentration and consolidation of academic marine research was also called for. This, as well as independent developments within NIOO, revived the interest in a CEME-NIOZ fusion. As a director in both institutes, Carlo Heip was ideally placed to realize this move. The process started in 2008 with an evaluation of the scientific costs and benefits of this merger. Following positive advice of two commissions, long and difficult negotiations followed and were concluded positively around the period of Carlo Heip’s retirement.
The directorship of Carlo Heip has resulted in a renewed and expanded NIOZ, a solid basis for excellent science and an institute that is prepared for the challenges of the future. We look back on this period with respect and gratitude.

New external projects

- Antarctic phytoplankton in a changing world and its consequences for the lower pelagic food web (ANTPHIRCO, NWO Polar Program).
  C.P.D. Brussaard.
- Biogeochemical cycling of organic matter in coastal marine sediments: Intact polar lipids as tracers for key microbes (DARWIN).
  E. Moore, J.S. Sinninghe Damsté. In cooperation with the Wageningen University.
- Cascading predator-prey effects in a pristine seagrass-based food web (NWO-ALW Open Programme).
  J.A. van Gils, R.A. Bom. In cooperation with Universiteit van Amsterdam and Sultan Qaboos University (SQU), Oman.
- Compound specific hydrogen isotopes as indicator of core metabolisms of benthic microorganisms in the Wadden Sea (NWO).
  S. Heinzelmann, M.T.J. van der Meer.
- Development of a large-scale application for offshore tidal energy. (European Regional Development Fund, ERDF).
  H.M. van Aken, J. de Vries, J. Nauw.
- Effects of invasive species on native predator-prey and pathogen-host webs (NWO & BMBF Germany, Transnational call on bilateral Wadden Sea research).
  D.W. Thieltges, P.C. Luttikhuizen, K. Camphuysen. In cooperation with AWI Sylt and IfM-Geomar Kiel, Germany.
- Food web model by ecological network analysis (ENA) for a western Wadden Sea ecosystem, the Balgzand area.
  H.W. van der Veer, C.J.M. Philippart. In cooperation with Alfred Wegener Institut für Polar und Meeresforschung.
- Long term Indian Ocean monsoon dynamics as revealed by a 25-kyr lipid biomarker record of Lake Challa: potential signals of natural climatic change.
  C.I. Blaga, J.W. de Leeuw, J.S. Sinninghe Damsté. In cooperation with the King Saud University and Ghent University.
- Saba Bank Expedition October 2011 (WWF grant).
  E.H. Meesters (IMARES), F.C. van Duyl. In cooperation with LVV, STENAPA, SABA Marine Park, Bonaire Marine Park, St Maarten Marine Park.
- Scanning sediment and coral climate archives applications of non-destructive nature (NWO-Middelgroot).
  G.J.A. Brummer, R. Tjallingii, J.-B.W. Stuut, W. Boer, R. Gieles.
- Seasonality of iron and other trace metals in relation to the rapidly changing ice/water cycle and plankton dynamics of the West Antarctic Peninsula (*NWO Polar Program).*
  H.J.W. de Baar.
- Sedimentary long-chain, mid-chain diols derived from marine phytoplankton: novel proxies for climate reconstruction (NWO).
  J.S. Sinninghe Damsté, L. Handley, S.W. Rampen (UU), G.-J. A. Brummer, K.R. Timmermans.
- The effects of changes in Wadden Sea habitats on behaviour, physiology, ecology and population dynamics of migrant waterbirds (Metawad-1, Waddenfonds).
  T. Piersma.
- The future of the Wadden Sea sediment fluxes: still keeping pace with sea level rise? (PACE, ALW/BMBF).
  H. Burchard (IOW), T. Gerkema. In collaboration with Deltares, IOW Warnemünde and HZG Geesthacht.
- Tracing chemoautotrophic microbes in present and past sedimentary environments (DARWIN).
  Y. Lipsewers, L. Villaneuva.
- Tracing the environmental significance of nitrite-driven anaerobic methane oxidation (DARWIN).
  D.M. Kool, J.S. Sinninghe Damsté. In cooperation with the Radboud University Nijmegen.

Multidisciplinary Theme

Tropical and cold-water coral research at NIOZ: branching out over multiple disciplines

Furu Mienis, Rolf Bak, Geert-Jan Brummer, Gerard Duineveld, Craig Grove, Marc Lavaleye, Benjamin Müller, Roel Nagtegaal, Judith van Bleijswijk, Fleur van Duyl, Tjeerd van Weering*

Coral reefs, with their profusion of colours and shapes, are well known from tropical regions. Despite early observations dating back to the mid-eighteenth century, the cold water pendant has virtually gone unnoticed until two decades ago, when an increasing number of observations established their existence in cold deep waters across all latitudes. Tropical and cold-water coral reefs seem to share many traits and functions, but recent studies indicate they are quite distinct in others. NIOZ has been involved in coral reef research since the 1970's, starting with ecological research on the reefs of Curaçao and Bonaire. Over the past decade NIOZ has expanded its scope to climate reconstruction applications, to ecosystem studies on cold-water reefs, and to the formation of carbonate mounds on geological time scales. This contribution presents an overview of our current and recent research on tropical and cold-water coral reefs, as carried out in four departments.

A most striking characteristic of both tropical and cold-water coral reefs is their high biodiversity. This diversity urged Bak and co-workers to address questions on the stability of tropical coral reef communities and on the impact of compositional change on ecological processes such as competition.

In 1973 a long term series was started of photographs of permanent quadrates for reef bottoms at water depths of 40, 30, 20, and 10 m in Curaçao and Bonaire. The overall picture over the past decades is one of great change, showing that coral cover has decreased from high overall values of 45% in 1973 to less than 25% at present (Fig. 1). How the process enfolds, in terms of the fate of coral colonies is shown in Fig. 2. This decrease in cover is particularly significant in the shallower reef depth of 10-20m. However, some species, such as *Madracis mirabilis* are showing an increase in coral cover over time. This invaluable series of photographic records is continued to date and is worldwide the longest time series available.

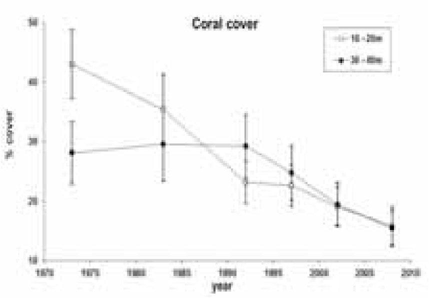

Fig. 1. Change in coral cover for deep and shallow reefs at Bonaire.

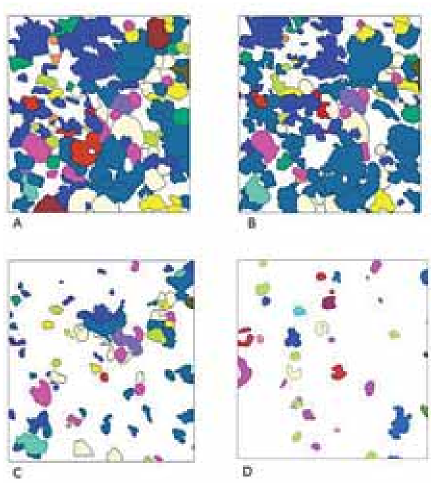

Fig. 2. Change in coral cover and community composition at Bonaire Karpata in 1974 (A), 1983 (B), 1991 (C), and in 2008(D). Colours indicate coral colonies of different species.

Tropical coral reefs being hotspots in biodiversity, in biomass and in productivity typically thrive in low nutrient environments. During his voyage on the Beagle, Darwin described tropical coral reefs as 'oases in the desert of the ocean' and reflected on the paradox that 'such diverse ecosystems could flourish surrounded by tropical ocean waters that provide hardly any nutrients'. It implies a fast turn-over and a highly efficient conservation of nutrients and energy within the reef community. 'Which are the key organisms in this community, can we identify their role(-s) and disclose the functional relationships between them?' Van Duyl and co-workers focus on the role of corals, macroalgae, and sponges, and their studies provide some nice examples how matter is recycled, resulting in the containment of energy and nutrients within the reef community.

Recently they demonstrated that sponges living in coral cavities rely for 90% of their diet on dissolved organic matter. This is a remarkable finding since it is generally assumed that sponges predominantly feed on pico-and nanoplankton. The coral reef itself appeared to be the main source through the release of dissolved organic matter by corals and benthic algae. Considering the amount of dissolved organic matter being converted into sponge tissue and faeces and the increasing biomass of sponges on coral reefs, it is evident that sponges play an important role in the cycling and conservation of energy and matter on reefs.

The functional role of endosymbiotic Bacteria and Archaea is currently under study. Both corals and sponges harbor nitrifying *bacteria* and *archaea.* These microorganisms derive their energy from the oxidation of ammonia to nitrite and reduce CO_2 to form organic carbon for growth. Since their metabolic end-product nitrite is a precursor in denitrification and in the anaerobic oxidation of ammonium, both of which result in the loss of nitrogen, nitrification may negatively affect the reef's nitrogen budget.

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Fluorescent in situ hybridization techniques have been applied to reveal the diversity in nitrifying microorganisms and showed that many are sponge specific, the *archaea* being most abundant. The nitrifying *bacteria* were more temperature and therefore more habitat related than the *archaea*. Currently, the rate of nitrification is assessed for various sponges living on cold-water and tropical coral reefs to estimate the overall impact of host associated nitrification on the reef's N budget. Previously, the fixation of CO_2 has been established for several intact cold-water coral reef sponges as well as for the cold-water coral *Lophelia pertusa*. This raises the question if CO_2 is fixed by the host directly, or indirectly through the trophic transfer of organic compounds from the endosymbiotic microorganisms actually reducing the CO_2. To finally resolve this long standing enigma in sponge metabolism, van Duyl and co-workers have recently incubated the cold-water coral encrusting sponge *Hymedesmia coriacea* with ^{13}C-DIC, in order to trace and track the label from specific biomarkers of bacteria and archaea into sponge markers.

Fig. 4. Bright red excavating sponges (*Cliona laticavicola*) colonizing a coral surface.

Environmental changes increase the competition for space between tropical corals and benthic macroalgae (Fig. 3). Upon contact with macroalgae, corals may bleach by expelling their endosymbiotic algae, the zooxanthellae. As a consequence, the prokaryotic community of the host deranges and the host appears more susceptible to diseases. How this process deranges the community was studied in the tropical coral *Porites* sp. in contact with the calcareous macroalga *Halimeda* sp.. Rhodobacteriaceae, the cyanobacterium *Oscillatoria spongelia* and several potential pathogens were identified in the stressed coral tissue. In a healthy control, the microbial community was characterized by a broad range of complex carbohydrate decomposing microbes, which may potentially produce antibacterial and cytotoxic substances. After removing the macroalga, the zooxanthellae returned within 25-40 days. This period appeared too short to re-establish the original microbial community, indicating that a full recovery of bleached coral is not yet attained. These results suggest that the status of the host-associated microbial community might represent a good index for the health condition of the coral.

Fig. 3. Tropical corals and benthic macroalgae are competing for space.

Not only the soft tissue of corals is under continuous threat by grazing and competing species, also the hard carbonate skeleton is under attack. Excavating sponges are among the main engineers in destructing coral skeletons (Fig. 4). They use etching cells to separate carbonate chips from the skeletons and may remove up to 22 kg carbonate.$m^{-2}.y^{-1}$. Van Duyl and Müller currently study the effect of food supply and composition on the rate of coral erosion by sponges both *in situ* and in experimental systems (Fig. 5).

Fig. 5. Experimental set up for measuring metabolic rates of corals and associated organisms.

Not all tropical coral reefs are 'surrounded by the desert of the ocean'. Coral reefs in the vicinity of continents may face an episodic increase in nutrients and in sediment load as a consequence of continental run-off. Grove, Nagtegaal and Brummer developed optical and chemical approaches to reconstruct variability in sediment discharge by rivers on Madagascar (see a detailed contribution elsewhere in this report) and in Indonesia, using the carbonate skeletons of giant corals as an archive from the present back to the pre-instrumental era.

The Berau delta/barrier reef system (Borneo, Indonesia) displays an exceptionally high biodiversity as it is located within the so called 'coral triangle', the global maximum in bio-diversity (Fig. 6). However, soil erosion related to changes in land-use within the Berau catchment area is believed to increase sediment fluxes within the Berau river systems. This is considered a potential threat to the Berau reef ecosystems as elevated levels of sediment can lead to eutrophication and increased turbidity of the water column. Due to the absence of monitoring data from this remote region, it is difficult to estimate if and how the elevated sediment discharge is affecting the reef system. Fortunately, corals can yield detailed climate and environmental information as they archive historical sediment discharge in the geochemistry of their skeleton. The optical and geochemical properties of cores drilled in giant corals of *Porites sp.* from the Berau reef system were investigated and a compelling relationship between the ratio of Barium and Yttrium over Calcium (Ba/Ca and Y/Ca ratios) and river discharge was demonstrated. High ratios corresponded to high sediment loads during periods of enhanced river discharge. Aligning this ratio with coral age as deduced from annual growth layers (Fig. 7) allowed a reconstruction of river discharge patterns over the past decades. This reconstruction showed that the timing in river discharge coincides primarily with the El Niño Southern Oscillation on inter-annual time scales. Secondly, a slight increase in terrestrial sediment input over the last decades appears related to changes in land use within the catchment area (Fig. 8). Thus, giant corals serve as biomonitors of environmental change.

Fig. 7. Vertical slabs from a core taken from the center of a massive coral reveal annual growth layers when exposed to UV-light (left), to X-rays (center), or ambient light (right).

Currently, the validity and applicability of the Ba/Ca- and Y/Ca-ratio are tested for other reef systems in order to retrieve high resolution climate data. This should fill the gap between the instrumental era and the archives obtained from marine sediments that are more apt to low resolution reconstructions on much longer time scales.

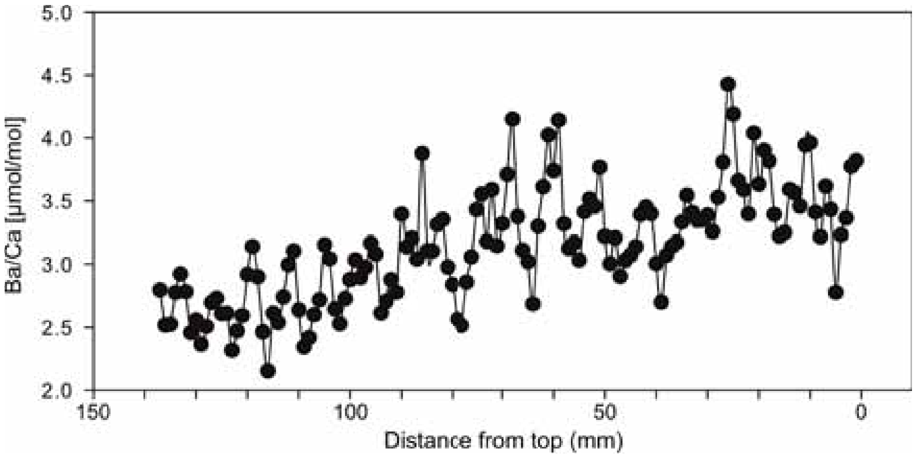


Fig. 8. Ba/Ca ratios (a proxy for sediment discharge) over the past 20 years suggest a steady increase in sediment supply to the Berau reef system.

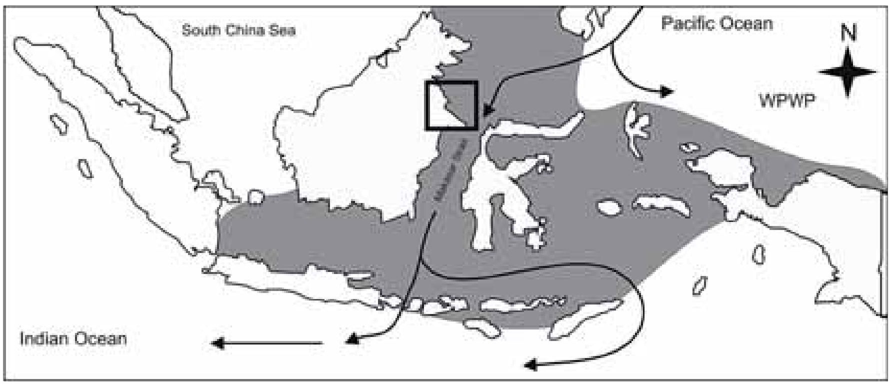


Fig. 6. The Berau delta/barrier reef system (located in the black square) is situated within the heart of coral triangle (grey area), the global center of bio-diversity.

The history of cold-water coral research dates back to the mid-18th century, with notes on corals in a book published in 1752 by Pontoppidan, the Bishop of Bergen (Norway). In 1860, P.H. Gosse published a beautifully illustrated book marking the first, biological investigations on British Sea anemones and cold-water corals. The most recent phase of cold-water coral studies, involving studies of their distribution and ecology, was triggered by the hypothesis of Hovland (1994) postulating that gas leakage from the sub-seabed would create a special biotope favouring cold-water coral growth, culminating in the development of carbonate mounds on geological time scales. Supported by the discovery of cold-water corals along the European margin and various clusters of carbonate mounds at the Irish margin, van Weering, Mienis, Duineveld and Lavaleye set off to study the ecology and formation of cold-water coral reefs and carbonate mounds within the framework of several EU funded international programmes.

Cold-water coral reefs are generally regarded as hotspots of biodiversity. This view is inspired by their resemblance with tropical coral communities, both having a prominent 3D structure formed by the dead coral skeleton, providing hard substratum for the settling of epifauna. Thus far, over 1300 species have been found living on *L. pertusa* reefs in the NE Atlantic. However, samples of macrofauna, collected in coral communities at several NE Atlantic sites (Norway to Mediterranean), yield diversity indices which are only slightly higher than those for nearby soft sediment communities. More strikingly, on reefs the numbers and biomass of macro organisms per unit area are much higher than for the surrounding areas (Fig. 9) although a proper quantification is hampered due to the difficulty in sampling the 3D coral framework (Fig. 10). The higher biomass on cold-water coral reefs infers a higher input and processing of food relative to the surrounding soft sediment communities. This hypothesis is corroborated by the first measurement of total community oxygen consumption for a cold-water coral reef in 2009 at Rockall Bank, which showed over a twofold higher rate than for soft sediments at this depth. Recent in-situ oxygen consumption measurements for a coral reef off Norway, using the eddy-correlation technique, suggest an even greater activity. Perhaps cold-water coral reefs may not be the ultimate hotspot of biodiversity but they certainly appear to be hotspots of carbon mineralisation.

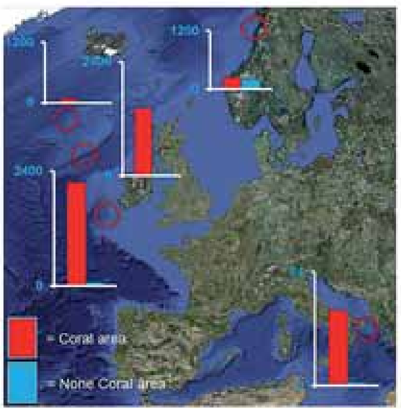


Fig. 9. A comparison of the macrofauna biomass (g.wetweight.m^{-2}) within (red) and outside (blue) various coral reefs.

Fig. 10. Coral colonies and associated benthic fauna as collected with a boxcore from the summit of a mound at the Rockall Bank (Irish margin). Most common framework building coral species on these mounds are *Lophelia pertusa* and *Madrepora oculata*.

A notable distinction between the tropical corals and the cold-water corals is the absence of phototrophic endosymbionts from the latter. Therefore, cold-water corals rely on the supply of food particles that originate from the sun-lit productive surface layers of the ocean. The travelling time of particles to arrive at the deep ocean ultimately determines the quality and quantity of food that remains for the communities. Therefore, considerable effort is made to characterize the hydrodynamic processes that support the supply of food particles to sustain the high biomass on cold-water coral reefs.

In the late 1990's, at the beginning of the recent surge in explorations of cold-water coral occurrences, it was suggested that cold-water corals are primarily associated with seeping hydrocarbons and thrive on the bacterial production fuelled by those seeps. Stable carbon isotope data of tissue samples from the principal reef-building species *Lophelia pertusa* from various locations including the Gulf of Mexico (where *L. pertusa* lives in the vicinity of seeps), showed without exception that *L. pertusa* feeds on marine organic carbon and not on hydrocarbons. This outcome however, did not explain the exact nature of the food e.g. zoo- or phytoplankton, neither the mechanisms transporting the food particles towards the deep coral reefs. Nowadays more information has been collected about *L. pertusa* food sources and mechanisms by means of bottom lander deployments on and off cold-water coral reefs. Bottom landers (Fig. 11), built and deployed by NIOZ have

Fig. 11. NIOZ bottom landers for defining the near-bed environmental conditions.

been instrumental in defining the near-bed environmental conditions in which cold-water corals grow in the NE Atlantic Ocean and beyond. Deployments lasting up to one year recorded daily, seasonal as well as annual variability in temperature, salinity, and current speed in conjunction with the amounts and quality of particles settling near cold-water coral reefs. The data show a large range in salinity and temperature with the largest range, i.e. 5-15 °C, measured near Cape Lookout on the US margin (Fig. 12). A more constant feature of cold-water coral habitats is the relatively strong current which enhances particle encounter rates with the coral polyps, prevent the polyps from being smothered by fine sediment, and resuspend recently deposited food particles. In few areas clear hydrodynamic mechanisms could be identified such as downwelling and Ekman drainage, which transport relatively fresh organic carbon from the photic zone directly to deep coral habitats. Biochemical and isotopic analysis revealed that in those cases phytoplankton forms the principal food source of the corals next to zooplankton. In some cases of cold-water coral habitats lacking such a fast transport route, daily vertical migration of scattering layers (zooplankton) was observed which could potentially form a food source for the corals. In many other habitats the food

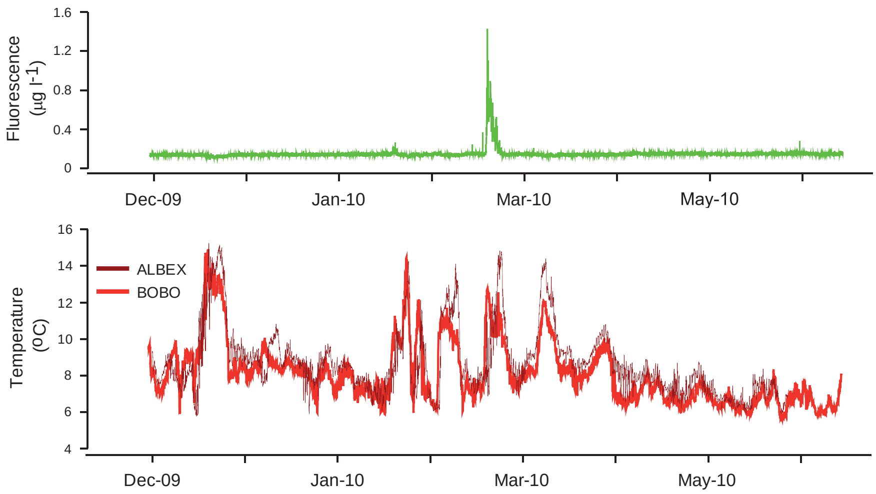
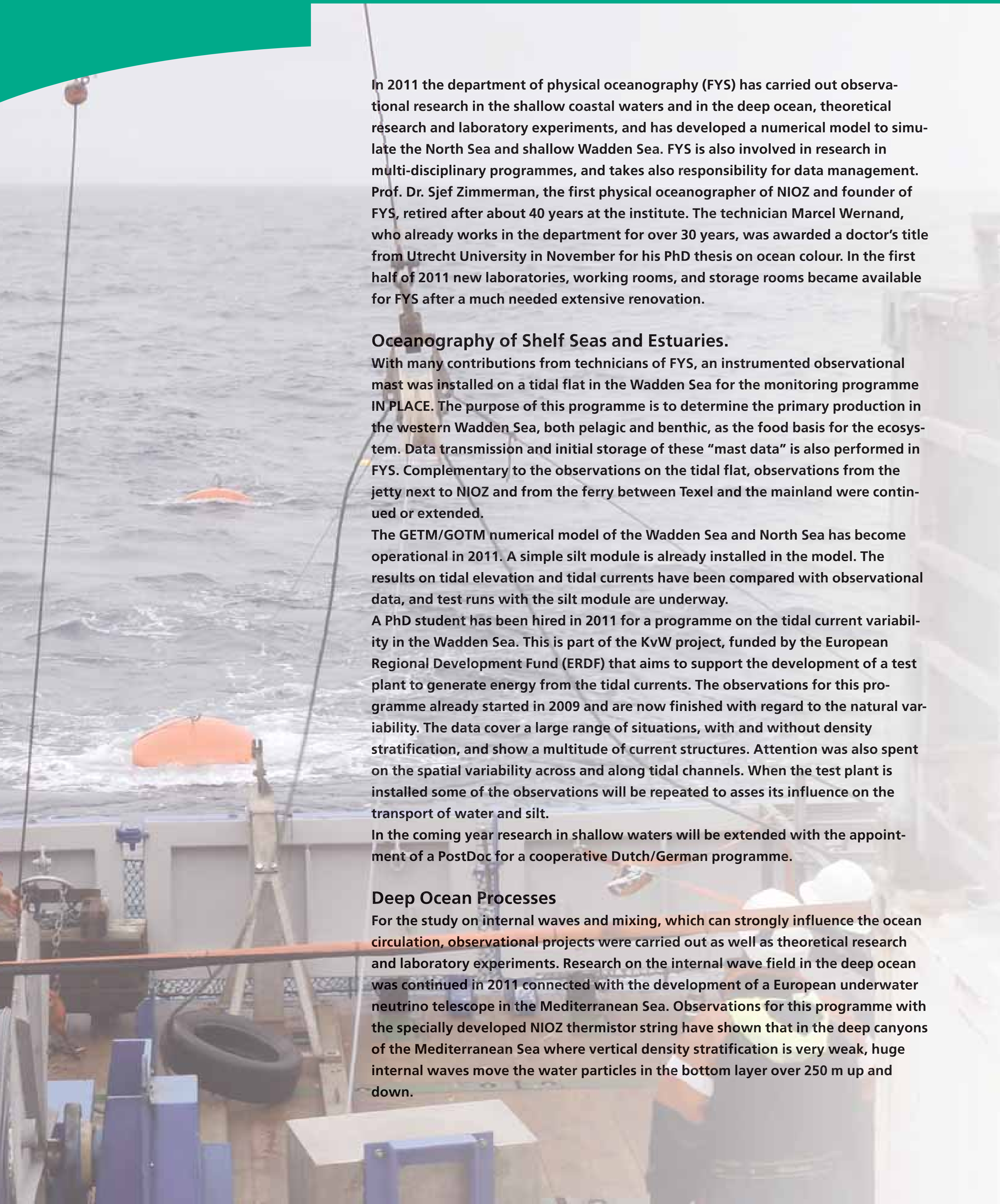


Fig. 12. A six-months recording of bottom water temperature and fluorescence, measured with BOBO and ALBEX landers near Cape Lookout on the US margin.

source and transport mechanisms of the local cold-water coral community remain to be resolved.

Especially the research on cold-water coral reefs represents an excellent example how the interactions between science and innovative technology for surveillance, sampling and in situ measurements has furthered our knowledge of the deep habitat. Coral reefs, be it in the deep ocean or in tropical areas, are vibrant and merit this interdisciplinary approach.

Physical Oceanography



In 2011 the department of physical oceanography (FYS) has carried out observational research in the shallow coastal waters and in the deep ocean, theoretical research and laboratory experiments, and has developed a numerical model to simulate the North Sea and shallow Wadden Sea. FYS is also involved in research in multi-disciplinary programmes, and takes also responsibility for data management. Prof. Dr. Sjef Zimmerman, the first physical oceanographer of NIOZ and founder of FYS, retired after about 40 years at the institute. The technician Marcel Wernand, who already works in the department for over 30 years, was awarded a doctor's title from Utrecht University in November for his PhD thesis on ocean colour. In the first half of 2011 new laboratories, working rooms, and storage rooms became available for FYS after a much needed extensive renovation.

Oceanography of Shelf Seas and Estuaries.

With many contributions from technicians of FYS, an instrumented observational mast was installed on a tidal flat in the Wadden Sea for the monitoring programme IN PLACE. The purpose of this programme is to determine the primary production in the western Wadden Sea, both pelagic and benthic, as the food basis for the ecosystem. Data transmission and initial storage of these "mast data" is also performed in FYS. Complementary to the observations on the tidal flat, observations from the jetty next to NIOZ and from the ferry between Texel and the mainland were continued or extended.

The GETM/GOTM numerical model of the Wadden Sea and North Sea has become operational in 2011. A simple silt module is already installed in the model. The results on tidal elevation and tidal currents have been compared with observational data, and test runs with the silt module are underway.

A PhD student has been hired in 2011 for a programme on the tidal current variability in the Wadden Sea. This is part of the KvW project, funded by the European Regional Development Fund (ERDF) that aims to support the development of a test plant to generate energy from the tidal currents. The observations for this programme already started in 2009 and are now finished with regard to the natural variability. The data cover a large range of situations, with and without density stratification, and show a multitude of current structures. Attention was also spent on the spatial variability across and along tidal channels. When the test plant is installed some of the observations will be repeated to asses its influence on the transport of water and silt.

In the coming year research in shallow waters will be extended with the appointment of a PostDoc for a cooperative Dutch/German programme.

Deep Ocean Processes

For the study on internal waves and mixing, which can strongly influence the ocean circulation, observational projects were carried out as well as theoretical research and laboratory experiments. Research on the internal wave field in the deep ocean was continued in 2011 connected with the development of a European underwater neutrino telescope in the Mediterranean Sea. Observations for this programme with the specially developed NIOZ thermistor string have shown that in the deep canyons of the Mediterranean Sea where vertical density stratification is very weak, huge internal waves move the water particles in the bottom layer over 250 m up and down.

Hydraulic models to study the internal waves in the laboratory were installed in the new laboratory. These models are also used by students of Utrecht University. Theoretical research on the generation of internal waves have shown that there exists a family of bottom topographies that don't support the generation of internal waves, when the barotropic tide moves stratified water over that topography.

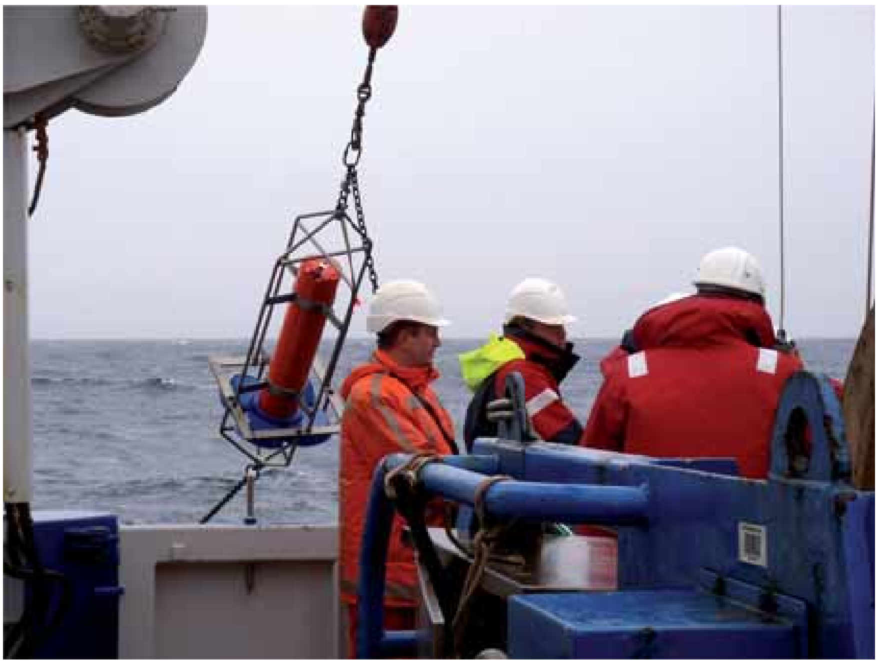
Regional Oceanography

In 2011 the mooring arrays of the INATEX programme on both sides of Madagascar stayed out. The temperature and salinity data from earlier deployments of the Mozambique Channel array were gridded on a regular vertical grid. Analysis of their variability has shown links with the variability of the large eddies in the Mozambique Channel, with variations in the deep counter current, and a remaining long-term variability which is likely connected to large-scale variations of precipitation and evaporation over the Indian Ocean and Indonesian Waters. The research in INATEX is now focused in the specific velocity, temperature, and salinity structure in the Mozambique Channel eddies.

Research on the hydrographic variability in the Irminger Sea, as part of the European THOR programme, was continued in 2011 with a hydrographic survey by RV Pelagia of the former WOCE AR7E line. The LOCO2 mooring in the centre of the Irminger Sea was recovered, serviced, and re-deployed. Eight years of continuous T and S profile data are now available. The hydrographic data of the AR7E survey, have been submitted to the ICES oceanographic data centre in Copenhagen. Research in the north-western North Atlantic was extended by participation in the deployment of an international current meter section just north of Denmark Strait.

Multi-disciplinary research

Scientist and technicians from FYS have participated, aboard or ashore, in the GEOTRACES survey of the South Atlantic with the British RSS James Cook. The hydrographic data from this survey and the GEOTRACES surveys by RV Pelagia in 2010 have been processed. They were submitted to the NIOZ Data Management Group and the international GEOTRACES data centre at BODC.



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Historical archives of ocean colour in global-change perspective

*Marcel R. Wernand **

'Historical Archives of Ocean Colour' refers to the many colours the oceans and seas can adopt and is the subtitle of my thesis 'Poseidon's paint box' (see Fig. 1), referring to the Greek God of the sea. The first part of the thesis deals with the historical development of challenging thoughts, ideas and theories on observations and analysis of the colour of the sea ('ocean colour') in the period 1600 to 2000. It is a prelude to a discussion on modern ocean colour observation methods using satellite-mounted sensors.

Spectral analysis of the Forel-Ule ocean colour comparator scale.

During the late 19th and the early 20th century, François Alphonse Forel (portrait Fig. 2) described numerous research studies on Lake Geneva. In his three-volume limnological monograph 'Le Leman' (1892-1904), he describes his search for the cause of the apparent colour of this lake. A simple but effective way to standardize this colour was his invention of the Forel scale in 1890, which covered the colour shades of the lake between blue and yellow-green in 11 steps. Two years later the German Willi Ule expanded the scale with green to brown colour shades in 10 additional steps. From then on, the colour of the sea was classified according to the Forel-Ule scale (*FU*, see Fig. 3) as a numerical value between 1 and 21. A contemporary colour classification is established through the use of hyperspectral radiometers, which results in a colour spectrum compiled of multiple bands. By means of colorimetric calculations, such an *in-situ* or remote sensing colour spectrum can be converted into one (*x, y*) chromaticity coordinate set. A similar conversion can be applied to the hyperspectral transmission spectra of the standard Forel-Ule shades (Fig. 3), which allows a comparison of historical and contemporary ocean colour data and forms the basis for my historical survey on ocean colour.

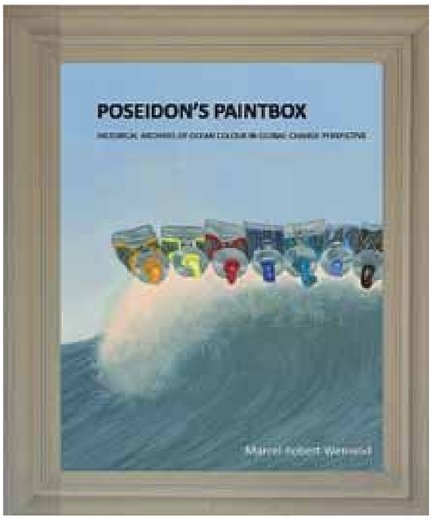

Fig. 1. The cover page of the thesis.

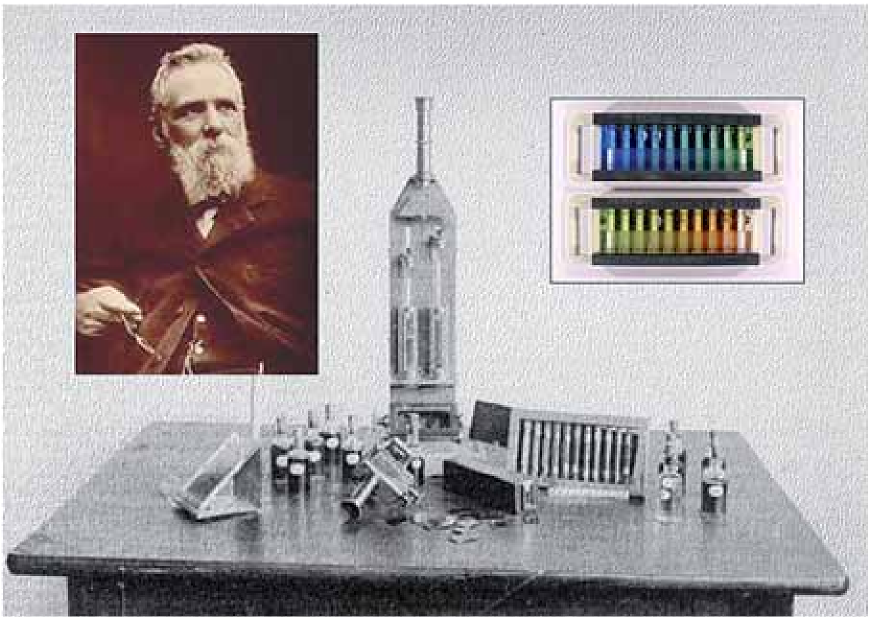

Fig. 2. François Alphonse Forel. On top of the table some chemicals and Forels' part of the scale. Inset: The Forel-Ule ocean colour comparator scale.

In addition to salinity, temperature and water transparency, Forel-Ule data belong to the oldest oceanographic data series. This dataset contains information on changes in water quality for locations all over the globe dating far back in time. Hence it provides indirect information on the chlorophyll concentrations in the past and provides insight into aspects of oceans and seas over the longer term, well before the arrival of ocean colour satellites that are deployed today. This way, ocean colour information from the past can be used to reconstruct historic climate-related data such as sea surface temperature, ocean currents, available sunlight and related surface phytoplankton biomass.

Trends in ocean colour and chlorophyll concentration from 1889 to 2000.

Current climate-ocean studies make use

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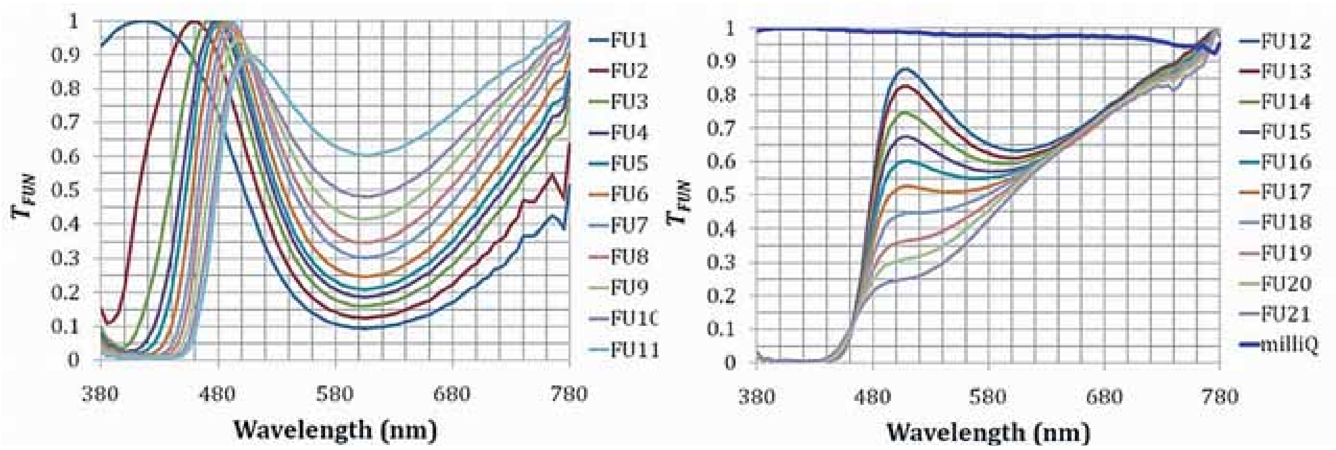

Fig. 3. The normalised transmission (T_{FUN}) of the 21 FU-tubes plus an extra tube containing purified water (bold blue line, milliQ).

of satellite data derived products such as the colour of the sea and the surface concentration of chlorophyll. Satellite data cover at most 30 years of observation, i.e. since the launch of the Coastal Zone Colour Scanner (CZSC) in 1978. A globally established long-term series of Forel-Ule data covers data over the period 1889 to 2000 and overlaps 20 years of ocean-colour satellite data. From *FU* data for open oceans, decadal means were established over the 20th century and were converted to chlorophyll concentrations using the two component bio-optical model Ecolight (see Fig. 4). Using this calibration, we have explored the long term *FU* database in order to provide information on changes in chlorophyll concentrations in surface ocean waters over the period that climate change became effective. Disclosing the *FU* archive appears a promising method to assess the impact of 'global change' on the ocean's phytoplankton biomass since changes in the concentration of chlorophyll in surface ocean waters can be reconstructed with confidence over the last century. The most extensive *FU* record has been established for the North Atlantic in terms of space and time, and therefore this data base has been used to test the validity of colour changes in relation to changes in chlorophyll concentrations over a time span exceeding a century. The results of our analyses for the world's oceans suggest that since the early 20th century, chlorophyll concentrations have decreased in the Indian Ocean and have fluctuated in the Pacific; they increased in the Atlantic Ocean (see Fig. 5), the Mediterranean (see Fig. 5), the Chinese Sea, and in the seas west and north-west of Japan. However, no systematic *global* increase or decrease in chlorophyll concentration, and therefore in phytoplankton abundance could be identified, which suggests that environmental effects due to the industrial revolution do not have a global impact on water quality. Therefore we should look on a local scale to clarify the mechanisms responsible for the varying trends in chlorophyll per ocean and sea.

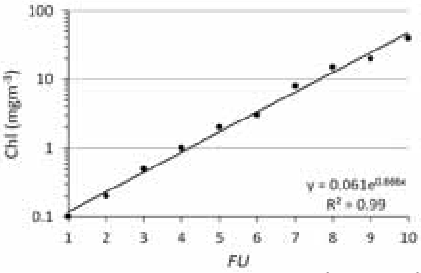

Fig. 4. Chlorophyll concentration as a function of *FU*-number. The *FU*-numbers were derived from the Ecolight RRS spectra. Chlorophyll was varied from 0.1 to 40 mgm^{-3} with a resulting span of *FU*1 to *FU*10.

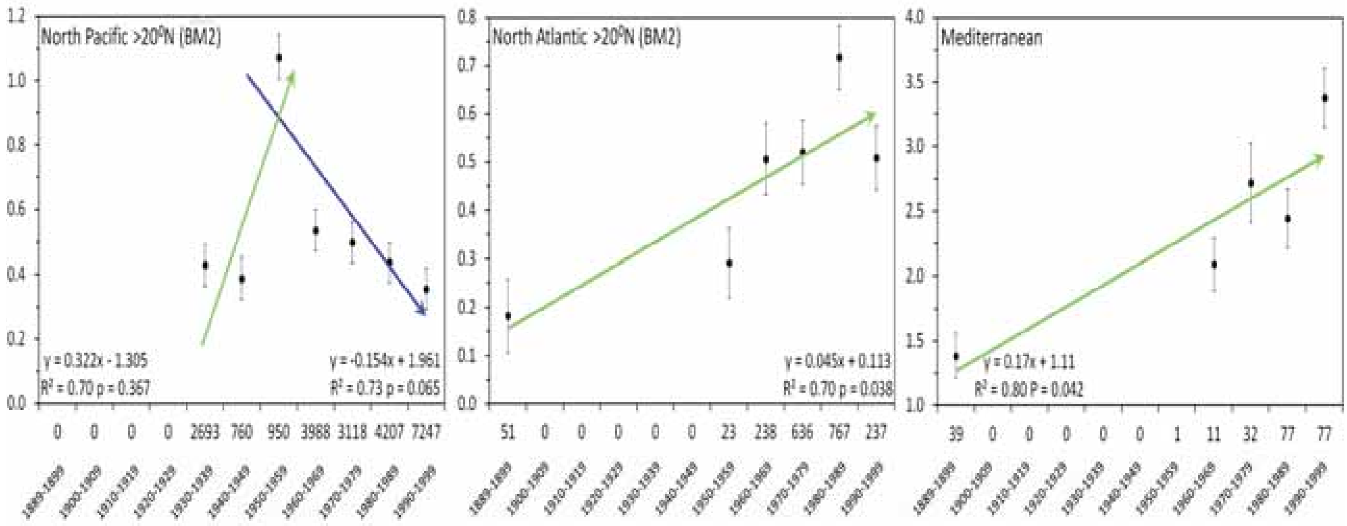

Fig. 5. The North Pacific fluctuates, the Atlantic Ocean and Mediterranean are greening: Scatter plots show the temporal evolution in chlorophyll (mgm^{-3}) per decade over the period 1889-1999.

Long-term ferry-based observations of the total suspended matter flux through the Marsdiep tidal estuary

Janine Nauw, Hendrik van Aken*

The Texel or Marsdiep inlet is one of the major connections between the North Sea and the Wadden Sea, the latter being part of a UNESCO heritage site. Computer simulations have shown that an extension of the port of Rotterdam, Maasvlakte 2, decreases the concentration of total suspended matter (TSM) in the Dutch coastal zone. In these simulations also a small effect is observed in the Western Dutch Wadden Sea. TSM is important for primary production, e.g. the growth of algae, which are at the bottom of the food web. On the one hand, light penetration is hindered by these particles in suspension, but on the other hand TSM is also a source of nutrients. Thus it is essential to monitor any changes in the TSM concentration.

The ferry Schulpengat passing the R.V. Navicula during intercallibration.

Since 1998, Royal NIOZ cooperates with the ferry company TESO (Texels Eigen Stoomboot Onderneming). In that year, the ferry 'Schulpengat' was equipped with an Acoustic Doppler Current Profiler (ADCP). When in 2006 the new ferry 'Dr. Wagemaker' was put into service, it too was fitted with such an instrument. An ADCP uses acoustic pings (sound) to determine profiles of the water velocity, not just in one point, but throughout the entire water column. The instrument records the reflected sound signals and determines the velocity from the Doppler shift in the frequency. Besides determining the water velocity profiles, the instrument also records the intensity of the reflected sound, the acoustic backscatter intensity. The latter is related to the amount of particles in suspension and thus the TSM concentration.


Filters containing sediment collected for the calibration of the TSM-backscatter relation.

The relation between the TSM concentration and the backscatter intensity is, however, not straightforward. It depends on many factors, such as the grain size distribution of the particles in suspension and also on the rate of turbulence. In order to calibrate this relation for the ferry observations we have regular calibration cruises with the R.V. Navicula. During these cruises we stay at anchor during 1 tidal period, e.g. 13 hours, in the Marsdiep close to tracks of the ferry. In this period we measure vertical profiles of temperature, salinity and TSM concentrations (via optical backscatter) every 20 minutes. Meanwhile an ADCP, which is mounted beneath a pole on the side of the research ship, continuously takes vertical profiles of the velocity and records the acoustic backscatter intensity. The actual calibration is done by comparing the profiles of the optically derived TSM concentrations with the profiles of the acoustic backscatter intensity of the ADCP beneath the Navicula. All profiles of the acoustic backscatter intensity from the R.V. Navicula are compared with the backscatter profiles from the ferry at the time that the ferry passes the research ship, which leads to a final acoustic backscatter-TSM relation for the ferry observations.
Based on an extensive analysis of all available data, the data in the period between early 2003 and the end of 2005 were considered most reliable. With the acoustically derived TSM concentrations

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Janine Nauw at sunrise dropping "the messenger" (e.g. a weight) in order to close the Niskin bottle to get a water sample at a certain depth.

and the velocities measured with the ADCP beneath the ferry, the entire cross-section of the Marsdiep is covered. Besides the cross-sectional averaged water transport and the TSM concentration also the flux of suspended matter through the Marsdiep was determined from these measurements.
The most obvious variation in water transport occurred on the semi-diurnal time-scale (12 hours and 25 minutes), which is the dominant tidal period (top panel in Fig. 1). The maximum amplitude of the transport varied on a time-scale of about 14 days, which is the spring-neap tidal cycle. This spring-neap tidal signal was also clearly visible in the time-series of the TSM concentration and even more pronounced in the TSM flux (middle and lower panel in Fig. 1). The TSM concentration varied four times per day as it peaks both during maximum flood and maximum ebb flow, when strong currents bring sediment into suspension.
The relation between the TSM concentration and the current speed was also obvious in the existence of clear spring-neap tidal cycle in the former.
The long-term average value of the transport of water amounts to 1500 m^3/s and was directed from the North Sea to the Wadden Sea. This mean water transport was only 2-3% of the total amount of water entering and leaving the Marsdiep twice per day due to the dominant semi-diurnal tidal cycle. The long-term averaged total suspended matter flux was about 9 Million ton/year also directed towards the Wadden Sea. This is a substantial part (36 %) of the 25 Million ton/year, which is the current estimate of the northward TSM transport along the Dutch coast. This raises questions about the validity of the latter value. NIOZ scientists from the Physical Oceanography department are therefore currently investigating the transport of suspended sediment along the Dutch coast within a Building with Nature project. Measurements in the North Sea have already shown high concentrations of suspended matter close to shore at a depth of about 10 m. This has not been observed before and is not found in computer simulations. Such a TSM core may add a significant contribution to the Northward transport along the Dutch coast, that was not included in the estimate mentioned before.
The long-term averaged TSM flux of about 9 Million ton/year provides an estimate of the TSM flux through Marsdiep before work started on the port of Rotterdam. Ongoing measurements with the ferry Dr. Wagemaker will be used to analyze the TSM flux through the Marsdiep to determine whether there is any influence on the TSM flux in the Marsdiep by the extension of the port of Rotterdam (Maasvlakte 2), which was finalized in 2008.

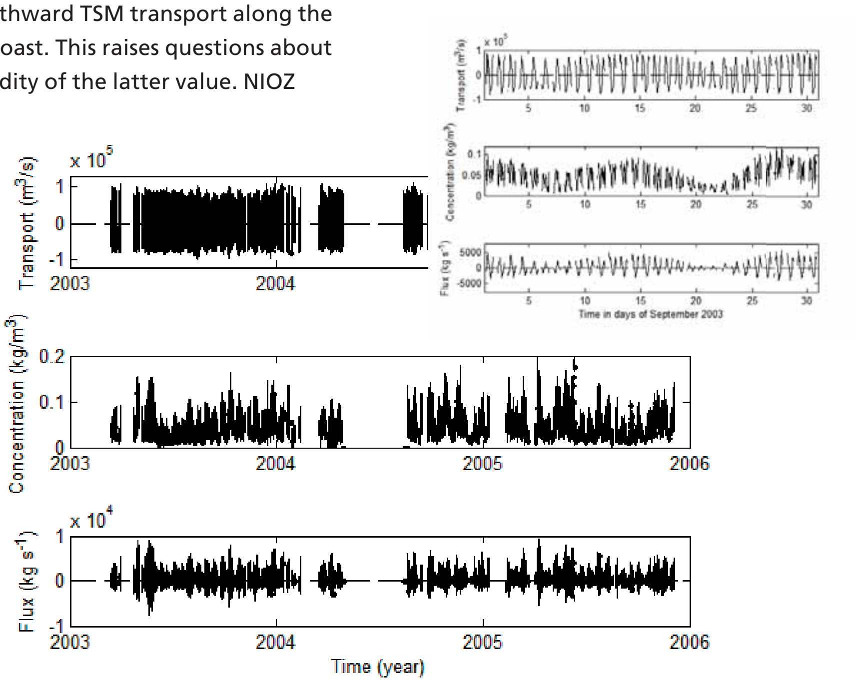

Fig. 1. Time-series of the water transport, cross-sectional averaged TSM concentration and flux of suspended matter for all available ferry crossings by the 'Schulpengat' in the period 2003-2005. The inset shows time-series of the same variables but then zoomed in to the single month of September 2003. A clear semi-diurnal cycle is present in the water transport and TSM flux time-series and a quarter-diurnal signal in the TSM concentration time-series. All three time-series show a spring-neap tidal cycle.

Numerical modelling of physical processes in the North Sea and Wadden Sea

Meinard Tiessen, Janine Nauw, Piet Ruardij, Theo Gerkema*

At the department of Physical Oceanography, several research projects are carried out on the concentration and transport of Suspended Particulate Matter (SPM) in the Southern North Sea and Wadden Sea. So far the focus has been on field data collection and analysis, but in recent years a numerical modelling capacity has been set up, using the GETM/GOTM model. The underlying purpose is twofold. Firstly, a numerical model can provide insight into the hydrodynamics and SPM transport, complementing field observations, helping to interpret and identify the key physical mechanisms. Secondly, it provides a much-needed tool in ecological studies, forming the basic physical core on which the transport of for instance nutrients and larvae depends; thus, these kinds of numerical models provide a valuable bridge in interdisciplinary studies. First steps in the use of the model are reported here, offering a synopsis of its potential.

Numerical model

The General Estuarine Transport Model (GETM) is a three-dimensional hydrodynamic model, which is coupled to GOTM (General Ocean Turbulence Model) that includes various ways of describing the vertical turbulence. This public domain model was developed by Burchard and Bolding and a growing number of modules are being added by the user community. Initially, the focus was on estuarine systems, where drying and flooding of parts of the domain are of great importance. More recently, coastal seas (such as the North Sea and the Baltic Sea) were investigated by different research groups using this model. The model can describe the inflow of fresh water and the stratification in the domain, both as a result of salinity and temperature gradients. The tides are prescribed at the sea-ward boundaries of the model domain. As a first application, the model will be used to describe the hydrodynamics, but subsequently it will be applied to study the transport and concentration of Suspended Particulate Matter (SPM). To this end, a module for the transport of SPM has recently been added, which is still under development. We will apply the model to the Southern North Sea and adjacent Wadden Sea; more specifically, on the seasonal variation of the East Anglia plume and on the net transport through the Marsdiep and Vlie inlet system.

Modelling the hydrodynamics and transport of suspended sediment

SPM is a bulk term encompassing fine-grained substances of organic and inorganic nature, such as silt. It is transported along with the flow while in suspension, but may sink to the bed during calm conditions and slack tides. High concentrations of SPM can impede sunlight to penetrate the water column, and therefore limit primary production. Especially in estuarine environments and tidal basins, SPM forms a considerable fraction of the total sediment supply and is therefore of great importance for erosion and accretion of morphological features and their change of form.

Using long-term ferry-based observations, the net SPM transport in the Marsdiep inlet is estimated to be 5 to 10 Mton/year into the Wadden Sea. A question that arises from these findings is

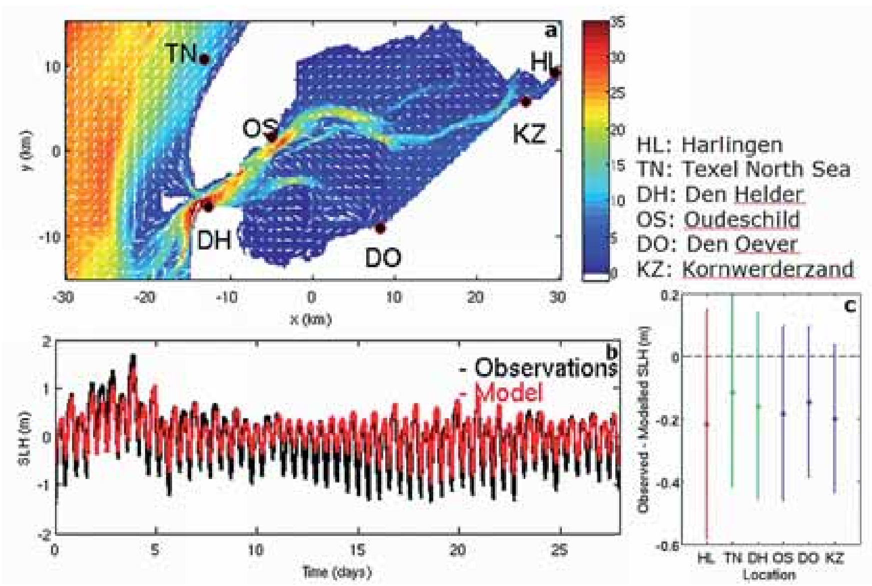

Fig. 1. Model set-up for the Marsdiep inlet system: a) Top-view of the bathymetry along with the locations of field-data stations. Sea Level Height (SLH) data from these stations is compared with model predictions (the white arrows indicate the modelled residual current circulation pattern). b) Comparison between predicted (in red) and observed (in black) sea level height over time at Den Helder (DH). c) The time-averaged comparison between the observed and predicted sea level height for the different stations along the basin-edge.

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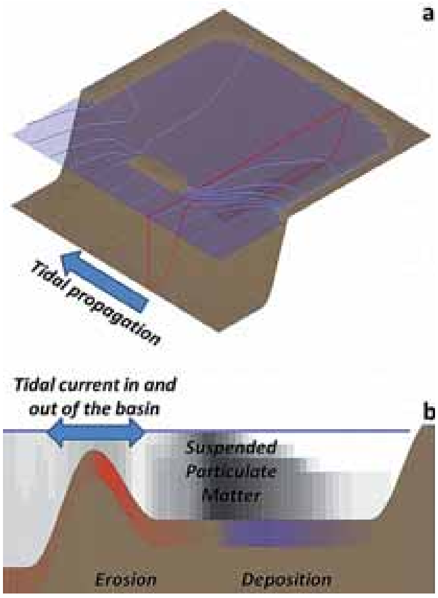

Fig. 2. a) An idealised model set-up of a barrier-island coastline: A tidal wave propagates along the open end of the domain, creating a tidal current in and out of the basin behind the island. b) The strong current results in sediment being eroded from the inlet and transported into the basin, where it is deposited.

what happens with this sediment within the Wadden Sea. After all, the Marsdiep forms one of the two main inlets of the Western Wadden Sea, the other one being the Vlie, and so one may expect that part of the imported sediment is exported again through the other inlet. As field data is only available from a limited number of stations, numerical modelling results should give a more comprehensive insight into the sediment fluxes within the Wadden Sea.

The transport and concentration of SPM is determined by the prevalent hydrodynamics set by tides, waves, currents, and density gradients. For the description of SPM characteristics in a numerical model, an accurate representation of the hydrodynamics is a prerequisite. An initial set-up for modelling the hydrodynamics of the Western Wadden Sea can be seen in Fig. 1; here, for simplicity, the Marsdiep basin is considered in isolation, ignoring the neighbouring Vlie basin by imposing a 'wall' along the watershed between the basins. Despite these simplifications, a comparison between modelled tidal elevation and data from coastal stations already shows a reasonable correspondence.

Currently, the GETM/GOTM model is extended with a simple experimental version of an SPM-module; however this has not yet been applied to actual field-locations. The sensitivities of this sediment module are currently investigated using idealised set-ups (see Fig. 2). Once a more comprehensive description of the suspended sediment dynamics is developed (involving for instance different sets of grain sizes with their corresponding settling velocities), this module can be applied to a range of different coastal seas and estuaries to investigate the SPM dynamics.

Coupling to ecology

Future application will see the hydrodynamical output of the GETM model also be used to study biological, ecological, and chemical shelf sea and estuarine processes in interdisciplinary studies. The model is currently linked to a biological model developed at NIOZ, in collaboration with the Centre for Environment, Fisheries and Aquaculture Science (CEFAS, UK), to study biological processes in the North Sea. The latest version is called BFM, Biogeochemical Flux Model, used to investigate the causes and variability in sub-surface oxygen minima at the Oyster Grounds, and nutrient cycling. Another example, for the North Sea as a whole, is shown in Fig. 3: the net primary production (production of new phytoplankton biomass). Fig. 3 shows a higher production near the coast than in off-shore areas. The high production in the Southern North Sea along the coast is caused by *Phaeocystis.* The biomass of these algae can increase to very high levels through the formation of colonies which are too large for grazing by meso-zooplankton. The relatively high production, modelled for the south of Norway, is mainly caused by low turbidity in the Skagerrak and Norwegian Trench, and the relatively deep mixing zone, allowing photosynthesis down to 50 m water depth. The low production in the Northern off-shore part of the North Sea is caused by relatively low nutrient concentrations, a shorter growth season and the stable vertical stratification in this area, limiting the mixing of nutrient depleted surface water with nutrient rich deep waters.

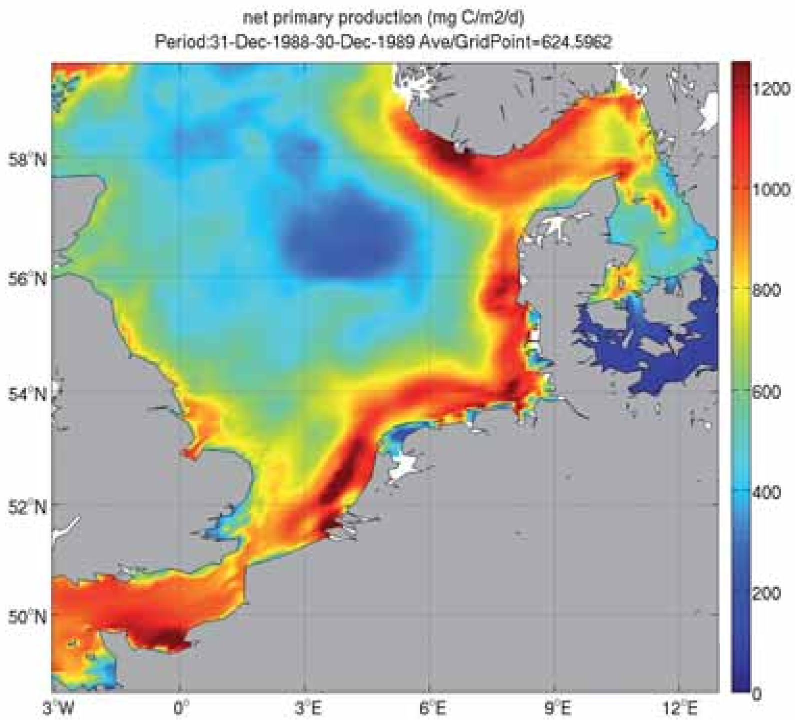

Fig. 3. Net primary production in 1989, calculated with GETM/GOTM and a coupling to ERSEM/BFM, see www.nioz.nl/northsea_model for more results.

Deep-ocean internal wave – turbulence quantified

Hans van Haren, Louis Gostiaux[1]*

The sun stores huge amounts of heat in the ocean, but this heat would stay near the ocean surface if it were not mechanically mixed into the deep. Warm water is less dense ('lighter') than cold water, so that heated surface waters 'float' on top of the cold deep waters. Only active mechanical turbulent mixing can effectively pump the heat down. Such mixing requires remarkably little energy, about one-thousandth of the heat stored, but it is crucial for ocean life and transport of nutrients and sediment. Although several mechanisms for ocean mixing have been researched in the past, including plankton motions, the dominant mechanism seems internal wave induced mixing. The ocean interior is constantly in motion via 10-100 m high internal waves, which only mix when they break, mainly above underwater topography. This internal wave mixing has now been quantified using high sampling rate NIOZ temperature sensors, that were moored above a large guyot in the Canary Basin, North-Atlantic Ocean. The mixing was found dominating sediment resuspension, being 100 times more turbulent than in the open ocean and, extrapolating, sufficiently effective to maintain the overall ocean heat balance.

The result of vertical mechanical mixing of heat is an ocean that is stably stratified in density from surface to bottom. Ocean's water density is mainly determined by temperature and salinity variations. The vertical density differences ('stratification') create a restoring force for wave motions in the interior: 'internal waves'. Compared to surface waves, internal waves are slow waves. They have periods varying from several minutes up to one day at mid-latitudes, and include tides. In spite of their slowness, the transition to turbulent mixing occurs quite rapidly with big 50 m high breaking waves passing within a minute. Quantification of such mixing process thus requires detailed observations using

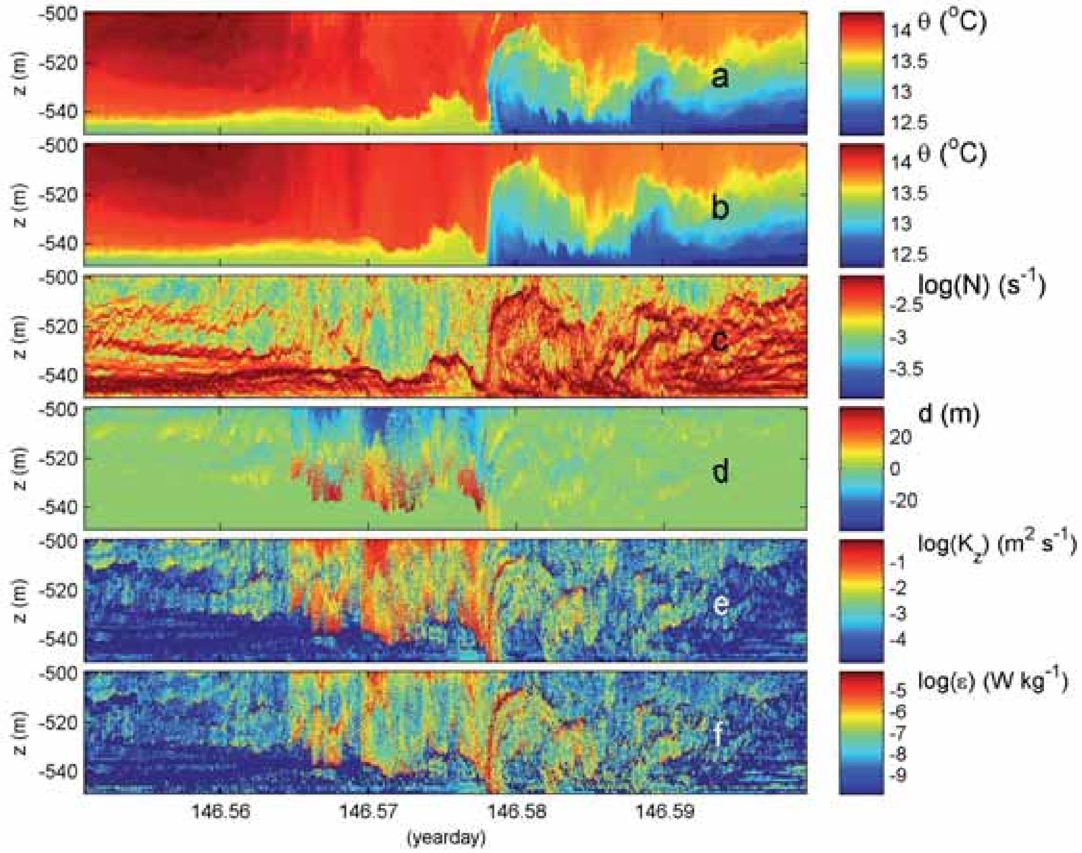

Fig. 1. Depth-time series of observed temperature and quantified turbulence during 75 minutes prior to and into an upslope tidal phase: a frontal passage and associated peaks in turbulent mixing. a. Potential temperature data, after pressure-corrected calibration of raw temperature data. b. Reordered potential temperature profiles every 1-Hz time-step. c. Stable stratification computed from b. d. Reordering displacements following comparison of a. and b. e. Turbulent diffusivity. f. Turbulence dissipation rate. In e., f. dark-blue also indicates below threshold.

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fast sampling, precise instrumentation. Here we present such detailed observations using 101 NIOZ-HST, high sampling rate thermistors, that have a precision better than 0.001°C and sample at a rate of 1 Hz (once per s). The thermistors were taped to a cable at 0.5 m intervals between 0.5 and 50 m above the bottom and moored at a 549 m deep site near the top of Great Meteor Seamount, North-East Atlantic Ocean. At this site, the temperature-density relationship was very tight so that the thermistor-data could be effectively used as a tracer for density. They could thus be used to quantify turbulent mixing. Turbulence makes a vertically stable water column locally unstable by overturning denser (colder) water above less dense (warmer) water during brief moments. This is clearly observed when a large breaking wave passes the sensors (Fig. 1a, around day 146.58). Quantification of mixing is done by re-enacting the turbulence of each 1-Hz vertical temperature profile: all unstable portions are computationally sorted ('reordered') to their stable positions in a profile. These reordering displacements are a measure for the turbulence, which is expressed in its main parameters 'turbulent exchange rate' or 'diffusivity' K_z and 'turbulence energy loss' or 'dissipation rate' ε.

In the open ocean, internal tidal waves have peak-trough heights that are typically larger than 50 m. When such a wave reaches Great Meteor Seamount it is observed to regularly move warm water down during one phase followed by cold water being moved up along the sloping bottom. However, in contrast with the rather smooth tidal variations seen in the open ocean, variations become rugged and steep above sloping topography. The sudden change from warming to cooling tidal phase, associated with an upslope moving frontal bore occurring once or twice a tidal period, is strongly turbulent (Fig. 1). Comparing the raw data (Fig. 1a) with the reordered ones (Fig. 1b) already enlightens part of the raw turbulence associated with the large backwards breaking wave: the turbulence-image has the lighting of a 3D-image like 17th-century Dutch paintings, whilst the stably reordered image has a flat 2D appearance. The reordering clearly straightens the large front that was originally curved.

The reordered stable stratification (Fig. 1c) shows very thin (down to lowest vertical resolution of 0.5 m) layering, approaching the bottom to within a meter just prior to the frontal passage. Reordering displacements (Fig. 1d) beautifully delineate the turbulent patches or overturns, and overturns within overturns down to about the scale of vertical resolution. Typical patches have sizes of 10 m in the vertical and 300 s in time, but smaller and also larger ones occur, even exceeding out-of-range of the thermistors (e.g., day 146.57).

Such large displacements result in turbulent diffusivity of locally up to K_z = 0.1-1 $m^2\ s^{-1}$ (Fig. 1e). Large K_z-values are generally estimated within layers of less stable stratification, with exceptions of high values in thin strongly stratified layers such as those forcing a big front or non-linear bore. The front stands-out more clearly in the dissipation rate image (Fig. 1f). Otherwise, smaller-scale turbulent patches are powered in part by extreme shortest freely propagating internal waves near the buoyancy frequency.

Considering the entire two-week record, the depth-averaged turbulence is seen to vary with tidal period including a barely visible spring-neap period, but it is most-dominantly peaked over periods shorter than tidal due to the (non-linear) frontal passages (Fig. 2). The semidiurnal and some higher frequency variations are more visible in the mean stratification time series (purple graph), but its one decade variation in value over the whole time span is much less than the four decades found in $\langle K_z \rangle$ (or $\langle\varepsilon\rangle$), despite the occasionally in-phase variability. Tidal motions thus generate turbulence, but not only in a direct manner but especially also intermittently via non-linear interactions.

Averaged over the entire period of time (18 days), nearly uniform profiles of turbulence parameters are observed, with mean $[K_z] = 0.003\pm0.001\ m^2\ s^{-1}$, $[\varepsilon] = 1.5\pm0.7\times10^{-7}\ W\ kg^{-1}$. If we use previous suggestions that about 3% of the ocean is occupied by turbulent boundary layers above sloping topography, we find a mean ocean-basin-interior $K_z \approx 10^{-4}\ m^2\ s^{-1}$, which is the value needed to maintain the overall ocean heat balance.

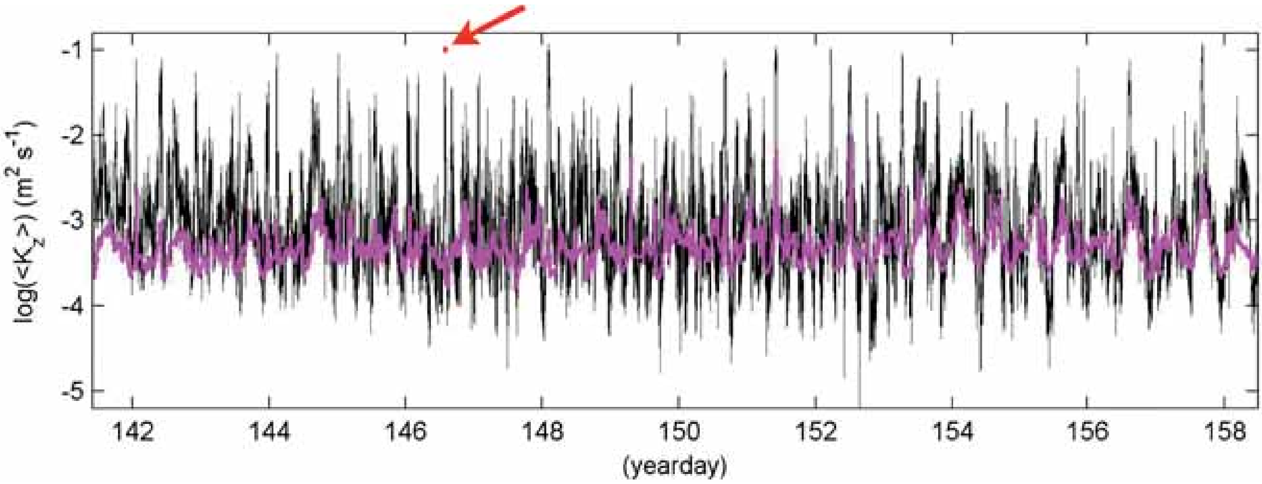

Fig. 2. Total time series of vertically averaged variables using 0.01-Hz data (data points every 100 s). Mean <Kz> (black), with for comparison mean inverse stratification (purple; arbitrary logarithmic scale). The short period including the front of Fig. 1 is indicated by the red dot.

External Projects Physical Oceanography

- Astronomy with a Neutrino Telescope and Abyss environmental RESearch (ANTARES)-funded via the National Institute for Subatomic Physics (Nikhef).
  H. van Haren, in cooperation with Nikhef and ANTARES-collaboration.
- Budget modeling of fines in the Dutch coastal zone. (Building With Nature/Ecoshape NTW3.1).
  C.M. van der Hout, J. Nauw, T. Gerkema, H. Ridderinkhof (BDS).
- Contemporary off shelf sediment transport on the Ebro Margin (COSTEM).
  H. van Haren, NIOZ participant in CSIC – CIM project, Barcelona, Spain.
- Cubic kilometre neutrino telescope (KM3NeT, NWO-Esfri).
  H. van Haren, in cooperation with NIKHEF, Amsterdam.
- Cubic kilometre neutrino telescope design study (KM3NeT-DS, EU).
  H. van Haren, in cooperation with KM3NeT-collaboration.
- Cubic kilometre neutrino telescope prepatory phase (KM3NeT-PP, EU).
  H. van Haren, in cooperation with KM3NeT-collaboration.
- Indian-Atlantic exchange in present and past climate (INATEX, NWO-ZKO).
  J. Ullgren, H. Ridderinkhof (BDS), H.M. van Aken.
- Integrated Network for Production and Loss Assessment in the Coastal Environment (IN PLACE, NWO-ZKO).
  M.R. Wernand, H.M. van Aken, H. Ridderinkhof (BDS).
- Long-term ocean climate observations (LOCO, NWO).
  H.M. van Aken, H. Ridderinkhof (BDS), H. van Haren, L.R.M. Maas, J.T.F. Zimmerman, T. Gerkema.
- Monitoring Mosselzaadinvanginstallaties (MZI) funded by IMARES.
  S. Groeskamp, L.R.M. Maas.
- North Atlantic Ocean Monitoring and Modelling (BSIK – Klimaat voor Ruimte).
  H.M. van Aken, L.R.M. Maas, H. van Haren, M.F. de Jong.
- Particle transport, deposition and resuspension in the Southern North Sea and biogeochemical consequences. (FOKUZ).
  M. Tiessen, J. Nauw, T. Gerkema.
- Study of global variability of water mixing in the World Ocean and its influence on convection and internal waves in Sub-Polar zones, Dutch-Russian cooperation (NWO).
  L.R.M. Maas, T. Gerkema, H. van Haren.
- Thermohaline Overturning - At Risk? (THOR, EU).
  M.F. de Jong, H.M. van Aken.
- Transport and circulation around Madagascar (NWO-ALW).
  H. Ridderinkhof, J. Ullgren.
- Wadden Sea ecosystem data assimilation and integrated modelling (NWO-ZKO).
  T. Gerkema, J. Nauw - van der Vegt.
- Waddenzee modellering (ZKO).
  H. Ridderinkhof, J. Nauw.

Marine Geology

Research in the Marine Geology department (GEO) focuses on seabed systems where the geo-, bio- and hydrosphere interact. GEO aims to:

- understand present day sedimentary processes and environmental conditions, that shaped the record of past climate change,
- develop and apply proxies for ocean temperature, rainfall and dust emissions from sediment and coral records,
- coupling modern to past, develop scenarios for anthropogenic change.

In comparison to the more 'turbulent' previous year, 2011 brought consolidation, full control of the renovated laboratories, the finalization of the cooperation agreement with the 'new' Avaatech XRF-core scanner company and strong commitment to multidisciplinary sea-going activities. GEO participated in research cruises and fieldwork around the world (7 cruises, ca. 131 days at sea). Cruise activities ranged from the southern hemisphere to almost 80 degrees north offshore Svalbard and from the west Atlantic to the east Indian Ocean and Australia. Several members of GEO joined a cruise with RV SONNE to re-investigate methane seep sites along the Hikurangi Margin offshore New Zealand. Others carried out fieldwork to drill high resolution coral-climate records off Mozambique or visited Lake Eyre in Australia for onshore dust collection.

With respect to scientific output, GEO published 30 papers in 2011, e.g. on 'Interhemispheric symmetry of the tropical African rainbelt over the past 23,000 years' (Nature Geoscience) as appeared from sediment cores offshore West-Africa. Another concerned the "Contrasting variability in foraminiferal and organic paleotemperature proxies in sedimenting particles of the Mozambique Channel (SW Indian Ocean)" using records from long-term moorings, together with the BGC and FYS departments. As part of a larger group GEO was also involved in studies "On the role of the Agulhas system in ocean circulation and climate" published in Nature. With 23 conference presentations (posters and talks), GEO was also active at EGU, INQUA, AGU and smaller meetings and chaired several sessions during these conferences. A large NWO Middelgroot grant could be secured by Geert-Jan Brummer and Rik Tjallingii to renew and advance the capabilities of the XRF core scanner as an (inter)national research facility, and invest in a digital X-ray system for the core lab.

Two PhD-students successfully defended their thesis at the VU-Amsterdam. Ulrike Fallet completed hers on the "Dynamic oceanography and paleothermometry in the Mozambique Channel, upstream of the Agulhas current"; Cees van der Land received his degree on the "Impact of diagenesis on carbonate mound formation" offshore Ireland. Meanwhile, Aneurin Henry-Edwards completed his work on oceanographic tracers in the Mozambique Channel (see elsewhere this volume). Jan-Berend Stuut started a 25% employment at MARUM (Bremen) and Thomas Richter was employed for data management support working closely with DMG. Replacing some of the technicians that left in 2010, GEO welcomed Bob Koster into the department; his expertise with the XRF-corescanner, lander instrumentation, camera systems and electronics is very welcome.

Finally, a thank-you goes to Henk de Haas for his great enthusiasm he brings into leading research cruises, e.g. in the interdepartmental cruises to the North Sea (MEE, GEO and BIO) or around Iceland with BGC. Furthermore, Rik Tjallingii is thanked for his support in setting up the agreement with XRF core scanner company Avaatech and the related cooperation with TU Delft for software development.

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It seeps and bubbles but where does the methane go?

Jens Greinert, Henk de Haas, Henko de Stigter, Aneurin Henry-Edwards, Piet van Gaever and Hans van Haren (FYS)*

Methane seeping out of the seabed is a common phenomenon observed on continental margins around the world. Where fractures or permeable layers in sediment deposits facilitate the upward migration and escape of fluids charged with dissolved methane and hydrogen sulphide, unique chemoautotrophic ecosystems with clams and tube worms develop at the seabed. Oxidation of methane by bacteria and archaea induces the formation of carbonates that cement the seafloor around seeps and locally lead to the growth of carbonate mounds. If the gas concentration is high enough gas bubbles are released into the bottom water, whereas under certain pressure and temperature conditions solid gas hydrates may form in the sediment. Much of the methane gas in bubbles dissolves in the water column but in some areas methane may reach the surface and enter the atmosphere. As methane is a powerful greenhouse gas, and the escape of methane from sediments appears to be accelerating under influence of global warming, the fate of methane released from seeps is currently a hot topic in environmental and climate research. In March and April 2011, members of GEO participated in a research cruise on board the German research vessel SONNE, directed at the study of methane seeps on the Hikurangi continental margin offshore New Zealand. Here, the subduction of the Pacific plate below New Zealand causes strong compression of marine sediments and expulsion of gas-charged pore waters.

The Sonne SO214-NEMESYS cruise was a follow-up of research carried out in the same area in 2006 and 2007, during which a large number of active seep sites, expelling methane bubbles and supporting specialised chemosynthetic communities, were identified. More detailed and higher-resolution seismic and geochemical studies as well as repeated hydroacoustic investigations were the topic of the 2011 cruise. The aims were to better track and map small fluid migration pathways in the seafloor, to link geochemical gradients to the high-resolution seismic profiles for spatial flux extrapolations, and to assess if seepage has changed in activity or location since the previous investigations in 2007. The main working area was Opouawe Bank at the SE tip of New Zealand's North Island (Fig. 1). The NIOZ-GEO team contributed with hydroacoustic mapping and analysis of gas flares, streams of gas bubbles rising into the overlying water column, signaling the presence of active seeps at the seabed. At active seep sites, water samples were collected along with CTD casts to determine methane concentrations in the water column. A NIOZ thermistor string was deployed at one of the flares to assess the physical perturbation of the water column by rising gas

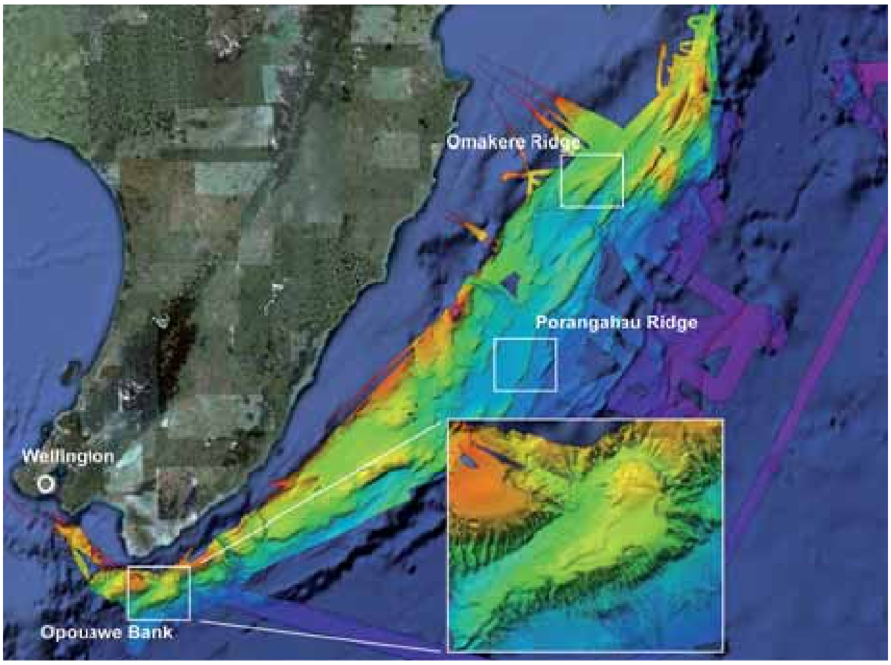

Fig. 1. Bathymetric map of the Hikurangi Margin on the east coast of New Zealand's North Island. Enlarged the Opouawe Bank working area, where detailed studies at the Takahe seep site were performed.

bubbles. Furthermore, gravity cores were collected of sediments across seep sites, to link features observed in high-resolution seismic profiles to sedimentary characteristics, and for geochemical analysis of sediment porewater.

At Opouawe Bank, work was focused on the Takahe seep site. High-resolution seismic profiling showed distinct gas reflectors in the shallow seabed, indicative of the accumulation of free gas below an impermeable layer of gas hydrate, and so-called gas chimneys, vertical acoustically opaque structures thought to represent permeable sediment zones through which gas-charged fluids migrate to the surface. Associated with these gas chimneys hydroacoustical surveys showed numerous gas flares rising hundreds of meters high into the water

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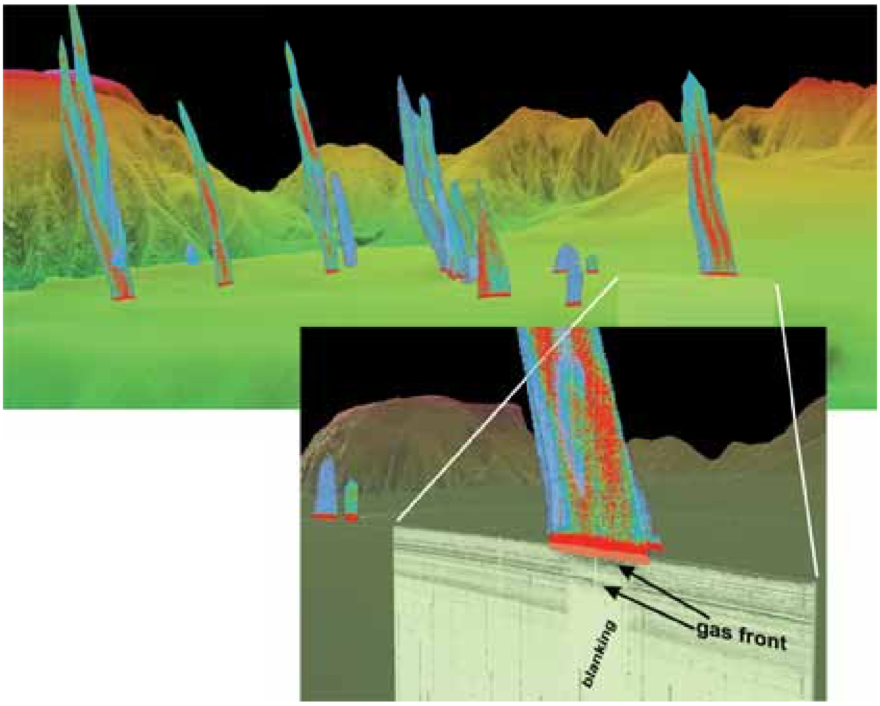
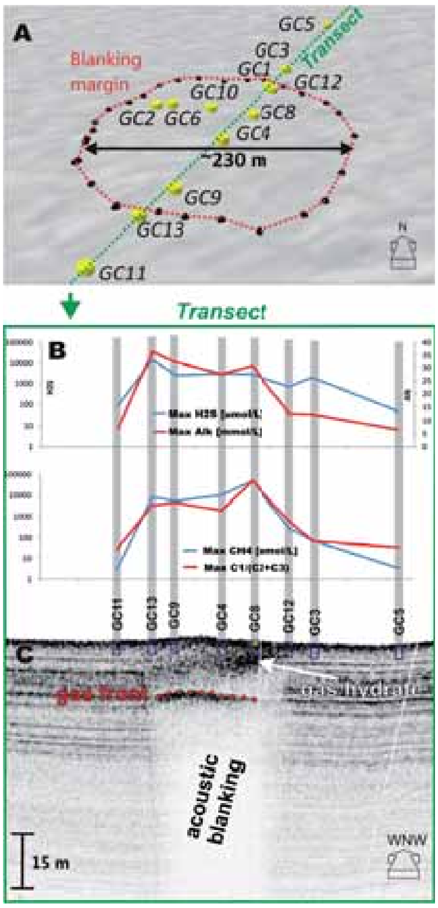


Fig. 2. 3-D view of the Takahe seep area, with gas flares rising up to 500 m in the water column. Inset shows 3.5 kHz sub-bottom profile of an active seep, with strong acoustic reflectors marking accumulation of free gas in subsurface sediment layers, and acoustic blanking below the seep where a gas chimney is present. Vertical exaggeration of the image is 6x.

column (Fig. 2). In total, 13 seep sites have been found in the area, many of them characterised by massive carbonate chemoherms at the seafloor with living tube worms and clams. Side-scan sonar images showed no indication of massive carbonate formation at Takahe. The last point was important for the successful recovery of gravity cores from the entire Takahe seep area.



CTD sections across Takahe, aimed at determining the amount of methane being released into the water column, showed only low concentrations. This was surprising and contradictory to results obtained previously in the area. Possibly the CTD casts missed the exact bubble release location (despite USBL navigation), or the methane release was not as high as the hydroacoustic data make us believe. Another likely explanation is that currents or some other mixing/distribution processes caused a rapid dilution of the methane in the water.

Fig. 3. A: Perspective view of gravity core locations across the Takahe gas chimney. B: Maximum concentrations of hydrogen sulphide, alkalinity, and methane measured in sediment pore water profiles, showing enhanced values where methane is oxidized anaerobically in the sediment. C: Higher concentrations and thus higher fluxes occur above the gas chimney, the limits of which are marked by cores GC 13 to GC12 from south to north. Strong reflections above the chimney mark the presence of gas hydrate. Image by G. Crutchley & A. Dale.

Pore-water analyses on the other hand showed distinctly enhanced concentrations of methane and hydrogen sulphide in sediments above the gas chimney at Takahe (Fig. 3). Fluid fluxes were strongly increased in the chimney area, whereas no measurable flux was detected outside. Despite this, sediment temperature profiling generally did not show elevated vertical gradients compared to the adjacent seabed; only at the GC6 coring site where a large amount of gas hydrate was found (Fig. 4) was the gradient higher, pointing towards a focused fluid flow at the northern rim of the chimney. This was also the area where bubbles where hydroacoustically detected and bacteria mats at the seafloor surface were most common.

The studies showed that methane is being released rather focused from seep sites at the Hikurangi Margin. Gas migration pathways in the sediment can be made visible with seismic methods, pointing to areas with highest fluxes and gas hydrate occurrences where the gas front is shallowest. These are also the locations where bubbles are released into the water column and bacterial mats are commonly found. Geochemical pore water studies confirm this pattern and the acquired coring section will be used to extrapolate the total methane flux from the Takahe seep site and use those data to extrapolate also to other seep sites at the Opouawe Bank.

Fig. 4. Gas hydrate flakes as found in several layers between 1 and 2 m depth of core GC6. Gas hydrate is a crystalline water-based solid resembling ice, in which gas molecules are trapped inside "cages" of water molecules. Gas hydrate forms under cold temperature and high hydrostatic pressure typically found in the deep sea, and it decomposes at atmospheric pressure releasing gas and leaving water behind.

Isotope-salinity relationships in the Mozambique Channel and Southwest Indian Ocean

*Aneurin Henry-Edwards, Jeroen van der Lubbe (VU-Amsterdam), Jens Zinke, Hendrik van Aken (FYS), Geert-Jan A. Brummer**

There is a growing international focus on the SW Indian Ocean, in particular on the role of the Agulhas Current in the exchange of water masses between the Indian and South Atlantic Ocean. This inter-ocean exchange has varied considerably in the past, with important consequences for global circulation and climate. In the modern ocean, different water masses can be traced using the relationship between the salinity and the isotope composition of oxygen ($\delta^{18}O$) and hydrogen (δD) of which the seawater consists. Since these isotopes are incorporated in carbonate shells and organic compounds of marine organisms, the salinity-isotope relationships derived from fossil material preserved in sediment cores can be used to determine past changes in circulation over much longer time scales. To improve our understanding of past and present circulation in the Southwest Indian Ocean, $\delta^{18}O$-δD-salinity relationships in the different water masses need to be better constrained. For this purpose, water samples were analysed, collected during a number of cruises in and around the Mozambique Channel (LOCO and INATEX programs) and various islands, supplemented by data from the Seawater Oxygen-18 Database in the Indian Ocean (Fig. 1).

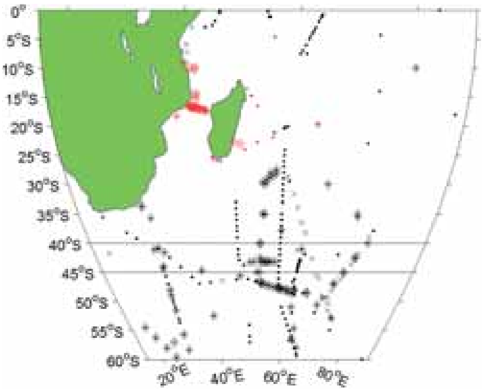


Fig. 1. Station locations of $\delta^{18}O$-δD-salinity observations in the SW Indian Ocean. Dots indicate $\delta^{18}O$, crosses mark $\delta^{18}O$ & δD, +s indicate only δD and diamonds indicate deep observations. New data is marked in red. The band marked between 40-45˚S shows the approximate location of the Agulhas and Subtropical Fronts.

Evaporation, precipitation and run-off (ice melt, rivers) cause changes in the isotope composition of seawater, which result in a causal correlation with salinity in much of the ocean. Generally, both $\delta^{18}O$ and δD are higher in regions where surface evaporation is important and lower in regions where precipitation reduces the salinity. Indeed, when plotted against salinity, the $\delta^{18}O$ observations show a clear correlation with salinity throughout the Indian Ocean with the notable exception of deep and bottom waters at depths greater than 1800m. These deep waters have low $\delta^{18}O$ values from melted Antarctic land ice.

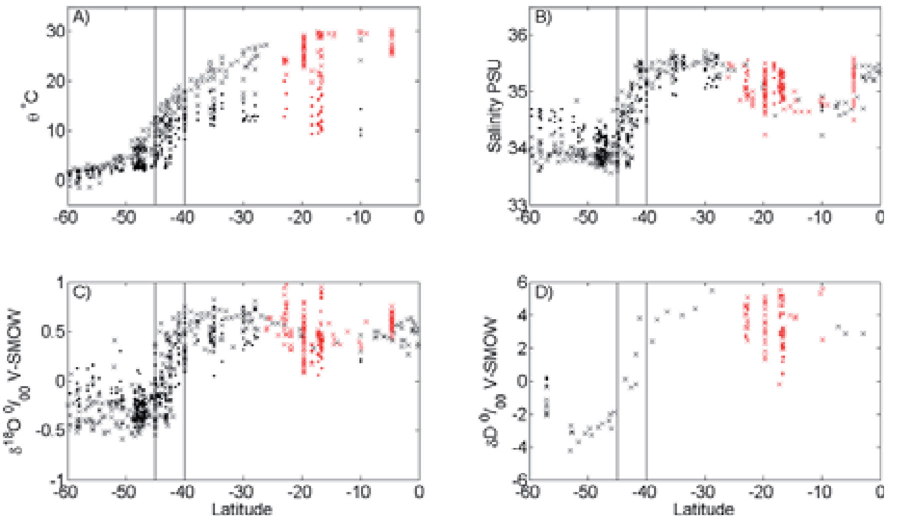


Fig. 2. Changes with latitude from 0-150m (dots) and 150-520m (crosses). A) temperature, B) salinity, C) $\delta^{18}O$, D) δD. Vertical lines indicate the frontal zone between the Indian Ocean gyre and the Southern Ocean. New measurements taken from the Mozambique Channel and east of Madagascar are marked in red.

Plotting the data from the upper 520m as a function of latitude, a clear north-south trend appeared (Fig. 2). The Agulhas/Subtropical Front becomes clearly visible between 40˚ and 45˚S as a sharp decrease in salinity and $\delta^{18}O$-δD between the Subtropical Water (STW) of the Indian Ocean to the north of the front, and the High Latitude Water (HLW) to the south. Water at intermediate depths between ~520 and 1800m is largely dominated by HLW with lower salinities and $\delta^{18}O$-δD values.

Observations were also analysed separately for STW, HLW and Frontal Zone Water from 40-45˚S (Fig. 3). The relationship between salinity and $\delta^{18}O$ was reasonably described by a single line of best fit. However, when investigated

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more closely it appeared that variations in local atmospheric forcing resulted in more regional variations in the isotope-salinity relationship with depth. These include small shifts caused by the influx of Zambezi river water in a thin surface layer spreading along the western Mozambique Channel, diluted saline waters from the Red Sea/Persian Gulf at mid depths, and (Ant)arctic bottom waters.

Our results show that the steep gradients in temperature and salinity across the Agulhas/Subtropical Front that borders the circum-Antarctic current system are paralleled by similar gradients in $\delta^{18}O$ and δD. Consequently, marked isotope shifts observed in the carbonates and organic compounds of cored sediments can be attributed to movements of this front during climate changes in the past. These shifts are independent of absolute changes in the isotope composition of ocean waters occurring during periods of deglaciation and sea level rise. In addition, isotope contrasts found between surface and deep water carbonate producers may provide insight in vertical water mass structure and reveal past changes in surface and deep ocean (re-)circulation.

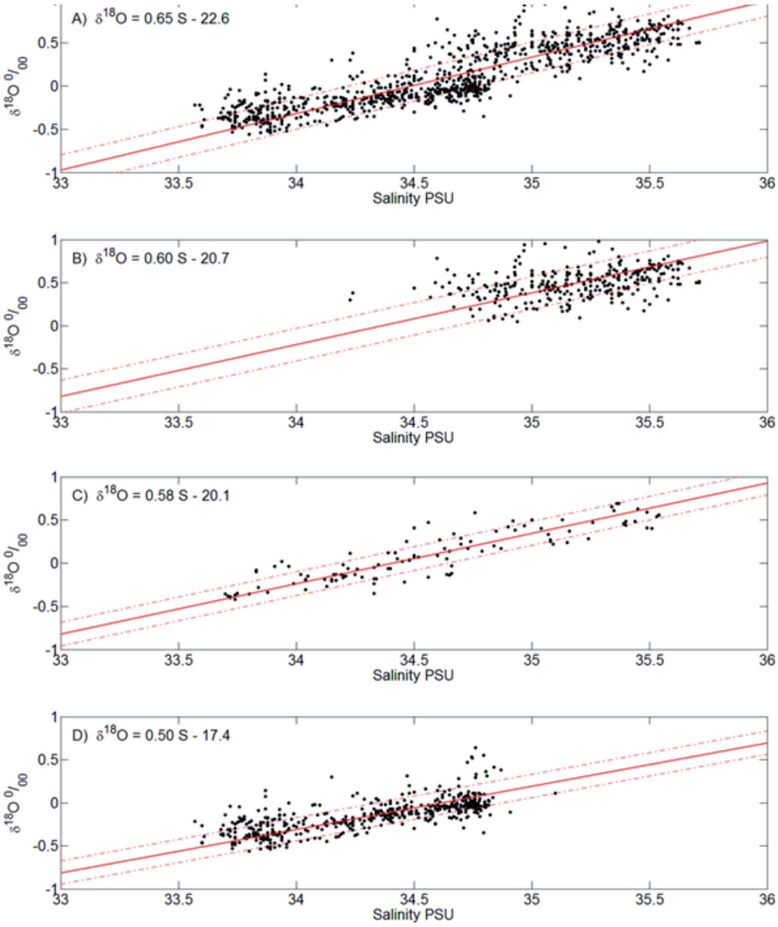

Fig. 3. $\delta^{18}O$ vs Salinity with lines of best fit and residual σ. A) Upper/intermediate water dominated by atmospheric forcing. B) Subtropical Waters, C) Frontal Waters and D) High Latitude Waters. Solid lines show fits calculated using the RMA method. Dashed lines indicate one σ of the residuals.

Aneurin Henry-Edwards takes water samples from a CTD.

Madagascar coral skeletons reveal past soil erosion and Indian Ocean climate

Craig Grove, Jens Zinke, Geert-Jan Brummer*

Corals archive chemical signals in their skeleton during growth which can be related to environmental change such as past climate and soil erosion. Soil erosion poses a mounting threat to coastal nations in the western Indian Ocean, resulting from land degradation and current climate change. For proper impact assessment of these fragile environments long-term observational data are unfortunately missing. Furthermore, environmental management strategies have been formulated at best on short-term instrumental records, even for the most sensitive river catchments. Coral skeletons offer continuous seasonally resolved data spanning multiple centuries, which faithfully record climate variability and the occurrence of events such as ENSO (El Niño Southern Oscillation) related floods, tropical cyclones and long-term rainfall patterns. The coral proxy based climate project (SINDOCOM) entailed drilling cores from living massive coral colonies, 1 – 4 m in height, to reconstruct past environmental change from reef complexes across northern and eastern Madagascar.

Massive corals grow at an approximate rate of 1 cm per year, archiving specific climate signals in their skeleton (Fig. 1). In order to read these climate signals a novel scanning technique (Spectral Luminescence Scanning/SLS) was devised at NIOZ that quantifies luminescence intensities of coral skeletons subjected to UV light. By splitting the total luminescence spectrum into three spectral domains (Red, Green, Blue) the amount of terrestrial humic acids can be determined that were flushed into marine catchments at the time of skeletal precipitation. As humic acids (Green) have a slightly longer emission wavelength than the skeletal aragonite (Blue), taking a Green/Blue (G/B) ratio provides a quantitative estimate of terrestrial erosion related to river runoff. The luminescence device developed has unprecedented sampling resolution. This has enabled weekly reconstructions of soil erosion and river discharge in northeast Madagascar over multiple centuries that resulted from natural rainfall cycles, intense cyclones and deforestation. Long-term runoff patterns were assessed by using a 300 year core from the northeast Madagascar region. Decoupling Madagascar's 20th century human deforestation from rainfall induced soil erosion, using luminescence and geochemistry in the coral archives, revealed a far-field precipitation link to the Pacific Ocean on multidecadal time-scales (Fig. 2). Indeed, the corals provide the first evidence for Pacific decadal forcing of rainfall over the western Indian Ocean. Positive phases of the Pacific Decadal Oscillation (PDO) are associated with increased Indian Ocean temperatures and rainfall across eastern Madagascar, while precipitation in southern Africa and eastern Australia decline (Fig. 2). Conversely, the negative PDO phase that started in 1998 should lead to reduced rainfall over northeast Madagascar and increased precipitation in southern Africa and eastern Australia. These results have important implications for understanding future multidecadal variability of rainfall in Africa where water resource management is increasingly important under the warming climate.

Atmospheric CO_2 emissions have accelerated over the last fifty years. We tested whether coastal eastern Madagascar has warmed significantly during that time. To do so, sea surface temperatures (SST) were reconstructed from two coral skeletal Sr/Ca records, yielding a SST rise of 0.9°C. This is significantly higher than the 0.44°C suggested by satellite derived SST data. As the predictability of coral reef survival is largely dependent on such data to assess regional SST-coral resilience relationships, these results suggest that satellite derived SST data may seriously underestimate trends at the reef scale. Localised SST trends therefore need to be taken into consideration when applying future coral mortality models, as larger than expected increases in SST are likely to result in higher coral mortality.

Fig. 1. Craig Grove and Jens Zinke drilling into a giant coral located in eastern Madagascar (left). As the tide level falls the drill pistol breaches the surface water (middle). Giant corals of the genus *Porites* are often used to reconstruct past climatic conditions (right).

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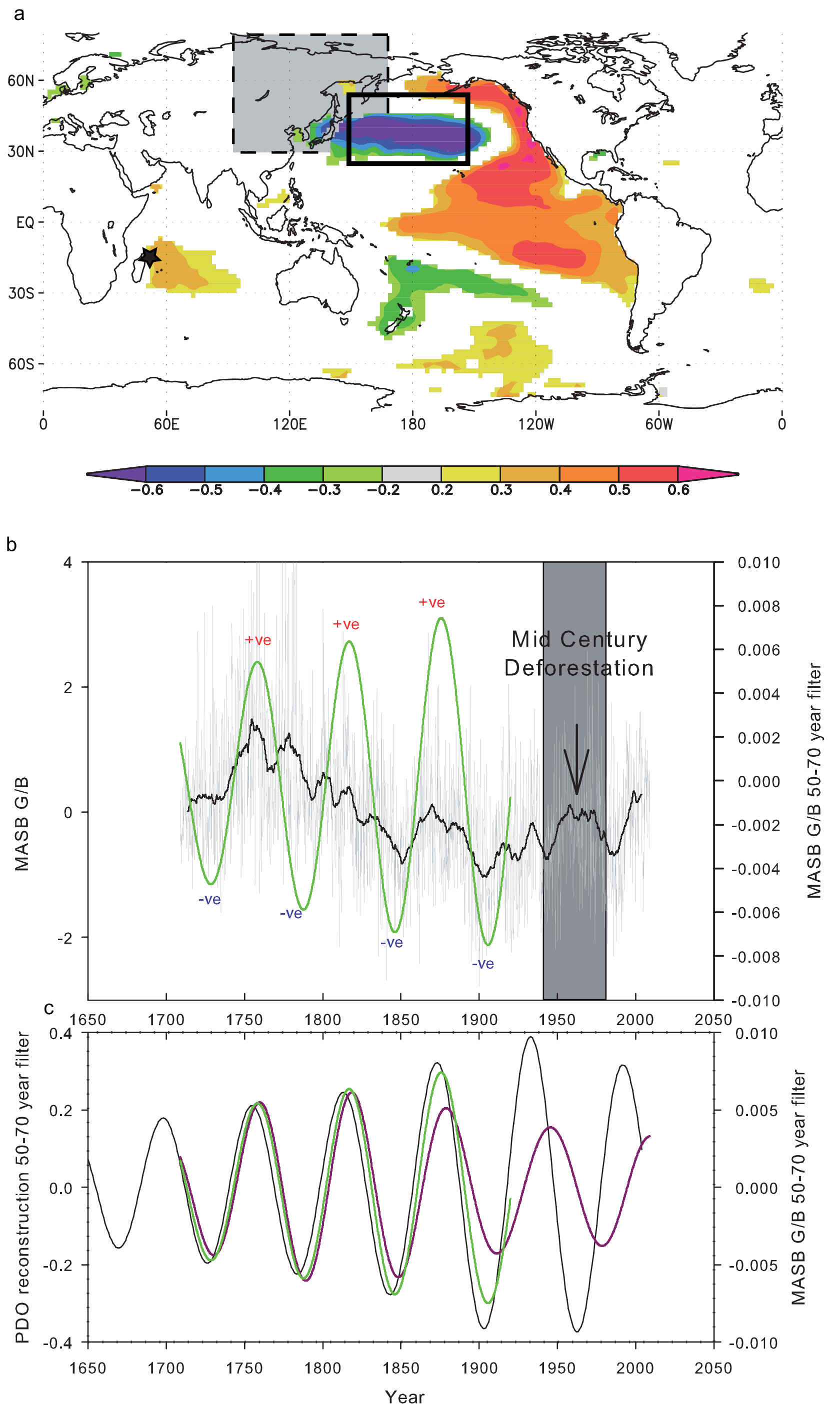

Fig. 2. (a) Typical positive PDO phase indicated by global SST anomalies. Global satellite derived SST data are correlated with the PDO index. Positive and negative anomalies at >90% significance level are indicated by colours. The black outlined box on the map shows the strong negative anomalies of the central north Pacific during a positive PDO phase. The grey shaded box indicates the region used to compile the NE Asian 500 year reconstructed tree ring PDO index. (b) Monthly coral G/B (grey line) and the 10 year running mean (black line) are shown together with the 50 – 70 year band-pass filtered data up to 1920 (green). Peaks and troughs (b) represent multi-decadal positive (red) and negative (blue) runoff anomalies. (c) The same 50 – 70 year band pass filter is also applied to the NE Asia tree ring based PDO reconstruction (black), coral G/B 1708 – 2008 (purple) and coral G/B 1708 – 1920 (green). Both the tree ring based PDO reconstruction and the coral G/B 1708 – 1920 are coherent (c), therefore positive PDO phases are associated with positive runoff anomalies. The relationship with the reconstructed PDO index breaks down post 1920 due to the deforestation period influencing erosion.

There is much scope for future climate research in the SW Indian Ocean region. Corals can reveal the SST related rainfall-drought cycles experienced over eastern and southern Africa during the last 300 years. This can be achieved by increasing the spatial and temporal resolution of coral cores in the region and by applying the novel SLS technique. Over the next two years coral cores collected from Mozambique and Mauritius will be analysed as part of the newly funded CLIMATCH project. We are confident that broadening our understanding of past rainfall variability will help us predict how future rainfall will change in response to current global warming conditions.

External Projects Marine Geology

- Climatic and anthropogenic shifts in seasonal river runoff into the Indian Ocean over the past Millennium resolved by coral geochemistry and photoluminescence (CLIMATCH, NWO-ALW).
  C. Grove, J. Zinke, G.J.A Brummer, in cooperation with Vrije Universiteit Amsterdam.
- Coral Reefs and Global Change – a historical perspective spanning the western Indian Ocean. (Western Indian Ocean Marine Science Association-Marine Science for Management; WIOMSA-MASMA).
  J. Zinke, G.J.A. Brummer, C. Grove, in cooperation with University of Cape Town (South Africa).
- Natural monitors benchmark environmental change: valorization of the NIOZ-Core Scanner (NWO-Valorization).
  G.J.A. Brummer, R. Tjallingii, B. Koster.
- Planktonic foraminiferal shell thinning due to anthropogenic CO2 emissions? (NWO-ALW).
  G.J.A. Brummer, in cooperation with Vrije Universiteit Amsterdam.
- Ocean variability and impact of water column properties on proxy formation (GATEWAYS, EU-FP7 Marie Curie International Training Network).
  A. Henry-Edwards, J. Steinhardt, S. Kasper (BGC), G.J.A. Brummer, S. Schouten (BGC), H. van Aken (FYS), in cooperation with University of Barcelona (Spain) and University of Cape Town (South Africa).
- Natural, climatic and anthropogenic change of the Berau Delta/Barrier reef system: High-resolution coral proxy analysis of the modern environment and reconstruction on a seasonal to centennial timescale (WOTRO-KNAW-ICOMAR).
  R. Nagtegaal, G.J.A. Brummer, R. Bak (MEE), in cooperation with Utrecht University and KNMI.
- Relationships between primary productivity and the benthic environment in upwelling regions during the last deglaciation (Vetenskaps Radet Sweden).
  J.B.W. Stuut, in cooperation with Lund University (Sweden).
- A high-precision stable isotope mass spectrometer for marine tracer analysis (NWO-Middelgroot).
  S. Schouten (BGC), G.J.A. Brummer, et al. (MEE, BIO).
- Assessment of tropical environmental change and its teleconnections for the last deglaciation by means of high resolution biomarker analysis (NEBROC2, NWO/NIOZ).
  I.S. Castañeda (BGC), S. Schouten (BGC), G.J.A. Brummer, J.S. Sinninghe Damsté (BGC), in cooperation with the University Bremen (Germany).
- European Multidisciplinary Seafloor Observatory - Preparatory Phase (EMSO-PP, EU-FP6).
  J. Greinert, H.C. de Stigter, T.C.E. van Weering.
- Hydroacoustic seafloor and water column mapping: New tools for multibeam backscatter analyses and 3D/4D visualization (NWO Valorization).
  J. Greinert, H. de Haas., L. Maas (FYS), K. Philippart (MEE), G. Duineveld (MEE).
- Spatial methane and CO2 flux quantification from a pockmark area in the Black Sea: SPUX. (ESF Eurofleets).
  J. Greinert, in cooperation with IFM-GEOMAR, Kiel (Germany), Ghent University, Ghent (Belgium), IOBAS, Varna (Bulgaria).
- Holocene desertification trends in NW Africa inferred from end-member modelling of grain-size distributions and provenance studies of terrigenous sediments (EUROPROX/DFG).
  J.B.W. Stuut, in cooperation with Vrije Universiteit Amsterdam and MARUM Bremen (Germany).
- Hotspot Ecosystem Research and Man's Impact on European Seas (HERMIONE, EU- FP7).
  H.C. de Stigter, T.C.E. van Weering, M.S.S. Lavaleye (MEE), G.C.A. Duineveld (MEE).
- Tracing past to modern Indo-Atlantic exchange in sedimentary records (INATEX-B, NWO/ZKO-Oceans).
  G.J.A. Brummer, R. Tjallingii, H. Ridderinkhof (FYS), T.C.E. van Weering, in cooperation with Vrije Universiteit Amsterdam, Utrecht University, KNMI, University Kiel (Germany).
- A process study on the impact of the Arabian Sea oxygen minimum zone on organic matter degradation, nutrient regeneration, trace metal cycling and foraminiferal proxies (PASOM, NWO-ALW).
  Utrecht University, J.S. Sinninghe Damsté (BGC) et al., G.J.A. Brummer (co-applicant).
- Permafrost and gas hydrate related methane release in the Arctic and impact on climate change: European cooperation for long-term monitoring (PERGAMON, ESF/COST).
  J. Greinert, A. Stadnitskaia (BGC).
- Scanning Sediment and Coral Climate Archives Applications of Non-destructive Nature. (NWO-Middelgroot)
  G.J.A. Brummer, R. Tjallingii, J.-B.W.Stuut, W. Boer, R.Gieles.
- Southern Indian Ocean/Tropical Pacific teleconnections assessed by a joint coral-in situ ocean monitoring database (SINDOCOM, NWO-ALW/Climate Change).
  C. Grove, J. Zinke, G.J.A Brummer, in cooperation with Vrije Universiteit Amsterdam and KNMI.
- Controls on sediment phosphorus release from temperate intertidal sediments (FCT, Portugal).
  C. Leote, H.G. Epping, in collaboration with Trinity College Dublin (Ireland).
- Temperature and salinity proxies of ocean thermohaline circulation and climate change: development and verification (NEBROC2, NWO/NIOZ).
  U. Fallet, G.J.A. Brummer, S. Schouten (BGC), in cooperation with AWI Bremerhaven and University Bremen (Germany).

Marine Organic Biogeochemistry

The BGC department addresses a field of research at the interface of the basic disciplines of chemistry, geology and biology. The basic questions are:

- Which organic compounds are present in the different compartments (biota, water, sediments) of the marine environment and what is their origin?
- What is their biochemical role in marine organisms?
- Which reactions (e.g. biotransformation and diagenesis) affect these components during transport in the marine environment? How are these reactions affected by environmental conditions and on which time scales? What can these components tell us on the biogeochemical cycling of carbon, nitrogen and sulfur in the ocean?
- What can be learned from organic matter deposited in marine sediments with respect to marine evolution, the functioning of past marine ecosystems, climate variability and organic carbon burial?

In 2011, members of BGC actively pursued fieldwork: in three cruises the water column and sediments of the North Sea were sampled to study archaeal nitrification and anaerobic ammonium oxidation in the ZKO project NICYCLE. For the ERC PACEMAKER project a cruise was made to the Portugese margin to trace the transport of soil derived organic matter into the ocean. Another cruise was made to the waters around Iceland for the NWO-ALW-funded “diol project” that aims to develop a new marine paleothermometer based on algal lipids. In collaboration with Utrecht University, BGC participated in three research cruises to the Mediterranean. Three new projects were started within the Darwin Centre for Biogeology where BGC collaborates with (micro)biologists at the Dutch universities and the sister institute of the NIOZ, the Netherlands Institute for Ecology (NIOO). At the same time, three graduate students obtained their PhD degree at Utrecht University: Angela Pitcher graduated on her work on the lipids of ammonia-oxidizing archaea, Francien Peterse on her work on validation and application of a continental paleothermometer based on microbial lipids, and Joost Brandsma on the environmental application of intact polar lipids in marine environments. The department also organized a well attended NEBROC course “Molecular Organic Biogeochemistry” for young researchers from all over Europe. A major scientific achievement in 2011 was the publication of two *Science* papers, one paper in *Nature* and one in *PNAS*. Three of these papers were about the reconstruction of past climate change, on a variety of time scales, the other dealt with the identification of a new microbe in the second step of nitrification.

A more detailed account of the results of some of the projects that ended in 2011 is given on the following pages.

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Investigating microbial communities in deep ocean hydrothermal vents

Robert A. Gibson, Marcel van der Meer, Ellen C. Hopmans, Stefan Schouten, Jaap S. Sinninghe Damsté*

Microbial communities indigenous to deep ocean hydrothermal vent systems are known to harbour some of the most primitive life on Earth today. In this project we developed methods to study the membrane lipids of microbial communities associated with hydrothermal vent ecosystems. Specifically, we targeted the intact membrane lipids of Archaea and Bacteria that are present in hydrothermal vent chimneys. Our analysis revealed a diverse and, in some cases, rather unusual array of microbial lipids. Comparison of our results with data generated by microbial ecologists, working on identical samples, allowed us to assign lipid groups to particular groups of microorganisms and provided insight into the relative amounts of Bacteria and Archaea in hydrothermal vent systems.

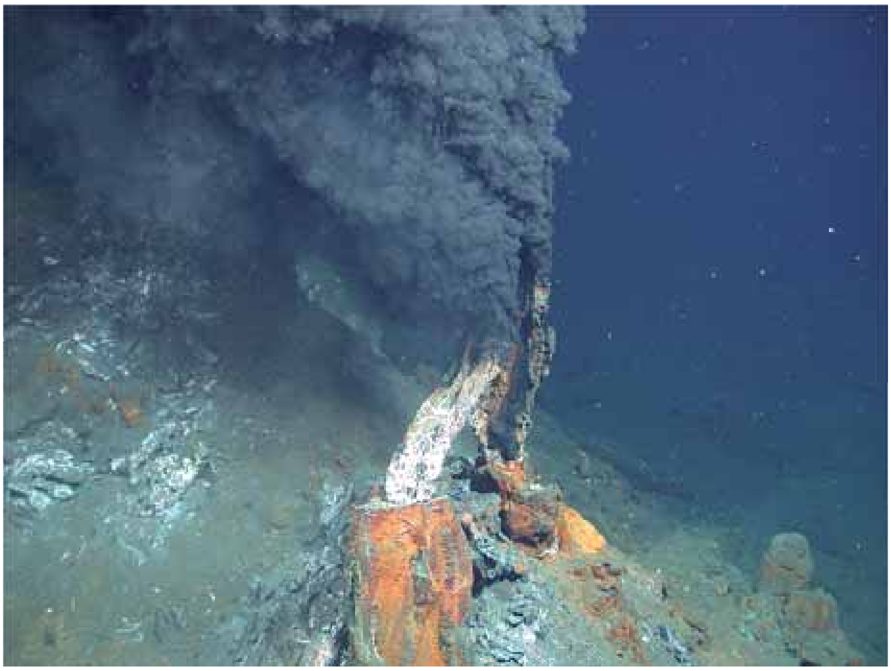

Fig. 1. A chimney at the Rainbow hydrothermal vent field (Courtesy of Woods Hole Oceanographic Institution and NSF; Dr. Reysenbach, PI, Portland State University).

Hydrothermal vents were first described after exploration of the Galapagos Rift in the eastern Pacific Ocean and are now known to be widespread throughout the oceans. When water and rock interact at high temperature and under high pressure deep within the Earth's crust, this results in the formation of hot, mineral-laden hydrothermal fluids that upon reaching the sea-floor, mix with cold water and form hydrothermal vent 'chimneys' (Fig. 1). These chimneys are home to diverse communities that derive energy and metabolic substrate directly from the venting fluids and the discovery of these ecosystems redefined our understanding of the limits at which life can survive.

Recent years have shown that hydrothermal vents occur in a number of forms and certain aspects of the systems, i.e. the composition of venting fluids, temperature and ecology, appears to be governed by geochemical and geological processes that occur in basement rocks below the vents. For instance, where vents are located on low silica containing rocks, venting fluids are found to be rich in H_2 and CH_4 and other reduced molecules that derive from degradation reactions in the Earth's mantle.

As a means to investigate the microbial populations associated with hydrothermal vent chimneys we studied the composition of so-called Intact Polar Lipids (IPLs) (see Fig. 2 for example). IPLs are the membrane lipids of microbes and are quickly degraded after cell death and thus likely reflect living biomass. Due to their large structural diversity they have become popular tools to study microbial ecology.

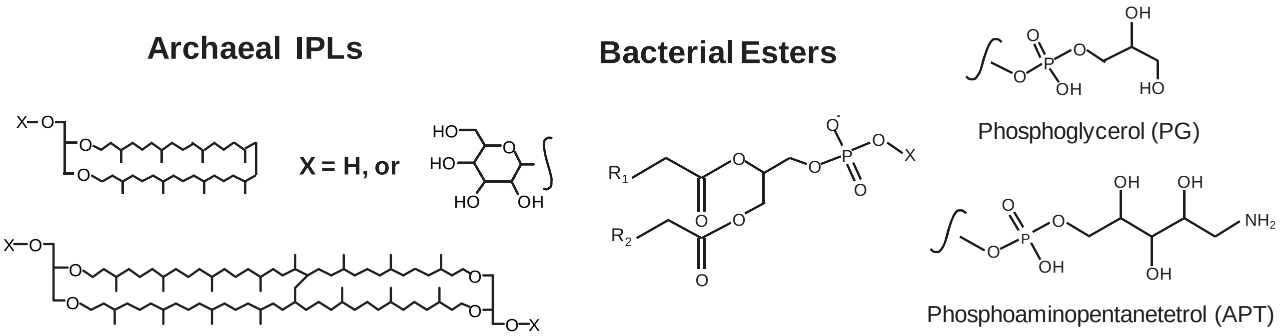

Fig. 2. Structures of selected compounds that were present in hydrothermal vent chimneys
R_1= , R_2= Saturated and mono-unsaturated alkyl chains resp.

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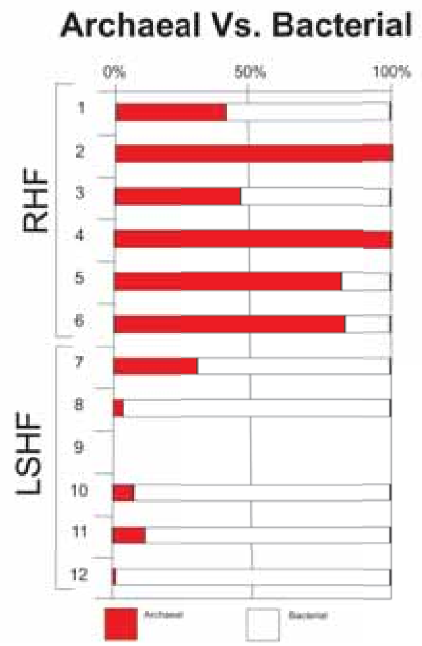

Fig. 3. Relative distribution (% of total identified IPL composition) of Archaeal and Bacterial IPLs found in Hydrothermal vent Chimneys. RHF = Rainbow hydrothermal vent field, LSHF, Lucky Strike hydrothermal vent field

A major focus was to study the chimneys from the Rainbow and Lucky Strike hydrothermal vent fields, located on the Mid-Atlantic Ridge. Previously the microbial communities at each location had been characterized using DNA based techniques. This provided us with a framework to assess how the IPLs reflected the known microbial populations. Our results showed that at Rainbow, where H_2 concentrations are high, we generally find an abundance of ether lipids that derive from hyperthermophilic methanogenic archaea. In contrast, at the Lucky Strike location, where conditions are more oxidizing, Archaeal lipids were present in only very minor amounts and Bacterial ester IPLs that derive from Epsilon- and Gammaproteobacteria were found to be far more dominant. For instance, Fig 3. shows that in Rainbow vents (samples 1 – 6) archaeal lipids dominate the observed lipid distributions, accounting for at least 45 % of the total lipids in each sample measured. At Lucky Strike (Fig. 3, samples 7 – 12), archaeal lipids account for only 35% in one sample and are generally observed as very minor components in other samples. The reason for the observed difference between locations is thought to derive from the availability of certain nutrients, such as H_2, at each site. The abundance of H_2 at the Rainbow site comes directly from a chemical reaction between seawater and fresh, newly-formed rocks in the Earth's crust. This allows H_2 consuming archaea and bacteria to dominate. At Lucky Strike, H_2 concentrations are two to three orders of magnitude lower and hence we do not observe similar IPL patterns.

The study adds to an expanding body of work contributing to a more 'in-depth' understanding of the factors that affect the microbial communities in deep-sea hydrothermal systems.

To conclude, the study demonstrated that intact polar lipids are useful tools to study the microbial ecology of hydrothermal vent communities and will be important tools in future studies concerned with hydrothermal vent microbial ecology.

Intact polar lipid analysis: a promising new tool in marine microbiology

Joost Brandsma, Ellen Hopmans, Stefan Schouten, Jaap Sinninghe Damsté*

Intact polar lipids (IPLs) are the basic building blocks of cell membranes, and because of their lability and large structural variety have the potential to act as specific biomarkers for detecting living microorganisms in the marine environment. However, it is virtually unknown which IPLs are present in marine waters, and what their relationship is to the *in situ* microbial community. In this study we measured IPLs in surface waters of the North Sea and their changes throughout the year. A very large variety of IPLs was detected, and some IPLs could be correlated with specific groups of microorganisms. However, it appears that a set of common and unspecific IPLs predominates throughout the world's oceans. In the future, targeted measurements of biomarker IPLs will therefore likely be more successful in detecting specific microorganisms in the marine environment.

Ever since the discovery of microorganisms and the realization that they are essential in Earth system functioning, efforts have been made to identify and count naturally occurring microbial communities. Direct microscope counting and enrichment cultures continue to yield important results, but are nowadays often complemented or replaced by a wide range of analysis based upon molecular techniques. These techniques use the measurement of a microorganism's cellular constituents, such as its DNA, pigments, proteins or lipids, as a proxy for the organism itself. Polar lipids are the basic building blocks of cell membranes and consist of a polar 'headgroup', a glycerol 'backbone' and one or two fatty acid 'tails' (Fig. 1 for examples). An enormous variety in headgroups and fatty acid tails exists, and over 10,000 different polar lipids have already been identified.

There are three main reasons why intact polar lipid (IPL) molecules are an attractive proxy for microbial ecological studies. First, not all organisms synthesize the same IPLs, and indeed some IPLs have been found that are unique to one particular (group of) microorganism(s). Such 'biomarker' IPLs are well suited to detect the presence of their source microorganisms in environmental samples. Second, IPL molecules are thought to break down within hours to days after a cell dies. This means that IPLs are indicative of living cells, and can thus be used to quantify living microorganisms. Finally, the IPL composition of a microorganism's membrane is not constant, but is continuously 'remodelled' in adaptation to environmental changes. IPLs can thus hold valuable information about the relationship between a microorganism and its environment.

As suitable analytical methods for the detection of IPLs - using high performance liquid chromatography coupled to multi-stage mass spectrometry - were developed only relatively recently, our knowledge of IPLs in the marine environment is still very limited. The aim of this study was therefore to determine which IPLs are present in marine waters, and what their relationship is with the *in situ* microbial community composition. Water samples were collected from the North Sea (RV Pelagia cruise MICROVIR; Fig. 2), and over a one-year period in the

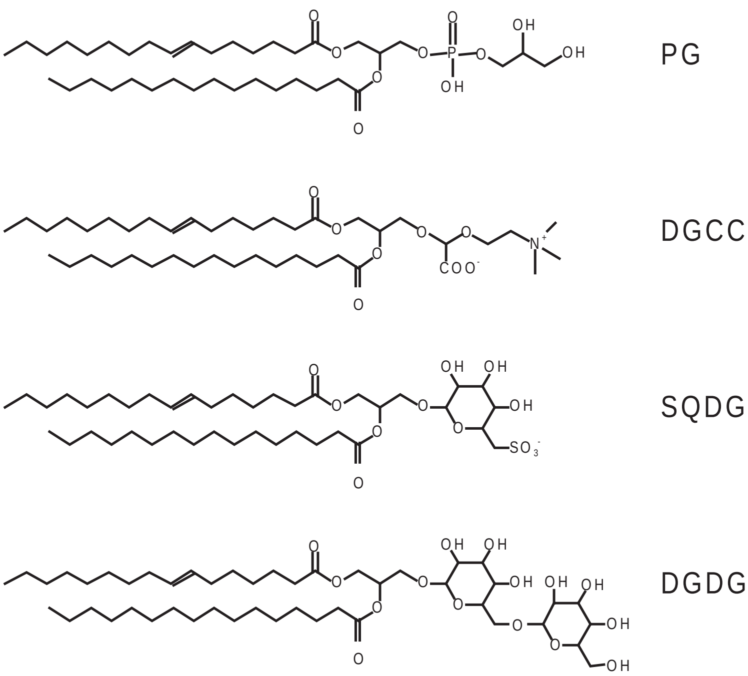

Fig. 1. Examples of the structural diversity of IPLs: the molecules can vary in their headgroup type and the number of carbon atoms and double bonds in each of their fatty acid tails. Shown here are the phospholipid phosphatidylglycerol (PG), the betaine lipid diacylglyceryl-carboxyhydroxymethylcholine (DGCC), and the glycolipids sulfoquinovosyldiacylglycerol (SQDG) and digalactosyldiacylglycerol (DGDG).

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Fig. 2. A filter full of algal biomass ready to be analysed.

Marsdiep, from the NIOZ jetty.
Comprehensive IPL analysis showed that a very large number of IPLs (at least 400, but likely more than 1000) is present in the surface waters of the North Sea.
These IPLs belong to three main groups: phospholipids, glycolipids, and betaine lipids (Fig. 3). It is slowly becoming clear that these are the main IPL classes throughout the world's oceans, as they have been found to predominate in the Pacific and Atlantic Oceans, the Sargasso Sea, and the Black Sea.
The IPLs were directly compared with the *in situ* microbial community, and although some general patterns emerged – for example between IPLs containing polyunsaturated fatty acids and abundances of large algae and diatoms - it was difficult to distinguish between the different microbial groups. Instead, our results show that at all of the investigated sites the same IPLs predominate, and that they do so throughout the year. This is remarkable, as major differences in microbial community composition occur between sites, and moreover the community composition changes rapidly and significantly throughout the year (for example algal blooms). It thus seems that the most common IPLs are also the least specific, being synthesized by a wide range of microorganisms. As these common IPLs dominate the IPL pool, it will probably be more useful for future environmental IPL studies to target previously identified more specific biomarker IPLs, rather than looking at the overall IPL composition.

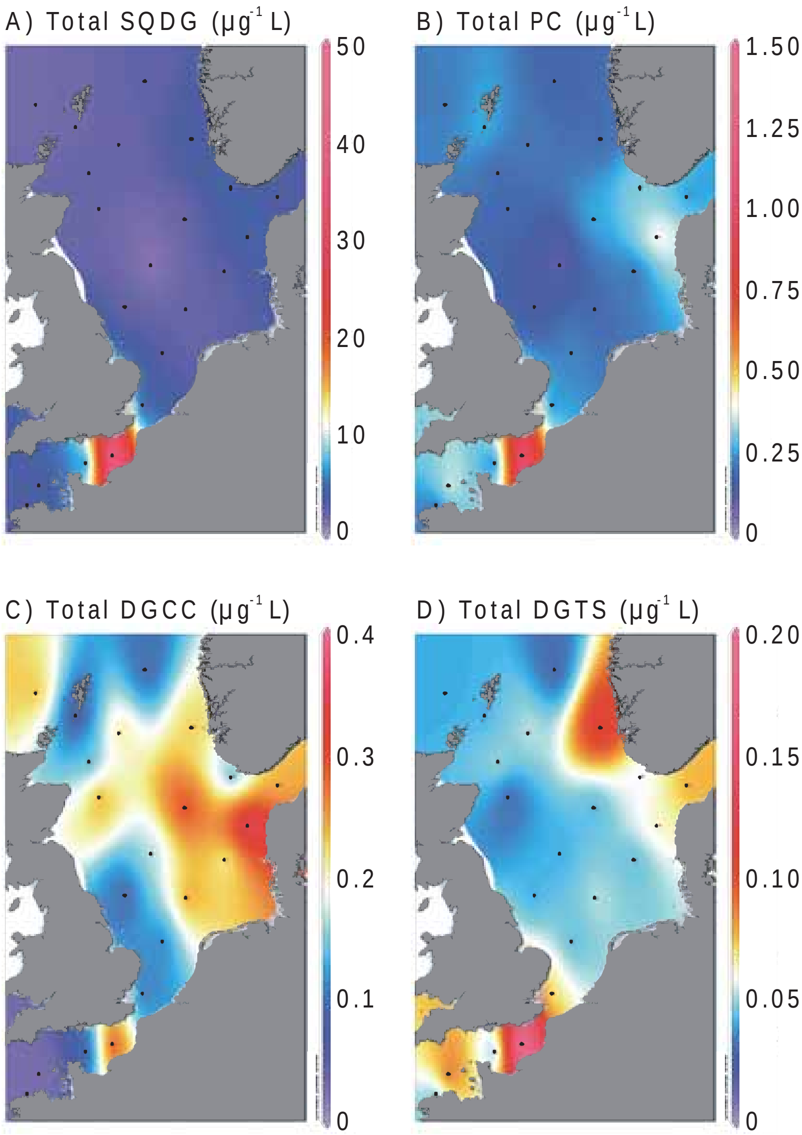

Fig. 3. Different IPL classes predominate in different parts of the North Sea. However, despite the very large number of IPL species present, the differences between sites and the variation throughout the year are not sufficient to identify sources beyond the level of for example 'diatoms' or 'cyanobacteria'. Specific biomarker IPLs are needed to distinguish down to microbial group or species level.

Soil bacterial lipids in marine sediments as recorders of past continental climate change

Francien Peterse, Stefan Schouten, Jaap S. Sinninghe Damsté*

Membrane lipids of specific bacteria that thrive in soils and peats worldwide have been found to vary in composition with changing conditions in their living environment. Their structure and abundance appear to be mainly influenced by temperature and soil pH and can thus be used to reconstruct these parameters for past environments. In this study we tested the influence of temperature and pH on the abundance and distribution of these membrane lipids and examined their distribution in marine settings. The results show that marine sedimentary records of these compounds may reveal important information of past continental climate change.

There are various methods to reconstruct past sea surface or air temperatures. A selection of these is based on the abundance and composition of organic molecules which serve as an indication of specific environmental conditions. The latest contribution to the array of organic proxies is based on membrane lipids of bacteria that thrive in soils and peats worldwide. The molecular structure of these branched glycerol dialkyl glycerol tetraether (brGDGT) membrane lipids can vary in the number of methyl branches and cyclopentane moieties that are attached to their tetraether backbone (Fig. 1). Their relative distribution in soils is determined by the annual mean air temperature (MAT) and pH of their living environment, and can be quantified using the Methylation of Branched Tetraether (MBT) index, and the Cyclisation of Branched Tetraether (CBT) index. Branched GDGTs are transported with soil organic matter by rivers and deposited in marine coastal regions, where down-core application of the so-called MBT-CBT proxy may yield an integrated paleoclimate record for the river drainage basin. Although the MBT-CBT proxy seems to be a promising tool to obtain information about continental climatic changes in the past, the validity and applicability of the proxy need further testing.

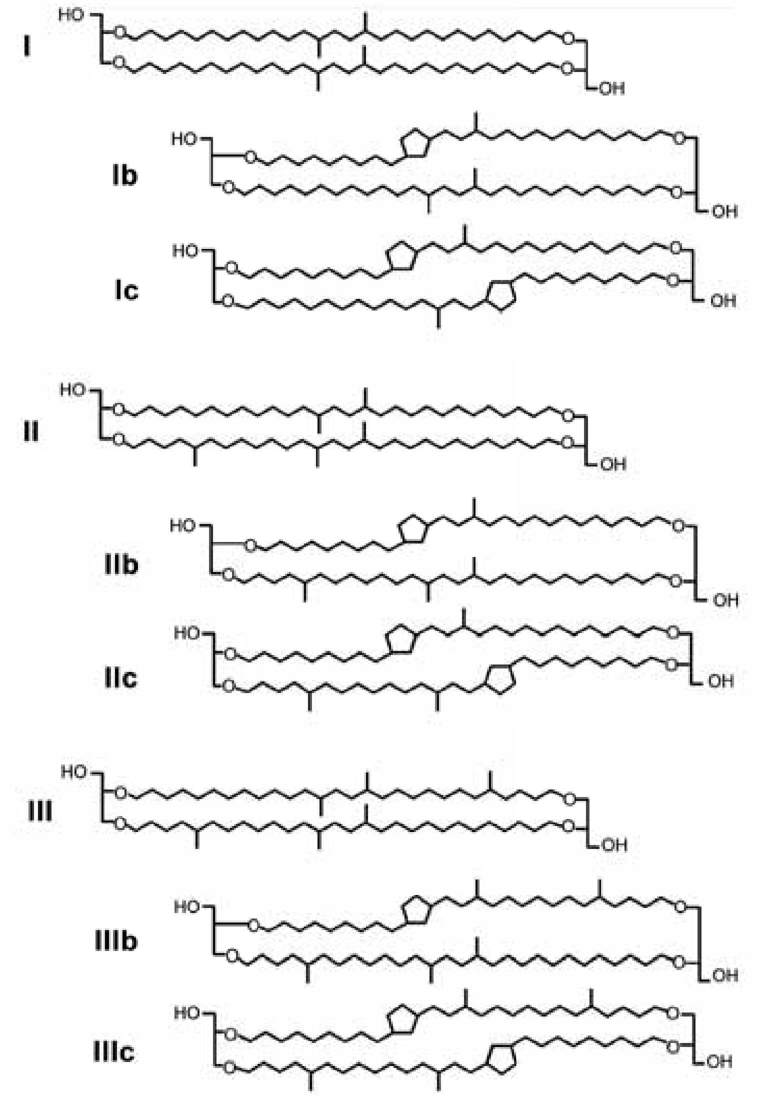

Fig. 1. Chemical structures of branched glycerol dialkyl glycerol tetraether (GDGTs) membrane lipids.

The influence of the two main environmental controls on the distribution and abundance of brGDGTs in soils (MAT and soil pH) was first tested in a variety of settings. Analysis of brGDGTs in geothermally heated soils surrounding hot springs and of long term pH manipulated field plots showed that their distribution was strongly affected by temperature

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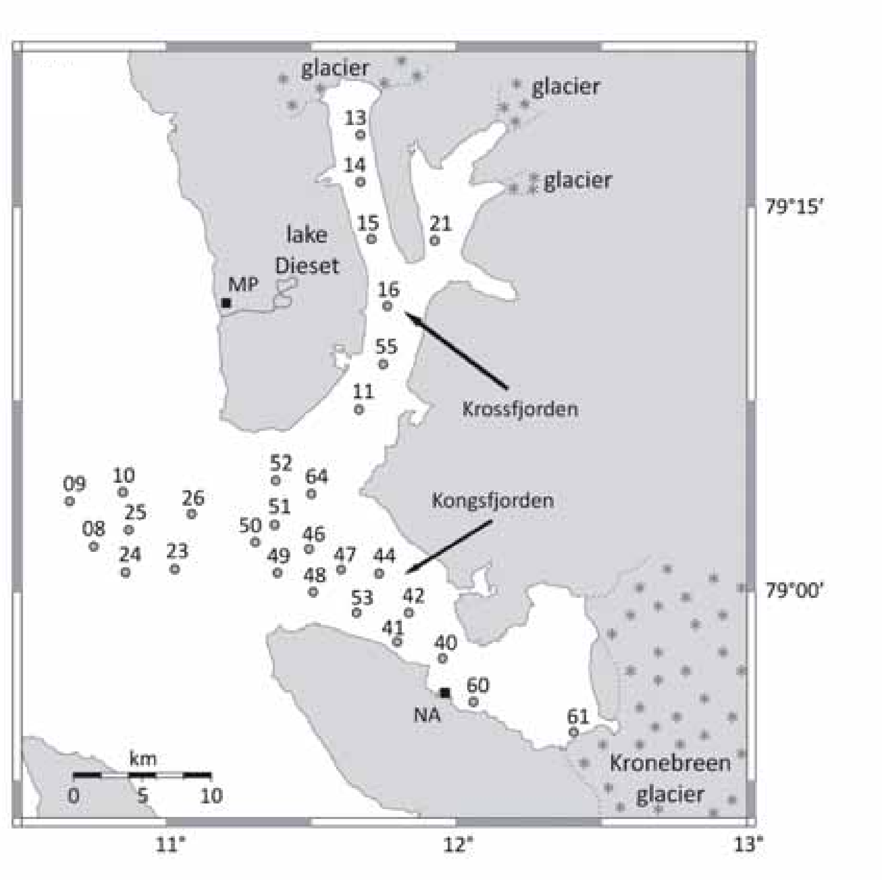

Fig. 2. Spatial distributions of branched GDGT concentration normalized to the sedimentary C_{org} in Kongsfjorden and Krossfjorden and soils (squares) in Mitra Peninsula and Ny Ålesund.

and pH, respectively. Analysis of brGDGTs in soils from an altitude transect along a mountain slope also confirmed that MAT and soil pH are indeed the two main controls on the distribution of GDGTs in a setting with many varying environmental factors. Finally, MBT-CBT-based MAT estimates were tested on bias towards a specific season, but no influence of seasonality could be ascertained.

Subsequently, it was determined to what extent the brGDGT distribution in coastal marine sediments reflects that of the nearby continent. To this end soils and marine fjord sediments of Svalbard were obtained and analysed for brGDGTs. The temperature estimates obtained from the brGDGTs in the soils from Svalbard were close to that of the mean annual air temperature. In contrast, GDGTs were low in concentration in the marine sediments and had a distribution quite different from that of soils on Svalbard (Fig. 2). This suggest that brGDGTs are not well transported from land to the ocean in this Arctic environment, probably due to a lack of riverine transport. In addition, the different distributions and slightly increasing concentrations towards open ocean sediments suggested that they can also be produced in situ in the marine environment, although in relatively low abundance. This leads to the recommendation to only use the MBT-CBT proxy at sites that receive substantial amounts of soil organic matter relative to the amount of marine organic matter, i.e. close to river mouths.

The data thus show that temperature and pH are indeed the main factors controlling the distribution of brGDGTs, but that marine sedimentary records of MBT-CBT proxy must be generated at sites with a relatively large input of soil organic matter.

External Projects Marine Organic Biogeochemistry

- The nitrogen cycle and changes in the carrying capacity of coastal waters (NICYCLE, Part 1, ZKO).
  N. Bale, J.S. Sinninghe Damsté, in cooperation with the NIOO - CEME.
- Long term Indian Ocean monsoon dynamics as revealed by a 25-kyr lipid biomarker record of Lake Challa: potential signals of natural climatic change.
  C.I. Blaga, J.W. de Leeuw , J.S. Sinninghe Damsté, in cooperation with the King Saud University and Ghent University.
- Passive sampler development for measuring dissolved organics.
  K. Booij, in cooperation with the US Geological Survey, the University of Queensland (Australia).
- The nitrogen cycle: foraminifera, bacteria and molecular paleontology of the marine deeper redox zone (NWO - ALW).
  J. Brandsma, J.S. Sinninghe Damsté, in cooperation with the Radboud University Nijmegen, Utrecht University.
- Application of the MBT and TEX_{86} temperature proxies in lakes (ERC, PACEMAKER-2).
  L. Buckles (UU), G.J. Reichart (UU), J.S. Sinninghe Damsté.
- Assessment of tropical environmental change and its teleconnections for the last deglaciation by means of high resolution biomarker analysis (NEBROC).
  I.S. Castañeda, S. Schouten, G.J. Brummer (GEO), in cooperation with the University of Bremen (Germany).
- Sedimentary long-chain, mid-chain diols derived from marine phytoplankton: novel proxies for climate reconstruction (NWO).
  L. Handley, J.S. Sinninghe Damsté , S.W. Rampen (UU), G.-J. A. Brummer (GEO), K.R. Timmermans (BIO).
- Testing a new terrestrial palaeothermometer: Tracing the transport of terrestrial soil membrane lipids through a major river system (Yenisei, Russia) to the Arctic Ocean (NWO - ALW).
  C. de Jonge, A. Stadnitskaia, J.S. Sinninghe Damsté.
- International Census on Marine Microbes / Census of Marine Life.
  J.W. de Leeuw, S. Schouten.
- Bacterial anaerobic methane oxidation in high temperature environments (DARWIN).
  R. Gibson, J.S. Sinninghe Damsté, in cooperation with the Wageningen University.
- Compound specific hydrogen isotopes as indicator of core metabolisms of benthic microorganisms in the Wadden Sea.
  S. Heinzelmann, M.T.J. van der Meer.
- Development, validation and application of compound specific hydrogen isotope analysis as a tool for reconstructing Agulhas Current paleo sea surface salinity variability (EU Marie Curie Initial Training Network GATEWAYS).
  S. Kasper, M.T.J. van der Meer, S. Schouten.
- SOURCE - Tracing Amazon soil organic carbon input from land to the ocean (EU).
  J-H. Kim, J.S. Sinninghe Damsté.
- Quaternary evolution of continental climate as revealed by the MBT/CBT proxies (ERC, PACEMAKER-3).
  L. Warden, J.S. Sinninghe Damsté.
- Tracing the environmental significance of nitrite-driven anaerobic methane (DARWIN).
  D. Kool, J.S. Sinninghe Damsté , in cooperation with the Radboud University Nijmegen.
- Impact of benthic processes on biogeochemical organic carbon cycling and organic proxy records in marine sediments (DARWIN).
  S. Lengger, S. Schouten , J.S. Sinninghe Damsté.
- Tracing chemoautotrophic microbes in present and past sedimentary environments (DARWIN).
  Y. Lipsewers, L. Villaneuva.
- Biogeochemical cycling of organic matter in coastal marine sediments: Intact polar lipids as tracers for key microbes (DARWIN).
  E. Moore, J.S. Sinninghe Damsté , in cooperation with the Wageningen University.
- Continental climate signals from marine sediments: validation of organic proxies based on membrane lipids of soil bacteria (DARWIN).
  F. Peterse, J.S. Sinninghe Damsté, in cooperation with the Wageningen University.
- Ecology and lipid chemistry of marine Crenarchaeota in present and past marine environments (DARWIN).
  A. Pitcher, J.S. Sinninghe Damsté , in cooperation with the NIOO - CEME, the Radboud University Nijmegen.

- Ladderane and other lipids of anammox bacteria as tracers for present-day and past oceanic nitrogen cycling (DARWIN).
  D. Rush, J.S. Sinninghe Damsté, in cooperation with the Radboud University Nijmegen.
- The impact of CO_2 concentrations and pH on marine microbial membrane lipids (DARWIN).
  P. Schoon, S. Schouten, J.S. Sinninghe Damsté in cooperation with NIOZ-BIO and NIOO-CEME.
- Past Continental Climate Change: Temperatures from marine and lacustrine archives (ERC, PACEMAKER).
  J.S. Sinninghe Damsté.
- Lipids as indicators of N-cycling in sub-oxic zones of present and past oceans (DARWIN).
  M. Sollai, J.S. Sinninghe Damsté, in cooperation with the Radboud University Nijmegen.
- Geobiology of deep-sea cold seep carbonates: biogeochemical interactions and feedback (NWO - Vernieuwingsimpuls, Veni grant).
  A. Stadnitskaia.
- Waddensleutels (Waddenfonds).
  E. Svensson, D. Rekers, J.S. Sinninghe Damsté, S. Schouten, in cooperation with MEE, Groningen University and Utrecht University.
- Developing new methods to estimate paleosalinity; understanding the past as key to future climate change *(NWO Innovational Research Incentives Scheme VIDI).*
  D. M'Boule, D. Sinke-Schoen, M.T.J. van der Meer.
- How salty was the sea? A crucial question to predict future climate change (NWO - ALW).
  D. Chivall, M.T.J. van der Meer, J.S. Sinninghe Damsté.
- From hothouse to icehouse: Evolution of Mesozoic and Cenozoic sea water temperatures (NWO - Vernieuwingsimpuls, Vici grant).
  R. Lopes dos Santos, I. Castaneda, J. Ossebaar, S. Schouten.
- Tracing the transport of soil organic matter to the ocean by rivers (ERC, PACEMAKER-1).
  C.I. Zell, J-H. Kim, D. Dorhout, J.S. Sinninghe Damsté.

Biological Oceanography

Within the department of Biological Oceanography (BIO) the main research is focused on the study of biological and chemical processes and their interaction within the lower food-web. The department is strong in sea-going research, with an interdisciplinary character (including physics and geology). Although there is a focus on the pelagic food-web also complex interactions of various components of coral reefs are part of the research in the department.

As part of the GEOTRACES project (NWO-ZKO Ocean) a cruise with R.V. James Cook covered high quality trace metal analyses in the Southern Atlantic from Punta Arenas (Argentin) to Fortaleza (Brasil). A rendez-vous of R.V James Cook and R.V Pelagia in Las Palmas (Canary Islands) allowed exchange of the clean sampling gear for deployment during the second STRATIPHYT (NWO-ZKO Ocean) cruise to Reykjavik. During this cruise the stratification of the watercolumn and its effects on phytoplankton production and loss was studied in great detail.

In the framework of EU-FORCE project, Benjamin Mueller spent 6 months on Curaçao (CARMABI) for fieldwork. Experiments were conducted to assess the dissolved organic carbon (DOC) release by corals and benthic macroalgae under different environmental conditions (light, nutrients). Two students of Utrecht University contributed with *in situ* DOC monitoring, coral reef transect work focusing on the cover of corals, algae and (excavating) sponges. In addition experiments addressing the oxygen consumption, uptake and release of different size classes of DOC (viruses, transparent exopolymeric particles (TEP) and truly dissolved organic matter) and bacteria by excavating sponges were performed. In October Fleur van Duyl joint an expedition to the Saba Bank with IMARES and delegates of the BES islands (Saba, St Eustatius, Bonaire) and St Maarten. Reef surveys were done and she collected sponges and benthic macroalgae for stable isotope analyses. In November-December she contributed to international master classes on mangrove, seagrass and coral reef ecosystems in Indonesia on invitation of the KNAW.

A successful 6th Aquatic Virus Workshop was organized by Corina Brussaard at NIOZ. The meeting was sponsored by KNAW, NIOZ and Gordon & Betty Moore Foundation. About 85 scientists participated and new research and data were presented and discussed.

The CHARLET project (ZKO-North Sea) started and a first cruise (out of 3) was executed. The CHARLET project targets the limiting factors for phytoplankton growth in the North Sea, and how these limiting factors affect the food quality and species composition of the phytoplankton. Novel approaches are combined with mathematical models, laboratory studies and field work during cruises with the R/V Pelagia in two contrasting areas of the North Sea: the productive coastal area with relatively high nutrient inputs from rivers and the central North Sea with much reduced nutrient levels especially during summer. The work will offer key insights into the impact of changes in resource limitation on the carrying capacity of the North Sea.

It was a turbulent year for the NIOZ Ballast Water Research Group and the associated European North Sea Ballast Water Opportunity (NSBWO) Interreg project of which BIO is the lead-beneficiary. Several team members left, while new ones were employed. Jan Boon and Louis Peperzak now form the new management team and

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THE BALLAST WATER TIMES

THIS IS THE FIRST ISSUE OF THE BALLAST WATER TIMES

The North Sea Ballast Water Opportunity (NSBWO) project is a cooperation between more than forty partners and sub-partners. They are located in the United Kingdom, Belgium, the Netherlands, Germany, Denmark, Norway and Sweden. The NSBWO project aims to reach regional cohesion, innovation and develop future strategies in ballast water policies and ballast water management. The project is co-funded by the INTERREG IVB North SeaRegion Programme of the European Regional Development Fund and is coordinated by NIOZ-Royal Netherlands Institute for Sea Research. In this newsletter you can read about the partners and sub-partners of this project and their recent developments. We hope you will enjoy this newsletter and that it´s helpful for future developments within and outside the NSBWO project.

For contact and more information regarding the project please check our website:

North Sea Ballast Water Opportunity project

Etienne Brutel de la Rivière (NIOZ)

Although the need for the Ballast Water Management Convention (BWMC) was obvious, a group of experts realized that a lot of work had to be done to get the BWMC adopted. Treatment techniques were not available and detection technologies were only partly available for application in well-conditioned laboratories. In addition, a lot of question marks were raised by ship owners, port state control officers, industry and policy makers.

The North Sea Ballast Water Opportunity (NSBWO) project started in 2009 to find scientific and mainly practical answers on all sorts of questions in relation to the ballast water and the governing convention. To stimulate the work in the project and useful outcomes, a set of very specific deliverables was identified at the beginning of the project.

This involves:

- Strengthening of regional cohesion and harmonization amongst North Sea countries in respect of certification and compliance enforcement;
- To boost research, innovation and knowledge exchange in respect of ballast water treatment systems;
- To develop practical methodologies and instruments for monitoring and compliance control;
- To get open access of information on marine / aquatic bio-invasive species and to develop models on their behavior;
- To develop future strategies on the knowledge gained and recommendations for the future accordingly; and
- To raise awareness in respect of the above.

The project lasts till the end of 2013 and comprises of over 40 partners and sub-partners within the North Sea Region, including policy makers, authorities, industry and research institutes. Although the initial focus was on the North Sea area, nowadays this project also has close co-operations in the international community, such as the IMO, GloBallast and the US Coast Guard, due to the high level of expertise and knowledge gained over the past years.

Review of the ballast water issue

Ruurd van der Meer (student RUG/NIOZ)

Shipping is an important vector of non-indigenous species introduction. Such species pose risks to the receiving ecosystem. Organisms are transferred along the globe by ship's ballast water and find their way along the global shipping network. Shipping routes, densities and climate simularity can predict and record patterns of new species introductions. An introduction of non-indigenous species in the aquatic environment can lead to adverse impacts on ecology, as well as human health and economy. The members of the International Maritime Organization (IMO) adopted the BWMC in 2004 in order to reduce the transfer of non-indigenous species by ship's ballast water. The BWMC requires ships to use ballast water management to ensure that ships only discharge a minor amount of species in the recipient area, according to the BWMC D-2 standard. Ships that cannot comply with the requirements for their type of ship or due to the operating area might be exempted of performing ballast water management, but only after performing ballast water risk assessment for which the ships have to comply with specific requirements. Risks from the ballast water are the risks of introducing an invasive species and establishing a population of the species in a recipient area (outside the species' native range).

Marieke Vloemans has been appointed to improve the Communication & PR. Three ballast water treatment installations were tested for type approval under Guideline G8 of the IMO Ballast Water Management Convention and three filter tests were performed at the NIOZ harbour. An open day of the test facilities at the NIOZ harbour was organised in May. In cooperation with our NSBWO partners the two day conference 'Ballast Water Management: threat or treat?' was organized as an event during the Maritime Exhibition 'Europort 2011' in November in Rotterdam. At this conference, the first issue of the 'Ballast Water Times' was presented, a magazine of the NSBWO project to increase the dissemination of the knowledge gained on this topic of marine environmental protection.

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Master students at work on Curaçao.

Physical and Chemical Speciation of Iron in the Polar Oceans

*Charles-Edouard Thuróczy, Loes Gerringa**

Binding to dissolved organic ligands and adsorption to sinking particles are the main processes controlling the residence time of Fe in the water column.

Iron (Fe) is essential for phytoplankton growth. Enzymes in many biochemical pathways active in phytoplankton contain an Fe atom. An important example of such a pathway is photosynthesis that uses light to convert carbon dioxide into biomass. In the surface of the open ocean, concentrations of Fe are extremely low due to its low solubility in seawater and the large distances to sources of Fe. As a consequence, phytoplankton growth is limited by Fe in over 40% of the world oceans. These regions are known as High Nutrient, Low Chlorophyll (HNLC) areas. Because Fe limits its phytoplankton growth, it also influences the food web that depends on phytoplankton as a source of food.

Due to the presence of organic molecules (*i.e.* organic ligands) that bind Fe, Fe is found at higher concentrations than expected based on its solubility alone. These ligands form strong organic Fe(III)-compounds and keep Fe in solution. Without the binding of Fe by organic ligands, Fe would, apart from adsorption to particles, form solid (hydr)oxides and sink out to the ocean floor. So, organic binding of Fe increases the residence time of Fe in the water column and therefore keeps Fe available for use by phytoplankton in the surface ocean.

The role of organic ligands in the distribution of Fe in the Arctic and Antarctic Oceans was investigated during three cruises in the framework of the International Polar Year in the GEOTRACES program (Fig. 1). To compare the saturation state of organic ligands with Fe, the ratio of the organic ligand concentration over the dissolved Fe concentration ([Lt]/[DFe]) was introduced. [Lt] represents the total concentration of ligands expressed as number of binding sites for Fe and [DFe] represents the concentration of dissolved Fe, including the ligand bound fraction. For the first time ever, trends in the distribution of organic Fe binding ligands were discovered for different geographical areas over different depth ranges and for different water masses. In the surface layer of the ocean, a decrease in DFe reflects the uptake of Fe by phytoplankton, whereas the ligand concentration is increased by a release of organic matter by bacteria and phytoplankton. This results in a strong undersaturation of the organic ligands and a high ratio [Lt]/[DFe] (Fig. 2). With depth, the ratio [Lt]/[DFe] becomes lower and constant (Fig. 2).

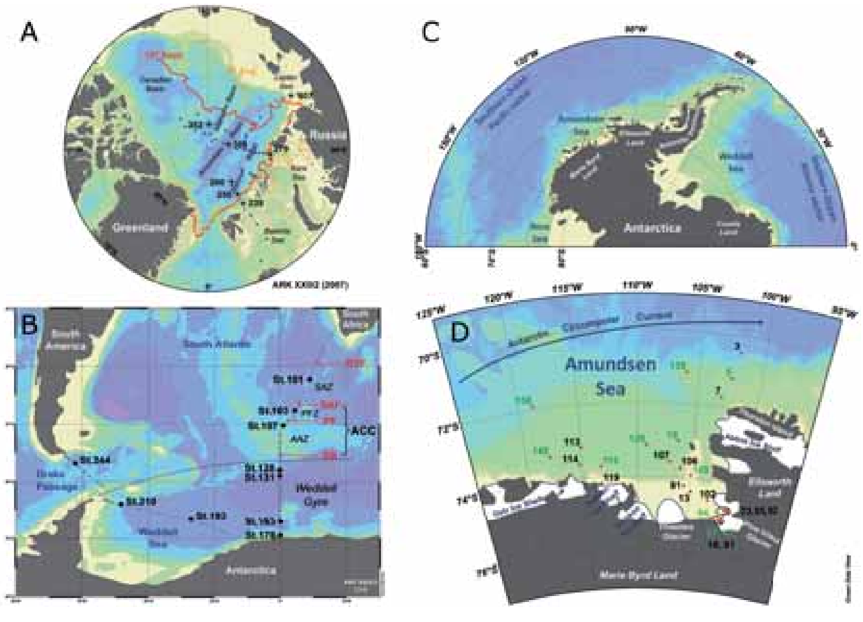

Fig. 1. Geographic locations of (A) stations of the Arctic Ocean sampled during the ARK XXII/2 cruise shown by black dots. The orange line corresponds to the sea-ice extend on the 8th of August and the red line to the sea-ice extend on the 13th of September 2007 (B) stations of the Atlantic sector of the Southern Ocean and location of the fronts and zones. The stations are indicated by large black dots. The dashed line delimits the Weddell Gyre. **STF** = Sub-Tropical Front; **SAF** = Sub-Antarctic Front; **PF** = Polar Front; **SB** = Southern Boundary; **SAZ** = Sub-Antarctic Zone ; **PFZ** = Polar Frontal Zone; **AAZ** = Antarctic Zone; **ACC** = Antarctic Circumpolar Current; Weddell Gyre. (C) the Western part of Antarctica with (D) the study area in detail. The stations sampled in the Amundsen Sea are shown as red dots.

Geographical (horizontal) trends in the concentration of the ligand bound Fe between different ocean basins were attributed to an increasing distance from Fe sources and to the adsorption of Fe to particles and subsequent sedimentation. This was observed in Antarctic waters in a southward direction along the zero meridian (Fig 3.) and in the Arctic from the shelf seas towards the Makarov Basin in the central Arctic Ocean. The ratio of particle adsorbed Fe over dissolved iron, [TDFe]/[DFe], revealed a relative enrichment of particulate Fe towards the bottom at all stations sampled, indicating export of Fe towards the deep ocean. The organic ligands became nearly saturated with depth in the Arctic Amundsen and Nansen Basins, as also found in the Antarctic Ocean. In the Makarov Basin, however, the ligands were less saturated

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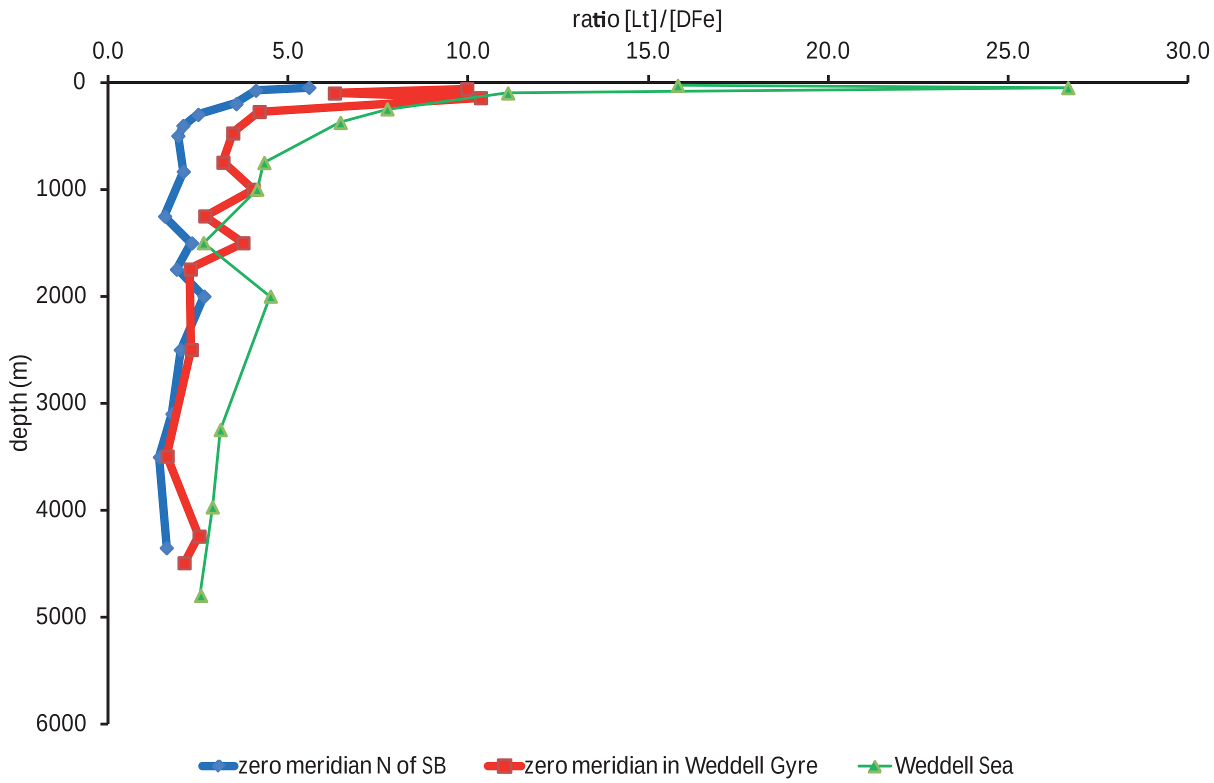

Fig. 2. The ratio of the organic ligand concentration over the dissolved Fe concentration [Lt]/[DFe] with depth for different areas in the Atlantic sector of the Southern Ocean.

with Fe towards the bottom, *i.e.* deeper in the water column were more ligands than Fe. This unexpected change in the saturation state of the ligands may be explained by a lower reactivity of the ligands and a lack of Fe sources in deep waters towards the central Arctic.
Despite the potential of the organic ligands to bind Fe in the deep Makarov Basin, the inputs of Fe from external sources may not be sufficient to counter-balance the continuous adsorption of Fe to settling particles, leading to a net export of Fe to the sediment.
During the last expedition to the Southern Ocean, a natural fertilization of the upper waters with Fe occurred by the melting of the large Pine Island Glacier (Fig. 1D). In the Amundsen Sea, the binding of dissolved Fe to organic ligands in the upper 300 m of the water column was proven to play a crucial role in sustaining the local stock of Fe for phytoplankton blooms. The dissolved organic ligands facilitated transport of Fe from the glacier to the polynya at a distance of 150-200 km from the glacier where phytoplankton blooms lasted 70 days.

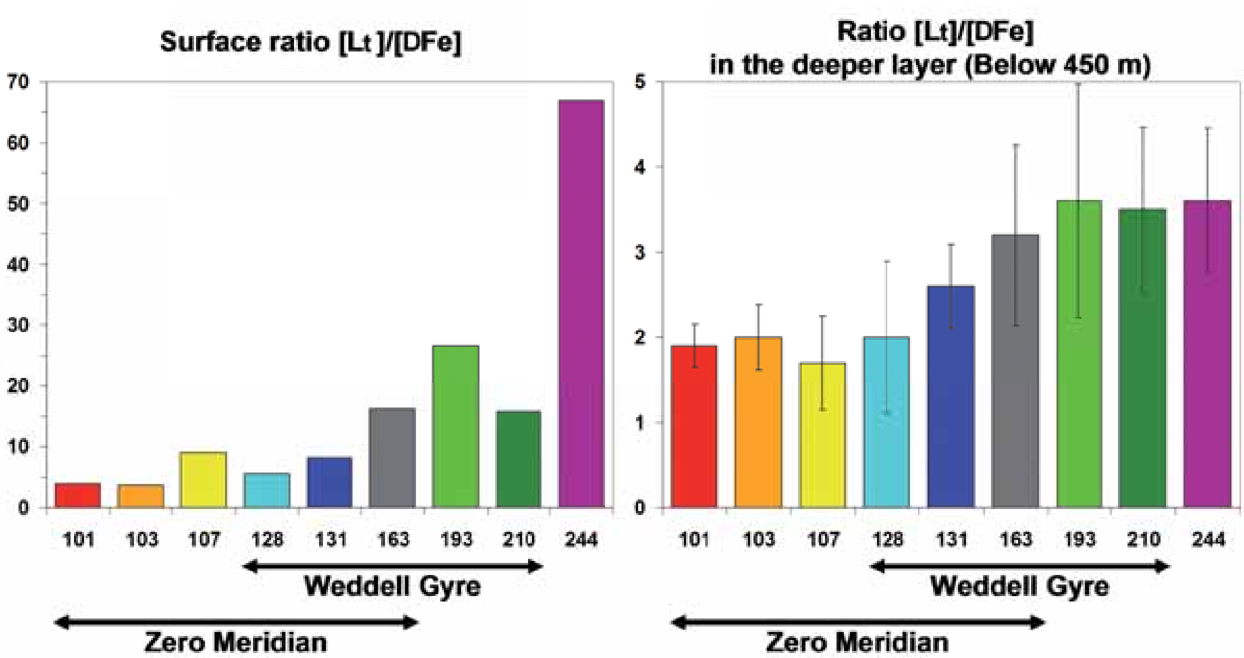

Fig. 3. The ratio of the organic ligand concentration over the dissolved Fe concentration [Lt]/[DFe] values show a trend over geographical areas in the Atlantic sector of the Southern Ocean. On the left side: surface values of [Lt]/[DFe]. On the right side: averaged values of [Lt]/[DFe] with standard deviations in the layer below 450 m depth. The numbers 101-244 correspond to stations plotted in Fig. 1B.

GEOTRACES in the International Polar Year: Dissolved iron in the Polar Oceans

Maarten Klunder, Patrick Laan, Hein de Baar*

For over two decades it has been known that dissolved iron (DFe) plays a key role in phytoplankton growth, especially in nutrient rich waters such as in the Southern Ocean. However, thus far it has been very difficult to accurately determine the extremely low dissolved Fe concentrations in ocean waters. Within the International Polar Year (2007-2008) GEOTRACES project, our study focused on high resolution sampling of dissolved iron in the Polar Oceans. Two major findings of this study are the strong input of DFe by hydrothermal vents in both the Southern Ocean and the Arctic Ocean and the fact that (Eurasian) river water is a major contributor to the relatively high DFe surface concentrations in the Central Arctic Ocean.

Ultraclean sampling during Arctic Polarstern expedition ARK XXII/2 in July-October 2007 by the "A-Team" from back to front Charles-Edouard Thuroczy, Rob Middag and Maarten Klunder.

The Arctic Ocean is linked to the global thermohaline circulation mainly through the strong contribution of Arctic Ocean waters to North Atlantic Deep Water. Due to ice cover and harsh conditions, the Arctic Ocean is one of the least studied oceans. Nevertheless, significant primary production is reported, most notably on the vast Arctic shelves. Recently, more has become known about the role of light, temperature and nutrients in primary production in the Arctic Ocean. However, little was still known about the distribution of bio-essential dissolved iron (DFe) hence the role of DFe in Arctic primary production. Within this project we report high resolution DFe concentrations in the Eastern and Central Arctic (Fig. 1 and 2). In a large part of the Arctic surface waters, DFe concentrations are relatively high (1-3 nM) compared to other ocean regions. By combining our data with $\delta^{18}O$, salinity and nutrient data we identified Eurasian river water as the main source of DFe to the Central Arctic, transported to the Central Arctic with the Transpolar Drift (TPD). Outside of the TPD and closer to the shelf, the melting of sea-ice and waters of Pacific origin, flowing over the shelf seas, are important sources (see Fig. 1). Deeper down in the water column of the Central Arctic, shelves are an important source of DFe. At the Gakkel Ridge, hydrothermal activity enriches deep waters at ~2500 m depth with DFe, which can be found everywhere in the Nansen Basin. The very low concentrations of DFe (~0.2 nM) in the remote deep waters of the Makarov Basin, in the absence of external sources, are mainly determined by the competition between organic ligand binding and adsorptive scavenging loss (see Fig. 2). Our findings indicate that DFe likely will not be a limiting factor in possible shifts in primary production in a changing Arctic and show that the waters leaving the Arctic and forming a substantial part of the North Atlantic Ocean are relatively high in DFe compared to common Atlantic waters and thus could be an DFe source to the North Atlantic.

For a vast area of the Southern Ocean, it has been shown that the major nutrients nitrogen, phosphate and silicate, cannot be fully used by phytoplankton due to a lack of trace metals, mainly iron. The

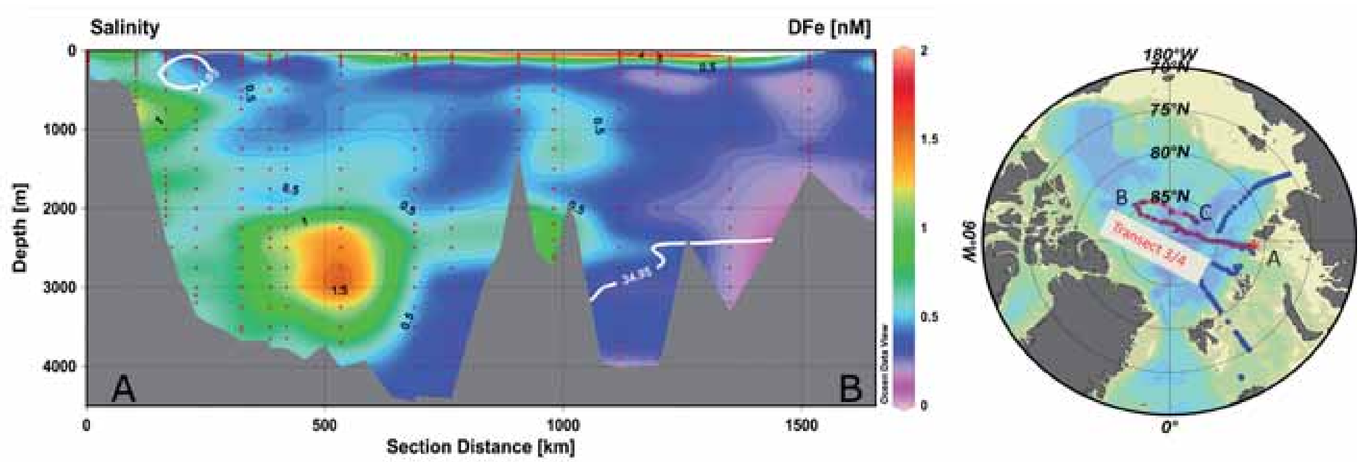

Fig. 1. Dissolved Fe (color scale and blue contours) and salinity (white contours) at the longest transect crossing the Central Arctic Ocean during ARK XXII/2 (AB).

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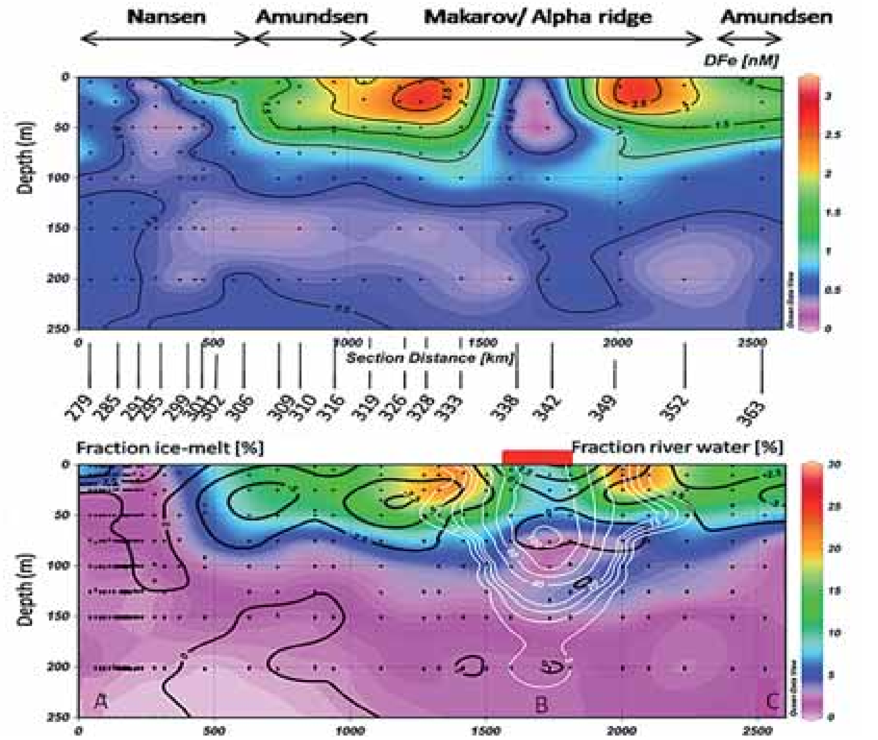
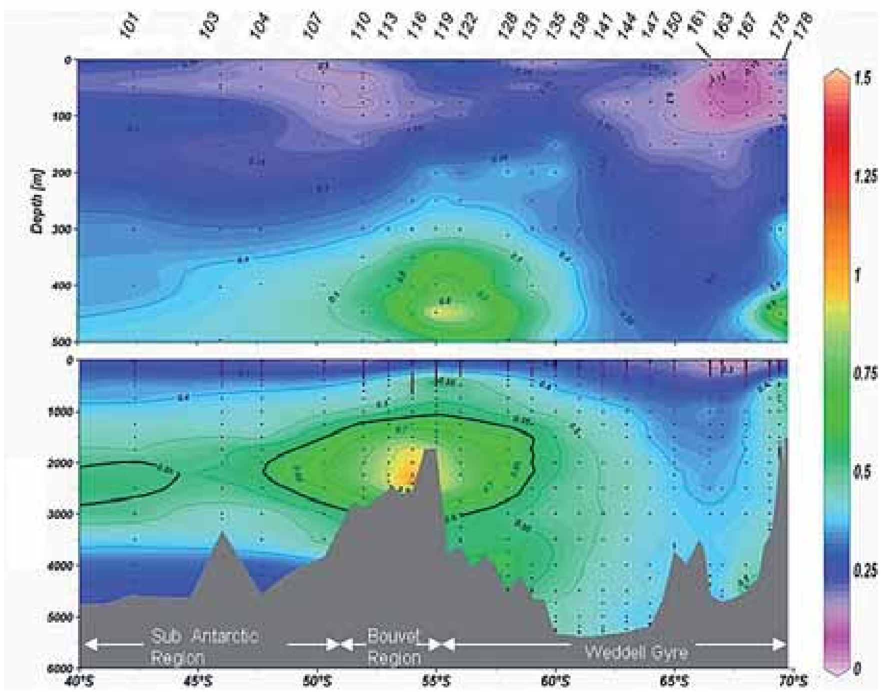


Fig. 2. This transect comprises the transect in Figure 1 but is further extended (AC) and only for the upper 250 meters. Upper graph: dissolved Fe at 20 stations numbered 279-363 along the about 2500 km long transect in the central Arctic Ocean. Lower graph: for the same stations the relevant fraction river water (color scale), fraction ice melt (black contours) and fraction Pacific water (white contours).



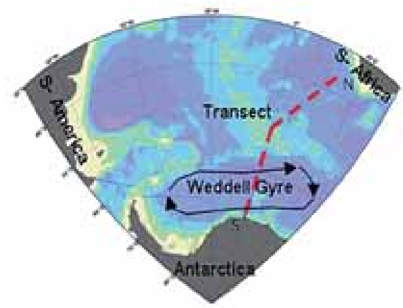


Fig. 3. Concentration of dissolved Fe in the upper water column (upper graph) and complete water column (lower graph) at the Greenwich meridian transect during Polarstern expedition ANT XXIV/3 in February-April 2008.

permanent ice sheet reduces contact between the Antarctic continent and the ocean and so limits the continental input that normally causes enrichment of surface waters with DFe. Antarctica is unique because its ice-sheet cover causes extremely low dissolved Fe around this frozen continent. Within this project, we reported 42 high resolution DFe depth profiles, yielding a good understanding of the distribution and sources of DFe. At the Greenwich meridian, the upwelling and mixing with deep waters was identified as the main Fe source to Southern Ocean surface waters. Within the Weddell Sea, the uptake by phytoplankton caused DFe to reach very low values (~0.02 nM). Wet and dry deposition of dust and melting of ice occasionally caused local DFe enrichment (see Fig. 3) in Antarctic surface waters. Also, input from the Antarctic Peninsula is an important source at both sides, i.e. into the Weddell Sea and into Drake Passage. In the deep waters of the Southern Ocean, the inflowing North Atlantic Deep Water (NADW) is a significant source of DFe. Moreover at Bouvet Ridge, the relatively high concentrations of iron and manganese indicate enrichment from hydrothermal vents. In the deep Weddell Gyre, it is found that the westward flowing limb of the gyre is significantly lower in DFe than the eastward flowing limb, where the Weddell Gyre flows close to Bouvet Ridge, causing extra Fe supply by particle resuspension from the Ridge and by hydrothermal activity. Within the IPY-GEOTRACES project, these newly obtained high resolution data give insight in the sources and sinks of DFe in the Southern Ocean surface waters, the key role of Fe as limiting factor in primary productivity and the distribution in the deep waters.

How human induced increased carbon dioxide levels affect marine phytoplankton

Astrid Hoogstraten, Klaas Timmermans, Hein de Baar*

Human induced changes in the ocean carbon chemistry are expected to influence marine primary productivity and therefore the entire marine food web, from viruses to whales. In order to study the effects of these changes, a range of different phytoplankton species was cultured under different carbon dioxide concentrations and different light intensities, mimicking past (ice age, low CO_2), present (intermediate CO_2) and future (high CO_2) conditions. The results of the experiments show that there is no uniform response of the different species to increasing CO_2 concentrations. Furthermore, the large effects of light and the combined effects of light and CO_2 show that CO_2 concentrations should not be considered as the only parameters, but that there is a need for combining different environmental parameters, such as light intensity, nutrient availability and temperature, before a clear picture can be drawn on future primary productivity.

Due to anthropogenic carbon emissions, the carbon dioxide (CO_2) concentration in the atmosphere is rising. Besides the commonly known effect of global warming, this has another major effect on the earth's marine ecosystems: Ocean Acidification, or OA. The oceans and the atmosphere are constantly exchanging gasses, such as oxygen and carbon dioxide, in order to maintain equilibrium. Due to the increasing CO_2 concentrations in the atmosphere, the presence of this gas in the ocean also increases, resulting in a lower pH of the seawater. At this time we do not completely understand what consequences these changes will have on marine phytoplankton and since these organisms are the base of the food web in the oceans, gaining knowledge is very important.

Fig. 1. Experimental culture vessel

In the scope of the European Project on Ocean Acidification (EPOCA) and Darwin project 2061, a range of different phytoplankton species was studied in order to understand the effects of the changes in carbon chemistry on these species. For these experiments, a specifically designed experimental set-up (Fig. 1), custom built by the NIOZ Marine Technology department, was used.

The phytoplankton species were cultured semi-continuously after a suitable adaptation period for each species. This resulted in stable culturing conditions, regarding the environmental parameters, such as light, $CO_{2(aq)}$ and nutrients. One of the first species that was studied in this set-up was *Proboscia alata*, a Southern Ocean diatom (Fig. 2). This species can grow up to 1 mm in length and forms long chains of cells. In the present Southern Ocean, it lives in an environment with a large natural variability in light and CO_2 conditions and the future changes will make this variability even larger. The results of the experiments showed that the different CO_2 concentrations did affect the physiology of the cells, which was mainly reflected in the morphology. Cells grown under low $CO_{2(aq)}$ conditions formed spirals, while cells grown under high $CO_{2(aq)}$ condi-

Fig. 2. A single cell of Proboscia alata.

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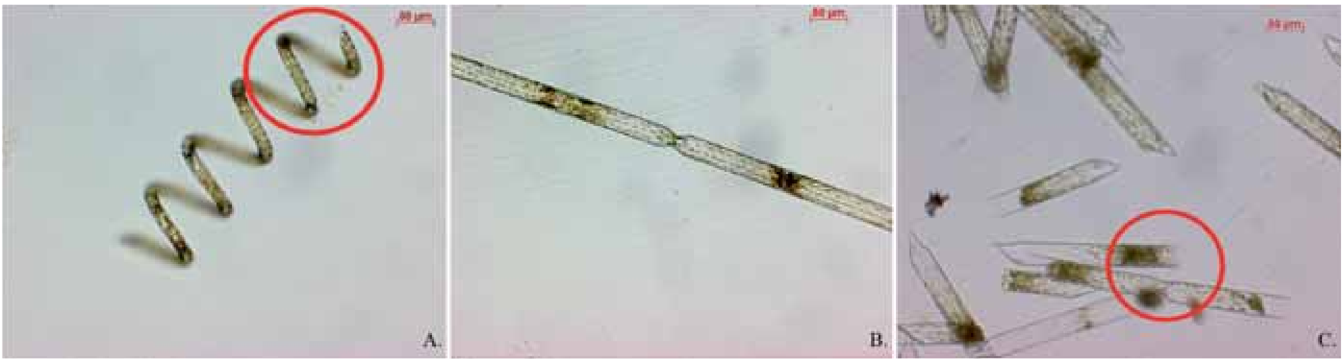

Fig. 3. The morphological changes in *Proboscia alata* in low (A), intermediate (B) and high CO_2 (C).

tions disintegrated (Fig. 3). Furthermore, light conditions co-determined the effects of $CO_{2(aq)}$ on this species in various ways, for example cellular organic carbon contents increased with increasing [$CO_{2(aq)}$] in high light conditions, while a decrease was found in low light conditions. Overall, the experiments have shown that *P. alata* is well adapted to the natural variability in both CO_2 and light, but is susceptible to future increases in $CO_{2(aq)}$ concentrations in the Southern Ocean. The morphological changes in *Proboscia alata* may affect grazing rates on this species, and its nutritional value to higher trophic levels. Furthermore, the formation of spirals at low CO_2 and the breaking of the cells at high CO_2 might affect the buoyancy of the cells and therefore the export of algal biomass to the deep ocean.

Another phytoplankton species that was studied is the temperate prymnesiophyte species *Phaeocystis globosa* (Fig. 4), infamous for its detrimental effects on shellfish and fish stocks and the foam that washes up the beaches when a bloom declines. Its effect on climate regulation is twofold. The large blooms formed by this species enhance the drawdown of inorganic carbon, countering the atmospheric increase in CO_2. Secondly, it produces dimethylsulfide which promotes the formation of clouds that help cooling the earth. The experiments with *P. globosa* showed that in high light conditions this species was growing significantly slower at high CO_2 concentrations than at low CO_2 concentrations (Fig. 5). However, at low light conditions growth rates were not affected by the CO_2 concentration, showing again that both light and CO_2 co-determine the response of phytoplankton species.

In summary, the experiments have shown that CO_2 cannot be considered as the only environmental parameter that will influence the future primary production, but that light conditions are equally or even more important. It became clear that in order to model future primary productivity, experimental work should be directed more towards a combination of environmental parameters.

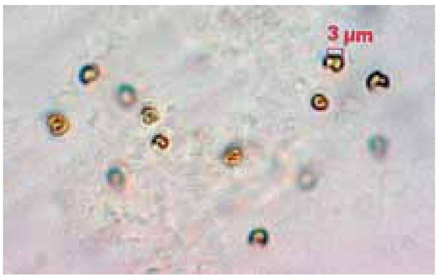

Fig. 4. Phaeocystis globosa

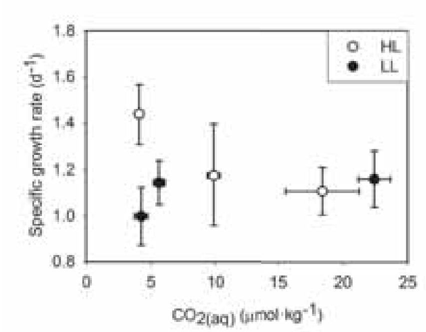

Fig. 5. The growth rate of *P. globosa* in the different treatments. HL is high light, LL is low light. Horizontal error bars denote the standard deviation of the CO_2(aq) concentration (µmol kg_{-1}), vertical error bars denote the standard deviation of the growth rate (d_{-1})

External Projects Biological Oceanography

- Antarctic phytoplankton in a changing world and its consequences for the lower pelagic food web (ANTPHIRCO, NWO Polar Program).
  C.P.D. Brussaard.
- Changes in vertical stratification and their impact on phytoplankton communities (STRATIPHYT, NWO Coastal and Marine Research ZKO).
  K. Mojica, C.P.D. Brussaard, in collaboration with NIOZ, UvA, RUG, UU-IMAU, VU-IVM.
- Comparative genomic analysis of viruses infecting *Phaeocystis globosa* and *Micromonas pusilla,* two eukaryotic microalga of global distribution (DOE-JGI, USA).
  C.P.D. Brussaard, in cooperation with University of Delaware, Newark (USA).
- Whole genome sequencing of a *Phaeocystis globosa* virus (GENOSCOPE).
  C.P.D. Brussaard, in cooperation with IGS CNRS-UPR, Marseille, France.
- Biochemical and ecological effects of resource co-limitation on key phytoplankton species (PHYTURE, NIOZ-HEIP-oio).
  D. Maat, C.P.D. Brussaard.
- Consequences of Ocean Acidification for phytoplankton production and losses (Double Trouble, Darwin Center for Biogeosciences).
  K. Crawfurd, C.P.D. Brussaard, in cooperation with Utrecht University and AWI.
- Virus Impact on Bacteria and Microalgae in Intertidal Sediments (Portugese funding).
  C. Carreira, C.P.D. Brussaard, in cooperation with University of Copenhagen.
- Influence of viruses on microbial nutrient assimilation (MPI-Bremen).
  A Sheik, C.P.D. Brussaard, in cooperation with MPI-Bremen.
- 454-sequencing of aquatic polar virus communities (IcoMM, NIOZ and UBC).
  C.P.D. Brussaard, in cooperation with University of British Columbia, Canada.
- North Sea Ballast Water Opportunity project (NSWBO-Interreg IVb – ESRF).
  L. Peperzak, J.P. Boon in cooperation with 40 partners in the North Sea region.
- Improved quantification of Southern Ocean diatoms as indicators for Carbon fixation (SRON).
  L. Peperzak, K. Timmermans, in cooperation with VU-Amsterdam.
- Multi-scale modelling of calcification in scleractinian corals, (MultiCalc, NWO).
  J.D.L. van Bleijswijk, in cooperation with Universiteit van Amsterdam.
- Modelling the causes and consequences of environmental change (NIOZ and CEFAS).
  P. Ruardij, in cooperation with CEFAS.
- Wadden Sea ecosystem data assimilation and integrated modelling (NWO-ZKO).
  J. Nauw (FYS), P. Ruardij, T. Gerkema (FYS), in cooperation with IMARES, NIOO.
- Factors controlling carbonate production and destruction of cold-water coral reefs in the E Atlantic Ocean.
  M. Carreiro-Silva, F.C. van Duyl, R.S. Santos (Marie Curie Fellowship EU, FRH-FCT Portugal)
- Future of reefs in a changing environment: an ecosystem approach to managing Caribbean Coral reefs in the face of climate change (FORCE).
  F.C. van Duyl, B. Mueller (EU-ENV).
- Chemoautotrophy and trophic translocations in cold water coral reef sponges. FP7 "Capacities" Specific Programme, ASSEMBLE grant agreement 227799.
  F.C. van Duyl
- Saba Bank Expedition October 2011, WWF grant.
  PI: E.H. Meesters (IMARES). F.C. van Duyl in cooperation with LVV, STENAPA, SABA Marine Park, Bonaire Marine Park, St Maarten Marine Park.
- Primary Production in the North Sea: Changes in Resource Limitation and Energy Transfer (CHARLET,NWO-ZKO).
  P. O'Connor, C. Brussaard, in cooperation with NIOO-KNAW and UvA-IBED.
- Global Change and Microbial Oceanography in the West Atlantic Ocean (GEOTRACES, NWO/ZKO – NSF(US)).
  R. Middag, H. de Baar, K. Bruland (UCSC), L. Gerringa, M. Rijkenberg, V . Schoemann, P. Laan, J. de Jong, G. Smith (UCSC), in collaboration with the University of California Santa Cruz, USA.
- Improved quantification of Southern Ocean diatoms as indicators for Carbon fixation (SRON).
  L. Peperzak, K. Timmermans in cooperation with Vrije Universiteit Amsterdam.
- European Project on OCean Acidification (EPOCA, EU-FP7).
  A. Hoogstraten, H.J.W. de Baar, C.P.D. Brussaard.

- Viral impact on microbes in coastal waters of the Antarctic Peninsula and its ecological implications (VIRANT, NWO Dutch polar programme).
  A. Hoogstraten, L. Peperzak, C. Evans, C.P.D. Brussaard, *in cooperation with the British Antarctic Survey (UK).*
- Microbial carbon fixation in past and future high CO_2 oceans (DARWIN).
  H.J.W. de Baar, K.R. Timmermans, A. Hoogstraten.
- CO_2 Buffering capacity of the North Sea (NWO/ALW).
  H.J.W. de Baar, L. Salt.
- GEOTRACES, Global Change & Microbial Oceanography in the West Atlantic Ocean (NWO/ZKO).
  H.J.W. de Baar, G. Herndl (University of Vienna), H.A.J. Meijer (Groningen University).
- Support of seasonal sea-ice ecosystems by essential trace nutrient elements iron and manganese (NWO/ALW).
  H.J.W. de Baar, V. Schoemann.
- GEOTRACES Netherlands-USA Joint Effort on Trace Metals in Atlantic Ocean (NWO/ALW).
  H.J.W. de Baar, K. Bruland (University of California Santa Cruz), R. Middag.
- Dynamics of acidification in the North Sea: documentation and attribution (NWO/ZKO).
  H.J.W. de Baar, N. Clargo, J. Middelburg (Utrecht University), F. Meysman (NIOO/CEME).
- Carbochange (European Union Framework Program 7).
  H.J.W. de Baar.

Marine Ecology

The Department of Marine Ecology has a focus on the functioning of intertidal, coastal zone, shelf and open ocean ecosystems. We aim for a mechanistic understanding of the structure and dynamic behaviour of marine populations and communities varying from plankton, benthos, fish and birds to marine mammals. Taking up one of the great challenges in modern ecology, we try to understand the properties of populations and communities on the basis of characteristics of individual organisms. We address both the role of bottom-up (food input, competition for food and other resources) and of top-down (predation) processes. Within the department three research clusters exist: [1] Intertidal systems; [2] Benthic continental shelf and open ocean systems, and [3] Global shorebird migrations and comparative mudflat ecology.

The Intertidal system cluster focuses on the population structure and dynamics of intertidal macrozoobenthos, with an emphasis on factors regulating recruitment. Knowledge of birth, death and migration rates, as a result of morphological (e.g., size), physiological (e.g., energy reserves, parasitism) and behavioural (e.g., susceptibility to interference) characteristics of the constituent individuals are linked to changes in the environment. Studies vary from trophic interactions to eco-physiological laboratory experiments, on energy allocation population genetics and community/food web dynamics.
The Benthic continental shelf and open ocean system cluster studies subtidal benthic communities in the Dutch coastal zone, North Sea, and open ocean. High resolution observations are obtained by state-of-the-art landers, allowing long term deployments of benthic observatory (video cameras) and autonomic samplers and sediment traps. In addition to benthic sampling, methods comprise in-situ video observations, analysis of stable isotopes and fatty acids of organisms. Long-term sediment trap moorings are used to compare and quantify particle supply and sources.
The Global shorebird migrations and comparative mudflat ecology cluster aims to mechanistically and evolutionarily understand the distribution and abundance of coastal predators, in particular shorebirds. Of focal interest are migrant shorebirds that depend on multiple coastal sites during the course of the year. This warrants work at many different levels, including (1) a solid description of the food conditions for birds over large spatial scales (the level of entire coastal systems up to worldwide comparisons), (2) understanding the details of food selection, (3) the role of predation by shorebirds on intertidal foodweb functioning, and (4) examining mechanisms of adaptive body composition (the flexible phenotype) that reflect the functioning of organisms in their natural environment. The group has a tradition in using state-of-the-art telemetry techniques, and in a strong embedding of field and experimental observations in ecological theory.
These research clusters are strongly linked which is reflected by their process-oriented approach, their cooperation (joint projects), the exchange of results and data, and the joint deployments and use of finances, facilities and assistants. The department of Marine Ecology contributes to all five multidisciplinary research themes of the Royal NIOZ Science Plan 2008-2012, but especially to theme 3: Wadden and Shelf seas. The Department of Marine Ecology aims to be the national and one of the international leading centres of knowledge with respect to intertidal and coastal zone ecosystem functioning and tries to achieve this by combining its research with and embedded it in long-term monitoring programmes on phytoplankton, macrozoobenthos, fish and birds.

In 2011 the department was again successful in the open competition at both the national and the international level. Worth mentioning are the INFOWEB project coordinated by Katja (C.) J.M. Philippart and Henk W. van der Veer and the prestigious TOP grant obtained by Theunis Piersma. The INFOWEB project aims to set up a food web model by ecological network analysis (ENA) for a Southern Wadden Sea ecosystem, the Balgzand area. This study is part of a project in the frame of the bilateral Dutch-German BMBF/NWO cooperation on the impact of biological invasions on the food web of the Wadden Sea. The topic of the TOP grant is Shorebirds in Space, whereby the focus is on development and application of third generation tracking tools tailored for small wading birds. Extending the resolution of previous findings by including all relevant temporal and spatial scales, the project will facilitate breakthroughs in the emerging fields of ecological demography and spatial and cognitive ecology.

This year Vania Freitas (Climate-induced changes in estuarine predator-prey systems: a DEB approach) and Jutta Leyer (Being at the right place at the right time: interpreting the annual life cycle of Afro-Siberian red knots) defended their PhD theses.

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Spatial patterns of the peppery furrow shell *Scrobicularia plana* (Bivalvia) along its distributional range

Sílvia Santos, Pieternella C. Luttikhuizen, Henk W. van der Veer*

Along the NE Atlantic coast, the peppery furrow shell *Scrobicularia plana* is one of the most common and abundant bivalve species in soft-sediment intertidal areas. Despite its abundance relatively little is known about the processes responsible for the species' population structure and pattern. In this study, we analyzed spatial patterns of population distribution, dynamics and genetic variation of *S. plana*. Our results show that spatial patterns are site-specific and mainly determined by local environmental factors which suggests a high sensitivity of the species to local habitat conditions. In the future, the effects may be even more marked as population differentiation and isolation are expected to increase over time leading to more locally adapted popultions.

The bivalve *Scrobicularia plana* (Fig. 1) is a key species of shallow water benthic communities and economically valuable in several countries. The species is distributed along the Atlantic coast, from the Norwegian Sea to Senegal, and also in the Mediterranean Sea with a wide latitudinal distribution usually being indicative of a high physiological tolerance and a good adaptive potential of the species. Nevertheless, a high sensitivity to local factors is suggested by *S. plana*'s patchy spatial distribution at a local scale. The study of patterns of spatial distributions and population dynamics of *S. plana* should help us better understand the different scales of variation and which processes operate at each scale, essential for determining how the species will respond to increasing environmental risks.

Broad scale distribution patterns and population history

Broad scale distribution and population history were determined for *S. plana* using two different approaches. First, the growth and reproduction patterns were analyzed for three populations in Portugal, The Netherlands and Norway to determine the processes responsible for the large scale patterns of this species. The seasonal variation in somatic and gonadal mass was different between the three populations (Fig. 2), and was attributed to differences in temperature and food availability. The relation between the species' physiological performance and large scale environmental factors suggests that future climate changes will likely result in a shift of *S. plana*'s distribution towards the north which would negatively affect its commercialization in southern countries. The second approach was to identify geographical patterns of genetic differentiation across the species' range, based on variation in a DNA fragment of the mitochondrial genome - a portion of the

Fig. 1. The bivalve *Scrobicularia plana*.

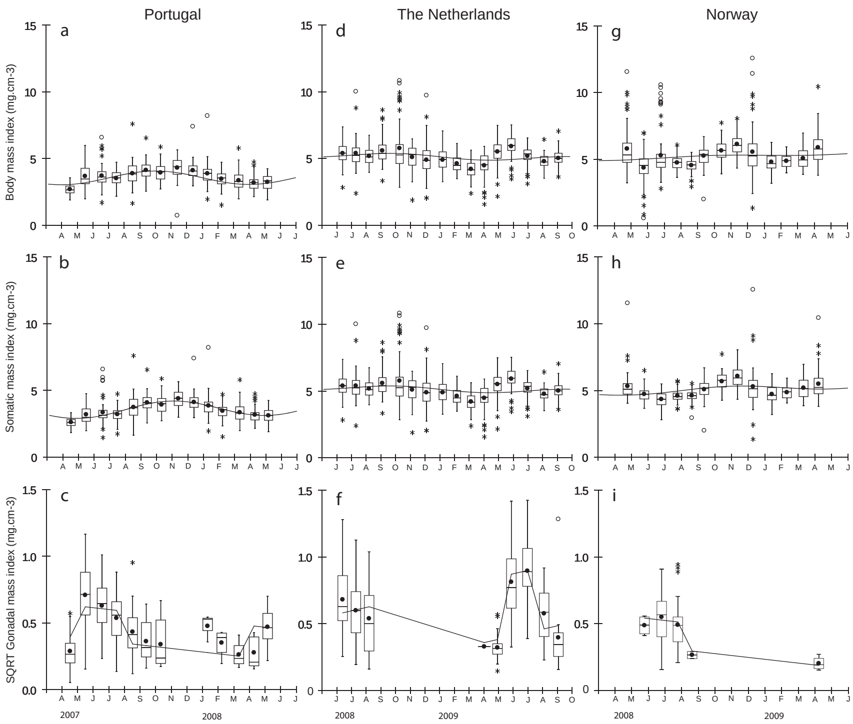

Fig. 2. Body mass index (mg.cm^{-3}), somatic mass index (mg.cm^{-3}) and gonadal mass index (mg.cm^{-3}) of *Scrobicularia plana* along the year, for three sampling locations. Gonadal mass index values are square root transformed. Curves and lines are model (β_1*Month + β_2* Season) predictions. Full dots and horizontal bars indicate mean and median values, respectively; boxes represent range within which the central 50% of values fall; bars correspond to data range excluding outliers; outliers and extreme values are, respectively, observations more than 1.5 and 3 times the box range and are represented by asterisks and open circles.

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cytochrome oxidase I gene, since by determining how differences in climatic conditions shaped the geographical distribution of a species we can get insight into how the species may respond to future climate change. Despite the suggestion that, in the present settings, *S. plana* is quite adaptive, results suggest a recent expansion (Fig. 3) which combined with low connectivity between populations will likely lead to increased population differentiation and isolation over time, ultimately decreasing the ability of populations to adapt to environmental changes.

Habitat-scale distribution

The spatial distribution patterns of *S. plana* were also determined at the habitat scale for four intertidal areas: Minho (Portugal), Westerschelde and the Wadden Sea (The Netherlands) and Trondheim (Norway, Fig. 4). While the individuals from the Norwegian population were randomly distributed, the populations of Portugal and the two populations from The Netherlands showed an aggregated (or patchy) pattern. For The Netherlands, patch size varied between locations. A significant correlation between the observed spatial patterns and sediment composition, namely grain size and/or percentage of silt, was found for The Netherlands and Norway suggesting that sediment type is an important factor influencing the species distribution pattern. The differences between patterns and the correlation found with sediment composition allows us to conclude that *Scrobicularia plana's* spatial patterns are specific to the site rather than the species and mainly determined by local factors. This suggests a high sensitivity of the species to local factors which may hamper the recovery of populations in case of e.g. overexploitation. Individuals may be too locally adapted to recolonize other areas or to survive rapid shifts in local conditions, which may lead to the extinction of the locally adapted population. In contrast, however, the high genetic diversity and large population sizes observed for *S. plana* could be interpreted as an indication of high adaptive potential of the species, allowing populations to recover from disturbance, although some recent studies suggested a weak correlation between genetic diversity and population fitness.

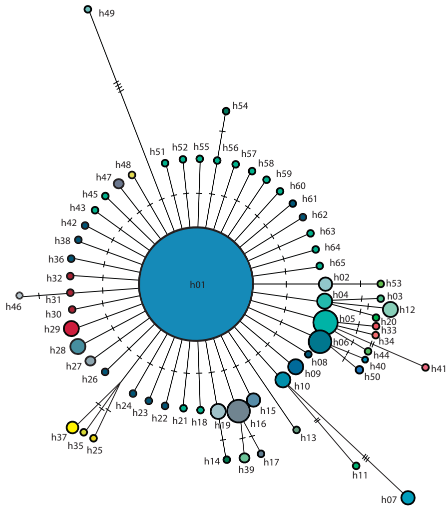

Fig. 3. Minimum spanning network reveals the genetic variation in *Scrobicularia plana* as well as the relationship between genetic types, as measured by mitochondrial DNA fragments. Each circle represents a different genetic type while the size of the circle is proportional to its frequency; dashes indicate the amount of genetic difference. Three groups are represented by different colors: Trondheim (yellow), Atlantic (blue/green) and Pisa (red). The star shape of the network (i.e., dominated by a single, high frequency, genetic type and many peripheral ones with low genetic difference) is indicative of recent population expansion.

Conclusion

While broad scale distribution patterns are shaped by temperature and food availability, at a more local scale sediment composition has an important role determining spatial patterns. As a consequence, changes in local conditions may lead to changes in densities and even extinction of local populations. This idea is strengthened by the observed low genetic exchange between populations which is expected to lead to increased population differentiation and isolation, reducing the ability for local populations to adapt to environmental changes. The expected changes not only will have ecological effects at the population, community and ecosystem levels but it may also affect the commercial importance of the species in southern European countries.

Fig. 4. Digging for *Scrobicularia plana*.

The total biomass of macrofauna relative to algal food resources across the entire Dutch Wadden Sea: the SIBES programme

Tanya J. Compton, Sander Holthuijsen, Daphne van der Wal, Anne Dekinga, Anita Koolhaas, Job ten Horn, Jeremy Smith, Maarten Brugge, Geert Aarts, Henk van der Veer, Jaap van der Meer, Theunis Piersma*

The Wadden Sea, recognised as Europe's largest wetland of international importance, is crucial for the provision of numerous economic and ecological services. To understand if current anthropogenic factors could influence these services we need to continuously monitor the benthic organisms for change. Since 2008 a "synoptic intertidal benthic sampling" (SIBES) programme has been implemented across the entire Dutch Wadden Sea (2483 km^2, ~4500 sampling stations) to examine the distribution of worm, crustacean and bivalve species with respect to environment and human factors. Here, we show on-going work to describe the spatial patterns of benthic organisms across the Dutch Wadden Sea.

Fig. 1. Samples being taken by rubber boat on the Wadden Sea.

Covering an area of almost ten thousand square kilometres and stretching from The Netherlands to Denmark, the Wadden Sea is Europe's largest Wetland of international importance. The Wadden Sea is important for the economic and ecological services it provides to the adjacent European Nations. Economic services include fisheries, and ecological services include essential habitat to migratory shorebirds who use this area to fuel-up prior to flying to the Arctic. Under the the convention of wetlands (Ramsar) the goal is "the conservation and wise use of all wetlands through local and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world"(www.ramsar.org).
The Dutch Wadden Sea forms a big part of this dynamic tidal system (2483 of the 9684 km^2). But due to human or other circumstances the Dutch Wadden Sea has undergone extensive changes over the course of the last century, e.g. the loss of seagrass beds due to a disease in 1932. In addition, there have also been changes due to human impacts, like the loss of tidal flat area after the closing of the Afsluitdijk in 1932. However, it is difficult to detect change in a system without monitoring both before and after an

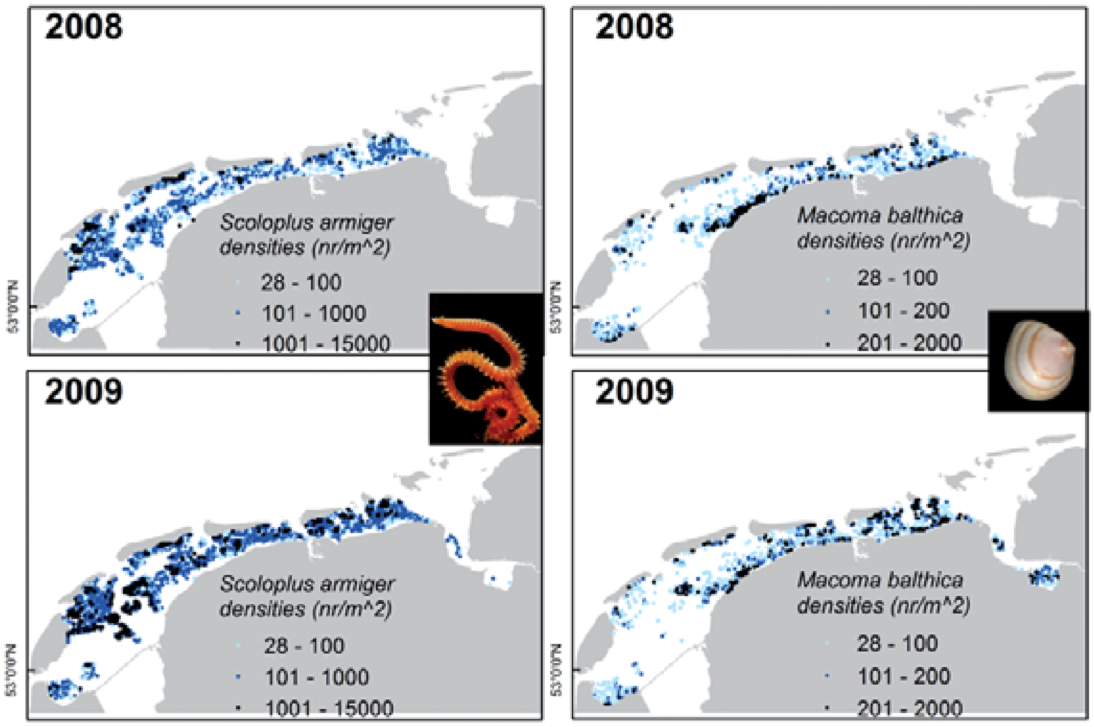

Fig. 2. Distribution of *Scoloplos armiger* and *Macoma balthica* in 2008 and 2009.

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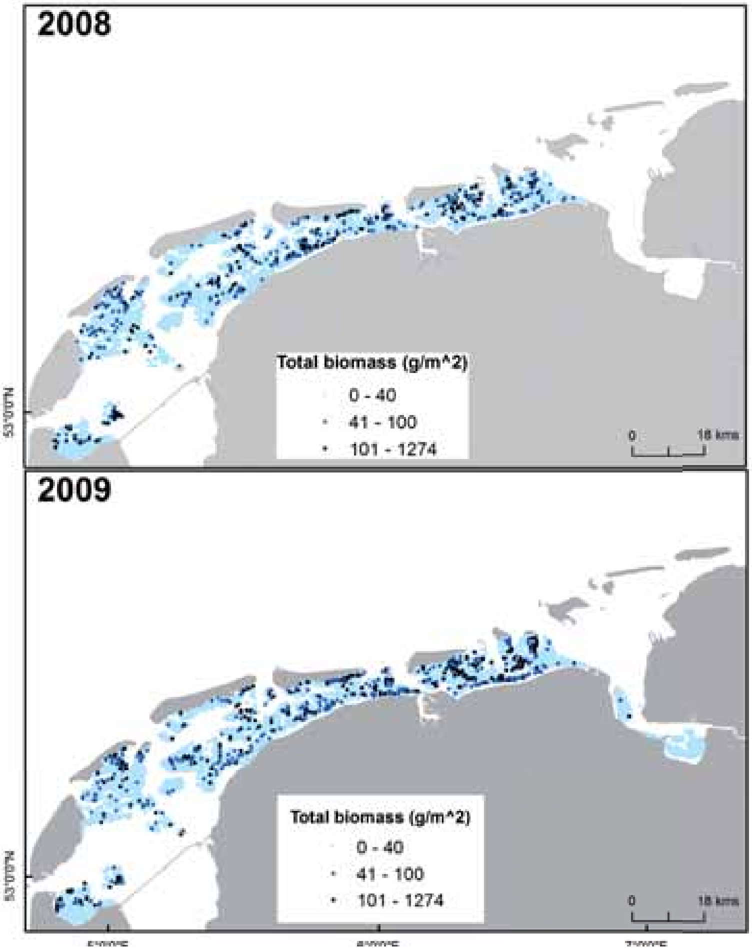

Fig. 3. The total biomass per sample point (grams/m^2) across the Dutch Wadden Sea in 2008 and 2009.

impact. In benthic sedimentary systems, the organisms living in the mud can quickly respond to change and thus provide the "canary in the coal mine". But sampling needs to be conducted across large enough spatial and temporal scales to tease apart the human from environmental effects.

Setting up such an extensive synoptic benthic sampling programme became possible a few years ago when simultaneously the ZKO Wadden Sea programme in the western Wadden Sea and ecological monitoring of the gas drilling in the eastern Wadden Sea by the NAM started. By combining these programmes a synoptic mapping across the entire Dutch Wadden Sea could be implemented from 2008 onwards. The programme aims to sample the entire intertidal area of the Dutch Wadden Sea: a "synoptic intertidal benthic sampling" (SIBES) programme. Each summer, from June to October, a team of 8 scientists and many volunteers go out with NIOZ's Navicula to take benthic samples. Since 2008, marine benthos have been sampled across an area of 1200 km^2 or 4500 sample points; between the Marsdiep and the Ems-Dollard.

Using a geographical positioning system the SIBES team then arrive at the specific grid points either by foot or via a small rubber dinghy (Fig. 1). At each point a benthic sample is sieved and a sediment core is taken.

The ~4500 samples are then taken back to NIOZ where a team of experts identify and measure the various worms, crustaceans and bivalve species encountered during the sampling.

Here, results are presented from the sampling of 3956 points in 2008 and 4422 points in 2009. In 2009 additional points were added to the sampling grid in the areas of the Ems-Dollard and also around Ameland.

In total approximately 94 species were sampled across the SIBES sampling area in 2008 and 2009. In both years, the most commonly found species across the entire sampling area were the bristleworm *Scoloplos armiger*, the ragworm *Hediste diversicolor*, and the Baltic tellin *Macoma balthica*. The distribution of two of these species, *Scoloplos armiger* and *Macoma balthica,* show different habitat associations, such that *Macoma balthica* is mainly found in the areas along the coast, where sediments are muddy, whereas *Scoloplos armiger* occurs broadly across the tidal flat areas where sediments are more sandy (Fig. 2).

In terms of biomass, five species were the most important: the common cockle *Cerastoderma edule*, the soft shell clam *Mya arenaria*, the razor shell *Ensis directus*, the mussel *Mytilus edulis* and a tubeworm, the sand mason *Lanice conchilega* A map of total biomass per m^2 shows that areas of highest biomass were located predominantly in the vicinity of Schiermonnikoog and Ameland and along the Frisian mainland (Fig. 3). Interestingly, areas with highest total biomass (Fig. 3) were associated with areas identified as having high benthic primary productivity. Benthic primary productivity was estimated from satellite imagery in 2009 (Normalised Differential Vegetation Index based on surface reflectance in the red and near-infrared, Fig. 4). The areas of highest productivity are especially high along the Frisian coast line and between Schiermonnikoog and the mainland. The total benthic biomass (Fig. 3) is also relatively highest along the Frisian coast and in between Schiermonnikoog and the mainland. Future work will aim to untangle the relationships between the macrobenthos and their physical environment, including information from satellite imagery, sediment characteristics and tidal exposure times.

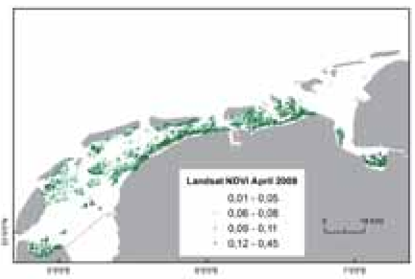

Fig. 4. Spatial distribution of microphytobenthos biomass, as determined using satellite imagery (Normalised Differential Vegetation Index, NDVI) from April 2009.

Climate change and European Marine Ecosystem Research (CLAMER)

Katja Philippart, Carlo Heip and Thalia Watmough*

In recent years a vast amount of European research has been directed at marine climate change issues. Summarizing this information was central to the CLAMER project, funded under the European Commission's Framework Programme 7, 01/04/2010-30/09/2011. In addition, the project aimed to find out how much the general public know about these issues. Last but not least, CLAMER strived to stimulate efforts to bridge the gap between scientific knowledge and that of the general public on the impacts of climate change on the marine environment.

As part of the CLAMER project, marine scientists drawn from a broad range of disciplines provided a summary overview of recent research on climate change impacts on the marine environment (with a particular focus on EU-funded research) and identified key scientific gaps and priorities for future research. The resulting CLAMER Synthesis Report (Heip et al; 2011; www.clamer.eu) brings together, in a consistent format, the analyses and recommendations of these experts according to thematic and regional categories. It illustrates beyond reasonable doubt that climate change has already impacted on all of the oceans and seas of Europe and beyond. It also identifies the clear variation in type and extent of impacts which can be found across Europe's regional seas.

Changes discussed in the Synthesis Report, and considered to be predominantly a consequence of climate change, include:

- Physical changes in the seas and oceans (e.g. sea-level rise, sea temperature increase and stratification);
- Melting of Arctic sea-ice and associated impacts (e.g. changes in the Arctic foodweb and trans-Arctic migrations);
- Changes in abundance and distribution of marine organisms (e.g. cod, haddock and herring which have extended northward and eastward at high latitudes);
- Shifts in seasonal migration patterns of marine species (e.g. shift from seasonal migration for spawning and feeding to overwintering of fishes such as dorado in a warming Black Sea);

Fig. 1. Word cloud of the results to the open-ended question 'Which three things, if any, come to mind when you think about the impacts of climate change on the coastline or sea?' [Source: Q7 of the CLAMER poll; Sample = all 10 countries combined; n = 10,106 respondents] (Buckley et al., 2011; www.clamer.eu).

Fig. 2. Illustration of the coastline of Belgium from the harbour of Zeebrugge looking south towards the Iberian Peninsula, with a sea level rise of 1m if the coastal protection were to fail (CLAMER booklet; © Glynn Gorick).

- Cumulative effects of multiple stressors (e.g. impacts arising from, or compounded by, a combination of climate change, ocean acidification, hypoxia, fisheries and eutrophication);
- Socio-economic consequences of all of these changes (e.g. impacts on commercial fisheries and tourism, coastal inundation and erosion, etc.).

In order to assess public knowledge on the impacts of climate change on the marine environment, CLAMER conducted a poll across 10 European nations, including questions like "Which three things, if any, come to mind when you think about the impacts of climate change on the

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Fig. 3. Carlo Heip and Katja Philippart (project coordinators) open the CLAMER Symposium "Living with a Warming Ocean", 14-15 September 2011 at Brussels (photo: Vivian Hertz Photography).

coastline or sea?" (Fig.1). The results show that public estimates for rates of sea level rise and temperature change match well with scientific consensus, suggesting the European public are aware of some of the fundamental messages. However, there was relatively low awareness about oceans becoming more acidic, despite ocean acidification being a major EU research theme. This may be due to the fact that ocean acidification is less 'visible' than for example sea level rise (Fig. 2), and doubts as to whether and how ocean acidification will impact people's daily lives.

Limited public awareness may also be the result of a lack of communication effort from the people that are in the know. According to the CLAMER Outreach Evaluation Report, most of the 64 EU research projects examined engaged in some sort of public outreach activity. However, this did not usually extend beyond one-way imparting of knowledge through project websites, brochures, scientific papers or conferences. This is contrary to the key message of several sociological and communication studies reviewed by the CLAMER literature review (Terry & Chilvers, 2011; www.clamer.eu), which is that scientific information about marine climate change needs to be presented in such a way as to *create engagement*, rather than merely to 'increase public knowledge'. Future projects should acknowledge the diversity among the public and be sensitive to how the public understand and engage with marine climate change issues. CLAMER itself has attempted to reach a wide range of audiences via interactive events at aquaria throughout Europe, the CLAMER film 'Living with a Warming Ocean', the CLAMER booklet and policy briefing fact sheets. The project closed with a symposium where the results were presented and discussed (Fig. 3). Speakers included representatives from directorates of the European Commission and the International Panel on Climate Change (Fig. 4). The main conclusion of the symposium was that despite an

Fig. 4. Prof. Dr Jean-Pascal van Ypersele (vice-chair IPCC) shares his latest insights on the impacts of global climate change during the CLAMER Symposium "Living with a Warming Ocean", 14-15 September 2011 in Brussels (photo: Vivian Hertz Photography).

EU-funding contribution towards relevant projects totaling over 300 million euro since 1998, major gaps in marine climate change research still exist. In order to formulate better adaptive strategies to address the consequences of climate change, it was considered essential to improve methods to reduce the uncertainty of climate change projections, to ensure the accuracy of measurements and predictions by means of an integrated monitoring and observation network, and to further improve the exchange of knowledge within the scientific community and between scientists, policy makers and the public at large. All CLAMER reports and outreach material can be downloaded from www.clamer.eu.

Monitoring the coastal zone and its fauna off Egmond aan zee: effects of beach nourishment on turbidity and bivalves

Rob Witbaard, Gerard Duineveld, Magda Bergman*

Continuing efforts to protect the Dutch coastline from erosion require large amounts of sand to be annually supplied onto the coastline (2012-16: ~ 32 million m^3). Since 1997 sand is not only deposited on the beach but also underwater on the shoreface. Meanwhile, a large portion of coastal zone has been designated as a special area of conservation in the framework of national and international agreements (e.g. NATURA 2000). This because of its ecological value for birds, sea mammals and juvenile fish. The government requested from the parties who are responsible for the beach nourishments research. Our group is now involved to study the ecological effects of their activities.

In this part of the coastal zone bivalves are particularly abundant and form a basic food source for overwintering birds such as diving ducks. In the 1990's, the most important coastal bivalve was *Spisula subtruncata* which occurred in dense beds. These dense *Spisula* beds have nowadays been replaced by the introduced American razor clam, *Ensis directus*, now used as food source by both birds and fish. Over a relatively short period *Ensis* has become dominant in the coastal zone and as a consequence of this invasion the bivalve biomass in the coastal zone has doubled over the past 15 years. Current estimates of *Ensis* biomass amount to 892 million kilogram fresh weight (Goudswaard et al, 2008). This figure might well be an underestimate since the shallow exposed shoreface from where high *Ensis* numbers have been reported, is undersampled. Ships suited to handle deep digging heavy gear such as boxcorers can not operate in this shoreface zone because of its shallowness. Such heavy and deep digging gear is however needed to sample this species quantitatively.

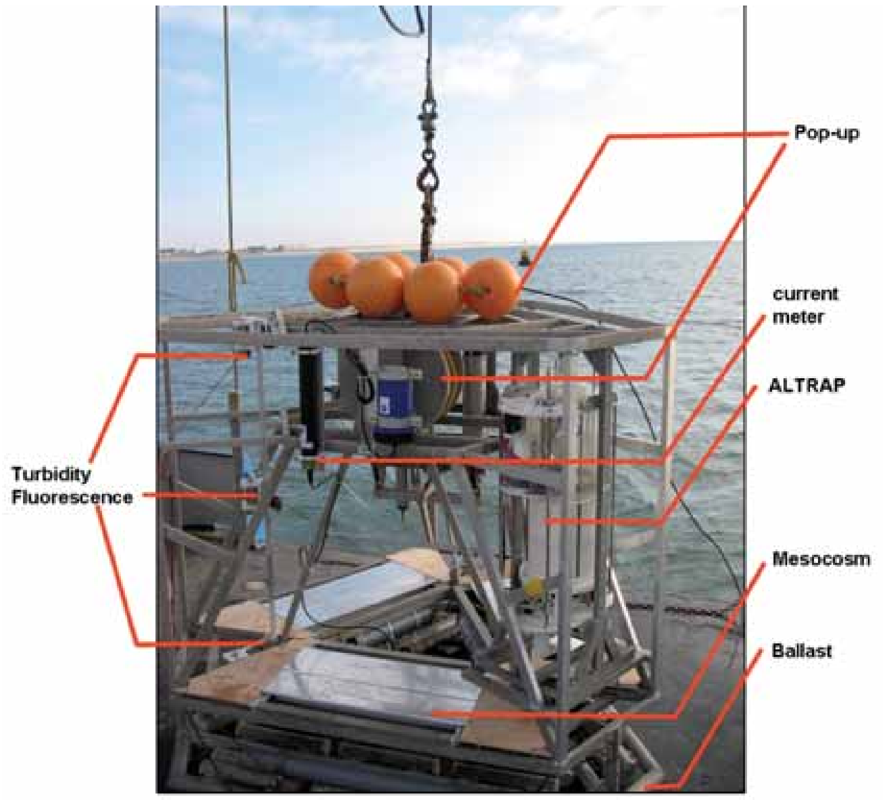

Fig. 1. Overview of one of the lander frames used in the environmental monitoring off the coast of Egmond in 2011.

Spisula subtruncata

Because of potential conflicts between the conservation of natural resources and the shape and protective function of the Dutch coast, a research program was initiated by RWS (Rijkswaterstaat) and LaMER (Stichting van Nederlandse waterbouwers). Part of this research aims to assess the impact of suspended mud released with sand deposition on the ecology of the near coastal zone and especially on *Ensis directus*. The effects of increased suspended sediment loads due to beach nourishments on bivalves inhabiting the Dutch coastal zone are unknown. No one knows whether the effects of beach nourishments are significant when compared to effects caused by variations in the natural concentrations of silt and mud. Studies on various bivalve species other then *Ensis* have shown that high concentrations of suspended silt and clay particles obstruct feeding and lead to reduced growth. Such effects may also exist for *Ensis directus.* This then might have large consequences for their productivity and affect higher trophic levels of this nearshore zone. Such potential negative effects are

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seen as an unwanted development in view of the assignment of the coastal zone as a marine protected area.

It is evident that the coastal area is subject to naturally high mud concentrations belonging to the murky 'coastal river' flowing northward along our coast. Despite numerous studies dealing with this 'coastal river', estimates of mud concentrations close to the coast and just above the seabed where *E. directus* collects its food by filtering large volumes of water, are extremely sparse. Hence, along with a study on effects of mud released by dredging vessels in the field, we monitored natural (background) concentrations of mud and the associated feeding behavior by *E. directus* during a one year campaign off Egmond aan Zee. This location was selected because of a planned shoreface nourishment in the summer of 2011.

In February 2011 we deployed bottom lander for the above monitoring project at 10m depth off Egmond (Fig. 1). The lander was equipped with a suite of sensors including several to record turbidity & fluorescence at different heights above the seabed, a Temperature and salinity logger, and various types' current meters. The in-situ feeding behavior of *Ensis directus* was measured simultaneously on eight individuals who were all attached to a valve gape monitor. The monitor measures the width of the opening between the valves (gape) by means of an electro magnetic induction and as such gives information about the behavior of each individual separately (Fig. 2). In order to link the conditions measured off Egmond with growth and abundance of the local *E. directus* stock, lengths, weights and condition of *E. directus* were measured at regular intervals. Additionally, a survey of the *E. directus* distribution in the wider coastal zone was made in early summer 2011. Preliminary results of the 2011 survey show that *E. directus* is a typical nearshore species with highest densities (300 m^{-2}) very close to the coast. Sediment inhabited by large numbers of *E. directus* is typically enriched in organic content and fine particles, probably through bioturbation activity of the bivalve. The bottom lander measurements revealed that mud concentrations in the lowest 0.5 m above the seabed were almost tenfold higher than at 2 m above the bottom, indicative of a mud blanket over the seabed. During stormy periods measured mud concentrations directly above the seabed reached maxima of 4000 mg l^{-1}. Winter measurements show that during severe storms large amounts of mud and attached chlorophyll are released into the water column (Fig. 3.). This is most likely material which has been buried in preceding summer months and released from the sediments

Fig. 2. Placement of sediment cores with live Ensis connected to a valve monitor in one of the trays which are mounted on the lander.

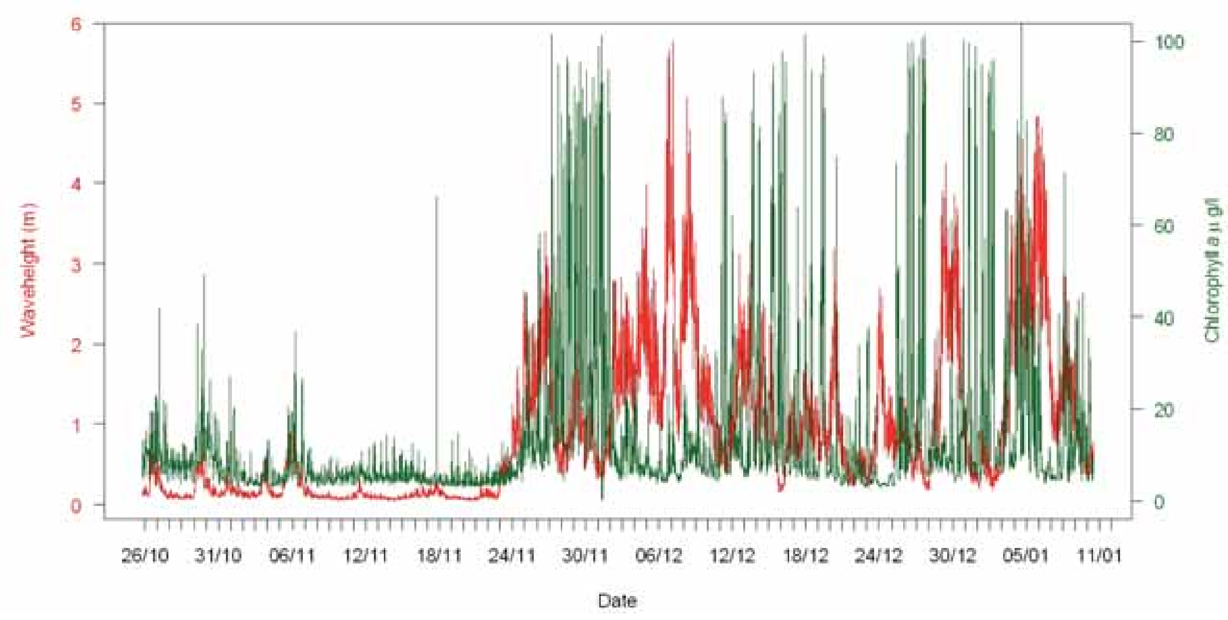

Fig. 3. A record of measured wave height and chlorophyll concentration at 30 cm above the seafloor off the coast of Egmond at 11 meter water depth. Wave events cause an increase in average chlorophyll contents of the near bottom water layer. Especially shortly after the first severe winter storm at the end of November with windspeeds of up to 80km/hr and waveheights up to 3 meter.

due to wave and current action.
Comparison between the records of valve gape and the records of environmental conditions, show that E*. directus* tends to close it valves when the mud concentration increases. This suggests that feeding is hampered when mud concentration increases beyond a certain level despite a co-increasing amount of chlorophyll.

Above findings shed new light on the abiotic environment in the nearshore zone and its potential for filter-feeding animals. Notably, the high near-bed mud concentrations and coupling with chlorophyll were unexpected. The high population density of *Ensis directus* along large parts of the Dutch coast and the massive filtration capacity of this population make it likely that this species effectively influences mud burial and particle transport along the Dutch coast.


Ensis directus

External Projects Marine Ecology

- Supplying long term quality control data of Curaçao and Bonaire coral reefs to authorities and stakeholders (NWO-WOTRO).
  R.P.M. Bak, in cooperation with University of Amsterdam IBED, Carmabi (Curaçao), Stinapa (Bonaire).
- The effects of the offshore wind park Egmond aan Zee (OWEZ) on recruitment of benthos (NZW, NUON/SHELL).
  M.J.N. Bergman, G.C.A. Duineveld.
- Effects of the construction of an offshore wind park on macrobenthos (NZW, NUON/Shell).
  M.J.N. Bergman, S. Ubels, M. Mulder, R. Daan.
- Beached bird surveys 2010/11 (contract Rijkswaterstaat).
  C. J. Camphuysen.
- Beached bird surveys 2011/12 (contract Rijkswaterstaat).
  C.J. Camphuysen.
- Harbour Porpoise Conservation Plan (contract Ministry EL&I).
  C.J. Camphuysen.
- Lesser Black-backed Gull studies (contracts Rijkswaterstaat).
  C.J. Camphuysen.
- Harbour Porpoise bycatch estimated (contract IMARES).
  C.J. Camphuysen.
- Age determination in bivalves: validation of the seasonality of shell growth bands along the European coast.
  J.F.M.F. Cardoso, H.W. van der Veer, in cooperation with CIIMAR/CIMAR (Porto, Portugal).
- Development of sensor algorithms for estimating primary production (IN PLACE; NWO-ZKO).
  M. van Dijk, C.J.M. Philippart, in cooperation with NIOO-CEME, IVM-VU, RWS and ITC.
- Assessment of the interaction between corals, fish and fisheries, in order to develop monitoring and predictive modelling tools for ecosystem based management in the deep waters of Europe and beyond (CoralFISH, EU).
  G.C.A. Duineveld, M.S.S. Lavaleye.
- Defining conceptual models on ecological functioning of the Wadden Sea system (WaLTER, Waddenfonds).
  E.O. Folmer, C.J.M. Philippart, in cooperation with CWSS, IMARES, RUG, RUN, SOVON, Ministry EL&I, NAM, SBB, NM, Province Fryslan, RWS, Ministry I and M.
- Pervasive impact of avian migrant predators on intertidal communities may connect ecosystems on a global scale (VIDI-NWO).
  J.A. van Gils
- Cascading predator-prey effects in a pristine seagrass-based food web (NWO-ALW Open Programme).
  J. A. van Gils, C.H.R. Heip
- Analyses of factors explaining success and failure in bridging the gap between scientists and policy makers (SPIRAL, EU FP7).
  E. van Haastrecht, C.J.M. Philippart, C.H.R. Heip.
- BIOdiversity and ecosystem FUNctioning in contrasting southern European deep-sea environments (BIOFUN, ESF).
  R. Jeffreys, G.C.A. Duineveld, M.S.S. Lavaleye.
- Advice concerning a proposal made by Dutch fishery organizations about fishery measures for the Cleaver Bank area (Directie Agroketens en Visserij, Ministry EL&I).
  M.S.S. Lavaleye.
- Hotspots of Biodiversity in the North Sea (IMARES & Directie Kennis en Innovatie of Ministry of Economy, Agriculture and Innovation).
  M.S.S. Lavaleye, M.J.N. Bergman.
- Hotspot Ecosystem Research and Man's Impact On European Seas (HERMIONE, EU).
  M.S.S. Lavaleye, G.C.A. Duineveld.
- Causes and consequences of selective feeding by juvenile bivalves, subproject of part of consequences of phosphorus reduction for the dynamic transfer of organic matter (P-REDUCE; NWO-ZKO).
  V. Lehmpfuhl, C.J.M. Philippart, in cooperation with NIOO-CEME.
- The trans-Arctic biotic interchange: snapshots-through-time of adaptive differentiation in the bivalve genus *Macoma* (NWO-MEERVOUD).
  P.C. Luttikhuizen
- Climate-related shifts in the NCP ecosystem and consequences for future spatial planning (BSIK, Klimaat voor Ruimte).
  J. van der Meer, G.C.A. Duineveld, R. Witbaard.
- Development of a dynamic biogeochemical sediment nutrient water exchange model (P-REDUCE, NWO/ZKO).
  L. Mulder, C.J.M. Philippart, in cooperation with NIOO-CEME.
- Integrated Network for Production and Loss Assessment in the Coastal Environment (IN PLACE; NWO-ZKO).

C.J.M. Philippart, in cooperation with NIOO-KNAW/CEME, IVM-VU, RWS and ITC.

- Wadden Sea Long-Term Ecosystem Research (WaLTER, Waddenfonds).
  C.J.M. Philippart, I. de Raad, , J. van der Meer, T. de Bruin (FYS), in cooperation with CWSS, IMARES, RUG, RUN, SOVON, Ministry EL&I, NAM, SBB, NM, Province Fryslan, RWS, Ministry I and M.
- The effects of changes in Wadden Sea habitats on behaviour, physiology, ecology and population dynamics of migrant waterbirds (Metawad-1, Waddenfonds).
  T. Piersma (general project-leader).
- Physiological performance of the Peppery furrow shell *Scrobicularia plana* (da Costa 1778) along the European coast (Portuguese Science Foundation).
  S. Santos, P.C. Luttikhuizen, H.W. van der Veer, in cooperation with CIIMAR/CIMAR.
- Modelling bivalves in coastal and estuarine systems.
  *S. Saraiva, J. van der Meer, in cooperatio*n with Vrije Universiteit and MARETEC/IST.
- AquaDEB (NWO).
  J. van der Meer, H.W. van der Veer, S. Saraiva.
- Mosselwad (Waddenfonds).
  J. van der Meer, A. Water, R. Dekker, J.IJ. Witte.
- Ensis Dynamic Energy Budget (RWS).
  J. van der Meer, J. Cardoso, H.W. van der Veer.
- Decentraal Aalbeheer (Ministry EL&I).
  J. van der Meer.
- Gesloten gebieden Rottum (Ministry EL&I).
  J. van der Meer.
- Food web model by ecological network analysis (ENA) for a western Wadden Sea ecosystem, the Balgzand area.
  H.W. van der Veer, C.J.M. Philippart, in cooperation with Alfred Wegener Institut für Polar und Meeresforschung.
- Impacts of climate change on European marine ecosystems (CLAMER, EU FP7).
  T. Watmough, C.J.M. Philippart, C.H.R. Heip, in cooperation with ESF - Marine Board, CEFAS and VLIZ.
- Budget modelling of fines in the Dutch coastal zone (NTW3.1 of BWN. Building with Nature, in cooperation with NIOZ-FYS).
  R. Witbaard.
- La Mer Long deploy. Longterm lander deployment in the Dutch coastal zone 2011.
  R. Witbaard.
- Pilot study of the applicability of the "NIOZ Mussel monitor for valve activity" on *Ensis directus* during a long period under controlled conditions (RWS-havenproef).
  R. Witbaard.
- Relation between valve activity of *Ensis directus* and environmental factors in the Dutch coastal zone in the spring (RWS – Ensis field experiment, in cooperation with BWN-NTW3.1 and Deltares).
  R. Witbaard.
- Relation between valve activity of *Ensis directus* and environmental factors in the Dutch coastal zone in the autumn (RWS – Ensis field experiment, in cooperation with BWN-NTW3.1 and Deltares).
  R. Witbaard.

2011 – A year of several commemorations relating to Antarctic events

*Johan van Bennekom**

The year 2011 saw some memorable events in the Antarctic history: The 100th anniversary of the Amundsen and Scott expeditions reaching the South Pole and the 50th anniversary of the ratification of the Antarctic Treaty. 30 Years ago NIOZ embarked in Antarctic research, and Dutch scientific research and lobbying in the decade that followed resulted in 1990 in the admission of the Netherlands as a consultative party in the Treaty. Steps towards more long-term research were laid in 2011, with the construction of three containerized laboratories that will be stationed at the British Antarctic base Rothera. Johan van Bennekom, the first NIOZ scientist joining an expedition to Antarctica in 1981, gives an account of a century of Antarctic research.

100 years ago the South Pole was reached for the first time

On 16 December 1911, a Norwegian team led by Roald Amundsen (1872-1928) was the first to reach the South Pole. The group of five did numerous observations with sextant and artificial horizon to be absolutely sure that they really were at the southern tip of the planet, the unique spot on the southern hemisphere with no maximum elevation of the sun at noon (Fig.1). The return journey of about 1500 km to the Antarctic coast took only 40 days, blessed by relatively good weather. They reached Hobart (Tasmania) on April 7, the first spot from where they could inform the world about their success. At that time, nobody knew about the tragic fate of the British team of Robert Scott (1868-1912) who reached the pole one month after Amundsen, and saw there to their great deception the Norwegian flag. His party met exceptionally adverse weather on their return journey and perished from exhaustion. The scientific value of Amundsen's achievement, well prepared and courageously carried out, was small; the objective of both Amundsen and Scott was to be at the Pole and to be the first to get there. The impact was mainly psychological: the end of the planet had been reached.

50 years ago the Antarctic Treaty became official

On June 23 1961, the Antarctic Treaty entered into force through ratification by the parliaments of the 12 countries that had signed the Treaty two years earlier. By this Treaty, the continent and adjacent shelves south of 60° S were reserved for science for the next 30 years. Claims for sovereignty were frozen with an "agreement to disagree", although claims were maintained by 7 of the original signatory countries, the so called claimant states. A moratorium to refrain from extraction of minerals or oil was also agreed upon. The Treaty was a diplomatic expression of the operational and scientific cooperation on the Antarctic ice during the International Geophysical Year (IGY) of 1957-1958. It marked a change in attitude of the international community toward the southern continent, where expeditions and stations were no longer primarily instruments for claiming sovereignty over parts of the continent, but were driven by scientific motives. The 12 countries signing the Treaty invested huge amounts of money and manpower, established new stations, e.g. the still existing Amundsen-Scott basis at the South pole and the – now buried - first King Baudouin Basis on the Princess Ragnhild coast. The scientists involved benefitted greatly from sharing logistics and results and they wanted to sustain this atmosphere of friendly cooperation, so contrasting with the cold war between some countries raging in the rest of the World. The 12 original signatories operated as a joint body to regulate Antarctic affairs satisfactorily for at least some 20 years.

Fig. 1. Norwegian measurements of the suns´ altitude at the south pole.

The Netherlands was not among the 12 countries who originally signed the Treaty. The Dutch IGY Committee, housed at the Royal Academy of Sciences, decided that Dutch expertise should traditionally better be used in the tropics. A costly expedition to the interior Mountains of New Guinea was therefore organized, subsidized by ZWO, the Dutch organization for pure scientific research. Budgets were scarce, making it difficult to start an entirely new field of research. Although Dutch whaling expeditions to the Southern Ocean still continued, and the whaling ship Willem Barendsz II had been launched in 1954, this could hardly figure as a scientific contribution to an IGY.

The enormous amount of money (36 million guilders) reserved for the gradual transformation of the Dutch Zoological Station at Den Helder into a multidisciplinary institute for marine research, now the Royal Netherlands Institute for Sea Research (NIOZ) at the island of Texel, could have played a role in the reservations towards major investments. But when a few years later Belgian scientific circles approached Dutch counterparts for collective Antarctic work, three Belgian-Dutch overwintering's (1965-1967) were organised with participation of technicians and scientists of KNMI. The Dutch financial support helped the Belgians to maintain their King Baudouin base. The Dutch work contained a wealth of routine meteorological data, some work on the seasonal cycle of ozone while a few sediment cores were investigated at NIOZ. Certainly interesting but the results failed to trigger enthusiasm towards a polar tradition and interest about Antarctica diminished in scientific circles.

30 years ago NIOZ made a first contribution to Southern Ocean research

In 1980, Prof. G. Hempel, director of the newly established Alfred Wegener Institute for Polar Research (AWI) in Bremerhaven, informed the NIOZ director Prof. J. Zijlstra that a Dutch marine scientist could take part in a six-week cruise to the Weddell Sea. The cruise with Hempel as chief scientist was one of the

Fig. 2. Antarctic Krill, an organism of 6-9 cm length, occurring in huge swarms. The total biomass is estimated to be second only to that of homo sapiens.

West-German contributions to the BIOMASS program (Biological Investigations on Marine Antarctic Systems and Stocks). Primary objective was to assess the quantities of *Euphausia superba* (Krill, Fig.2). The invitation was passed on to me, since for my research on the relationships between diatoms, dissolved silica and aluminium work in the Southern Ocean was vital. And thus, in February 1981, I embarked in Ushuaia, Argentina, on F.S. "Meteor", as the first NIOZ scientist to go to Antarctica. The results showed extremely low concentrations of aluminium in the water column and in diatoms, giving new insights into the marine cycle of aluminium: continental weathering and atmospheric dust as the source and uptake by diatoms as the sink. One extreme was the landlocked Mediterranean with high concentrations of Al, much dust, many rivers and few diatoms. The Southern Ocean was the other extreme; no rivers, hardly dust and abundant diatoms (Fig. 3).

More interest for Antarctic science and Dutch consultative influence?

Hempel invited a Dutchman also because he would appreciate more Dutch contributions to Antarctic science. West Germany, recently admitted as a consultative member in the Antarctic Treaty, was a strong advocate of nature conservation issues. With the revision of the Treaty in 1991, including the possible lifting of the moratorium on exploitation, casting its shadow ahead (Fig.4), the involvement of the Netherlands as a potential ally in protection of Antarctica's fragile ecosystems could turn the scales in a possible stalemate.

Lobbying at NIOZ to raise more interest in Antarctic research failed at first since the expeditions to the North Atlantic and Snellius II in Indonesia were in full preparation. Elsewhere in scientific, political and conservationist circles, the interest in Antarctica was growing, however. Representatives met regularly in the "Working Group Antarctica", established in 1980 by the Dutch division of the International Union for the Conservation of Nature and natural resources (IUCN). It was soon realized that the only way to gain influence was to strive for the status of consultative member of the Antarctic Treaty. This required "To demonstrate interest in Antarctica by conducting substantial research activity there", elucidated with "such as organizing an expedition or establishment of a research station", but none of those requirements

Fig. 3. *Corethron spec*. dominating in my samples. They have a crown of spines at the top, therefore their nickname "Queen of the Bransfield Strait".

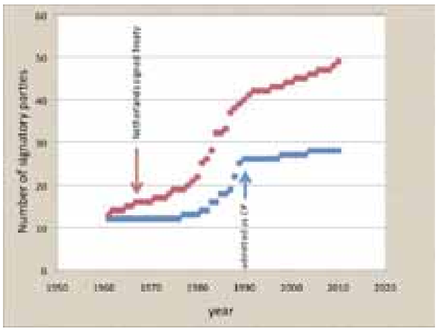

Fig. 4. The number of countries with consultative status in the Antarctic Treaty (blue) and the number of countries that only agreed to its aims (red). Note the near doubling of consultative countries between 1981 and 1990, the period of negotiations about possible revision of the Treaty towards exploitation of minerals and oil. Data Antarctic Treaty Secretariat.

could then be met for lack of expertise in the Netherlands and financial constraints.

Nevertheless, intensive lobbying campaigns by the IUCN working group eventually resulted in the course of 1984 in the funding of pilot projects, with in total 300.000 guilders for a period of three years and employment for 3 scientists.

To create maximum support, both scientifically and politically, the projects paid tribute to institutes that had shown interest: NIOZ (marine research), RIN (nature management), RGD (geology and mineral resources) and IMAU (department of glaciology, Utrecht university). A second Antarctic working group was established at the Council for Sea Research (NRZ) for coordination and selection of projects. It goes without saying that the execution of all projects heavily depended on the hospitality of host countries, where especially the German F.S. Polarstern should be acknowledged, but also Australia provided facilities for research on birds. These favours were in the pilot phase compensated by offering training of foreign scientists at Dutch institutes as well as Dutch expertise in the on-board analyses of major nutrients and trace metals. At NIOZ we all contributed to a smooth start of the Antarctic work; the extra scientist was paid with the money saved with a nation-wide cut in salary, imposed to ease the lack of jobs for graduated scientists around 1985.

A complete list of projects carried out is beyond the scope of this article, even for the NIOZ contributions. Some highlights were the extreme 89 meters Secchi disc visibility in Southern Ocean waters (Fig. 5), providing evidence for low productivity in iron-limited polar waters, and the first use of radioactive silicon-32 to measure the production of diatoms. Most projects certainly met the criterion of "substantial research" qualifying the Netherlands for consultative status, which was granted in November 1990.

21 years ago, The Netherlands joined the Antarctic Treaty as a Consultative Party

On first application in 1989 this status had been refused, on grounds that there had never been an independent Dutch enterprise. To fill in this gap, a Dutch expedition to King George Island took place from December 1990 to January 1991, with support from the Polish authorities who were happy to rent part of the facilities in their station Arctowski to the Dutch scientists. Already before this expedition even started, a special meeting of the consultative members in Viña del Mar, Chile, on November 19 1990, unanimously agreed upon the consultative status for the Netherlands. The policy of the Netherlands remained to not establish a Dutch station on Antarctica, but rather cooperate with other countries and share facilities – of course with reasonable financial contribution. This policy was appreciated by SCAR, which had expressed its concern about the proliferation of stations and had pleaded for more cooperation and sharing of facilities. Long term commitment and quality of research was considered more important than constructing new buildings mainly just to be there. Even so, the Dutch budget for Antarctic research now had to adjust to the new situation with a substantial increase, mainly to contribute to the infrastructure of host countries and at the NWO bureau (Fig. 6).

Fig. 5. The Secchi disc used to record extreme visibilities in Southern Ocean sea water. Courtesy Kees Veth.

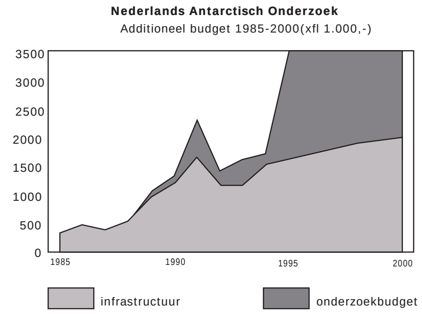

Fig. 6. Progressive budgets allocated to Dutch scientific projects in Antarctica.

2011 and the future, a new semi-permanent research facility

The choice for not establishing a permanent station excluded certain projects requiring more extended presence, for example those involving investigation of seasonal processes. For these kind of studies the British station Rothera on Adelaide Island has hosted many Dutch scientists with terrestrial projects.

Recently this cooperation has been extended with studies in coastal waters. Rothera station lies near the Antarctic Peninsula (Fig. 7), where effects of climatic change are already clearly visible. The fact that the British have been monitoring seasonal parameters for quite a number of years is another advantage to jointly study various biological phenomena and to extend work on trace metals and their effect on primary production in coastal waters. To meet the required ultra clean working conditions and precise temperature control, NIOZ constructed three containerized laboratories in 2011 with funding from NWO. Some of these are presently underway to Rothera, where they will be housed in a building specially developed for this purpose (Fig. 8). This opens perspectives to long term presence of Dutch scientists on Antarctica, and marks a new era in our country's research on the southern continent.

Fig. 8. The new building at Rothera that will house the four laboratory containers built at NIOZ.

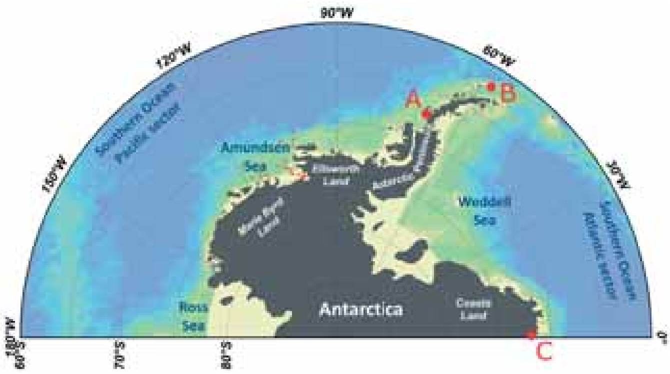

Fig. 7. Map showing the stations mentioned in the text. A: Rothera, B: the Polish Arctowski, and C: the now buried Belgian station King Baudouin.

Scientific Support Services

MARINE RESEARCH VESSELS AND FACILITIES

*Erica Koning**

The NIOZ research vessel Pelagia sailed 301 operational days for 18 cruises. Of these 18 cruises, 9 were performed within the National Programme for Sea Research (ZKO: Zee- en Kustonderzoek), 6 were EU/ESF or NIOZ programmes and 3 were charter or barter cruises. Our active participation in the Ocean Facilities Exchange Group (OFEG) continued.

Marine Research Facilities

The Marine Research Facilities (MRF) is a national structure integrated within NIOZ. MRF advises the Earth and Life Sciences branch (ALW) of the Netherlands Organisation for Scientific Research (NWO) on the technical, logistic and financial aspects of the National Programme for sea research, maintains the national equipment pool and runs facilities, including several marine research vessels. NIOZ-MRF supplies suitable ship capacity, dedicated technicians and sea-going equipment to teams of scientists from Dutch research institutes and universities and assists the chief scientists in planning, preparation and execution of the cruises. NIOZ participates with RV Pelagia and its equipment pool in the Ocean Facilities Exchange Group (OFEG), wherein ship time is exchanged between 6 European partners on a bartering basis.

Research vessels

Research vessel Navicula is a 25 m ship specially designed for working in the shallow Wadden Sea. Navicula was built in 1980 and elongated in 1999, with another major upgrade in 2004. This year, a major revision was carried out on the hull platework. In 2011 RV Navicula sailed for 165 days and worked mainly in the Dutch Wadden Sea with a few excursions to the coastal North Sea. 55 days of Navicula ship time were funded by NWO within the National Programme for Sea and Coastal Research (ZKO) and by third parties. In 2011 Navicula was used as a platform for a variety of student courses and activities for a total of 24 days.

RV Pelagia is our largest sea-going facility, a 66 m research vessel developed for oceanographic research in coastal seas, on continental shelves and on the open ocean. RV Pelagia was built in 1991 (ISM Certified) and was designed as a multi-purpose research vessel. Onboard scientific activities include seismic surveys, the operation of a variety of CTD and water sampling systems, diverse biological sampling instruments and coring devices as well as the deployment and recovery of deep-sea moorings and bottom landers, including a deep-sea crawler (MOVE!). A major midlife refit was carried out in 2010, during which all the ship's facilities were updated and Pelagia was outfitted with a USBL-system (Ultra Short Base Line) enabling state-of-the-art communication with underwater instrumentation.

RV Pelagia cruise programme

In 2011 RV PELAGIA sailed for 301 operational days divided over 18 cruises. The cruise programme included two charter cruises and one barter cruise. The first charter cruise of 28 days was carried out in the subtropical North Atlantic in October for a science team from the University of Vienna, Austria led by former NIOZ scientist prof. dr. Gerhard Herndl. A second charter cruise of 10 days sailed from Cadiz in November for the University of Granada. This cruise was led by chief chientist Prof. Menchu Comas. Pelagia's cruise schedule for 2011 ended with an 8-day barter cruise for IFM-GEOMAR in the Gulf of Sirte with chief scientist Dr. Warner Brückmann.

The Netherlands Research Council NWO funds seagoing science projects within the National Programme for Sea and Coastal Research (ZKO). In 2011, 33 days of ship time were funded by NWO for the 2009-2011 ZKO STRATIPHYT cruise that had to be postponed in 2010 because of the midlife refit. Another 9 days were funded by NWO for the programme CHARLET. Furthermore, NIOZ funded 216 days, 131 of which were to enable ZKO programmes, 37 days were for matching of EU/ESF projects, charterers funded 36 days and 8 days were barter days. To allow additional ship time for programmes that ran in previous

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years but needed follow-up ship time, NIOZ and NWO pooled resources and set up the VTLP programme (VaarTijd Lopende Projecten), where NIOZ funded 70 days of ship time and NWO provided additional funding to cover project costs. The NiCYCLE, HYPER, PACEMAKER and MOCCHA programmes were funded within this VTLP programme.
Furthermore, NIOZ funded ship time to enable the North Sea programmes NORTH SEA ACIDIFICATION and CHARLET and the NWO Open call programme LONG CHAIN DIOLS. An overview of the 2011 Pelagia cruises (including charters and barters) is presented below; the overview also shows cruises with Dutch participation on foreign research vessels. Details of the cruises within the National Programme (funded by NWO) are given in the next subchapter.
To accommodate the cruises by RV Pelagia, diplomatic clearance has been granted by Denmark (including Greenland), Estonia, Germany, Greece, Iceland, Ireland, Italy, Latvia, Morocco, Norway, Portugal, Spain, Sweden, Tunisia and UK. Clearance was refused by Malta and Algeria failed to respond to the requests for clearance. Besides calling at homeport Texel, port calls for changes of crew and scientific party as well as for (un)loading of scientific equipment took place in Porto (Portugal), Lisbon (Portugal), Las Palmas (Spain), Reykjavik (Iceland), Stavanger (Norway), Vigo (Spain), Cadiz (Spain), Almeria (Spain and Catania (Italy).

National Programme for Sea Research

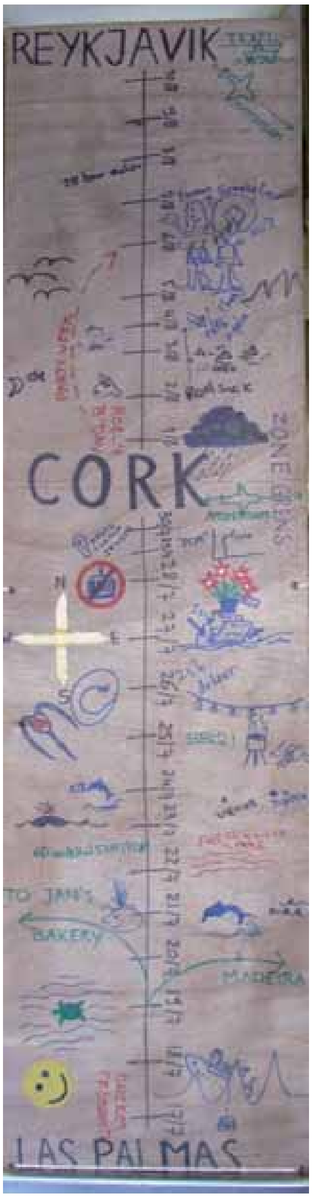
In 2011 the National Programme, facilitated by NWO/ALW grants and NIOZ ship time, consisted of 9 cruises, all on RV Pelagia. In chronological order the following programmes, some of which are highlighted below, were carried out in 2011:

1. NiCYCLE I
2. PACEMAKER
3. STRATIPHYT
4. HYPER
5. NiCYCLE II
6. LONG CHAIN DIOLS
7. NiCYCLE III
8. NORTH SEA ACIDIFICATION
9. MOCCHA

Pelagia Cruises	departure	arrival	area	Project	Chief Scientist
64PE329	Texel	Texel	North Sea	NICYCLE	N. Bale (BCG)
64PE330	Texel	Texel	North Sea	NOORDZEE WIND	M. Bergman (MEE)
64PE332	Texel	Lisbon (P)	North Atlantic	PACEMAKER	J-H. Kim (BCG)
64PE334	Las Palmas (ES)	Reykjavik (IS)	North Atlantic	STRATIPHYT	C. Brussaard (BIO)
64PE336	Gotheborg (S)	Texel	Baltic Sea	HYPER	C. Slomp (U. Utrecht)
64PE337	Texel	Texel	North Sea	NICYCLE/FOKUZ	N. Bale (BCG)
64PE339	Texel	Texel	North Sea	BWN	R. Witbaard (MEE)
64PE338	Texel	Texel	North Sea	NORMOMAP	M. Bergman (MEE)
64PE340	Texel	Texel	North Sea	NIOZ-MONITORING	H. de Haas (GEO)
64PE341	Texel	Reykjavik (IS)	North Atlantic	LONG CHAIN DIOLS	H. de Haas (GEO)
64PE342	Reykjavik (IS)	Texel	North Atlantic	THOR	H. van Aken (FYS)
64PE343	Texel	Texel	North Sea	NICYCLE/CHARLET	N. Bale (BCG)
64PE344	Texel	Texel	North Sea	NORTH SEA ACIDIFICATION	E. Jones (BIO)
64PE345	Texel	Vigo (ES)	North Atlantic	CORALFISH/HERMIONE	M. Lavaleye (MEE)
64PE346	Vigo (ES)	Cadiz (ES)	North Atlantic	MEDEA	G. Herndl (U. Vienna)
64PE347	Cadiz (ES)	Almeria (ES)	Alboran Sea	CASALB	M. Comas (U. Granada)
63PE348	Almeria (ES)	Catania (I)	Ionian Sea	MOCCHA	G. de Lange (U. Utrecht)
64PE349	Catania (I)	Catania (I)	Gulf of Sirte	BARTER IFM-GEOMAR	W. Brückmann (GEOMAR)
Other ships					NIOZ participant / PI
METEOR	Cadiz (ES)	Corfu (EL)	Ionian Sea	MOCCHA	G. de Lange (U. Utrecht)
METEOR	Corfu (EL)	Valletta (MT)	Off Greece	KM3-net	H. van Haren (FYS)
Polarstern	Cape Town (SA)	Punta Arenas (CI)	South Atantic	AWI	E. Jones /K. Bakker
James Cook	Punta Arenas (CI)	Las Palmas (Es)	South Atantic	GEOTRACES	M. Rijkenberg (BIO)
Osprey	Dar es Salaam (Tz)	Dar es Salaam	Indian Ocean	GLOW	J. Schilling / S. Gonzalez
Sonne	Wellington (NZ)	Auckland (NZ)	W. Pacific	NEMESYS	J. Greinert (GEO)
Poseidon	Tromsø (N)	Tromsø	Off Svalbard		J. Greinert (GEO)
Southern Surveyor	Fremantle (AU)	Fremantle	S. Indian Ocean		J. Greinert (GEO)
Knorr	Reykjavik (IS)	Isarjordur (IS)	Denmark Strait	Sources DSOW	L .de Steur (FYS)

1: PACEMAKER (Past Continental Climate Change: Temperatures from marine and lacustrine archives); Chief scientist Jung-Hyun Kim (BCG).
The PACEMAKER cruise took place from 9 to 31 March with participants from NIOZ, Instituto Hidrográfico (Portugal), Edinburgh University (UK), Bordeaux University (France), and LNEG (Portugal). The objectives of the ERC project PACEMAKER were to investigate the dispersal of riverine material on the Portuguese continental margin and various other aspects of this margin. Early morning on 14th of March RV Pelagia arrived at the first station off Douro River. During the subsequent two weeks, cruise activities focused on six transects running approximately at a right angle to the coastline from about 15 m down to 2000 m water depth. Along each transect, CTD profiling and water sampling were carried out to investigate the hydrographic characteristics of the water column, in particular the distribution and dynamics of turbid water layers. Detailed bathymetry and seismic profiles were acquired from each of the transects using multibeam echosounder in combination with seismic. Surface sediment cores were collected for analysis of sedimentological, geochemical, and biological characteristics. Piston cores were collected in the mud belt areas to study paleoenvironmental changes during the Holocene on decadal-centennial timescales.

2: STRATIPHYT (Changes in vertical STRATIfication and its impacts on PHYToplankton communities); Chief scientist Corina Brussaard (BIO).
The STRATIPHYT project studies the influence of global warming on vertical stratification, which starts earlier in spring and lasts longer in autumn. Changes in stratification will have major



effects on the production and species composition of phytoplankton. This will subsequently impact grazing, virally induced mortality and sedimentation rates, with cascading effects on ecosystem functioning and biogeochemical fluxes. STRATIPHYT investigates how changes in vertical stratification affect phytoplankton communities along a north-south gradient in the Atlantic Ocean on a transect from the Canaries to Iceland, by combining advanced models of hydrodynamics and plankton growth and detailed laboratory experiments with representative phytoplankton species. We have chosen for the Northeast Atlantic Ocean, because this is a key area in global ocean circulation, a large sink for atmospheric CO2, and a major determinant of the climate in Western Europe. Furthermore, the Atlantic Ocean offers a gradient from weak seasonal stratification in the North to strong permanent stratification in the (sub)tropics. This gradient offers ideal opportunities for the comparative study of different stratification regimes. Our integrated approach of physical, chemical, and biological processes will enable a better understanding of the implications of global warming for plankton growth in the North Atlantic Ocean.

3. NICYCLE II/III (The nitrogen cycle and changes in the carrying capacity of coastal waters); Chief scientist: Nicole Bale (BCG).
The NICYCLE project completed 4 cruises onboard the R/V Pelagia; in November 2010, February 2011, May 2011 and August 2011. The first 3 cruises (in collaboration with the FOKUZ project) sampled 7 stations along the 'Terschelling transit', starting at the Dogger Bank, 235 km from the Dutch coast, and finished approximately 5 km from Terschelling. The final cruise (shared with the CHARLET project) sampled along an extension of this transect, starting around 400 km from the Dutch coast. The NICYCLE project aims to identify key microorganisms in the nitrogen cycle of selected coastal ecosystems in the Netherlands and examine the relationships between external nitrogen loading and the population dynamics of these key players. In order to reach this aim we have, during these cruises, collected surface and bottom seawater samples as well as surface sediment cores, that are now being by different project members. Haoxin Fan (NIOZ Yerseke) and Laura Villanueva (NIOZ Texel) are studying the diversity of the microorganisms involved in the nitrogen cycle and identifying their key functional genes, diversity and expression. Nicole Bale (NIOZ Texel) has been using intact membrane lipids to further examine the abundance,

distribution and activity of these micro-organisms. Samples were also collected for single cell analyses of ^{15}N and ^{13}C uptake by Nano-SIMS by Ishraga Taha (NIOZ Texel). Alessia Moneta (NIOZ Yerseke) carried out on-deck incubations in order to examine water column nitrogen uptake and assimilation, nitrification and primary production using different substrates with ^{13}C and ^{15}N additions.

4: LONG CHAIN DIOLS; Chief Scientist: Henk de Haas (GEO)
From 7 to 22 July RV Pelagia sailed around Iceland to collect samples within the different types of water masses present around the island for a series of projects related to paleoceanographic and climate change studies. On this cruise the scientific party consisted mainly of members of the NIOZ department of Biogeochemistry, with additional scientists from the NIOZ department of Marine Geology and the Universities of Edinburgh and Rutgers University (New Jersey, USA). Technical support was provided by NIOZ-MRF technicians. During the cruise a mooring with 2 sediment traps was deployed, to be recovered next Summer. Seabed sediments and water column samples were collected in order to study algae, micro-organisms living in the deeper part of the water column and in the sea bed sediments and various organic compounds all the above mentioned organisms produce with the aim to understand the functioning of these organisms, their role in the oceanic ecosystem and to what extend the organic molecules produced by these organisms can be used as proxies in paleoceanographic and climate change studies. In addition benthic foraminifera were collected for paleoceanographic studies.

5: MOCCHA: Chief Scientist Gert de Lange (Utrecht University)
In November the final cruise of the MOCCHA programme took place. During this cruise 2 sediment trap moorings would be recovered from the Central Mediterranean and Ionian Seas, thereby ending the 10-year long trap series run by Gert de Lange (Utrecht University) and his group. The cruise turned out to be a succession of highlights. First the science party recovered the mooring near Lybia that had been left behind during the METEOR cruise in January because the ship failed to get diplomatic clearance. At the second location the ship intended to dredge for a mooring that had been lost in 2010 and had been replaced with a new one at the same location. During recovery it became apparent that the cables of the two moorings had become entangled so 7 sediment traps came up together, although some were upside down. Finally, shortly before the end of the cruise on December 5 Pelagia was visited by Sinterklaas and his 2 companions.

NIOZ North Sea Monitoring cruise

In addition to the ALW-funded National Programme NIOZ funds a number of cruises for follow-up ship time or general interest NIOZ projects. In 2011 a pilot study was carried for a multi-year programme with participation from all NIOZ departments, the NIOZ North Sea monitoring cruise. NIOZ has the intention to continue this program by providing ship time for an annual research cruise in the years to come.

From 17 June to 4 July representatives of the NIOZ departments of Marine Geology, Marine Ecology and Biological Oceanography assisted by NIOZ-MRF technicians joined the first of a series of North Sea Monitoring cruises with RV Pelagia. Chief scientist was Henk de Haas (GEO). The research was mostly carried out within the Dutch sector of the North Sea. The topics of investigation where 1) the seepage of methane from a natural gas field below the seabed through the water column, into atmosphere 2) a benthic biological survey in various habitats (muddy, sandy and rocky areas) in the North Sea, 3) primary and secondary production, zooplankton biomass and grazing rates 4) the role of viruses in the North Sea ecosystem system. The aim of this NIOZ North Monitoring Program is to improve our understanding of processes on longer term time scales and by integrating various scientific disciplines come to a better understanding of the processes active in the North Sea.

NIOZ scientists on foreign ships

In addition to the National Programme, NIOZ scientists participated in a number of cruise programmes on OFEG and non-OFEG ships. From November 2010 until February 2011, Elizabeth Jones (BIO) and Karel Bakker (MRF) sailed from Cape Town (South Africa) to Punta Arenas (Chili) on FS Polarstern Germany). In January and February, NIOZ technicians and scientists sailed on a double barter cruise on board the German FS METEOR for the MOCCHA and KM3-net programmes. In March a large scientific party led by chief scientist Micha Rijkenberg (BIO) joined the OFEG vessel RRS James Cook (UK) for the final leg of the ZKO programme GEOTRACES. This cruise sailed from Punta Arenas to Las Palmas (Spain), where James Cook met up with Pelagia to transfer the Kley France winch and other essential equipment from one ship to another.

In May, Jack Schilling (MTM) and Santiago Gonzalez (BIO) boarded the Kenyan tugboat Osprey to recover the GLOW sediment trap mooring off Dar es Salaam.
Jens Greinert (GEO) joined a number of cruises on foreign vessels: FS Sonne (Germany) on the Hikurangi Margin, New Zealand in March – April with a group from the GEO department for the NEMESYS project, FS Poseidon (Germany) in August offshore Svalbard and RV Southern Surveyor (Australia) in October offshore Geraldton, Western Australia together with Bob Koster (GEO). In August, Laura de Steur (FYS) and Leon Wuis (MTM) joined RV Knorr for a cruise to the Denmark Strait.

Ocean Facilities Exchange Group (OFEG)

OFEG's main purpose is to use resources from its 6 European member states efficiently by bartering (exchanging) ship time and large equipment without the need to exchange money. This arrangement has significant advantages because it allows scientists access to areas of the ocean that would otherwise be out of reach. Furthermore, OFEG invests in the interoperability and exchange of marine technicians for training and support on board. Within this framework, several training cruises were organized in 2011, dedicated to piston coring and seismic cooperation.

In 2011 NIOZ completed 3 barter cruises on OFEG ships; a 30-day cruise on FS METEOR (BMBF Germany) for the MOCCHA and BIOFUN programmes followed by a 15-day cruise on the same ship for the KM3-net programme. The third and final leg of the ZKO GEOTRACES programme was carried out as a 17-day barter cruise on RRS James Cook (NERC, UK).

In November Yvo Witte travelled to the Cape Verde Islands to join James Cook for an OFEG ROV training cruise but due to technical problems the ship could not sail.

OFEG meetings and other international activities

This year OFEG met twice for regular meetings, in April at IFREMER in Paris, France and in November at NOC in Southampton, UK. Alongside with OFEG, the OFEG-TECH group met in November in Southampton as well.

Erica Koning participated in the UNOLS Research Vessel Operators Committee meeting (RVOC) meeting that convened in San Diego, USA in April. Furthermore she participated in the International research Ships Operators Meeting (IRSO) that convened in Seattle, USA in May.

MARINE TECHNOLOGY

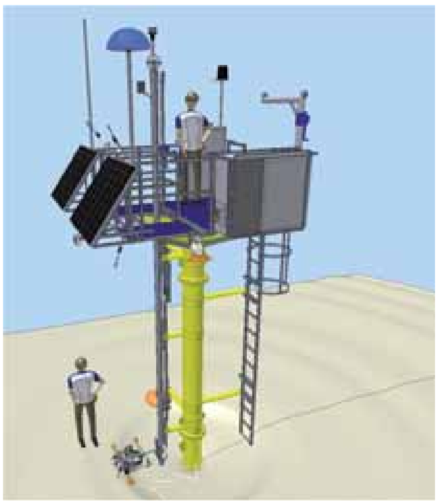
Marck Smit, Marcel Bakker, Roel Bakker, Jan Blom, Barry Boersen, John Cluderay, Ruud Groenewegen, Johan van Heerwaarden, Bob Koster, Martin Laan, Walther Lenting, Lars Okel, Harry de Porto, Jack Schilling, Laura de Steur, Jan-Dirk de Visser, Leon Wuis.*

As for the second half of 2010, a substantial part of the 2011 workload resulted from the support for seagoing cruises. Support was not restricted to the RV Pelagia but included some barter-cruises with the vessels of our OFEG partners as well, such as the Utrecht University cruise with the German vessel ”Meteor” and the GEOTRACES cruise with the UK vessel “James Cook”. In total, we have been working on 373 projects, increasing the total amount of work with 7% as compared to 2010. Some of the major projects are highlighted below.

Measuring pole for the IN PLACE project

For the IN PLACE project, a Wadden Sea observatory has been set up app. 3 km east of Den Helder. The observatory is conceived to monitor meteorological, hydrographical and biological variables at high temporal resolution. To this end the observatory is equipped with various sensor packages and local power supply. Data will be transmitted to NIOZ via a bi-directional radio link.

An array of sensors that will move up and down with the tide to attain a constant monitoring depth below the sea surface



IN PLACE Wadden Sea observatory with solar panels, instruments and cabinets for control units and batteries

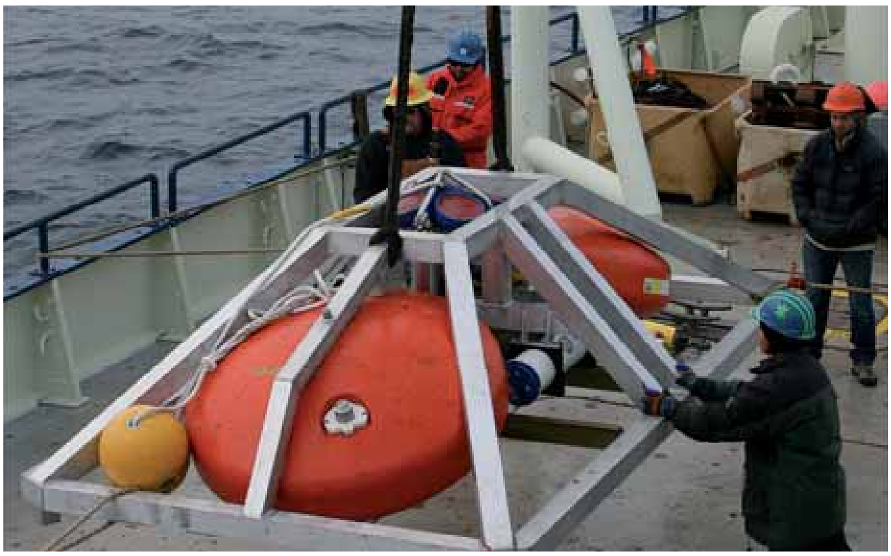
Deep Sea HD video system

The surveillance of deep sea habitats or gear is strongly improved by the in house development of a new High Definition camera system suspended in a hopper frame. Using the new fiber optic cable on the Pelagia we are now able to view live HD video recordings in real-time.

New HD video system in the hopper frame

Special bottom lander for East Greenland

Intense fisheries near Greenland preclude long term deployments of conventional moorings for current measurements. A new bottom lander has been designed to minimize damage by trawling activities and icebergs and has successfully been deployed from the American RV Knorr to a depth of 300 m during the “Sources of the Denmark Strait Overflow” project. The lander was equipped with a CTD and ADCP to measure current velocities and to determine the flux of fresh water.



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Modular laboratories for the Netherlands Antarctic program

In order to improve the facilities for Dutch scientists working in the Antarctic, NWO (Netherlands Organization for Scientific Research) will establish a Dutch Science Facility in collaboration with the British Antarctic Survey at their Antarctic base Rothera. Because of its extensive experience with building containerized seagoing laboratories, NIOZ was approached to be partner in building these labs. Four of the 20 foot container labs will be placed in a protective envelope. In 2010 the planning and engineering of the project started. Three labs were built in 2011 and extensively tested in a special climate testing facility at temperatures down to -25 °C, simulating the harsh Antarctica environment.

Minus 25°C climate testing facility

Improvements in Piston Coring

Taking long sediment cores in the deep sea by piston corer is a basic, but important technique in marine geology. As a result of a close collaboration with Ifremer (France) and NOC (UK), NIOZ has made substantial improvements in the piston coring system. Thicker liners and stronger joints have been introduced in order to withstand a higher vacuum inside the core barrel. An onsite 'joint adaptation machine' was developed, resulting in a strong, glued socket joint connecting the liners.

'Joint adaptation machine'

The Antarctica Labs were well received by the media

Overhaul ROV

During a geology cruise on the Australian research vessel Southern Surveyor, the ROV of Ghent University could be used. In close collaboration with the Belgium technicians the ROV was overhauled at NIOZ. For our engineers this was a new challenge, generating a lot of experience on ROV technology as well as on the vulnerability of these systems.

ROV Ghent University

ROV bubbling gas sampler

To sample and quantify gas, bubbling up from sea bed seeps, a ROV mounted and operated gas sampler was required by the Geology Department. Our instrumentation engineers developed a sampler with a depth rating of 6000 m, allowing sampling and measuring at full ocean depth.

ROV gas sampler during trials in the test basin.

Ultra Clean Dust collectors for Antarctica

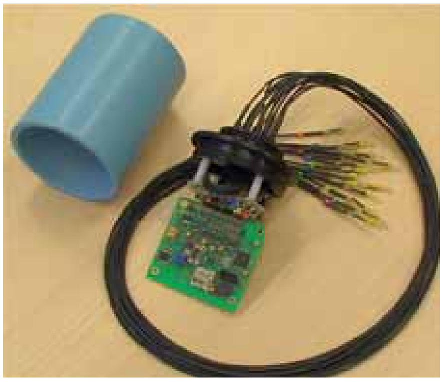
Collecting aerial dust is a specialty by its own, and is normally done by the vacuum cleaner principle in combination with a filter. Collecting dust in an ultra-clean manner for measuring trace metals means the sample is not to be contaminated by any metallic part in the sampling equipment. A real challenge is the sampling of dust in the remoteness of Antarctica with limited power supply. One of MTec's instrumentation engineers tackled all these contradicting design specifications in an elegant solution.

Ultra clean dust collector in operation in the Antarctic

Improvements in the bivalve opening monitor

The extent a bivalve opens its valves is an indicator of how 'happy' it feels about its environment. For the Waddenzee monitoring project IN PLACE, two improvements were implemented. The first one was to make it extremely energy efficient, enabling stand- alone deployments in bottom landers. Secondly, the monitor was adapted for using the fragile ensis bivalve.

State of the art geo location



Bivalve opening monitor

equipment for birds

For the MEE bird research group, our electronics department developed, in cooperation with Cornell University (USA), a bird tracking system that enables scientists to study the foraging behavior of Red Knots in the Wadden Sea. The system should work at high accuracy, it should be fast and be applicable to high numbers of birds. Moreover, the radio tags should fit small birds like the red knot and not affect their natural behavior.

We developed a system of 10 receivers mounted to poles on the tidal flats together with 100 tags to be attached to birds. The tags transmit a signal every second, which is received by the poles. The delay in receiving the signal between the various receivers allows the positioning of the bird by triangulation (TDOA system). The calculated positions are subsequently sent to the base station by means of GPRS.

Example track of one red knot

Red knot with radio tag

John Cluderay debugging the hardware

Receiving tower

Investments in digital electronics

In the field of electronics, it is good practice to digitize analogue measurements as an early step in signal processing. The electronics department is keeping pace by appointing a second software engineer and updating hard- and software tools.

Digital electronics work bench

Data Management Group

Taco F. de Bruin, Ronald X. de Koster, Jan Nieuwenhuis, Rob Louws, Ira van den Broek*

Without any doubt, this year's highlight for the Data Management Group (DMG) was the prestigeous Laureate in the category Environment that Ronald de Koster received from The Computerworld Honors Program in recognition of his work in the '… innovative application of IT to reduce waste, conserve energy, or create and implement new products, processes, programs or services to help solve global or regional environmental problems.'
Furthermore, a new website providing an overview of and access to data collected by the Dutch Zee en Kust Onderzoek (ZKO) – programme, was launched in 2011. Many other activities, such as those for the International Polar Year (IPY) data management and preserving data from the various NIOZ research projects and from the polar programme, were continued and consolidated.

The DMG is a separate group within the department of Physical Oceanography, funded by NWO-ALW and NIOZ, with a NIOZ-wide and national responsibility for oceanographic and Polar data management. The DMG represents NIOZ and the Dutch academic oceanographic community within the National Oceanographic Data Committee (NODC). It also serves as the National Polar Data Centre (NPDC). The main tasks of the DMG are to assist scientists during all phases of a project with data management and, secondly, to archive and keep accessible all relevant data colected on NWO- and NIOZ-sponsored cruises or field campaigns.

Ronald de Koster, senior systems analyst and data base administrator, is responsible for all data and information systems. This year, the CASINO system for logging the measurement activities onboard a research vessel, was installed onboard RV Navicula. The same system was installed onboard RV Pelagia in the previous year. The DMG instructed crew and scientists how to use this system onboard both research vessels. In close collaboration with the Geological Department, multibeam data were processed and provided to the EMODNET – Hydrography project, contributing to a pan-European high resolution bathymetry. The regular activities, such as safeguarding the (raw and final) data in a secure archiving system, entering data into the data sharing systems the DMG manages and contributing to the national and European data infrastructures, were continued. Since the NIOZ archiving system suddenly started to disintegrate, a new and more secure system was set up, tested and the data were transferred, checked and secured.

The NIOZ data systems are being used very frequently. The Centralized Oceanographic Data and Information System (CODIS) with hydrographic data, now contains 7195 CTD profiles from 195 cruises. It has an average of 677 hits per day. CODIS also contains over 340,000 bottle data records from 2514 casts. The Corebase system with sediment core metadata is maintained by the Geological Department. It now contains data on 1282 sediment cores and has an average of 350 hits per day. In numbers, these figures pale by the increase in records of the Coastal Long-term Optical Remote Sensing (COLORS) database, with optical oceanography data. The COLORS database grew with 67 Million records to over 300 Million records of above-water optical measurements collected from the NIOZ-jetty. Biological, morphological, chemical and physical data from various ZKO Wadden Sea-, North Sea- and ocean-projects are now becoming available and accessible through the new ZKO data portal. In 2011 more than 3000 datasets were downloaded from the NIOZ data bases. Especially important for NIOZ as a whole is expanding the scope of the NIOZ data systems by linking these to larger national and international systems, such as the data infrastructures of the National Oceanographic Data Committee (NL-NODC) and the European SeaDataNet and EMODNet systems. These in turn, are the European contribution to global systems such as GMES and GEOSS.

Jan Nieuwenhuis is in charge of long term archiving of all raw and final data collected during cruises onboard RV Pelagia and other research vessels. As a member of the committee which started to modernise the NIOZ website, he contributed his experience as web-developer for the DMG to make several project websites as well as maintaining the cruise diaries on the NIOZ website. A major effort went into transferring data to a new archiving system, when the old system suddenly started to disintegrate. The integrity of all data had to be rigorously checked.

In October, the ZKO data portal, developed by Rob Louws, the national data manager for the ZKO Wadden Sea projects, was launched. It was decided to broaden the scope of the data portal to include information on and data from all ZKO projects and not limit it to the Wadden Sea Carrying Capacity projects, as originally intended. The ZKO data portal now contains information on 70 ZKO projects and links to 30 ZKO- or ZKO-related data sets. In some cases, the data are online available and accessible, while in other cases the data holder can be contacted. The number of online available datasets will increase, following the ZKO Data Policy.
One special dataset to highlight is the series of daily Temperature and Salinity

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measurements of the Marsdiep inlet, Wadden Sea. This measurement series was started in 1861 on the Den Helder side of the Marsdiep and continues to this day on the Texel side. With over 150 years of daily measurements it is one of the longest records of seawater surface temperature in the world.

Ira van den Broek, the Dutch National IPY Data Coordinator, continued to provide extensive support on data preservation to the Dutch polar researchers, the Dutch IPY projects and the National Polar Programme (NPP). Now that the IPY projects are coming to an end, it is crucially important to ensure that the data are preserved as one of the major IPY legacies. However, even two years after the formal end of IPY, many scientists are still reluctant to make the data available. Ira van den Broek is also leading an international project to develop an ISO19115 compliant polar metadata profile.

The DMG staff participated in a series of national and international meetings related to oceanographic and Polar data management. At these meetings, DMG staff members gave 12 oral presentations and presented 9 posters on various aspects of scientific data management.

Taco de Bruin is the NIOZ representative in the National Oceanographic Data Committee (NODC) and chairs the NODC. As participant in the NODC, NIOZ actively participates in international organizations as the IOC Committee on International Oceanographic Data and Information Exchange (IODE) and the ICES-Working Group on Data and Information Management. Taco de Bruin is also the Acting Chief Officer of the SCAR Standing Committee on Antarctic Data Management and co-chairs the CODATA Task Group on Governance of Polar Data.

Photo: Sander Asjes NIOZ.

Publications

Dissertations

1. Brandsma, J. The origin and fate of intact polar lipids in the marine environment. Utrecht University, 224 pp.
2. Fallet, U. Dynamic oceanography and paleothermometry in the Mozambique Channel, upstream of the Agulhas Current, Vrije Universiteit Amsterdam, 160 pp.
3. Freitas, V. Climate-induced changes in estuarine predator-prey systems: a DEB approach. Vrije Universiteit Amsterdam, 192 pp.
4. Leyrer, J. Being at the right time at the right place: interpreting the annual life cycle of Afro-Siberian red knots. University of Groningen, 163 pp.
5. Peterse, F. Environmental controls on the distribution of bacterial tetraether membrane lipids: Constraints on the MBT/CBT paleothermometer. Utrecht University, 144 pp.
6. Pitcher, A.M. Intact polar lipids of ammonia-oxidizing Archaea: Structural diversity and application in molecular ecology. Utrecht University, 228 pp.
7. Thuróczy, C-E. Physical and chemical speciation of iron in the polar oceans. University of Groningen, 206 pp.
8. van der Land, C. Impact of diagenesis on carbonate mound formation, Vrije Universiteit Amsterdam, 191 pp.
9. Wernand, M.R. Poseidon's Paintbox: historical archives of ocean colour in global-change perspective, Utrecht University, 240 pp. ISSN 978-90-6464-509-9.

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5. Ageron, M. et al. (ANTARES-collaboration incl. H. van Haren). ANTARES: the first undersea neutrino telescope. Nuclear Instruments & Methods in Physics Research Section A-Accelerators Spectrometers Detectors and Associated Equipment 656, 11-38.
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Symposia, Courses & Public Outreach

Symposia

at NIOZ

International Symposium on the Ecology of the Wadden Sea, 10-14 October.

The symposium was centered on a number of topics related to the overall focus of the importance of scale and connectivity in the functioning of the Wadden Sea ecosystem. Each topic was introduced by a key-note, followed by a number of oral presentations. In addition, various poster sessions dealt with all topics. In total about 125 scientists participated. The symposium was organised by NIOZ, IMARES and Deltares and supported by ZKO and the Wadden Academy.

WS 2011

The 6th International Aquatic Virus Workshop (AVW6), 30 October-3 November.

Sharing the common interest of aquatic viruses as research field has led to the recurrent organization of an international meeting. The Aquatic Virus Workshop (AVW) has its origin in the Algal Virus Workshop, held for the first time in 1998 in Bergen, Norway. Subsequent workshops have been held every 2-3 years. The International Organizing Committee has decided in 2005 to expand the scope of the workshop from algal viruses to aquatic viruses in order to increase the communication among a wider range of researcher in a steadily expanding research field.
Also during AVW6 the original idea behind this workshop - to establish a forum where we present the most recent results in the field, exchange ideas, discuss new methods and developments, meet old friends and make new, encourage future collaboration, and promote the research field – still stood firmly.
The numerical dominance of viruses in aquatic environments is acknowledged the last decades, and it became evident that viruses are important regulating factors in aquatic ecosystems. The study of viruses infecting microorganisms, which make up more than 95% of the organic carbon in the oceans and are responsible for driving biogeochemical cycles, is rapidly evolving. AVW6 was timely and has been able to attract many new participants (86 participants in total). Moreover, the intimacy of the meeting, coupled with the high quality of the science presented, has made it an outstanding environment for allowing graduate students and other junior scholars to mingle with the leaders in aquatic-virus research.
The workshop was organized by C.P.D. Brussaard and the success of the meeting was also the result of the support we received from sponsors: The Gordon and Betty Moore Foundation, the Royal Netherlands Academy of Arts and Sciences and Royal NIOZ.

Symposia

elsewhere, organised by NIOZ scientists

Living with a warming ocean, 14-15 September.

The international CLAMER conference "Living with a warming ocean: European research and public perception of climate change impacts in the marine environment" took place at the Royal Flemish Academy of Belgium for Science and the Arts in Brussels. Leading experts in climate change science and related mitigation and adaptation strategies addressed the audience, among them Dr. Rajendra Kumar Pachauri, Chairman of the Intergovernmental Panel on Climate Change (IPCC), Prof. Jean-Pascal van Ypersele (vice-chair) and Ms. Manuela Soares – Director Environment, DG Research & Innovation. One of the project coordinators, Carlo Heip, also gave a key-note lecture. At the pre-event the CLAMER booklet was officially unveiled, a presentation for a wider audience on climate change impacts on the marine environment with Iceland as a case study was delivered by the other project coordinator, Katja Philippart, and the CLAMER documentary, 'Living with a warming ocean' was premiered.

An International Conference on Oman as a Gravitational Center in the Global Flyway Network of Migratory Shorebirds, 14-16 November.
The symposium aimed to raise awareness about wetlands in the Middle-East and stressed their international importance for the world's biodiversity. More specifically, it focused on the Middle-East - East African flyway, in which Barr al Hikman, a large pristine coastal wetland in the Sultanate of Oman, is a key wintering and stopover site for migratory birds. This symposium was organized by Jim de Fouw (NIOZ), in cooperation with CESAR /Sultan Qaboos University, Ministry of Environment and Climate Affairs (MECA) Government of Oman, Shell Development Oman.

Courses at NIOZ

Nebroc and Ecolmas PhD course, Molecular Organic Biogeochemistry, 7-11 February.

The course was organised by Stefan Schouten and Ellen Hopmans in collaboration with several other members of the BGC department. It was organized in the framework of the Netherlands Bremen Oceanography collaboration and also partially funded through this network. The course consisted of lectures given by Stefan Schouten, Jaap Sinninghe Damsté, Jan de Leeuw, Ellen Hopmans, Marcel van der Meer (NIOZ), and Stephanie Kusch (AWI-Bremerhaven). The topics covered included instrumental techniques, biomarker lipids, organic proxies, kerogen formation, stable isotopes and radiocarbon isotopes and intact polar lipids. In addition to the lectures there were demonstrations of analytical equipment at the BGC lab and working group sessions led by BGC department members on the interpretation of analytical data. The day was ended by student presentations in which PhD students briefly presented their (future) research project. The course was attended by 3 NIOZ students and 22 external students from countries such as Germany, Switzerland, UK, France, and Spain.

Ballast water workshop 10-50 µm: Phytoplankton and microzooplankton, 28-31 March.

Hands-on workshop was held on counting and assessing the viability of organisms in the 10-50 micron size class specified in the IMO Ballast water Management Convention. The goal of this workshop was to discuss the different counting methods used with their specific strengths and weaknesses with the goal to develop a joint 'best method'. The workshop was held at the Moss Landing Marine Laboratories (CA, USA). For NIOZ, Ph.D. students Isabel van der Star and Peter-Paul Stehouwer participated. Peter-Paul Stehouwer gave an oral presentation entitled 'Single cell detection and phytoplankton viability: application of flow cytometry and PAM fluorometry'. The rresults of the workshop will be a submission to the respective IMO Committees via the member states involved in the North Sea Ballast Water Opportunity (NSBWO) project.

Annual field course Marine Biology & Oceanography, in conjuction with B.Sc program Marine Biology of Groningen University, 28 March-15 April.

This year there were 25 students organized in 6 groups of 4-5 students. Each group did two thematic projects of one-and-half week per project, with two suites of final project presentations at 6 April and 15 April, respectively. Ten of twelve theme projects included field work in the Wadden Sea aboard RV Navicula or in the Mok Bay. Major themes were: Trace Metals in the Wadden Sea, Ships as vectors affecting biodiversity, Primary and secondary biomass and production in the Wadden Sea, The role of cryptic species in understanding marine ecosystems, Biodiversity and disease risk in marine ecosystems, Competition between zooplanktontivorous predators in the Wadden Sea, Top-down effects in marine ecosystems, Archeal nitrification in the Wadden Sea, Time series at the NIOZ jetty. Some major themes were done twice adding up to overall twelve projects. The students were in residence at campus 'De Potvis' with evening meals served by Catering Service Ruud Boom. Thanks to the enthusiasm of overall 33 project supervisors, in the end the students kindly provided an overall very positive evaluation of the course. Overall coordination was by H.J.W. de Baar, M.E. Feis, M.B. Klunder, P.C. Luttikhuizen, M.J.W. Veldhuis.

Multibeam course 'Advanced Marine Surveying for Science and Industry', 7-12 May.

Block course organised by Jens Greinert*, as part of an integrated course in Marine and Lacustrine Sciences of Ghent University, Belgium. The course deals with general and specific issues of multibeam surveying, data processing and map creation. Practical parts include the installation of a multibeam system, acquisition of multibeam data on board research vessel Navicula, and data processing with different software packages. The theoretical part explains acoustic wave propagation, multibeam systems and their functioning as well as survey techniques and calibration. 14 students participated in the course, all from Ghent University.

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FOKUZ Marine Masters Course 'Exploring the Wadden Sea', 3–14 July.

The course was organised by Herman Ridderinkhof and Henko de Stigter* in collaboration with members of all NIOZ scientific departments. The course has its origin in the FOKUZ (Fundamenteel Onderzoek Kust en Zee) collaborative initiative of NIOZ and NIOO-CEME, and is part of the National Dutch Marine Sciences Educational Program, in which NIOZ participates together with universities of Utrecht, Groningen and Amsterdam (UvA and VU). Intended for masters students in studies related to oceanography, the course program covers all main disciplines of oceanography: physics – chemistry – biology – geology. This year, a total of 23 students from five different universities attended the course. During lectures on the first day, the main oceanographic disciplines were introduced. In the following days the emphasis was on practical work in the western Wadden Sea, onboard the research vessels Navicula and Stern and in NIOZ laboratories. In groups of three, students worked on various thematic projects: hydrography and tidal dynamics of the Marsdiep tidal inlet, multibeam imaging of migrating sand dunes in the tidal inlet, reconstruction of the silting-up of a tidal channel, unraveling organic matter sources and food web relations using stable isotopes, plankton community of the western Wadden Sea, bivalve filtration capacities along an estuarine gradient, and estimation of shore crab abundance on a littoral mussel bed. The course was concluded by two days for data analysis and a full final day on which students presented and discussed the results of their practical work.

Students were accommodated in campus 'De Potvis' with catering arranged by Texel Catering. Thanks to the joined efforts of all supervisors and technical staff involved, the students provided an overall very positive evaluation of the course.
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First Darwin Summer School of Biogeosciences was held from 4-15 July in both Utrecht and Texel.

This summer school was an initiative of the Darwin Center for Biogeosciences organized by the coordination office of this center and Lennart de Nooijer (Utrecht University) and Laura Villanueva (Royal NIOZ). 25 Master students and early PhDs from different nationalities attended this course that covered different topics related to the perturbation of the carbon cycle. The topics covered ranged from ocean acidification, terrestrial carbon cycle, organic geochemistry, and microbiology. Lectures were combined with practicals (modeling, paleoclimatology, analytical techniques in biogeochemistry, molecular biology). Two invited speakers gave plenary lectures and practical's: Ann Pearson (Harvard) and Howard Spero (UC Davis). Speakers from the NIOZ included: Klaas Timmermans (BIO), Hein de Baar (BIO), Stefan Schouten (BGC), Ellen Hopmans (BGC), and Laura Villanueva (BGC).

Public Outreach

Eric Epping

NIOZ public outreach efforts in 2011 have been made mostly by individual scientists, sharing facts and opinions on a changing sea as a consequence of climate change or due to more local human impact. Internationally, 'NIOZ' has been reported 433 times in newspapers, television, radio, and internet media with a potential viewer equivalent of over 400 million. In total 233 reports were made in national media, 22 of which in national newspapers, 2 on national television, 9 on national radio, and 23 in regional newspapers, overall equivalent to over 3 million potential viewers (source: Meltwater News).

Regional newspapers especially enlarged on the work of Lodewijk van Walraven studying the comb jellyfish (a.o. 8/1 Noord Hollands Dagblad, 8/1 Gooi en Eemlander, 22/1 de Gelderlander, 10/3 Limburgs Dagblad). This jellyfish, native to the western Atlantic, invaded the Black Sea in the 1980's probably as a consequence of ballast water exchange. Feeding on fish eggs and larvae, this species is held accountable for the collapse of the commercially important anchovy stock in the Black Sea. Its appearance in the North Sea in 2006 triggered an international monitoring campaign as part of the 'MEMO' project. The project, granted 3.5 million euro, aims to develop a proper identification key, to establish the jellyfish' menu and to make a risk assessment for the ecosystem of the North Sea and adjacent waters.

Of a much longer duration, lasting now for over four decades, is the monitoring of benthic fauna on the Balgzand tidal flat. Rob Dekker reported a remarkable increase in the diversity of benthic fauna (1/8 Noord Hollands Dagblad). New species, such as the Atlantic jackknife and Pacific oyster, may have been introduced deliberately or accidentally by ballast water release from merchants' ships, whereas species native to coastal North Sea waters such as common cockle, brown shrimp and the thin tellin may have settled on the tidal flats as a consequence of mild winter periods. The abundance of some species, such as the Baltic tellin, has declined relative to earlier times. It serves a good illustration that a reference to the past is helpful in establishing changes and identifying potential causes in a changing world.

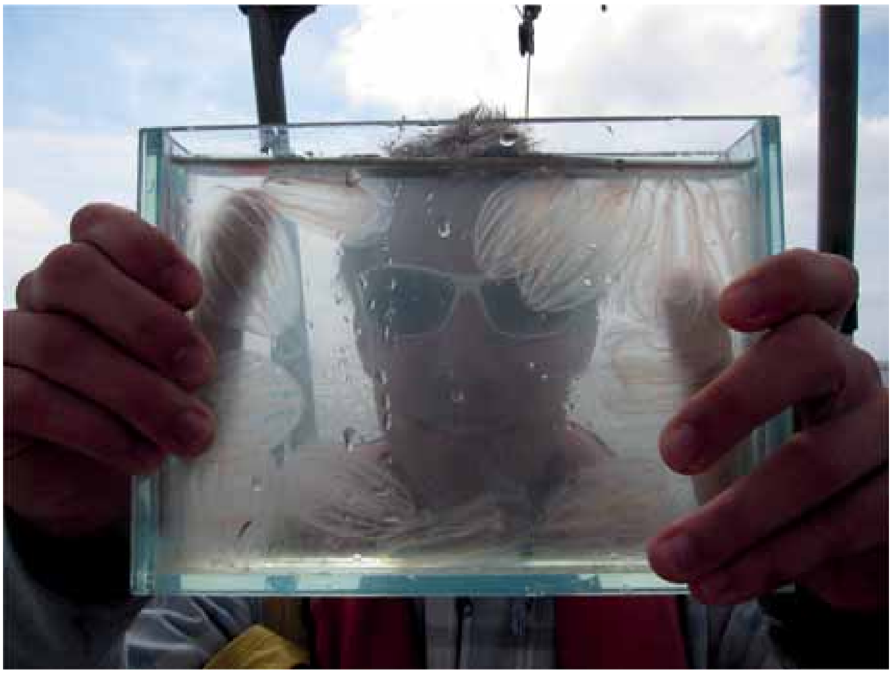

Photo: Lodewijk van Walraven NIOZ

In a full page contribution to NRC newspaper (10/9), Kees Camphuijsen takes a critical stance on the rescuing of individual animals such as the Emperor Penguin 'Happy Feet' or the stranded orca 'Morgan'. "No matter how good the intention", he states, "it obscures the real issue; large scale destruction of resources and habitats".

The humpback whale showing up in the Marsdiep area early June is the 11th juvenile spotted in Dutch waters since 2003 which contrasts their absence for a period of 3 centuries. Equally puzzling are the increased numbers of harbour porpoise strandings on Dutch beaches. Recent observations suggest an increased coastal abundance as well as a more southward distribution of the species. It is unclear however, if this is the consequence of a growing population, or due to the migration from other areas of the North Sea. In a concerted effort with fisheries and nature conservation organizations, Kees Camphuijsen advocated an all-inclusive study to estimate the population strength of the harbour porpoise and to identify the causes for the increased number of strandings. Their report and recommendations have been well received by the State Secretary for Economic Affairs, Agriculture and Innovation, Henk Bleker, who will install a scientific steering committee for the research on harbour porpoise.

Jaap Sinninghe Damsté was interviewed for Dutch Radio 1 (6/8), de Volkskrant (5/8) and Het Parool (13/8) for his recent work on the climatology of East Africa,

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triggered by the humanitarian crisis. He co-authored a Science publication on interannual climate variability since the last ice age, using a 25,000 years sediment record from Lake Challa, a freshwater crater lake on the lower slope of Mount Kilimanjaro (Kenya/Tanzania). Thick layers of annual sedimentation corresponded to dry La Niña years and, conversely, thin layers corresponded to wet El Niño years. This finding allowed the authors to use the thickness record for a reconstruction of climate or, more specifically, rainfall variability in East Africa over the past 25,000 years. During the last ice age, a more stable and arid climate prevailed, whereas a more variable climate with extremity excursions developed since 3,000 years.

Extrapolation of these findings suggests that future warming will probably intensify interannual variability of East Africa's rainfall, in line with climate model simulations. The study strengthens the idea that the La Niña-El Niño indices should be considered an 'early warning system' for massive drought and potential humanitarian crises in the area.

Finally, the international media paid great attention to the findings of the Climate Change and European Marine Ecosystem Research (CLAMER) project, a collaboration of 17 institutes in 10 countries, coordinated by Katja Philippart and Carlo Heip. Within this project, an inventory has been made of the results of almost 300 climate change related research projects, that were funded by the European Union over the past 13 years. Each of three press releases in April, June, and September, gave rise to reports on hundreds of news sites, newswires, newspapers, online media and to radio interviews with the coordinators and with Laura de Steur who contributed to the synthesis of results for the press release.

Organization

BOARD AND SCIENCE COMMITTEE

Board

As per 31 December 2011, the Board consisted of the following members:

prof.dr.ir. P. Vellinga (chairman)	Wageningen University and Research Centre
prof.dr. E.A. Koster	Utrecht University , Faculty of Geosciences
prof.dr. J.T.M. Elzenga	CEES, Groningen University
G.F.C. van der Kamp	Naarden
ir. A. Lubbes	Fugro, Leidschendam

In the report year 2011, Board and directors convened five times, on 14 January, 24 March, 19 May, 22 September and 24 November.

As advisor on behalf of the NIOZ Science Committee, the meetings were attended by prof.dr. W.P.M. de Ruijter (IMAU, Utrecht University).
On behalf of the general director of NWO, the meetings were attended by drs. R.M.L. Schorno (NWO-CPI).
The minutes were made by mrs. C.S. Blaauboer-de Jong.

Science Committee

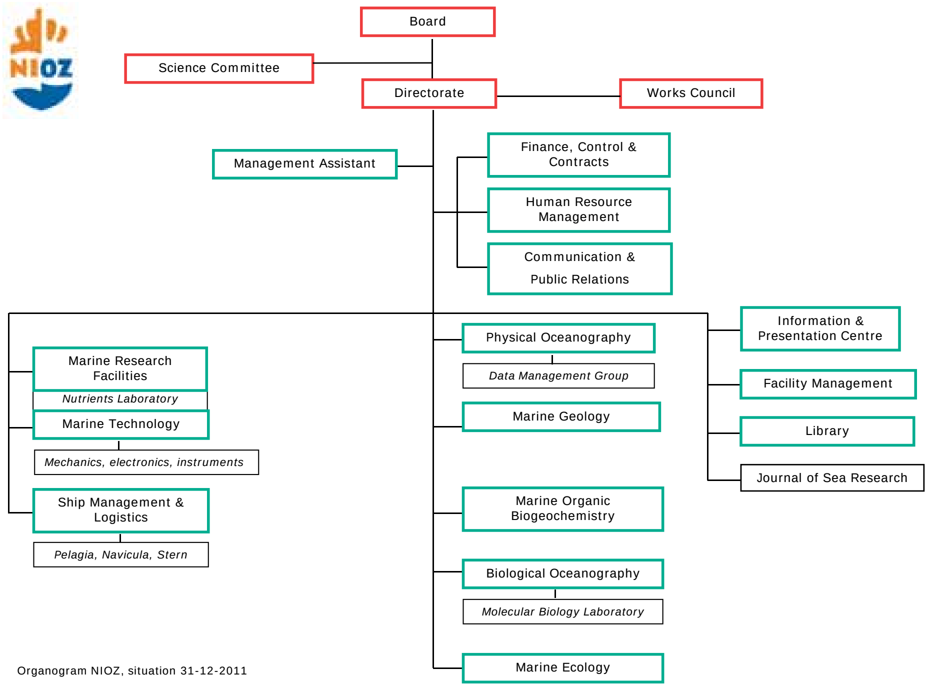
The Science Committee advises the Board and the directors with regard to the general scientific policy of the Foundation and the Institute, she evaluates periodically the scientific programme of the institute.

As per 31 December 2011, the Science Committee consisted of the following members:

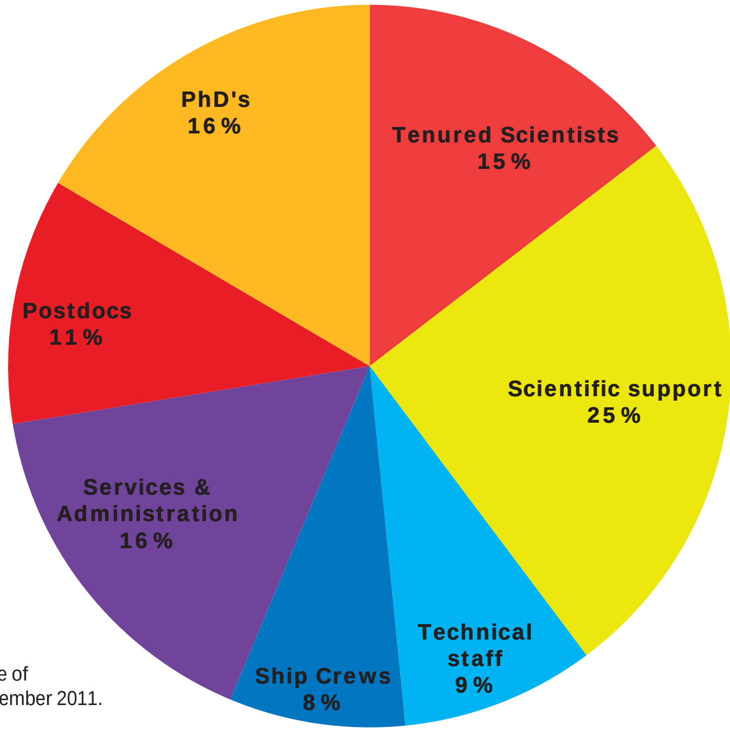
prof.dr. W.P.M. de Ruijter (chairman)	IMAU, Utrecht University, The Netherlands
prof.dr. A. Boetius	MPI for Marine Microbiology, Bremen, Germany
prof.dr. P. Burkill	PML Plymouth, United Kingdom
prof.dr. J.J. Middelburg	Utrecht University, The Netherlands
prof.dr. P. Weaver	NERC, Southampton, United Kingdom

In 2011, the Science Committee convened on Texel on 19 and 20 May.

Organogram



Organogram NIOZ, situation 31-12-2011



NIOZ formation as percentage of
total FTE's (227.24) at 31 December 2011.
Total of employees was 254
(undergraduate students not included)

Staff list

Directors and Staff
Brinkhuis H. prof. dr.
Heip C.H.R. prof. dr.
Ridderinkhof H. prof. dr.
Koning F.A. dr.
Bakker K.M.J.
Crayford S.J.
Gonzalez S.R.
Ooijen J.C. van
Kralingen P. van
Blaauboer-de Jong C.S.
Raad I. de

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Arkel M.A. van MSc
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Dapper-Maas M.A.
Gootjes J.P.
Groot S.P.
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Honkoop P.J.C. dr.
Keijser A.
Kooijman-Biermans M.H.M.
Poleacov-Maraiala C.
Tuinen H.A. van
Wernand-Godee I.

Human Resource Management
Vooijs P.C.
Evers J.M.E.
Dapper R.
Kuip T.
Moerbeek-Sikma S.
Mulder-Starreveld J.P.

Communication & Public Relations
Boon J.P. dr.
Bloksma N.R.

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Maas L.R.M. prof. dr.
Eijgenraam F.
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Groeskamp S.
Haren J.J.M. van dr.
Heide R.H.E. van der
Hiehle M.A.
Hillebrand M.T.J.
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Vries J.J. de MSc.
Wagemaakers F.F.M.
Wernand M.R. dr.
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Koster R.X. de
Louws R.J.
Nieuwenhuis J.

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Brummer G.-J.A. prof. dr.
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Epping H.G. dr.
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Gaever P.A.J. van
Grove C. MSc
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Steinhardt J.J. MSc
Stigter H.C. de dr.
Stuut J.B.W. dr.
Tjallingii R.H. dr.
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Schouten S. prof. dr.
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Blaga C.I. dr.
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Boon J.P. dr.
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Weerlee E.M. van
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Dapper-Maas M.A.
Heerschap J.H.
Hillebrand-Kikkert A.
Lakeman R.
Trap B.

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Porto H.H. de

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Bakker R.
Boekel H.J.
Keijzer E.J.H.

Marine Technology Electronics
Lenting W.A.
Groenewegen R.L.
Asjes A.J.
Cluderay J.M.N.
Franken H.
Koster B.
Laan M.

Marine Technology Mechanical
Schilling J.
Bakker M.C.
Blom J.J.
Boersen B.
Boom L.
Gieles S.J.M.
Grisnich P.W.
Okel L.A.G.
Visser J.D. de
Witte Y.
Wuis L.M.

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Adriaans E.J.
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Boon W.J.
Burkhard I.
Dresken J.T.
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Feij B.
Frankfort M.
Haaren J. van
Heide R. van der
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Nieboer A.L.
Puijman E.A.
Seepma J.
Star C.J. van der
Stevens C.T.
Vermeulen G.P.
Vis P.C.A. van der
Vorsselen W.S.F. van
Vries H. de
Vries M.J. de

Emeritus Scientists

Baars M.A. dr.
Bak R.P.M. prof. dr.
Beukema J.J. dr.
Cadée G.C. dr.
Leeuw J.W. de prof. dr.
Vooys C.G.N. de dr.
Wolf P. de dr.

Guest scientists

Cardoso J. dr.
Carreira C. MSc.
Corte D. De Msc
Fuhr F. MSc
Goeij P.J. de dr.
Hallers-Tjabbes C.C. ten dr.
Jager C. de prof. dr.
Leote C. MSc
Lok T. MSc
Santos S. MSc
Saraiva S.A. MSc
Sliwinska K.K. dr.

Financial report

Financial Report

*Tjerk Vos**

All amounts should be multiplied by € 1000 and are rounded to the next € 1000.
Negative amounts are given in brackets.

Balance sheet

ASSETS	**31-12-2011**	**31-12-2010**	**LIABILITIES**	**31-12-2011**	**31-12-2010**
Fixed assets			**Capital and reserves**		
Intangible fixed assets	-	-	Foundation capital	-	-
Tangible fixed assets	37,587	35,028	Free reserve	(6,770)	(6,920)
			Designated reserve	7,104	6,847
			Special reserve fund	36,207	32,542
	37,587	35,028		36,541	32,469
Current assets					
Stocks	140	39	**Provisions**	819	1,266
Receivables	7,678	9,689	**Long term debts**	1,692	1,846
Cash and cash equivalents	2,830	1,245	**Short term debts**	9,184	10,421
	10,648	10,974		11,695	13,533
Total assets	**48,235**	**46,002**	**Total liabilities**	**48,235**	**46,002**

***Corresponding author: tjerk.vos@nioz.nl**

Profit and Loss account

	2011 actual	2010 budget	2010 actual
Profit			
Grants			
NWO basic funding	11,426	11,666	11,426
NWO investment funding	6,050	2,134	6,175
NWO additional funding	1,180	1,160	1,630
Contributions by third parties	9,677	8,656	10,860
Total grants	28,333	23,616	30,091
Change project liabilities	2,872	1,265	(1,422)
Other operating income	587	388	589
Available provisions	299	92	408
Interests received	39	15	15
Total other income	925	495	1,012
Total profit	**32,129**	**25,376**	**29,681**
Costs			
Personnel costs	15,037	15,158	13,717
Other operating costs	9,603	6,968	7,174
Depreciation	3,171	3,780	3,584
Allocation provisions	188	60	105
Interest paid	59	71	66
Total costs	**28,058**	**26,037**	**24,646**
Operating result	**4,072**	**(661)**	**5,035**
Profit appropriation	(3,921)	1,524	(4,354)
Result after profit appropriation	**150**	**863**	**680**

Cashflow statement

	2011		2010	
Operating cashflow				
Balance income and expenses	4,072		5,035	
Adjustments				
Depreciation	3,171		3,584	
Movement provision	(447)		(770)	
	2,724		2,814	
Moving working capital				
Receivables	2,011		(4,180)	
Stocks	(101)		43	
Short term liabilities	(1,237)		1,480	
	673		(2,658)	
	7,468		5,191	
Moving working capital		7,468		5,191
Receivables				
Stocks				
Short term liabilities				
Investments intangible fixed assets	-		-	
Investments tangible fixed assets	(5,730)		(8,586)	
Drop in investments	-		188	
Investment cashflow		(5,730)		(8,398)
Financing cashflow				