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SCIENCE FOR A SUSTAINABLE DEVELOPMENT

"Biodiversity of three representative groups of the Antarctic Zoobenthos - Coping with Change"

«BIANZO II»

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Antarctic Biodiversity

FINAL REPORT PHASE 1

Biodiversity of three representative groups of the Antarctic Zoobenthos - Coping with Change

"BIANZO II"

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Polar regions experience greater rates of climate change than any other region in the world. Especially the Antarctic Peninsula is one of the fastest warming regions on earth. The Antarctic fauna is known to be generally stenothermal and vulnerable to increased temperatures, and might therefore be severely impacted by a changing (warming) environment. Global climate warming also has secondary effects on the environment and its inhabitants, *e.g.* large-scale ice-shelf disintegration events, changes in the availability, quantity and quality of food (regime shifts), ocean acidification, increased glacier melting (incl. freshening and increased sedimentation)… The complexity of effects, responses and interactions can only be understood if we increase our knowledge of the biology of our target group, *i.c.* the Antarctic zoobenthos. It is crucial to establish comprehensive baseline information on Antarctic marine biodiversity as a sound benchmark against which future change can reliably be assessed. It is also imperative to better understand the ecological role of biodiversity in the functioning of the Southern Ocean ecosystem and to assess how its structural and functional characteristics might be affected by a changing climate. These aspects are addressed in the BIANZO II project, by focusing on representatives of three zoobenthic size classes: Nematoda (meiobenthos), Amphipoda (macrobenthos) and Echinoidea (megabenthos).

The project is constructed around three complementary work packages: NOWBIO, DYNABIO and FOREBIO. NOWBIO deals with the characterization of Antarctic benthic biodiversity and its distribution along bathymetric and geographical gradients, and the explanation of its underlying processes. Special attention is devoted to cryptic speciation and ectosymbiosis. The DYNABIO work package focuses on the ecofunctional role of benthic biodiversity and the ability of the benthos to cope with change. This includes the study of trophodynamic and metabolic aspects of the investigated fauna, as well as the impact of temperature-related change, including direct temperature impact, changes in food availability and composition, and seawater acidification, on functional and structural aspects of the benthic communities. Information collected during previous projects and in the first two workpackages are also used to develop a model on the possible changes in benthic communities due to global environmental change (FOREBIO WP).

During phase 1 of the project, the focus of our research was put on biogeography and phylogeography, the trophic position of the three benthic groups, their ability to cope with warming and acidification, and their response to large-scale ice-shelf disintegration.

Samples were collected during several expeditions in the Weddell and Scotia Sea: ANDEEP I, II, III; ANDEEP-SYSTCO; ANT-XXIII-8 and BENTART'06. The meiobenthos was sampled by means of a multicorer (shelf and deep sea) or by divers (shallow subtidal), the macro- and megafauna with a variety of sampling gear, such as Agassiz trawls and Rauschert dredges. Genetic characterization of amphipods was based on the analysis of COI, 28S and 18S sequences. The trophic position of the target groups was investigated by biomarker analyses ($\delta^{13}C$ and $\delta^{15}N$ stable isotopes; fatty acids), gut content analyses, and characterization of the gut microflora. The ability of the benthos to cope with temperature increase, the influence of trophic stress on the energy budget of amphipods, and the impact of acidification on skeletal growth and larval development in echinoids, were investigated by means of a laboratory experiment.

The FOREBIO GIS model is currently being constructed. The frame, based on latitude and longitude data, is already finished (ahead of schedule), and both sediment and depth data are already added. Data on marine currents and surface + sea floor temperatures are being added at this moment. Specific data for echinoids have also been added already, including taxonomic information, sampling coordinates, and complementary data on taxon ecology. Taxon ecology includes life mode, nutrition, reproduction and symbiosis.

A thorough examination of new specimens and museum material of the amphipod genus *Liljeborgia* lead to the description of 15 new species and a detailed revision of the genus. A biogeographical survey of *Liljeborgia* suggests recent faunal exchanges between shelf and abyssal species in the Antarctic, and a certain degree of endemism, with certain species limited to the high Antarctic and others to subantarctic areas. Similar levels of endemism were observed in the family Phoxocephalidae. The absence of eyes in Arctic representatives of the *Liljeborgia georgiana* group suggests an origin of this group on the Southern Ocean shelf and a loss of eyes during migration to the north at abyssal depths. Although *Liljeborgia georgiana* specimens from the same location have the same haplotype, specimens from distant locations and different depth ranges are genetically distinct, even to the extent where the deeper representatives of the species will be described as a new species. An in-depth revision of the Antarctic amphipod fauna also resulted in the desription of two new families: the Alicellidae fam. nov. and the Valettiopsidae fam. nov. A molecular (COI) analysis of representatives of the orchomenid group within the family Lysianassoidea revealed new species, and the species *Orchomenella pinguides* and *O. cavimanus* are now recognized as complexes of cryptic, sympatric species. These findings have important implications with regard to the biogeography and biodiversity of the Antarctic amphipod fauna.

On the genus level, nematode diversity is comparable to that in the Atlantic and Mediterranean, and much higher than in the Arctic Ocean. For amphipods, the Weddell Sea, Antarctic Peninsula (+ South Shetland Islands), Ross Sea, South Georgia, Kerguelen Islands and Bouvet Island are recognized as biodiversity hotspots. Out of 900 echinoid species, 79 occur south of the Antarctic Polar Front. In the Southern Ocean, many nematode species are new to science and rare. They can be either very restricted in their distribution, or they can occur in a very broad area. On the species level, nematodes might have a high degree of endemism in the Antarctic, although pathways towards lower latitudes exist. Within the gammaridean and corophiidean amphipods, endemism rates may be as high as 79.8% in the Southern Ocean. Endemism is particularly high in Antarctic echinoids: 68% of the species are endemic to the Southern Ocean. More than 80% of all Cidaridae and Schizasteridae are also endemic. Distribution patterns of the Antarctic zoobenthos are also influenced by bathymetry. Nematode genera might have a wider depth range in Antarctica in comparison to other parts of the world, and eurybathic distribution patterns might also be common in this group. There are three distinct groups within Antarctic amphipod species, with regard to bathymetry: a shelf group, a deep shelf-upper slope group and a deep slope-abyssal group. Although some species appear to have wide bathymetrical distributions, molecular analyses are needed to rule out cryptic speciation. In echinoids, there are stronger similarities between shelf and upper slope than between slope and deep sea.

It remains unclear what drives the high local meiobenthic diversity in the deep-sea, although it could be related to primary productivity. This is investigated by comparing the communities at a Polar Front station and at a station located more to the south. There is also growing evidence that bacteria might constitute an important fraction of the food ingested by nematodes. An *ex situ* enrichment experiment with a ^{13}C label was carried out with deep-sea material from Maud rise. First results are still underway, but a parallel experiment in the Arctic Ocean revealed little or no uptake of bacteria by nematodes.

Another *ex situ* feeding experiment was carried out on King George Island, with material from the shallow Potter Cove. The experiment aims to unravel nematode feeding preferences. ^{13}C-labeled bacteria and diatoms were added to sediment cores under controlled conditions. The samples are currently being processed, but a preliminary survey of the natural community composition revealed high meiobenthic and nematode densities (6315 nematodes/10 cm^2 on average), and a nematode assemblage dominated by *Aponema*, *Daptonema*, *Amphimonhystrella* and *Halalaimus*. This might indicate high amounts of organic food.

In the same area, direct temperature effects on Antarctic benthic communities were investigated by means of a laboratory benthic respiration experiment with closed sediment and water cores incubated at 0°C, 2°C, 4°C and 6°C. There is a strong decline in oxygen concentration for all sediment treatments, although the rate of decrease becomes higher with each temperature increase. The "anoxic" phase is reached after 7 days in the 6°C treatment, whereas the 0°C treatment had not yet reached this phase after 14 days. Benthic respiration was also higher in food-enriched cores, and the decline in oxygen concentration occurred much more rapid in these cores.

Peracarid fatty acid composition, focused on amphipods, revealed distinct differences between pelagic species, which are carnivorous or omnivorous and mainly feed on flagellates, and scavengers, characterised by an intensive *de novo* biosynthesis. In Antarctic scavengers, the speed of adjustment in body tissue stable isotope ratio as a reaction to new food sources differs between species and depends on their lifestyle. The Specific Dynamic Activity (SDA) experiment, designed to obtain a detailed picture of post-prandial metabolism increase, encountered many problems. However, it revealed that scavengers have a strong ability to cope with long periods of starvation.

The echinoid *Sterechinus antarcticus* from the Antarctic Peninsula is a carnivore and deposit feeder, feeding mainly on a wide range of animals and sediments. In contrast, Antarctic Cidaridae only feed on hydrozoans and bryozoans and the temperate species *Paracentrotus lividus* is either an exclusive herbivore (Mediterranean), or an omnivore feeding on plants, algae and animals (Brittany). *Sterechinus antarcticus* is clearly a generalist feeder, and might therefore be well-adapted to cope with changes in food resources that might result from global climate change, whereas Cidaridae are probably more sensitive. Gut content analysis and stable isotopes analysis revealed that *Sterechinus antarcticus* ingests large amounts of sediment (and the organic matter associated with it). Most of the bacteria found in the gut of this species were related to inhabitants of marine sediments, and even bacterial groups occurring in cold-seep sediments. Other bacteria were known to be associated with sea ice, marine water or marine invertebrates. To conclude, the gut microflora of *S. antarcticus* is not symbiotic or specific, but consists of (transient) bacteria occurring in its environment, and probably associated with the sediment ingested by the echinoid. Cidaridae are characterized by a poorly developed gut microflora.

Global climate change may lead to the collapse of large ice shelves. In 2002, 500 billion tons or 3250 km² of ice from the Larsen B ice shelf collapsed at the eastern side of the Antarctic Peninsula, and this in only one month's time (31/01-07/03/2002). A few years before, in 1995, the ice shelf of the nearby Larsen A region had already disintegrated completely. Ice-shelf collapse initially leads to increased iceberg disturbance and may have detrimental effects on surface primary productivity, but later, the formerly ice-covered area opens up, leading to increased primary production and the opportunity to enter the area for scientific investigations. The area was investigated between 11/01/2007 and 22/01/2007. Meiofauna was collected at one station close to the former ice-shelf edge (B_South), two stations deep inside the Larsen B area (B_North; B_West), and one station deep inside the Larsen A area (A_South), at depths between 229 and 427 m. Pre-collapse, sub-ice conditions were unfavourable because food was limiting, and the meiobenthic community underneath the ice shelves was, although certainly present, clearly impoverished in abundance and diversity. The situation at station B_West, with low densities, low genus richness and high dominance of *Halomonhystera*, indicate pre-collapse conditions. Meiobenthic and nematode communities at all investigated stations were significantly different from each other. Only at station B_South were meiobenthic and nematode densities higher or in the range of densities found at other sites in the Southern Ocean. The 'inner' stations were still impoverished 5 years after the 2002 Larsen B ice-shelf collapse event. After ice-shelf disintegration, densities increased only slowly as a response to locally increased food availability (phytoplankton blooms) and the arrival of quick colonizers from the nearby Weddell Sea. An extrapolation of iceberg scour recolonization speed by nematodes revealed that it would take more than 1000 years for the nematode community in the deeper parts of the Larsen embayment to fully recover its abundance levels. At the other hand, first colonizers might reach the inner Larsen stations within a decade or more. Quick colonizers might have seized the opportunity to swiftly invade the new space. The nematode genus *Microlaimus*, dominant at station B_South, is a rather important and usually (sub)dominant genus in the Antarctic and subantarctic, and is known as an opportunist, successful and fast colonizer. The inner stations B_West, B_North and A_South were not yet colonized by nematodes from the open Weddell Sea at the moment of sampling. Differences in the local genus pool between these stations are probably the result of changes in local environmental conditions. The close resemblance between stations B_North and A_South, although physically separated by the Drygalski Glacier Cliff, is probably the result of a recent phytoplankton bloom in the area. Differences between these stations are attributed to differences in sediment composition. The high diversity at A_South is related to a high amount of fresh food and relatively coarse sediment at this station. On the other end, station B_North is characterized by low diversity, which is attributed to high dominance of nematodes and of *Thalassomonhystera* within the nematode community.

Ectosymbiosis on cidaroid echinoids positively influences local epibiont biodiversity. However, in the Larsen area, which became recently free of ice cover, the symbiotic communities on cidaroids are poor and resemble epibionts communities found on stones in the same area. This could indicate that the recolonization of the area by echinoid ectosymbionts is still in an early phase, and that a climax community has not yet been established.

The three echinoid species encountered in the Larsen area are all widely distributed, indirect developing non-brooders, characterized by high dispersive capacities. They are also deposit feeders, which feed on a variety of food sources. Such attributes are typical for quick colonizers, indicating that these species might be pioneers in the recolonization of the formerly ice-covered Larsen area.

Increased anthropogenic CO_2-emission has led to a decrease in ocean surface pH. An experiment with controlled lower pH values was carried out to investigate the effect of ocean acidification on larval and adult sea urchins. At lower pH, significantly more larvae showed an abnormal morphology and a reduced size. In adult sea urchins, the internal pH decreased significantly with the decrease of external seawater pH. This indicates that sea urchins have a poor acid-base compensation mechanism. In the subantarctic species *Arbacia dufresneii*, no skeleton dissolution mechanism takes place to compensate the coelomic fluid acidosis. No significant differences in spine regeneration speed with decreased pH were observed, and it is hypothesized that calcification in the endoskeleton of adult sea urchins is not affected by medium-term exposure to low pH. In the Antarctic cidaroid species *Phyllacanthus imperialis*, a certain degree of corrosion was observed, which was higher in young spines at lower pHs, indicating that these structures, characterized by an epithelium cover, are more fragile than the mature, naked spines.

The BIANZO II project succeeded in achieving most of its aims. Future work within phase 2 of the project includes an increased effort in the integration of the results of the separate partner institutions, and the construction and application of the FOREBIO GIS model. Integration will be achieved by a collaborate effort to synthesize the effects of global climate change on the Antarctic zoobenthos, which will result in a joint review paper on this topic.

Our research indicated that global climate change, both warming itself and warming-related changes, clearly affects the Antarctic zoobenthos. Although some effects, such as the disintegration of large ice shelves, are not considered to be entirely detrimental for the benthic fauna, other effects, such as ocean acidification, have been shown to have a negative effect on the development of benthic organisms, *i.c.* echinoids. The work performed within the framework of the BIANZO II project also revealed the complexity of the intimate interactions between organisms and their environment, and the vulnerability of many Antarctic benthic taxa to a changing environment. BIANZO II provides policy decision makers with additional arguments for the acute threat of global warming and for the promotion of environmentally friendly alternatives for current energy supply.