



Expedition Programme No. 47

RV "Polarstern"

ANTARCTIC XV/3-5
1998

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RV "Polarstern"

**ANTARCTIC XV/3-5
1998**

Coordinator: W. E. Arntz

ANT XV/3

**Ecology of the Antarctic Sea Ice Zone (EASIZ II)
Capetown - Punta Arenas (13 January - 26 March)
Chief Scientist: W. E. Arntz**

ANT XV/4

**Chief Scientist: E. Fahrbach
Punta Arenas - Capetown (28 March - 21 May)**

ANT XV/5

Capetown - Lisbon - Bremerhaven (23 May - 21 June)

1. **Cruise Leg ANT XV/3 (EASIZ II)**
Capetown - Punta Arenas: 13 January - 16 March 1998
Chief Scientist: Wolf Arntz

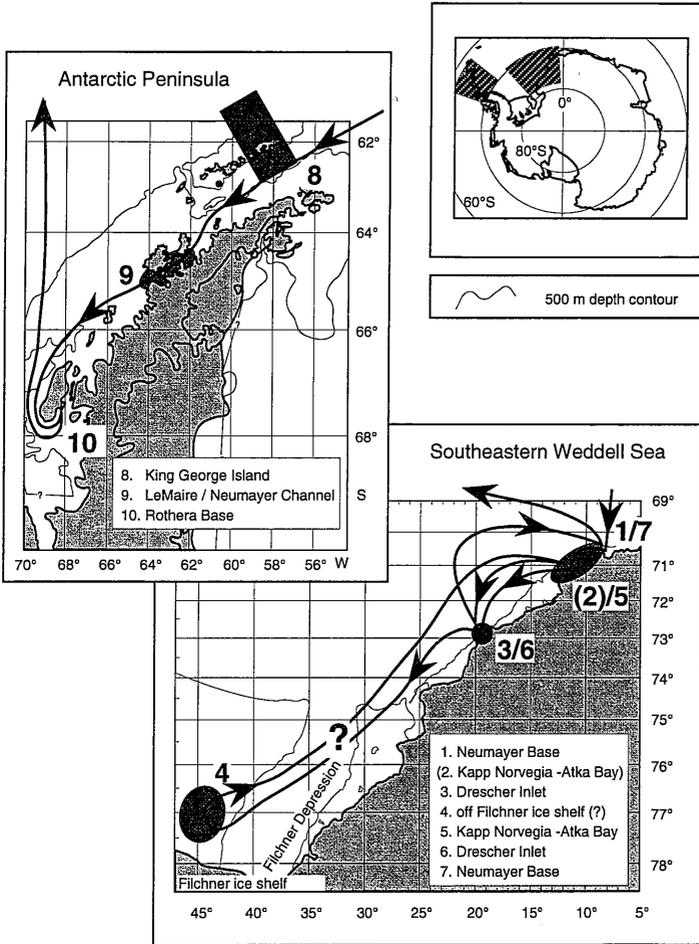


1.1 **Scientific background, objectives and itinerary**

The EASIZ (Ecology of the Antarctic Sea Ice Zone) programme of SCAR, planned as a complementary approach to SO-JGOFS and SO-GLOBEC and with emphasis on the ecology of the Antarctic sea ice zone, combines investigations from the shore stations around Antarctica with ship-board work on the shelf and slope. Its terms of reference were approved at the SCAR XIII meeting in Rome (1994):

"The aim of the EASIZ Programme is to improve our understanding of the structure and dynamics of the Antarctic coastal and shelf marine ecosystem, the most complex and productive in Antarctica, and likely the most sensitive to global environmental change. Particular attention will be paid to those features that make the biology of this ice-dominated ecosystem so distinctive, and to understanding seasonal, interannual, and long-term changes."

The first international EASIZ cruise on RV "Polarstern" took place in early 1996. 40 scientists, 17 of them from European neighbour countries, worked in the pack-ice zone of the southeastern Weddell Sea, focussing their research primarily on the benthos and fish communities.



ANT XV/3, map of investigation.

Numbers indicate planned sequence of working areas.

Two core projects were carried out: i) the study of iceberg impact on the bottom fauna using mainly visual methods, and ii) the investigation of the trophic relations between different components of the high Antarctic ecosystem including benthopelagic coupling. In addition, many studies which had been initiated during EPOS (European Polarstern Study) were continued or complemented, including benthic and demersal fish community structure, population dynamics and reproductive biology of fish and benthos, and ecophysiological as well as taxonomic work.

EASIZ cruise II (ANT XV/3) will continue the same approach as during EASIZ I, concentrating on few localities ("box concept") and a limited number of joint projects rather than on large-scale sampling. The principal projects to be undertaken include:

- (i) **the effect of iceberg scour on macro- and meiobenthic, and demersal fish, communities.** During EASIZ I, recurrent patches of benthic fauna were found ranging from very poor stages on fresh scours to mature, obviously old "cabbage type sponge" stages. We suspect them to be successional stages during the process of recolonization after an iceberg impact. We need finer identification and separation of these stages, and we need to place them in a temporal sequence, to assess the capacity of recovery (resilience) of these communities. Parallel to these studies, a long-term experiment on benthic colonization of hard bottoms (tiles) will be initiated.
- (ii) **bentho-pelagic coupling in the high Antarctic ecosystem and the role of suspension feeders.** Analyses of the food of benthic suspension feeders (hydroids, gorgonarians, pennatularians) during EASIZ I revealed very little connection between the strong rain of larger particles and aggregates sinking to the seafloor in Antarctic summer and the food intake by these organisms. Careful sampling and experiments aboard the vessel will be carried out to learn what kind of food the high Antarctic suspension feeders subsist on. An attempt will be made also to collect hard-bottom suspension feeders from a shallow (60 m) mound which was detected by ROV during the former cruise.
- (iii) **diving and foraging behaviour of Weddell seals in relation to the available food.** In the Drescher Inlet, Weddell seals will be equipped with various instruments indicating their diving frequency and depth, and their intake of pelagic or benthic food. At the same time, food availability will be studied using different trawls (benthopelagic, Agassiz) in open water and at the seafloor. During EASIZ I, sampling in the pycnocline yielded only minute

specimens of notothenioid fish whereas former studies on Weddell seal food intake had suggested adult *Pleuragramma* to be the staple food of these seals.

- (iv) **biodiversity and evolutionary links of the high Antarctic Weddell Sea with the Antarctic Peninsula area** (and the Magellan region which has been sampled recently). Major gaps still exist in the taxonomic inventory of many groups, and specific sampling by epibenthic sledge and multibox corer is required to account for smaller species, the hyperbenthic fauna above the seafloor, and latitudinal diversity gradients.

In addition to these core projects, studies will be undertaken, among others, on secondary metabolites and their role in species interactions, carbon and silica storage and flow on the Weddell Sea shelf and slope, benthic distribution and respiration, ultrastructure and population genetics of benthic fauna, migratory behaviour of crabeater and Weddell seals, physiology of benthic invertebrates, lipid storage of copepods, shelf sources of iron, and the ice platelet layer.

"Polarstern" will leave Cape Town on January 13, 1998 for Atka Bay to deliver personnel and equipment at Neumayer station, and, after deployment of some moorings at Kapp Norvegia, will head for the Drescher Inlet to get the seal and sea ice groups working. At the mouth of the inlet a number of trawl hauls will be taken (app. 4 days) to evaluate seal food availability in the water column and at the seafloor, and to provide some material for other working groups. Then a decision will be made, depending on the ice situation (to be derived from satellite pictures), whether the vessel will return to the EASIZ I box off Kapp Norvegia, or whether ice conditions allow it to proceed to the area off the Filchner Ice Shelf. As this area is usually covered by pack ice, it would make an interesting comparison to the Kapp Norvegia area, where there normally is a polynya. Depending on the selected working area, there will be about 3 weeks or a little more available for core projects i, ii and iv with some accompanying work, before the vessel returns to Drescher Inlet (latest arrival: 24 February) for a second phase of trawling which is to last another 4 days. Thereafter, the benthopelagic trawl and the demersal trawls will be stowed away, the Drescher crew will be taken aboard, and "Polarstern" will head for Atka Bay to take passengers and freight on board (max. 3 days), and continue towards King George Island. Jubany station must be reached no later than March 13 to pick up some samples and live material, and to be able to do some sampling off the Potter Cove, on the southern slope of the Drake Passage and -if ice conditions are favourable- in the Neumayer and/or

LeMaire Channel. The latter is on the way to Rothera where the vessel is to supply the station with some fuel. Rothera must be left in time to arrive on schedule in Punta Arenas, on 26 March 1998.

1.2 Zusammenfassende Übersicht

Das EASIZ (Ecology of the Antarctic Sea Ice Zone) - Programm des SCAR entstand als komplementärer Ansatz zu den Programmen Southern Ocean GLOBEC und JGOFS und berücksichtigt insbesondere die antarktische Packeiszone. Es verbindet die land- und eisgestützten Untersuchungen der Küstenstationen mit Schiffsinsätzen auf dem Schelf und Kontinentaltang. Seine Ziele wurden während des XIII. SCAR-Treffens in Rom (1994) festgelegt:

"Das Ziel des EASIZ-Programms ist, unser Verständnis von Struktur und Dynamik des antarktischen küstennahen und Schelf-Ökosystems zu erweitern, welches das komplexeste, produktivste und wahrscheinlich auch das gegenüber globalen Klimaveränderungen empfindlichste antarktische System ist. Dabei werden jene Eigenschaften besonders berücksichtigt werden, welche die Biologie dieses eisbeherrschten Ökosystems so unterschiedlich machen, darüber hinaus aber auch solche, die zu einem besseren Verständnis saisonaler, inter-annueller und langfristiger Veränderungen beitragen."

Die erste internationale EASIZ-Expedition auf der "Polarstern" wurde zu Jahresbeginn 1996 durchgeführt. 40 Wissenschaftler, 17 von ihnen aus europäischen Nachbarländern, arbeiteten in der Packeiszone des südöstlichen Weddellmeeres. Die Betonung lag dabei vor allem auf den Benthos- und Fischgemeinschaften. Die Reise hatte zwei Schwerpunkte: (i) die Untersuchung des Eisbergeinflusses auf die Bodenfauna mit vorwiegend visuellen Methoden und (ii) Klärung der Nahrungsbeziehungen zwischen verschiedenen Komponenten des hochantarktischen Ökosystems incl. der benthopelagischen Kopplung. Darüberhinaus wurden viele Ansätze fortgeführt oder vervollständigt, die während der EPOS-Reise (European Polarstern Study) begonnen worden waren; u.a. zur Struktur von Bodentier- und Fischgemeinschaften, zur Populationsdynamik und Fortpflanzungsbiologie von Fischen und Benthostieren sowie ökophysiologische und taxonomische Arbeiten.

EASIZ II (ANT XV/3) wird sich, wie schon EASIZ I, auf wenige Gebiete ("Box-Konzept") und eine begrenzte Zahl gemeinsamer Projekte konzentrieren, anstatt weiträumig Material zu sammeln. Die wichtigsten Projekte sind:

- (i) **der Pflugeffekt von Eisbergen auf die Gemeinschaften des Meio- und Makrobenthos und der Bodenfische.** Während EASIZ I wurden immer wiederkehrende Bodenfaunastadien beobachtet, die von stark verarmten Gemeinschaften auf frischen Pflugspuren bis zu reifen, offensichtlich sehr alten Stadien vom "Kohlkopfschwamm-Typ" reichten. Dabei handelt es sich offenbar um Sukzessionsstadien im Verlauf einer Wiederbesiedlung. Wir müssen lernen, diese Stadien genauer zu unterscheiden und sie zeitlich einzuordnen, um die Erholungsfähigkeit (Resilienz) dieser Gemeinschaften beurteilen zu können. Parallel zu diesen Studien soll ein Langzeitexperiment zur Besiedlung von Hartböden (Ziegeln) begonnen werden.
- (ii) **die benthopelagische Kopplung im Ökosystem der Hochantarktis und die Rolle der Suspensionsfresser.** Analysen der Nahrung benthischer Suspensionsfresser (Hydroiden, Gorgonarien, Pennatularen) während EASIZ I zeigten sehr schwache Beziehungen zwischen dem dichten Regen an größeren Partikeln und Aggregaten im antarktischen Sommer und der Nahrungsaufnahme dieser Organismen. Wir werden vorsichtig sammeln und Experimente an Bord durchführen, um zu lernen, wovon sich die hochantarktischen Suspensionsfresser ernähren. Es soll auch versucht werden, Hartboden-Suspensionsfresser von einem unterseeischen Hügel abzusammeln, der auf EASIZ I mit dem ROV in nur 60 m Tiefe entdeckt wurde.
- (iii) **Tauch- und Beutefangverhalten von Weddellrobben in Beziehung zum Nahrungsangebot.** Weddellrobben werden mit verschiedenen Instrumenten versehen, die Tauchfrequenz und Tauchtiefe der Robben sowie ihre pelagische oder benthische Nahrungsaufnahme anzeigen. Gleichzeitig soll unter Einsatz verschiedener Schleppnetze (benthopelagisches Netz, Agassiztrawl, Grundsleppnetz) die Nahrungsverfügbarkeit im offenen Wasser und am Meeresboden untersucht werden. Während EASIZ I ergab die Probennahme in der Dichteschicht im Gegensatz zu früheren Untersuchungen, nach denen die Nahrung von Weddellrobben vorwiegend aus adulten *Pleuragramma* besteht, lediglich winzige Fischchen verschiedener Notothenioidenarten.

- (iv) **Biodiversität und evolutionäre Verknüpfungen des hochantarktischen Weddellmeeres mit dem Gebiet der Antarktischen Halbinsel** (und der Magellanregion, aus der Proben bereits vorliegen). In der taxonomischen Inventur vieler Gruppen bestehen noch große Lücken, und gezieltes Sammeln mit dem Epibenthoschlitten und dem Mehrfachgreifer ist notwendig, um auch kleinere Arten und das über dem Boden stehende Hyperbenthos angemessen zu berücksichtigen und Aussagen über Breitengradienten zu machen.

Zusätzlich zu den genannten Schwerpunkten werden u.a. Untersuchungen zu folgenden Themen durchgeführt: Sekundärmetabolite und ihre Rolle für Interaktionen zwischen Arten, Speicherung und Fluß von Kohlenstoff und Silizium auf Schelf und Kontinentalhang des Weddellmeeres, benthische Verbreitung und Respiration, Ultrastruktur und Populationsgenetik benthischer Evertebraten, Wanderverhalten von Krabbenfresser- und Weddellrobben, Physiologie benthischer Evertebraten, Fettspeicherung von Copepoden, Eiseneintrag von der Küste, Untereis-Plättchenschicht.

"Polarstern" wird Kapstadt am 13. Januar 1998 mit Fahrtziel Atka-Bucht verlassen, wo Personal und Geräte für die Neumayer-Station abgeliefert werden. Von dort geht das Schiff nach Ausbringen von Verankerungen am Kapp Norvegia zum Drescher-Inlet, um die Robben- und Meereisgruppe abzusetzen. In der Mündung des Inlets werden eine Reihe von Schleppnetzfangen durchgeführt (ca. 4 Tage), um das Nahrungsangebot für die Robben in der Wassersäule und am Meeresboden zu untersuchen und Material für die anderen Arbeitsgruppen zu beschaffen. In Abhängigkeit von der Eissituation (aus Satellitenbildern) muß dann eine Entscheidung getroffen werden, ob das Schiff zur EASIZ I-Box vor Kapp Norvegia zurückfährt, oder ob die Eislage eine Weiterfahrt zum Seegebiet vor dem Filchner-Schelfeis gestattet. Da dieses Gebiet gewöhnlich von einer geschlossenen Packeisdecke überzogen ist, wäre ein Vergleich mit dem Kapp Norvegia-Gebiet sinnvoll, wo in der Regel eine Polynja offen ist. Je nach Arbeitsgebiet stünden dann 3 Wochen oder etwas mehr zur Durchführung der Schwerpunktthemen i, ii und iv und etwaige Nebenarbeiten zur Verfügung, bevor das Schiff zum Drescher-Inlet zurückkehrt (Ankunft spätestens am 24.2.), wo eine zweite Trawlphase von 4 Tagen Dauer beginnt. Danach werden das benthopelagische Netz und das Grundschleppnetz eingepackt, die Drescher-Crew an Bord genommen, und "Polarstern" dampft zur Atka-Bucht, um Passagiere und Fracht aufzunehmen (max. 3 Tage), bevor sie in Richtung King George Island abläuft. Die Station Jubany soll spätestens am 13. März erreicht werden. Dort werden Proben und Lebendmaterial aufgenommen sowie Fänge und

Unterwasseraufnahmen vor der Potter Cove, auf dem Südhang der Drake-Passage und - falls die Eissituation günstig ist - im Neumayer oder/und im LeMair Kanal gemacht. Letztere liegt bereits auf dem Weg nach Rothera, wo das Schiff die britische Station mit Brennstoff versorgen wird. Die Abreise von Rothera erfolgt so, daß "Polarstern" rechtzeitig am 26. März 1998 in Punta Arena eintrifft.

1.3 Benthic ecology (macrofauna)

1.3.1 Begin of a long-term experiment of benthic colonization and succession on the high Antarctic continental shelf (AWI)

Scientific background

Most ecologists believe that the Antarctic marine ecosystem should be particularly sensitive to disturbance. As reasons for this assumption they usually refer to the prevailing lack of physical and anthropogenic disturbance ("pristine ecosystem") and the specific life strategies of Antarctic organisms ("Thorson's rule"). Both these characteristics are not valid in an absolute sense. Disturbances are quite common in the zones where drifting icebergs scour the seafloor or where growlers and brash ice abrade the intertidal and upper subtidal. Among the organisms that live in the Antarctic ecosystem, some take the risk of mass production and rapid dispersal instead of investing -like the majority- in few, well-equipped, often carefully brooded descendants that start reproducing late in their life cycles and grow slowly.

The few colonization experiments which have been carried out in the Antarctic to date have yielded contradictory results. In McMurdo Sound Paul Dayton waited 12 years in vain for a colonization of substrates; however, in the 13th year there was a mass recruitment of many species. Rauschert managed to retrieve only one of his experimental substrates after an exposure of 3 years off King George Island, however, this one was densely colonized with ascidians of considerable size and other fauna. Interestingly, the colonization of Dayton's and Rauschert's substrates occurred during the "ENSO of the century" 1992-94 which also had strong effects on hydrography, krill and warm-blooded animals in the Antarctic. Both experiments were carried out in the shallow water of the scuba diving zone at about 30 m. On colonization plates exposed at about 600 m Gerdes & Klages did not find any organisms after one year.

Perhaps the Antarctic fauna which normally suffers from little disturbance is particularly sensitive (reduced resistance), recolonization is slow and occurs only occasionally under specific hydrographic conditions, and succession is -due to the retarded growth of many species such as most sponges- a slow process which takes a long time. Compared with communities living, e.g. in temperate latitudes and used to all kinds of disturbance, the return to a mature, complex association may take a much longer time in the South Polar Sea (reduced resilience). These hypotheses seem plausible at least for the deeper benthos below the zone of ice impact, where there is also an opportunity to work experimentally without running the risk that the substrates are destroyed or dislocated by ice after a short time. In the iceberg drift zone, this risk is much higher; on the other hand, a comparative experiment in this zone is also attractive because the disturbance-adapted fauna living here may reveal a much faster process of colonization.

Experiment

For a long-term experiment lasting at least ten years, two areas at about 200 and 400 m off Kapp Norvegia will be selected using ROV and satellite navigation. At each of these sites, about 1000 hard-bottom substrates (burned tiles without chemical treatment) will be exposed in several piles. For this purpose, about 330 tiles will be located on a palette for each release and shed into the sea while the vessel is at drift. The freshly exposed tiles will be photographed by ROV to document the virgin state. During future cruises, ROV series and samples will be taken to follow succession at each of the two sites. This experiment will, at the same time, serve the validation of growth of benthic organisms under natural conditions.

The proposed experiment will not yield data on soft-bottom colonization. For this purpose, a technically more advanced underwater vehicle will have to deploy (and later, retrieve) sediment containers at depth. What might be done during this cruise, however, is repeated trawling with heavy equipment in a restricted area as has been done during the "IMPACT" project in the North Sea, however at much lower depth.

1.3.2 Study of the hard-bottom fauna on an underwater hilltop at 55-60 m depth (AWI, ICM)

During EASIZ I, the remotely operated vehicle (ROV) took an interesting video transect ascending an underwater hilltop off Four Seasons Inlet (NE of Kapp Norvegia), the surface of which is only 55-60 m from the

water surface. Such extreme shallow areas are very scarce in the southeastern Weddell Sea due to the shelf ice edge which normally covers all bottoms down to 150-200 m depth.

The hilltop was covered with large rounded boulders which revealed an interesting hard-bottom fauna. As we have no samples from such shallow sites in the Weddell and Lazarev Seas, it is suggested to take some hauls with a very large bottom grab or alternatively, if this should turn out unfeasible, with a geological chain dredge.

It is hoped to recover the fauna in good condition which might also provide live material for the aquarium experiments with suspension feeders planned by the Spanish group. Photographs will be taken of the boulders and their fauna before the latter is sampled. To make optimal use of the rare material, it will be necessary to keep the fauna in one hand (e.g. RAS St. Petersburg) to avoid its being scattered among a multitude of experts all over the world.

The material may also help to test a number of hypotheses, e.g. that put forward by Hain that boulders in the Antarctic are colonized by brachiopods which are taking the place of the bivalves in other areas. However, the principal goal of this proposal is to sample shallow-water hard-bottom fauna unknown to science to date.

1.3.3 Biological interactions as indicators for secondary metabolites to be used by man (AWI, UBC)

Rationale

Benthic animals contain secondary metabolites, which may be beneficial to the future of human life. The potential for finding these substances in the Antarctic bottom fauna is assumed to be high, due to the large number of invertebrate species which inhabit exclusively the Antarctic shelf areas. A study of this ecosystem is required to increase the efficiency of the search for these biochemical compounds.

Objective

The objective is to carry out an ecological survey to identify biological interactions between species and the environmental factors that control them, for the purpose of increasing the efficiency of the search for secondary metabolites. Two approaches are proposed:

- (1) Investigation of biological relationships. Benthic assemblages in the Antarctic are known for their high number of parabioses

ranging from one-sided commensalism or amensalism to mutualism. We want to detect relationships that give evidence for a positive or negative chemical communication. These relationships should be determined through the use of direct observations in the natural habitat and by statistical analyses.

- (2) Identification of environmental parameters that control benthic assemblages. The knowledge resulting from this allows scientists to predict the location of benthic communities which are rich in biological interactions. In addition, ecological demands of the benthic communities which are relevant for intra- or interspecific relationships may be described.

1.3.4 Chemical interactions in benthic communities (AWI, CEAB)

Secondary metabolites can be carriers of intra- and interspecific interactions in marine benthic communities. Preliminary studies showed Antarctic ophistobranchs to contain various interesting chemical substances, which may be used for protection from enemies. During ANT XV/3, ophistobranchs will be collected and immediately prepared for extraction of these chemicals aboard "Polarstern". Aquarium experiments on the function of the chemicals will be carried out on board.

1.3.5 Assessment of the relative value of Antarctic benthos based on its resilience (AWI, UBC)

Rationale

The "Madrid Protocol" on environmental protection of the Antarctic states that the person or organisation that has caused damage to the Antarctic ecosystem is obliged to compensate, or the respective government will be held liable. To be able to determine the extent of the damage done, it is required that the resilience of the ecosystem is known. Unlike plankton and nekton, most benthic life forms cannot escape when the environment is severely disturbed and invade immediately after. Thus the benthic environment is highly sensitive to pollution events, e.g. by oil spills or introduction of sewage. In general it is expected that anthropogenic disturbance should have a significantly stronger long-term effect at the sea-floor than in the water column.

Our knowledge about the resilience of the Antarctic benthos is still poor to meet the standards required by the "Madrid Protocol". The resilience does not only depend on difficult-to-measure growth rates of benthic species, but also on complex ecological relationships.

Most of the few benthic invertebrate species that have been studied are known to exhibit slow growth rates. This leads to the conclusion that the resilience of this part of the ecosystem should be low. It is also known that part of the benthos inhabiting the high Antarctic shelf is regularly affected by natural disturbance which may contribute to high diversity.

Objective

The objective is to investigate the process of recolonization through a study of iceberg scour marks. Scour marks are found at different stages of recolonization. Thus, it is not necessary to observe the process of recolonization, which may last centuries. Two aspects should be studied:

- (1) Local quantity of scour marks. The comparison between the intensity of physical disturbance and the regional benthic structure may help to estimate the role of this effect for benthic life.
- (2) Species composition and diversity of disturbed areas. To estimate the period after which the initial benthic structure is reestablished, and to describe the succession of the recolonization of formerly devastated areas, an assessment of the benthic structure inside and outside the disturbed areas will allow a relative age determination.

1.3.6 Macrobenthic distribution and respiration (IPÖ)

Research programme

Our investigations are part of a joint project integrating the studies of several scientific working groups. They will primarily contribute to the main scientific objective iii of the EASIZ cruise (i.e. the study the ecological role of suspension feeders). The results will be interpreted in the framework of concomitant benthological studies of cooperating scientists. Moreover, they will be compared to those from Arctic regions (Greenland Sea, Barents Sea, Laptev Sea).

Objectives

The approach of our benthological studies basically comprises two topics:

- (1) quantitative inventories of the suspension-feeding epifauna by seabed imaging, and
- (2) respiration measurements of selected species.

The following issues will be addressed:

- (1) What are the absolute densities (and biomass) of suspension-feeding epibenthic species? What are the dispersion patterns related to different spatial scales? Which are most probably the principal factors controlling the patterns observed?
- (2) What are the routine respiration rates of selected species? Does the metabolic performance (measured as respiration rates) indicate an adaptation to seasonally pulsed nutrient supply?

Combining the information derived from these two lines of investigations (densities and individual respiration rates, respectively), we can provide estimates of population carbon mineralization potential and, hence, population carbon demand of the species selected.

Within the frame of the cooperation with benthological working groups covering other community fractions, it will be possible to assess the relative contribution of the species selected to the total benthic carbon flow. Moreover, productivity values estimated from metabolic measurements by assuming a certain growth efficiency can be compared to those derived from other methods.

Study plan

For a quantitative inventory of mega-epibenthos a still camera system will be employed at selected sites located in meso-scale boxes which are defined by the overall EASIZ station planning. This gear will supplement ROV video images by providing high-resolution "close-up" pictures of the seabed. Seabed photographs will be evaluated according to the following aspects: (a) "in situ" observations of epibenthic habitat structures, (b) determination of absolute population densities and (c) identification of small-scale distribution patterns, and possibly (d) assessment of size spectra of large epibenthic organisms.

Live specimens will be collected from trawl catches and/or grab samples in agreement with cooperating scientists. For the intended comparative analyses, the species list will comprise various size fractions and ecotypes (e.g. suspension feeders, deposit feeders, predators). The specimens will be maintained on board in a cooled lab container to investigate autecological adaptations through measurements under controlled conditions. For continuous undisturbed observations a

low-light video system will be used to record activity and behaviour of the organisms under natural light conditions. Using an intermittent-flow respirometric system, individual oxygen uptake rates will be measured to assess routine metabolic activities.

1.3.7 Carbon and silicon flux on the Weddell Sea shelf and slope (AWI)

Benthic communities of shelf and slope areas play a significant role in Antarctic carbon and silicon cycling. In order to understand this role, we have to identify the major pathways of carbon and silicon through the benthic communities. Our long-term effort in the analysis of trophic relations and populations dynamics aims at a balanced carbon flow model for the Weddell Sea shelf and slope communities. Sponges and sponge needle mats are the major benthic compartments in the Antarctic silicon cycle. In order to evaluate their function in this cycle, we have to know more about sponge energy metabolism and silicon chemistry.

During ANT XV/3 our work will focus on the following topics:

- Trophic links between different species of the benthic community. Samples will be collected for stomach content analysis and analysis of stable isotope ratios (N, C).
- Respiration rates of echinoderms (Asteroidea and Holothuroidea) and sponges. We are not able to determine individual age in these taxa. Therefore mass specific respiration rates of abundant species will be measured on board. These data are subsequently used to estimate consumption and production via empirical relations.
- Silicon uptake and release of sponges and sponge needle mats. Samples of sponges and sponge needle mats will be collected and prepared for silicon chemistry analysis. These samples will be transferred to the AWI to perform experiments on silicon uptake and release.

1.3.8 Ecofunctional biodiversity of the amphipod taxocoenoses in the eastern and southern Weddell Sea (RSNB, AWI-FP)

Rationale

In the Antarctic benthic communities, the peracarid crustaceans (Amphipoda, Isopoda, Tanaidacea, Cumacea, Mysidacea,...) are by far the

most speciose group and probably the most "ecologically" diversified, at least in terms of trophic types, habitats and size spectra (De Broyer & Jazdzewski 1996). The peracarid crustaceans (and in particular the most numerous group, the amphipods), despite their low biomass, are a dominant group in terms of energy fluxes in the high Antarctic shelf ecosystem (Weddell Sea: Jarre-Teichmann et al. 1997), and they can show high densities e.g. in the maritime Antarctic sublittoral communities (Jazdzewski et al. 1991). They provide, on the other hand, an important food resource to many Antarctic and Subantarctic fishes (e.g. Gon & Heemstra 1990, Kock 1992). One promising approach of the role of biodiversity in ecosystem functioning -which has some significance in the potential stability and resilience- is the study of the functional roles of species or species groups, in particular in trophodynamics (see e.g. Martinez 1996).

The ecofunctional role, and in particular the trophodynamic role, of most of the Antarctic peracarid crustaceans is still poorly known, despite notable contributions this last decade. The preferential or exclusive trophic types have been studied in less than 10% of the amphipod species, for instance, with extremely few quantitative approaches so far. A qualitative and quantitative characterization of these trophic roles, at the level of the key species and of the whole taxocoenoses, could significantly contribute to a more accurate image of the trophic structure and fluxes in Antarctic benthic communities.

Objectives

(1) Ecofunctional biodiversity.

To continue, in the eastern and southern Weddell Sea shelf region, the trophodynamic approach undertaken in Kapp Norvegia region during the 1996 "Polarstern" EASIZ I campaign: i.e. to characterize and quantify the trophodynamic role of the amphipod taxocoenoses in the southern Weddell Sea, and compare it on a latitudinal scale with the eastern Weddell Sea (Kapp Norvegia), the West Antarctic (Admiralty Bay system), and the Magellan region. The particular topics to investigate are: diet composition, food consumption and assimilation efficiency, characterization and functional role of the amphipod trophic guilds, significance of amphipods as preys for other macrobenthos and demersal fishes. New emphasis will be put on the quantification by feeding experiments of the trophic role of:

- the necrophagous component (to be collected by systematic trap sampling, very successful during the 1996 campaign)
- the filter feeders amphipod component (close cooperation with the "suspension feeders" study group will be sought).

(2) Structural biodiversity

- To document on a latitudinal scale the faunistical and ecological traits of the amphipod taxocoenoses (southern Weddell Sea, eastern Weddell Sea, West Antarctic, Magellan region)
- To contribute by taxonomical material and distributional and ecological data to the preparation of the "Synopsis of Antarctic Amphipods" (De Broyer, Andres, Bellan-Santini, Coleman, Jazdzewski, Rauschert, Takeuchi, Vader, Wakabara in prep.), and the development of the first "EASIZ-SA2000 Antarctic Biodiversity Research Reference Center" (focussing on amphipod Crustacea).

1.3.9 Small/medium scale macrobenthos distribution patterns in relation to environmental and biotic parameters (AWI)

The zoogeographical results from several expeditions carried out in the past provide quite a good overview of the distribution patterns of macrozoobenthos assemblages along the Weddell Sea shelf. Our knowledge about the rich fauna off Kap Norvegia is especially advanced, we meanwhile also have rather good data sets concerning the bottom topography, the water current regime, and we have rough ideas about the disturbance of this area due to iceberg scours.

Based on this information the general aim of the planned investigation is to study in more detail environmental and biological factors, which structure this shelf ecosystem. Of special interest for us are the following ecologically relevant factors:

- the mesoscale bottom topography such as e.g. innershelf depressions or plateaus,
- small scale artefacts due to iceberg scours,
- the current regime close to the seafloor,
- vertical particle flux (food input to the benthic system).

The studies will be carried out by means of multiple corers (MG and RG), attached with UW cameras and with moorings, equipped with current meters and sediment traps. A close co-operation with other groups (e.g. macro- and meiobenthos, bathymetric group) is desired.

The questions to be addressed will be:

- What do disturbed areas look like (differences in abundance, biomass, composition)?
- How does recolonization occur?

- In which way is the environment affected by iceberg scours (changes in the current regime close to the bottom and consequently changes in food availability)?

1.3.10 Trophic ecology of some species of benthic cnidarian suspension feeders in the Weddell Sea (ICM, AWI, UBC)

Rationale

The high degree of seasonality in the supply of fresh food in the Antarctic may be a factor conditioning the life strategies of benthic organisms, to the point of limiting their growth and reproductive strength.

The apparent scarcity of the food supply for Antarctic suspension feeders as a factor conditioning the growth of such organisms is in contrast with the large assemblages of suspension feeders that exist on the continental shelf off Antarctica.

Recent studies carried out in Antarctic waters have yielded a hydrozoan species that feeds basically on resuspended benthic diatoms, which contrasts with the diets of other species in that same group based chiefly on zooplankton. At the same time, dissection of hundreds of zooids from different species of suspension feeders on the last Polarstern ANT XIII/3 survey did not yield any prey items of larger size in the contents. Subsequent electron microscopy detected a variety of small particles in the stomach contents, the nature and source of which remain unknown.

The objectives of the present project are:

- To ascertain the diets of cnidarian benthic suspension feeders and their relationships to possible prey items or food sources in both the water column and the sediment.
- To observe variability in the diet at the colony level and community level.
- To determine experimentally the prey capture rate, to ascertain which portion of the fine fraction is most important in the diet of each species.
- To confirm whether certain species have undergone the biochemical adaptations enabling them to digest macromolecules of plant origin.
- To determine the nature and characteristics of possible food sources in the surface layer of the sediment and to ascertain whether they are related to microbial activity.

- To analyse the stoichiometric composition of colonies of various species and to relate the composition to different life strategies. To evaluate intraspecies variability in colony composition in different geographic areas, within the same community and within the same colony.
- To quantify the reproduction at the levels of colony and population and to study spawning effort and variability in different species.

1.3.11 Life cycles, ultrastructure, and population genetics of Priapulida and other benthic invertebrates (UHZ)

Priapulida are the oldest known living fossils among Metazoa, persisting from an early Cambrian radiation (e. g. Burgess Shales, Canada, and Yunnan, China). In Cambrian sea floors, they were among the dominating soft-bodied invertebrates. Extant macrobenthic species occur preferably in northern and southern polar seas, meiobenthic forms are known predominantly from tropical regions. All Priapulida are marine, *Halicryptus* is an important soft bottom dweller of brackish waters.

Extant sibling species of *Priapululus* and *Priapulopsis* occur in northern and southern polar seas. An understanding of the evolution of bipolar range disjunctions is required. Another open question is the molecular differentiation of bipolar priapulids which is in contrast to their structural bradytely. To approach this goal, further detailed data are necessary of the life cycle of Antarctic species (number of larval stages, ultrastructure) to allow a precise comparison with the nordic species. The same applies to the population genetic work. So far, only one northern species has been analyzed to a good extent.

Priapulida often carry intestinal parasites, e. g. coccidians. Recently, several species were investigated in this respect. With the exception of the circumantarctic species, *Priapululus tuberculatospinosus*, they contained one species of coccidians, *Alveocystis intestinalis*. Further data are needed to prove if this negative finding can be generalized.

In conjunction with our work on Priapulida, which was published in over 20 research papers, similar work is planned on Echiura (and Holothuroidea).

1.4 Benthic ecology (meiofauna)

1.4.1 Meiobenthos (UGZ)

During former Antarctic expeditions to the Weddell Sea the meiobenthos has been studied in many aspects. From EPOS we have an extensive overview in which the questions dealing with production (biomass) and diversity on a gross spatial scale were investigated. Specific meso- and small-scale factors, responsible for the observed distribution patterns of the meiofauna, were addressed during the EASIZ I expedition. Two main questions result from these investigations:

- (1) Stability and resilience of the meiobenthos in relation to iceberg scouring activity.

One of our major interests is the (re)-establishment of diversity in association with iceberg scouring. As the sublittoral zone along Kapp Norvegia is regularly abraded by calving icebergs from the ice shelf, disruption of sediment and associated depauperation of the macrofauna must be a major factor structuring the meiofauna living there. Depauperation, (re)distribution and (re)colonization of the meiobenthos need to be described and clarified, parallel to what happens to the other benthic components (e.g. micro- and macrofauna).

- (2) Meiobenthos distribution along a latitudinal gradient (South America-high Antarctic shelf) at the southern slope of the Drake Passage.

The meiofauna in South American and high Antarctic sublittoral biotopes has been studied in detail. However, the connection between the two continents has not been considered so far. Yet, as Antarctica is seemingly the most isolated of all the continents, this is a most interesting region putting the biogeographical establishment of the Antarctic benthic populations in daylight. Broadly, the meiobenthic (nematode) populations show a homogeneous distribution with a remarkable similarity in the generic composition. Our focus will be put on the biogeography of the entire meiobenthic populations and on a limited standardized set of nematode species, in order to answer the question on the origin of the Antarctic meiofauna.

1.4.2 Zoomorphologic relationships and comparisons of species diversity between the harpacticoid faunas of the Antarctic and Patagonia (UOB)

Targets

The research emphasis of the Zoomorphology group in the University of Oldenburg is on the diversity and distribution of the Harpacticoida (Crustacea, Copepoda) in Arctic and Antarctic waters. In the context of the EASIZ II cruise the comparison of associations of Arctic and Antarctic Harpacticoida is of special interest.

Objectives

Comparison of species diversity along vertical transects in Antarctica and along the Chilean continental slope. Changes in the patterns of diversity in relation to depth and the characteristics of the environment will be studied on family-, genera-, and species level.

Taking the Copepoda Harpacticoida as an example, the following questions will be studied:

- (1) What is the similarity of species composition along the depth transects in Antarctica and the Chilean coast?
- (2) Is species composition increasingly similar with increasing depth?
- (3) Does species diversity increase or decrease with increasing depth?
- (4) Do changes in the structure of the community appear?

Work at sea

In order to answer these questions, multicorer samples (taken in 1989 during the EPOS cruise) will be studied quantitatively and compared with samples taken in 1996 on ANT XIII/4 on the South American continental slope, as well as with samples that have to be taken near King George Island. During ANT XV/3, quantitative samples will be taken there with the multicorer from different depths.

1.5 Zoogeography

1.5.1 Biodiversity and zoogeography of Mollusca, Crustacea and Polychaeta (ZIZM)

During EASIZ II, investigations on the biodiversity and zoogeography of the Mollusca, Peracarida (Crustacea) and Polychaeta will be done. The background of this research are faunistic studies along latitudinal

gradients (South America - Antarctica) and with respect to potential benthic-pelagic coupling mechanisms.

Objectives

(1) Zoogeographic and molecular-genetic comparison of the Malacofauna (Bivalvia & Gastropoda) between South America and Antarctica.

The horizontal and vertical distribution of the Mollusca of the southern Weddell Sea and the region of the Antarctic Peninsula (King George Island) shall be investigated and compared with data from the Magellan area in order to improve the knowledge of both areas.

This malacological comparison shall also serve the investigation of the history of the colonization of Antarctica by the Mollusca. To follow this aim, a phylogenetic analysis of selected, abundant taxa, e. g. of the genera *Cerithiella* or *Limopsis* is necessary - besides the morphological comparison - and a phylogenetic analysis of these taxa is planned for the future on a molecular basis. In this context the molecular genetic approach should serve to provide reliable data on genetic distances of closely related species from South America and Antarctica.

(2) Biodiversity of Peracarida (Crustacea, Malacostraca) in the Southern Ocean. A comparison with the European northern seas.

Besides Euphausiacea and Copepoda the Peracarida are the most successful taxon of Crustacea in the Southern Ocean occurring with a high percentage of endemic species (~90%). During the expedition ANT XV/3 with RV "Polarstern", the biodiversity of these crustaceans will be investigated from the shelf (~200 m) down to the deep sea (~4000 m, if feasible) along transects in the southeastern Weddell Sea as well as off King George Island, in order to sample both, high- and Subantarctic Peracarida.

A comparison of the results from this expedition with data from the Magellan area and the background of published phylogenetic analyses might help to elucidate further the origin of these taxa in Antarctica.

Finally, the biodiversity of Antarctic Peracarida shall be compared with our knowledge from the European northern seas.

(3) Biodiversity of the Polychaeta (Annelida) in the Southern Ocean. A comparison with deep sites of the northwest Atlantic and northeast Pacific.

Within the benthic community Polychaeta are most important besides Crustacea, Mollusca and Echinodermata concerning biodiversity and abundance. They can also be considered key species with regard to ecological function (in terms of bioturbation, resuspension, creation of microhabitats, resettlement of disturbed environments, etc.).

Many Antarctic polychaetes are endemic (~40%) and part of a unique ecosystem. On the basis of the zoogeographical knowledge of the Polychaeta, the composition of the polychaete fauna in Sub- and high Antarctic benthic communities shall be investigated. This study shall focus on the dependence of the biodiversity and dominance of the Polychaeta on biotic and abiotic environmental factors such as substrate quality, water depth, current regime, particle transport, etc. Besides the species composition of the polychaetes, life types shall be characterized (e.g. detritus or suspension feeders, filter feeders, predators, vagile and sessile life style etc.). The aim is to document the usage of ecological niches by the Polychaeta, especially at greater depths of the Southern Ocean, and to analyse the potential ecological role of polychaete suspension feeders.

Finally we want to find out, whether numerically dominant polychaete families from deep Antarctic stations can be distinguished from those of other deep communities (>200 m). The potential interdependence or interspecific competition for food and space with other important taxa such as Peracarida or Mollusca will be analysed in a community analysis.

(4) Inventory of chemo- and mechanoreceptive sensilla and lipid storage in Antarctic and boreal Isopoda (Crustacea, Malacostraca).

Chemo- und mechanoreceptive sensilla of Antarctic Isopoda shall be compared with those of phylogenetically closely related boreal species, e. g. *Cyathura carinata* (Anthuridea) or *Saduria entomon* (Valvifera) (predators) and *Munna krøyeri* (Munnidae, detritivor) from boreal areas and *Accalathura gigantissima* (Anturidea) or *Glyptonotus antarcticus* (Valvifera) (predator) and *Munna antarctica* (Munnidae, detritivor) from the Antarctic.

First position and structure of the sensilla of these species shall be compared using both scanning- and transmission electron microscopy. The hypotheses on the possible function of some of the mechanoreceptors of boreal species will also be tested electrophysiologically. The aim of this project is to find out, whether the sensory inventory of Antarctic and boreal Isopoda differs. Furthermore, these analyses will be performed on two different lifetypes - predators and herbivores or detritivores, in order to investigate whether a relation between feeding mode and sensory equipment might exist.

Histologic investigations of the alimentary canal (especially the midgut gland) are planned to analyze whether quality and amount of storage lipids can be distinguished between boreal and Antarctic species and whether there is a relation between lipid storage and feeding mode.

Work at sea (for all projects)

For the above described projects sampling is necessary during approximately 4 station days. Along three transects samples shall be taken by means of an epibenthic sledge, the Agassiz Trawl, and a giant box corer at different depth levels. Help of other scientists is needed concerning the analysis of CTD data.

Three transects in the following areas shall be sampled (preferably on each transect at 200, 600, 1500, 2000 und 4000 m depth):

- Kapp Norvegia * ~ at 71°S 13°W (200-4000 m)
- Halley Bay/Filchner * ~ at 76°S 25°W (200-2000 m)
- King George Island * ~ at 62°S 58°W (200-4000 m)

* = eastern Weddell Sea

+ = Bransfield Strait and Drake Passage

For the planned investigations on molluscs with molecular-genetic techniques, it is necessary to freeze material on board and to continue with the final analysis in the laboratory at home. Material for electron microscopy has to be prefixed on board, if possible also the following necessary treatment of fixation until the embedding within epoxy resins shall be done on "Polarstern", whereas serial sections and electron microscopy will be performed at home in Hamburg. Prior to fixation, animals will have to be kept in aquaria on board for some time.

1.5.2 Distribution and ecology of polychaetes, with particular attention to filter feeding forms, along a latitudinal gradient from South America to the high Antarctic shelf (SZI)

The Southern Ocean is characterized by strong seasonality in the phytoplankton production and consequently by short pulses of conspicuous amounts of suspended and deposited organic matter to the benthic system, mainly concentrated in late summer and followed by a long period of apparently oligotrophic conditions of the water column. In apparent contrast, the shelf benthic communities of the Antarctic seas are characterized mainly by dense populations of suspension feeders such as sponges, cnidarians, echinoderms and polychaetes, that often show a conspicuous individual biomass and community standing crop. Active filter feeding may be characterized as "Life in a nutritionally diluted environment", and most suspension feeder forms possess low-energy pump systems which enable continuous feeding at low rates

rather than discontinuous and high rates and which efficiently retain small suspended food particles (see Rüsger and Larsen 1995 for a review). The ecological adaptations of such filter feeding forms to the unique polar hydrological and energetic regime are still poorly known and present one of the crucial steps to understand, and possibly solve, the so-called "paradox of the polar benthos".

Polychaetes, one of the most abundant and diversified groups of benthic organisms also in the Antarctic shelf communities, show a large variety of feeding types and strategies and play an important role at many levels of the benthic food web. Among the trophic strategies, filter feeding has independently evolved in different groups of these marine worms. They include both active suspension feeder forms, such as Sabellariidae, Sabellidae and Serpulidae, which live inside permanent tubes and feed through a highly modified projection of the head (branchial crown); and facultative filter feeders that can switch their trophic behaviour from deposit to suspension feeding, according to the local hydrological conditions, mainly related to the load of the suspended matter. There are some representatives of this strategy in the Nereididae, Chaetopteridae, Spionidae, Oweniidae and Terebellidae. The distribution of suspension-feeding polychaetes, especially of the tubicolous forms, has been often associated to high hydrodynamic energy environments (e.g., sandy coastal sediments, bottom currents, macrotidal systems), and their ecological role in stabilizing the bottom, by means of tubes and fecal pellets production, and in interacting with other functional groups (amensalism hypothesis), has been studied mainly in temperate coastal systems (see Weinberg, 1984 for a review).

Studies on the distribution, feeding ecology and ecological role of filter-feeding polychaetes in the Southern Ocean are very scarce, and for this reason the proposed programme will mainly focus on distribution and ecology of species of this functional group. The EASIZ I campaign on the shelf of the Eastern Weddell Sea (ANT XIII/3, January-March 1996), revealed, in fact, the occurrence of dense populations of filter feeders, such as the sabellid *Perkinsiana littoralis* (Giangrande & Gambi, in press), that were second only to Polynoidae, as concerning frequency and number of species and individuals collected (Gambi, in press). Besides, many large sabellids (probably belonging to the above cited species) were often observed in the videos recorded during the same cruise.

The proposed research programme for the EASIZ II cruise on board R/V "Polarstern" will involve two interconnected aspects:

- (1) distribution of polychaetes, with particular attention to filter-feeding forms, along a latitudinal gradient from South America to the high Antarctic shelf;
- (2) autecology and feeding features of the most abundant suspensivorous species by means of a laboratory experimental approach.

As regards aspect (1), polychaetes will be collected on board R/V "Polarstern" by means of various sampling gears (mainly the Agassiz trawl and the bottom trawl). Among the sampled worms, filter feeders including the facultative suspensivorous forms will be sorted out on board and first analyzed for species determination. Their diversity of adaptations and abundance pattern will be correlated with the local environmental conditions. The possibility to sample along such a wide latitudinal range, from south America to the shelf of the Weddell Sea through the southern slope of the Drake Passage, will allow, in fact, the analysis of different environments and to evaluate in which conditions filter-feeding forms are present and more abundant in comparison to other functional groups.

As regards aspect (2), for the most abundant suspension feeder species some autoecological observations will be performed. They include population structure (size frequency), as well as gut content analysis in order to estimate the size spectrum and the type of food ingested. Some specimens will be maintained alive and reared in aquaria inside a cooled container in order to perform some experiments on their feeding rate and type of particles ingested under laboratory conditions. Some attempts on polychaete rearing in aquaria, performed during the ANT XIII/3 cruise, indicated that these filter-feeding forms survived the stress due to sampling, and were easily reared for some days in the cooled container. Furthermore, for these abundant taxa, various individuals will be fixed for electron microscopy analyses, and other specimens will be preserved in ethanol or frozen at -80°C for genetic analyses by means of a biomolecular (DNA markers) approach.

1.5.3 Latitudinal gradients of macrobenthos distribution (AWI)

The majority of benthos investigations carried out so far by AWI biologists has been done along the southeastern Weddell Sea shelf. During a recent workshop on benthos investigations in waters around the tip of

South America it turned out that presently only little information is available on the benthic fauna around the Antarctic Peninsula and the areas directly south of the Drake Passage. In order to fill this gap a station transect will be worked up from Potter Cove (Bransfield Strait) across the Drake Passage, covering a depth range from the intertidal zone down to 2500 m. At each station the whole range of qualitative, quantitative and imaging gears should be deployed in order to cover as many aspects about the benthos as possible.

1.6 Fish biology

2.6.1 The role of demersal fish for the structure of benthic communities during the recolonization of disturbed areas (impact of iceberg scouring) (AWI, IEO, ICM)

In- and exclusion experiments in coastal areas of boreal latitudes showed that epibenthic predators, such as fish and decapods, have a pronounced influence on structuring macrobenthic communities during different successional stages.

In close co-operation with the Zoobenthos Working Group (AWI), the fish species spectrum of potential predators will be estimated in areas affected by iceberg scouring. The food preferences of dominant fish species will be investigated by analysing the gut content.

1.6.2 Characterization of the pelagic fish communities near the ice shelf of the Drescher Inlet (ICM, AWI, IEO)

Studies on the diving and feeding behaviour of seals in the Drescher Inlet showed that feeding activities were most intense within the pycnocline between 130 and 210m of the water column. Above the pycnocline and down to the sea floor at a depth of 420m feeding activities were significantly lower (see Mammals Working Group, AWI). The composition, distribution, densities and size spectra of possible prey are still unknown. The aim of the proposed research is to determine the vertical migration behaviour, distribution, relative abundance and species composition of the pelagic fish community near the ice shelf of the Drescher inlet and to estimate the biomass of possible prey for seals. The research is closely linked to the investigation of the Mammal Working Group.

The relative abundance, migration patterns and spatial distribution will be determined by means of electronic echosounding in combination with demersal and pelagic fish catches. The spatial distribution will be related to abiotic factors such as water temperature and stratification. Population studies (age structure, growth, diet, maturity) will be carried out on dominant species.

1.7 Ecology of seals

1.7.1 Migratory behaviour and feeding ecology of pack ice seals (AWI)

During the field campaign at Drescher Inlet in January/February 1995 electronic data loggers were deployed on adult Weddell seals to measure their diving depths and jaw movements simultaneously. The seals' jaw activity was most intense within the pycnocline, i.e. in the upper 130 to 210 m of the water column. Above the pycnocline and down to the sea floor at a depth of about 400 m the jaw activity of the seals was significantly lower. These measurements of feeding events (or at least prey catch trials) are the first to provide new insights into the highly adapted diving behaviour of Weddell seals in relation to their vertical distribution and density of their prey (fish, cephalopods) under the sea ice. The composition of pelagic prey species and their size classes and local abundance are still unknown. For the 1998 campaign at the Drescher Inlet we developed a multi-channel electronic data logger which measures during 3 weeks of continuous recordings the seals' movement and feeding activity in their three-dimensional underwater environment. Data will be provided on the number of dives and of mouth openings at particular dive depths, the diurnal diving and feeding behaviour, the exact locality where dives are made, and the horizontal and vertical swimming speed and direction. The data logging system will also measure water temperature and light intensity to determine physical parameters which may be important for the vertical distribution of prey. Towards the end of the field campaign ARGOS satellite transmitters will be deployed on Weddell seals and crabeater seals to obtain data on their diving activity and seasonal migration to the feeding and wintering areas. The seal studies at the Drescher Inlet are closely linked to the aerial census on pack ice seals (stock assessment) and the fish ecological studies carried out on board Polarstern. The results of the three groups will be compared to gain new insight into the trophic relationships between the top consumers and their prey.

1.7.2 Distribution and abundance of pack ice seals in the Weddell Sea (UPR, AWI)

The percentage species contribution of pack ice seals in the eastern Weddell Sea between 1983 and 1992 was significantly different from that recorded in the early 1970s. The densities of Ross seals, crabeater seals and leopard seals showed a two- to five-fold decrease between the 1983 and 1992 aerial censuses. Furthermore, the perceived dramatic decline in crabeater seal numbers in the western Weddell Sea between 1968-69 and 1983 and the unknown current status of the Weddell, crabeater, Ross and leopard seals resulted in the development of the international APIS (Antarctic Pack Ice Seals) programme. This five-year programme (1996 - 2000) was initiated by the SCAR Group of Specialists on Seals. The goals of the present study are to assess the density, distribution, species composition and possible change in the status of pack ice seals within the eastern Weddell Sea, and to reconcile it with pack ice conditions and other environmental parameters. To this end helicopter (two north-south transects per day of maximally 50-60 nautical miles [nm] each, spaced at 10 nm, requiring a total of about 2.0 hours of continuous flying time at 200 ft and 60 knots anywhere during the period 11:00 - 15:00 LAT) and shipboard (10:00 - 16:00 LAT as the ship sails through the pack) strip and/or line transect surveys of the seals will be done during January/February, and complemented with satellite imagery to estimate the pack ice distribution over the whole region. Routine collection of floe size, floe surface nature, pack ice density and cover (ideally using video images during airborne surveys), air and water temperature, barometric pressure, together with the recording of bathymetry, and physical and biological profiling of water column (chlorophyll, plankton, cephalopod and fish densities and distribution) by other disciplines during shipboard surveys.

1.8 Zooplankton ecology

1.8.1 Zooplankton communities in the near-bottom layer in the Weddell Sea (ICM, ZIZM)

The overall biomass of pelagic organisms decreases exponentially with depth in the deep sea. However, near the benthopelagic boundary there is an increase in the biomass and species diversity of the plankton and the nekton. This may be due to increased food availability thanks to the resuspension of organic matter. Additionally, species diversity near the bottom may increase due to greater

availability of niches for benthopelagic organisms. For instance, certain copepods and medusae have been found to dwell exclusively in the near-bottom environment.

Little is known about the ecological importance of the benthopelagic zooplankton in the Southern Ocean, though it is presumed that the zooplankton biomass at the benthopelagic boundary may be relatively high.

The objective of the present project is to sample the benthopelagic boundary using an epibenthic sledge for the purpose of:

- Identifying the principal gelatinous organisms inhabiting that layer.
- Determining the species composition of the gelatinous community.
- Estimating the abundance and biomass of gelatinous organisms.

1.9 Physiology/biochemistry

1.9.1 Physiological adaptations to cold in Antarctic ectotherms (AWI)

Rationale

Living in the Antarctic requires special physiological adaptations to low temperatures. Antarctic animals permanently experience temperatures around freezing, while boreal species are only seasonally exposed to cold. Thus, cold acclimation in stenothermal Antarctic or eurythermal boreal species certainly requires different adaptational mechanisms. Eurythermal animals must be able to adapt to a wide range of temperatures. However, these animals may reduce their metabolism during cold periods to maintenance levels and limit growth and reproduction to warmer, more favourable periods of the year. Stenothermal animals, on the other hand, must be able to maintain growth rates and reproductive functions despite low temperatures. Cold adaptation in these stenothermal Antarctic animals seems to lead to a limited tolerance to warm temperatures; their upper lethal temperature usually does not exceed 6 - 10°C.

Objectives and work at sea

Our work on board will deal with the basic mechanisms that allow Antarctic fish to maintain a high aerobic capacity and the capacity for growth and reproduction in the cold. Our studies will be carried out on Antarctic eelpout (Zoarcidae), one of the few Antarctic fish species that is not endemic to the Antarctic. Zoarcids are widely distributed

and are very abundant at our latitudes as well. Thus, these species may serve as a model to investigate the differences between seasonal and latitudinal cold adaptation. Antarctic zoarcids occur at depths below 400m. We will use fish traps to obtain our experimental animals because this is the most gentle way of catching fish from deeper waters.

Previous investigations suggest that an increase of aerobic capacity in the cold is achieved by increasing the number of mitochondria in the tissues. We will investigate if indeed the number of mitochondria does change during cold adaptation and if the characteristics of the individual mitochondrion are altered. We will take tissue samples to do electron microscopy to determine number and morphological characteristics of these organelles. Furthermore, we will determine the activity of the key enzyme of the oxidative phosphorylation (cytochrome c oxidase) and the aerobic capacity of the mitochondria. We will compare these data to seasonally cold adapted eelpout from the North Sea. Occurring differences in mitochondrial characteristics may be related to the differences in temperature tolerance of the two investigated species. We assume that the upper lethal temperature may be correlated with the mitochondrial characteristics of a species.

The ability for growth and reproduction of an organism is determined by its capacity for protein synthesis. We will estimate the rates of protein synthesis of different tissues of Antarctic eelpout by determining oxygen consumption of these tissues in the presence and absence of protein synthesis inhibitors. Besides these physiological parameters, age, growth rates and fertility of these fish will be measured by standard fish-biological methods (otolith reading, gonosomatic index, number of eggs in female animals). The data will be compared with the results of the physiological investigations to identify possible coherencies between physiological adaptation and the growth and reproduction potential of species in different climatic regions. Preliminary analysis will be carried out in invertebrates and fish for a complete energy budget at low temperatures.

Besides the experiments we plan to do aboard "Polarstern", an important goal of this cruise is to catch Antarctic animals from different phyla and ship them to the Alfred Wegener Institute for additional and more sophisticated experiments.

1.9.2 $^{13}\text{C}/^{12}\text{C}$ ratio in lipids of polar copepods (AWI)

Measurements of stable carbon isotope ratios ($^{13}\text{C}/^{12}\text{C}$) will be taken in order to quantify and characterize the carbon flux between different trophic levels. Another goal is to identify food sources of animals and to study the carbon cycle on a global scale.

In the marine environment the biggest fractionation of carbon isotopes occurs during photosynthetic carbon assimilation. This process results in ^{13}C depletion in marine biomass relative to DIC. Within the marine food web an increase of ^{13}C with every trophic level occurs because ^{12}C disappears during respiration. Further fractionations occur during biosynthesis of biochemical fractions.

Polar copepods develop large lipid deposits to adapt to the pronounced seasonality of food availability as well as to the constantly deep temperatures. The genus *Calanus* and its relatives represent the biggest part of the biomass of zooplankton. In the food web they are the link between the primary producers (phytoplankton) and fish. Copepods store lipids and transfer energy to higher trophic levels.

Lipids synthesized *de novo* show an increase of ^{13}C compared to fatty acids from diets because they are derived from metabolic substances. The goal of the proposed research is to get information about the origin of fatty acids from the $^{13}\text{C}/^{12}\text{C}$ ratio. Furthermore $^{13}\text{C}/^{12}\text{C}$ ratios provide new information about lipid biosynthesis.

An additional aspect of the lipid investigations is the support of ongoing projects dealing with the reproduction of decapod shrimps from different climatic zones. Lipid class and fatty acid composition will be investigated. The background of these analyses is the suspected influence of the nutritional status of the females on production and biochemical composition of the eggs. Additional investigations will be carried out on the consumption of lipids during embryonic development. The goal of these investigations is to find out possible latitudinal gradients. The results obtained should contribute to the understanding of the relationship between latitude, expenditure of energy for egg production and kind of larval development.

1.10 Sea-ice biology

1.10.1 Investigations on the under-ice platelet layer in the Drescher Inlet (AWI, UWB)

Platelet ice is formed beneath the shelf ice in several regions of Antarctica. In addition to its importance for shelf ice dynamics (accumulation under the shelf leading to formation of marine ice), the platelet ice accumulates as a layer of loosely aggregated crystals underneath land fast ice, in proximity to the shelf ice barrier. These layers are sites of intensive biological activity. Beneath the fast ice in the Drescher Inlet, the platelet ice layer may attain a thickness of up to 4 m. During the spring, a rich algal bloom develops in this layer, supporting a diverse microbial community of exceptionally high biomass. The processes leading to ice formation, as well as the establishment of the microbial community in the platelet ice matrix, are not well understood. Furthermore, we have no quantitative estimates of the productivity nor do we know the role this platelet ice assemblage plays in pelagic food webs ("cryo-pelagic coupling") or for the underlying benthic community. We suspect that biomass derived from the platelet ice layer before onset of ice melt, i.e. prior to pelagic primary production, may constitute a significant food source for both pelagic and benthic consumers.

Hence, the development of a platelet ice assemblage in the high Antarctic may not only be of importance for the ecology of the ice organisms themselves, but pelagic and benthic communities may also depend on particulate organic carbon exported from the platelet layer.

In addition to standard biological investigations of the platelet ice assemblages, we intend to study platelet ice formation in the water column in relation to local hydrography by means of a portable CTD and an echo sounder as well as video observations. We will deploy small sediment traps below the sea ice for the duration of the study period in order to determine rates of sedimentation of organic material out of the platelet layer.

1.11 Geochemistry

1.11.1 Radium-228 as tracer for shelf sources of iron in the Southern Ocean (AWI)

It has been shown that iron plays a role in controlling primary productivity in the Southern Ocean. The limited data on the distribution of Fe in surface waters of the Antarctic Circumpolar Current (ACC) appears to support this growth-stimulating effect, but we do not know by what routes the iron reaches these surface waters. The major possibilities are: upwelling of deep waters, atmospheric input, and input from continental shelves. It is important to know which source is the major transport route, as this determines how primary production and CO₂ drawdown in the productive frontal regions of the ACC will react to changes in climate such as the changes in dust transport linked to glacial-interglacial transitions.

²²⁸Ra can serve as a tracer for one of these potential iron sources: prolonged contact of water masses with continental shelves. ²²⁸Ra in surface ocean waters is derived from sedimentary fluxes generated by the decay of ²³²Th which is ubiquitous in sediments. In estuaries, salt marshes, and on the continental shelf above fine-grained sediments, high flux rates and low water depths allow ²²⁸Ra to accumulate to high activities. If the enhanced Fe concentrations observed in surface waters near the Polar Front are due to shelf inputs, it is to be expected that these waters carry a ²²⁸Ra signal as well.

Available data on the distribution of ²²⁸Ra show an enrichment on the Weddell Sea continental shelf, but data from the Drake Passage/Antarctic Peninsula region as well as high-quality data of the expected low activities in the circumpolar current are as yet missing. During leg ANT XV/2 radium samples from the surface ocean will be collected in the ACC in the SE Atlantic, and in the Scotia Sea. The EASIZ II expedition offers the opportunity to extend this data base with another transect through the ACC (in the SE Atlantic), more detailed data from the Weddell Sea, and a completely new transect across the Drake Passage, which is expected to include the land-remote signal from the SE Pacific as well as the continental signals both from South America and from the Antarctic Peninsula.

We plan to measure Ra in surface waters by continuous underway sampling. Besides, we will deploy a continuous centrifuge to collect suspended material from surface water. This material will be analysed for Al and for the isotopic composition of Nd in a project related to the

identification of dust inputs, and for ^{231}Pa and ^{230}Th isotopes in a project on the scavenging of these radionuclides in relation to plankton productivity and export production. In support of this latter work, we plan to measure the depletion of ^{234}Th relative to its parent ^{238}U at selected stations in order to quantify the extent of export productivity.

2. Cruise Leg ANT XV/4
Punta Arenas - Capetown: 28 March - 21 May 1998
Chief Scientist: Eberhard Fahrback

2.1 Itinerary and summary

The "Polarstern"-cruise ANT XV/4 will start on 28. March 1998 in Punta Arenas and will lead to the Weddell Sea (Fig. 1). The major scientific aim of the cruise is the investigation of the role of the Weddell Sea in global climate variations. The cruise will consist of two parts - the first will take place in the western Weddell Sea and the Weddell-Scotia Confluence, whereas the second will concentrate on investigations along the Greenwich Meridian between the coast of Antarctica and the Southwest Indian Ridge.

A major part of the deep and bottom waters of the global ocean are ventilated by water mass formation in the Weddell Sea. Its intensity controls the global thermohaline circulation and consequently the effect of the ocean on large scale climate change. Water mass formation in the Weddell Sea is driven by cooling in winter and consequent sea ice formation as well as by the interaction between the ocean and the ice shelves. On the shelf, water masses can be generated which are dense enough to sink to the bottom of the Weddell basin. During their descent, they mix with ambient water masses and are carried with the cyclonic Weddell Gyre circulation to the north where they partly leave the Weddell Sea towards the Antarctic Circumpolar Current and partly recirculate.

To investigate the water mass formation processes and their role in the thermohaline circulation, the programme consists of two components: to measure the outflow of newly formed waters from the Weddell Sea into the Antarctic Circumpolar Current in the Weddell-Scotia Confluence (Fig. 2) and to measure the characteristics of the water masses in the central Weddell Sea and their exchanges between the eastern and western Weddell Sea across the Greenwich Meridian. For this purpose, the water mass properties and the transport will be measured on sections across the Weddell-Scotia Confluence (Fig. 2) and along the Greenwich Meridian with a CTD-probe (Conductivity/Temperature/Depth) combined with a rosette water sampler and an ADCP (Acoustic Doppler Current Profiler). From the water samples, measurements of the following tracers will be carried out: CFCs (Freon-11 and Freon-12, Freon-113, CCl₄), tritium, ³He, He,

and Ne. The CFC measurements will be done onboard by gas chromatography. For the other tracers, samples will be collected for subsequent analysis on shore. Salinity will be measured from the water bottles to control the CTD and the water samples. Current meter moorings will be recovered and redeployed along the Greenwich Meridian (Fig. 3, top) and in the western Weddell Sea off the Joinville Island (Fig. 3, bottom).

The physical oceanography programme onboard is part of the international DOVETAIL project (Deep Ocean VEntilation Through Antarctic Intermediate Layers), a contribution to the SCOR affiliated iAnzone programme (Scientific Committee on Oceanic Research). In this context, the instruments in the moorings in the western Weddell Sea will be provided by the Universitat Politècnica de Catalunya in Barcelona, Spain.

A project of sea ice investigations with remote sensing techniques aims to develop a new algorithm for cloud masking with infrared images. For this purpose in-situ data, e. g. observations of clouds and surface conditions, weather charts and radiosonde measurements, will be collected to validate the analyses.

Measurements of the CO₂-system and nutrients will be performed to investigate the processes which determine the potential of Weddell Sea to take up atmospheric CO₂. For this purpose, the total inorganic carbon content, TCO₂, the total alkalinity, the partial pressure of CO₂ (pCO₂) and pH will be measured.

The microbiology programme aims to estimate the contribution of the microbial community to the biological activity within the sea ice and the water column during autumn and its role in the carbon cycle. For this purpose, bacterial elemental diversity will be measured with X-ray microanalysis (XRMA) and dissolved organic carbon (DOC) production and degradation will be determined in reference to the algal standing stock. The colonization of sinking particles will be investigated with water samples from which pure strains of attached heterotrophic bacteria are to be isolated. In the samples, the bacterial cells of the water column, as well as the bacteria attached to particles, will be counted.

Laboratory experiments on silicon uptake and release of sponges and sponge needle mats will take place in the framework of the benthos programme to establish a benthic silicon budget.

The cruise will end on 21 May 1998 in Cape Town.

2.1 Fahrtverlauf und Zusammenfassung

Die Polarsternreise ANT XV/4 wird am 28. März 1998 in Punta Arenas beginnen und in das Weddellmeer führen (Abb. 1). Das wissenschaftliche Ziel ist die Durchführung von Messungen, um die Bedeutung des Weddellmeeres für globale Klimaveränderungen zu ermitteln. Die Reise ist in zwei Abschnitte gegliedert. Während des ersten werden Arbeiten im westlichen Weddellmeer und der Weddell-Scotica-Konfluenz stattfinden und während des zweiten am Meridian von Greenwich zwischen der antarktischen Küste und dem Südwestindischen Rücken.

Im Weddellmeer erfolgt ein wesentlicher Teil der Bodenwasserbildung des Weltmeeres, deren Intensität den Anteil des Südpolarmees an der globalen thermohalinen Zirkulation beeinflusst. Diese kontrolliert die dämpfende Wirkung des Ozeans bei Klimaveränderungen. Im Weddellmeer wird die Wassermassenbildung durch die winterliche Abkühlung und die Eisbildung auf den Schelfen sowie die Wechselwirkung zwischen Ozean und Schelfeis verursacht. Durch diese Prozesse können auf dem Schelf Wassermassen entstehen, die dicht genug sind, um bis zum Boden der Tiefsee abzusinken, wobei sie sich mit dem umgebenden Wasser vermischen und im zyklonalen Zirkulationssystem des Weddellwirbels nach Norden geführt werden.

Der Ausstrom im westlichen Weddellmeer besteht aus oberflächennahen und tiefen Komponenten. Die oberflächennahen stellen im wesentlichen Schelfwasser dar, das in der Weddell-Scotia-Konfluenz auf das Wasser des Zirkumpolarstromes trifft. Dabei entsteht ein System von zwei Fronten, der Weddell- und der Scotiafront, die einen Wasserkörper einschließen, dessen Eigenschaften einerseits durch die Vermischung der beiden konvergierenden Wassermassen, andererseits durch lokale Wechselwirkung zwischen Ozean und Atmosphäre bestimmt werden. Dieses Wasser könnte im Frontalsystem absinken und so zur Erneuerung des globalen Tiefenwassers beitragen, ohne im Weddellmeer, dem traditionell angenommenen Wassermassenbildungsgebiet, jemals Tiefen- oder Bodenwasser gewesen zu sein. Die tiefen Komponenten des Weddellmeerwassers strömen am Scotiarücken nach Osten und dringen durch Spalten im Rücken in unterschiedlichen Tiefen nach Norden vor, wo sie die tiefen Becken des Atlantischen und des Indischen Ozeans erreichen.

Am Greenwich Meridian findet der zonale Austausch zwischen Wassermassen statt, die im östlichen Weddellmeer durch Einspeisungen

aus dem Zirkumpolarstrom modifiziert werden, und solchen, die aus dem westlichen Weddellmeer zurückströmen und neugebildetes Bodenwasser enthalten. In den vergangenen Jahren wurde eine Erwärmung des aus dem Zirkumpolarstrom stammenden Warmen Tiefenwassers und des neugeformten Weddellmeer-Bodenwassers gemessen. Die Fortsetzung dieser Entwicklung soll verfolgt werden, um festzustellen, ob sie durch lokale Veränderungen der Eis-Ozean-Atmosphären-Wechselwirkung verursacht wird, oder, ob sie durch Veränderungen des Einstroms aus dem Zirkumpolarstrom bewirkt wird. Von besonderer Bedeutung ist dabei der Einfluß dieser Veränderungen auf die Stabilität der Wassersäule und die Eis-Ozean-Atmosphären-Wechselwirkung westlich der Maudkuppe. Dort wurde in den Siebziger Jahren eine riesige Polynja beobachtet, die zur Bildung von Tiefenwasser im offenen Ozean geführt hat. Der Wechsel der Wassermassenbildung im Weddellmeer von Prozessen auf dem Schelf und am Kontinentalabhang zu solchen im offenen Ozean ist ein Vorgang, der die Ursache abrupter Veränderungen der thermohalinen Zirkulation sein könnte und möglicherweise Auswirkungen auf großräumige Klimaveränderungen hat.

Um die Prozesse der Wassermassenbildung und deren Auswirkung auf den globalen Ozean besser zu verstehen, enthält das Programm zwei Komponenten: Die Messung des Ausstroms aus dem westlichen Weddellmeer in den Antarktischen Zirkumpolarstrom im Bereich der Weddell-Scotia-Konfluenz (Abb. 2) und die Messung des Austauschs zwischen dem östlichen und westlichen Weddellmeer über den Meridian von Greenwich. Dazu werden hydrographische Schnitte mit einer CTD-Sonde (Conductivity/Temperature/Depth), einem Kranzwasserschöpfer und einem ADCP (Akustischer Doppler-Profilstrommesser) ausgeführt. Zusätzlich werden Strömungsmesserverankerungen auf dem Meridian von Greenwich (Abb. 3, oben) und bei Joinville Island (Abb. 3, unten) aufgenommen und wieder ausgelegt.

Die Messungen dienen u. a. zur Validierung von Modellen, welche die Zirkulation und Wassermassenbildung im Weddellmeer simulieren. Sauerstoff, Nährstoffe und die Spurenstoffe Freon-11, Freon-12, Freon-113 und CCl_4 , sowie Tritium, ^3He , He und Ne werden als zusätzliche Information zur Charakterisierung der Wassermassen und der Ausbreitungsprozesse herangezogen.

Die Arbeiten im Rahmen der physikalischen Ozeanographie sind ein Teil des internationalen DOVETAIL (Deep Ocean Ventilation Through Antarctic Intermediate Layers) Projektes, das im Rahmen des von SCOR (Scientific Committee of Oceanographic Research) betreuten iAnzone

Programms stattfindet. In diesem Zusammenhang werden die Geräte der Verankerungen im westlichen Weddellmeer von der Universität Politecnica de Catalunya in Barcelona, Spanien bereitgestellt.

Die Boden- und Tiefenwasserbildung trägt zur Aufnahme des Ozeans von atmosphärischem CO₂ bei. Allerdings kann im Weddellmeer durch den Auftrieb von CO₂-haltigem Tiefenwasser aus dem Nordatlantik CO₂ an die Atmosphäre abgegeben werden, wenn dies nicht durch die Abkühlung des aufquellenden Wassers in der ozeanischen Deckschicht und die Eisbedeckung verhindert wird. Die biologische Produktion entzieht der Deckschicht das eingebrachte CO₂ und befördert es als absinkendes Material in größere Tiefen. Die relative Intensität der unterschiedlichen Prozesse bestimmt die Rolle des Weddellmeeres als Quelle oder Senke für atmosphärisches CO₂. Deshalb sollen Messungen der einzelnen Komponenten des CO₂-Systems dazu beitragen, diese Vorgänge zu quantifizieren.

Im Rahmen der Meereisuntersuchungen werden meteorologische Daten zusammen mit Infrarot-Fernerkundungsdaten von Satelliten erfaßt, um einen neuen Algorithmus zur Wolkenmaskierung zu entwickeln.

Das mikrobiologische Programm konzentriert sich auf den Beitrag der Bakterien-Lebensgemeinschaften zum Kohlenstoff-Umsatz in polaren Breiten im Herbst. Dazu soll die Elementverteilung in den Bakterien mit Röntgen-Mikroanalyse ermittelt werden und die Konzentration des gelösten organischen Kohlenstoffs gemessen werden. Die mikrobielle Besiedelung in der Wassersäule sinkender Partikel ("Marine Snow") wird mit Wasserproben untersucht werden, aus denen Reinkulturen von heterotrophen Bakterien isoliert werden sollen. Sie sollen die Zählung der Bakterienzellen ermöglichen, die Aggregate besiedeln und die in der freien Wassersäule vorkommen.

Das Benthosprogramm des vorhergehenden Abschnitts wird mit der Härtung von Organismen fortgeführt, um mit Laborexperimenten die Aufnahme und Abgabe von Silikat durch Schwämme und Schwammnadelmatten zu messen und damit einen Beitrag zur Untersuchung des Silikatshaushalts zu leisten.

Die Reise wird am 21. Mai 1998 in Kapstadt enden.

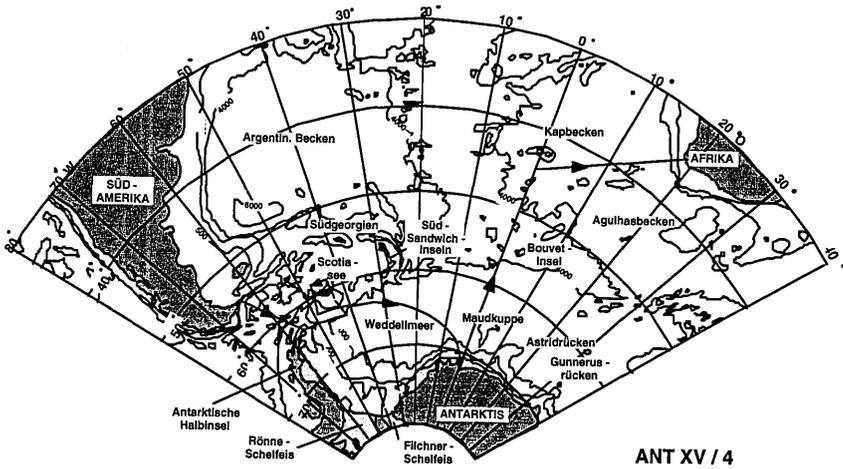


Fig. 1: Cruise track during leg ANT XV/4.

Abb. 1: Fahrtroute während des Fahrtabschnitts ANT XV/4.

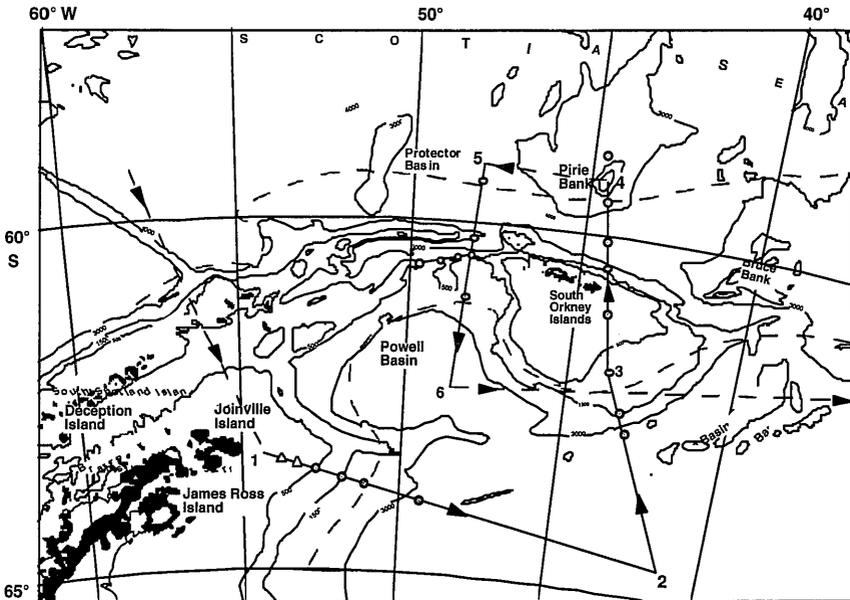


Fig. 2: Cruise track in the area of the Weddell-Scotia Confluence during leg ANT XV/4. The dots indicate the locations of moorings which were deployed during the DOVETAIL project.

Abb. 2: Fahrtroute im Bereich der Weddell-Scotia-Konfluenz während des Fahrabschnitts ANT XV/4. Die Punkte stellen Verankerungen dar, die im Rahmen des DOVETAIL Projektes ausgebracht wurden.

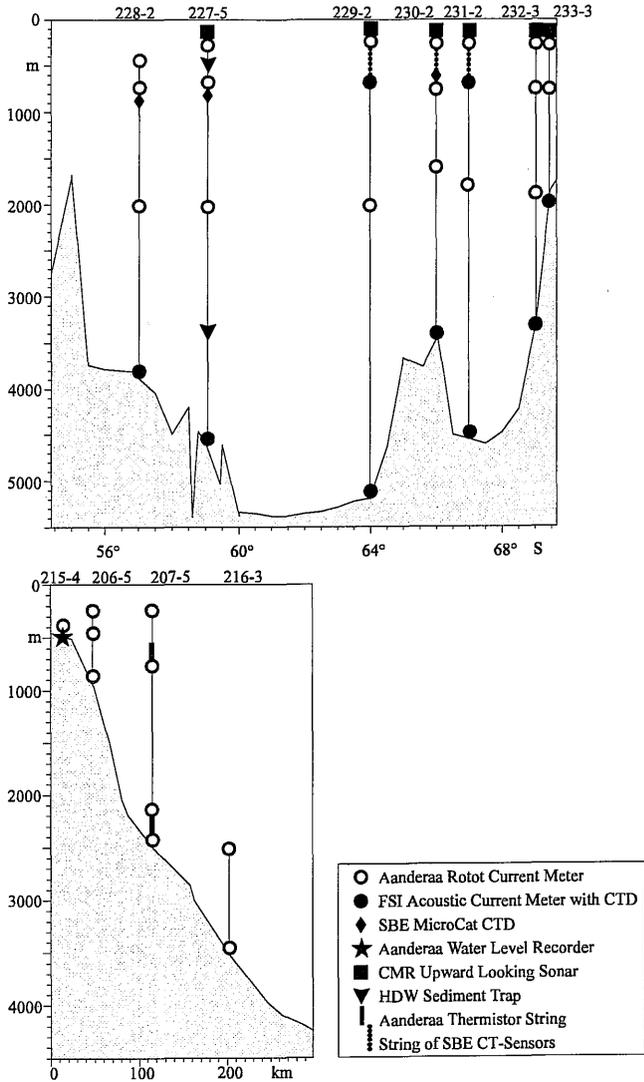


Fig. 3: Current meter moorings which will be recovered and redeployed along the Greenwich Meridian (top) and off Joinville Island (bottom).

Abb.3: Strömungsmesserverankerungen, die am Meridian von Greenwich (oben) und bei Joinville Island (unten) aufgenommen und ausgelegt werden.

2.2 Scientific programmes

2.2.2 Physical Oceanography

2.2.2.1 Water mass formation in the Weddell Sea and exchanges between the Weddell Sea and the Antarctic Circumpolar Current (AWI, FURG)

Objectives

A major part of the deep and bottom waters of the global ocean are ventilated by an injection of waters from the Weddell Sea. Cooling in winter and sea ice formation, as well as the interaction between the ocean and the ice shelves, induce water mass modifications which form water masses on the shelf which are dense enough to sink to the bottom of the Weddell basin. During their descent, they mix with ambient water masses and are carried with the cyclonic Weddell Gyre circulation to the north where they partly leave the Weddell Sea towards the Antarctic Circumpolar Current and partly recirculate.

A basic precondition for these processes is the inflow of relatively saline deep water of the Antarctic Circumpolar Current in the eastern Weddell Sea where this water mass is observed as Warm Deep Water. The inflow is subject to intense fluctuations which are partly generated by the interaction of the flow with the bottom topography. The kinematics and dynamics of the fluctuations will be investigated to understand the variations of the inflow. In the Weddell Sea, those fluctuations can substantially modify the water mass formation and the ice cover because of their effect on the vertical stability. Decreasing stability can enhance vertical mixing to an extent that open ocean polynyas can occur and possibly lead to deep water formation by open ocean convection.

To quantify the effect of the water mass formation processes on the global thermohaline circulation, it is aimed to measure the water mass characteristics and the transport of the exchanges between the eastern and the western Weddell Gyre and the outflow into the Weddell-Scotia Confluence. The outflow from the western Weddell Sea into the Weddell-Scotia Confluence consists of a shallow and deep component. The near-surface component is mainly made of shelf water from the western Weddell Sea which encounters the water of the Antarctic Circumpolar water belt. By this convergence, a system of two fronts is established, the Weddell and the Scotia Fronts, which include a new water mass, the characteristics of which are partly determined by

mixing of the two source water masses and partly by local ocean-ice-atmosphere interaction. It is probable that water, appropriately modified in the Weddell-Scotia Confluence sinks by frontal processes and subsequently contributes to the deep ocean renewal without having previously been deep or bottom water in the Weddell Sea. The deep component of the western Weddell Sea outflow is trapped by the Scotia Ridge and escapes partly through gaps of different depths to the north.

Measurements during the last years have indicated a gradual warming of the Warm Deep Water and the bottom water in the Weddell Sea. The further development of this process will be investigated to determine the origin of the variations. It could be of remote origin by changes in the intensity or the characteristics of the water mass entering the Weddell Sea from the north and thus the source water masses of subsequent water mass formation. An alternative hypothesis is local origin by the modification of water mass formation processes, either by variations in intensity or by switching between different processes. A possible scenario would be the reduction of the formation of ice shelf water underneath the Filcher Ice Shelf, which in consequence would lead to the domination of direct outflow from the western shelf.

To estimate the dominant time scales of the observed processes, long term measurements of the inflow, the mixing depth and the characteristics of the deep water are planned. Because of the impact of the sea ice formation on the water mass modification, the variations of the meridional profile of the sea ice thickness and concentration will be measured to identify possible correlation between sea ice and mixing variability.

The measurements will be used to validate models of the Weddell Gyre circulation and water mass formation. For this purpose, long time series of oceanic currents and water mass characteristics, as well as of the atmospheric forcing and the sea ice cover, are required to investigate the response of the system to variations of the forcing conditions.

The physical oceanography programme onboard is part of the international DOVETAIL project (Deep Ocean VENTilation Through Antarctic Intermediate Layers), a contribution to the SCOR affiliated iAnzone programme (Scientific Committee on Oceanic Research). In this context, the instruments in the moorings in the western Weddell Sea are provided by the Universitat Politecnica de Catalunya in Barcelona, Spain.

The cruise track in the Weddell-Scotia Confluence is partly a repeat of a survey carried out with the U.S. ice breaker "Nathaniel B. Palmer" in August 1997. During this survey, moorings were deployed in the operation area (Fig. 2).

Work at sea

The programme consists of two components:

- measurements of the outflow in the northwestern Weddell Sea into the Weddell-Scotia Confluence
- measurements of the exchanges between the eastern and the western Weddell Sea on the Greenwich Meridian.

The following measurements are planned for the two components:

Component 1:

- three hydrographic sections with a CTD-probe combined with a rosette water sampler and an ADCP (Fig. 2)
- the recovery and deployment of current meter moorings across the northwestern Weddell Gyre off Joinville Island (Fig. 3, bottom)
- the deployment of expendable current meters in the Weddell-Scotia Confluence.

Component 2:

- a meridional hydrographic section with a CTD-probe combined with a rosette water sampler and an ADCP
- the recovery and deployment of current meter moorings across the Weddell Gyre on the Greenwich Meridian (Fig. 3, top)

From the water samples, salinity will be measured to control the CTD and the quality of the water samples. Concentrations of oxygen will be determined for the use in water mass analysis.

2.2.2.2 Tracer measurements (IUPT)

Objectives

On the hydrographic sections, measurements of the following tracers will be performed: CFCs (Freon-11 and Freon-12, Freon-113, CCl₄), tritium, ³He, He, and Ne. CFCs, tritium and partially ³He are transient tracers of anthropogenic origin. Measured distributions of these tracers provide information on subsurface water renewal from the ocean surface layer on yearly to decadal time scales. F-113 has been released into the atmosphere since the early sixties and is therefore a tracer for the younger waters while CCl₄ concentrations in the atmosphere have

increased since about 1920 and can be used to characterize the older waters. Sections investigated during the expeditions METEOR 11/5 (1990), ANT X/4 (1992) and ANTXIII/4 (1996) will be repeated to evaluate the increase of the tracer concentration with time. The comparison between the atmospheric and the in-situ increase will be used to study the water transport processes. Tracer concentrations are detectable through the water column everywhere except for the Cape Basin and the Drake Passage. The natural tracers ^3He , He, and Ne will be used to quantify the ventilation from the surface layer and for water mass analysis, e.g. the contribution of Ice Shelf Water.

Work at sea

The CFC measurements will be done onboard by gas chromatography. For the other tracers, samples will be collected for subsequent analysis on shore. The tracers are those required by the World Ocean Circulation Experiment (WOCE) and measurements will be done according to the WOCE quality standards. The CFC measurements will keep up with the rosette water sampling as far as possible. About 55 measurements per day are feasible. Sampling for the other tracers will be restricted to a subset of the hydrographic stations (about 50 in total).

2.2.2.3 Validation and Application of a Cloud Masking Algorithm (IUPF)

Objectives

The project aims to develop a new algorithm for cloud masking with infrared images of the sensor OLS onboard the DMSP platforms. The present algorithm also uses the data of the microwave sensor SSM/I. Up to now, only ice concentrations are used but in the future atmospheric parameters (liquid water path etc.) will also be included. Especially near the ice edge, the simultaneous analyses of the atmosphere and surface parameters offer a great potential for the improvement of the algorithm. Furthermore, the data of the sensors SSM/T1 and SSM/T2 will be used to classify clouds. For these tasks, in-situ data (observations of clouds and surface conditions, weather charts, radiosonde measurements) are necessary to validate the analyses. The goal of the project is to provide these data in the framework of the project HYPAM C (remote sensing of HYdro-meteorological PARameters by Microwave radiometry in polar regions) funded by the Deutsche Forschungsgemeinschaft.

The algorithm has been developed with gridded (5 km) data obtained during March 1992. The application to other data will extend the validation. A new data set which uses better analysed data should improve the performance of the algorithm. Furthermore the better resolution will improve the classification which is based on texture parameters.

Work at sea

During the cruise the following tasks will be carried out:

- receiving of OLS (full resolution), SSM/I, SSM/T1, SSM/T2, and AVHRR data
- storage of the data to gain a representative set for different weather situations (cloud and surface conditions)
- radiosonde measurements near the ice edge (10 selected days with at least 4 measurements per day)
- visual classification of the infrared images
- application of the cloud detection algorithm
- application of the ice edge determination with SSM/I data.

AVHRR: Advanced Very High Resolution Radiometer (NOAA-Satellites)

DMSP: Defence Meteorological Satellite Program

NOAA: National Oceanographic and Atmospheric Administration

OLS: Operational Linescan System (DMSP-Satellites)

SSM/I: Special Sensor Microwave Imager (DMSP-Satellites)

SSM/T1: Special Sensor Microwave Temperature (DMSP-Satellites)

SSM/T2: Special Sensor Microwave Water Vapor (DMSP-Satellites)

2.2.3 Marine Chemistry

2.2.3.1 Carbon dioxide, pH and nutrients in the Atlantic sector of the Antarctic (AWI, IUPT, NIOZ, PML)

Objectives

The level of atmospheric carbon dioxide (CO₂) has been rising due to anthropogenic causes, and it is thought certain that the CO₂ content of the oceans has increased as well. Whilst the atmospheric CO₂ increase is well documented, the oceanic increase is hard to monitor due to the high natural variations and the large amount of CO₂ present in the oceans. High-latitude areas are prominent in this issue because in these regions there is intense interaction between the deep and the surface waters. Recently observed variations in atmospheric CO₂ were

attributed to processes occurring in the Southern Ocean. Our overall objective is to trace the anthropogenic CO_2 in the deep and surface waters of the Antarctic Ocean and to investigate what factors exert an influence on the CO_2 distribution. It should be appreciated that substantial progress can only be made when long data series become available. Data from this cruise will supplement earlier data collected by our labs.

Particular objectives during this cruise are:

- to examine the possible increase of total CO_2 in the recent bottom water of the western Weddell Sea,
- to determine the exchange of CO_2 between the ocean and the atmosphere in austral autumn and compare this with previous data for interannual variations,
- to correlate pCO_2 and pH with other parameters to obtain the factors causing variations in the surface waters,
- to use pH, which can be determined accurately and rapidly, to investigate small-scale and meso-scale features of the CO_2 system in the surface ocean,
- to extend our data base of total CO_2 of the Weddell Sea to combine this with transient tracers (freons) for obtaining the temporal scale of the invasion of anthropogenic CO_2 ,
- to use nutrients data as an additional tracer of water masses in the Weddell Gyre.

Work at sea

We will determine total CO_2 (TCO_2) and pH onboard ship from discrete water samples taken from the rosette sampler. TCO_2 is the sum of all dissolved inorganic carbon species and is analysed by a precise coulometric method. The accuracy is set by internationally recognised certified reference material for TCO_2 measurements. The pH (the degree of acidity) is determined using a recently developed spectrophotometric method with very high precision and accuracy as compared to the earlier pH measurements with glass electrodes. In addition, on-line data of surface water pCO_2 (partial pressure of CO_2) and pH will be collected from the ship's pumping system. The pCO_2 is obtained using an infrared analyser, both from seawater using a shower-head equilibrator and from the atmosphere, the air being pumped in from the crow's nest. On hydrographic stations, we will measure the values of three different parameters of the CO_2 system (TCO_2 , pH and pCO_2), thus overdetermining the system. This allows us to check the internal

consistency of the measurements. Nutrients will be measured with a fully-automatic auto-analyzer system.

2.2.4 Marine Biology

2.2.4.1 Decomposition of sinking particles (UFT)

Objectives

Rapidly sinking particles in the water column, so called "Marine Snow", consist of dissolved and colloidal organic matter which aggregates together, e.g. phytoplankton aggregates, fecal pellets and detritus. Bacteria and protozoa seem to play an important role in decomposition of "Marine Snow", the main decomposition taking place in the mesopelagic zone.

In this investigation, single strains of bacteria attached to "Marine Snow" will be isolated. By means of these isolates, the microbial decomposition of "Marine Snow" by different species of bacteria will be investigated. In addition, preparations for light and electron microscopy will be made. The results will be compared with those of two cruises in the equatorial Atlantic in 1996 and 1997.

Work at sea

In order to investigate the colonization of sinking particles in the water column, ("Marine Snow") samples from different water depths (0 - 250 m) will be taken with a Niskin-Watersampler. Pure strains of attached heterotrophic bacteria will be isolated from samples which have been filtered to increase particle concentration. In order to quantify the bacteria, it is planned to fix sampled material with formalin. The samples will be treated with the epifluorescence dye DAPI in order to count the bacterial cells of the free water column as well as the attached bacteria. The fixed material has to be examined with a scanning electron microscope to determine the colonization with attached bacteria.

2.2.4.2. Contribution of the microbial community to the biological activity in autumn (IM)

Objectives

To determine the contribution of the microbial community to the biological activity within the sea ice and the water column during

autumn and its role in the carbon cycle, bacterial elemental diversity and dissolved organic carbon (DOC) production as well as degradation will be determined. By measuring single cells from this environment, it should be possible to obtain information about which properties enable these organisms to survive in such an environment. Nutrient ratios of microorganisms normally reflect their growth. Whether this is also the case in waters where nutrients are non-limiting for growth is not known. By using both X-ray microanalysis (XRMA) and as well as DOC measurements, it may be possible to obtain information about bacterial activity and changes in elemental composition of bacteria. Samples from pelagic and ice associated microorganisms will be taken to determine whether they have different strategies for survival. Incubation experiments will be carried out on the ship to obtain data from individual cells.

Background data such as chlorophyll (standing stock) and DOC (dissolved organic carbon) will be taken to relate and identify the physico-chemical properties of the environment to observed changes in microbial nutrient ratios. Measurements of DOC in conjunction with those of inorganic carbon allow conclusions on the carbon cycle in the Southern Ocean. This information is essential for modelling the pool of net biological carbon harvest in these areas.

Work at sea

X-ray microanalysis (XRMA) is used to analyse the elemental composition in single cells. It provides information on the physiological state of single organisms as well as on variations within and between microbial communities. The elemental composition of individual bacteria living in an environment with high concentrations of nitrogen and phosphate have not been measured before and the planned analyses should provide important information for our understanding of community structure in Antarctic microbial communities.

Samples for Chlorophyll-a measurements will be taken three times every day from the sea surface. XRMA measurements will be carried out mainly on samples from stations with ice cover, taken once a week from the surface and from 400 m depth. DOC measurements will be made every day from 3 surface samples. The required sample size is 2 l from each sampled station, 5 l from the surface once a week and 2 kg ice when present.

2.2.4.3 The role of sponges in carbon and silicon flux in the Weddell Sea (AWI)

Objectives

Sponges and sponge needle mats are assumed to be major benthic components in the Antarctic carbon and silicon cycle. To evaluate their function in the Antarctic system, the sponge energy metabolism and silicon chemistry will be investigated. Consumption and production of sponges can be determined via mass specific respiration rates of abundant sponge species. Laboratory experiments on silicon uptake and release of sponges and sponge needle mats will allow the calculation of the benthic silicon budget.

Work at sea

The work includes:

- determination of mass specific respiration rates of sponge species collected during ANT XV/3
- preparation of sponges and sponge needle mats sampled during ANT XV/3 for silicon uptake and release experiments
- maintenance of benthic invertebrates kept in aquaria for transport to AWI laboratories.

Participants / Fahrtteilnehmer

ANT XV/3

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ANT XV/3

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DWD	Deutscher Wetterdienst, Geschäftsfeld Seeschifffahrt Bernhard-Nocht-Str. 76 D - 20359 Hamburg Germany
HSW	Helicopter Service Wasserthal GmbH Kättnerweg 43 D - 22393 Hamburg Germany
ICM	Instituto de Ciencias del Mar Paseo Joan de Borbó s/n E - 08039 Barcelona Spain
IEO	Centro Oceanografico de Santander Instituto Español de Oceanografía Promontoriode San Martin s/n, Apdo. 240 E - 39080 Santander Spain
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UFT Zentrum für Umweltforschung und Technologie (UFT) Abt. Marine Mikrobiologie Universität Bremen Postfach 330 440 D-28334 Bremen	1
IUPT IUP - Institut für Umwelphysik Abt. Tracer-Ozeanographie Universität Bremen, FB 1 Postfach 330 440 D-28334 Bremen	6
IUPF IUP - Institut für Umwelphysik Abt. Fernerkundung Universität Bremen, FB 1 Postfach 330 440 D-28334 Bremen	1

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