RV „POLARSTERN"

Expedition Programme No. 40

ANTARCTIC XIII/2-3

1996

ALFRED WEGENER INSTITUTE FOR POLAR AND MARINE RESEARCH
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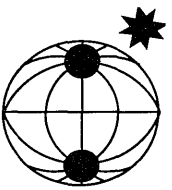

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ANT XIII/2
Chief Scientist: V. Smetacek

ANT XIII/3
Coastal Shelf-Ecology of the Antarctic Sea Ice Zone (CS-EASIZ)
Chief Scientist: W. Arntz

Coordinator: E. Augstein

Alfred Wegener Institute for Polar and Marine Research Bremerhaven
October 1995

1. Cruise Leg ANT XIII/2

Capetown - Capetown: 4 December 1995 - 24 January 1996
Chief Scientist: Victor Smetacek

1.1 SCIENTIFIC BACKGROUND, OBJECTIVES AND ITINERARY

Processes occurring along frontal zones, although restricted in their spatial extent, have a major impact on the physics, chemistry and biology of the Southern Ocean. A prerequisite to understanding these processes and the various causative mechanisms is data collection at much smaller scales than those addressed by the average cruise because of the complex dynamics of frontal systems. The towed undulating instrument SeaSonar enables rapid, detailed mapping of the surface ocean down to about 500 m depth and the main aim of ANT XIII/2 is to measure physical, chemical and biological parameters using this instrument along a productive frontal zone. A suite of additional properties will be assessed simultaneously in water samples taken from the sea surface. Two small-scale (10km grid spacing) three-dimensional surveys (ca. 100 x 100 km) will be carried out in the beginning and end of the cruise. Between these surveys, a meridional transect comprising a number of water column stations will be carried out through the survey area. Gear deployed at these stations will include a CTD rosette, multinet, Bongonet, Rectangular Midwater trawl and in situ pumps. A larger-scale SeaSoar survey is also planned upstream from the boxes to gain an impression of the overall hydrography and biology of the frontal system.

The cruise ANT XIII/2 is part of the international Joint Global Ocean Flux Study (JGOFS) dedicated to measurement of the carbon cycle with particular focus on processes leading to CO2 drawdown from the atmosphere and transfer of biogenic matter via vertical flux to the ocean interior. To this end a number of core parameters have been identified to ensure adequate coverage of relevant processes and whose measurements are mandatory for JGOFS studies. We will not assess all core parameters during ANT XIII/2 but will concentrate on mesoscale processes along a frontal zone.

The first JGOFS cruise of RV Polarstern (ANT X/6) was conducted during October/November 1992 by repeating transects along the 6°W meridian that extended from the ice edge at 58° S, crossed the open waters of the southern Antarctic Circumpolar Current (ACC) and entered into the Polar Frontal Zone as far north as 47° S. In the course of this cruise, build-up of almost mono-specific blooms of diatoms were observed in waters associated with the Polar Front concomitant with strong undersaturation of CO2. As higher iron concentrations were found here that were depleted with progress of the blooms, a strong case could be made for iron limitation of Southern Ocean productivity. However, the region was also characterised by shallower mixed layers although substantial diatom biomass often extended to depths where growth rates must have been light-limited. It was assumed that the phytoplankton distribution pattern was caused by the dynamics of the frontal zone

which led to subduction of surface layers. Hence the blooms must have arisen under favorable light conditions prevailing in a shallow mixed layer. A major outcome of ANT X/6 was the need to assess mesoscale dynamics of water masses along fronts in order to understand chemical and biological processes occurring there.

Southern Ocean phytoplankton can be grouped into two categories: pico and nanoplanktonic flagellates belonging to various algal classes and the diatoms which tend to be chain-forming or possess large cells. Whereas the biomass of flagellates rarely exceeds about 0.3 mg Chlorophyll m-2, diatoms give rise to blooms of much higher biomass that are, however, spatially and temporally restricted in their occurrence. Understanding the factors leading to build-up of diatom blooms is essential to understanding and quantifying marine biogeochemical cycles as it is this group which has the greatest impact on vertical flux and CO2 drawdown.

Diatom biomass accumulation can be achieved in two ways: a) by increasing growth rates and/or b) by decreasing mortality due to cell death, sinking, parasites and grazing.
a) Growth rates can be enhanced by improving light climate in shallow mixed layers (<40 m depth) or increasing availability of iron which has been shown to occur at very low concentrations in most areas of the Southern Ocean. The source of high iron concentrations (>1 nM) recorded in the Polar Frontal region during ANT X/6 is not clear but the presence of elevated particulate aluminium strongly suggests continental rather than a deep-water source. Transport could either be via aeolian dust or shelf sediment (from the Falkland or S. American shelves) in the polar jet. During ANT XIII/2 factors influencing growth rates in terms of underwater light climate, macronutrients and iron in relation to hydrography will be studied in detail. Growth rates of phytoplankton will be assessed using various direct and indirect measurements although no in situ incubations will be possible due to time constraints.
b) Mortality rates are more difficult to assess but it is hoped that live counting of diatoms will reveal losses due to cell death by unfavourable environmental factors and parasitoids. The biomass and composition of proto- and metazooplankton will be measured and grazing rates calculated using conversion factors to be estimated on board but also from the literature. Sinking out of particulate matter will be followed by Thorium budgets.

FS "Polarstern" will leave Cape Town on 4th December 1995 and proceed for the German station Neumayer. Immediately after leaving South African waters, SeaSoar will be deployed and towed continuously at about 8 - 10 kn till the first pack-ice floes are sighted, probably at about 56° S. The cruise track south will meet positions (50°06.0'S, 05°55.4'E; 54°19.91'S, 03°20.57'W; 57°37.8'S, 04°02.3'E) where oceanographic moorings will be served. Surface registration of various parameters including the CO2 system, macronutrients, dissolved iron, discrete chlorophyll measurements and species composition of plankton will be carried out. The first test station employing the CTD rosette and various nets will be

conducted after retrieving SeaSoar at the ice edge after which the ship will proceed directly to Neumayer and unload equipment, supplies and personnel.

The ship will then steam north to the investigation area located on a productive front and selected on the basis of the first SeaSoar transect. Because of the prevailing ice conditions, the Polar Convergence at about 50°S will probably be the most suitable area. A mooring with sediment traps, current meters, ADCP will be deployed here and the first small-scale SeaSoar survey carried out immediately afterwards. The grid will be about 100 x 100 km with 10 km grid spacing. The survey will take about 5 days of continuous towing and will be accompanied by surface registration of various properties and collection of surface samples for various measurements. The long transect crossing the area mapped by SeaSoar will be conducted next. Gear deployed at the various stations will include the CTD rosette, Multinet, Bongo net, Rectangular Midwater Trawl and in situ pumps. After completion of this transect, which will take about 3-4 days, SeaSoar will be towed again, but this time a larger area to the West of the first survey site will be covered with broader grid spacing. Following this survey the area of the first grid will be mapped again. Depending on time available, a second transect with water column stations will be repeated after which the ship will proceed south to the pack-ice edge and repeat the first SeaSoar transect on the way back to Cape Town.

1.2 ZUSAMMENFASSENDE ÜBERSICHT

An ozeanischen Fronten ablaufende physikalische, chemische und biologische Prozesse beeinflussen die angrenzenden Ozeanbereiche weiträumig und nachhaltig, obwohl diese Prozesse selbst nur geringen räumlichen Ausdehnungen haben. Vorbedingung zum Verständnis dieser Prozesse und den ihnen zugrunde liegenden Kausalzusammenhänge ist eine Datendichte, die sehr viel kleinräumiger ist im Vergleich zu der, die während normaler Expeditionen gewonnen wird. Das Schleppsystem SeaSoar ermöglicht durch sein schnelles Durchstreifen des Wasserkörpers bis zu einer Tiefe von 500 m eine detaillierte Aufnahme physikalischer, chemischer und biologischer Daten und wird daher während ANT XIII/2 in einem Hochproduktionsgebiet an einer Ozeanfront zur kleinräumigen Erfassung der entsprechenden Strukturen im Wasser eingesetzt. An kontinuierlich genommene Proben des Oberflächenwassers (8 m Tiefe) werden weitere wichtige biologische und chemische Parameter bestimmt. Zwei kleinräumige dreidimensionale Untersuchungen (10 km Transektabstand) werden in Gebieten mit 100 km Kantenlänge am Anfang und am Ende der Fahrt durchgeführt. Dazwischen wird auf meridionalen Transekten eine Reihe weiterer Stationen durchgeführt, an denen Wasserproben mittels CTD-Rosette aus diskreten Tiefen bis zum Meeresboden genommen werden. Die eingesetzten Geräte umfassen neben der CTD, das Multi- und Bongonetz, das Rectangular Midwater Trawl (RMT) und in situ Pumpen. Eine großräumige Aufnahme der Hydrographie mittels SeaSoar gegen die Hauptstromrichtung soll

Informationen über die Vorgeschichte der vermessenen Wasserkörper der Untersuchungsgebiete an der Front liefern.

Die Expedition ANT XIII/2 ist Teil des internationalen Programms "Joint Global Ocean Flux Study" (JGOFS), das dem marinen Kohlenstoffkreislauf gewidmet ist mit Schwergewicht auf der Erfassung von Austauschprozessen von CO2 zwischen Ozean und Atmosphäre. Dazu gehört der Einbau von CO2 in organisches Material und dem anschließenden Transport in große Ozeantiefen. Für Untersuchungen im Rahmen von JGOFS wurden eine Reihe Basisparameter identifiziert, um alle relevanten Prozesse quantitativ zu erfassen. Während ANT XIII/2 werden wir nicht alle dieser Parameter berücksichtigen, da wir uns auf mesoskalige Prozesse an Ozeanfronten und deren Mechanismen konzentrieren werden.

Die erste JGOFS Expedition mit RV Polarstern (ANT X/6) in die Antarktis wurde im Oktober/November 1992 durchgeführt. Auf dem 6°W Meridian wurden Transekte von der Meereisgrenze bei 58° S über den südlichen Antarktischen Zirkumpolarstrom (ACC) bis in die Polarfrontzone (47° S) hinein aufgenommen. In dieser Zone wurde der Aufbau von zwei jeweils fast monospezifischen Diatomeenblüten beobachtet, die zur starken Untersättigung des Oberflächenwassers mit CO2 führten. Im selben Gebiet waren anfänglich die gelösten Eisenkonzentrationen sehr hoch und nahmen im Verlauf der Blütenentwicklung ab; es ist anzunehmen, daß das Phytoplanktonwachstum in diesem Bereich des Südpolarmeeres - vor allem im ACC - eisenlimitiert ist. Hinzu kam, daß in der Polarfrontzone die Durchmischungstiefen der Oberflächenschicht gering waren und daher förderlich für den Aufbau von Phytoplanktonblüten. Zusätzlich wurde die Verteilung der Phytoplanktonbiomasse durch die Dynamik in der Frontenzone bestimmt, die zu Überlagerungen von Wasserkörpern führte. Nur so ist zu verstehen, daß bis in über 100 m Wassertiefe hohe Phytoplanktonkonzentrationen auftraten, deren Heranwachsen nur oberflächennah erfolgt sein konnte. Ein wichtiges Fazit von ANT X/6 war die Erkenntnis, daß die Aufnahme der mesoskaligen Prozesse der Wassermassen an Fronten notwendig zum Verständnis der dort ablaufenden chemischen und biologischen Prozesse sind.

Das Phytoplankton im Südpolarmeer kann in zwei Gruppen eingeteilt werden: Pico- und Nanoplankter (Flagellaten), zu denen zahlreiche Algenklassen beitragen und die Diatomeen, die entweder lange Zellketten oder große Zellfortsätze ausbilden. Die Biomasse der Flagellaten übersteigt selten 0.3 mg Chlorophyll m-3. Diatomeen bilden Blüten (also viel höhere Algenbestände), die allerdings räumlich und zeitlich begrenzt sind. Nur das Verständnis der Faktoren, die zu solchen Blütenbildungen führen, erlaubt uns, marine biogeochemische Zyklen zu verstehen und zu quantifizieren. Die Diatomeen stellen den größten Anteil am vertikalen Stoffffluß im Ozean und somit am CO2 Vertikalfluß.

Der Aufbau großer Diatomeenbiomassen kann über zwei Wege erfolgen: a) durch hohe Wachstumsraten und/oder b) durch

Reduktion der Verluste durch Zelltod, Absinken, Parasiten und Wegfraß.
a) Wachstumsraten werden durch gutes Lichtklima in einer flachen (<40m) durchmischten Oberfläachenschicht und/oder durch hohe Eisenkonzentrationen begünstigt, die aber in weiten Gebieten des Südpolarmeeres sehr niedrig sind. Die Quelle der hohen Eisenkonzentrationen (>1 nM) in der Region der Polarfront während ANT X/6 ist immer noch unklar, obwohl die parallel hohen Konzentrationen partikulären Aluminiums stark auf kontinentalen Ursprung hinweisen. Der Transport kann entweder über die Luft (Staub) oder durch den Frontenjet erfolgt sein, der Schelfsedimente (der Falkland Inseln oder von Südamerika) berührte.

a) Während ANT XIII/2 werden die Wachstumsfaktoren Hydrographie, und die Verteilung des Unterwasserlichtklimas der Makro- und Mikronährsalze im Detail vermessen. Wachstumsraten des Phytoplankton werden durch direkte und indirekte Methoden bestimmt, da eine in situ Inkubation aus Zeitgründen nicht möglich sein wird.

b) Verlustraten sind schwieriger zu bestimmen. Zählungen an Lebendmaterial sollen helfen die Verluste durch Zelltod und Parasiten abzuschätzen. Biomasse und Zusammensetzung von Proto- und Metazooplankton werden bestimmt, sowie die jeweiligen Freßraten. Letztere werden entweder anhand von Literaturwerten abgeschätzt oder direkt gemessen. Sinkraten partikulärer Substanz werden über ein Thorium/Uran Budget bestimmt.

Am 4. Dezember 1995 wird der Fahrtabschnitt ANT XIII/2 in Kapstadt beginnen. Das wissenschaftliche Programm wird nach dem Verlassen der Hoheitsgewässer mit Oberflächenregistrierungen (bis zu 500 m Wassertiefe mit Hilfe von SEASOAR) von Temperatur, Salzgehalt, und in 8 m Wassertiefe mit der Registrierung des Karbonatsystems (u.a. CO_2) und des Chlorophyllgehaltes des Meerwassers beginnen. Die Fahrtroute wird uns über die Polarfront zuerst an die Schelfeiskante zur Neumayer Station führen und drei Verankerungspositionen (50°06.0'S, 05°55.4'E; 54°19.91'S, 03°20.57'W; 57°37.8'S, 04°02.3'E) überlaufen, an denen wir biologisch-ozeanographische Meßsysteme auswechseln werden. Anhand der vorliegenden Ergebnisse wird dann nach dem Entladen der Versorgungsgüter bei Neumayer in einem Zielgebiet zwischen 60° und 47°S um 0°E (Abb. 1) für weitere Untersuchungen ausgewählt, das sich durch hohe Planktonbiomasse an einer ozeanischen Front auszeichnet. In diesem Gebiet wird eine Verankerung ausgebracht, in der mehrere wissenschaftliche Meßgeräte (Sinkstoffalle, Strommesser, ADCP) die Dynamik der Wassermassen und die Exportproduktion aufnimmt.

Die mesoskalige Aufnahme der hydrographischen Dynamik in dem ca. 100 mal 100 km großen Untersuchungsgebiet wird durch einen gitterförmigen Kurs mit einem Abstand von ca. 10 km zwischen den Transekten mittels SEASOAR erfolgen. Bei SEASOAR handelt es sich um ein geschlepptes Sytem, daß mittels Schwimmflächen zwischen

0 und 500 m Wassertiefe kontinuierlich undulieren wird und Meßdaten von Temperatur, Leitfähigkeit, Druck und Trübung liefert. Für das Schlepppprogramm werden 5 bis 7 Tage veranschlagt.

Im Anschluß an die räumliche Auflösung der Hydrographie mittels SEASOAR werden umfangreiche Messungen im Wasser bis zum Tiefseeboden erfolgen. Die eingesetzten Geräte umfassen u.a. CTD, Multinetz, Bongonetz, RMT und in situ-Wasserpumpen, um diskrete Proben zur Bestimmung von physikalischen, chemischen und biologischen Parametern zu erhalten. Zu diesen zählen die biologisch wichtigen chemischen Nährsalze (z.B. Nitrat, Phosphat, Silikat), der partikuläre organische Kohlen- und Stickstoff, die Verteilung stabiler und Radioisotope (^{15}N, ^{13}C, ^{234}Th) im Meerwasser und in den Partikeln, und die Bestände des Phyto- und Zooplanktons. Ein Schwerpunkt der Feldarbeiten wird in den klein- bis mesoskaligen Aufnahmen der Verteilung von Phyto- und Protozooplanktern in Abhängigkeit vom hydrographisch-chemischen Umfeld liegen. Diese Arbeiten sollen durch Mikroskopie von Lebendmaterial direkt nach der Probennahme im Stundenabstand erfolgen.

Die Untersuchungen in den verschiedenen Wassermassen werden durch umfangreiche Experimente an Bord des Forschungsschiffes ergänzt. In diesen werden Umsatzraten wie die Primärproduktion, Aggregatbildung und die Freß- und Reproduktionsaktivitäten von Zooplanktern bestimmt. Es erfolgt zudem eine genaue Analyse der Einbauwege von stabilen Isotopen (^{15}N, ^{13}C) im Plankton, um ein Maß für Neue bzw. Regenerierte Produktion zu erhalten.

Weitere quasi-synoptisch Aufnahmen der Hydrographie einer "Box" und weitere Transekte mit diskreten Wasserproben wechseln sich im Folgenden ab. Während der Rückfahrt nach Kapstadt, wo wir am 26. Januar 1996 einlaufen wollen, werden wie auf der Hinfahrt das SEASOAR geschleppt und Oberflächenwasserproben genommen.

1.3 SEA ICE CONDITIONS
(IBN-DLO)

Distribution and characteristics of sea ice are of importance to the Southern Ocean JGOFS program because sea ice cover strongly influences physical, chemical and biological parameters of the system studied. Sea ice conditions will be recorded in two ways:

1.) At each oceanographical station (or other regular distance), ice conditions will be recorded following the SO-JGOFS protocol. Cover, floe-size, thickness, development, ridging and algal discoloration are recorded in detail, but have a relatively low frequency.
2.) Secondly, ice conditions within a 300 meter transectband are surveyed for each 10 min time-block in which top predator censuses are conducted. Less parameters are recorded, but the obversations have a high frequency and give a good impression of small scale variability. Iceberg observations are included in both methods.

1.4 *PHYSICAL CONTROL OF PRIMARY PRODUCTION AT FRONTS IN THE CIRCUMPOLAR CURRENT CLOSE TO THE GREENWICH MERIDIAN*

Physical processes relevant to the marine primary production play a central role in the climate system as a feedback mechanism between possible climate changes which may result from alterations of the CO_2 concentration in the atmosphere and the drawdown of carbon to the deep ocean and sediment by way of the biological pump. The proposed measurements aim at revealing those physical processes which can explain the existence of the 'Antarctic Paradox', the low mean level of primary production within a nutrient rich environment. As the general antithesis to the iron hypothesis (limitation of primary production due to the shortness of iron availability) it will be tested whether physical processes alone can account for limitation.

The relevant physical processes will best be revealed by comparison of physical measurements made in the productive and the less productive regions within the circumpolar current. Existing data suggest that fronts are regions of enhanced production. One example is the Polar Front with the opal belt found at the sea bottom below, indicating a sedimentation of silica rich biogenic material which is increased in the climatological mean.

The physics of fronts can influence the primary production by horizontal advection, or by the frontal dynamics which forces vertical motion and the associated variation of stratification during frontogenesis and frontolysis. The vertical motion can resupply the photic zone with nutrients (macro and micro nutrients) in the one place and carry phytoplankton down into the dark and force sedimentation in the other place, and the variation of stratification influences the depth of the mixed layer within which the densest blooms favourably occur. The relevant horizontal scales, however, may be quite small (few tens of kilometres) and the time scales quite short (some days), posing considerable demands on the measuring system being used.

The fundamental physical measurements during this cruise are planned to be made by use of an instrument package (SeaSoar+ADCP) which proved its abilities before, e.g. in the North Atlantic where it revealed the typical size of phytoplankton patches, having the horizontal scale of the internal Rossby radius (of the order of a few tens of kilometres) and being explained by the enhancement of primary production due to mesoscale upwelling at fronts, and also in the Southern Ocean where a narrow band of high chlorophyll concentration associated with a front in the Bellingshausen Sea was recently identified. The SeaSoar+ADCP package allows the density and velocity structures of a front being measured simultaneously with other physical and biological variables down to 400 m depth at high horizontal resolution in quasi-synoptic manner. The SeaSoar undulates vertically through the water column while being towed behind the ship moving at almost cruising speed; it will carry sensors for the measurement of temperature, conductivity, and

pressure (salinity and density as derived variables), of solar irradiance, the chlorophyll fluorescence and oxygen content, and optionally an optical plankton counter. The vessel mounted ADCP (Acoustic Doppler Current Profiler) enables the measurement of the horizontal current profile in the depth range of the top few hundred meters. In addition to its main purpose the ADCP can be used as an detector for zooplankton abundance by evaluating the echo amplitude. The SeaSoar+ADCP measurements will be complemented by a number of ocean-deep CTD (Conductivity Temperature Depth) stations revealing the deeper hydrographic structure, and allowing the collection of water samples from depth by use of the attached rosette sampler. The water samples are to be analyzed for salinity (by a salinometer for calibration purposes), for the concentration of chlorophyll, plankton species composition, nutrients, carbon compounds, dissolved gases, etc.

The measurement strategy is to perform two long SeaSoar transects extending between the South African shelf break and the ice edge off Antarctica, one transect at the begin of the cruise and the second repeated along the same line at the end, to reveal the temporal changes of the upper ocean physical conditions and the associated changes in primary production on the large scale. On basis of results of the first long section the decision will be made where to centre a 3-dimensional mapping of an interesting (productive) frontal structure. The temporal development of the mesoscale front and eddy structure is planned to be studied from repeating the frontal mapping in exactly the same region with a delay of one to two weeks. The time period in between the two mappings shall be used for conducting the CTD stations and to perform a coarse resolution SeaSoar survey of the upstream area to asses the influence of advection. To achieve synoptic mapping of the frontal structures it is essential that these surveys are conducted as fast as possible, i.e. without being interrupted by other work.

1.5 NUTRIENTS AND DISSOLVED AND PARTICULATE MATTER (AWI)

In comparison with former "Polarstern" expeditions it is planned to investigate the distribution and dynamics of the major nutrients in the frontal zone. In contrast to the large scale measurements during the cruises ANT X/4 and ANT X/7, our interests on this expedition are focussed on the nutrient distribution in the upper layer and the interactions between phytoplankton and nutrients during the development of phytoplankton blooms.

The nutrient distribution will be the basis for intense investigations concerning the transformation of dissolved inorganic nitrogen (DIN) to the particulate and dissolved organic nitrogen pools (PON/DON). Additionally, the concentration of dissolved organic carbon (DOC) will be determined. In this context formation processes of dissolved organic matter as well as breakdown and uptake by heterotrophic organisms will be considered.

To elucidate the interactions and relative importance of the different dissolved and particulate nitrogen pools during the course of a phytoplankton bloom stable carbon and nitrogen isotopes will be measured later by mass spectrometry. For a better comparison of the isotopic composition of the dissolved and particulate organic matter it is necessary to split up the particulate material in different size fractions. These values are compared with the stable carbon and nitrogen isotope distribution in dissolved organic substances which should lead to conclusions about formation processes involved. Beside these processes the uptake of organic matter by plankton organisms (microbial-loop) will be investigated.

The sampling program includes on-line sampling by means of the membrane pump installed on board "Polarstern" as well as bottle samples from CTD-casts. In the area of the selected boxes in the Polar Front Zone a filtration system for collecting size fractionated POM will be used. This system must be supplied by the membrane pump since large filtration volumes are necessary to collect sufficient amounts of particulate material. From this POM the isotopic carbon and nitrogen composition of the different size fractions will be determined. The on-line filtration system will be connected to an extraction unit which separates inorganic from organic dissolved nitrogen and enriches dissolved organic carbon.

Additional to the sampling of organic matter nitrate and silicate concentrations will be measured underway using a modified Autoanalyzer II System. During the CTD-transects all nutrients (nitrate, nitrite, ammonium, silicate and phosphate) and dissolved parameters mentioned above will be measured in the samples drawn from the rosette bottle system.

1.6 BIOGENIC PRODUCTION OF NEUTRAL AND IONIC METHYL HEAVY METAL SPECIES IN POLAR WATERS

(IACUR)

In polar regions only determinations of the total concentration of heavy metals have been carried out, and little is known about the speciation of these heavy metals. Different species of heavy metals have different properties, especially with regard to geochemical transport, the toxicity or the bioavailability. Therefore, it is necessary to identify and determine heavy metal species to acquire more precise and detailed information for example, on geochemical cycles and the global sources and sinks in whcih connection biomethylation is an important biogeochemical process. In anthropogenic influenced areas it is difficult to relate organo-metal compounds in the environment to definite primary sources. It is, in principle, possible to prove the feasible biogenic production of such compounds in the "clean room" environment of the Antarctic. By that it is also possible to determine the contribution of these compounds to the global biogeochemical cycle of the heavy metals. For the determination and specification of neutral and ionic methylated heavy metal

compounds, the elements mercury, lead, cadmium and thallium will be considered.

High enrichment factors, especially for cadmium and lead in Antarctic snow samples suggest an emission of volatile organic heavy metal compounds from the polar seas. A correlation and determination of biogenic activity is needed because of the presumed biological production of these compounds. In samples of the Atlantic ocean methylated compounds of mercury, lead and cadmium could already be detected. The proportion of such compounds can reach up to 50 % of the total metal concentration in the ocean. The evidence of a possible biomethylation of thallium could be shown in laboratory experiments, but the corresponding compound could not be detected in the environment up to now.

The determination of mercury species will be carried out by CVAFS (Cold Vapour Atomic Fluorescence Spectrometry). With the help of DPASV (Differential Pulse Anodic Stripping Voltammetry) lead and cadmium species will be examined. Both methods will be applied on board RV "Polarstern". The corresponding thallium species will be assessed with IDMS (Isotope Dilution Mass Spectrometry) in the home laboratory.

1.7 EXCHANGE OF CARBON DIOXIDE BETWEEN THE SOUTHERN OCEAN AND THE ATMOSPHERE

(NIOZ)

Mankind has brought extra CO2 into the atmosphere by combustion of fossil fuels, currently at a rate of 5.2 x 1015 gram C (5.2 gigaton, GtC) per year. A smaller but not well known amount of presumably ~1 GtC is contributed by the loss of tropical forest biomass. Only 60% of the total fossil fuel emission of CO2 corresponds to the increase of the atmospheric CO2 content. The other 40% of the fossil fuel input, as well as the minor forest biomass source, is distributed over the oceans and, less important, terrestrial vegetation. Although 40% of the total annual industrial emission of CO2 is a considerable amount (about 2-3 GtC) it is not clear which parts of the ocean are responsible. It is also superimposed on the pre-industrial exchange of CO2 with the atmosphere, where at steady state the flux of CO2 from over saturated (e.g. upwelling) waters in certain regions is deemed to be similar to the influx of CO2 in undersaturated waters elsewhere. In general those regions, where surface waters are both undersaturated as well as generally sinking to greater depth, are prime candidates as a sink for the background steady state input as well as the additional anthropogenic term (2-3 GtC).The objective of this project is to understand, as well as quantify, the air/sea exchange in crucial regions of the Southern Ocean. Such understanding, in combination with findings of ongoing research in other oceanic regions is essential towards assessing the often assumed anthropogenic sink term of the Southern Ocean.

It is often assumed that the Southern Ocean as a whole acts as a net sink for atmospheric CO2. However, only restricted areas may be

sinks, while other regions of the Southern Ocean may in fact be mostly sources of CO2. The aim of this research is to investigate which chemical, biological and physical factors make certain regions of the Southern Ocean a CO2 source or sink. In order to realise this, RV Polarstern will be equipped with coulometers, infra-red analysers and an alkalinity titrator to be able to fully interpret the CO2 system of judicially selected regions of the Southern Ocean. The main regions of interest are the Polar Frontal Zone and the Weddell Sea. During ANT X/6, ANT XI/2, ANTXI/4 and ANTXII/4 high temporal variability of pCO2 and TCO2 values was found in the Polar Frontal Zone. Also in both regions sinking down of watermasses is known to take place. The sinking water is partly flowing northward. This flow is compensated by surface waters flowing into the Southern Ocean, where the general cooling of southward flowing water will cause under saturation versus the atmosphere. In regions like the Polar Front, photosynthetic removal of CO2 during seasonal plankton blooms would be another cause for under saturation. Obviously, the dynamics of the CO2 system in these two highly variable regions contribute significantly to the global carbon budget.

1.8 PHYTOPLANKTON AND HETEROTROPHIC PROTISTS
(AWI)

Phytoplankton studies during ANT XIII/2 will focus on diatoms as it is this group which has the greatest impact on Southern Ocean biogeochemistry. As a rule, systematic microscopical assessment of phytoplankton populations is conducted on preserved samples in the home laboratory. However, on-board visual observation of live plankton indicates that many important features of the cells pertaining to growth and mortality are lost in preserved samples. Whereas it is now common practice to study pico- and nanoplankton under the microscope on board ship, to date few comparable studies of live diatoms have been conducted. We intend carrying out a quantitative assessment of the diatom populations of surface samples during the SeaSoar surveys with an aim to elucidating the mesoscale distribution patterns of dominant species in relation to growth conditions (hydrography, iron availability) and mortality due to parasitoid attack and grazing by proto- and metazooplankton. Depth-related distributions will be assessed during the CTD-transect.

During ANT X/6 large diatom blooms dominated by few species developed in the Polar Frontal region. The pennate diatom responsible for the bulk of the silica deposited in the underlying sediments - *Fragilariopsis kerguelensis* - dominated biomass in the southern border of the Front. This species has very thick-walled frustules and occurs in long, ribbon-shaped chains that should have a high sinking rate. We postulate that this species accumulates most biomass in upwelling eddies that conteract its sinking. The much larger, single-celled species *Corethron criophilum* dominated biomass in the more northerly water mass with the closely related species *C. inerme* inbetween. We suggest that these species, in contrast to *F. kerguelensis*, accumulate biomass in counter-clockwise eddies. These hypotheses will be tested during the mesoscale survey.

The dominant role of only a few species was a striking finding of ANT X/6 conducted from early to late spring. It was not clear whether this was achieved by more rapid growth of the respective species or lower mortality rates in the respective water mass. A possible role of sinking has been pointed out above. However, selective grazing by various heterotrophs ranging from nanoflagellate parasitoids, large dinoflagellates and metazooplankton can also influence species composition. For instance, the thick cell walls of *F. kerguelensis* might well act as an effective defence against attack by one or several of the above grazers. The effects of such an ability or lack of it might be ascertainable by studying small-scale gradients from the centre to the borders of the various patches. ANT XIII/2 will cover the period late spring into summer and will hence encounter a later stage in succession than recorded during ANT X/6. This might enable a better assessment of the effects of grazing, as grazer populations will have increased by then.

Surface-water samples will be taken at hourly intervals during the SeaSoar survey and the dominant diatoms assessed following concentration by reverse filtration for the following properties: chain length, frequency of dividing cells, cell-size class, occurrence of sexual stages, incidence of parasitoids and feeding by protists. Although the focus is on diatoms, other representatives of the microplankton (cells >20 µm): dinoflagellates, foraminifera, radiolarians, silicoflagellates, will also be assessed during the live counts. Preserved samples will be used for detailed studies of size distribution and species identification. Samples for estimation of chlorophyll, particulate organic carbon and nitrogen and various other properties listed by the other groups will be taken togther with those for live examination.

Representative photographic records of different phytoplankton communities and also parasitoids will be made at regular intervals. In some cases species will be isolated into culture when the condition of the cells allows and where the taxa, particularly parasitoids, are of special interest. Vigorous attempts will be made to isolate *C. inerme* and *F. kerguelensis* into culture using a variety of culture conditions.

1.9 SIZE-FRACTIONATED UPTAKE OF CARBON AND NITROGEN IN THE SOUTHERN OCEAN

(AWI)

Export pathways of significance for Climate Change are those that produce significant quantities of carbon with very long turnover times (e.g. sequestered pools). Recent conceptual work shows that the turnover times of carbon are linked to trophic structure and the size of phytoplankton (Legendre and Le Fevre 1991). There is evidence of size- differential limitation of phytoplankton production by new and recycled nitrogen sources (Dortch and Postel 1990; Stolte et al. 1994), iron (Morel et al. 1991), and CO2 (Riebesell et al. 1993). In all cases, the production of size fractions may be largely regulated by nitrogenous feedback interactions, including the release

of NH4 by grazers, uptake/release of NH4 by bacteria, competitive advantage of small phytopankton, and inhibition of NO3 and carbon uptake by NH4. These processes may be important in parts of the southern ocean that exhibit HNLC conditions and high NH4 concentrations. Understanding the uptake of carbon and nitrogen by phytoplankton size groups, and subsequently tracking their fate through the ecosystem (e.g. sedimentation, herbivorous grazing, regeneration) is a promising step toward assessing the time scales linking primary production to the export of biogenic carbon. The present projects aim at understanding some of the processes underlying size-fractionated carbon and nitrogen uptake. Shipboard experiments:

Simulated in-situ abtake

At selected stations, water will be collected at 5 optical depths in the euphotic zone, or from 8 m only along transects. Measurements will include determination of nutrients and size-fractionated chlJa. Incubations will be conducted in deck incubators using a combination of blue and neutral density filters. The uptake of 15N-NH4, NO3, urea, and of 13C will be measured in parallel to 14C. Incubations will be kept short in order to avoid isotope dilution. Isotope additions will be targetted at 10% of ambiant concentrations. At selected depths, detailed size-fractions will be obtained by post-screening (2J5m, 5 5m, 10 5m, and 20 5m, depending on ambiant chl a concentrations). Some filters will be preserved for latter examination under electron microscopy. Uptake rates will be determined after the cruise, using a dual isotope mass spectrometer. Size-fractionated 14C uptake will be measured on board, using a scintillation counter. Results will be interpreted using the framework of Tremblay and Legendre (1994).

Enrichment experiments

In parallel with simulated in-situ measurements (one depth near the surface), the concentrations of NO3 and NH4 will be modified using additions ranging from 10% of ambiant concentrations to saturating levels. Two size-fractions will be obtained by post-screening. The same procedure will be performed using pre-filtering, in order to sever interactions between size groups. Photosynthetic responses will be monitored using simultaneous additions of 13C. Some experiments will be coordinated with the teams working on iron and grazing.

Uptake kinetics

Light-dependent uptake of 13C and different 15N labelled nitrogen sources will be measured simultaneously under controlled light conditions. Samples will be from one (8 m) to three depths and will be incubated shortly in the laboratory. Size fractions will be obtained by post-screening on 2 5m. This will allow to assess, from the same samples, the relationships between photosynthesis and the uptake of different nitrogen sources.

1.10 *PHOTOADAPTIVE STRATEGIES OF ANTARCTIC PHYTOPLANKTON (AWI)*

Because of very unstable hydrographical conditions in the Antarctic Ocean the underwater light climate, on both spatial and time scales, is very heterogeneous. To a certain degree phytoplankton can adapt to an underwater light field by altering the photosynthetic pigment apparatus. These adaptative mechanisms can be seen as strategies to optimise the efficiency of light utilisation.

Until now there are only theoretical models dealing with the influence of vertical mixing on the photosynthesis of Antarctic phytoplankton (MITCHELL & HANSEN 1991), and no field data exist. This study will investigate to what degree natural samples from different light fields algae can photoadapt. For this purpose certain characteristics of algae's photosynthetic apparatus will be quantified.

Different physical and biological parameters will be measured on vertical profiles:
- Measurements of conductivity, pH, salinity and temperature by a CTD.
- Measurements of up welling and down welling radiation to a depth of 100m using Licor sensors (attached to the CTD).
- Measurements of the spectral distribution in the underwater light field, both up and down welling. A MER 2040 from Biosperical Instruments will be used which records light intensity at 12 wave lengths within the PAR spectrum and an additional two UV-wavelengths.
- Water samples taken from a biorosette in different depths depending on the 1% light level and the upper mixed layer (UML). From these samples pigment composition (HPLC analysis), biomass (Chl a content), activity of the photosystem II (using a Fast Repetition Rate Fluorometer (FRRF)) will be determined. Incubation experiments with radioactive ^{14}C will be carried out in order to find photosynthesis- versus- irradiance-characteristics. The dynamics of the underwater light field will be simulated by a rotating filtration system.

1.11 *PHYTOPLANKTON PRODUCTIVITY IN THE SOUTHERN OCEAN (UTC, SURRC)*

Marine Biogeochemistry

Novel methods of stable isotope chemistry will be used to measure phytoplankton productivity in the Southern Ocean. These measurements will enable estimates of carbon drawdown to the deep ocean to be made, which will be input into global carbon cyling models. Carbon and nitrogen uptake rates of phytoplankton will be measured both during a cruise to the Weddell Sea with the Alfred Wegener Institute (AWI), and during culture experiments in conjuction with the AWI and the Dunstaffnage Marine Laboratory (DML).

The objective of the research is to use new techniques to improve on current estimates of primary productivity in the Southern Ocean. The Southern Ocean is a key area to determine primary production, as globally it exerts a strong influence in terms of water mass formation, atmospheric circulation and perturbation of the climate. At present, our ability to measure primary production in the oceans is disputed to within a factor of ten. If we are to understand the effect that primary productivity has on global climate perturbations, it is essential to estimate primary productivity accurately. This will be achieved by using stable isotope methods developed at SURRC on an antarctic cruise run by the AWI, and during culture experiments to be carried out in collaboration with the AWI and DML.

At SURRC we have been working on the application of 13C and 15N methods to measure new and regenerated productivity in two consecutive grants: NERC Special Topic Biogeochemical Oceanic Flux Study (BOFS) grant (GST/02/385) "Nitrogen assimilation, regeneration and flux: a nitrogen isotope study"; and NERC Special Topic British Antarctic Survey (BAS) grant (GST/02/654) "Phytoplankton nitrogen relationships in the Southern Ocean". Within these grants we have been developing methods in the laboratory to improve techniques of productivity measurements. These methods have now been field tested and are ready for use within a comprehensive field programme.

The main project plan is to carry out primary productivity measurements in the Southern Ocean and to carry out additional culture experiments on selected phytoplankton species to investigate the uptake kinetics of nitrogen under varying conditions. It is hoped that a minimum of one cruise and a maximum of two will be carried out over a period of three years. The cruise will be centred on biological process measurements in a high productivity frontal area in the Weddell Sea. A suite of measurements will be carried out on board which will be available for individual's use and which will be essential for the interpretation of individual's data in the context of the biological system as a whole. Measurements planned will be closely co-ordinated within the framework of the overall cruise programme and should help contribute to the overall success of the cruise. The main aims whilst on this cruise will be to determine what controls the phytoplankton productivity in those regions, and to make detailed and precise measurements of the productivity using 14C, 13C and 15N techniques. Using new methods of analysis the aim is to rigidly quantify the contribution of regenerated productivity by more accurately constraining the dissolved organic nitrogen (DON) contribution to phytoplankton production. This will be achieved by analysis of the urea and DFAA uptake by phytoplankton, in addition to the measurement of ammonium regeneration levels. The main aims are to: i) to define carbon fluxes in the Southern Ocean more accurately by measuring the DON pool uptake in more detail. This will be accomplished by measuring the rates of assimilation of a range of nitrogen substrates (nitrate, ammonium, urea and DFAA) using 15N methods in

conjunction with carbon assimilation measurements using 13C. Ammonium regeneration will also be measured using isotope dilution techniques. ii) to quantify carbon fluxes in contrasting areas of the southern ocean and, in conjunction with satellite data collected, to estimate the global importance of such fluxes. iii) to compare productivity estimates from the standard 14C method with the 13C method with a view to introducing the 13C method as a replacement technique (with advantages of being non-radioactive and therefore safer, and potentially more accurate) iv) to measure bacterial activity and to estimate the proportion of heterotrophic uptake of ammonium, urea and DFAA in the DON uptake experiments.

The second aspect of the planned project is that of culture experiments. Culture work will be carried out in collaboration with the AWI in Bremerhaven, Germany and the DML in Oban, Scotland. There will be two aspects to the culture work:

a) Continuous cultures of selected species of antarctic phytoplankton (collected from the 1995 POLARSTERN cruise and selected from the culture collection of the AWI) will be set up in conjunction with the curator of the Culture Collection of Algae and Protozoa (CCAP), Michael Turner at DML. Dr. Richard Crawford will assist with identification of species at the AWI. Cultures will subsequently be taken back to the Dunstaffnage Marine Laboratory (DML) in Oban. Through current collaboration with Michael Turner, it is planned to introduce antarctic species to the Culture Collection of Algae and Protozoa. This is an internationally recognised collection which at the moment has no antarctic species.

The planned culture work will involve investigations of the kinetics of nitrate, ammonium and urea uptake which will be carried out on a minimum of three size classes of algae. Michealis-Menten Ks and Vmax parameters will be measured to be utilised in a model developed by Eugene Murphy at the British Antarctic Survey (BAS). An investigation will also be made on the effect of ammonium suppression of nitrate uptake which is thought to be an effective process regulating new production in areas of large krill swarms.

b) Cultures of antarctic phytoplankton will be used in laboratory experiments to test the compatability of 13C and 14C productivity estimates under very controlled conditions to compare with results obtained at sea. Culture experiments on species already available at AWI and DML will be used prior to the POLARSTERN cruise. This project aims to combine the expertise of individuals involved in methods development with an institute which has recognised experience and facilites to successfully carry out research to a high standard in the Antarctic.

It is an important issue to quantify levels of productivity in the Southern Ocean to more accurately measure carbon drawdown in this area, and to estimate the effect of the Southern Ocean on global climate change. Using new methods, and through collaboration with an institute experienced in antarctic biological research this project

aims to improve on current estimates of primary productivity in the Southern Ocean. A field and laboratory comparison of standard and new methods of primary productivity measurement will be made and recommendations made to the wider oceanographic community based on the results. This could have important implications not just to the marine community, but also to scientists working in freshwater and terrestrial environments.

1.12 ZOOPLANKTON STUDIES
(AWI)

Very little is known about the influence of physical or biological parameters on zooplankton distribution and behaviour on smaller scales. The variability of such parameters is especially high at frontal systems. This study will investigate the impact of different physical and biological parameters on zooplankton ecology, e.g. zooplankton distribution, feeding, reproduction, migration etc.

Zooplankton biomass and distribution

The Optical Plankton Counter (OPC) will be employed to achieve a higher resolution of zooplankton small scale distribution. This instrument will be attached to the SeaSoar. On station, the OPC will be fixed on a Multinet to obtain vertical profiles of zooplankton distribution simultaneous to net catches. Net catches (Multinet 200) will be carried out at five depth intervals according to hydrographic patterns such as the depth of the pycnocline etc. The samples are split (Folsom plankton splitter) and one sample will be stored in 4% buffered seawater formalin solution for later analysis of species composition and abundance. The other subsample will be divided into size fractions and filtered onto preweighted GF/C-filters for later analysis of AFDW (ash free Dry weight). Other subsamples will be taken for POC-PON-analyses with a Carlo Erba CHN 1500 analyzer. Some individuals of the dominant species will be stored in glass vials at -80°C for later analysis of lipid content.

The Acoustic Doppler Current Profiler (ADCP) will be used in cooperation with V. Strass to record the distribution patterns of larger organisms such as krill, simultaneous to Rectangular Midwater Trawl (RMT)-net catches.

Zooplankton grazing, faecal pellet- and egg-production

In order to assess the ecological impact of zooplankton species on the ecosystem on the one hand and to investigate their changing behaviour corresponding to different physical and biological conditions, (e.g. depth of the wind-mixed layer, chlorophyll distribution etc.) on the other, grazing experiments, faecal pellet and egg production experiments with dominant species will be carried out. Grazing rates will be determined following the JGOFS-protocol by using the gut-fluorescence-technique (Mackas and Bohrer 1976, JGOFS 1992). These measurements will be accompanied by determination of faecal pellet production determinations in order to

assess the impact of these organisms on vertical flux. Some samples of dominant species will be deep-frozen for later gut-pigment analyses by HPLC-measurements.

Determination of reproduction success will be determined by means of egg production measurement (JGOFS 1992).

1.13 BACTERIA
(LIUK)

Formation and microbial degradation of organic aggregates and turnover of labile organic compounds by bacterioplanktion

During this cruise we want to assess the growth dynamics of planktonic bacteria and their control by labile organic substrates (dissolved free and combined amino acids and carbohydrates). The measurements are based on uptake of 14C- and 3H-labelled model substrates (amino acids, proteins, monosaccharides) into heterotrophic bacteria and the analysis of concentrations of dissolved amino acids and carbohydrates by HPLC. They will be done in the home lab after the cruise. The investigation during the cruise also includes measurements of the release processes of these compounds by various groups and size-fractions of the plankton community by an approach which measures the extracellular isotope dilution of added 14C- and 3H-labelled model substrates (see above). All measurements will be done in connection with bacterioplankton JGOFS parameters (bacterial abundance, bacterial production).

We want to perform these experiments at the pack-ice station, at the ice-edge and during the transects in daily profiles (morning). We need samples of 1 L from 6-8 depths between the surface and 200 m and 5 L from the layer of the chlorophyll maximum. In addition we need samples of 1 L from 300 and 500 m every third day.

In connection with these studies we also want to examine the formation and microbial decomposition of aggregates in rolling tanks. For these incubations we need water samples of 100 L at the first and last day of a transect from the chlorophyll max layer.

Significance of phage-infection for bacterioplanktion growth

In this context we want to assess the abundance of free phages by epifluorescence microscopy and the number of phage-infected bacteria by electron microscopy. In addition we are going to do adsorption experiments of phages to their hosts with fluorescently labelled phages. The phages will be concentrated by ultrafiltration and subsequently labelled with a highly fluorescent dye. These phage concentrates then are added to their natural host community in order to test how many hosts are labelled by specifically adsorbed phages.
For concentrating phage assemblages we need 100 L from the chlorophyll max layer at the pack-ice station, the ice edge and at

every morning during the transects. The experiments are done with small amounts of water collected for the project above.

1.14 TOP PREDATORS
(IBN-DLO)

Study of top predators in the Weddell Sea during Polarstern's cruises EPOS Leg 2 1988/89 and SO-JGOFS 1992 (ANT X/6) revealed strong patterns in distributions and numbers. Results have been used to analyse the pelagic ecology of individual species, as well as the role of the pelagic top predator community as a whole within the ecosystem (in terms of food and carbon fluxes). As distributional patterns of top predators change with seasonal changes in especially sea ice cover, the rationale for this proposal is that the ANTXIII/2 cruise of Polarstern in 1995/96 offers very good opportunity to expand the time-scale observed during (ANT X/6): ANTXIII/2 operates in the same longitude as (ANT X/6) at a time of the season where this cruise ended, and travels as far south as the shelf ice all the way through the melting sea ice zone.

The major question of the proposed project is: how strong are the changes in distributions and numbers of Antarctic top predators in the pelagic environment during the period of most rapid environmental change (sea ice retreat and frontal bloom developments) and what is their quantitative role as consumers of lower trophic levels. Again, such knowledge is relevant for both individual species and the top predator community as a whole.

Top predator censuses will be conducted from an observation post on top of the bridge and will use band transect methods according to international standards. Related to current discussions on standardization in Southern Ocean top predator studies some new approaches will be added in experimental observations. Considering the importance of sea ice distribution, not only for the top predator studies but for all research on board, ice conditions will be recorded in the same way as during (ANT X/6), that is fine-scale patterns will be recorded in association with bird counts, and larger scale patterns will be recorded in accordance with the JGOFS protocol for ice observations. Special attention will also be paid to the presence of "brown spots": these discolorations of the water surface were observed during (ANT X/6) but their background remained unexplained. A closer look into this phenomenon during ANT XIII/2 could be rewarding.

Quantitative top predator data and detailed sea ice information are closely linked to many other projects during the cruise in terms of environmental patterns and fluxes between ecosystem compartments. The mapping mode grids with SeaSoar and other continuous measurements will allow fine scale links of distributional patterns of top predators with subtle spatial and temporal changes in the environment.

Top predator distribution and abundance

Densities of birds, seals and whales are recorded during continuous series of 10-min counts. Birds are recorded within a 300m transect-band in time-blocks of 10 minutes, using snapshot methodology for birds in flight. Seals are recorded with band-transect methods, although we will also try to use (and compare) line-transect methodology which seems to become the future standard for studies of Antarctic pack-ice seals. Whale censuses are complicated due to the low number of observations, but methods will be adapted to the best possible ways for data-analysis.

Results of the work will be available as food-consumption or carbon-consumption figures of the top predator community.

1.15 SEDIMENTATION
(AWI)

The determination of the flux of carbon and other organic matter from the surface ocean to its interior is one important measure to qualify and quantify the importance of the Biological Pump in transporting CO_2. Sediment traps moored below oceanic features give time series information about the export flux in these special regions.

Two approaches to deploy sediment traps will be followed during this cruise. We will serve three long-term (5 years) arrays of moored instruments. Information derived from analysing the collected matter will be done in the institutes at home. The second approach is to deploy one array of two sediment traps moored in the vicinity of the Antarctic Polar Front for the duration of the cruise and time the samples for every second day. This sampling mode will record short term pulses of export production and the analysis will allow to combine these events to specific short term processes in the overlying water column. These processes will be studied simultaneously by the entire scientific programme of this cruise.

1.16 EXPORT PRODUCTION MEASURED BY THE NATURAL TRACER TH - 234
(AWI)

The export of particles from the euphotic zone can in principle be derived from sediment trap deployments (see previous chapter) or from budgets of dissolved and particulate constituents. In an area as variable as the Antarctic Circumpolar Current (ACC) these approaches pose significant problems. Logistically, as we would need a large number of traps to cover the various hydrographical zones and to increase the chance of having a trap operating in an area where a bloom might happen to develop. And theoretically, as the complicated hydrography around the fronts prevents us from following an individual water mass, and consequently from monitoring changes in its composition with time.

234Th is an alternative tool for the quantification of export flux (Coale and Bruland, 1985; Eppley, 1989). One of its advantages is the long oceanic residence time, and consequently conservative distribution of its parent 238U. This means that the production rate of 234Th is known irrespective of the history of the water mass. A depletion of 234Th with respect to its parent 238U is evidence of export flux also in those cases where it is not possible to follow the same water mass over the course of time. A proper calculation of the export flux requires, however, information on the development of the depletion with time.

We plan to measure the distribution of 234Th in the water column, both in vertical profiles and in horizontal transects. Vertical profiles will be obtained by sampling the upper water column (down to approx. 600m) with the Rosette sampler. Samples of approx. 50L from 6 depths will be combined and filtered. The filtrate will be analyzed for 234Th by a new technique (Rutgers van der Loeff, in Kuhn, 1995) involving coprecipition on MnO2, which is subsequently collected by filtration. The filters, containing the particulate matter and MnO2 precipitate, are beta counted on-board to obtain the particulate and dissolved 234Th activities, respectively. Horizontal transects will be obtained by an on-line filtration and adsorption system (Buesseler et al., 1992) connected to the ship´s surface seawater supply. These samples will be analyzed later at NIOZ. The data will be combined into a three-dimensional and time-dependent picture of 234Th depletion which should allow us to quantify the export flux of 234Th on an areal basis. Samples for POC and PON will also be collected in order to allow the estimation of C and N export fluxes from the calculated export of 234Th. These data will then be linked to studies on primary production (Bracher) and on Fe and CO2 (De Baar).

2. Cruise Leg ANT XIII/3 (CS-EASIZ)

Capetown - Capetown: 26 January - 15 March, 1996
Chief Scientist: Wolf Arntz

2.1 SCIENTIFIC BACKGROUND, OBJECTIVES AND ITINERARY

The sea ice zone in the vicinity of the Antarctic continent, covered by pack ice during most of the year except for a few larger areas of open water (polynyas), has been the subject of marine ecological research only during the past two decades, when the use of ice-breaking vessels began and a few "land"-based stations were founded. While these stations, principally the American base of McMurdo Sound, concentrated on nearshore approaches applying mainly diving techniques, the deeper waters off the ice shelves have mostly been studied in a large-scale manner. The idea was to provide an insight into the benthic, pelagic and sea-ice communities, to collect the organisms inhabiting these communities for taxonomic and biogeographic purposes, and to sample material for the study of

physiology, population dynamics, reproductive biology and the description of life strategies. The principal area of work of the German ice-breaking vessel "Polarstern" has been the shelf and slope of the southeastern Weddell Sea. This work culminated in the third leg of the "European Polarstern Study" (EPOS I/3), which provided substantial scientific information and stimulated European Antarctic cooperation.

In 1994, the Biology Working Group of SCAR agreed on the need of another initiative to study the ecology of the sea ice zone on the continental shelves of the Antarctic, thus continuing international cooperation in the BIOMASS programme and to complement the Southern Ocean JGOFS and GLOBEC programmes which are principally aiming at the study of the open waters and deep-sea floors of the Southern Ocean. The objectives of this CS-EASIZ programme, which will combine investigations from the shore stations around Antarctica with shipboard approaches on the shelf and slope, have beed approved at the SCAR XIII meeting in Rome (1994):

The aim of the CS-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, inter-annual, and long-term changes.

Within the scope of these CS-EASIZ objectives, the forthcoming "Polarstern" ANT XIII/3 expedition will make a contribution to the ecological study of the high Antarctic shelf of the Weddell Sea. This area best reflects typical polar conditions such as a short primary production phase, distinct seasonality, extremely low water temperatures and the impact of ice in its different ways. It also contains some of the most interesting benthic assemblages in the South Polar Sea with an overwhelming dominance of suspension-feeding epifauna, a three-dimensional structure, and great faunal richness (biodiversity). Due to former work in the area, much of the faunal components and large-scale structures are fairly well known, and in a first trophic interaction model an attempt has been made to acount for the energy fluxes among the major faunal groups.

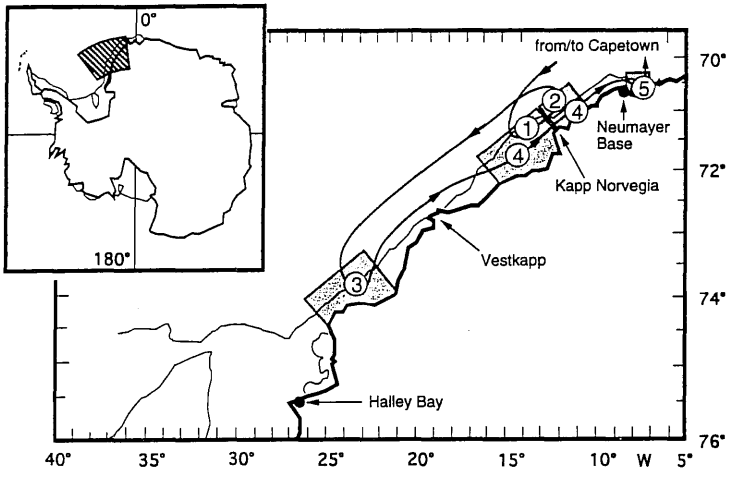
In contrast to former expeditions, the CS-EASIZ cruise aims at a higher resolution of factors and processes, both abiotic and biotic, that shape the faunal structures and dynamics under high Antarctic conditions. For this purpose the investigations are planned to concentrate on a few localities ("box concept") rather than applying large-scale registering and sampling. However, the combination of different gears and methodological approaches which has proved to be useful in former expeditions will be continued, including for the first time the use of hydrosweep/parasound techniques. Also, international cooperation as outlined by the CS-EASIZ programme

will be strengthened with the participation of many scientists from other European countries.

RV "Polarstern" will leave Cape Town on 26 January 1996 to reach the principal area of study off Kapp Norvegia (Fig. 1) on 5 February. The vessel will remain in this area for about 5 days for benthic sampling according to bottom topography features which include an inner shelf depression, perpendicular to the coastline, and to deploy a number of moorings. After that the ship will sail to the iceberg "cemetery" north of Kapp Norvegia, where parallel to benthic work fishing with the benthopelagic trawl will be carried out mainly at the shelf edge. This phase will last about 6 days.

During the second phase, fishing perferably by the benthopelagic trawl will be done in the area south of Vestkapp for 4 days, with a maximum of 3 trawls per day, complemented by some benthic sampling. An alternative to this programme, in case of being better on schedule than expected, would be to go to Halley Bay instead, which would involve 3 days steaming and 3 days sampling. This will have to be discussed on board.

During the third phase the idea is to go back to Kapp Norvegia and work on another short transect perpendicular to the coast and on a transect along the coastline. For fishing at the shelf edge, a decision will be necessary either to use the bottom trawl or the benthopelagic trawl. Five days before leaving the high Antarctic shelf RV "Polarstern" will have to return to Atka Bay for three days of logistic work at the Neumayer Base. After that there will hopefully be another opportunity for work in the Kapp Norvegia area before starting the return to Cape Town which will last approximately 9 days. If additional time should be available, it was proposed to sample a few deep benthic stations in the 500 - 1000 m range and to take a couple of samples in Atka Bay. The arrival at Cape Town is scheduled for 15 March.



ANT XIII/3, map of investigation area. Numbers indicate planned sequence of working areas.

2.2 *ZUSAMMENFASSENDE ÜBERSICHT*

Die Meereiszone in der Nähe des antarktischen Kontinents, die mit Ausnahme einiger offener Wasserflächen (Polynyas) den überwiegenden Teil des Jahres mit Packeis bedeckt ist, ist erst in den letzten beiden Jahrzenten ökologisch untersucht worden. Gelegenheit dazu gaben der Einsatz eisbrechender Forschungsschiffe und die Gründung einiger Stationen "an Land". Während diese Stationen, insbesondere die amerikanische Station am McMurdo Sound, sich auf küstennahe Forschung verlegten und dabei vor allem die Taucherei anwendeten, erfolgte die Untersuchung des tiefen Wassers vor den Schelfeisen eher großräumig mit dem Ziel, einen ersten Überblick über die benthischen, pelagischen und Meereis-Gemeinschaften zu gewinnen, die Organismen aus diesen Lebensräumen für taxonomische und biogeographische Zwecke zu fangen und Material für das Studium von Physiologie, Populationsdynamik, Reproduktionsbiologie und die Beschreibung von Lebensstrategien zu sammeln. Hauptarbeitsgebiet des deutschen eisbrechenden Forschungsschiffes "Polarstern" war bisher der Schelf und Kontinentalhang des südöstlichen Weddellmeeres. Diese Arbeiten erreichten ihren Höhepunkt im dritten Fahrtabschnitt der "European Polarstern Study" (EPOS I/3), der einen erheblichen Zuwachs an wissenschaftlicher Information erbrachte und die europäische Antarktiskooperation intensivierte.

Im Jahr 1994 einigte sich die Biology Working Group des SCAR auf die Notwendigkeit einer neuen Initiative zur Erforschung der Ökologie der Meereiszone auf dem antarktischen Kontinentalsockel, welche die internationale Zusammenarbeit im BIOMASS-Programm fortsetzen und die Southern Ocean JGOFS- und GLOBEC-Programme, die vor allem auf das Studium des offenen Pelagials und der Tiefseeböden abzielen, ergänzen sollte.

Die Ziele dieses Coastal Shelf-EASIZ-Programms, das Untersuchungen von den Landstationen mit Schiffseinsätzen auf dem Schelf und Kontinentalhang verknüpfen wird, wurden während des 13. SCAR-Treffens in Rom (1994) festgelegt:

"Das Ziel des CS-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 sensibelste antarktische System ist. Dabei werden jene Eigenschaften besondere Beachtung finden, welche die Biologie dieses eisbeherrschten Ökosystems so unterschiedlich machen, darüber hinaus aber auch solche, die zu einem besseren Verständnis saisonaler, interannueller und langfristiger Veränderungen beitragen."

Im Rahmen dieser CS-EASIZ-Ziele soll die geplante ANT XIII/3-Expedition der "Polarstern" zur Erforschung des hochantarktischen Schelfs des Weddellmeeres beitragen. Dieses Gebiet spiegelt am besten typisch polare Bedingungen wie kurze

Primärproduktionsphase, ausgeprägte Saisonalität, extrem tiefe Wassertemperaturen und den Einfluß des Eises in seinen verschiedenen Erscheinungsformen wider. Es beherbergt auch einige der interessantesten benthischen Gemeinschaften des Südpolarmeeres mit überwältigender Dominanz filtrierender Epifauna-Organismen, dreidimensionaler Struktur und großem Artenreichtum (Biodiversität). Aufgrund früherer Arbeiten in dieser Region sind viele Faunenkomponenten und großflächige Strukturen recht gut bekannt. In einem ersten trophischen Interaktionsmodell wurde zudem der Versuch gemacht, die Energieflüsse zwischen höheren Taxa aufzuzeigen.

Im Gegensatz zu den vorangegangenen Expeditionen zielt die CS-EASIZ-Reise auf eine höhere Auflösung von abiotischen und biotischen Faktoren und Prozessen, welche die Struktur und Dynamik der Fauna unter hochantarktischen Bedingungen prägen. Daher sollen sich die Arbeiten auf wenige Lokalitäten konzentrieren ("Box-Konzept"), anstatt die Strategie des großräumigen Registrierens und Sammelns fortzuführen. Allerdings soll die Kombination verschiedenartiger Geräte und methodischer Ansätze, die sich auf früheren Expeditionen bewährt hat, fortgesetzt werden. Dabei sollen erstmalig auch Hydrosweep/Parasound-Techniken eingesetzt werden. Auch die im CS-EASIZ-Programm angesprochene internationale Zusammenarbeit soll durch Teilnahme vieler Wissenschaftler aus anderen europäischen Ländern gestärkt werden.

FS "Polarstern" wird Kapstadt am 26. Januar 1996 verlassen und soll das Hauptarbeitsgebiet vor Kapp Norvegia am 5. Februar erreichen. Das Schiff wird sich dort ca. 5 Tage aufhalten und unter Berücksichtigung bestimmter Bodenstrukturen (v. a. im Bereich der senkrecht zur Küste verlaufenden inneren Schelfabsenkung) benthische Arbeiten verrichten sowie Verankerungen ausbringen. Danach wird das Schiff zum Eisberg-"Friedhof" nördlich von Kapp Norvegia verholen, wo parallel zu den Benthosarbeiten auch Fischerei mit dem benthopelagischen Schleppnetz, v. a. an der Schelfkante, betrieben werden soll. Diese Phase wird etwa 6 Tage dauern.

Während des zweiten Abschnitts soll 4 Tage lang Fischerei, vorzugsweise mit dem benthopelagischen Netz, im Gebiet südlich des Vestkapps durchgeführt werden. Die maximale Anzahl von Hols pro Tag wird 3 betragen; darüber hinaus kann eine gewisse Zahl von Benthosproben genommen werden. Als Alternative zu diesem Programm (für den Fall, daß der Zeitrahmen unterschritten werden sollte) bietet sich an, stattdessen vor Halley Bay zu arbeiten. Dies würde 3 Tage Dampfen und 3 Tage Sammeln bedeuten. Eine endgültige Entscheidung muß an Bord getroffen werden.

Während des dritten Abschnitts soll wieder vor Kapp Norvegia gearbeitet werden. Vorgesehen sind ein Transekt quer zur Küste und ein weiterer in küstenparalleler Richtung. Vor einer Fortsetzung der Fischerei an der Schelfkante muß entschieden werden, ob das Grundschleppnetz oder erneut das benthopelagische Netz eingesetzt werden soll.

Fünf Tage, bevor FS "Polarstern" den hochantarktischen Schelf verläßt, muß das Schiff in die Atka-Bucht zurückkehren, um drei Tage logistische Arbeiten an der Neumayer-Station zu verrichten. Danach ergibt sich hoffentlich noch einmal die Gelegenheit, im Gebiet vor Kapp Norvegia zu arbeiten. Sollte vor der etwa neuntägigen Rückreise noch Zeit verfügbar sein, so könnten - wie vorgeschlagen - einige Tiefenstationen um 500 - 1000 m bearbeitet und einige Proben in der Atka-Bucht genommen werden. Das Schiff soll am 15. März wieder in Kapstadt eintreffen.

2.3. ENERGY METABOLISM OF BENTHIC KEY ORGANISMS

Previous investigations on Weddell Sea benthos were primarily focused on the necessary stocktaking of the benthic community, including analysis of large-scale distribution patterns of macro- and partly meiofauna. Through these activities, some general structural characteristics of the benthic ecosystem became sufficiently well known that we can now shift part of the emphasis onto process oriented studies, i.e. benthopelagic coupling and flows within the benthic system.

To this end, investigations on different aspects of the energy metabolism of benthic key organisms form one of the focal points of this cruise. Especially the question whether reproductive processes are directly linked to, or even triggered by, patterns of food input will be considered, as well as problems related to animal adaptation to the polar environment.

Sampling of experimental animals will be achieved by Agassiz trawl, epibenthic sledge, large box corer and multicorer. A high degree of cooperation between different specialists promises data sets complementing and validating each other.

In detail, the following studies will be performed:

2.3.1 Feeding and respiration activity of macrobenthos organisms
(ICM, IFM)

In recent years, benthic suspension feeders have been shown to play a major role in the energy transfer processes in marine ecosystems. In the Antarctic, suspension feeders can be quite abundant on both hard and soft substrates. Especially sponges are dominant members of many Antarctic benthic communities and have been shown to exert an important structuring effect on benthic communities. Many macrobenthic organisms may have a considerable trophic dependence on pelagic seston. In several species of temperate seas, high capture rates of organic seston (from zooplankton to bacteria) were estimated. There is little information on the trophic role of Antarctic suspension feeders, especially on food type and possible temporal patterns in feeding. In this study, the trophic ecology of

different suspension feeders (e.g. sponges, hydrozoans and anthozoans), but also deposit feeders and predatory organisms abundant in the Weddell Sea, will be investigated. This includes respiration measurements, but also the identification of food items and measurement of feeding rates (counting gut contents), as well as energy content of the food (laboratory analysis of tissue composition). In the case of sponges, feeding with standardized inert particles will clarify which particle size spectrum is available to different species and at which rates particles are taken up. The energy transfer from plankton to benthos by the species investigated will be calculated. Investigations of suspension feeder and food item distribution and density in conjunction with analysis of the hydrodynamic regime at different locations will yield information on the controlling effect of physical factors on feeding performance and thus energy transfer by various components of the suspension feeder community. Reaction of organisms to changes in current regimes and availability of food will be checked by video-monitoring of selected species in laboratory experiments.

A combination with previous investigations on large-scale distribution and biomass of various macrobenthic organisms in different Weddell Sea benthic communities will allow an overall assessment of their contribution to benthopelagic coupling.

2.3.2 *Feeding biology of selected meiofauna taxa*
(UOB)

An area of potential importance in understanding the link between the ice, pelagic and benthic components of the Antarctic coastal and shelf ecosystem (ACSE) is the role of sediment metabolism. The sediments contain an active microbial and meiofaunal community which can receive a substantial input of organic material following pelagic blooms or melting processes of sea ice. Remineralization processes in the sediment and its potential in returning essential nutrients to water column and atmosphere are generally poorly known, even less so in polar regions.

Meiofauna organisms either directly use POM (possibly also DOM) or the microbiota developed on particulate matter as food. Gut contents and fecal pellet analysis, feeding and preference experiments of selected meiofauna taxa will provide qualitative results on which quantitative studies can be based. It is of special interest to see whether the feeding biology of selected meiofauna taxa has a key role for their reproductive performance. Data from the shelf ice coast of the Weddell Sea will be compared with results from King George Island (Dallmann Laboratory).

2.3.4 *Aerobic metabolism and antioxidant defense in Antarctic sipunculans*
(AWI)

Compared with marine invertebrates from boreal zones, polar marine invertebrates are exposed to low temperatures and elevated oxygen

levels. These factors have been demonstrated to determine the rate of aerobic metabolism. In addition, these factors and also the level of ambient H2O2 concentrations will influence the generation of reactive oxygen species and the level of antioxidant enzymes which remove toxic oxygen species generated during regular aerobic metabolic reactions. However, the combined effect of temperature, O2 and H2O2 concentrations on the physiology of marine invertebrates is, in general, incompletely understood as is the specific importance of each of these factors in the physiology of polar species. Therefore, the aerobic metabolic activity and the enzymatic antioxidant defense of Antarctic sipunculans will be studied.

For the evaluation of abiotic factors in the environment of Antarctic sipunculans we will determine temperature and the levels of 02 and H2O2 in the sediment-water boundary layer and, in addition, will collect sediment samples for porosity and organic carbon determinations at the stations where sipunculans are found. The metabolic rate (i.e. the rate of oxygen consumption) and the in-situ activities of antioxidant enzymes will be measured on board. One toxic effect of reactive oxygen species is the peroxidation of lipids, which can be assessed by measuring malondialdehyd concentrations. For this analysis tissue samples of Antarctic sipunculans will subsequently be analysed at the AWI. In further experiments the influence of temperature, different external H2O2 concentrations (i.e. oxidative stress), and food availability on aerobic metabolic rates and the levels of antioxidant enzymes will be studied. Continuation of the investigations will require maintenance and home transport of live specimens.

2.4 POPULATION DYNAMICS OF ZOOBENTHOS AND DEMERSAL FISH

(AWI, IEAB, IFM, SZI, UOGB)

Reproduction, recruitment, growth and mortality are the main processes which determine the dynamics of a population in space and time, and therefore also the role of this population in the food web and the interaction web of the community. During the last decade our knowledge of the population dynamics of high-Antarctic benthos and fishes increased substantially, but is still very limited. Moreover, most of the work has been carried out in shallow water areas. Only very few shelf species have been investigated in more detail, and especially data on reproduction and recruitment are lacking.

The cruise ANT XIII/3 will provide the opportunity to fill some of the gaps in the present knowledge of the population dynamics of high-Antarctic animals. The background are the effects of seasonal variability of the system, especially of food supply, on high-Antarctic populations, and the adaptation of the animals to these particular conditions. Emphasis will be put on reproductive biology and recruitment of benthic meio- and macrofauna, but other parameters of population dynamics will be analyzed, too.

- Meiobenthos
  The main topics of meifaunal studies are:
- The role of demersally drifting life cycle stages for recruitment.
- Recruitment performance of selected taxa, with emphasis on gonad maturity, reproductive output, larval development and behaviour.

- Distribution of developmental stages of harpacticoid copepods.

- Macrobenthos
  Macrobenthic studies will focus on reproductive strategies and production biology, and on possible links between Antarctic and deep-sea fauna:
- Reproductive strategies of sponges; their effect on mesoscale distribution patterns of populations and on population structure.
- Reproductive biology of the polychaete superfamily Aphroditacea; adaptations to Antarctic conditions and variability within the Antarctic.
- Reproductive parameters of Weddell Sea species of the groups Cnidaria, Crustacea and Echinodermata; comparison with related deep-sea species.
- Examination of pressure tolerance of early embryos of echinoids and asteroids.
- Examination of recently recruited postlarvae and juveniles of echinoids and asteroids.
- Growth and productivity of echinoderm key species on the Weddell Sea shelf.

- Demersal fish
  Severals aspects of population dynamics of abundant species will be investigated:
- Spatial distribution and relative abundance of populations.
- Size and age structure of populations as well as growth and reproductive patterns.

2.5. BENTHIC BIODIVERSITY

The biodiversity crisis and the follow-up of global change effects emphasized the need for a better and more complete basic knowledge and understanding of marine biodiversity in general.
In the Southern Ocean, the benthic communities are known to be mostly rich and diverse. If the taxonomic and distribution knowledge of the most important benthic groups is relatively well developed, significant gaps nevertheless remain in specific groups, taxonomic levels, localities, or depths, and in phylogenetic history.

The causes of the high benthic diversity remain to be properly understood as well as its role in ecosystem function, for example with regard to its productivity and resilience.

In the Kapp Norvegia area and in the SE Weddell Sea in general, previous investigations have brought a large amount of taxonomic as well as qualitative and quantitative distributional information on the

benthos. The present proposals concentrate on the assessment of biodiversity at the faunal, species or population levels as well as on its origins and its role in some key processes (colonization, production, trophodynamics).

The following projects have been suggested in the biodiversity context:

2.5.1 *Genetic isolation of benthic Isopoda (Crustacea) and speciation mechanisms in the Southern Ocean*
(UOB)

The biodiversity of extant Antarctic benthos is the product of a long history of isolated evolution in a relatively constant polar environment. Not only large numbers of species but probably also diversity at the population level are the result of this evolutionary radiation. Our previous taxonomic and biogeographic studies have shown that several benthic isopod species have local phenotypes that differ considerably between localities. During the season 1995/96 it is intended to study the genetic polymorphism within species, comparing local populations of isopods on a small scale (Kapp Norvegia area) and, as far as the cruise itinerary allows, over longer distances along the ice shelf of the Weddell Sea. Material from the South Shetland area will be sampled during leg ANT XIII/4. The results will be compared with already known morphological polymorphism, with the different mobility of species and with dispersal barriers. We want to use sequences of the rRNS gene (especially the ITS-regions) and RAPDs for intraspecific studies. A second aspect is the study of genetic distances between monophyletic groups of species (genera) in correlation with biogeography. Phylogeny inferred from sequences can be compared with results from classical morphological studies to reconstruct part of the history of the Antarctic fauna. For this purpose related species of the Magellan area (expedition ANT XIII/4) will also be used.

Isopods will be taken from bottom-trawl and Agassiz-trawl samples. It is essential to get material from topologically separated populations.

2.5.2 *Taxonomic and ecofunctional biodiversity of the amphipod taxocoenoses in the eastern Weddell Sea benthos*
(AWI, IRSNB)

In the quasi-absence of decapod crustaceans, the peracarid crustaceans (amphipods, isopods, tanaids, cumaceans, mysids) are by far the group richest in species and possibly the ecologically most diverse group in the Antarctic benthic communities.

The most numerous taxon, the amphipods, with 702 benthic species in the whole Southern Ocean and 174 spp. in the SE Weddell Sea, have been the subject of a very intense adaptive radiation, apparently unparalleled in other oceans. The origins of this high biodiversity remain to be precisely understood as well as its role in the structure

and functioning of the benthic system. If the taxonomic richness of amphipods is well established, their taxonomic knowledge is still insufficient in particular to produce the synthetic identification tools which are crucially needed. In connection with the study of the trophodynamics of the amphipod taxocoenosis at Kapp Norvegia, the biodiversity approach will focus on the continuation and refinement of previous taxonomic work and on further distribution, habitat and microhabitat documentation.

A second topic is the characterization of the ecofunctional diversity of the benthic amphipods in the perspective of better understanding their adaptive radiation.

2.5.3 *Sponge fauna of the Weddell Sea shelf and its integration in benthic sprocesses*

(IFM, ZMK)

Previous investigations have shown sponges to be a dominant and highly diverse component of Weddell Sea benthic ecosystems. During this cruise, the faunal survey will be continued with special attention to small forms, like thinly encrusting demosponges, calcareous sponges, and young hexactinellids. Many species, especially among the hexactinellids, are so far only recognizable in their adult growth forms, so important focal points will be the identification of juvenile forms and the establishment of life history patterns.

On the basis of fresh specimens some special taxonomic problems will be examined, among them the old question of bipolarity which is still unsolved in sponges. Generally, better knowledge on details of distribution will further the analysis of Antarctic faunal history characteristics, i.e. the relation between different parts of the Antarctic shelf, and of the Antarctic fauna to that of neighbouring continents.

An earlier investigation on the fauna associated with Antarctic sponges will be taken an important step further by trying to analyze relationships of associated faunal elements to each other (e.g. predator-prey relationships), and population dynamics of organisms spending their whole life in sponges.

Investigations on structural and dynamic aspects of sponge spicule mats, a typically Antarctic benthic habitat, will be intensified.

2.5.4 *Genetics and taxonomy of Southern Ocean octopods*

(BAS, ULML)

At present the taxonomy of the octopodids is in a particularly unsettled state and there is a general need for systematic revision in the group. Lack of reliable morphometric characters on which to base systematics has led to numerous taxonomic controversies, with confusion arising even at subfamily level. It is becoming clear that octopus phylogeny cannot be solved by traditional taxonomy alone

and that molecular and biochemical genetic techniques need to be implemented in conjunction with the classical methods.

Phylogenetic resolution of Antarctic octopods has been hampered by a paucity of specimens and often by the poor conditions of existing samples.

Octopodid phylogenetics will be investigated using the established method of starch gel electrophoresis in conjunction with modern molecular techniques involving the polymerase chain reaction (PCR). Both methods allow calculation of genetic diversity between groups of samples, using established indices.

The shipboard research will request rapid freezing of small tissue samples for biochemical and molecular genetic studies. A variety of morphometric measurements will be taken, preferably with the animals still alive, and the animals will be sexed and staged. Specific samples sites are not required, provided trawling is undertaken at a range of bottom depths.

2.5.5 *Taxonomy, systematics and anatomy of demersal fish of the SE Weddell Sea assemblages*

(COC, IEAB)

In addition to the main programme aiming at determining the structure and function of the demersal fish assemblages and to point out the factors that influence and regulate these assemblages, much of the material collected will be used for taxonomical and systematic studies as well as for specific anatomical approaches.

2.5.6 *Faunistic analysis of fish parasites*

(IPW)

The presence, taxonomy and distribution of fish parasites (mainly Acanthocephala, Digenea and Cestoda) wil be studied with new material from the Weddell Sea. Until now, parasites are well known from the Atlantic Subantarctic area (South Georgia, South Shetlands), especially notothenioids and rays have been investigated in great detail. Teleosts other than notothenioids need further study; furthermore infection in colder areas of the Southern Ocean has not been analyzed yet. It is not known if diversity of parasite species and the percentage of endemisms of the Antarctic Peninsula are comparable with the fauna of the high Antarctic.

Samples will be taken from benthic habitats, since pelagic species are usually free of adult parasites and harbour mainly indeterminable larval cestodes. It is intended to use material caught with bottom trawls or with Agassiz trawls. Since parasites are difficult to find and to determine when fixed in formalin or when taken from frozen fish, fresh samples are needed.

2.5.7 *The role of demersal drift for dispersal and distribution of meio- and macrofauna*
(UOB)

Although near-bottom driftng organisms might be an important link between the water column and the sea-bottom, research on demersal drift has been limited. Demersally drifting organisms may be derived from the pelagic realm as holoplankton usually occurring higher up in the water column, or, as a community of plankton always close to the bottom („hypoplankton„). On the other hand, there are many early life-history stages of otherwise benthic meroplanktonic and possibly demersal („hyperbenthos„) macrofauna. Emergence of various meiofauna taxa has been recently documented. Besides ist trophic significance (e.g. hypoplankton as predators of benthic fauna or benthic drift stages using water-column derived nutrients), demersal drift will enhance the dispersal pontial of the involved taxa. This is of autecological (e.g. resource utilisation, recruitment), syn-ecological (competitive exclusion, predator avoidance) or zoogeographic importance (e.g. colonization over an evolutionary time scale). It may also influence the distribution pattern of taxa, horizontally and from shallow to deeper waters.

Demersal drift will be investigated by a sledge net. Whole sediment cores will be used for *in vitro* experiments on the emergence potential of benthic fauna in plexiglass tubes and kept in a cooling lab at various combinations of physical parameters (water flow/light/ temperature).

If some meiofaunal or macrofaunal taxa are dispersed by demersal drift, their vertical and horizontal distribution should be more uniform than that of less motile fauna. Therefore, benthos will be collected along a vertical transect by a bottom corer. This fauna will be compard with the samples obtained by the sledge net.

The demersal dispersal modes of Antarctic macrofauna are fairly unknown. Evidence from sledge net hauls should complement our knowledge on this topic as well as on hypoplanktonic communities and resting stages.

2.5.8 **Meiobenthos diversity under typical polar conditions**
(UGZ)

Preliminary results of ecological research in the Weddell Sea showed that meiobenthic communities at Kapp Norvegia are characterised by a high diversity. Among the several factors inducing the heterogeneity and complexity of a deep-sea habitat in general, typical polar conditions (see project 4) certainly affect the species richness and functional diversity of the benthic fauna.

Bottom structure and topography, sediment quality and food availability are the main factors controlling meiofaunal communities. Changes due to the particular conditions in the high Antarctic will certainly affect the diversity patterns of these organisms.

The proposed biodiversity study of the meiobenthic communities will address the species richness, trophic and body-size diversity topics. An investigation on the role of biodiversity in production and resilience of the system will be challenged.

2.6 *ABIOTIC-BIOTIC INTERACTIONS AND RESILIENCE IN MACRO- AND MEIOBENTHIC COMMUNITIES*

(AWI, UGZ, ZISP)

Faunistic research on the benthic fauna along the southeastern Weddell Sea shelf and slope has been carried out during the last decade. The zoogeographical results from several expeditions give a good overview of the large-scale pattern of benthic assemblages for macro- and meiofauna. From these investigations we know that in general large areas are rich in number of epibenthic species as well as in abundance, and that they are dominated by sessile suspension feeders. In other regions the infauna seems to be relatively more abundant, however, with a lower diversity. Within such different benthic assemblages extremely patchy mesoscale spatial dispersion patterns were found which may differ for different taxa.

According to the present state of knowledge, both the macro- and meiobenthic fauna of the Weddell Sea are influenced by a complex environment which in some ways is unique. This raises the question, What is the effect of typically polar conditions on the structure and dynamics of the benthos and the fish fauna?

As primarily ecologically relevant "typical polar conditions" we consider for this study:

(1) the mesoscale bottom topography such as inner shelf depressions and the small scale topography affected by iceberg scours,
(2) the effect of the ice shelf edge,
(3) the short phase of primary production and its high interannual variability caused by variations in the amount and duration of the sea ice cover,
(4) sponge spicule mats and bryozoan/hydrozoan debris,
(5) near-bottom mesoscale current regime affected by the ice-shelf coast and bottom topography, regulating the food input to the benthos.

The general goal of this project is to study the major direct and indirect interactions between the biotic and non-biotic South Polar environment in order to understand the relevance of different environmental factors. The investigations on the structure of the ecosystem should answer the question as to which long-term processes have shaped recent benthic communities. The expected results should enable us to draw conclusions as to the resiliency of the ecosystem after events of disturbance. For example, we know that icebergs run aground and destroy the bottom fauna.

The questions to be addressed will be:

(a) Which species will initially colonize areas devastated by iceberg scours, are there species that exclusively occur in such areas, which in long term - in an advanced stage of recolonisation - may lead to an increase in diversity? Due to the low growth rates of most macrobenthic species we expect a long-lasting direct effect on these organisms which can be detected by an assessment of the size spectra of large epibenthic organisms. At which rates and with which phases of succession will recolonization occur? Does the meiofauna recolonise such areas faster than the macrofauna? To what depth into the sediment are animals affected?

(b) What are the indirect effects of the scouring of icebergs? As a consequence of iceberg scouring the small-scale bottom topography will be altered and consequently, also the food input to the benthos. Along an uneven bottom topography, locally extremely high concentrations of sessile suspension feeders have been observed. It should be investigated whether there is a general relation between small-scale bottom topography (slopes, depressions, mounts, plateaus), the currents close to the seafloor, icebergs and benthic community structure.

(c) What is the effect of the ice-shelf coast and the bottom topography with their specific current regimes (e.g., innershelf depressions), on the abundance and composition of benthic assemblages? One key factor affecting the benthos is the transport of particulate organic matter by currents close to the bottom. This material serves directly as food for primary consumers and indirectly for scavengers and predators. In areas of recent ice island calving and in the vicinity of large grounded icebergs a substantial change of the near-bottom current regime must be presumed. Preliminary investigations have shown an extraordinary degree of patchiness for the benthos close to the ice-shelf edge, presumably due to specific physical, geological, and biological environmental conditions. It should be examined in which way different current regimes (from the open ocean towards underneath the ice shelf, vice versa, or parallel to the coast) serve as transport mechanisms for the food of the benthos and to what extent these processes can explain the patchiness of the fauna. Within selected taxonomic groups also the importance of these processes for reproductive and feeding strategies will be assessed. Additionally with this background pore-water nutrients, organic matter, and pigments will be measured.

(d) To what extent do sponge spicule mats and bryozoan/hydrozoan debris provide a special habitat for the meiofauna and for macrobenthic species? To what extent is the vertical distribution of the meiofauna in this microhabitat different to other areas?

The study will rely on the knowledge and experience of the collective Antarctic group of the Zoological Institute of St. Petersburg (20 specialists) for processing the material, elaborating precise lists of species as well as bottom biocoenosis distribution maps, for the needs of the succession and colonisation study.

These investigations should be realized by a combination of imaging methods with partly optically controlled sampling at those stations, for which the above mentioned characteristics are known to exist from previous expeditions. In oder to find iceberg scours and other special features of the bottom topography a detailed mapping of the seafloor will be carried out as a first step on the shelf by the bathymetric working group. According to the results obtained by this group, sampling will follow using dredges, and corers and imaging methods will be applied. Another strategy will be to concentrate part of the ecological work on areas where icebergs frequently run aground; in such areas an attempt should be made to observe directly by the ROV the a grounded iceberg and the fauna around it. For an ecological interpretation of the biological results, several moorings will measure sedimentation rates, currents close to the seafloor, and the amount of particulate organic material. A large-scale registration of sea ice extension from space for the time of investigation is planned.

2.7 *BATHYMETRIC AND SIDE LOOKING SONAR STUDIES WITH HYDROSWEEP*

(AWI)

As on former expeditions, bathymetric data will be collected almost continuously during leg ANT XIII/3 with the Hydrosweep multibeam bathymetry system.

Data collected on tracks between Cape Town, Neumayer station and the working areas on the shelf of the southeast Weddell Sea will supplement the existing bathymetry for the Southern Atlantic and the continental slope of Antarctica. On the basis of the collected multibeam data, existing bathymetric charts such as GEBCO and AWI-BCWS (Bathymetric Chart of the Weddell Sea) will be improved.

The Hydrosweep system now also provides side-looking sonar (SLS) data. These data consist of the amplitude of the backscattered energy returned from the sea bottom. For every ping 1000 amplitudes values are sampled and stored. These data can be plotted as a map to provide a view of relative scattering strength of the seafloor. The scattering strength depends on the direction and the angle of sea bottom. Because of the high resolution of the SLS data small features on the sea bottom, such as iceberg ploughmarks, may be discovered and surveyed.

During leg ANT XII/3 Hydrosweep SLS data were collected in areas of medium depth (200 - 1000 m) with great success. This generated the idea of using SLS data for surveying and mapping the areas of

investigation on benthic fauna in great detail. In particular iceberg ploughmarks, formed by icebergs running aground, should be detected and mapped. The results of bathymetry and SLS surveys may supplement information obtained by other imaging methods (ROV) used for benthic investigations.

2.8 CEPHALOPOD ECOLOGY AND PHYSIOLOGY

2.8.1 *Biology and taxonomy of Antarctic cephalopods*
(AWI, IFM, ULML)

In contrast to fish and crustaceans the research on Antarctic cephalopods is still at a very early stage, although the ecological importance of this faunal group within the Antarctic marine food web is widely acknowledged. In the eastern Weddell Sea cephalopods, and in particular the highly mobile squids, are key prey organisms for top predators such as emperor penguins and Weddell seals. On the other hand, squids seem to be very efficient in preying upon Antarctic krill, as first gut content analyses have recently shown. However, sufficient data to quantitatively elaborate their role as prey and predator within the Antarctic marine food web are still missing. Even information on cephalopod species composition, species life cycles and general biology of the most abundant species is still fragmentary.

During the forthcoming "Polarstern" cruise to the eastern Weddell Sea all cephalopods will be sampled from the catches with various sampling gears. The collected specimens will be the basis for a variety of investigations on key questions of Antarctic cephalopod ecology and for determining the role of this group in the energy flow of the high Antarctic.

First, we will study the general distribution patterns of the sampled specimens. A variety of morphometric measurements will be taken, and all animals will be identified to the lowest possible taxon, sexed and staged. When all data have been collected, the animals will be fixed in formalin for long-term preservation to allow later investigations such as classical taxonomy studies. Special attention will be paid to the different life stages of the most abundant species as cephalopods change their morphological characters markedly during their life cycle. It is the aim to describe in detail the armature of the brachial crown, particularly of arms and tentacles from various life stages of selected taxa. These investigations will be done later in the home laboratory using light microscopy and SEM techniques. In close conjunction with gut content analyses these studies will reveal the potential prey spectra which cephalopods are encompassing during their different life stages. All data from the field samples will be collected for further calculations of cephalopod biomass in the study region.

Second, we will investigate maturity, fecundity and age of collected squids. Maturity will be measured according to maturity scales

available from the literature. Fecundity will be estimated by describing gonad structure and oocite size and number of female squid. Statoliths will be extracted from the head and preserved. Age will then be determined by reading statolith rings by means of light micoscopy and SEM techniques later in the home laboratory. These investigations will provide first results on Antarctic squid fecundity and age.

Third, it is intended to collect and preserve mandibles from all cephalopod species. The collection will be kept as a reference collection of Antarctic cephalopod beaks to allow future identification of beaks sampled from predator stomachs.

Fourth, the genetics and taxonomy of southern octopi will be studied. At present the taxonomy of the octopodids is in a particularly unsettled state and there is a general need for systematic revision in the group. Lack of reliable morphometric characters on which to base systematics has led to numerous taxonomic controversies with confusion arising even at subfamily level. Phylogenetic resolution of Antarctic octopods has been hampered by a paucity of specimens. Furthermore, of the seventeen species reported from the Southern Ocean, many of the descriptions are based on female or juvenile specimens alone. Rapid progress in the field is almost certainly dependent on sampling opportunity. Aboard ship, the rapid freezing of small tissue samples for biochemical and molecular genetic studies would be of primary importance. In addition, morphometric measurements will be taken, preferably with the animals still alive. In later laboratory studies octopodid phylogenetics will be investigated using established methods of starch gel electrophoresis in conjunction with modern molecular techniques involving the polymerase chain reaction (PCR). Even if samples of some species are only available in limited numbers this will not affect the biochemical and molecular studies; previous work has shown that a species can be placed in a phylogenetic tree fairly accurately on the basis of a single specimen. Finally, the possibility of capturing previously undescribed species should not be overlooked as sampling at these extreme latitudes has been limited.

Fifth, food composition studies of all specimens obtained will enable us to identify the position of squids and octopods in the food web of the high Antarctic ecosystem.

2.8.2 *The ecological physiology of Antarctic cephalopods (AWI)*

A deeper understanding of the specific adaptations of polar cephalopods calls for additional, physiological studies and for a comparative view of the ecophysiology of polar species and species from boreal and even warmer environments. It is important in this context to consider the physiological characteristics of coleoid cephalopods in general. These animals exhibit the highest rates of aerobic metabolism among marine invertebrates and, among cephalopods, the highest rates are generally found in squid. These

features must be seen in relation to the performance characteristics of squid which are the only invertebrates competing with fish and even mammals in their pelagic environments. Molluscan design characteristics led to the development of specific physiological solutions to meet the extreme energy requirements of this group. Maximum performance and metabolism are associated with the maximum use of availabe resources. This statement not only refers to the food requirements of cephalopods. In muscular squid from the North Atlantic, the maximum use of available oxygen was demonstrated to be achieved and supported by a maximum use of the extracellular blood pigment, haemocyanin, and by significant oxygen uptake via the skin of the mantle already under resting conditions.

We intend to elaborate the physiology of Antarctic cephalopods under conditions of low temperature and elevated ambient oxygen levels considering also the influence of nutrient availability to these animals. Low temperatures may lead to specific adjustments in the relationship between the use of aerobic and anaerobic resources during activity. Elevated oxygen levels might on one side facilitate oxygen transport to tissues but on the other side imply elevated oxygen toxicity. Constantly low temperatures may have supported the development of ammoniacal buoyancy which is, otherwise, typical for deep sea environments. The use of an energy-saving buoyancy mechanism in this environment may be an adjustment to reduced maximum energy turnover at low temperatures and/or reduced availability of prey.

For being able to address some of these general questions during the cruise, available cephalopod species, mainly octopods and if possible squid, will be collected and life specimens will be maintained in aquaria (also for the purpose to transport some of the intact animals to the AWI). Species will be identified and the ecological background will be elaborated in cooperation with the colleagues working on biology and taxonomy of cephalopods. In accordance with this information the physiological questions will be formulated and experiments will be designed. For an evaluation of critical temperatures and in order to evaluate the coordination of acid-base regulation and energy metabolism at low temperature, tissue samples will be taken from animals incubated at different temperatures and will be analysed for intracellular pH and metabolite levels. Activities of key enzymes of aerobic and anaerobic energy metabolism will be measured in various tissues including the temperature dependence of their kinetic properties. The problem of oxidative stress associated with high rates of aerobic metabolism and high ambient oxygen levels will be addressed by analysing the activities of antioxidant enzymes as well as the influence of temperature on their activity and kinetic properties. Since allometric relationships may interfere, different life stages and sizes should be compared. We shall attempt to analyse hydrogen peroxide in the blood as an indicator of oxidative stress.

Up to now nothing is known about the role of the haemocyanin in oxygen uptake and transport to tissues in Antarctic cephalopods.

Therefore, blood of different species will be sampled and the haemocyanin concentration, the 02-binding capacity as well as the oxygen binding properties will be determined. Haemocyanin properties will be seen in the context of measurements of oxygen consumption rates at rest, during activity and at different temperatures. Measurements of oxygen consumption as well as ammonia and urea excretion rates permit a calculation of the O:N ratio which is indicative of which substrate is predominantly used for energy production.

Several species of cephalopods achieve neutral buoyancy by storing ammonia in tissue or coelomic fluid compartments. Depending on the species caught during the cruise the ammonium concentration in body fluids will be measured and samples will be prepared for electron microscopy and the determination of ammonium compartments.

The results obtained by the cephalopod physiology group will be combined with those taken by the ecology group to arrive at a more substantial judgement as to the function of this group in the Antarctic marine ecosystem.

2.8.3 *Ecological, physiological and genetic studies on notothenioid fish*

(AWI, COC , IEAB, IPÖ, UOBS, UKK)

Notothenioids are the dominant fish by number and biomass in all inner shelf areas of the Southern Ocean including the southeastern Weddell Sea. In a habitat historically underutilized by non-notothenioids, they have undergone a depth related diversification directed away from the ancestral benthic toward the pelagic habitat. In addition to phyletic diversification, and unlike the situation in most other teleostean lineages, notothenioids have experienced substantial ecological and organismal diversification. This diversification has produced different life history types similar in the magnitude to those displayed by taxonomically unrelated shelf fishes elsewhere in the world. On the basis of habitat dominance and ecological diversification, notothenioids are probably the only example of a marine fish species flock. They are also a striking example of the nature of the Antarctic marine biodiversity.

Joint projects among different participants of the cruise ANT XIII/3 will investigate the phylogeny of notothenioids, interspecific trophic relationships and the physiological mechanisms underlying the perfect adaptation to the extreme polar environment, that has been achieved by these fish.

A phylogenetic classification of notothenioids will be established based on molecular as well as morphological characters. Notothenioids show an evolutionary trend toward pelagization and although lacking swim bladders, about 50% of the species in the family Nototheniidae occupy non-benthic habitats. The vertical distribution is accompanied by an evolutionary alteration of buoyancy.

The phylogenetic relationships between species will be elucidated on the basis of measurements of buoyancy and the evaluation of the morphological features that change density or provide static lift, especially in the skeletal, integumentary, muscular, visceral and lipid storage system. Interspecific trophic relationships will be investigated by analyzing food preferences, food composition, activity patterns and evaluating feeding success. These data will be linked to microscopical studies on morphological adaptations of sensorial structures involved in the detection of food, such as lateral line system, eyes, taste buds and olfactory structures. Together with morphological studies on different cell types involved in the digestion of different types of ingested food these investigations will reveal possible differences in feeding strategies in different geographical areas.

Environmental conditions in the Antarctic habitat with temperatures as low as -2°C are lethal to virtually all other fish. Notothenioids produce antifreeze glycopeptides (AFGPs) which prevent ice crystal formation in the body fluids at subzero temperatures. It has been proposed that AFGPs may have been the key innovation which allowed the speciation and domination of the Antarctic fish fauna by notothenoids. Nucleotide sequences of different genes coding for antifreeze proteins will be determined and used to design a phylogenetic hypothesis of the Notothenioidei. The comparison of phylogenies based on morphological versus molecular data will be a compelling result of the cooperative work aboard.

The upper lethal temperature of different notothenoids is only about 6°C, the lowest value known for any animal. The influence of temperature on the metabolic rate and on important physiological parameters and processes such as acid/base and ion regulation and energy status will be investigated. The results will be compared with data obtained from temperate teleost fish with a similar lifestyle. This may contribute to elucidate physiological tradeoffs characterizing survival at low temperatures and, at the same time, give reasons for temperature dependent geographical distribution limits of species.

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Anm.:
Wegen des Wechsels der Reederei zum 1.1.1996 sind zur Zeit keine zuverlässigen Angaben über das Schiffspersonal möglich

Since a new company will operating Polarstern from 1 January 1996, presently no reliable information is available on the ship's crew members

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