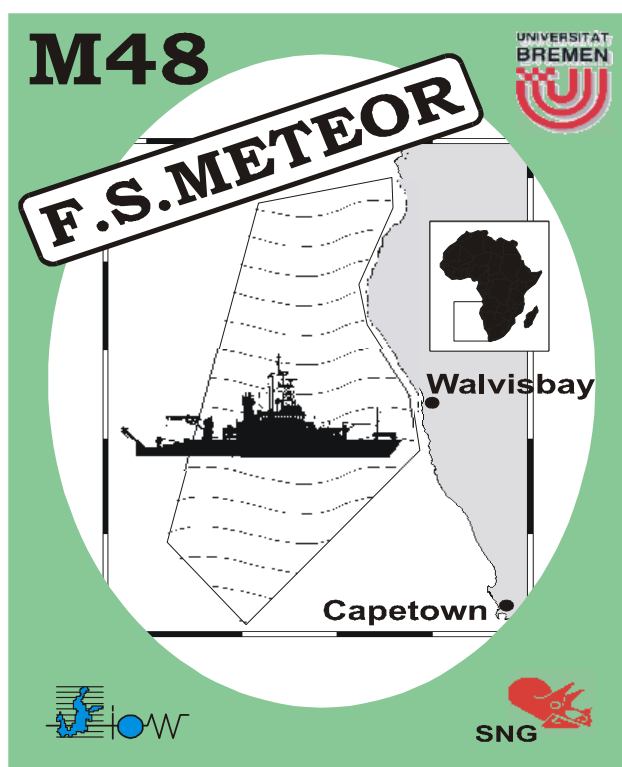


METEOR-Berichte 06-5

South-East Atlantic 2000

Cruise No. 48

6 July 2000 – 3 November 2000, Walvis Bay - Walvis Bay



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2006

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Abstract

Consisting of five legs, the German Research Vessel METEOR carried out its 48th cruise from July 6, 2000 to November 3, 2000 in the South Atlantic. All the legs of this cruise started and ended in Walvis Bay. The high organic productivity in the upwelling region off Namibia and its impact on numerous pelagic and benthic processes was the primary focus of the investigations during the METEOR cruise M48. A second focus centered around physical, biological and chemical studies in the Angola current system, the Angola basin and the Cape basin. The first leg was devoted to biodiversity studies of benthic organism communities in the abyssal Angola basin. In the coastal upwelling off Namibia the second leg focussed on sediments for the reconstruction of past environmental conditions, on diagenesis and on studies of novel nitrate-storing sulfur bacteria. The third leg studied the integration of the Angola and Benguela current into the circulation system of the South East Atlantic with emphasis on the coupling of the different current branches by the Angola gyre and their response to the wind field. During the fourth leg dissolved and particulate trace elements and radioisotopes were sampled for a comparison of coastal upwelling with oligotrophic conditions in the remote Angola basin and Cape basin. The fifth leg studied the impact of meso-scale physical structures and processes on zooplankton production and fish recruitment, with emphasis on the questions where the nutrients of the Lüderitz cell generate the food chain link from phyto- to zooplankton, and whether it has a direct impact on the fish spawning grounds much farther north. This report summarizes the main goals of the various working groups, provides complete lists of all stations of each leg, and presents preliminary results obtained during the cruise. The cruise was funded by the *Deutsche Forschungsgemeinschaft* (German Research Foundation).

Zusammenfassung

Die 48. Reise des deutschen Forschungsschiffs METEOR fand in fünf Abschnitten vom 6. Juli 2000 bis zum 3. November 2000 im Südatlantik statt. Alle Fahrtabschnitte begannen und endeten in Walvis Bay. Die hohe organische Produktivität im Auftriebsgebiet vor Namibia und ihr Einfluss auf verschiedene pelagische und benthische Prozesse bildeten den ersten Schwerpunkt der Reise M48. Ein zweiter Schwerpunkt befasste sich mit ozeanographischen, biologischen und chemischen Studien im Gebiet des Angola-Stroms, im Angola-Becken und im Kap-Becken. Der erste Fahrtabschnitt galt Biodiversitätsstudien von benthischen Organismengemeinschaften im abyssalen Angola-Becken. Auftriebssedimente vor Namibia wurden während des zweiten Abschnitts bezüglich der Rekonstruktion vergangener Umweltbedingungen und der frühdiagenetischen Prozesse sowie in Hinblick auf kürzlich entdeckte nitratspeichernde Schwefel-Bakterien untersucht. Der dritte Abschnitt befasste sich mit der Integration des Benguela und Angola-Stroms in das südatlantische Zirkulationssystem, wobei die Kopplung verschiedener Stromzweige mit dem Angola-Wirbel im Vordergrund stand. Bei den Untersuchungen von gelösten und partikulären Spurenelementen und Radioisotopen während des vierten Abschnitts sollten die Effekte auftriebsgestützter Hochproduktion mit den oligotrophen Verhältnissen im landfernen Angola- und Kap-Becken verglichen werden. Der fünfte Abschnitt untersuchte den Einfluss mesoskaliger Strukturen und Prozesse in der Wassersäule auf Zooplankton- und Fisch-Produktion; dabei ging es insbesondere um die Frage, wo die Nährstoffe der Lüderitz-Auftriebszelle in der Nahrungskette über das Phyto- zum Zooplankton führen und

welchen Einfluß dies auf die Fischlaichplätze sehr viel weiter im Norden hat. Dieser Bericht fasst die wichtigsten Arbeitsziele der verschiedenen Arbeitsgruppen zusammen. Er enthält vollständige Listen der Stationen sowie erste an Bord erzielte Ergebnisse. Die Expedition wurde durch die Deutsche Forschungsgemeinschaft (SFP METEOR-Expeditionen) gefördert.

Research objectives

The high organic productivity off Namibia, which is based on the upwelling in the Benguela system, and its impact on numerous pelagic and benthic processes was the focus of the investigations during the METEOR cruise M48. Additional investigations centered around physical, biological and chemical studies in the Angola current system, the Angola basin and the Cape basin. The working areas of the five legs of METEOR cruise M48 are shown in Fig. 1, periods, ports and chief scientists of the individual legs are listed in Tab. 1.

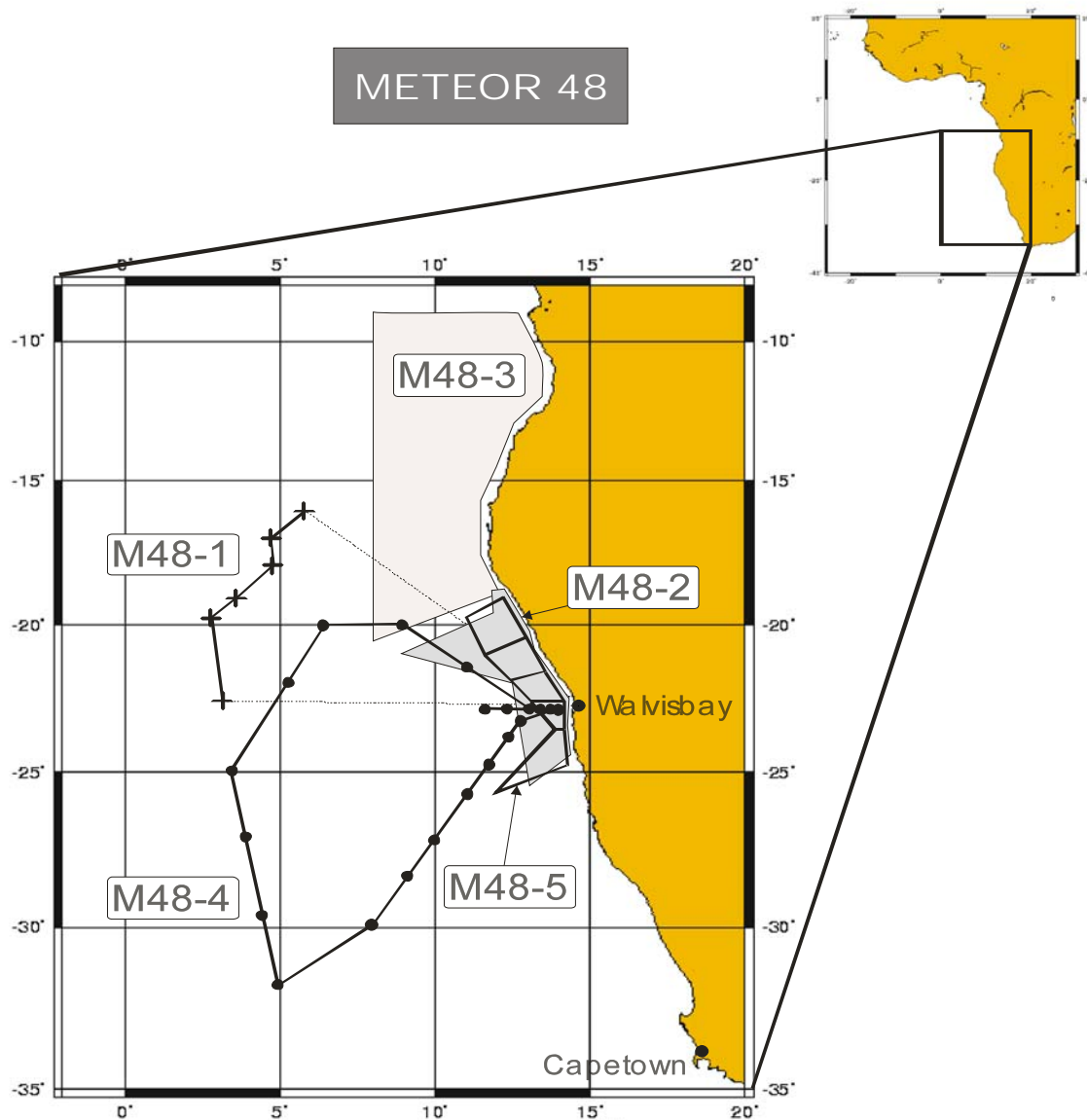


Fig. 1: Working areas of the five legs of METEOR cruise M48. Cruise tracks and sampling stations are illustrated in the respective reports

Table 1: Legs and chief scientists of METEOR cruise M 48

Leg	Period	Ports	Chief Scientist
M48/1	06.07.00-02.08.00	Walvis Bay-Walvis Bay (Namibia)	Dr. M. Türkay
M48/2	05.08.00-23.08.00	Walvis Bay-Walvis Bay (Namibia)	Prof. Dr. K.-C. Emeis
M48/3	28.08.00-16.09.00	Walvis Bay-Walvis Bay (Namibia)	Dr. H. U. Lass
M48/4	19.09.00-10.10.00	Walvis Bay-Walvis Bay (Namibia)	Prof. Dr. W. Balzer
M48/5	13.10.00-03.11.00	Walvis Bay-Walvis Bay (Namibia)	Dr. J. Alheit

Masters: N. Jakobi (M48/1-M48/3), M. Kull (M48/4-M48/5)

The **first leg** of the present cruise was mainly targeted at surveying compositional changes in the benthic organism assemblages along a transect of about 700 km in the abyssal Angola Basin. Analysis of the large scale spatial variability of such benthic communities leads to conclusions about the distribution area of individual species and thus contributes to a realistic picture of the biodiversity of the world ocean. For this purpose it is essential to work in large and homogeneously structured deep sea basins in order to avoid the obscuring of results by small scale ecological variability, whose effect has not realistically been taken into account during former studies. The present study was also aimed at investigating zoogeographic patterns and their constancy within a deep sea basin usually referred to as a homogeneous region. Differentiation processes, including organism speciation, are to be examined with morphological and genetic methods. As a result, we expect to reach a better understanding of the role of geographic distance in speciation as well as in regionalisation processes and to distinguish these from ecologically driven differentiation. This study therefore aimed at critically testing the paradigm that all differentiation processes in the marine realm are driven by ecology.

Therefore, the deep sea benthos was examined with reference to all size classes (nano-, meio-, macro-, and megabenthos). For this purpose the following gear was used: a box corer for macrofauna, a multicorer for nano- and meiofauna, an epibenthic sledge for meio- and macrofauna and an Agassiz-trawl for the megafauna. For all benthic surveying activities the mapping with HYDROSWEEP and PARASOUND was an indispensable prerequisite in order to have information for reproducible sampling. In order to be able to relate faunistic results to environmental parameters a self registering CTD-probe was attached to the box corer. This ensured hydrographic measurements at sampling locations rather than T/S-profiles taken separately in the same area. In the home laboratory sediment properties, which are related to nutrient availability, are determined from samples gathered from box-corer and the multicorer. This includes total organic carbon, which reflects the sedimentation/advection of organic material, and the chlorophyll content of the sediments. The C/N ratio gives first insights to the origin of the material (terrestrial or marine). The chlorophyll content in the sediments may give hints to the deposition of fresh organic matter.

Six specific working areas of about equal distance to each other were selected in the Angola Basin at depths > 5000m. A full sampling scheme took 4-5 days, but could not be performed in every working area due to adverse weather and bottom conditions. Measurements of near bottom temperature and salinity (T: $2.48 \pm 0.02^\circ\text{C}$; S: 34.81 ± 0.03) did not reveal any significant difference between the working areas. Sediments are still under examination so that nothing can be said presently on their characteristics. The fauna sorted and observed on board was quite

diverse with few specimens of every species. Particularly diverse were the small sized animals, both in the epi- and endobenthos. Evidently coal and slags of old steamers form an environment of a secondary hard bottom type that houses a very diverse fauna. The full results will be available after sorting and identification in the home laboratories. As last operation of the cruise, the Agassiz-trawl was towed pelagically along the echo scattering layer at its highest density at 360m during the day.

The overarching goal of the **second leg** was to investigate processes of sedimentation and diagenesis in the modern diatomaceous mud belt off Namibia, and to use this knowledge to reconstruct past conditions in the coastal upwelling system. Sediments rich in opal and organic carbon accumulate in a narrow belt on the inner shelf beneath the upwelling area off Namibia at high sedimentation rates. Their distribution and facies are determined by water depth, the physical energy at the sea floor, biological productivity (both pelagic and benthic), terrigenous input, and diagenesis. Due to high sedimentation rates together with suboxic and anoxic conditions of the bottom water, the sediments provide a detailed archive of the climatic and paleoceanographic history in this coastal upwelling area since the Holocene transgression. Both the modern sedimentary regime and diagenetic processes are directly or indirectly linked to oceanographic and climatic factors that affect upwelling intensity, biological production, and advection of oxygenated waters to the shelf environment. Biogeochemical processes at the sediment-water interface are determined by very high accumulation rates of organic material which result in high oxygen and sulfate consumption at the sea floor. High concentration of nitrate in the bottom waters support partially endemic bacterial assemblages, which dominate benthic processes on oxygen-deficient seafloors.

The specific objectives of this leg were: (i) To recover short and long sediment cores from the "diatomaceous mud belt" and the neighbouring lithogenic and carbonate sediments of the upper continental slope. Sampling was carried out along transects parallel and perpendicular to the coast. Surface sediment samples were used to map the microbiological assemblages, as well as geochemical, micropaleontological, isotopic and mineralogical indicators of recent environmental conditions. These include gradients of temperature, water column structure and physical processes at the sea floor, and the nutrient regime. Once established, the set of proxy indicators will help to reconstruct the climate control on the intensity of upwelling and the prevailing wind regime, as well as the aridity in the hinterland during the Holocene. (ii) To investigate populations of nitrate-storing sulphur bacteria, their metabolism, their living conditions and interrelationship with other bacterial communities, and their role in biogeochemical processes in sea floor deposits offshore Namibia. We thus hope to elucidate mechanisms of anaerobic sulphide oxidation and the coupling of nitrogen and sulphur cycles in upwelling sediments. The endemic spherical species of sulphur bacteria *Thiomargarita namibiensis* stores nitrate in its vacuole and it can oxidize sulphide in the seafloor for months. One important objective of the expedition was the investigation of this recently discovered species of sulphur bacteria. (iii) To clarify biogeochemical cycles in the unconsolidated, organic-rich and anaerobic sediments, in particular the rates of sulphate and nitrate reduction, methanogenesis and methane oxidation. (iv) To service two sediment trap moorings on the upper continental slope, one located beneath the perennial upwelling cell off Lüderitz, the other beneath the seasonal upwelling area off Walvis Bay. A part of the expedition 48-2 of R/V

METEOR continued work performed in 1997 and 1999 during a series of expeditions with R/V PETR KOTTISOV and R/V POSEIDON.

The objectives during the **third leg** were to study the integration of the Angola and Benguela current into the circulation system of the South East Atlantic consisting of the subtropical gyre and the equatorial current system with emphasis on the coupling of the different branches of the current system by the Angola gyre and their response to the wind field. The upwelling in the Benguela system drives an intensive flux of matter which is distributed over the different branches of the circulation system in the South East Atlantic. The cruise M 48/3 aimed at a better understanding of the interaction of the circulation and the biochemical processes maintaining the balance of the fluxes of dissolved and particulate matter in the South East Atlantic. The objectives of the oceanographic field measurements were (i) to understand the location and the structure of the south-eastern Angola gyre and their variability in response to the large scale wind field; (ii) to better understand the location of the Angola-Benguela front; (iii) to estimate the exchange of material between the Angola and the Benguela current; and (iv) to study the structure of the current off the shelf at the core depth of the Antarctic Intermediate Water.

Since suboxic and hypoxic waters have a significant impact on the ecosystem in both the Angola Dome area and on the Namibian shelf, the oxygen budget of the area including the nutrient regimes have to be understood. Productivity and distribution of phytoplankton is closely related to the variability of stratification, upwelling and circulation in the area. The phytoplankton has an essential impact on the oxygen budget by its remineralisation. The abundance determination of different plankton species was expected to help identifying water masses. Different water masses, their boundaries and transition zones are characterised by zooplankton communities with a typical species composition. The zooplankton investigations aim at the estimation of species composition in the area of the Angola current, the Benguela current, and the Angola Dome and to identify characteristic regions. The investigations of trace metals aim at a better understanding of the cadmium budget in the water off South West Africa. The amount of cadmium that is advected by the Congo River plume to the study area and the cadmium release from the sediments to the water column were to be estimated.

The upwelling region off Namibia is characterized by extremely high biological production and relatively low rates of dust deposition and, hence, low atmospheric inputs of trace elements. During the **fourth leg** the focus was laid on trace element chemistry and (radio) isotope chemistry in this upwelling system and the adjacent oligotrophic deep-sea basins. One goal was to investigate the impact of high and low productivity regimes on the distribution of trace elements in the water column and their transport from the photic layer towards the sediments. Studies of the availability of the essential trace metals and their role as micronutrients under conditions of strong removal processes was one of the particular research interests. Particle-solute interaction is a key process in the biogeochemical cycling of the chemical elements in the ocean. Comparison of the trace element composition of the particles and the distribution of the trace elements between different phases (dissolved, suspended particles, large sinking particles) allow conclusions on transport and sorption mechanisms as well as on the general geochemical behavior of these elements in the ocean. With Fe being a prominent example, many of the trace elements are essential for marine productivity. The trace elements which were studied during this project cover a broad range of chemical properties, enabling to investigate the relevant biogeochemical processes in greater detail. In contrast to the upwelling system off Northwest

Africa, where high biological productivity is accompanied by high rates of dust deposition, in the upwelling system off Namibia the "pure" biological effects on trace element cycling can be studied more easily. Thus, the results from studying the Namibian upwelling system were intended to be used also for a comparison of these two differing upwelling systems with respect to element cycling. Dissolved and particulate trace elements by means of GoFlo[®] bottles and in-situ pumps, respectively, during two transects from the upwelling zone towards locations in the open Angola basin and Cape Basin. To study the imprint of the vertical material flux on the sea floor, sediments have to be collected with a multi corer

The major objective of the Radiochemistry group during M48/4 was to determine the effects of the bioproductivity, the composition of the particle flux and of the hydrography on the distribution of the radioisotopes ²³⁰Th, ²³²Th, ²³⁴Th, ²³¹Pa, ²¹⁰Pb, ²¹⁰Po and the Nd-isotopes in the water column and in the sediments of the Angola basin and the Cape basin. While there is much information about these effects already available for the North Atlantic and for the Atlantic sector of the Antarctic ocean, no such studies have been conducted in the upwelling region off Namibia. A further objective was to investigate the relation between primary productivity and authigenic uranium enrichment in the (anoxic) sediments. Along two transects from the upwelling area off Namibia to reference stations in the Angola Basin and the Cape Basin, water column sampling at up to eight depth levels were conducted. At corresponding water depths, in-situ pumps were deployed for the determination of particulate (radio) isotopes. Also solid sediments were sampled for the determination of radioisotopes; an additional separation of the pore water was conducted to trace uranium transport into the sediment.

Coccolithophores together with other planktonic organisms form the basis of marine ecosystems. The occurrence and distribution of coccolithophores is directly dependent on the hydrography of the water masses. Their fossil remains are therefore important indicators for the reconstruction of previous ecological conditions of the water masses. The main goal of the present research of the Marine Geology group was to study the ecological conditions for the composition and distribution of coccolithophore communities in the upwelling area off Namibia and adjacent deep-sea basins in order to broaden our knowledge of the paleoceanographic and climatic evolution of the late Quaternary coccolith assemblages. Therefore, water samples from several depths in the upper 250 m of the water column for the plankton analysis were taken. Additional surface water samples by using the seawater pump during steaming and surficial sediments from the multi corer were also obtained.

Little is known about plankton and fish production processes in the northern Benguela Current off the Namibian coast. Therefore, the overall objective of the **fifth leg** was to better understand the impact of meso-scale physical structures and processes on zooplankton production with reference to fish recruitment. Studies were carried out within the *Small Pelagic Fishes and Climate Change (SPACC)* programme of *GLOBEC* and the regional *BENEFIT* programme and centered around four main questions: The impact of the nutrients generated by the Lüderitz upwelling cell is not clear. It is hardly known, which production processes are initiated further offshore and further north by the Lüderitz cell, where these processes are taking place, which final products are generated and what proportion of plankton production finally ends up as fish production. The context of the study was to see where (how far offshore and north) the Lüderitz nutrients generate the food chain link from phyto- to zooplankton and whether there is any direct impact on the spawning grounds farther north. The main spawning

centers of anchovy and sardine are outside the upwelling cells off Lüderitz and Cape Frio. It will be examined why these regions offer good survival conditions for fish larvae. The waters off Namibia encompass a wide range of different physical regimes: upwelled, non-upwelled and oceanic waters. All these contrasting environments will affect growth rates and production of plankton in different ways. Special attention was given to determine species composition, distribution, abundance and biomass of zooplankton and to estimate daily production rates of copepods in contrasting environments and to assess the hatching success of copepod eggs produced under contrasting feeding conditions. A series of bio-optical measurements was carried out to get ground-truth data and to validate novel bio-optical models for remote ocean colour sensors, and to examine the feasibility of determining photosynthetic rates from *in situ* Fast Repetition Rate Fluorometry.

Between 23° and 19° S, including the known spawning grounds of anchovy and sardine, several transects (perpendicular and parallel to the Namibian coast) were sampled. An autonomous Undulating Oceanographic Recorder UOR was towed behind the ship and recorded depth, temperature, salinity, fluorescence and light attenuation. The data were analysed directly after each tow and yielded a synoptic picture of the biophysical conditions along the transect. The UOR tow was followed by intensive biological sampling for phyto-, zoo- and ichthyoplankton. Throughout the cruise, ADCP measurements were carried out continuously. At all stations, temperature, salinity, oxygen and chlorophyll *a* were determined by CTD casts. To determine the relationship between primary production, photosynthetic pigments and light, samples were taken from CTD bottles for the analysis of pigments by HPLC, Gelbstoff and particle absorption. *In-situ* optical measurements were performed with a bio-optical profiler equipped with sensors measuring reflectance at the SeaWiFS and MERIS wavelengths, a fast repetition rate fluorometer to measure photosynthetic parameters, and a CTD to verify alignment of the water samples with the bio-optical profiles. Water samples were collected at each CTD station to determine the changing nutrient concentrations within the upper 200 m of the water column. Phytoplankton was collected with the micro net of 20 µm mesh size. The samples served to study species composition and to determine indicator species communities for different upwelling scenarios. Taxonomic studies focused on dinoflagellates which have different nutritional strategies. In order to determine species composition, distribution and abundance of zoo- and ichthyoplankton a suite of different multiple opening/closing plankton samplers with differing mesh sizes was deployed. Daily egg production and moulting rates of copepods were measured in areas of contrasting thermal and food conditions to estimate secondary production. Hatching success of copepod eggs was assessed under contrasting feeding conditions.

The cruise leg also served for training of young scientists and technicians from Namibia, South Africa and Germany in modern methodologies. Intensive biological measurements and sampling were carried out on 5 transects perpendicular to the Namibian coast to sample in a range of contrasting environments from newly upwelled to oceanic waters.

Acknowledgement

The scientific parties of R/V METEOR cruise M48 acknowledge the friendly cooperation and efficient technical assistance of Captains N. Jakobi and M. Kull and their crews. We also appreciate the most valuable help of the Leitstelle METEOR in Hamburg. The work was funded by the *Deutsche Forschungsgemeinschaft*.