

## **Dietary acquisition of UV photoprotective compounds in marine zooplankton**

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Solar ultraviolet B (UV-B, 290-320 nm) levels have increased significantly due to stratospheric ozone reduction, not only in Antarctica but also at mid-latitudes of both hemispheres. Early life stages of crustacean zooplankton and ichthyoplankton live at the ocean surface and are susceptible to UV radiation. Solar radiation can affect negatively the activity, development and survival of zooplankton. Zooplankton must acquire photoprotective compounds including carotenoid pigments and mycosporine-like amino acids (MAAs) from their diet as they lack the synthetic pathway required for *de novo* carotenoid or MAA synthesis. Some preliminary studies of the MAA content of surface dwelling copepods showed a clear seasonal change in MAAs accumulation as well as interspecies and development stages variation in MAA composition. These results raise questions regarding potential competitive advantages of different photoprotective strategies and selective absorption or ingestion of specific compounds or compound sources.

In June 2005, two contrasting sites - one in a productive upwelling area off the western coast of the Iberian Peninsula and an oligotrophic site further off shore - where sampled during a 3 week cruise to study how the atmosphere interacts with the upper few meters of the ocean. Zooplankton were collected with a floating WP2 neuston net and microplankton with a non-toxic pump from the surface layer. Associated UVA and UVB depth gradient intensity in the water column were measured (Trios UV spectrometer). For phytoplankton pigment and MAA analyses, surface sea water was filtered on to GF/F filters in triplicate. Filters were flash frozen and stored in liquid nitrogen prior to analysis. Zooplankton was sorted by species, sex and stage of development and then starved for several hours before being deep frozen and stored at -80°C. High Pressure Liquid Chromatography (HPLC) and Liquid Chromatography coupled to Mass Spectrometry (LC-MS) were used to characterise and determine MAAs and carotenoid pigments. Photoprotective compounds quantities were expressed per unit of carbon body weight to permit comparison between species.

We present an extensive dataset on MAAs and carotenoid pigments composition of various groups and species of marine zooplankton in contrasting environments. Environmental parameters (e.g. UV-A and UV-B radiations as well as phytoplankton diversity and photoprotective compounds composition) were considered to understand zooplankton photoprotective strategies and selective absorption or ingestion of specific compounds or compound sources.

**Application for a talk- Speaker RL. Airs- Need a video projector**

## Teleconnection patterns of impact of climate variability on pelagic ecosystems across Europe

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The North Atlantic Oscillation (NAO) is the dominant mode of climate variability over Europe. NAO variability impacts directly on aquatic ecosystems across Europe as described recently for marine systems such as the North Sea, the Baltic Sea or the Mediterranean as well as for lakes in central Europe. The shift to a mainly positive NAO index after the late 1980s was clearly mirrored in the population dynamics of zooplankton species in marine and freshwater environments which exhibited dramatic synchronous changes in abundance. For some systems such as the central Baltic sea ecological regime shifts have been described in the late 1980s which have reorganized marine communities and trophodynamic relationships and induced changes in mix of dominating species [Alheit et al. 2005]. Crustacean zooplankton played a pivotal role in these climatically induced processes, however, mechanisms linking the NAO signal to the dynamics of zooplankton are very different in the different ecosystems. The impact of decadal-scale climate variability on contrasting marine and freshwater ecosystems will be interpreted by a comparative approach and teleconnection patterns will be described.

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## ***Oithona brevicornis* Giesbrecht: new copepod species in the Black Sea**

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One individual of *Oithona brevicornis* Giesbrecht, 1891 was registered in the Sevastopol Bay (south-western coast of Crimea, the Black Sea) at the beginning of October, 2005. A month later, its density reached 1089 ind./m<sup>3</sup>. The population was represented by all stages with the prevalence of females, some of them with egg-sacs.

It should be noted, that first for the Black Sea *O. brevicornis* was mentioned in the Sevastopol Bay in December, 2001 [Zagorodnyaya, 2002] but later, right up to 2005 it was not found.

*O. brevicornis* is widely spread in the coastal waters of Atlantic, Pacific and Indian Oceans both in tropical and temperate places due to high tolerance to salinity variations [Shuvalov, 1980].

Appearance of the new copepod species in the Sevastopol Bay is an evidence of instability of the zooplankton community. It confirms the hypothesis about possibility of forthcoming changes in the copepods community structure and species composition [Gubanova et al., 2002].

Features of seasonal dynamics and spatial distribution of *O. brevicornis* in the coastal waters near Sevastopol are discussed.

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## Short-term changes in the zooplankton community during the summer-autumn transition in the open NW Mediterranean

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Short-term changes in the zooplankton community were investigated at a fixed station in the open NW Mediterranean during the DYNAPROC 2 cruise (September/October 2004). Results, from day and night sampling in the 0-1000 m water column, are presented for the major taxa of copepods (>500 µm), macroplankton and micronekton. Over the 4-week sampling period, density of the zooplankton community exhibited a decreasing trend, but irregular, and either delayed or amplified at several times. The migrant or epipelagic species, such as the copepods *Neocalanus gracilis*, *Euchaeta acuta*, *Pleuromamma gracilis* and *Nannocalanus minor* and the euphausiids *Meganyctiphanes norvegica* and *Nematoscelis megalops*, exhibited strong variations in their abundance throughout the sampling period. In contrast, density of the non-migrant and deep-living species, such as the copepods *Calanus helgolandicus* and *Monacilla typica* and the fish *Cyclothone*, remained more or less constant. One of the most drastic changes was concomitant with an intrusion of low-salinity coastal waters in the upper 100 m; copepod density showed a 2-fold increase, while concentration of euphausiids decreased drastically. Copepod diversity was then low, with *Neocalanus gracilis* being largely dominant in the upper 250 m. The omnivorous euphausiid species, *Meganyctiphanes norvegica*, became relatively rare compared to the carnivorous one, *Nematoscelis megalops*, which induced changes in terms of grazing pressure. Species population dynamics would have also influenced the trophic relationships. For example, higher abundances of thecosomes, which are efficient phytophagous organisms, were recorded during the second part of the sampling period, due to active reproduction. These changes and their influence on the ecosystem trophodynamics are discussed in relation to environmental features and hydrological events, and in the context of seasonal variability (transition from summer to autumn conditions). This study also documented the overwintering behaviour of *Calanus helgolandicus* which contributed to more than 75% of the copepod catches in the 550-1000 m stratum.

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## A one-dimensional approach of the pelagic ecosystem observed in various hydrological and seasonal conditions

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A 1-D physical-biological coupled model of the mixed layer was applied to the multidisciplinary data sets acquired in the North-Est Atlantic during the POMME cruises (winter, spring and late summer 2001). Several sites, representative of frontal areas or of cyclonic and anticyclonic eddies, were occupied during each cruise. The applicability of the same model to different hydrological and seasonal conditions was therefore tested, i.e. changing neither the structure nor the parameter values of the biological model. Eleven compartments were considered in the 3MZOO model: three classes of phytoplankton (diatoms, flagellates, picoplankton) and herbivorous zooplankton (ciliates, copepods, gelatinous microphages), dissolved organic matter, and two classes of nutrients (nitrate, ammonium) and detritus. Diel vertical migration of zooplankton was also parameterized in the model. Assuming stationary physical processes, steady state and convergent solutions obtained for the biological variables are presented. The general features observed during the cruises, such as seasonal changes in total chlorophyll a content and in proportions of the three phytoplankton groups, were well reproduced by the model. Simulated and observed values were generally in good agreement for inorganic nitrogen assimilation, micro- and mesozooplankton standing stocks and exported fluxes of particulate organic matter. The underestimation of nitrate in the surface layer in winter is discussed in relation to the pluristratified and deep mixed layer occurring at this season. Such a modelling approach should be performed in order to set the initial conditions for 3-D models.

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## On the ecological role of Copepods in the complex Tunis North Lake –Kherreddine Canal marine ecosystem

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Species-specific abundance of copepods was determined at monthly intervals at 3 stations in the North Lake of Tunis and 1 station in the Kherreddine Canal waters between April 2001 and March 2003. A total of 30 copepod species belonging to 20 genera within the orders Calanoida, Cyclopoida, Poecilostomatoida and Harpacticoida were recorded in the present investigation. The densities of total copepods were higher in the canal than those in the lagoon. Copepod nauplii and copepodites formed almost 87 % of the total copepod abundance, while the rest comprised the adult copepods, in the complexe. Only 3 species formed the main bulk of copepods, namely: *Oithona nana* (Giesbrecht, 1843), *Acartia clausi* (Giesbrecht, 1881), and *Euterpina acutifrons* (Dana, 1847) in the two areas. Calculation and representation of the rank-species diagrams showed that the planktonic copepods assemblages were permanently in a juvenile stage (stage 1 of Frontier, (1976)) in the lagoon. However, they reach the climax stage (stage 3 of Frontier (1976)) in the canal. Moreover, the importance of copepods in the marine food web and secondary productivity in the complex North Lake-Kherreddine Canal, as well as their response to environmental variations ecosystem were discussed.

Keywords : planktonic copepods, coastal ecosystem, taxonomy, rank-species diagrams.

## Mesozooplankton community structure in Belgian coastal waters analysed by mean of a digital imaging system

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A new digital imaging system, the ZOOSCAN ([www.zooscan.com](http://www.zooscan.com)), was used for counting, measuring, and identifying net mesozooplankton collected from March 22 to December 3 2001 in the Belgian coastal waters. Different zooplankton assemblages characterized the different seasons. ZOOSCAN results concerning enumeration, morphometric measurements and classification were compared with those obtained with traditional microscopic analysis. The following issues will be discussed : (1) reliability and further applicability of the ZOOSCAN for routine zooplankton monitoring but also as aide for taxonomists and (2) the relationship between the size diversity and the taxonomic diversity.

Abstract submitted for a poster presentation

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## ENSO effects and long-term trends in the zooplankton off Paita, northern Peru (1994 to 2004)

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The coastal upwelling areas off Peru support highly productive marine ecosystems, accounting for an important fraction of the world's primary production, fisheries, and global carbon and nitrogen cycles. The objective of the present study is to verify possible seasonal, inter-annual and long-term changes in the zooplankton off Paita (northern Peru), an upwelling area located closely to the northernmost extension of Humboldt Current waters. Zooplankton was sampled from August 1994 to December 2004 at four stations located 2 to 30 km offshore. Sampling was performed at subsurface with a WP-2 net (300µm mesh size).

A total of 213 taxa were identified and counted in the present study. Copepods were clearly dominating, with 72 % of all individuals collected. Among copepods, the most abundant species were: *Paracalanus parvus* (28%), *Acartia tonsa* (26%), *Calanus* spp. (10%), *Centropages brachiatus* (4 %), *Subeucalanus mucronatus* (1 %), and *Centropages furcatus* (1%). Several species exhibited strong seasonal and inter-annual changes in density and relative abundance. The strong 1997-98 El Niño (EN) event led to drastic changes in species composition that were reversed during the 1998-99 La Niña (LN) event. Community parameters such as total abundance, diversity, equitability and species richness displayed marked variations associated to the 1997-98 EN and to decadal-scale long-term trends. Long-term trends were significant at  $\alpha = 0.05$  for the following parameters: Total abundance (increase), Species richness (Margalef's D and number of species S, increase), and Evenness (J, decline), while the (negative) trend was not significant for Shannon Diversity (H'). El Niño effects and long-term changes were clearly visible in multidimensional scaling plots based on presence-absence data of the 47 most important taxa. Significant differences in community structure between four sampling periods (pre-EN, EN, LN, post-LN) were confirmed by ANOSIM at  $\alpha = 0.05$ . Our results have demonstrated the importance of long-term plankton monitoring studies in upwelling areas, and confirmed the idea of decadal-scale changes in pelagic ecosystem structure occurring in the central East Pacific.

## Predatory impact of invertebrates in the Bornholm Basin (central Baltic Sea)

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Due to the low salinity in the central Baltic Sea the diversity of invertebrate predators in this area is low compared to other marine environments. Scyphomedusa, mysidacea and chaetognatha are most important in the Bornholm Basin. Due to their wide prey spectrum they may affect the zooplankton communities and compete for food with fish. To assess the predatory impact of these groups their seasonal distribution, abundance and food in the Bornholm Basin in 2002 and 2003 were investigated in the frame of German GLOBEC.

Only two medusae occurred in the study area. *Aurelia aurita* was caught from July to November with a maximum mean abundance of 2.3 ind. 100 m<sup>-3</sup> in August, whereas *Cyanea capillata* was caught in much smaller numbers from July to September. The cladoceran *Bosmina coregoni maritima* was the most important prey item of *A. aurita* during the whole investigation, while copepods and bivalve larvae were of minor importance. Copepod nauplii, young copepodites, fish eggs and larvae were not found in the medusae guts. In August, when mean abundance of *A. aurita* was highest, only 0.1 % of the copepod and 0.5 % of the cladoceran standing stock were eaten per day.

Mysidacea were mainly caught in summer and autumn. The maximum mean abundance of *Mysis mixta* (8 Ind. 100m<sup>-3</sup>) was observed in Oct. 2002. Frequent prey items were *B. coregoni maritima*, *Podon* spp. and *Temora longicornis*.

Chaetognatha were caught only occasionally in low abundance (max. 1.1 Ind. 100m<sup>-3</sup>). Their appearance in the central Baltic is probably connected to the inflow of North Sea water. They are assumed to live at the limit of their range and therefore do not feed and reproduce in this area [Maciejewska and Margonski, 2001].

We conclude that due to their low abundance predation by scyphomedusa, mysidacea and chaetognatha did not regulate the zooplankton community in the Bornholm Basin during this investigation. Most important predators in this area are probably fish. Although they feed on the same prey as the invertebrate predators, fish should not suffer from competition.

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## **Annual variability of the gelatinous invertebrate zooplankton of the South Adriatic coast**

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Species composition and annual variability in abundance of gelatinous invertebrate zooplankton in the South Adriatic coast were investigated at intervals of 1 - 3 weeks from January to December 1996. Sixty-four species were identified: 18 hydromedusae, 13 siphonophores, 3 ctenophores, 2 heteropods, 12 pteropods, 8 polychaetes, and 8 chaetognaths. The numerically dominant calycophorans, pteropods, and polychaetes were different from those found in previous studies. Highest total abundance was from February - March and August - November. (Maximum: 2074 ind/10m<sup>3</sup> on August 19) Based on the occurrence of life-history stages, most of the numerically dominant hydromedusans, pteropods, and chaetognaths reproduced throughout the year, but with higher intensities in particular seasons. Juveniles of the planktonic polychaeta *Pelagobia longicirrata* were found only from May - August and October - December; this suggests semi-annual reproduction. Temperature and food abundance both play important roles in the dynamics of these species.

## Calibration and validation of a size structured model of *Calanus helgolandicus* in European waters

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A size structured dynamical population model of the copepod calanoid *Calanus helgolandicus* is developed. The model is forced by temperature, food and gelatinous predation data compiled from several studies conducted in the European waters. We consider the different life stages from eggs to adults. The paper focuses on the study of biological functions used in the model to represent growth and development of *C. Helgolandicus* in the Atlantic and Mediterranean sea. Physiological processes (i.e. respiration and ingestion rates) are related to weight with allometric relationships. Parameter values come from a synthetic review about *C. helgolandicus* based on Bonnet (2005)'s paper. Mesocosm data sets (Rey, 2000) of reared C.h. cohorts in various food and temperature conditions were used for complementary calibration of unknown parameter values. Simulations with real forcing at different stations of the North western Mediterranean coast and at the CPR in Atlantic coast are compared with time series data. Bonnet (2005) pleads for the existence of a unique species in all the European waters. The model allows to discuss this assumption based on a sensitivity study of physiological parameters in their range of variability.

## Biogeochemical fluxes through mesozooplankton

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Mesozooplankton are significant consumers of phytoplankton, and have a significant impact on the oceanic biogeochemical cycles of carbon and other elements. Their contribution to vertical particle flux is much larger than that of microzooplankton, yet most global biogeochemical models have lumped these two plankton functional types together. In this paper we bring together several newly available data syntheses on observed mesozooplankton concentration and the biogeochemical fluxes they mediate, and perform data synthesis on flux rates for which no synthesis was available. We update the equations of a global biogeochemical model with an explicit representation of mesozooplankton (PISCES). We use the rate measurements to constrain the parameters of mesozooplankton, and evaluate the model results with our independent synthesis of mesozooplankton concentration measurements. We also perform a sensitivity study to analyse the impact of uncertainty in the flux rates. The standard model run was parameterised based on the data synthesis of flux rates. The results of mesozooplankton concentration in the standard run are slightly lower than the independent databases of observed mesozooplankton concentrations, but not significantly. This shows that structuring and parameterising biogeochemical models based on observations without tuning is a strategy that works. The sensitivity study showed that by using a maximum grazing rate of mesozooplankton that is only 30% higher than the poorly constrained fit to the observations, the model mesozooplankton concentration gets closer to the observations, but mesozooplankton grazing becomes higher than what is currently accounted for. This is an indication that food selection by mesozooplankton is not sufficiently quantified at present. Despite the amount of effort that is represented by the data syntheses of all relevant processes, the good results that were obtained for mesozooplankton indicates that this effort needs to be applied to all components of marine biogeochemistry. The development of ecosystem models that better represent key plankton groups and are more closely based on observations should lead to better understanding and quantification of the feedbacks between marine ecosystems and climate.

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## Lethal and sublethal effects of naphthalene and 1,2-dimethylnaphthalene on the marine copepod *Acartia grani*

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The catastrophe of the fuel cargo Prestige (NW Spain, 2002) revealed the lack of knowledge on the consequences of crude oil spills for the dynamics and functioning of marine planktonic food webs, and especially for zooplankton. In the present study we evaluated the effects of 2 quantitatively very important components of the soluble fractions of fuel oils (naphthalene and 1,2-dimethylnaphthalene) on the survival, feeding and egg production rates of the coastal copepod *Acartia grani*. Acute toxicity responses, measured as the lack of motility after 48-h of aqueous exposures, resulted in LC50 of 19.3 and 1.03  $\mu\text{molL}^{-1}$  for naphthalene and 1,2-dimethylnaphthalene, respectively. None of the toxics had evident narcotic effects on the copepods. Naphthalen sublethal effects, measured as pellet production rates, appeared at concentrations 5 times lower than those causing death. On the other hand, 1,2-dimethylnaphthalene reduced pellet production rates following a kinetic resembling that of mortality. 24 h exposure to the contaminants also had evident negative effects on egg production rates, although seemed to not impair egg hatching. The significance of the effects of oils spills on marine zooplankton communities is discussed in light of the results presented in this study..

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POSTER

## Vertical distribution and diversity of calanoid copepods within the Spermonde Archipelago, SW Sulawesi

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The coastal waters of southwest Sulawesi are characterized by an extensive shallow shelf covered with coral reefs and islands of the Spermonde Archipelago. The biodiversity of the copepods within this area was examined in relation to hydrography, nutrient concentrations and phytoplankton biomass. Sampling was carried out along four cross-shelf transects across the Spermonde archipelago between SW Sulawesi coast and Makassar Strait. Zooplankton was collected at each station from 3 - 4 water layers in the upper 30 m during day by vertical tows with an Apstein net (200 µm).

The most abundant calanoid copepod species on all stations were found within the genus *Paracalanus*. The species composition changed considerably from the near shore (15 – 40 m) to offshore stations (>100 m). Species like *Cantocalanus pauper*, *Cosmocalanus darwini* and the Eucalanidae were found only offshore whereas *Parvocalanus* occurred in higher abundances nearshore. At all stations independent of region the majority of copepods was encountered below 10m and diversity was highest.

The results will be discussed in relation to various environmental parameters such as temperature, salinity, chlorophyll *a*, phytoplankton composition, seston, POC and PON.

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## **An overview on the distribution and diversity of mesozooplankton along the Tunisian coast during the last decade**

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Very few studies on mesozooplankton exist in the south Mediterranean Sea, even though they have been intensively studied around the European coast. Since 1994, a large monitoring program of the Tunisian coastal ecosystems and surrounding lagoons has been undertaken.

The mesozooplankton communities play a key role in pelagic and coastal ecosystems as a link between bacterioplankton, nano and microplankton and planktivorous fishes.

The study of specific richness and diversity of planktonic communities, can be used to understand the structure and stability of pelagic ecosystems but also the trophic state of the environment.

The aim of this study was to identify and describe abundance, distribution and biodiversity of mesozooplankton assemblages along the Tunisian coast from 1994 to 2004.

On the taxonomic point of view, the mesozooplankton of the Tunisian coast is composed by about 197 species belonging to Copepods (70 species), Medusae (38 species), Mysidaceans (23 species), Siphonophores (19 species), Appendicularians (8 species), Chaetognaths (7 species), Cladocerans (6 species) and Pelagic Mollusc (6 species). The other mesozooplanktonic groups are Amphipods, Ostracods, Isopods, Pelagic Polychetes, Doliolids and Salps.

In order to characterise given specific associations within the mesozooplankton with environmental gradients, we made a hierarchical classification of our different studied sites represented by 5 lagoons (Bizerte, Ghar El Melh, Tunis North, Tunis South and Bou Ghrara), 3 bays (Bizerte, Tunis and Sousse) and one offshore ecosystem, the gulf of Tunis.

Our results show that during the autumn and winter period, the mesozooplankton community is generally composed by a mixture of neritic and oceanic species with a large influence of Atlantic species associated with high diversity value. During the spring and summer season, the mesozooplankton community is reduce to a neritic community with cosmopolitans species and a low specific diversity.

**Keywords :** mesozooplankton community, distribution, diversity, South Mediterranean Sea

## Short time study of Copepods populations in Gabes gulf (Mediterranean sea)

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Copepods hold is key position in marine food webs are the major secondary producers of the world's ocean. In the present study, we have interested in copepods dynamics from Gabes gulf which located in the southern of Tunisia; it is part of Mediterranean sea. Thirteen stations were established for the study on planktonic copepods and their relations to hydrological structures such as suspension matter, turbidity, temperature, pH and salinity.

The composition of zooplankton showed a predominance of pelagic copepods making nearly 80 % of the total zooplankton abundance. The others zooplankton (20 %) are represented by Ostracoda, Radiolaria, Foraminifera, Cladocera, Appendicularia, protozooplankton, eggs diversity, Mysidiacea, Neogasteropoda, Doliolida. The whole set of zooplanktonic copepods collected can be divided in three different stages (adult, copepodit, nauplii) which presented respectively (71 %, 24 % and 5 %). The copepods are composed of thirteen families (Acartiidae, Centropagidae, Oithonidae, Temoridae, Onceidae, Euterpinidae, Megacalanidae, Corycaeidae, Tachydidae, Clytemnestridae, Ectinosomidae, Pontellidae, Megcalanidae). The Acartiidae and Oithonidae are the dominate families with 42 % and 35 % respectively, each which was represented respectively by 3 and 4 species. The females contribution is 80 % of the total copepods as well as males witch showed just 20 %

In the other hand, we have noticed the presence of copepods was correlated with the hydrological parameters: suspension matter, turbidity, temperature, pH and salinity).

## Spring recruitment of Baltic Sea zooplankton and its sensitivity to climate/physical forcing

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Long-term investigations in the Baltic Sea have documented large inter-decadal fluctuations in the standing stock of dominant copepod species which are potentially linked to climate variability. Results from the GLOBEC field campaign in the Bornholm Basin revealed that the winter/spring development and recruitment of the pelagic community varies greatly among species. In contrast to *Pseudocalanus acuspes* and *Temora longicornis*, hatching of resting eggs from the sediment is the dominant source for an early recruitment of *Acartia* spp. populations in the Baltic Sea in spring. This strong benthic-pelagic coupling is of particular interest for the understanding of the control of zooplankton by physical forcing and climate variability. In the presentation, we summarize the results of a recent investigation of the dynamics of resting eggs in the sediment compared to the zooplankton spring development in the Bornholm Basin. The factors determining the resting egg distribution, the timing of emergence and recruitment success via resting eggs are discussed with regard to the observed inter-annual variation in standing stocks of *Acartia* spp. populations in the Baltic Sea. Additionally, we will present an example for the future incorporation of resting egg dynamics into modelling of Baltic Sea zooplankton.

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## Composition and distribution of protozooplankton and metazooplankton in six ponds of different salinity: a seasonal succession in Sfax salt marshes (Tunisia)

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The seasonal and spatial distribution abundance and biomass of ciliates and metazooplankton was studied in six ponds of different salinity in Sfax solar salterns from January to December 2003. The total ciliates abundance ranged from 0,0 to  $20,4 \times 10^4$  ciliates per litre, and biomass varied between 0 to 618  $\mu\text{gC.l}^{-1}$ . The community composition varied greatly with salinity. In the first ponds (salinity < 50 p.s.u), the ciliates numbers were dominated by oligotrichs that are commonly found in marine coastal waters. A small *Urotricha* largely dominated the prostomatids and was found in a large range of salinity values (< 200 p.s.u). In contrast, large-size species recorded during this study seem to be physiologically adapted to high salinity such as *Fabrea salina*, *Blepharisma* sp. and some other genus (*Uronema* sp., *Encheylodon* sp., *Loxodes*). Total metazooplankton abundance varied from 0,0  $\text{ind.m}^{-3}$  to  $18,5 \times 10^4$   $\text{ind.m}^{-3}$ . In the first three ponds, the community was dominated by copepods averaging 71% of total metazooplankton densities. Copepods were absent in the other ponds ( $S > 150$  p.s.u) in which *Artemia salina* largely dominated the metazooplankton community (95%). Our data also suggest that *Fabrea salina*, a common halophile ciliate, act as a competitor of the brine shrimp *Artemia salina* in the saline of Sfax. Biomass estimates for metazooplankton were often higher than measured biomass of ciliates. Salinity had a negative effect on the abundance of zooplankton, which were not present in the ponds with the highest salt concentration. Proto- and metazooplankton are missing in the crystallizer pond in which to carbon was represented by *Archaea* and *Dunaliella salina*. Salinity and prey availability seems to be the main factors for the distribution of ciliate taxa and controlling abundance of metazooplankton in this hypersaline environment.

## Copepod diversity and abundance along the Atlantic coast of Morocco

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In March 1998 and July 1998, zooplankton communities have been studied, along the southern part of the Moroccan Atlantic coast, between cape Blanc (21°N) and cape Boujdor (26°30'N). The zooplankton collected during those surveys was composed of several taxonomic groups. Copepod was the dominant group, representing 86% of the total zooplanktonic biomass in March and 73% in July.

A total of 79 species have been identified, with 60 species indexed in March and 50 in July: 31 species were commonly found in March and July, while the other species were observed either in March or in July. The dominant species were: *Calanus helgolandicus*, *Paracalanus parvus*, *Acartia clausi* and *Corycaeus typicus*.

The intensification of the upwelling in July could be responsible for the trophic affinities observed between species during this season. Sometimes, the taxonomic adherence permits some regroupment of species; it is the case for the calanidae (*Calanus helgolandicus*, *C. carinatus* and *C. minor*) during the two seasons. The clear distinction between the summer and the winter zooplankton assemblage was closely related to the environmental changes that occurred regularly in the water column, such as surface heating and cooling, stratification and mixing and other ecological processes.

## Elemental composition, biochemical composition and calorific value of Antarctic krill

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Samples of Antarctic krill were analyzed for elemental composition, biochemical composition, weight and caloric content. Sexes and maturity stages were separated. Mature females showed the highest caloric values (joules) and juveniles the lowest in a per animal basis. On unit of wet weight per animal basis, spent females showed the lowest caloric values. For the caloric values by animal, a significant difference was found between males, mature females, spent females and juveniles, either on a per animal basis or in the basis of one gram of wet weight, showing a real difference between the groups, regardless of their individual size. Significant differences were found for carbon, nitrogen and lipids, but not for proteins, analyzed in per cent of dry weight. Carbon was lowest for spent females and highest for mature females. On the contrary, nitrogen values were lowest for mature females and highest for males. Mature females had the highest lipid content and males the lowest. All variables were significantly correlated. For the linear regression analysis, the best correlation found was between joules and carbon, followed by carbon vs. dry weight and joules vs. dry weight. In an analysis with two independent variables, the best correlation was found for joules vs. lipids and dry weight followed by joules vs. carbon and nitrogen, and joules vs. lipids and proteins. The results obtained were used to make an analysis of the energy fluxes through the food chain in the sampled area, showing higher energetic "densities" in frontal areas, the POM calorific values showed an opposite pattern than that of krill. The results are analyzed in relation to formerly published literature.

## Spatial approach to the morphological and biochemical differentiation in Antarctic krill

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During the February 1981 cruise FIBEX MD-25 between 30 - 50°E and 61-64°S, hydrography showed the presence of a big gyre with two smaller inside east and west gyres, at the borders of which, concentrations of highly morphologically differentiated krill were found. Gaussian component analysis of krill samples, pooled by sectors, showed three cohorts of *Euphausia superba* in the western sector and one in the eastern sector. Across the sampling area, *Thysanoessa macrura* and *Euphausia superba* occurred at separate stations. Analysis of cohorts in *T. macrura* separated two size groups in both the western and the eastern sectors. The use of a Differentiation Index (DI) (Färber-Lorda, 1990), based on somatic lengths, allows studying certain morphological differences within the populations sampled. Morphologically different and bigger Males II (DI from 2.8 to 3.5) were present only in the southern transect while smaller Males I (DI from 3.5 to 5.0) were present over the whole area. Biochemical composition of both species showed significant differences among stations for protein, lipids and carbohydrates. A significant difference in lipid content was found between Males I and Males II. For *T. macrura*, percentage of lipid content in mature animals was much higher than that in *E. superba*. The DI size distribution showed that when populations of *E. superba* were highly differentiated, (corresponding to mature animals) in morphology, lipid content was high and they were located near a gyre. It is shown that together with hydrography and trophic conditions, lipid content and morphometry of krill populations, are different but complementary aspects that help to understand krill distribution.

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## **The interannual zooplankton variability in relation to water masses influence in The Balearic Sea: a case of boundary area in the Western Mediterranean.**

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Zooplankton abundance patterns in relation to hydrography are given for a monitoring station of the Balearic Sea platform (Western Mediterranean). The results based on 11 year samples were collected every 10 days during the period from April 1993 to December 2003. They showed strong but different relationship between the abundance of the major mesozooplankton groups and the influence of the area water masses, as main drivers of their biological variability. The pattern of major zooplankton groups and main species composition were defined, as well as the physico-chemical variables characterizing the area during the period study. Almost all of them exhibited annual cycles and recurrent patterns were particularly observed in the copepods, appendicularians and cladocera. Temperature manifested clear seasonal cycles while salinity showed larger variability, indicating interannual changes in the hydrological regime of the surface Balearic sea waters. Meanwhile salinity revealed a clear increasing trend during the time-series due to the higher northern water influence during the last years of the study, temperature performed a slightly and not significant positive trend. In relation to them, a zooplankton decline was observed in both indices, biomass and abundance, more important during those years when the temperature performed higher values (1997 and 1998). Lineal regression models suggested that temperature and salinity were significant environmental parameters accounting for the variability of zooplankton abundance. The relationship between the patterns of the main zooplankton group abundance and changes in the hydrological regime in the context of the climate-oceanographic time-series is discussed.

## Seasonal and interannual dynamics of mesozooplankton biomass in the Gulf of Trieste, Northern Adriatic

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The problem concerning the effect of size and taxonomic structure of zooplankton community on alternative pathways of carbon flux (rem mineralization vs. export) is still of recent interests for the concept of the functional role of mesozooplankton and the effects of zooplankton dynamics on biogeochemical fluxes. Zooplankton standing stock in terms of organic carbon could be assumed as about 40 % of the dry mass and it is a fundamental parameter in biogeochemical carbon budget in the ecosystems. The stoichiometry of carbon, nitrogen, and phosphorus in zooplankton has become important in the context of the nutrient flux between autotrophs and heterotrophs in aquatic environment (Elser, George, 1993, Anderson, Hessen, 1995). The content of organic nitrogen is in the range of 10 % of the dry mass and its occurrence is mainly restricted to protein. The contribution of zooplankton to nitrogen regeneration varies from 1 % to 5 % in neretic waters and from 10 to 50 % in oligotrophic waters. Some studies have focused on the relationship between the elemental composition of zooplankton, particulate sediment material and seston. Attention has been paid to the nutrient status (e.g. C:N:P) of zooplankton prey and behavioural responses of zooplankton species (e.g. eggs production, grazing). So far as mesozooplankton is a food source of many important commercial fishes and it is a consumer of primary production, the dynamic of mesozooplankton biomass is of a great importance to get better understanding of pelagic food web functioning. Zooplankton biomass may be used as an indicator of trophic conditions.

The aim of the present study is to reveal seasonal and interannual variations in mesozooplankton standing stock, carbon and nitrogen content of the dry mass in the Gulf of Trieste (Northern Adriatic) in relation to taxonomic structure and temperature. The study is based on data obtained from mesozooplankton samples collected monthly by a vertical WP2 net (200  $\mu\text{m}$ ) from January 1986 to December 2000 at one monitoring station (st. C1, depth 21 m) in the Gulf of Trieste. Mesozooplankton dry mass ( $\text{mg DM}\cdot\text{m}^{-3}$ ), total mesozooplankton abundance, dominant taxonomic groups (copepods, cladocera) and water temperature were under consideration. Additional data for dry mass and temperature for the period 1972-1980 were also discussed. Monthly data for organic carbon ( $\text{mg C}\cdot\text{m}^{-3}$ ) and nitrogen content ( $\text{mg N}\cdot\text{m}^{-3}$ ) of the DM determined using a CHN Elemental Analyzer for the period 1991-2000 were analysed. Statistical, Principal component analyses, together with time series analyses (Spectral Fourier analysis) were performed to the data set of the above mentioned parameters in order to figure out the frequency of cycle oscillations in the coastal ecosystem.

The results reveal great seasonal and interannual variability of mesozooplankton dry mass during the period 1972-2000. The range was from  $1 \text{ mg}\cdot\text{m}^{-3}$  (in January 1977) to  $95 \text{ mg}\cdot\text{m}^{-3}$  (in March 1990). The average mesozooplankton dry mass was the highest during late spring-summer period and it has reached to  $20.48 \pm 13.56 \text{ mg}\cdot\text{m}^{-3}$ . Maximum values corresponded to high Copepod abundance. Likewise the content of organic carbon and nitrogen of the dry mesozooplankton manifested great temporal variability. High C and N contents were found in the dominance of copepods to the mesozooplankton taxonomic structure and indicate optimal adaptation of copepods to nutritional conditions and high proteins proportions of the zooplankton. Large-scale temporal variability of mesozooplankton standing stock in the coastal ecosystem correlated to the shift in mesozooplankton taxonomic structure and abundance.

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## **Grazing experiments and stable isotope signatures of *Temora longicornis* during a time series at Helgoland Roads, North Sea: Indication for a shift in feeding strategy**

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The in-situ feeding habits of female *Temora longicornis* were investigated during a time series in spring 2005 at Helgoland roads, including grazing experiments and the determination of  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  stable isotope signatures of female copepods and of the seston. Grazing experiments were conducted with triplicates of 30 females each in 1 L bottles attached to a plankton wheel for 24 or 7 hrs, respectively, depending on chlorophyll a concentration in the water column. In addition, triplicates of 20 or 30 *T. longicornis* were pooled for stable isotope analysis. The experiments show that *T. longicornis* feeds selectively on dinoflagellates ciliates and to a lesser extent on pennate diatoms in early spring. In April and May, a shift towards pennate and centric diatoms was found. Feeding was not related to algal cell size. These findings are supported by the stable isotope signatures of the seston and *T. longicornis* females from the field. Assuming an enrichment of approximately 3.4% in  $\delta^{15}\text{N}$  per trophic level, *T. longicornis* females in March were approximately two trophic levels higher than the females in April and May.

## Carbon transfer and fatty acid biosynthesis in the Arctic herbivorous food web

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There is still a need to quantify the trophic flow of individual components from phytoplankton to polar herbivorous copepods in order to assess their contribution to biogeochemical fluxes. Hence, the dominant polar copepods *Calanus hyperboreus*, *C. finmarchicus* and *C. glacialis* were collected in the Greenland Sea and fed  $^{13}\text{C}$  labelled diatom *Thalassiosira weissflogii* for 14 days to follow the transfer and assimilation of carbon and individual fatty acids and alcohols. Total carbon increased in the copepodite stages V of *C. hyperboreus* and *C. finmarchicus*, whereas carbon remained almost constant in *C. glacialis* females. Highest lipid accumulation occurred in *C. hyperboreus* in which nearly all lipids were exchanged already after 11 days of feeding. In the other species lipid accumulation made up between 22% (*C. finmarchicus*) and 45% of total lipid (*C. glacialis*). During the feeding period the highest  $^{13}\text{C}$  labelling was always found in the C16 polyunsaturated fatty acids and in the 16:1(n-7) alcohol. Because the components occurred only in trace amounts in the copepods they totally originated from the diet explaining the high labelling. It is noteworthy that the 16:1(n-7) alcohol originated only from the corresponding dietary fatty acid and not from the abundant internal fatty acid. The long chain monounsaturated fatty acids and alcohols, 20:1(n-9) and 22:1(n-11), are not existent in phytoplankton and have to be produced de novo. They were less labelled in the smaller species but highly  $^{13}\text{C}$  enriched in *Calanus hyperboreus*. Balance calculations revealed that these fatty acids are synthesized from dietary proteins and carbohydrates and not from fatty acid precursors. It seems that fatty acids or even lipids were selectively accumulated due to bodily requirements, and thus, essential polyunsaturated fatty acids were preferentially retained. During feeding a mixing, accumulation and exchange of internal and dietary fatty acids and alcohols occurred as well as utilisation of lipids from both sources for metabolic requirements. The difference in lipid assimilation fits to the different life strategies of the copepods. The assessment of carbon flow in Arctic copepods provides new insights in our understanding of zooplankton contribution to trophic flow and biogeochemical cycles.

## Feeding habits of larval and juvenile *Pleuragramma antarcticum* in the Western Ross Sea (Antarctica)

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*Pleuragramma antarcticum* is the dominant pelagic fish in the high-Antarctic zone and plays a fundamental role in the food web of the Antarctic marine ecosystem. Despite larvae and juveniles of *P. antarcticum* account more than 98% of the summer ichthyoplankton community in the Western Ross Sea (Guglielmo *et al.*, 1998; Vacchi *et al.*, 1999; Granata *et al.*, 2002), few studies have been conducted on its life-cycle ecology. To extend our knowledge, this paper provides preliminary information on feeding habits of larval and juveniles stages of *P. antarcticum* collected in the Ross Sea.

During four spring-summer Italian Antarctic expeditions to Terra Nova Bay and the Western Ross Sea in 1988, 1989-90, 1994-95 and 1996, zooplankton and ichthyoplankton were collected by a multinet BIONESS (250 µm and 500 µm) and PHN (500 µm).

The diets of three size classes of postlarval *Pleuragramma antarcticum* were examined. Of the 280 fishes investigated, 260 specimens (92.8%) contained food. Prey sizes in *P. antarcticum* guts were clearly related to fish lengths. Postlarval fishes from 8-17 mm fed primarily on prey between 0.13 and 0.51 mm length (calanoid eggs, tintinnids and Limacina), while juvenile *P. antarcticum* from 36 to 50 mm SL switched to larger prey between 0.34 and 1.73 mm (*Oncaea curvata* and *Metridia gerlachei* CIII-IV). In this size range the prey length mode at 0.6 mm was due to the large number of cyclopoid copepod *Oncaea curvata* in the guts (85.1%). The much larger *Metridia gerlachei* CIII-IV (1.41-1.73 mm length) were of minor importance numerically but had a frequency of occurrence of 58.5% and were frequently found in guts of *P. antarcticum* from 45 to 50 mm SL (30.1%). In the same size class larval stages of *Euphausia crystallorophias* (mainly furciliae 2.81-2.92 mm length), started to become an important prey (FO 10.8%).

Positive food selection of both postlarval and juvenile *P. antarcticum* was revealed for *Oncaea curvata* and *Metridia gerlachei* CII-CIV.

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## Distribution of *Acartia tonsa* Dana (Copepoda, Calanoida) in the European Seas

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*Acartia tonsa* Dana, 1848 is a neritic species, widely spread in the coastal areas of the West Atlantic, Indian and Pacific Oceans [Raymont, 1983]. First mention of the species in the coastal waters of Europe appeared not so long ago – in 1927 [Remy, 1927]. However, H. Redeke, who discovered *A. tonsa* while inspecting old samples, supposes that it appeared off-shore of Netherlands before 1916 but later than in 1912 [Brylinski, 1981]. After the first announcement, the species was registered in the bays, estuaries, gulfs and coastal waters of Germany, Netherlands, France, Denmark and Great Britain for more than 50 years [Brylinski, 1981].

In the Mediterranean Sea *A. tonsa* was first revealed in the coastal waters near Marseilles at the middle of 1980s [Gaudy and Vinas, 1985].

At the end of XX century, it was recorded in the Black, Azov and Caspian Seas [Gubanova, 2003].

The map of the European places in which the bibliography mentions the presence of the species is provided.

The possible reasons for wide distribution of *A. tonsa* in the European area are discussed.

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## **Assessment of the growth potential of the rotifer *Brachionus plicatilis* by evaluating morphometric characteristics**

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Biological characteristics such as egg ratio, tolerance to chemical toxicity and lorica length [Janssen et al. 1994; Korstad et al. 1995] have been good indices to understand the population growth of rotifers. The L-type strain of *Brachionus plicatilis* was used in this experiment. This strain was cultured using two algae species *Chlorella vulgaris* and *Isochrysis galbana* at a density of approximately  $1 \times 10^6$  and  $3 \times 10^6$  cells ml<sup>-1</sup>.

Morphometric characters in terms of lorica length and width, spines length and the distance of the two marginal anterior spines were measured for rotifers that were fed *Isochrysis* and *Chlorella*.

The algal species and their concentration influenced the degree of morphological plasticity size. The slopes of the relation body length/width were the same for the rotifers fed *Isochrysis* and *Chlorella*. Lorica length (spine included) increases linearly with lorica width at a high significant level ( $r=0.92$ ;  $P<0.01$ ). Lorica length of rotifer fed  $1 \times 10^6$  cell of *Chlorella* ( $182 \pm 26 \mu\text{m}$ ) was much higher than that fed *Isochrysis* ( $153 \pm 40 \mu\text{m}$ ) at the same food level, but similar to those fed  $3 \times 10^6$  cell of the two algae. At this concentration the big rotifers were 276 and 284  $\mu\text{m}$  when rotifer population growth was close to peak abundance (61 and 499 ind ml<sup>-1</sup> with *Chlorella* and *Isochrysis*, respectively). Consequently, Life span was longer when rotifers were fed *Isochrysis*, but shorter when fed *Chlorella*. On the other hand, the population showed, mainly with rotifer fed *Isochrysis*, small size group of 104-130  $\mu\text{m}$ . The former are may be offspring. Rotifer fed both algae at  $1 \times 10^6$  cell ml<sup>-1</sup> possess longer spines ( $16 \pm 3 \mu\text{m}$ ) than that fed at  $3 \times 10^6$  cell ml<sup>-1</sup> ( $13 \pm 3 \mu\text{m}$ ). The rate of population increase per day ( $r$ ) for *B.plicatilis* when fed *Isochrysis* was of 0.27, but not overtake 0.1 when fed *Chlorella*.

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## Biogeochemical implications of top-down effects in the ocean

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Planktonic productivity in the ocean is intimately related to turbulence *sensu lato* (vertical mixing, upwelling,...) and large-, meso- and microscale phenomena are also the result of ocean climate. Both conditions affect the nutrient richness and the accumulation of planktonic biomass. However, the presence or not of predators also structure the biota in the water column. A recent finding about the relationship between zooplankton biomass and moon illumination, similar to that described in lakes, have prompted to appraise the role of the top-down forces in the ocean. This lunar cycle in zooplankton could account for a rather large percentage of the gravitational flux and help to explain the periodicity in the sinking flux observed in sediment traps in subtropical waters. This effect of light in the ocean produces a cascade downward the food web, promoting changes in the structure of the ecosystem. A review of these top-down effects suggests that moonlight drive energy in the ocean from the recycling loop to large zooplankton enhancing active flux.

## The effects of temperature and salinity on egg production, hatching success and naupliar survival of Baltic *Temora longicornis* (Copepoda: Calanoida): A laboratory investigation

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Hydrographic conditions of the Baltic Sea are periodically altered due to low frequency, major inflows of North Sea water. These large inflow events can result in widespread changes in salinities (S) and temperatures (T). Inflow events, seasonal changes in river runoff, and other factors affect the strength of thermoclines and haloclines often creating depth differences of S and T exceeding 5 psu and 10 °C. Moreover, depending upon the location, seasonal ranges in Baltic Sea temperatures can exceed 20 °C. In this laboratory study, we characterized the population response of Baltic *Temora longicornis* (Copepoda: Calanoida) to potential changes in hydrographic conditions (e.g., differences in temperature and salinity). First, daily egg production (EP, # female<sup>-1</sup> d<sup>-1</sup>) was determined for four days at 12 different temperatures between 2.5 and 24°C and the success of hatching was evaluated at ten different temperatures between 2.5 and 24°C. The highest mean rates of EP were observed at 14°C (16 eggs female<sup>-1</sup> d<sup>-1</sup>) whereas hatching success was highest at temperatures between 20 and 22°C (85%). Secondly, the effect of salinity (0 to 34 psu) on egg hatching success was also examined. Therefore four cohorts acclimated to salinities of 8, 14, 20 and 26 psu were used to produce eggs. When incubated at 12°C, HS increased asymptotically with increasing S and was maximal (82.6 to 84.3%) between 24 and 26 psu. However, HS depended upon the adult acclimation salinity; eggs produced by adults at low salinities profited most from incubation at higher salinities. Finally, naupliar survival was tested at six different temperatures between 10 and 20°C at each of two salinities (7 and 20 psu). At 7 psu, 72-h naupliar survival increased from 36.8% to 73.3% as temperature decreased. However, at 20 psu, temperature had only a weak impact on survival; maximum survival was 98.3% at 10°C and  $\geq 73.3$  at all other temperatures. Our results provide estimates of the responses of *T. longicornis* reproductive success and early survival to the wide ranges of temperatures and salinities experienced in the Baltic Sea. This and other ongoing experiments will aid in the parameterization of population models constructed for this species in this region.

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## Towards the Black Sea zooplankton diversity- an assessment and uncertainties

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Biodiversity is a complex concept for which no single measure exists, but efforts on the development and implementation of an agreed set of biodiversity indicators are needed. The definition of “Biodiversity” used by the Convention on Biological Diversity (CBD) includes three components of diversity: ‘within species’, ‘between species’, ‘diversity of ecosystems’. The efforts of the scientific community involved in the process of biodiversity assessment and protection is to suggest, apply and implement appropriate measures (indices, indicators) for monitoring, evaluation and communication of biodiversity problems to the general public and to decision-makers. Biodiversity is still an issue on which is difficult to communicate. Although the oceans cover 70 % of the Earth's surface our knowledge of marine plankton diversity is still very limited. Diversity of small plankton species could not be easily achieved. Clearly, it is a time consuming process which needs a substantial amount of field and laboratory work, standard methodology, regular intercalibration and taxonomists. More, present-day pattern in pelagic biodiversity is a result of interactions of many factors (anthropogenic impact, climate forcing, etc.). Seasonality, currents, tides, depth, short life cycle, vertical migrations, spatially patchiness, size sample dependence, trophic relations are factors which further puzzling the investigations of plankton diversity. Biological complexity should not be viewed as a problem, but as a diversity characteristic to be described.

Recent interest in biological monitoring as a tool for marine ecosystem assessment has encouraged the development of a number of biotic indices designed to evaluate the ecosystem integrity, but zooplankton have rarely been included in biomonitoring schemes. There are still no widely agreed indices for zooplankton diversity. Moreover, there are difficulties clearly to discriminate between measures of biodiversity and those aspects of diversity that indicate environmental health, environmental quality and ecosystem integrity. Studies on the functional role of zooplankton diversity and abundance for the coastal ecosystem functioning and stability are still rare.

The core objective of the present study is to apply some common measures of diversity and integrity to zooplankton community in the Black Sea aimed to reveal the mesozooplankton structure of different Black Sea regions with dissimilar trophic and hydrophysical conditions. Independent data sets on mesozooplankton species composition for the period 1995-2004 from the following investigated regions were used: North-Eastern; Western and Northern Black Sea. Zooplankton samples were collected at the shelf (< 200 m depth) and offshore (> 200 m depth) stations. Under consideration were the measures: mesozooplankton species composition; total number of species; presence/absence of species; dominant groups and their ratios; time spatial distributional pattern of key stone non-indigenous species; Simpson's index of diversity; the Shannon-Wiener index; Pielous' evenness. SIMPER analysis was performed to reveal mesozooplankton species composition and to find out similarity/dissimilarity of the zooplankton community structure in between the regions. Available historical data (1967-1998) were used to find out the trend of long-term zooplankton dynamic in the Black Sea.

The results reveal a great interannual variability of mesozooplankton taxonomic composition, amount of dominant groups and species to all investigated regions. However, the groups which dominated the Black Sea mesozooplankton structure are copepods, cladocera and benthic larvae. The dominant and discriminating species in between the regions were identified. *Acartia clausi* dominated the three investigated areas with 16-18 % contribution to the abundance structure. The results from SIMPER analysis suggest similarity of 59 % of the mesozooplankton community composition in the Northern and Western Black Sea regions, in contrast to North-Eastern part which seems to be dissimilar in terms of numerical abundance of zooplankton species. We have applied univariate community measures, which collapse information on the number and distribution of species within a community to a single measure such as Simpson's index of diversity; the

Shannon-Wiener index and Pielous' evenness. A decision about which taxa to include is problematic. A relationship between mesozooplankton biomass and univariate community measures was found. A revision of what exactly we measure (diversity, stability, uniformity) using univariate methods could be debated.

In respect to irreversible bioinvasions, among the other enclosed basins Black Sea is ranked as highly invasive environment. The ctenophore *Mnemiopsis leidyi*, which is a key stone alien with the great ecological impact, has demonstrated a distributional shift along the investigated regions. It constantly maintained a relatively high concentration and frequency distribution at the Western shelf stations with the exception of 1999, in contrast to North-Eastern part where *Mnemiopsis* was constricted to not more than 10 ind.m<sup>-3</sup>. *M. leidyi* dynamic could provide signals for the pressures to which the Black Sea is undergo and to the quality of all biological elements.

In the context of short and long-term succession, abiotic parameters (temperature, light, nutrient concentrations and hydrodynamics) are driving factors to the plankton communities. Further investigations of how changes in species diversity and community structure affect marine ecosystems functioning are of crucial necessity. Assessments of functional diversity, trophic relations are among the most significant processes structuring plankton communities on shorter time scales (one focus should be on the identification, characterization and quantification of interactions between key species and their prey). Functional groups and their shifts are also of great interest because of significant differences in their ecological impacts.

## Oxygen minimum zone and assemblage of micronekton in the Andaman Sea during winter monsoon

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The planktonic organisms which are referred to as micronekton are invariably multispecies in nature and generally range in size between 1-12.5 cm. The Andaman Sea had a fair representation of mesopelagic micronektonic fauna such as the myctophids, photichthyids and pelagic shrimps in the upper 1000 m depth during the winter monsoon season have shown. They occurred in higher abundance during night (64.5%). Among the myctophids *Benthosema fibulatum* constituted maximum biomass followed by *Myctophum spinosum*. The pelagic shrimp, *Sergestes seminudus* was represented at all depths (up to 1000 m) and their distribution pattern suggested strong diurnal vertical migration. Temperature decreased from the mixed layer to downwards but salinity did not show any major variation. Dissolved oxygen ranged between 4.8 to 2.8 ml/l in the upper water column (0-75 m), and decreased to 0.2 to 0.5 ml/l in the 150 to 650 m but gradually increased in the bottom layers (>0.8 ml/l). A congregation of major groups of micronekton such as myctophids and pelagic shrimps occurred in the oxygen minimum zone (150-650 m).

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Keywords: micronekton; oxygen minimum zone; vertical migration; mesopelagic depth, winter monsoon, Andaman Sea

## Development and growth of *Temora longicornis* on diatom diets

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Recent studies have shown arrested development in several copepod species when cultured on diatom diets, assumed to be connected to the production of inhibiting aldehydes [e.g., *Ianora et al.* 2004]. I tested this hypothesis with one of the dominant spring bloom copepods in the North Sea, using common diatoms at ecologically relevant concentrations. Calanoid copepod *Temora longicornis* was raised from early nauplius stages with 10 different diatom species / strains, and development, growth and nauplii mortality were measured. In addition, grazing experiments were conducted to check that arrested development would not be due to low ingestion, and the aldehyde content of algae was measured. Growth and development of *T. longicornis* were comparable to control algae *Rhodomonas* sp. with 4 of the diatom species (*Thalassiosira weissflogii*, *Thalassiosira rotula* CCMP1647, *Skeletonema costatum* and *Leptocylindricus danicus*), whereas with 6 of the diatoms development stopped at late nauplii stages. However, 4 of these diatoms (*Chaetoceros affinis*, *C. sociales*, *C. descipiens* and *Thalassiosira pseudonana* CCMP1010) were not ingested by nauplii. Of the two remaining diatoms producing low development and growth rates, *T. rotula* CCMP1018 contained high amount of polyunsaturated aldehydes, whereas *T. pseudonana* CCMP1335 contained none. Of the species inducing high development and growth rates, *T. rotula* CCMP1647, *S. costatum* and *L. danicus* contained aldehydes. I conclude that although some diatom species are poor food for *T. longicornis* development, this is unlikely to be connected to the amount of polyunsaturated aldehydes in the diet.

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## Physiological adaptations of *Temora longicornis* females (Crustacea, Copepoda) to changing nutritional conditions in the North Sea

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The present work illustrates physiological changes of *Temora longicornis* females during the phytoplankton development in spring. Zooplankton samples were collected weekly from March to May 2005 off the island of Helgoland, North Sea. Immediately after capture, females were sorted from the samples and deep-frozen. The samples were analysed for dry mass, protein content, total lipid content and fatty acid composition, as well as the activity of digestive (proteinases, amylase) and metabolic enzymes (citrate synthase, pyruvate kinase). Fatty acid biomarkers reveal that females first fed primarily on dinoflagellates and later on diatoms. Dry mass and protein content were highest by the end of April, associated with maximum metabolic activity. By the end of May, the activities of citrate synthase and pyruvate kinase had decreased but were still higher than in March. The activities of the digestive enzymes (proteinases and amylase) decreased between March and mid-April. Thereafter, the digestive activity increased slowly, however, it did not reach the initial activity. Thus, in times of highest metabolic activity, digestive activity was lowest. This points to times of high-quality food, as not much energy needs to be allocated to digestion. These results indicate that the metabolisms of *Temora longicornis* females is strongly adapted to the changing nutritional conditions during spring in the North Sea.

## Simulation and Measurements of Copepod Stages

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Modelling of copepod distributions can provide insight into the dynamics of prey fields for fish larvae and can help to identify the key factors for fish recruitment success. To address these issues we performed a set of simulations with our 3d ecosystem model of the Baltic Sea. The model comprises a general ocean circulation model (MOM3.1-IOW) linked to a biological model component which simulates the nutrient cycle, primary production and zooplankton, where the zooplankton model component resolves five copepod model stages.

The paper presents results of our model simulations, which show the time variations of spatial distributions of two copepod genera with different habitats, and compares the model results with measurements from the German GLOBEC project. During this project in 2002 and 2003 measurement campaigns were conducted in the Bornholm Basin in the Baltic Sea. The observations provide unique data sets to characterize the physical-biological system. For example, from March 2002 to May 2003 Bongo-Net and Multi-Net catches were collected at a net of stations in regular intervals. These data give horizontal and vertical distribution patterns for the most important copepods in the Bornholm Sea.

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## Seasonality in observed and simulated zooplankton prey fields in the German Bight (southern North Sea) and habitat suitability for clupeid fish larvae.

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As part of the “GLOBEC Germany” program there have been regular cruises in the German Bight (southern North Sea), to obtain information on seasonal changes in the abundance and distribution of key copepod species and spatio-temporal trends in trophodynamic structure. In this presentation we illustrate the impact of seasonal changes in prey fields on the habitat suitability for the larvae of a clupeid fish species, sprat (*Sprattus sprattus*, L.). The stage-specific abundance data of copepods were compiled from bongo tows conducted at a grid of stations during each of five cruises from February to October 2004. All copepodite stages and adults of two genera (*Pseudocalanus* and *Acartia*) were targeted for this study since these prey items occurred most frequently in the gut contents of 10 to 15 mm standard length (SL) larval sprat. In the present analysis, we first discuss spatio-temporal patterns of in situ copepod data and then use them to corroborate the seasonality of modelled copepod abundance. Modelled copepod estimates for the 2004 station grid in the German Bight were obtained from a stage-based copepod model that was parameterised for a North Sea population of *Pseudocalanus elongatus*, and then coupled to an ecosystem model (ECOHAM3). By combining the spatially resolved in situ point estimates and modelled estimates, we were able to generate both temporally (weekly) and spatially resolved prey fields. Finally, we evaluate the impact of seasonal changes in prey fields on the habitat suitability for larval sprat by applying a foraging and growth model for early life stages of this species that was constructed in collaboration with the DFG-funded project “RECONN1”. Indices of habitat suitability were derived from model estimates of potential short-term survival and growth of 10 and 15 mm SL larvae.

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## **BIODIVERSITY OF THE PLANKTON COMMUNITY IN THE LEBANESE SEAWATERS ( Eastern Mediterranean)**

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Long-time plankton series were collected at different periods from 1970 up to 2004- at several nearshore and offshore stations in Lebanese waters (Levantine Basin, East Mediterranean). Sampling process including vertical profiles for phytoplankton and zooplankton with standard plankton nets, was accompanied with hydrobiological parameters such as temperature, salinity, dissolved oxygen, nitrate, phosphate, water transparency, chlorophyll-a and PH. These data were taken during monthly or seasonally oceanographic cruises, providing 2500 samples. Most of these samples were submitted for taxonomic and biodiversity study and quantitative analysis. The Lebanese waters, including the Levantine Basin is situated in a warm temperate region and are characterized with a high oligotrophy and impoverished plankton. The shortage of nutrient input induce a low primary productivity and thus poor zooplankton. Annual hydrothermal cycle of the seawater is characterized with two annual phases: a cold thermohaline phase in winter ( December-March) and a warm phase in summer ( June-November). A short interseason (April-May) splits the two annual phases. During winter the water is characterized with an isothermic conditions of  $T=16-17^{\circ}\text{C}$  in the hole water column and low phytoplankton standing crop and small species diversity. The warm phase is marked by a high surface temperature up to  $30-31^{\circ}\text{C}$ , a high salinity ( 39.75 ‰) and a sharp forming thermocline in the water layer 35-75 m. The plankton is poor in diversity and in biomass. During the interseason, phytoplankton growth may reach small bloom in May showing a high cell density. Up to date 400 phytoplankton taxa were identified and more than 750 zooplankton species. Many Lessepsian species of Indo-Pacific origin have adapted themselves to the Levantine waters where they have established permanent populations. These introduced species have affected the biodiversity of the plankton community. Some species of them became very important, they began to overcome or even to replace some native species. Several exotic alien species compete with some autochtone species. The Lessepsian migration into the East Mediterranean is a continuous phenomena, indicating a certain "tropicalization" of the Levantine Basin.

## Is intra-specific genetic variation in *Calanus helgolandicus* European populations associated with latitudinal and environmental differences?

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The marine calanoid copepod, *Calanus*, is of considerable importance in the marine food web. It has been the focus for large national and international marine science programmes, broad scale surveys, physiological processes and ecosystem studies. *Calanus helgolandicus* plays a critical role in marine ecosystems as a grazer of microplankton and as a major food source for larvae, juveniles and adults of commercially important fish. The distribution of *C. helgolandicus* in European coastal waters covers a wide range of habitats, from open ocean to coastal environments. Recent studies [Reid et al., 2003; Bonnet et al., 2005] have shown that *C. helgolandicus* is sensitive to change in climate particularly along the European seaboard of the northeast Atlantic. On the fringes of its distribution the range and abundance of *C. helgolandicus* has increased as water in the North Atlantic has warmed over recent decades, in other geographical areas populations have moved or expanded.

The main work on distinguishing *C. helgolandicus* populations in European waters is by Flemming & Hulsemann, (1987) in the Mediterranean Sea. They determined two distinct populations, one encompassing the Atlantic and western Mediterranean and the second in the Eastern Mediterranean using morphological discriminants (e.g. frequency of supernumerary pores). To date, the only work on *C. helgolandicus* European population structure using a genetic approach is from [Unal et al., in press] comparing the Adriatic to the English Channel populations. Building on the network of laboratories created by Bonnet et al. for their review on *C. helgolandicus* (2005), we collected samples in 95% ethanol from 13 European sites. For a number of individuals from each site ( $n \approx 20$ ) a region of the mitochondrial large subunit (16S) ribosomal RNA (rRNA) gene was amplified and sequenced.

Our study provides a molecular evaluation of the intra-specific genetic variation and biogeography in the key species *C. helgolandicus* in relation to climate change by linking such variation with metabolomics, physiology and 'adaptation' to differing habitats/conditions. This work is the first genetic comparison of *C. helgolandicus* populations within various sites in Europe (13 sites).

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**Application for a talk- Speaker P. Lindeque- Need a video projector**

## **The Role of gelatinous zooplankton in the structure of the northern adriatic planktonic ecosystem (june 1996 – july 2000)**

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The abundance, temporal and spatial distribution of gelatinous zooplankton was investigated during 43 cruises from June 1999 to July 2002 at three fixed stations in the open northern Adriatic. Population densities of dominant gelatinous species were compared with the abundance of their potential mesozooplankton and microzooplankton prey. Hydrographic factors were important in determining the abundance of the smallest and largest components of the food chain. Mucilaginous macroaggregates affected the entire basin in spring - summer 2000 and 2002; these had particularly negative effects on the abundance of some gelatinous species. *Muggiaea atlantica*, a highly adaptable calycophoran siphonophora, dominated cnidarians and *Sagitta setosa* was the most numerous chaetognath. Of Tunicata, *Oikopleura dioica*, *Oikopleura longicauda*, *Oikopleura fusiformis*, and *Doliolum* spp. were numerous seasonally. There were significant differences in the species composition of gelatinous zooplankton in the eastern, middle, and western parts of the northern Adriatic, but no such differences in density. This study confirms earlier work on the importance of the Po River and middle Adriatic water masses on the northern Adriatic plankton ecosystem.

## Zooplankton distribution in the central Canary Upwelling System over the last ten years: a modelling experiment confronted with observations.

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A modelling approach has been chosen to study the interactions between physical and biological processes and their role in structuring the first trophic levels within the central part of the Canary Upwelling System, a region where a permanent upwelling occurs throughout the year. The model used is the Regional Oceanic Modeling System (ROMS) coupled to a simple biogeochemical model (NPZD). The domain covers a large part of the Canary Current and a grid refinement (5 km resolution) has been conducted around the area of interest in order to represent the full range of mesoscale activities. Indeed, the development of fronts, offshore squirts and filaments, and eddies plays an important role in the dynamic of upwelling systems and have been recognized as important features to take into account when studying interactions between phytoplankton and zooplankton communities ([*Martin, 2003*]). A ten year experiment covering the years 1994 to 2004 is achieved. The main interannual signals and their impact on the spatio-temporal distribution of zooplankton will be presented. The parametrisation of the zooplankton component will be discussed by comparing modelled zooplankton distribution with *in situ* samples collected during this period.

This work is a contribution to the upwelling system research program of the EUR-OCEANS Network of Excellence.

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<sup>22</sup> Complete adress for the first institution using the « Adresses » style.

<sup>23</sup> Second adress using the « Adresses » style.

## Ichthyoplankton of Tunis Bay: Composition and distribution

MAHJOUB S.<sup>(1)</sup>, DALY YAHIA- KÉFI O<sup>(1)</sup> AND DALY YAHIA M.N.<sup>(2)</sup>

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The bay of Tunis (South Western Mediterranean) is characterized by its shallow waters. This bay receives flows from the Meliane river in its South-Western part. Thus, the nutrient concentrations show a clear decreasing gradient from the South-West to the North-East.

From July to December 2004, 11 stations were prospected during six spatio-temporal surveys of zooplankton and ichthyoplankton.

Copepods dominated the zooplankton with more than 92% of the individuals. Cladocerans were the second group with 4.9% followed by the meroplankton (1.6%) and the Appendicularians (0.6%). Ichthyoplankton represented only 0.015% of total zooplankton.

The ichthyoplankton was mainly composed by the following taxonomic groups: *Engraulis encrasicolus*, *Callionymus* sp, *Sardina* sp, *Sardinella* sp, the Families of Labridae, Blennidae, Gobiidae and Carangidae.

Mean total ichthyoplankton abundance during the study period was 12.57 ind/10m<sup>3</sup>. The highest mean concentration was observed in July and has reached 37.96 ind/10m<sup>3</sup>.

Spatial distribution shows that the ichthyoplankton was more abundant in the coastal zones of the bay. During the anchovy peak of spawning, the ichthyoplankton was mainly concentrated in the center and the South-Western zone of the bay affected by the fresh water discharge of the Meliane River.

Maximum ichthyoplankton abundances were recorded during June in the central part of the bay for the larvae (30 ind/10m<sup>3</sup>) and in the South-Western part of the study area for the eggs (90 ind/10m<sup>3</sup>).

Keywords: Bay of Tunis, Zooplankton, Ichthyoplankton, distribution.

## Carbon limits egg production in *Calanus finmarchicus* before the spring bloom

MAYOR, D. J.<sup>1</sup>, ANDERSON, T. R.<sup>2</sup>, IRIGOIEN, X.<sup>3</sup> AND POND, D.<sup>4</sup>

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*25National Oceanography Centre, Southampton, U.K.*

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*4British Antarctic Survey, U.K.*

The growth (egg production) of marine copepods correlates with a range of variables, including food nitrogen (N), and the polyunsaturated fatty acids 20:5(n-3) (EPA) and 22:6(n-3) (DHA). However, a consensus on which substrate is typically limiting in the natural environment has yet to be reached. Five consecutive 24 hr incubation experiments were conducted with female *Calanus finmarchicus* under in situ conditions in the Irminger Sea to examine the biochemical limitation of egg production. Quantities of C, N, EPA and DHA invested in the eggs during the 5-day experimental period were determined simultaneously with measurements of the amounts of these substrates derived from copepod biomass and ingestion while feeding on natural plankton assemblages. Molar ratios of N:C, EPA:C and DHA:C in the ingested food were then compared to those in the eggs produced, and after taking into account utilisation efficiencies, the substrate that was limiting was predicted using simple stoichiometric theory. Contrary to the current dogma of N-limitation in marine copepods, C was predicted to have limited egg production during the experiments. Limitation by carbon was particularly strong in instances when the animals had to use their own biomass, rich in N, to supply the substrates necessary for egg production.

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## Size spectra and distribution of zooplankton in the German Bight measured by a Laser Plankton Counter (LPC)

MENGEDOHT DM, SCHULZ J, AND HIRCHE H-J

*Alfred Wegener Institute for Polar and Marine Research, Germany<sup>1</sup>*

Zooplankton plays an important role in the energy transfer in the pelagic food web. Its temporal and spatial distribution is changing rapidly on various scales, which cannot be adequately covered by common sampling strategies as expeditions and the analysis of the samples are time consuming and require a high effort. The Laser Plankton Counter (LPC) provides a relatively cheap and simple technology, which delivers high resolution data of the distribution of particles in the range of mesozooplankton together with hydrographic parameters. Data are stored digitally and can be transferred by remote access. The measurement is based on the shadow method. Plankton particles pass between the emitter and the photo receiver of the LPC, their shadow sizes are recorded on the photo receiver. The optical electronic sensors distinguish 128 size classes from 0.125 to 16 mm. The LPC is constructed for the estimation of zooplankton concentration and size mounted in combination with CTD-probes or undulating towed vehicles. Furthermore, it is suitable for autonomous use on buoys or platforms. LPC applications performed in the German Bight during Globec-Germany are introduced and first results are shown.

### REFERENCES

Special technical equipment for the presentation:

An internet connection on the stage computer for the oral presentation (or wlan for my own computer at a poster presentation) would be fine to demonstrate data transfer online from a LPC at a research platform in the North Sea. (just optional, not necessary)

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## The role of zooplankton in cryo-pelagic coupling in the Southern Ocean

JAN MICHELS, GERHARD DIECKMANN, SIGRID B. SCHNACK-SCHIEL

*Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany*

The distribution, composition and abundance of zooplankton and sea ice meiofauna were studied based on multinet, ice core and slush ice samples taken in the western Weddell Sea, Antarctica, in summer 2004/2005. Grazing experiments with different developmental stages of dominant pelagic and sea ice inhabiting copepod species were conducted. In addition the contents of copepod and krill faecal pellets were analysed by means of scanning electron microscopy and samples from sediment traps that had been installed under the sea ice were investigated. Goal of the study was the quantification of the impact of zooplankton on particle and energy fluxes between sea ice and water column.

Copepods were dominant in the zooplankton and the sea ice meiofauna. All of them were active and fed on phytoplankton and ice algae. In the sea ice large amounts of copepod faecal pellets could be found, most of them containing high numbers of unbroken frustules with living cells of the abundant diatom genus *Fragilariopsis*. The faecal material in the sediment trap samples consisted mainly of krill faecal pellets originating from large krill swarms that could be observed feeding on algae on the underside of the sea ice. No copepod faecal pellets could be found in the sediment trap samples leading to the assumption that they had been completely degraded in the water column. Large amounts of broken diatom frustules contributed considerably to the total amount of phytoplankton in the trap samples indicating relatively high grazing activity in the sea ice and the water column.

The results show that sea ice inhabiting copepods and krill played an important role in the transport of relatively fresh organic material from the sea ice into the upper meters of the water column. Since phytoplankton concentrations in the water column were very low copepod and krill faecal pellets are assumed to have been a significant source of organic material for pelagic organisms.

## Seasonal dynamics of *Pseudocalanus elongatus* in different regions of the North Sea using population modelling embedded into the ecosystem model ECOHAM3 with competing bulk zooplankton.

MOLL, A.<sup>1</sup>, CARLOTTI, F.<sup>2</sup>, KÜHN, W.<sup>1</sup> AND KREUS, M.<sup>1</sup>

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This paper outlines an approach to couple a structured zooplankton population model with state variables for five stage groups adapted to *Pseudocalanus elongatus* into the complex marine ecosystem model ECOHAM3. For the carbon and nitrogen cycle, 14 state variables represent the functional units phytoplankton, bacteria, detritus, dissolved organic matter, and bulk zooplankton, which stands for all zooplankton other than the structured population. Mesocosm studies under temperature and food conditions comparable to the North Sea conditions were used for parameterisation of the stage-dependent copepod life cycle processes. Annual cycles under realistic weather and hydrographic conditions were studied applying a 1d version of the coupled ecosystem-zooplankton model at two contrasting regimes: the southern and northern North Sea. The main ecosystem state variables were validated against observed monthly means. The vertical profiles of selected state variables were compared with respect to the impact of the physical forcing on differences between bulk and structured zooplankton biomass. The simulated generation durations are more affected by temperature than by food availability. Regional differences in generation times were studied. The results from the northern North Sea were compared to a simulation in the southern North Sea (GLOBEC position in the German Bight) where data for zooplankton biomass and *Pseudocalanus elongatus* abundances were available. Simulation runs to investigate competition in the northern North Sea showed a time lag of about 1 month between bulk and structured zooplankton biomass maxima in spring and reduced biomass levels for both zooplankton types during summer. In the southern North Sea the structured and bulk population exhibited an earlier biomass development compared to the northern region; further on during the whole production period bulk and structured zooplankton showed several biomass peaks.

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<sup>27</sup> Université de la Méditerranée, COM, Rue de la Batterie des Lions; F-13007 Marseille, France.

## Indirect effects of climate change on commercial fish populations: copepods as major driver for regime-shift in fish community.

CHRISTIAN MÖLLMANN<sup>1</sup>, FRIEDRICH W. KÖSTER<sup>1</sup>, GEORGS KORNILOVS<sup>2</sup>, GERD KRAUS<sup>3</sup>, RÜDIGER VOSS<sup>3</sup>, ANDREI MACARCHOUK<sup>2</sup> AND CHRISTOPH PETEREIT<sup>3</sup>

<sup>28</sup>*Danish Institute for Fisheries Research, Charlottenlund, Denmark*

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Climate change has been identified as a major driver for long-term changes in zooplankton communities. Further, climate change can affect fish stocks directly, e.g. through a temperature effect on physiology, but also indirectly through changes in their food supply impacting on growth and recruitment. In the Central Baltic Sea, a climate-induced decrease in salinity and an increase in temperature have caused a dominance shift in the calanoid copepod community from *Pseudocalanus* sp. to *Acartia* spp. In the fish community, a regime shift from a cod (*Gadus morhua*)-dominated to a sprat (*Sprattus sprattus*)-dominated ecosystem was observed, which was mainly caused by opposite recruitment success. We demonstrate that the change in the zooplankton community exerted a strong bottom-up control on the dominating commercially important fish stocks. Using analyses of long-time series on hydroclimatic variables, zooplankton biomass as well as fish stock recruitment, we show that the change in the copepod community is a major driver of the opposite reproductive success of cod and sprat, thus representing an indirect effect of climate on marine fish stocks.

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## **Role of the zooplankton community composition on the mineralisation and the vertical flux of organic matter at a fixed station in the Ligurian Sea**

MOUSSEAU LAURE<sup>1</sup>, LEFEVRE DOMINIQUE<sup>2</sup>, ANDERSEN VALERIE<sup>1</sup>, NARCY FANNY<sup>1</sup>, NIVAL PAUL<sup>1</sup>,

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<sup>31</sup> *LMGEM UMR CNRS 6117, France*

Zooplankton play a key role both in the vertical transfer of particulate organic matter and in the mineralisation of organic matter. As this compartment exhibits specific and functional diversities, there is a need for more accurate estimates of the specific physiological rates to assess and quantify the role of zooplankton on biogenic element cycling and on trophic web.

At a fixed station in the Ligurian Sea, we sampled the zooplankton (> 150µm) community 20 times during the summer-autumn transition (13 sept.-17 oct. 2004). Vertical biomass and species composition were described. Then specific physiological rates (CO<sub>2</sub> and O<sub>2</sub> respiration; N-NH<sub>4</sub> excretion) as well as specific gut contents were estimated for the major taxa. Simultaneous measurements of the 3 physiological rates allowed to estimate the respiratory (RQ) and the metabolic (MR) quotients. Our results suggest a variety of physiological activities among the species, underlining the importance of studying the zooplankton not as a whole, but as a multifunctional association. We attempted to estimate (1) the metabolic activity of the whole zooplankton community by combining specific physiological rates and species composition, and (2) the proportion of organic carbon being remineralised within the upper water column against the exported carbon.

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## Simulation of Copepods in 3-dimensional Eulerian Models

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To understand the reason for the interannual variability of fish recruitment success, the German GLOBEC project investigates *inter alia* the cause effect chain from physical forcing to prey fields of fish larvae. For the understanding of the complex relations among the involved processes an interaction of experimental and theoretical research is required.

In this paper we introduce a three-dimensional model of the Baltic Sea which includes a biogeochemical as well as a stage resolving copepods model. The biogeochemical part simulates the nutrients cycle and primary production. On top of the biogeochemical component a stage resolving copepods model is implemented, which describes the aggregated model stages nauplii, copepodites 1, copepodites 2 and adults. Each stage is represented by abundance and biomass. For a realistic representation of the dominant copepods groups two model species with different behavioural rules and live cycles have been defined. Based on the behavioural rules the model copepods occupy different habitats and therefore are influenced by different environmental conditions.

First simulations are encouraging and reproduce reasonable the seasonal cycle and special distributions of the dominant copepods species. Nevertheless, during the ongoing German GLOBEC project we expect improved understanding of the copepods life cycles that could lead to further refinement of the model formulations.

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No special equipment is required.

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## **From dormancy to activity: life cycle strategies of the Arctic copepods *Calanus glacialis* and *C. hyperboreus* during the winter-spring transition**

BARBARA NIEHOFF<sup>1</sup>, TOBIAS KREIBICH<sup>1</sup>, WILHELM HAGEN<sup>2</sup>

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The dominating copepods in Arctic waters, *Calanus glacialis* and *C. hyperboreus*, spend the winter period at depth in a resting stage (diapause). During this time *C. hyperboreus* females fuel reproductive processes with internal lipid reserves, whereas reproduction of *C. glacialis* peaks later in the season when food becomes available. To study the changes in physiology due to gonad maturation and the onset of feeding after over-wintering, *C. glacialis* and *C. hyperboreus* females were caught during an expedition with RV Polarstern at the end of winter in March and April. Onboard, one half of the females were kept for three weeks in pre-screened seawater and the other half in seawater inoculated with diatom cultures. Fecal pellet and egg production rates were determined daily. In addition, carbon, nitrogen and lipid content and composition as well as the activity of digestive and metabolic enzymes were monitored. Feeding *C. glacialis* produced high numbers of fecal pellets immediately after exposure to food; the females matured and reproduced at maximum rates within a week. Metabolic enzyme activity increased as did carbon, nitrogen and lipid content. In *C. hyperboreus* females, maximum fecal pellet production was measured after ten days, and feeding had no significant effect on gonad maturation and egg production. Moreover, carbon, nitrogen and lipid content remained stable or increased only slightly. These results indicate different life cycle strategies with regard to resource allocation and mirror species-specific adaptations to the highly seasonal polar environment.

## Zooplankton grazing impact in the Barents Sea: an interplay between size structure of the grazers and phytoplankton succession.

PASTERNAK A<sup>1</sup>, ARASHKEVICH E<sup>1</sup>, WASSMANN P<sup>2</sup>, REIGSTAD M<sup>2</sup>, AND WEXELS RISER C<sup>2</sup>

<sup>33</sup> *P.P. Shirshov Institute of Oceanology, Russia*

<sup>34</sup> *Norwegian College of Fishery Science, Tromsø University, Norway*

Most of the studies on trophodynamics of pelagic ecosystems were focused on mesozooplankton species with body length from 0.5 mm to 4 cm that are efficiently caught with plankton nets. Of this size group, herbivorous and omnivorous copepods play the dominant role in the grazing food webs. Attention of the researchers has recently been shifted to another, much smaller group of pelagic inhabitants, microzooplankton (body size  $\leq 50\text{-}100\ \mu\text{k}$ ), comprised mainly of protozoans. They are among the main players in the microbial food web. However, there is a group of plankton animals (body length of  $100\text{-}500\ \mu\text{k}$ ) that is usually neglected, because they are too large and not sufficiently abundant to be adequately sampled with microzooplankton methods, but too small to be quantitatively sampled with plankton nets. This group, “sub-mesozooplankton” (SMZ), is comprised of cosmopolitan and sometimes very abundant *Oithona* species, other small copepods, nauplii of different crustaceans, younger copepodite stages of copepods, small Appendicularia, pelagic larvae of benthic animals, etc. How important could be their role in the trophic webs of different ecosystems and how does it change with the season or phase of ecological succession? Animals of this group produce small faecal pellets, so pelagic environments where SMZ dominate are likely to be characterised by retention food webs. Previously, we have shown that the biomass of SMZ was similar to that of “net” mesozooplankton in a subarctic Norwegian fjord from March to October [Pasternak *et al.*, 2000]. Their small pellets contributed considerably to the total faecal pellet biomass. The fate of phytoplankton-derived matter in the fjord was suggested to be influenced by grazing, resulting in either rapidly or slowly sinking faecal matter, depending on the size spectrum and the prevailing feeding modes of the grazer community. We estimated grazing impact of the SMZ size group in the pelagic community of the marginal ice zone of the Barents Sea during three cruises of the CABANERA project in 2003, 2004 and 2005. Mesozooplankton was sampled with standard plankton nets in 3 vertical layers, SMZ with 30 l water bottles from 10, 30, 50 and 90 m. To assess grazing impact, gut fluorescence and gut passage time of all the dominant groups was estimated. During the most pronounced diatom bloom in May 2005, grazing of the SMZ had a minor impact (<1 to 4 % of phytoplankton biomass). It was higher (2 to 14%) in the previous cruises (July-August) when phytoplankton concentrations were lower, and comparable with that of the mesozooplankton. The role of nauplii and young copepodites was considerable. SMZ outnumbered the larger copepodites by several orders of magnitude and their weight-specific feeding activity was 2-3 times higher. An exceptionally high grazing impact was estimated at a station with high abundance of gelatinous herbivorous plankton (larvaceans). Thus, the SMZ could increase estimated grazing impact by a factor of 2 and more, depending on zooplankton composition and seasonal phase of plankton succession.

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<sup>33</sup> Complete adress for the first institution using the « Adresses » style.

<sup>34</sup> Second adress using the « Adresses » style.

## Impact of food quantity and quality on reproductive success of the copepod *Temora longicornis* in the North Sea - a fatty acid marker perspective.

PETERS J<sup>1</sup>, DUTZ J<sup>2</sup> AND HAGEN W<sup>1</sup>

<sup>35</sup>Marine Zoology, University of Bremen, Germany

<sup>36</sup>Baltic Sea Research Institute Warnemünde, Germany

Egg production and hatching success of the copepod *Temora longicornis* as well as POC, PON and fatty acid composition of seston and *T. longicornis* eggs were measured during two cruises to the southern German Bight, North Sea (May and July 2005). A principal component analysis on egg production and quantitative seston parameters revealed a strong dependency of the temperature-standardized specific egg production on POC and PON concentration of total seston, as well as on the 16:0 fatty acid content, as the major seston component. Most coherences were observed with fatty acids in total seston, as well as with seston in the size class 1-30 µm, especially with the diatom markers 16:1(n-7) and 20:5(n-3). In contrast negative correlations were found between relative diatom marker contents in the eggs and hatching success. However, hatching success was high at all stations with values between 77 % and 94 %, suggesting that food quantity rather than quality determined the reproductive success of *T. longicornis* at that time.

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## Exceptionally high abundance of overwintering *Calanus helgolandicus* populations in the North Aegean Sea (eastern Mediterranean)

RAMFOS ALEXIS, ISARI STAMATINA AND FRAGOPOULU NINA

*University of Patras, Greece*

During stratified sampling carried out in summer 2003 and 2004 in the Lemnos Deep (NE Aegean Sea), populations of overwintering *Calanus helgolandicus* with exceptionally –for the Mediterranean standards– high abundance were found. Abundance values of more than 100ind.m<sup>-3</sup> for the species were found in the 700-1200m layer in July and September 2003, approximately one order of magnitude higher than those reported in literature for the Mediterranean Sea [Bonnet et al., 2005]. In the next summer (July 2004), abundance in the deeper sampled layer (500-1000m) was approximately 20ind.m<sup>-3</sup>.

Abundance values were found lower in the 200-700m layer in 2003 (40 and 20ind.m<sup>-3</sup> in July and September respectively). *C.helgolandicus* individuals were totally absent in the 200-500m layer in July 2004 as well as in the upper 200m during all cruises, verifying the seasonal migration of the species. During all cruises, populations consisted almost exclusively of copepodite stage V individuals, containing oil-sacs full of lipids, both characteristics of diapausing populations of the genus [Bonnet et al., 2005]. Adult females constituted less than 1% of the population, whereas adult males were entirely absent.

The NE Aegean Sea is an area of higher zooplankton standing stock, when compared to the southern –more oligotrophic– part of the Aegean Sea, mainly due to the Black Sea water influence, the extended continental shelf and the outflow of rivers located in the area [Isari et al., 2005]. The complex topographical and hydrological characteristics of the area seem to create favorable environmental conditions for the reproduction and development of *C.helgolandicus* population during spring, a fact also supported by the large size of individuals found. Mean prosome length of adult females was comparable with those reported by Flemming & Hulsemann, (1987) for Northern Europe, significantly higher than those reported for the Aegean Sea and close to those of the Black Sea (named *C. euxinus* [Hulsemann 1991]). The ratio of prosome to urosome length (i.e. a character used to distinguish Black Sea and Atlantic/Mediterranean populations) was also very close to that described by Flemming & Hulsemann, (1987) for the Black Sea population.

The data of the present study provide information about the vertical distribution, population structure and morphometric characters of *C. helgolandicus* in an area strongly influenced by Black Sea water and, seemingly, suitable for the special demands of the species.

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## ***Pseudocalanus acuspes* in the Central Baltic Sea-an arctic relict species as key prey**

RENZ J AND HIRCHE H-J

*Alfred Wegener Institute for Polar and Marine Research, Germany*<sup>1</sup>

In the Central Baltic Sea, *Pseudocalanus acuspes* is considered to be an arctic relict species. It serves as a major food organism for commercially used fish such as sprat and herring. We used data collected in the Bornholm Basin between March 2002 and May 2003 during German GLOBEC to describe life history patterns and population dynamics of *P. acuspes* in relation to the hydrographic conditions. As our study covered the transition period from a long stagnation beginning in 1993 to several intrusions of North Sea water during summer and fall and a major Baltic inflow event (MBI) of cold, saline North Sea water in January 2003, we were also able to study the effect of changing hydrography on *P. acuspes*. The species showed an ontogenetic vertical distribution with youngest stages highest up in the water column and older stages distributed deep within the halocline. This vertical distribution patterns did not save *P. acuspes* from its most important predators and may be the result of physiological requirements rather than predator avoidance. Both, extremely low moulting rates and the stage structure indicate that *P. acuspes* produces only one generation per year. We propose, that the slow development coupled with sub-optimum growth conditions leads to low production of this species in the Central Baltic Sea, when compared to production of congener species from other areas. After the MBI, abundance at some stations increased markedly. However, there was no difference between reproduction rates before and after the inflow. Our results are discussed on the background of earlier suggestions from time series studies that biomass of *P. acuspes* is strongly related to salinity and high salinities are needed for reproduction.

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## Ocean basin-scale patterns of microzooplankton herbivory and bacterivory

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Ecosystem processes are key determinants of upper-ocean biogeochemical cycles that are affected by climate, and in turn influence climate. The structure and activity of the microbial food web, in particular, the microzooplankton, have a disproportionately large influence on the cycling and flux of key biogeochemical and climatically important properties. Microzooplankton are thought to consume and recycle a large fraction of biogenic carbon in the sea and are in turn are important food for metazoan zooplankton. However, there are few studies that have characterized the rates and patterns of herbivory and bacterivory over large spatial and temporal scales. Studies of this process tend to be unidimensional along a single temporal or spatial gradient. As part of the Canadian Surface Ocean Lower Atmosphere Study, and the Atlantic Meridional Transect program we quantified microzooplankton bacterivory and herbivory in diverse biogeochemical provinces of Atlantic Ocean; including five biogeochemical provinces, and across a 22-deg C temperature gradient within the Northwest Atlantic during three seasons, and the North and South Atlantic gyres, and higher latitude, temperate biomes. We characterized the seasonal and spatial patterns in microzooplankton abundances and in the rates of growth and grazing mortality for heterotrophic bacteria and pico- nano-phytoplankton. Grazing mortality for all taxa and sizes of prey varied seasonally and spatially, with the highest mortality rates in regions of greatest microbial activity. Growth and loss processes were regulated by temperature and resource availability, with rates of microzooplankton grazing being highly correlated with prey growth. This suggests a strong physiological control and feedback on important biogeochemical fluxes.

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## A study on the effects of microzooplankton grazing on the diurnal vertical migration (DVM) of dinoflagellates in the Huon Estuary (Tasmania)

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The Huon estuary is located in the south-east of Tasmania; over the last two decades there has been a significant increase in aquaculture activity in the Estuary and D'Entrecasteaux Channel, raising concerns about the impact of these activities on the health of the ecosystems and ultimately the ecological sustainability of this industry. Blooms of *Gymnodinium catenatum* occur seasonally (summer and autumn blooms) in the Huon Estuary. The impacts of these blooms are felt in many ways: human health is placed at risk; biogeochemical pathways are altered; and the fishing, aquaculture, and recreation industries suffer substantial economic losses. To reduce the impacts of harmful algal blooms, the understanding of the many factors that regulate the dynamics of HABs (Harmful Algal Blooms) and the manner in which they cause harm is essential.

In this study, we evaluated the impact of the top-down control of zooplankton on phytoplankton by using the dilution technique of Landry and Hassett (1982). Night-time and day-time sampling allowed us to compare the grazing impact throughout a 10 m water column (Port Huon). The characterization of the phytoplankton community was done by combining a HPLC analysis and a treatment of the results with CHEMTAX. Phytoplankton and microzooplankton were counted for each depth at sampling times T<sub>0</sub> and T+24 h. The results clearly demonstrated that the grazing impact was very high both during night- and day-time and that zooplankton could graze up to 175% of the primary production during the night-time.

In order to determine the impact of grazing on different classes of algae, grazing rates were calculated using chlorophyll *a*, fucoxanthin, peridinin and alloxanthin. These results showed that diatoms were most heavily grazed upon and that similar grazing rates were observed for the peridinin (dinoflagellates) and alloxanthin (cryptophytes) during the night.

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<sup>37</sup> Complete adress for the first institution using the « Adresses » style.

<sup>38</sup> Second adress using the « Adresses » style.

<sup>39</sup> Complete adress for the first institution using the « Adresses » style.

## Plankton biodiversity in the South Adriatic Sea: an integrated water/sediment approach

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In marine coastal areas, many planktonic species produce resting stages (cysts) to overcome adverse periods. These cysts accumulate into the bottom sediments where they represent a biodiversity bank. Recently their morphology has been ascertained to be taxon specific, thus suggesting an alternative possibility to the description of species (normally seasonal) distributions. Encystment/excystment patterns can influence the plankton dynamics moving the biomass to/from the benthos. Classical sampling methods don't "see" the plankton stocks which rest in the sediments as cysts, neglecting a temporarily unexpressed ("potential") biodiversity fraction.

In the framework of "Interreg II Italy-Albania Project" one oceanographic survey was carried out aboard on the r/v "Italica" from 20 to 31 October 2000 along the two opposite coasts of the southern Adriatic Sea, collecting water and sediment samples (integrated sampling) from a total of 14 stations. A total of 88 cyst morphotypes were recognized; 30 of them were exclusive of the Albanian coast, 18 of the Italian one, 40 being found on both sides of the South Adriatic Sea. The phytoplankton was represented by 115 taxa, mostly dinoflagellates; Microzooplankton was represented by a total of 88 taxa, mostly Cilifora (Tintinnina); 19 of them were found only along the Albanian coast, while 14 were typical in the Italian one. Only few taxa (about 5%) were recognised both in the water column, as plankton, and in the sediments, as resting stages. Furthermore, the most abundant species in the water column were not equally dominant as resting stages in the sediments, and active stages of some abundant cysts were not found at all in the water column. This suggests that species other than those observed in the plankton during the present work (i.e., those found as dominant among resting stages in the sediments) characterised the plankton in past periods. They probably will characterise the future plankton, according to seasonal cycles, starting from sediment reservoirs.

Notwithstanding to the still pristine state of the studies on cysts, it is evident that the analysis of sediments in the present work added information to the biodiversity description of marine areas, encouraging to perfection cyst-identification in the future with the aim to avoid spread of sample collections over long time intervals.

## Climate change and ichthyoplankton distribution: the case of *Sardinella aurita* in the North-western Mediterranean

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During the last decades an increase of temperature has been recorded in the Western Mediterranean Sea, both at intermediate levels as well as in deep waters. In addition, there is some evidence that the distribution range of fishes and benthic organisms characteristic of warm waters has expanded, and their presence is more and more frequent in the northern part of the sea. At a large scale, the immediate effect of the global warming on ichthyofauna is the variations in the geographic limits of their distribution resulting in both local extinctions and expansions by species from warmer environments. This effect will be more noticeable on those populations located on the geographic distribution limit of the species. Round sardinella, *Sardinella aurita*, is a thermophilic small pelagic species, having a tropical to subtropical distribution in the Eastern Atlantic and in the Mediterranean. In the Western Mediterranean, *S. aurita* is particularly frequent in the southern part, its abundance gradually decreasing northwards; the study area, the Catalan coast, is its northern boundary distribution in the Western Mediterranean. This study analyzes the spatial distribution of *S. aurita* summer spawning (2003, 2004) and its relationship with environmental parameters affecting the Catalan coast in that period. In both years, surface temperature showed a marked latitudinal gradient with higher values in the south than in the north. The structure of the water column was representative of summer conditions, with a strong thermocline around 20 m depth. The spatial distribution of *S. aurita* eggs and larvae was clearly linked to vertical and horizontal gradients of temperature. Eggs and larvae were mainly located in the upper levels of the water column, above the thermocline, in the warmer waters. They were much more abundant in the southern part of the study area, being their distribution northwards limited by 25°C surface isotherm.

## Effects of PAHs on the naupliar and copepodite stages of the marine copepod *Oithona davisae*.

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We have studied the lethal and narcotic effects of three PAHs (naphthalene, methyl naphthalene and dimethyl naphthalene) on a small neritic copepod, the cyclopoid *Oithona davisae*. These hydrocarbons are quantitatively very important components of the soluble fractions of fuel oils, and are relevant to evaluate the ecotoxicological effects of oil spills on marine zooplankton. Separate experiments were conducted for the naupliar and the adult stages at a range of PAH concentrations, and the LC50 (lethal dose) and NC50 (narcosis dose) determined. Sublethal effects on feeding were also contemplated. The effect of stage (size) on the sensitivity of the copepod to the PAHs is discussed.

**PRESENTED AS A POSTER**

## The impact of nauplii abundance and diversity on fish larval survival: Baltic cod as a theoretical case study.

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*Leibniz-Institut für Meereswissenschaften, Germany<sup>40</sup>*

Existing coupled biophysical models for Baltic larval cod drift, growth and survival use idealised mean prey fields of nauplii distributions. Model simulations using mean prey fields revealed best feeding conditions for cod larvae larger than 6 mm. For smaller, first feeding larvae (> 4.5 mm) model runs predict pronounced differences in growth and survival, which depend on food availability and to a lesser degree on ambient temperature. In the present study, we performed model runs with an Individual Based Model (IBM) for Baltic cod larvae in order to demonstrate how natural variability in prey abundance influences survival success of first feeding larvae. In the Baltic Sea newly hatched larvae dwell between 20 and 40 m depth and feed exclusively on nauplii of different calanoid copepods (*Acartia* spp., *Pseudocalanus* sp., *Temora longicornis* and *Centropages hamatus*). Vertically stratified plankton samples revealed strong spatial and temporal variability of nauplii abundance in the Bornholm Basin, Central Baltic Sea, in 2001 and 2002. We calculated larval survival and growth in relation to the magnitude of the natural variations in prey fields, i.e. considering observed variation in species specific nauplii abundance. The results of the model runs revealed larval survival rates from 60% to 100% if a mean size of nauplii was assumed and lower survival if prey consisted of early nauplii stages only.

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## Variation in calanoid copepod abundance and composition along a latitudinal transect in the Atlantic

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Stratified zooplankton sampling was carried out in the upper 300 m along a latitudinal transect in the Atlantic in November 2002. Independent of latitude, copepods occurred in highest abundance in the upper 50 m of the water column. 147 different calanoid species belonging to 60 genera were identified. Highest species number and diversity was found in just south of the Equator. At all stations the calanoid copepod population was dominated by *Clausocalanus* species accounting between 30 and 70 % of the total numbers. *Calocalanus* ranked second in abundance, followed by *Paracalanus* and *Parvocalanus*. In tropical and subtropical waters south of the Equator, *Mecynocera* contributed also a large fraction varying between 5 and 16%. All other genera accounted for less than 5%. The abundance of most species varied greatly between latitude, and a significant difference between regions could be shown.

Within the adult *Clausocalanus* specimens, nine *Clausocalanus* species could be identified (*C. furcatus*, *C. pergens*, *C. paululus*, *C. jobei*, *C. arcuicornis*, *C. lividus*, *C. mastigophorus*, *C. parapergens*, *C. ingens*). *C. pergens* was abundant in temperate to subtropical regions at the northern hemisphere. In the tropics *C. furcatus* contributed the largest fraction while *C. paululus* were most abundant in the subtropics in the south. *C. ingens* was found only at the most southerly, *C. lividus* only at the most northern stations.

The horizontal and vertical distribution pattern of the most dominant species/genera will be discussed in relationship to the hydrographic features.

## Differential grazing impact of dominant copepod species in the Antarctic Polar Frontal Zone – towards a concept of the functionality of copepod populations in HNLC areas

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The role of copepods in the pelagic ecosystem and in ocean biogeochemistry is linked to the structure of the pelagic food web and the feeding preferences of grazers. Grazing activity of *Calanus simillimus* and *Rhincalanus gigas* was monitored before and during an iron-fertilized diatom bloom in the Antarctic Circumpolar Current (ACC; EisenEx). Results from *in vitro* incubations, gut fluorescence and respiration measurements were compared for both grazers and indicate differences in feeding behavior. *C. simillimus* heavily grazes large diatoms before and during the bloom which leads to a differential mortality of diatom species that is high enough to influence diatom population dynamics. *R. gigas* apparently feeds on detritus and microzooplankton before the bloom, a finding that can only be deduced through the combination of all three methods. Grazing activity of *R. gigas* in turn is strong enough to intercept the fecal pellet flux produced by *C. simillimus*. Furthermore, both copepods show a different vertical distribution. Habitat and resource partitioning leads to an effective retention of organic matter in the surface layer under pre-bloom conditions. Prey switching of *R. gigas* from detritus to diatoms during the bloom weakens the 'retention system' and leads to increased export. Feeding behavior and vertical distribution of the studied Antarctic copepods are similar to findings for *Neocalanus plumchrus* and *Neocalanus cristatus*, two dominant copepods of the sub-arctic Pacific gyre, indicating a similar functionality of copepod populations and that common principals are at work in both HNLC systems.

## Vertical zonation in the Baltic Sea

SCHULZ J AND HIRCHE H-J

*Alfred-Wegener-Institute for Polar and Marine Research, Germany*

The most important clines for marine organisms are formed by temperature and salinity. They separate water layers of different conditions and put constraints on the dispersal of zooplankton species. While stenoeicous species are bound to a layer euryoeicous can even live under non optimal conditions and enter adjacent strata. The spatial overlap of predators with the zooplankton defines the prey-field. Consequently clines may cause inhomogeneous resource distribution in the water column and affect energy transfer within the food web.

The hydrography of the central Baltic Sea is characterised by a permanent halocline in approximately 60m depth and a summer thermocline which separates the winter water from the warm surface layer. While the brackish water above the halocline is permanently renewed, the haline waters often face long stagnation before they are replaced during inflow events from the North Sea. To analyse the vertical zooplankton composition in relation to the hydrography of the Bornholm Basin we used a GLOBEC-Germany time series of vertically stacked multinet samples. It covers the period between March 2002 and May 2003 in the Bornholm Basin and includes data from an inflow event.

By means of multivariate discriminant function and canonical analysis we show a vertical zonation of the composition in the water column. In this mathematical analysis species contribute with different loadings to distinguish between samples. Three dominant distribution patterns are found:

- (1) Species inhabiting the warm summer surface layer above the thermocline.
- (2) Species inhabiting the layer of the winter water, which is temporarily constrained in volume when the thermocline develops.
- (3) Species inhabiting water masses below the halocline.

## Imaging the small Lightframe On-sight Keyspecies Investigation (LOKI)

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In-situ imaging of plankton taxa is a helpful tool to identify the occurrence of an individual in relation to the environmental parameters in its vicinity. These data contribute to the understanding of small scale effects in addition to results from net samples, which are biased by method-borne integration. To image small individuals with high magnifications and short shutter times in moving water masses the available light is a limiting factor. Here we demonstrate a new system developed for in-situ dark-field imaging of particles on small scales in optically defined volumes.

With a combination of different cylindrical lenses and a linear light source a beam of high flux is projected into the water. The beam is precisely constrained in one dimension and creates a light frame along the principal axis. Particles within this frame scatter light by internal or surface refraction, recorded by a camera that aims orthogonally at this beam. With a telecentric objective the sampled volume is quantified by width and height of the image and the extension of the constrained light frame. It allows to obtain detailed information on the structure of the particles, while objects out of the lightframe are nearly invisible. With this illumination sensitive cameras allow shutter times below 1 ms to image objects on scales of 10  $\mu\text{m}$  per pixel and provide images of high quality sufficient for taxonomic identification. Here we show first in-situ results of an improved video-plankton-recorder concept, based on the new developed Lightframe On-sight Keyspecies Investigation (LOKI) method.

## Tidal Transport of Decapoda at Catuama Inlet (Pernambuco, Brazil).

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It is well known that tropical mangrove estuaries are the habitat of innumerable invertebrate species, that may build up high adult biomasses in these areas. Although larval production may be one of the main processes of benthic-pelagic coupling in mangrove areas, the mechanisms involved in larval export from tropical estuaries have been limited to few investigations. The present study is the first attempt to describe and model the dynamic transport of decapod crustacean larvae in a tropical estuarine inlet using high-resolution 3-D current data and vertically and horizontally discrete plankton sampling. Sampling was performed at Catuama Inlet, which separates the northern margin of Itamaracá Island (Pernambuco State, northeastern Brazil) from the adjacent continent. Samples were taken in 3-hour intervals during spring tide (05 to 06 August, 2001) and neap tide (11 to 12 August, 2001). Plankton samples were taken with a pump at three stations along a transect across the inlet. Additionally, 3-D current profiles were obtained with an ADCP (acoustic doppler current profiler) probe that was attached alongside to the boat. The ADCP profiles showed the predominance of vertically and horizontally heterogeneous current fields. Accordingly, zooplankton transport was not homogeneous, with higher organism and biomass transport rates in the surface layer. The average instantaneous biomass transport was  $98.1 \pm 75.9 \text{ mg m}^{-2} \text{ s}^{-1}$ , during spring tide and  $31.46 \pm 26.52 \text{ mg m}^{-2} \text{ s}^{-1}$ , during neap tide. The main biomass transport peaks were related to peak densities of decapods and calanoid copepods. Average instantaneous zooplankton transport was  $831.5 \pm 1192.5 \text{ ind. m}^{-2} \text{ s}^{-1}$ , and  $342.3 \pm 445.8 \text{ ind. m}^{-2} \text{ s}^{-1}$ , for spring and neap tide, respectively. Most of the plankton export (at biomass and organism level) from the estuary occurred during the night. We identified 27 taxa of Decapoda (larvae of Sergestidae, Porcellanidae, Upogebiidae, Caridea and Brachyura). The dominant taxa were the first larval stages of the planktonic shrimps *Lucifer faxoni* and *Acetes americanus*. Most species and stages showed characteristic vertical migration patterns in phase with tidal and diurnal cycles, enhancing retention or export from the estuary.

## Variability of mesozooplankton spatial distribution in the N.Aegean Sea, as influenced by the Black Sea waters outflow

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The North Aegean Sea occupies an important position within the Mediterranean Sea since in its eastern part the mesotrophic, low salinity and relatively cold water from Black Sea (out flowing from the Dardanelles strait) meets the oligotrophic, warm and very saline water of Levantine origin, thus forming thermohaline fronts. Mesozooplankton samples were collected at 15 stations and at discrete layers (according to the hydrology) in May 1997 and September 1998. During May highest biomass and abundance values (up to 66.82 mg m<sup>-3</sup> and 14157 ind m<sup>-3</sup>) were detected in the halocline layer of the stations positioned close to the Dardanelles straits. In September the front has moved slightly southwards, characterized also by high biomass and abundance values within the halocline layer. In both periods values were lower at the stations positioned at distance from the straits, but zooplankton was richer in the uppermost low salinity layer, than in deeper layers. Hierarchical clustering has distinguished in both periods the group of samples collected at the stations and layers more influenced by the Black sea waters from those collected at layers and/or stations with higher salinity. In May the first group was characterized by the copepods *Acartia clausi*, *Centropages typicus*, *Clausocalanus paululus*, *C.pergens*. The abundance of the above species decreased gradually with increasing salinity in the area, either in the horizontal or in the vertical scale; at these stations and/or layers the copepods *Clausocalanus jobei*, *C.arcuicornis*, *Ctenocalanus vanus*, *Oithona plumifera* were found abundant. In September the low salinity area was highly dominated by the cladoceran *P.avirostris* and appendicularians characterized the frontal stations. Their abundance declined as salinity increased following the spreading and mixing of the Black sea water. The temporal variability of these processes seems to affect the spatial and temporal variability in mesozooplankton abundance and composition. The influence of these hydrological characteristics has been proved to be significant on the mesozooplankton community of the area, especially in terms of standing stock, which could support higher trophic levels.

## Parameterisation of a zooplankton population model for *Pseudocalanus elongatus* in the North Sea using stage durations from mesocosm experiments.

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A zero-dimensional population model based on a copepod model by Fennel [Fennel,2001] was parameterised according to population dynamics of *Pseudocalanus elongatus*. The model consists of state variables for five stage-groups, representing aggregated live stages (non-feeding eggs-NII, NIII-NVI, CI-CIII, CIV-CV and adult CVI). Biological functions were chosen particularly with regard to physiological behaviour to get realistic characteristics of growth and development under conditions of temperature and food reported for the North Sea.

Parameter values for weight, feeding and metabolism were taken from the literature where possible, implying robust values from various published studies and parameters derived from similar species. Values not possible to get experimentally were obtained indirectly by successive fitting of developmental times to stage durations observed from mesocosm studies. A data set from Klein Breteler *et al.* [Klein Breteler *et al.*, 1995] was used, which includes estimates at temperatures of 5, 10, 15 and 20°C each at food concentrations of <70, ~100 and >300 µg C l<sup>-1</sup>. Simulations at each scenario shows the coherence of adjustment.

The sensitivity of model parameter values was tested in terms of variances in generation times. The analysis shows the sensitivity of development to specific metabolic processes, while the importance of temperature is reflected in its recurrence within processes. The model is able to represent consistent development comprising physiological complexity of a copepod population.

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## **Planktonic Copepods and Their Food: a Lesson in Nano-Technology**

STRICKLER J. RUDI

*WATER Institute, University of Wisconsin – Milwaukee, USA*

Microfluidics provides a new outlook at the feeding performances of planktonic copepods and cladocerans. Besides new instrumentation, novel first principals have been found and astonishing results achieved. In light of this progress I will examine the interface of suspended particles and grazing animals using the nano-technologist's approach to see whether or not our common picture of the interface needs a revision. Additionally, I will report from experiments where we used epi-fluorescence microscopy and high-speed video to observe the fate of particles of sizes well below the setule spacings. I will illustrate with videos the results during the talk.

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I WILL NEED TO HOOK UP MY OWN PC-LAPTOP TO A VIDEO PROJECTOR. I CANNOT PROVIDE A CD/DVD BECAUSE MY AVI-FILES ARE TOO LARGE.

## Diel changes of phyto- and zooplankton (Gdańsk Deep, Baltic Sea) – a simultaneous field study

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The key to understanding of the role of zooplankton in the pelagic ecosystem is learning its interactions with biotic and abiotic elements of its environment. The direct relations between zooplankton and phytoplankton are the first chain to investigate. The majority of studies on these relations have been conducted under experimental conditions and it is much more difficult to investigate the same interactions directly in the environment, where many additional factors can influence the observed effect.

Our studies consisted of simultaneous observations of phyto- and zooplankton in the diel cycle directly in their environment. We focussed on following the behaviour of both components in the water column at different times of a day and night and discovering their interrelations.

Studies were conducted in the Gdańsk Deep (Southern Baltic) in the diel cycle in June 1998. Phytoplankton was sampled with the Patalas sampler and vertical hauls of the zooplankton were done using a Copenhagen net (closed type, entrance diameter 0.5m, 100µm mesh size). Planktonic material was examined the laboratory according to a standard methods.

The detailed analysis of the dynamics of diel changes in phytoplankton showed that the species composition and vertical distribution of its components did not change distinctly during the diel cycle. Irrespective of the depth, phytoplankton was dominated by cyanobacteria, among which the genus *Aphanizomenon* was the most abundant.

Zooplankton was represented by taxa characteristic of this region – Copepoda (mainly *Temora longicornis*, *Pseudocalanus elongatus*, *Acartia longiremis*), Cladocera (*Evadne nordmanni*, *Podon polyphemoides*), Rotatoria (*Synchaeta* spp.), Appendicularia (*Fritillaria borealis*) and meroplankton. None distinct diel vertical migrations of the whole zooplankton or any of its components were observed. This type of behaviour was noted only in some species of copepods at some stages of their ontogenetic development. The distribution of the remaining organisms in the water column was uniform or reflected their preferences for occupation of certain layers of the water column, irrespective of the time of a day.

Both phyto- and zooplankton in the region of the Gdańsk Deep in the studied period concentrated mainly in surface layers and the number of organisms decreased with the depth. The vertical distribution of a different character than this pattern was observed while analysing each taxon separately. No negative influence of the mass occurrence of cyanobacteria on the presence of zooplankton was observed.

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## **GLOBEC Germany data base for zooplankton and fish larvae measurements: cruise data overview and sampling strategy.**

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This paper outlines the structure and content of the project database GLOBAN (**Globec Baltic Sea –North Sea**) of the GLOBEC Germany project. GLOBEC Germany is focussing on trophic interactions between zooplankton and fish under the influence of physical processes. This will be done by using a combination of field studies, experimental investigations and modelling recruitment success. The aim of the field studies is to get measurements of the two planktivorous clupeids *herring* and *sprat* on one hand and the copepods *Pseudocalanus spec.*, *Acartia spec.* and *Temora longicornis*.

The sampling strategy was realised by station grid sampling. The same gears were employed on a predefined grid every cruise. For the identification of the front systems in the North Sea (tidal mixing front and river plume front) the sampling was carried out on transects.

Currently the GLOBAN-database contains metadata of 39 cruises from the years 2002 to 2004. The Baltic Sea was addressed by 26 cruises and the North Sea by 13 cruises. This leads to a total of 10367 records with metadata. Additionally there is already field data available from the database. 2822 Bongo- and Multinet hols have produced a number of 89505 records with abundance or length of zooplankton. The target species are determined with regard on their developmental stages nauplii, copepodite stages CI – CV and adult stage CVI (separated into male and female). Stage resolved length class diagrams will elucidate this data.

Furthermore field data is available from the fish trawls (519 catches). 15842 records with length classes (mainly clupeids) and 9327 single fish records with length, weight, maturity, liver weight and gonade weight (mainly cod) are available. A subdivision from the length measurements of sprat had been classified for the maturity of the gonades (7068 records).

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## **Plankton in spatially variable systems can be preadapted to environmental fluctuations and change.**

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Most animals are mobile, and can choose their home range and habitat. Therefore, they do not have to be able to cope with all the spatial environmental variability of their ecosystems. Further, emigration out of temporarily unfavourable patches into temporarily favourable ones can reduce the experienced temporal environmental variability of animals. The situation for plankton is very different from that outlined above, since they by definition are unable to choose their horizontal position. Although some level of retention can be achieved through vertical migration within a stratified water column, oceanic plankton go with the flow, and therefore, to a large extent, have to deal with whatever environment the currents give them. Because of this, plankton living in large, spatially variable systems will experience temporal environmental variability even in static environments, and may therefore be preadapted to environmental fluctuations and changes. Building on the model of [Lynch and Gabriel 1987], I present a generic analysis of this mechanism.

### REFERENCES

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## Recent bloom of the giant jellyfish *Nemopilema nomurai* (Scyphozoa: Rhizostomeae) in East Asian waters: cause and consequence

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*Nemopilema nomurai* (Cnidaria: Scyphozoa: Rhizostomeae) is one of the largest jellyfish species in the world, attaining a bell diameter of ca. 2 m and a wet weight of ca. 200 kg. Previous reports on its occurrence indicate that the main habitat of this species is in the northern part of the East China Sea, Yellow Sea, and Bohai Sea. This species is also carried by the Tsushima Current to the Sea of Japan, usually in small numbers, but very rarely in extreme abundances (e.g. tens of thousands of medusae entrapped in a set-net per day) sufficient to seriously damage local fisheries. To our knowledge, such mass occurrences of *N. nomurai* took place in 1920, 1958, 1995, 2002, 2003 and 2005, indicating that the blooms have become much more frequent and larger in extent over the last decade.

We demonstrated the seasonal life cycle of this species, by obtaining scyphistomae and rearing them through to the young medusa stage in the laboratory. Asexual reproduction of scyphistomae occurred by means of podocyst formation. A thermal increase from 13 to 23°C induced strobilation, followed by liberation of 3-7 ephyrae from a strobila. The ephyrae developed to metephyrae having a complex canal system and characteristically possessing long reddish purple filiform appendages. By 40-days post liberation, the metephyrae grew to medusae in which the central mouth had closed and been replaced by numerous mouthlets on both oral wings and scapulets.

In years of blooming, abundant young medusae which might be originated from Chinese and western Korean coastal waters began to appear in the Tsushima/Korea Straits in July/August. Then, they were transported northward by the Tsushima Current to the northern Sea of Japan. The bloom of 2005 was perhaps the largest ever in history, giving severe nuisance to fisheries, particularly net-fisheries. The problems included: 1) clogging and bursting of the nets, 2) lower catches of finfish, 3) high mortality of finfish by nematocyst venom and low commercial value, 4) heavy labor in removal of medusae from the nets, 5) higher risk of capsizing trawl boats, 6) painful stings caused by medusae, etc.

It has been argued that environmental changes, such as increased eutrophication, habitat modification, over-fishing, and global warming, may be responsible for the enhancement of the jellyfish populations. Indeed, such environmental changes are significant in Chinese coastal waters. Hence, we speculate that both recent ecosystem change and annual hydrographical conditions (e.g. Changjiang River discharge, expansion of low salinity water mass, strength of the Taiwan-Tsushima Current) in the nursery ground of *N. nomurai* may be responsible for the frequent bloom occurrence in the Sea of Japan.

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## Carbon cycling in coastal upwelling areas at the Humboldt Current System off Chile

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Planktonic food web structure and carbon dynamics were studied in two coastal embayment off Northern (23 °S) and Central Chile (36.5 °S) over a seasonal time-scale. In northern Chile, upwelling is intermittent throughout the year, whereas in Central Chile, upwelling events are seasonal, mostly concentrated during the spring/summer months. During upwelling events, the water column is characterized by the presence of a shallow (30 to 40 m depth) oxygen minimum layer (OML), where chain-forming diatoms that were grazed by small zooplankton and h-dinoflagellates comprised most of the autotrophic biomass. H-nanoflagellates were largely bacterivorous in both ecosystems, with a substantial removal of bacterial biomass mostly associated to productive surface waters and with depth of the OML. Protozooplankton biomass removed a significant fraction of h-nanoflagellate production (12 to 22 % d<sup>-1</sup> of its production). Thus, the microbial food web could transfer bacterial carbon to protozooplankton and thereafter to zooplankton. The impact of small zooplankton on primary production (PP) was relatively low both in coastal areas of northern and central Chile. Copepods and appendicularians removed between 0.6 to 5 % of PP d<sup>-1</sup>. Appendicularians were the only zooplankton able to graze on bacteria, but grazing impact was not sufficient to regulate bacterial biomass. The microheterotrophic pathway might be an important link in highly productive upwelling embayment. Results showed that a large part of the photosynthetically fixed carbon was mostly channeled through the *microbial* food web by the grazing pressure of protozooplankton, and only a small part directly toward to copepods and appendicularians in the *classical* food-web. The food web structure in both embayment of northern and central Chile can be classified as multivorous, where herbivorous and microbial grazing has important roles in carbon export.

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## State-dependent phenology and resource allocation of the Southern Ocean copepod *Calanoides acutus*

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Many plants and animals can grow or reproduce only at certain periods of the year. Herbivorous copepods at high latitude depend on the seasonal phytoplankton production for food, and their life history and behaviour are fine-tuned to match the intensive bloom period. Here we model the optimal life cycle of the abundant Southern Ocean copepod *Calanoides acutus*. Recent modelling results suggest that the life cycle is typically completed within a year, but that two years are needed in some cases. Timing of key life cycle events may therefore be particularly important to ensure development from egg to a copepodite stage capable of surviving the winter as well as maturing and reproducing next spring. *C. acutus* migrate between the relatively food rich but risky surface waters in the summer and deeper and safer waters in the winter. Large energy reserves are stored to sustain metabolism during winter and maturation and reproduction in advance of the phytoplankton bloom the following spring. We expect individuals to behave differently depending on developmental stage and condition. Therefore, a dynamic state variable model is used to predict, on a daily time scale, optimal habitat choice and allocation decisions for individuals with different combinations of structural body mass and energy reserves. The model predicts timing of seasonal migration and egg-production as well as how resources are allocated to structural growth, energy reserves and reproduction. Furthermore, we perform population simulations of individuals following this behaviour and compare the results with observed dynamics. Some predictions are also made where field observations are scarce, for instance by exploring how optimal strategies change under different seasonal patterns of predator abundance.

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## Indications of bottom-up control of sprat recruitment in the Baltic Sea.

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Sprat (*Sprattus sprattus* L.) is an important commercial fish species in the Baltic Sea, and variable recruitment and large fluctuations in stock size have been observed in recent years. Within the GLOBEC-Germany program, we have performed a comprehensive study of the processes affecting zooplankton-fish interactions and their impacts on recruitment variability of sprat in the Central Baltic Sea. The present analysis focuses on mechanisms acting during the 2002 sprat spawning. To assess potential bottom-up control, we combined monthly data on larval sprat abundance, gut contents, growth and condition proxies (RNA/DNA, otoliths, lipid contents) and mortality estimates with highly-resolved *in situ* zooplankton data. Additionally, young-of-the-year (YoY) sprat were sampled in late autumn from the same study region to determine characteristics of survivors. Otolith microstructure analysis indicated that the majority of YoY individuals caught in October 2002 hatched during a confined window (mid June-mid July) that did not coincide with the main period of egg and larval production (April). Strong evidence for selective survival was also reflected in the temporal pattern of variations in larval gut contents and condition proxies during the spawning season. By adequately monitoring the species composition and the size- and stage-specific abundance and distribution of zooplankton, it was possible to 1) determine the spatial overlap of larval predators and their potential prey, and 2) identify a bottom-up mechanism potentially limiting larval survival. Specifically, throughout the 2002 spawning season, first-feeding (<10 mm) Baltic sprat larvae were always food-limited and larger (>16 mm) larvae were not food limited. In contrast, marked temporal variability in food limitation was found for medium-sized larvae. Our results suggest that, as sprat larvae grow, larval survival depends upon encountering a succession of suitable, available prey organisms. We hypothesize that medium-sized larvae form a critical life stage where most of the inter-annual variability in larval sprat survival is generated. Evidence from the Baltic suggests that larval survival can be governed by match-mismatch dynamics occurring between larval cohorts and the phase of the seasonally developing plankton cycle.

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## Cannibalism in North Sea copepods

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Mortality is an important factor controlling seasonal and annual community structure and abundance patterns of copepods. Among the factors causing mortality cannibalism has received only a little attention and data on feeding rates. In this study feeding of dominant adult female copepods (*Acartia* spp., *Centropages hamatus*, *C. typicus*, *Temora longicornis*) on eggs and early nauplii was investigated in the German Bight (southern North Sea). In bottle incubation experiments different densities of single prey and mixtures of different prey species were offered. Additionally experiments with different concentrations of algae (*Thalassiosira weissflogii*) at a constant concentration of eggs were conducted. In single prey experiments cannibalism on eggs and early nauplii stages occurs in all species but with different rates. Lowest predation rates on eggs and nauplii were observed in *Acartia* spp. while the two *Centropages* species showed highest rates. Ingestion of *Centropages* spp. eggs was in general lowest, eventually due to their spiny surface. In contrast, predation on *Centropages* spp. nauplii was highest in all species. When eggs and nauplii were offered at the same concentration *T. longicornis* preferred eggs whereas *Acartia* spp. and *C. typicus* selected nauplii. Predation on copepod eggs by *Acartia* spp. and *C. typicus* was enhanced with the addition of algae. The opposite was seen for *T. longicornis* where ingestion of eggs decreased when alternative algae food was offered.

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## **Vertical carbon flux of biogenic mater in a coastal area of the Aegean Sea. Importance of appendicularians and phytoplankton**

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The contribution of phytoplankton and zooplankton in the vertical carbon flux of particulate biogenic matter was studied during spring in a coastal area of the northern Aegean Sea (Thermaikos Gulf). Arrays of cylindrical sediment traps were deployed for 10 days at 2 depths (7.5 and 12.5 m) and samples were taken approximately every 48 h. The magnitude of the vertical flux of particulate organic carbon (POC) ranged between 310 and 723 mgC m<sup>-2</sup> d<sup>-1</sup>. The proportion of phytoplankton carbon in the POC vertical flux was up to 45%. The vertical flux of phytoplankton was dominated by a large variety of diatoms, dinoflagellates and flagellates.

Appendicularian houses with attached detritus were also an important component of the biogenic carbon flux (exceeding 300 mgC m<sup>-2</sup> d<sup>-1</sup>) and they contributed up to 30% and 38% of the total vertical carbon flux (at 7.5 m at 12.5 m respectively). This value is among the highest reported in the Mediterranean Sea. Zooplankton community during the period of study was dominated by the appendicularians (246-1012 ind m<sup>-3</sup>) followed by copepods (74-263 ind m<sup>-3</sup>). However the abundance of appendicularians can reach 3860 ind m<sup>-3</sup> in this area, thus their contribution to the vertical carbon flux is expected to be higher. The carbon flux from zooplankton faecal pellets (up to 27 mgC m<sup>-2</sup> d<sup>-1</sup>) and dead animals was negligible. Consequently, phytoplankton and the appendicularian houses were the most important constituents of the vertical carbon flux in Thermaikos Gulf contributing equally to the biogenic carbon flux and both of them overwhelmed the 70% of the total sinking POC. Considering the shallowness of the area (~15m) all this carbon arrives to the bottom. The considerable role of appendicularians to carbon fluxes indicate that they should be included in future flow models of coastal areas.

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## **Zooplankton Size Structure Shift in the Moroccan upwelling area: A retrospective analysis**

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The 24°N transect offshore of Dakhla bay is a very interesting area of study, in terms of fishing (pelagic resources, cephalopods, demersal resources), and from a scientific point of view. In fact this area is submitted to a permanent upwelling activity. This phenomenon is responsible for maintaining high productive area.

From 1994 to 2004, zooplankton have been collected along the Dakhla transect, where pelagic fish recruit each year. Retrospective analysis of 10 years zooplankton collections showed a shift in the community size structure. This variability is related to the variability of the environmental conditions of the area, particularly to upwelling variability.