

4th International Zooplankton Production Symposium

**Human and Climate Forcing of
Zooplankton Populations**

28 May - 1 June 2007

Hiroshima, Japan

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Welcome

On behalf of the symposium organisers, I warmly welcome fellow zooplanktologists from all over the world to Hiroshima, a peace city revived from the ruins after the atomic bomb some 60 years ago. At this symposium there will be more than 450 delegates from 54 countries, which may be the largest meeting of zooplanktologists ever. The scientific focus of this symposium “Human and climate forcing of zooplankton populations” is timely reflecting our current concerns about global warming, climate change, coastal ecosystem degradation and decreases in fisheries. It is also of great significance that this is the first such meeting to be held in Asia, where serious degradation of the marine ecosystem is occurring although holistic studies on the relationship between zooplankton and the environment are still at an early stage in many Asian countries. I hope that this symposium will provide an opportunity for all participants to present their own research findings, exchange experiences and data, obtain new ideas and techniques, and of course, make warm mutual friendships. The traditional name of this symposium, “Zooplankton Production Symposium” may not fit with today’s multidisciplinary approach to zooplankton studies. We may need a new framework for future zooplankton symposia in the same way that we need a new barrel for new sake (Japanese rice wine). I hope that this symposium may give future directions for zooplankton studies.

The organisation of this symposium started after an informal request to me over the extravaganza dinner table in Gijón. I have explored the availability of conference facilities, hotels, manpower, etc., and decided to hold the symposium in Hiroshima, my hometown. I have been given enormous support from many sectors during the preparation, and the organisers are very happy to be able to open the door of the Hiroshima International Conference Center on 28 May. I wish that both this symposium and your stay in Hiroshima are memorable for all participants.

Shin-ichi Uye

Symposium Convenor and Chair of the local organising committee

Background

Zooplankton play a key role in the pelagic food web by controlling phytoplankton production and shaping pelagic ecosystems. In addition, because of their critical role as a food source for larval and juvenile fish, the dynamics of zooplankton populations have a critical influence on recruitment to fish stocks. It is this latter role which has made zooplankton ecology of particular interest to ICES.

In 1961, ICES convened the 1st Zooplankton Production Symposium in Charlottenlund (Denmark). ICES also had a lead role in the 2nd Symposium on “Zooplankton Production: Measurement and role in global ecosystems dynamics and biogeochemical cycles”, held in Plymouth (UK), in 1994. The increasing importance of international programmes such as GLOBEC (Global Ocean Ecosystem Dynamics) and the general concerns about global change and the changing role of zooplankton in ocean ecosystems have been reflected in the development of these Symposia.

This trend was further enhanced in the 3rd Zooplankton Production Symposium “The role zooplankton in global ecosystem dynamics: Comparative studies from the world oceans”, which was held in 2003, in Gijón (Spain). For the first time the Symposium was co-sponsored by ICES, PICES and GLOBEC. The Gijón Symposium attracted 333 participants from 38 countries from around the world.

The 4th Zooplankton Production Symposium again co-sponsored by ICES, PICES and GLOBEC, will be held 28 May - 1 June 2007 at the International Conference Centre in Hiroshima, Japan. The Symposium is the first of the series to be held outside Europe, and will focus on “Human and climate forcing of zooplankton populations”. As such, it represents a timely topic and will provide an important opportunity to further develop the truly international nature of zooplankton research.

The organisation and sponsors

Symposium Convenors

Michael J. Dagg (USA/PICES)

Roger P. Harris (UK/GLOBEC)

Shin-ichi Uye (Japan)

Luis Valdés (Spain/ICES)

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North Pacific Marine Science
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International Council for the
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Local sponsors

Hiroshima University

The Japanese Society of Fisheries Oceanography (JSFO)

The Plankton Society of Japan (PSJ)

With additional support from

Hiroshima Convention and Visitors Bureau

Shibuya Scholarship Foundation

Commemorative Organization for the Japan World
Exposition ('70)

Scientific Committee on Oceanic Research

Financial support was also gratefully received from:

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Notes for guidance

Registration

The registration desk will be located in the lobby of the 2nd basement floor and will be open from 09:00 to 17:30 on 28 May and from 08:00 to 17:30 on 29 May. The symposium secretariat will be based in room Ran 1.

Presentations

In order to allow the sessions to run smoothly and in fairness to the other speakers, please note that all presentations are expected to adhere strictly to the time allocated. The time for your presentation can be found in the agendas starting on page 1 of this abstracts book. Please give a copy of the electronic file of your presentation to the Symposium secretariat at registration or at least one day before your presentation. Operating systems available are Windows XP (Powerpoint 2003) and Mac OS10 (Powerpoint 2004).

Posters

Posters will be on display after the afternoon break on 29 to 31 May (noon) in the Himawari room. Posters may be put up from the afternoon of 28 May. Poster presenters are expected to be available to answer questions during the two evening poster sessions/receptions on 29 and 30 May from 18:00-20:00.

Refreshments

There will be morning and afternoon tea/coffee breaks (please see the agenda on pages 1-39 for times). Tea and coffee will be served in the lobby on the morning of 28 May and on 31 May - 1 June. The Himawari room will be used for tea/coffee breaks in the afternoon of 28 May and for both breaks on 29-30 May.

A Japanese style lunch box including tea (price: 800 JPY) and a sandwich and juice (price: 600 JPY) will be sold at the Conference Center. It is necessary to buy the lunch ticket on the previous day. A complimentary lunch (sandwich and juice) will be provided on 31 May prior to the afternoon excursion.

Internet access

Free internet access via wireless LAN is available in the International Conference Center building in the poster session room (Himawari) and lobby area of the 2nd basement floor.

Standard: IEEE802.11b/g base

Connection: Automatic assignment of IP-address by DHCP server

SSID: FREESPOT

Please note that the organisers are unable to lend wireless LAN cards and that no extra security measures are implemented. Each user is responsible for adjusting their own PC settings and the organisers will not be held responsible for any mechanical failures and other damage that may arise from the use of this service.

Social activities

28 May: Welcome reception (International Conference Center, Himawari Room)

29-30 May: Two evening poster sessions/receptions (International Conference Center, Himawari Room)

30 May: Afternoon excursion to the Itsukushima Shrine in Miyajima and Symposium Dinner (ANA Hotel)

General programme

Time		Events		
Monday 28 May	10:00 - 18:00	Workshop 1 (Cosmos 1)	Workshop 2 (Dahlia 1)	Workshop 3 (Dahlia 2)
	18:00 - 20:00	Welcome reception (Himawari)		
Tuesday 29 May	09:00 - 12:30	Plenary (Himawari)		
	14:00 - 17:40	Session 1 (Dahlia 1)	Session 2 (Dahlia 2)	
	18:00 - 20:00	Poster session (Himawari)		
Wednesday 30 May	09:00 - 12:40	Session 7 (Dahlia 1)	Session 8 (Dahlia 2)	
	14:00 - 18:00	Session 7 (continued) (Dahlia 1)	Session 10 (Dahlia 2)	
	18:00 - 20:00	Poster session (Himawari)		
Thursday 31 May	09:00 - 12:40	Session 5 (Dahlia 1)	Session 6 (Dahlia 2)	
	12:40 - 17:00	Excursion to Miyajima		
	19:00	Symposium dinner (ANA Hotel)		
Friday 1 June	09:00 - 12:40	Session 3 (Dahlia 1)	Session 9 (Dahlia 2)	
	14:00 (S3) - 17:00 13:45 (S4) - 17:00	Session 3 (continued) (Dahlia 1)	Session 4 (Dahlia 2)	
	17:00 - 18:00	Closing ceremony (Dahlia 1 and 2)		

P Plenary

S1 Global comparisons of zooplankton time series

S2 Importance of zooplankton in biogeochemical cycles

S3 The role of zooplankton in food webs: changes related to impacts of climate variability and human perturbation

S4 Mortality impacts on the ontogeny and productivity of zooplankton

S5 Zooplankton functional groups in ecosystems

S6 Microbial loop vs classical short food chains: implications for appraisal of food web efficiency and productivity

S7 Environmental and other constraints on zooplankton behaviour, life histories and demography

S8 Zooplankton biochemistry and physiology: practical and potential biotechnology applications

S9 Advances in image technologies and the application of image analysis to count and identify plankton

S10 Analysis and synthesis: modelling zooplankton in aquatic ecosystems

W1 Temporal and regional responses of zooplankton to global warming: phenology and poleward displacement

W2 Zooplankton research in Asian countries: current status and future prospects

W3 Krill research: current status and its future

Agenda and orders of the day by session

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P Plenary

Co-convenors: *Michael J. Dagg (USA/PICES), Roger P. Harris (UK/GLOBEC), Shin-ichi Uye (Japan) and Luis Valdés (Spain/ICES)*

Tuesday 29 May 2007 09:00 - 12:30

- 09:00 ***Opening ceremony***
- 09:45 **Victoria J. Fabry, Brad A. Seibel, Richard A. Feely and James C. Orr**
Impacts of ocean acidification on marine zooplankton: knowns and unknowns (Plenary-3738)
- 10:30 ***Tea / coffee break***
- 11:00 **Anthony J. Richardson**
In hot water: zooplankton communities now and in the future (Plenary-3798)
- 11:45 **Albert Calbet**
The role of microzooplankton in a changing ocean (Plenary-3401)
- 12:30 ***Lunch***

S1 Global comparisons of zooplankton time series

Co-convenors: David L. Mackas (Canada) and Luis Valdés (Spain)

Invited speaker: Evelyn C. (Chris) Pielou (University of Lethbridge, Canada)

Zooplankton time series are now being collected in many widely-separated ocean regions. Several important within-region analyses of the longer time series were completed during the past decade, and a new SCOR Working Group (#125) was recently formed to promote between-region comparisons. In this session, we invite papers that provide either new within-region zooplankton time series data and analyses, or make between-region and between-variable comparisons. We are especially interested in zooplankton time series that go beyond biomass to include information on variability of community composition, zoogeographic distributions, phenology, and/or physiological “condition”, and in papers that examine the role of zooplankton in how entire marine ecosystems might respond to climate variability and change.

Tuesday 29 May 2007 14:00 - 17:40

- 14:00 **Welcome by convenors**
- 14:05 **E. Chris Pielou**
Plankton, from the last ice age to the year 3007 (S1-3357)
- 14:35 **Rabea Diekmann, Christian Möllmann, Georgs Kornilovs and Ludvigs Sidrevics**
Direct and indirect effects of climate on the zooplankton community of the Central Baltic Sea (S1-3446)
- 14:55 **Sergey A. Piontkovski**
Zooplankton time series of the World Ocean: pilot results of a global comparison (S1-3603)
- 15:15 **Carmen Garcia-Comas, Lars Stemmann, M. Grazia Mazzocchi, Elvire Antajan, Gregory Beaugrand, Frederic Ibanez, Marc Picheral, Maurizio Ribera d'Alcalà and Gabriel Gorsky**
Comparison of copepod decadal variability in the coastal Ligurian and Tyrrhenian Seas (Mediterranean Sea) (S1-3544)
- 15:35 **Tea / coffee break**
- 16:00 **William T. Peterson and Cheryl A. Morgan**
The influence of ENSO events and the PDO on copepod biodiversity and community structure in the Northern California Current: is climate change a contributing factor? (S1-3528)
- 16:20 **Sanae Chiba**
Transformation of zooplankton community in the western North Pacific with warming condition after the 1990s (S1-3573)
- 16:40 **Patricia Ayón, Katia Aronés, Carmela Nakazaki and Roberto Quesquén**
Variability in zooplankton community indexes at two coastal areas of Peruvian coastal waters between 1994 and 2006 (S1-3688)
- 17:00 **Hans M. Verheye, Fabienne Cazassus, Anja Kreiner, Sakhile Tsotsobe, Tebello Mainoane, Rudi Cloete and Ferdi Kotze**
Long-term changes in abundance and community structure of copepods in the northern Benguela upwelling system off Namibia, 1950s-present (S1-3567)
- 17:20 **George Wiafe, Hawa B. Yaqub, Martin A. Mensah and Christopher L.J. Frid**
The impact of climate change on long-term zooplankton distribution in the Gulf of Guinea upwelling region (S1-3508)

S1 Posters

- S1-3257 **Elayaraja Paramu and Ramanibai Ravichandran**
Composition, abundance and diversity of zooplankton in Ennore creek, Tamilnadu, India
- S1-3295 **Mohammad Ali and Faiza Al-Yamani**
Distribution and abundance of *Oikopleura* spp. in Kuwait Bay during 2003-2005
- S1-3317 **Fabiana L. Capitano, Mariela L. Spinelli, Rubén M. Negri, María Delia Viñas and Graciela B. Esnal**
Spatio-temporal distribution and ecological role of appendicularians off the La Plata River estuary (34°-39°S, 52°-58°W), southwestern Atlantic Ocean
- S1-3321 **Jens Rasmussen and Johanna Sidey**
Zooplankton in the Irminger Basin: a comparison between 1963 and 2002 surveys, and the CPR time series
- S1-3323 **Gisèle Champalbert, Marc Pagano and Pierre Séne**
Changes in zooplankton and micronekton community structure induced by human action in the Senegal River estuary
- S1-3343 **Rosamma Stephen, K.J. Jayalakshmi, P. Sabu, J. Jacob, G. Sumitha and C.T. Achuthankutty**
Variability of zooplankton and calanoid copepod community in the eastern Arabian Sea, an evaluation
- S1-3384 **Kazuaki Tadokoro, Yuji Okazaki, Tsuneo Ono and Hiroya Sugisaki**
Decadal scale variations in *Neocalanus* copepod biomass in the Oyashio and Kuroshio-Oyashio Transition waters of the western North Pacific
- S1-3443 **Cheryl A. Morgan, William T. Peterson, Jeannette E. Zamon, Julie E. Keister, Jesse F. Lamb, Moira Galbraith, Molly V. Sturdevant, David L. Mackas, Joseph A. Orsi, Stephen J. Romaine, Mary E. Thiess, Marc Trudel, David W. Welch and Bruce L. Wing**
Latitudinal gradients in copepod community composition in the northern California Current and the southern Gulf of Alaska during years of varying ocean conditions
- S1-3444 **Anja Kreiner, Hans M. Verheye and Rudi Cloete**
Spatial and temporal variability of the copepod community along a monitoring transect in the northern Benguela during 2000-2006
- S1-3450 **Moira Galbraith and David Mackas**
Changes in the chaetognath community along the Vancouver Island continental margin and in the subarctic NE Pacific
- S1-3465 **Vijayalakshmi R. Nair**
Phenomenal changes in chaetognath community of the Andaman Sea, Indian Ocean
- S1-3466 **Claudia Castellani, Anthony J. Richardson, Sonia Batten, Graham W. Hosie, Xabier Irigoien and Roger P. Harris**
Temporal and spatial variability of *Oithona* spp. abundance and phenology in the North Atlantic, North Pacific and Southern Ocean using the CPR data
- S1-3509 **Webjørn Melle, Jörg Assmus and Cecilie T.Å. Broms**
Diversity, seasonal cycles and recruitment processes of zooplankton in coastal and oceanic waters in relation to environmental variability; a time series study at a standard section off western Norway
- S1-3514 **Todd D. O'Brien, David L. Mackas, Hans M. Verheye and remaining WG-125 members**
SCOR WG-125: Global Comparisons of Zooplankton Time Series
- S1-3519 **Steve Hay, S. Robinson, J. Fraser, J. Rasmussen, K.B. Cook, J. Dunn, M. Heath, E. Bresnan, S. Fraser, D. Lichtman and M. Rose**
Zooplankton community description and comparison of seasonal population development for common species and groups, sampled weekly at time series sites on the Scottish east and west coasts

- S1-3523 **Rubén V. Escribano, Carmen E. Morales, Osvaldo Ulloa, Humberto H. González, Alvaro Araneda, Valeria Anabalón, Karen Manríquez, Pamela Hidalgo, Daniela Böttjer, Gadiel Alarcón, Ramiro Riquelme, Ricardo Giesecke, Paula Mendoza, Rita Riquelme, Eduardo Menschel and Carola Aparicio**
Plankton time series in the coastal upwelling off central-southern Chile (Station 18): driving forces on planktonic community structure
- S1-3534 **Astthor Gislason and WGZE**
ICES Working Group on Zooplankton Ecology
- S1-3542 **Serena Fonda Umani, Valentina Tirelli and Alessandra de Olazabal**
Long time series in the Gulf of Trieste (northern Adriatic Sea): *Penilia avirostris* vs copepod abundance
- S1-3545 **Eilif Gaard, Høgni Debes and Karine Nolsø**
Calanus finmarchicus changes in the southern Norwegian Sea, 1990-2006
- S1-3548 **Astthor Gislason, Hildur Petursdottir and Olafur S. Astthorsson**
Interannual variability in abundance and community structure of zooplankton south and north of Iceland in relation to environmental conditions in spring 1990-2006
- S1-3550 **Katia Aronés, Patricia Ayón, Carmela Nakazaki and Roberto Quesquén**
Trends of copepods from Peruvian northern zone – Humboldt Current System, from 1994 to 2005
- S1-3551 **Catherine L. Johnson and Erica J. H. Head**
Spatial and temporal variability in Scotian Shelf zooplankton communities
- S1-3559 **Maria Grazia Mazzocchi, Paola Rumolo, Benedetta Ciaschi, Iole Di Capua and Mario Sprovieri**
Long-term and seasonal variability of abundance and stable N isotope signature in coastal copepods
- S1-3571 **Rebecca Jones and Jeffrey Runge**
A cooperative partnership with the fishing industry for long time series observing of zooplankton abundance and composition in the Gulf of Maine
- S1-3610 **Elena G. Arashkevich and Alexander G. Timonin**
Long-term changes in zooplankton community of the Black Sea: biological and climatic aspects
- S1-3613 **Toru Suzuki, Yutaka Michida, Shuhei Nishida, Hiroshi Hasumoto and Shin-ichi Uye**
Zooplankton data archaeology and rescue by universities in Japan
- S1-3618 **Russell R. Hopcroft and Kenneth O. Coyle**
Inter-annual variations of zooplankton in the northern coastal Gulf of Alaska
- S1-3623 **Fabienne Cazassus, Coleen L. Moloney, Sakhile Tsotsobe and Hans M. Verheye**
Changes in zooplankton community structure in the northern Benguela during 1978-1989
- S1-3646 **W.J. Sydeman, J. Jahncke, C.L. Abraham, A. Harding, K. Reid, S. Kitaysky, J.M. Hipfner and R. Brodeur**
Planktivorous predators as indicators of changes in zooplankton: importance of time-series on trophic ecology
- S1-3653 **Ioanna Siokou-Frangou, Georgia Assimakopoulou, Epaminondas D. Christou, Harilaos Kontoyiannis, Kalliopi Pagou, Alexandra Pavlidou and Sultana Zervoudaki**
Long-term mesozooplankton variability in a Mediterranean coastal area, as influenced by trophic relationships and climate
- S1-3655 **Angel Lopez-Urrutia, Gregory Beaugrand, Wulf Greve and Roger P. Harris**
The mid-eighties regime shift and appendicularian abundance
- S1-3657 **Jesus Cabal, Luis Valdés, Angel López-Urrutia, Maite Alvarez-Ossorio, Antonio Bode, Ana Miranda, Manuel Cabanas, Iñaki Huskin, Ricardo Anadón, Florentina Álvarez-Marqués, Marcos Llope and Nicolas Rodríguez**
A decade of sampling in the Bay of Biscay: what are the zooplankton time series telling us?

- S1-3671 **Kyoung-Soon Shin, Woo-Jin Lee, Min-Chul Jang and Dong-Hyun Son**
Relationship of mesozooplankton and population variations of jellyfish (*Aurelia aurita*) in Masan Bay, Republic of Korea
- S1-3691 **Hideo Miyaguchi, Victor S. Kuwahara, Tomohiko Kikuchi and Tatsuki Toda**
10-year variations in biomass, production and ecological role of *Noctiluca scintillans*
- S1-3695 **M^aLuz Fernández de Puelles and Juan Carlos Molinero**
Decadal changes in hydrographic and ecological time-series in the Balearic Sea (Western Mediterranean), identifying links between climate and zooplankton
- S1-3720 **Mark D. Ohman, Greg H. Rau, Pincelli Hull and Annelies Pierrot-Bults**
Zooplankton stable N isotopes as an index of climate variation in the NE Pacific
- S1-3756 **Carmela Nakazaki and Patricia Ayón**
Euphausiid abundance trends in two Peruvian upwelling zones

S2 Importance of zooplankton in biogeochemical cycles

Co-convenors: Hiroaki Saito (Japan) and Deborah K. Steinberg (USA)

Invited speaker: Laurence P. Madin (Woods Hole Oceanographic Institution, USA)

Zooplankton play an integral role in the cycling of elements in the sea. As key drivers of the biological pump, zooplankton feed in surface waters and produce sinking faecal pellets, and actively transport dissolved and particulate matter to depth via vertical migration. Zooplankton grazing and metabolism transforms particulate organic matter into dissolved forms, affecting primary producer populations, microbial remineralisation, and particle export to the ocean's interior. The elemental stoichiometry of zooplankton and their prey often differ, resulting in non-Redfield cycling of C, N, and P. We invite papers on the role of zooplankton (both metazoan and protozoan) in biogeochemical cycles reflecting the significant strides that have been made in this area, as well as identifying crucial gaps in our knowledge. Topics may include, but are not limited to: the role of zooplankton in the biological pump, mesopelagic and deep sea processes, trophic interactions and nutrient cycling, ecological stoichiometry, effects on biogeochemical cycling (measured or modelled) of human- or climate-influenced changes in zooplankton community structure, and regional or global syntheses of the importance of zooplankton in biogeochemical cycles. This session theme is closely related to research goals within IMBER (Integrated Marine Biogeochemistry and Ecosystem Research) and GLOBEC.

Tuesday 29 May 2007 14:00 - 17:40

- 14:00 **Welcome by convenors**
- 14:05 **Laurence P. Madin**
Gelatinous grazers: an underestimated force in ocean carbon cycles (S2-3717)
- 14:35 **Humberto E. González, Ricardo Giesecke, Eduardo Menschel, Claudio Barria, Rodrigo Vera, Carola Aparicio and José Luis Iriarte**
Functional groups and key species of the zooplankton as pivotal drivers of the biological pump in the Humboldt Current System off Chile (S2-3479)
- 14:55 **Constantin Frangoulis, Khalid El Kalay, Nikos Skliris, Gilles Lepoint and Jean-Henri Hecq**
Vertical flux of zooplankton products in an oligotrophic coastal ecosystem: importance of copepod carcasses and faecal pellets (S2-3575)
- 15:15 **Angela D. Hatton, Samuel T. Wilson, Mark Hart and David Green**
The importance of zooplankton in unravelling the ocean methane paradox (S2-3451)
- 15:35 **Tea / coffee break**
- 16:00 **Deborah K. Steinberg, Stephanie E. Wilson, Toru Kobari and Ken O. Buesseler**
Zooplankton processing of sinking particle flux in the mesopelagic zone (S2-3547)
- 16:20 **Kazutaka Takahashi, Akira Kuwata, Hiroya Sugisaki and Hiroaki Saito**
Downward carbon transport by diel vertical migration of *Metridia* spp. in the subarctic Pacific Ocean: respiratory and mortality fluxes (S2-3685)
- 16:40 **Hiroaki Saito, Atushi Tsuda, Yukihiko Nojiri, Takefumi Aramaki, Isao Kudo, Jun Nishioka, Koji Suzuki, Shigenobu Takeda and Takeshi Yoshimura**
Efficient transport of primary production to the mesopelagic layer by *Neocalanus plumchrus* in the subarctic Pacific (S2-3419)
- 17:00 **Ida A. Wendt and Peter Thor**
Absorption of organic carbon into copepods changes with phytoplankton concentration and species composition (S2-3416)
- 17:20 **Sanna Rönkkönen, Eveliina Lindén, Miina Karjalainen and Markku Viitasalo**
Stoichiometry of zooplankton in the Baltic Sea: spatial and interspecific variation (S2-3511)

S2 Posters

- S2-3265 **Daniel J. Mayor, Thomas R. Anderson, David W. Pond and Xabier Irigoien**
Limitation of egg production in *Calanus finmarchicus* in the field: a stoichiometric analysis
- S2-3339 **Atsushi Yamaguchi, Keiichiro Sasaoka, Yoshihiko Kamei, Taekeun Rho and Tsutomu Ikeda**
Respiratory carbon flux by the diel vertical migration of the copepod *Metridia pacifica* in the subarctic Pacific Ocean
- S2-3367 **Qing Yang, Wen-Qing Cao, Yuan-Shao Lin and Wei-Di Yang**
Studies on biological processes of the phosphorus turnover in surface water of Xiamen Harbour I: grazing of microzooplankton on phytoplankton
- S2-3369 **Wei-Di Yang, Yuan-Shao Lin, Wen-Qing Cao and Qing Yang**
Studies on biological processes of the phosphorus turnover in surface water of Xiamen Harbour II: species composition of copepods and feeding impact
- S2-3395 **Lingfeng Huang, Ke Pan, Shiquan Lin and Feng Guo**
Distribution, feeding and remineralisation role of heterotrophic nanoflagellates in the East China Sea
- S2-3408 **Yuichiro Nishibe and Tsutomu Ikeda**
Metabolism and chemical composition of four oncaeid copepods in the western subarctic Pacific
- S2-3428 **Miguel Alcaraz, Theodor T. Packard, Enric Saiz, Albert Calbet, Isabel Trepas and Alf Skovgaard**
Micro- and mesozooplankton respiratory metabolism: comparison of simultaneous incubation experiments and ETS activity
- S2-3456 **Todd W. Miller, Koji Omori, Hideki Hamaoka and Hidejiro Onishi**
Sources of production to subsystems of the Seto Inland Sea, Japan
- S2-3468 **Hideki Kaeriyama, Toshiaki Ishii, Teruhisa Watabe and Masashi Kusakabe**
Concentrations of trace elements in zooplankton off northeastern Japan
- S2-3477 **Toru Kobari, Toshiyuki Nagaki, Masatoshi Moku and Kazutaka Takahashi**
Importance of expatriated boreal copepods in the Oyashio-Kuroshio mixed region
- S2-3520 **Julie E. Keister, William T. Peterson and Timothy J. Cowles**
Climate effects on zooplankton biomass, species composition, and cross-shelf delivery of carbon in a coastal upwelling system
- S2-3556 **Sandra Jansen, Joachim Henjes, Lars Friedrichs, Sören Krägfesky and Ulrich Bathmann**
Fate of copepod faecal pellets during an iron induced phytoplankton bloom (EIFEX) in the Southern Ocean
- S2-3633 **Hyung-Ku Kang, Chang Rae Lee and Sinjae Yoo**
Vertical distribution of suspended faecal pellets and production of copepod faecal pellets in the Ulleung Basin in the Japan/East Sea
- S2-3682 **L. Felipe M. De Gusmão and A. David McKinnon**
Mesozooplankton biomass and copepod growth rates in the Whitsunday Islands, Great Barrier Reef, Australia
- S2-3736 **Sébastien Putzeys, Lidia Yebra, Carlos Almeida, Pierrick Bécognée and Santiago Hernández-León**
Carbon fluxes due to diel vertical migrant zooplankton during the late winter bloom in the Canary Islands waters
- S2-3754 **Hongbin Liu, Michael Dagg, Jeffrey Napp and Riki Sato**
Grazing impact of *Neocalanus* spp. compared to remainder mesozooplankton in the coastal and shelf water of the Gulf of Alaska
- S2-3777 **Hyoung Chul Shin, Dongseon Kim, Dong Yup Kim and Yoon Hee Jung**
Krill faeces as a key vehicle of the downward particle flux in Southern Ocean

S3 The role of zooplankton in food webs: changes related to impacts of climate variability and human perturbation

Co-convenors: Hans G. Dam (USA) and Mike A. St. John (Germany)

Invited speaker: Phillip C. Reid (Sir Alister Hardy Foundation for Ocean Science, UK)

Global change, a combination of both natural and anthropogenic processes, impacts heavily upon the marine environment and its services (e.g. fisheries, green house gas sequestering). A critical issue facing marine and climate researchers is developing a predictive understanding of how changes in climate and food web structure due to exploitation of marine resources feed back to global climate. Marine zooplankton perform a critical role in this change via structuring of higher and lower trophic levels. This structuring impacts upon the population dynamics of exploited species, as well as modifying the flux of organic materials to deep ocean. In this session, we encourage contributions highlighting the effects of climatic processes and changes in anthropogenic forcing on individual and population rates, life cycles and distributions as well as the structure of marine communities, in order to further our understanding of the role of zooplankton in global change.

Friday 1 June 2007 09:00 - 17:00

- 09:00 **Welcome by convenors**
- 09:05 **Juha Flinkman, Jari-Pekka Pääkkönen, Soili Saesmaa and Janne Bruun**
The relation of northern Baltic zooplankton to climatic forcing, eutrophication and clupeid stocks in 1979-20006: bottom-up regulation revisited (S3-3576)
- 09:25 **Philip C. Reid**
The importance of zooplankton in reducing levels of atmospheric CO₂ via the biological pump (S3-3767)
- 09:55 **Daniel J. Mayor, Ceri A. Matthews, Kathryn B. Cook and Steve Hay**
Sub-lethal effects of elevated CO₂ on *Calanus* spp. (S3-3264)
- 10:15 **Haruko Kurihara, Shinji Kato, Masaaki Matsui and Atshushi Ishimatsu**
The effects of rising seawater CO₂ on marine zooplankton (S3-3478)
- 10:35 **Tea / coffee break**
- 11:00 **Christian Möllmann, Michael A. St. John, Rabea Diekmann and Georgs Kornilovs**
Indirect effects of climate- and overfishing- induced zooplankton changes on ecosystem structure – regime shifts, trophic cascades and feedback loops in a simple ecosystem (S3-3276)
- 11:20 **Eugene J. Murphy, Philip N. Trathan, Jonathan L. Watkins, Keith Reid, Michael P. Meredith, Jaume Forcada, Sally E. Thorpe and Nadine Johnston**
Interannual variability in Southern Ocean ecosystems: impacts of climate-driven fluctuations in Scotia Sea food webs (S3-3697)
- 11:40 **I. Noyan Yilmaz, Asli Aslan-Yilmaz, Ahsen Yuksek and Erdogan Okus**
Changes in mesozooplankton community structure in a highly stratified basin due to anthropogenic forcing (S3-3664)
- 12:00 **Galina A. Finenko, Zinaida A. Romanova, Galina I. Abolmasova, Boris E. Anninsky, Tamara V. Pavlovskaya, Levent Bat and Ahmet Kideys**
Ctenophores - invaders and their role in trophic dynamics of the planktonic community in the coastal regions off the Crimean coast of the Black Sea (Sevastopol Bay) (S3-3473)
- 12:20 **Maiju Lehtiniemi and Elena Gorokhova**
Predation and ecological impact of an introduced predatory cladoceran *Cercopagis pengoi* on native copepods in the Baltic Sea (S3-3540)
- 12:40 **Lunch**

- 14:00 **Jennifer E. Purcell, Wen-Tseng Lo, Jia-Jang Hung, Huei-Meei Su and Pei-Kai Hsu**
Consequences of extensive aquaculture-structure removal: the relative importance of planktonic versus structure-related changes (S3-3396)
- 14:20 **Wim Kimmerer**
Indirect human impacts on an estuarine food web illustrate the false dichotomy of top-down and bottom-up (S3-3597)
- 14:40 **Hans G. Dam, David T. Avery and Sean P. Colin**
Copepod resistance to toxic phytoplankton (S3-3755)
- 15:00 **Tarsicio Antezana**
Euphausia mucronata a central link in the Humboldt Current food web (S3-3391)
- 15:20 **Marina Marrari, Kendra L. Daly and Chuanmin Hu**
Influence of chlorophyll and sea ice dynamics on the reproduction and recruitment of the Antarctic krill *Euphausia superba* in waters west of the Antarctic Peninsula (45-75°S, 50-80°W) (S3-3409)
- 15:40 **Tea / coffee break**
- 16:00 **Brian P. V. Hunt, Evgeny A. Pakhomov and Graham W. Hosie**
Pteropods in Southern Ocean ecosystems (S3-3565)
- 16:20 **Guang-Tao Zhang, Song Sun, Zhao-Li Xu and Qi-Long Zhang**
Dominant zooplankton species shift in the Changjiang River estuary: possible causes (S3-3394)
- 16:40 **Richard R. Kirby, John A. Lindley, Gregory Beaugrand, David G. Johns, Anthony J. Richardson, Martin Edwards and Philip C. Reid**
Genetic analysis of Continuous Plankton Recorder (CPR) samples (S3-3710)

S3 Posters

- S3-2775 **Nagwa El-Sayed Abdel-Aziz and Mohamed Moussa Dorgham**
Zooplankton biodiversity relative to long-term ecological variations in the southeastern Mediterranean
- S3-3238 **Kourosh Haddadi Moghaddam**
Study on the role of zooplankton in the sturgeon food web
- S3-3239 **Kourosh Haddadi Moghaddam**
Study of zooplankton populations effective in nutrition of *Acipenser stellatus* fingerlings
- S3-3247 **Ramanibai Ravichandran and Elayaraja Paramu**
A comparative account of the distribution of copepods in five estuaries along the northeast coast of Tamilnadu, India
- S3-3266 **Nallamuthu Godhantaraman, Akira Hoshika, Shin-ichi Uye, Yasufumi Mishima and Terumi Tanimoto**
Seasonal and geographical variations in abundance, biomass, production rate and grazing impact of microzooplankton in eutrophic northern Hiroshima Bay, the Inland Sea of Japan
- S3-3285 **Roxana De Silva-Dávila, Ricardo Palomares-García, Alán Zavala-Norzagaray and Diana Cecilia Escobedo-Urías**
Changes in zooplankton community related to environmental and anthropogenic influences in a subtropical lagoon
- S3-3307 **Sergey M. Ignatyev and Vladimir Grinzov**
Amphipods (hypheriidae) in the macroplankton community of the antarctic waters (Pacific part of Antarctic, PPA)
- S3-3313 **Zhao-Li Xu and Qian Gao**
Causal analysis to HAB and zooplankton in the East China Sea

- S3-3342 **Marc Pagano, Gisèle Champalbert, Pierre Sene, Patrice Got, Marc Troussellier, El Hadji N'Dour, Daniel Corbin and Marc Bouvy**
Man-induced changes in trophic pathways of metazooplankton in the Senegal River estuary (West Africa)
- S3-3353 **Fang Zhang and Song Sun**
Distribution and biomass of large jellyfish assemblages and association with oceanographic features in the Yellow Sea and northern East China Sea
- S3-3361 **Yang-Chi Lan, Ming-An Lee and Ding-An Lee**
Seasonal variations of the copepod community derived by the seasonal monsoon system in the southern East China Sea
- S3-3381 **Maria Isabel Criales-Hernandez, Ralf Schwamborn, Patricia Ayón, Sonia Sanchez, Hans-Jürgen Hirche and Matthias Wolff**
Seasonal and spatial changes in abundance, vertical distribution, grazing and egg production of dominant copepods in the Humboldt Current System off central Peru
- S3-3420 **Kwang-Hyeon Chang, Yuichiro Nishibe, Hideyuki Doi, Yumiko Obayashi, Ipppei Ninomiya, Takako Yamamoto, Mizuho Yoshihara, Mary Shime, Akiko Kihara and Shin-ichi Nakano**
Impact of artificial eutrophication on coastal zooplankton communities: a comparative study of zooplankton communities receiving different human activities (fish and pearl oyster farming)
- S3-3429 **Maria Pöllupüü, Mart Simm and Arno Pöllumäe**
Distribution and population structure of the non-indigenous cladoceran *Evadne anonyx* in comparison with the native *Evadne nordmanni* in the north-eastern Baltic Sea
- S3-3432 **Lyudmila Kamburska and Serena Fonda-Umani**
Shifts in composition and community structure of pelagic copepods in the Gulf of Trieste (Northern Adriatic Sea)
- S3-3438 **Tamara Shiganova, Yulia Bulgakova, Ioanna Siokou-Frangou, Epaminondas D. Christou and Alenka Malej**
Changes in ctenophore *Mnemiopsis leidyi* phenology and population dynamics linked to environmental variability and climate forcing in its recipient areas of the Southern Seas
- S3-3441 **Claudia Castellani, Xabier Irigoien, Roger P. Harris, Dan J. Mayor, David J.S. Montagnes and David Wilson**
Grazing dynamics of *Calanus finmarchicus* and *Oithona similis* on the microplankton assemblage in the Irminger basin, North Atlantic
- S3-3445 **A. David McKinnon**
Plankton production and the abundance and feeding of larval fish in contrasting El Niño and La Niña years at Australia's North West Cape
- S3-3463 **Evgeny I. Barabanshchikov and Nikolay V. Kolpakov**
Seasonal variability and production of zooplankton community of Razdol'naya River estuary (the Peter Great Bay, Sea of Japan/East Sea)
- S3-3484 **Michele Casini, Juan-Carlos Molinero and Georgs Kornilovs**
Threshold dynamics in the regulation mechanism of central Baltic Sea zooplankton: causes, mechanisms and ecological implications
- S3-3503 **Miwa Hayashi and Shin-ichi Uye**
Biomass, production rate and trophic roles of the net-zooplankton community across the environmental gradient in Yatsushiro Bay, Japan
- S3-3504 **Lyudmila Kamburska, Kremena Stefanova, Tamara Shiganova and Wolfram Schrimpf**
Summer distribution and abundance of the invasive ctenophore *Mnemiopsis leidyi* (Agassiz A., 1865) in the Black Sea
- S3-3517 **Susana Garrido and Carlos Mendes**
Can the Continuous Plankton Recorder (CPR) be used to infer sardine diet?
- S3-3526 **John M. Klinck, Eileen E. Hofmann and Eric N. Powell**
A model of the growth and development of *Crassostrea virginica* larvae

- S3-3537 **Priscilla Licandro, Martin Edwards, David G. Johns, Sonia Batten, Anthony John, Tanya Jonas and J. Alistair Lindley**
Long-term changes in North Atlantic zooplankton biomass
- S3-3541 **Valentina Tirelli, Diego Borme, Alessandra de Olazabal, Sara Legovini, Simone Libralato, Cosimo Solidoro and Serena Fonda Umani**
Zooplankton fluctuations in the Gulf of Trieste (Northern Adriatic Sea): what is the role of small pelagic fish?
- S3-3554 **Jari-Pekka Pääkkönen, Juha Flinkman, Kai Kivi, Heikki Peltonen, Miina Karjalainen and Markku Viitasalo**
Spatial distributions, community structure and trophic interactions of phytoplankton, micro- and mesozooplankton and planktivorous fish in the Gulf of Finland, Baltic Sea
- S3-3601 **Jinhui Wang, Yuanli Yang, Caicai Liu and Haofei Zhang**
Has the Three Gorge Project influenced zooplankton and ichthyoplankton populations in the Changjiang estuary?
- S3-3643 **Evgeny I. Barabanshchikov**
Zooplankton production of estuarine systems of Primorye (Russia)
- S3-3645 **Ho-Seop Yoon, Keun-Hyung Choi, Chul Won Park and Sang Duk Choi**
Night illumination-induced zooplankton community change and feeding and weight increase of juvenile black seabream, *Acanthopagrus schlegeli*
- S3-3648 **Hao-Hsien Chang and Barbara K. Sullivan**
Occurrence of the ctenophore *Beroe ovata* in Narragansett Bay, Rhode Island, 2006
- S3-3662 **Barbara Niehoff, Tobias Kreibich, Stephane Plourde, Michael Starr and Pierre Joly**
Feeding of *Calanus finmarchicus* and *Metridia longa* females during the spring bloom in the St. Lawrence estuary, Canada: evidence from stable isotope analysis and trophic biomarkers
- S3-3686 **Elena Gorokhova and Maiju Lehtiniemi**
A combined approach to understand trophic interactions between *Cercopagis pengoi* (Cladocera: Onychopoda) and mysids in the Gulf of Finland
- S3-3698 **Solvita Strake, Arno Pöllumäe, Baerbel Müller-Karulis, Piotr Margonski and Natalja Demereckiene**
Factors affecting zooplankton changes in the south-eastern Baltic Sea coastal ecosystems
- S3-3712 **Eike Gentsch, Karen H. Wiltshire and Barbara Niehoff**
Meroplanktonic larvae in the marine food web - a combination of grazing experiments and stable isotope analyses at Helgoland Roads, North Sea
- S3-3723 **Lenin B. Kamepalli, K.V. Umesh Raju and Shobhan K. Pattanayak**
Impact of urbanisation and possible climate change on welfare of traditional fisheries: a case study on the south western coast of India
- S3-3743 **Rana El-Sabaawi, Martin Kainz, John F. Dower and Asit Mazumder**
Consequences of interannual variability in the trophic status of *Neocalanus plumchrus* in the Strait of Georgia, British Columbia
- S3-3747 **Luis Chícharo, Maria Alexandra Chícharo and Radhouane Ben-Hamadou**
Use of a hydrotechnical infrastructure (Alqueva Dam) to regulate planktonic assemblages in the Guadiana estuary: basis for sustainable water and ecosystem services management
- S3-3753 **Amy N. S. Siuda and Hans G. Dam**
Effects of elemental stoichiometric imbalance and prey size on cascading trophic interactions
- S3-3757 **Katia Aronés and Patricia Ayón**
Temporal variability of the first stages of *Euphausia mucronata* and its relation with oceanographic conditions off northern Perú (1994–2006)
- S3-3811 **Enric Saiz, Carles Barata, Albert Calbet, J.I. Movilla and Lidia Yebra**
Lethal and sublethal effects of PAHs on marine copepods
- S3-4022 **Jonna Engström-Öst and Maiju Salonen**
Can zooplankton escape predation in turbid water?

S4 Mortality impacts on the ontogeny and productivity of zooplankton

Co-convenors: Mark Ohman (USA), Serge Poulet (France) and Anthony Verschoor (The Netherlands)

Invited speaker: Anthony M. Verschoor (Netherlands Institute of Ecology, Netherlands)

Understanding the patterns and causes of zooplankton mortality has been an elusive goal. Yet both theoretical and empirical studies illustrate the sensitivity of virtually all domains of zooplankton research to this understudied component of population dynamics. In recent years, it has become clear that a multiplicity of factors may account for mortality in different phases of the life history, ranging from chemical compounds to predators and parasites. The aim of this session is to bring together contemporary research approaches that address issues such as the estimation of mortality rates in natural zooplankton populations, the causal agents of mortality at different ontogenic stages, trade-off models exploring the costs and benefits of different behaviours and life history traits that influence mortality risk, and related studies. Participants are invited to present appropriate methods, up-to-date results, key issues and perspectives in order to better understand and further model the complex processes linking mortality and zooplankton productivity processes.

Friday 1 June 2007 13:45 - 17:00

- 13:45 **Welcome by convenors**
- 13:50 **Antonie M. Verschoor**
Variation in phytoplankton food quality and effects on plankton community structure and functioning (S4-3448)
- 14:20 **Serge A. Poulet**
Parental phytoplankton diets indirectly induce variable mortality rates in copepods (S4-3288)
- 14:40 **Kerrie Swadling, Anita Alexander, Malcolm O'Toole, Susan Blackburn and Angela Holmes**
Effects of a recently introduced toxic dinoflagellate on grazing rates, egg production and survivorship of marine copepods (S4-3582)
- 15:00 **Verónica L. Fuentes, Irene R. Schloss and Graciela B. Esnal**
Zooplankton mortality events in Antarctic coastal areas: a relation with global change? (S4-3359)
- 15:20 **Atsushi Tsuda, Hiroaki Saito, Kazuhiko Hiramatsu and Ryuji J. Machida**
Estimations of development and mortality rates of ontogenetically migrating copepods in the SF6 labelled water mass during iron-enrichment experiments (S4-3587)
- 15:40 **Tea / coffee break**
- 16:00 **Hongsheng Bi, Mark C. Benfield, Kenneth A. Rose and William T. Peterson**
A comparison of four techniques for estimating stage-specific mortality rates of copepods (S4-3345)
- 16:20 **Pierre Pepin**
Predation by the myctophid *Benthosema glaciale* on copepods of the genus *Calanus* in the Labrador Sea (S4-3488)
- 16:40 **Sigrun H. Jonasdottir, Carsten Jespersen and Andy W. Visser**
Effects of mediocre diets on reproductive fitness of a common copepod (S4-3724)

S4 Posters

- S4-3407 **Christian Möllmann, Jasmin Renz, Joerg Dutz, Janna Peters, Hans-Juergen Hirche and Axel Temming**
Stage-specific mortality of calanoid copepods in the southern North Sea
- S4-3472 **Hans-Uwe Dahms, Kerstin Elwers and Jiang-Shiou Hwang**
Mesozooplankton assemblages and the life cycles, hibernation and production estimates of copepods at Potter Cove (King George Island) and Marguerite Bay (Antarctic Peninsula)
- S4-3543 **Stéphane Plourde, Pierre Joly, Marc Ringuette, Frédéric Maps and Louis Fortier**
Mortality rate in eggs and early naupliar stages of *Calanus* spp. and *Metridia longa*: opposite effects of cannibalism/predation and phytoplankton biomass and their role in the control of population dynamics in sub-arctic and arctic ecosystems
- S4-3555 **Peter Tiselius, Marc Andersen, Benni Winding Hansen, Per Juel Hansen, Torkel Gissel Nielsen and Bent Vismann**
Extremely high reproduction but low biomass - mortality of the copepod *Acartia tonsa* during a *Skeletonema costatum* bloom
- S4-3699 **Yuji Tanaka**
Escape ability of copepods - 3-D high-speed video observations
- S4-3718 **Mark D. Ohman and Chih-hao Hsieh**
Spatial domains of increased mortality of *Calanus pacificus* within the California Current System
- S4-3735 **Santiago Hernández-León, Marta Moyano, Sébastien Putzeys, Pascal Lehette and Claire Schmoker**
The interplay between growth and mortality during the late winter bloom in subtropical waters

S5 Zooplankton functional groups in ecosystems

Co-convenors: Sanae Chiba (Japan) and Sun Song (P.R. China)

Invited speaker: Akira Taniguchi (Tokyo University of Agriculture, Japan)

Zooplankton play vital roles in aquatic ecosystems. Biodiversity and biomass change will shape the ecosystem, but it are only general concepts. The most important aspect is to ascertain the main contributor to the structure and function of the ecosystem. In previous research, the focus was mostly on biodiversity, dominant species and the key species population dynamics of zooplankton. This is not practical from the point of ecosystem modelling, because we must consider the role of zooplankton in the ecosystem. Since many species have similar roles, we divide them into different functional groups, based on size, morphology, trophic level, or physiological parameters. In this session, we will focus on the zooplankton functional groups in ecosystems: composition, shift under the force of human activities and climate change, its effects to the food web structure and biogeochemical cycling. Our particular interests are toward the mechanisms and consequences of the alternation of major functional groups. What kind of environmental perturbation causes the alternation, and what are the ecological and biogeochemical consequences? In addition to the presentations from field- and laboratory-based studies, suggestions and proposals from theoretical and modelling approaches are welcome.

Thursday 31 May 2007 9:00 - 12:40

- 09:00 **Welcome by convenors**
- 09:05 **Akira Taniguchi**
An aspect of functional groups of zooplankton in oceanic ecosystems (S5-3609)
- 09:35 **David Mackas and Jackie King**
Classification of zooplankton life history strategies (S5-3569)
- 09:55 **Juan-Carlos Molinero, Michele Casini and Emmanuelle Buecher**
Climate and gelatinous carnivores in semi-closed, small-oceans: the NW Mediterranean case study (S5-3740)
- 10:15 **Santosh Kumar Sarkar and Bhskar Dev Bhattacharya**
Community structure and trace elements in zooplankton in Sunderban mangrove wetland, northeast part of Bay of Bengal, India (S5-3282)
- 10:35 **Tea / coffee break**
- 11:00 **Jesse F. Lamb, William T. Peterson, Cheryl A. Morgan and Julie E. Keister**
Biological responses to oceanic climate variability off Oregon and Washington, USA in three calanoid copepods: *Acartia tonsa*, *Calanus pacificus*, and *Paracalanus parvus* (S5-3418)
- 11:20 **Martha Jeannette Haro-Garay and Leonardo Huato-Soberanis**
Dominant zooplankton shift in the Strait of Georgia: an educated guess on the trophic implications and the probable biophysical context (S5-3388)
- 11:40 **Song Sun and Yuanzi Huo**
Spatial and seasonal variations in distribution and abundance of net zooplankton functional groups on the continental shelf of the Yellow Sea (S5-3398)
- 12:00 **Natalia T. Dolganova**
Modern status of zooplankton in the northwest Japan Sea (S5-3335)
- 12:20 **Elena Dulepova**
North-south comparisons of plankton communities in the Okhotsk Sea (S5-3332)

S5 Posters

- S5-2767 **Mohamed M. Dorgham, Mohsen M. El-Sherbiny and Mahmoud H. Hanafi**
Bioecological observations on epipelagic zooplankton in Sharm El-Sheikh, Red Sea
- S5-3277 **Tariq Al-Najjar, Bracha-Viviana Farste and Amatzia Genin**
Zooplankton biomass along the Jordanian and Israeli sections of the Gulf of Aqaba, Red Sea
- S5-3279 **Evelyn Zoppi de Roa**
Recent zooplankton research from the Caribbean and Atlantic coasts of Venezuela
- S5-3292 **Federico González, Evelyn Zoppi de Roa and Edie Montiel**
Upwelling index and zooplankton dynamics in Mochima Bay, Venezuela
- S5-3306 **Sergey M. Ignatyev**
Seasonal variability of the biological state of krill (*Euphausia superba* Dana, 1852) in the coastal waters of the Argentina Islands (Antarctic)
- S5-3308 **Alexander Sirota, Vyacheslav Lidvanov and Natalia Zhigalova**
Zooplankton assemblage and water mass distribution off the northwest African coast
- S5-3318 **Gastón E. Aguirre, Fabiana L. Capitanio, Gustavo A. Lovrich and Graciela B. Esnal**
Seasonal changes in the species composition of mesozooplankton in the Beagle Channel, southern tip of South America
- S5-3330 **Qian Gao, Zhao-Li Xu and Yao Ji**
Zooplankton dynamics in the near water of the Yangtze estuary
- S5-3376 **Agustín Schiariti, Diego A. Giberto and Hermes W. Mianzan**
Gelatinous zooplankton off the Argentinian continental shelf: winter distribution, estimated biomass and significance for the pelagic community
- S5-3434 **Jay O. Peterson and William T. Peterson**
Influence of the Columbia River (USA) plume on zooplankton abundance, distribution and size structure over the continental shelf
- S5-3494 **Yukihiko Matsuyama**
Effects of water temperature, light, and prey organisms on growth of the heterotrophic dinoflagellate *Gyrodinium dominans* (Dinophyceae)
- S5-3502 **Masato Kawahara, K. Ohtsu and S.-I. Uye**
Growth, respiration and food requirement of the giant jellyfish *Nemopilema nomurai* (Scyphozoa: Rhizostomeae)
- S5-3525 **Jerry D. Wiggert, Eileen E. Hofmann and Gustav-Adolf Paffenhofer**
The effect of sampling preference and environmental conditions on the foraging success of oligotrophic copepod populations: a modelling study
- S5-3535 **Gladis A. López-Ibarra, Sergio Hernández-Trujillo, Antonio Bode and Robert Olson**
Stable isotopes and trophic structure of pelagic copepods in the tropical eastern Pacific Ocean
- S5-3553 **Chang-hoon Han, M. Kawahara and S.-I. Uye**
Seasonal variations in abundance and biomass of the scyphomedusa *Aurelia aurita* and its predation impact on mesozooplankton in a brackish-water lake, Japan
- S5-3614 **Takashi Kamiyama, Toshiyuki Suzuki and Yutaka Okumura**
Microzooplankton as a food source for the Pacific oyster *Crassostrea gigas*: seasonal variation in the gut contents and food availability

- S5-3638 **Sergey A. Tsarin**
A role of planktonic Crustacea in the food of Myctophidae
- S5-3644 **Mutsuo Ichinomiya, Miwa Nakamachi, Mitsuo Fukuchi and Akira Taniguchi**
Role of heterotrophic dinoflagellates in the fate of ice algal production released into the water column under fast ice near Syowa Station, Antarctica
- S5-3650 **Ken Kato and Naonobu Shiga**
Biogeography of appendicularians in the North Pacific Ocean
- S5-3663 **I. Noyan Yilmaz, Ahsen Yuksek and Erdogan Okus**
Succession of ultra fine particle feeders: the role of environmental variability
- S5-3687 **Momoko Ichinokawa and Masayuki M. Takahashi**
Effects of taxonomic resolution on estimates of plankton food web structure in the epi-pelagic equatorial Pacific
- S5-3700 **Silke Laakmann, Holger Auel and Marc Kochzius**
Ecological niches in an almost homogeneous environment: deep-sea copepods in polar seas
- S5-3704 **François Carlotti**
A comparison of OPC-derived zooplankton size structure in different marine ecosystems
- S5-3708 **Marcelo A. Pavez, Cristian A. Vargas and Humberto E. González**
The trophic importance of gelatinous carnivorous zooplankton in an upwelling area of the Humboldt Current System (36°S)
- S5-3759 **Pham Quoc Huy**
Species composition and distribution of fish eggs and larvae in Vietnam Sea waters
- S5-3769 **Rita Borges, Radhouanne Ben-Hamadou and Emanuel J. Gonçalves**
An integrated approach to the study of very nearshore larval fish assemblages in the Arrábida Marine Park (Portugal)
- S5-3783 **Kajsa Tönnesson, Torkel G. Nielsen and Kristine E. Arendt**
Feeding of carnivorous zooplankton in West Greenland waters
- S5-4023 **Sunan Patarajinda, Pailin Jitchum and Nattawadee Phukom**
Eipelagic copepods in the Andaman Sea, with 10 new records in Thailand

S6 Microbial loop vs classical short food chains: implications for appraisal of food web efficiency and productivity

Convenor: *Ulf Båmstedt (Sweden)*

Invited Speaker: *Michael R. Landry (University of California, USA)*

Theoretically, the productivity at the top level of a pelagic food web is determined by the productivity at the basic level (here defined as phytoplankton and bacteria), the number of trophic links, and the efficiency by which energy or carbon is transferred between subsequent trophic levels. This implies that habitats with a dominance of organisms in the size below a few microns at the basic level will generate longer food chains and thereby relatively lower productivity at the mesozooplankton level, i.e. they have a lower food web efficiency. However, this theoretical consideration has not been verified from more than a few field-based and experimentally-based studies. We therefore invite papers in this session that can highlight how contrasting food web structure is controlled and demonstrate what consequences the food web structure has on productivity at higher trophic levels such as mesozooplankton or fish. Studies from marine as well as freshwater habitats are welcome since they usually complement each other by showing different trophic structures. Reports from field studies, laboratory experiments and mesocosm studies are all welcome.

Thursday 31 May 2007 09:00 - 12:40

- 09:00 **Welcome by convenors**
- 09:05 **Michael R. Landry**
From primary production to mesozooplankton: trophic transfers through microbial food webs (S6-3719)
- 09:35 **Ulf Båmstedt and Agneta Andersson**
The Baltic Sea as a natural ecosystem to study the significance of the phytoplankton/bacterioplankton production ratio for pelagic food web efficiency (S6-3538)
- 09:55 **Jean-Pierre Bergeron, Daniel Delmas and Noussithé Koueta**
Microbial loop vs short food chains: what do mesozooplankton enzymatic indices tell us about differences in food web efficiency and productivity? (S6-3311)
- 10:15 **Neil A. James, Andrew G. Hirst, David J.S. Montagnes and David Atkinson**
The effect of temperature and food on zooplankton gross growth efficiency (S6-3489)
- 10:35 **Tea / coffee break**
- 11:00 **J. Anthony Koslow, Joanna Strzelecki, Harriet Paterson and Stéphane Pesant**
Classical food webs and the microbial loop off Western Australia: test of a new method to simultaneously estimate micro- and mesozooplankton grazing impacts (S6-3500)
- 11:20 **Danilo Calliari, Anamar Britos and Daniel Conde**
Low grazing pressure and high egg production by copepods in a productive estuarine lagoon (S6-3701)
- 11:40 **Cristian A. Vargas, José Luis Iriarte, Rodrigo Martínez, Paulina Contreras, Cynthia Valenzuela, Luis A. Cuevas, Carolina Cartes, David Opazo and Rubén V. Escribano**
Food web structure and carbon flows in a river-influenced and non-river influenced continental shelf at the coastal upwelling area off Central Chile (36°S): importance of mixotrophy and omnivory (S6-3454)
- 12:00 **Michael J. Dagg, Suzanne L. Strom and Hongbin Liu**
Neocalanus and the lower trophic levels of the subarctic Pacific Ocean (S6-3414)
- 12:20 **Maiko Kagami, Ellen van Donk, Eric von Elert, Arnout de Bruin and Bas W. Ibelings**
Parasitic fungi may bridge the gap between inedible algae and zooplankton (S6-3770)

S6 Posters

- S6-3284 **Ricardo Palomares-Garcia, Jose Bustillos-Guzmán and David Lopez-Cortés**
Pigment-specific rates of phytoplankton growth and microzooplankton grazing in a subtropical lagoon
- S6-3370 **R. Almeda, M. Alcaraz, F. Peters, E. Romero and A. Sabata**
Effects of turbulence on clearance and ingestion rates of metazoan microzooplankton feeding on a natural microplanktonic community
- S6-3371 **R. Almeda, M. Alcaraz, A. Calbet, J.I. Movilla, E. Saiz, V. Salo and I. Trepas L. Yebra**
Role of metazoan microzooplankton in marine food webs: trophic impact and feeding performance
- S6-3455 **Shin-ichi Nakano, Yuji Tomaru, Wataru Makino, Masashi Onji, Toshiya Katano, Shin-ichi Kitamura, Yumiko Obayashi, Michinobu Kuwae, Kwang-Hyeon Chang, Hideyuki Doi and Yuichiro Nishibe**
The dynamics of microbial and herbivorous food webs in a coastal sea with special reference to physical events
- S6-3459 **Jun Sun and Shuqun Song**
Estimating *Calanus sinicus* grazing rate on phytoplankton and microzooplankton communities in the harmful algal bloom area of the East China Sea
- S6-3481 **Jose Luis Iriarte, Marcus Sobarzo, Humberto E. González, Nicolas Sanchez, Cynthia Valenzuela, Jorge Mardones and Luis A. Cuevas**
Phytoplankton carbon flux in a highly stratified Chilean fjord: the role of zooplankton in the pelagic food web
- S6-3483 **Sergio Hernández-Trujillo, Gabriela Ma. Esqueda-Escárcega, Gerardo Aceves-Medina, Alejandro Zárate Villafranco, José Reyes Hernández-Alfonso and Rocío Pacheco-Chávez**
Microzooplankton grazing in La Paz Bay 2003-2004
- S6-3491 **Koichi Ara and Juro Hiromi**
Temporal variability in plankton food web structure and trophodynamics in Sagami Bay, Japan
- S6-3493 **Takeshi Okutsu, Koichi Ara and Juro Hiromi**
Plankton food web structure and trophodynamics in Sagami Bay, Japan, in spring–summer 2006
- S6-3584 **Akiko Kihara, Toshiya Katano, Rie Asaumi, Mizuho Yoshihara, Yumiko Obayashi, Kwang-Hyeon Chang, Yuichiro Nishibe and Shin-ichi Nakano**
Trophic coupling of *Synechococcus* and nanoflagellates in a bay of the Uwa Sea, Japan
- S6-3594 **Valentina Tirelli, Alessandra de Olazabal and Serena Fonda Umani**
First estimate of copepod grazing on the tintinnid *Stenosemella nivalis* in the Gulf of Trieste (northern Adriatic Sea)
- S6-3629 **William T. Peterson and Linda O'Higgins**
Temporal variations in microplankton species composition off the central Oregon coast (2001-2005) and its influence on copepod population structure and biomass
- S6-3636 **Eun Jin Yang, Joong Ki Choi and Hyung-Ku Kang**
Contribution of planktonic protozoa to *Acartia hongii* diets in Kyeonggi Bay, Yellow Sea
- S6-3640 **Victor Aguilera and Rubén Escribano**
Reproductive responses of copepod species in the Chilean northern upwelling system: the role of the nanoplankton fraction
- S6-3647 **Ipppei Ninomiya, Kwang-Hyeon Chang, Yuichiro Nishibe, Hideyuki Doi, Takako Yamamoto, Mizuho Yoshihara, Akiko Kihara, Hiroyuki Ueno and Shin-ichi Nakano**
Possible controls on the abundance of planktonic ciliates in a bay of the Uwa Sea
- S6-3696 **Mangesh Uttam Gauns**
Spatio-temporal and ecological role of microzooplankton in the central and eastern Arabian Sea

S7 Environmental and other constraints on zooplankton behaviour, life histories and demography

Co-convenors: Charles B. Miller (USA) and Atsushi Tsuda (Japan)

Invited speaker: Claudia Halsband-Lenk (The University Centre in Svalbard, Norway)

Egg and copepodite dormancy, egg-sac carrying and free spawning, vertical migration, depth selection, feeding rhythms, growth rates and generation lengths of zooplankton have evolved as adaptations to fluctuating environmental factors. These include cyclic food availability, predation pressure, patterns in advection, oxygen supply and temperature variations. Behaviours and phenologic patterns also respond to inter- and intra-species competitions. Zooplankton activity variations and life cycle timing are key parameters for the survival of animals at higher trophic levels. For example, fish may spawn at times that anticipate availability of copepod eggs or nauplii for larval feeding. Many findings in these regards have accumulated from widespread areas of the ocean in recent decades, especially with the attention given to zooplankton in the GLOBEC programme. Presentations and posters are sought addressing any aspect of zooplankton phenology or behaviour, including effects on biogeochemical cycles.

Wednesday 30 May 2007 09:00 - 18:00

- 09:00 **Welcome by convenors**
- 09:05 **Claudia Halsband-Lenk, Ketil Eiane and Thomas Kiørboe**
Phenotypic variability in life history traits: is intra-population variability important for zooplankton dynamics? (S7-3368)
- 09:35 **Langdon B. Quetin, Robin M. Ross and Maria Vernet**
Linkage between Antarctic krill (*Euphausia superba*) and primary production (S7-3639)
- 09:55 **Sünnje L. Basedow, Kurt S. Tande and Are Edvardsen**
Multiscale patchiness of *Calanus finmarchicus* in an oceanic environment (S7-3375)
- 10:15 **Satu Viitasalo**
The impact of macrozoobenthos on the benthic life stage of zooplankton (S7-3585)
- 10:35 **Tea / coffee break**
- 11:00 **Margarita Zarubin, Amatzia Genin, Shimshon Belkin and Michael Ionescu**
Eat, glow and die: predation by nocturnal fish on zooplankton which graze on bioluminescent bacteria (S7-3536)
- 11:20 **Jiang-Shiou Hwang, Chien-Huei Lee, Shin-Hong Cheng and Hans-Uwe Dahms**
Effects of turbulent flow fields on fish predation and mating success of *Pseudodiaptomus annandalei* (Copepoda: Calanoida) (S7-3470)
- 11:40 **Lawrence J. Buckley, R. Gregory Lough and David Mountain**
Phenologic patterns result in an optimal window for survival of Atlantic cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) larvae on Georges Bank (S7-3625)
- 12:00 **Sigrid B. Schnack-Schiel, Franz Josef Sartoris, Astrid Cornils, Stathys Papadimitriou and David N. Thomas**
Life strategies of dominant Antarctic calanoid copepods in late winter/early spring (S7-3620)
- 12:20 **Ksenia N. Kosobokova and Russell R. Hopcroft**
Population structure and reproduction of the chaetognath *Eukrohnia hamata* in the Canada Basin, Arctic Ocean (S7-3642)
- 12:40 **Lunch**

- 14:00 **Catherine L. Johnson, Andrew Leising, Jeffrey Runge, Erica J.H. Head, Pierre Pepin, Stéphane Plourde and E. Durbin**
Control of *Calanus finmarchicus* dormancy patterns in the northwest Atlantic: the Lipid Accumulation Window hypothesis (S7-3570)
- 14:20 **Øystein Varpe, Christian Jørgensen, Geraint A. Tarling and Øyvind Fiksen**
Capital and income breeding as reproductive strategies in zooplankton (S7-3595)
- 14:40 **Takumi Nonomura, Ryuji J. Machida, Jun Nishikawa and Shuhei Nishida**
Life histories of *Calanus sinicus* and *Calanus jashnovi* (Copepoda: Calanoida) in the 1000 m water of Sagami Bay, central Japan (S7-3607)
- 15:00 **Jenny A. Huggett**
Comparative ecology of *Calanoides carinatus* and *Calanus agulhensis* in the southern Benguela and Agulhas Bank ecosystems (S7-3733)
- 15:20 **Erica Goetze and Thomas Kiørboe**
Chasing all kinds: heterospecific mating, reproductive isolation and population dynamics of planktonic marine copepods (S7-3485)
- 15:40 **Tea / coffee break**
- 16:00 **Marja Koski, Wim Klein Breteler and Jörg Dutz**
Seasonal changes in food quantity and quality for the development and egg production of the common North Sea copepods *Temora longicornis* and *Pseudocalanus elongatus* (S7-3505)
- 16:20 **Teruaki Yoshida, Chin Fong Liong, Tatsuki Toda and Bin Haji Ross Othman**
Effect of temperature on egg development time and hatching success of three congeneric Acartiid species (Copepoda: Calanoida) from the Straits of Malacca (S7-3360)
- 16:40 **Thomas Kiørboe and Andrew G. Hirst**
Predicting development times in marine copepods using an optimal life-history approach (S7-3304)
- 17:00 **Jasmin Renz and Hans-Jürgen Hirche**
Pseudocalanus species in the Baltic Sea and North Sea: comparative field studies on the life cycles of congener species in adjacent waters (S7-3377)
- 17:20 **Astrid Cornils, Sigrid B. Schnack-Schiel, Andrea Bäurle and Claudio Richter**
The impact of hydrographic parameters on the vertical and spatial distribution of calanoid copepod species on the shelf off SW Sulawesi (Indonesia) (S7-3412)
- 17:40 **A. Srinivasan, Rajdeep Dutta and J.D. Jameson**
Zooplankton distribution in the sewage polluted coastal waters of Thoothukudi coast, Gulf of Mannar, southeast coast of India (S7-3437)

S7 Posters

- S7-3262 **Ramanibai Ravichandran**
Effect of photoperiod on the egg production of *Neodiatomus satanas* (Calanoida: Copepoda)
- S7-3271 **Rosamma Stephen, Vijayalakshmi R. Nair, K.V. Jayalakshmy, Karlekar Geetha and S.N. Gajbhiye**
Diminishing density and diversity of copepods in the semi-enclosed docks of Mumbai Port, west coast of India
- S7-3283 **Ricardo Palomares-García and Roxana De Silva-Dávila**
Reproductive cycles of dominant calanoid copepods in a subtropical lagoon

- S7-3310 **Subhro. K. Mukhopadhyay, Abhishek Roy Goswami, Ashitava. Chatterjee and Buddhadeb. Chattopadhyay**
Spatial variations in zooplankton diversity in composite wastewater
- S7-3315 **Katie A.J. Hill, Valerie J. Smith and Andrew S. Brierley**
Regulation of diapause in the copepod *Calanus finmarchicus*
- S7-3320 **Kathryn B. Cook, Steve Hay, Susan Robinson and Claire Skinner**
Seasonal patterns of abundance, egg production and egg viability of the calanoid copepods *Calanus helgolandicus* and *Calanus finmarchicus* at a station off the north-western North Sea coast
- S7-3337 **Rey Donne Papa, J.T. Wu, S.F. Baldia, C. Cho, M.A. Cruz, A. Saguiguit and R. Aquino**
Impact of *Botryococcus braunii* blooms on the zooplankton of Paoay Lake
- S7-3358 **Chaolun Li, Shiwei Wang and Song Sun**
Reproductive responses of *Calanus sinicus* to food availability in Jiaozhou Bay, China
- S7-3365 **C.B. Lalithambika Devi and M.S. Binu**
Diversity of ichthyoplankton with reference to seasonal variation in the Arabian Sea
- S7-3382 **Rubén V. Escribano and Alvaro S. Araneda**
Combining time series data with spatial variability to study population dynamics of the large-sized calanoid copepod, *Rhyncalanus nasutus*, off central/southern Chile
- S7-3383 **Charles B. Miller**
Copepod growth dynamics in detail; challenging the limits of carbon analysis
- S7-3387 **Tarsicio Antezana and Carlos Melo**
Alternative pathways of larval development of Humboldt Current krill, *Euphausia mucronata*
- S7-3403 **Wen-Tseng Lo, Shwu-Feng Yu, Shih-Hong Wu and Don-Chung Liu**
Effects of water masses and seasonal monsoons on the distribution of siphonophores in Taiwanese waters
- S7-3406 **Irina Yu. Prusova and Sharon L. Smith**
Vertical distribution of species of Eucalanidae (Copepoda: Calanoida) in the Arabian Sea
- S7-3415 **Pamela Hidalgo, Erika Jorquera, Paula Mendoza and Rubén V. Escribano**
Diel vertical distribution of zooplankton as constrained by the upper boundary of the oxygen minimum zone at the coastal upwelling region off northern Chile
- S7-3417 **C. Tracy Shaw, Leah R. Feinberg and William T. Peterson**
Growth of *Euphausia pacifica* and *Thysanoessa spinifera* in the coastal NE Pacific
- S7-3421 **Jaime Färber-Lorda, Paul Fiedler and Miguel Lavín**
Night-day differences in zooplankton biomass in the eastern tropical Pacific
- S7-3424 **Ken-Ichi Sato, Atsushi Yamaguchi, Naonobu Shiga and Tsutomu Ikeda**
The effect of temperature on the development of the copepod *Eucalanus bungii* reared in the laboratory
- S7-3425 **Yasuko Onoue, Shinji Shimode, Tatsuki Toda, Syuhei Ban and Tomohiko Kikuchi**
Relationship between seasonal occurrences of planktonic population and types of diapausing eggs in *Acartia steueri* from three geographically different sites in Sagami Bay, Japan
- S7-3427 **Yoshinari Endo, Fuhito Yamano and Kenji Taki**
How does molting affect reproductive and feeding activities of *Euphausia pacifica*?
- S7-3431 **Stella Mudrak and Maria I. Zmijewska**
What do interannual changes of zooplankton tell us about long-term trends?
- S7-3436 **Ricardo Giesecke, Humberto E. González and Rubén V. Escribano**
What determines the success of *Sagitta enflata* as a major zooplankton predator in the Humboldt Current System?

- S7-3447 **Leah R. Feinberg, C. Tracy Shaw and William T. Peterson**
The timing and location of spawning for the euphausiids *Euphausia pacifica* and *Thysanoessa spinifera* off the Oregon coast, USA
- S7-3460 **Kunio T. Takahashi, Tsuneo Odate, Megumu Tsujimoto and Mitsuo Fukuchi**
Spatio-temporal variability in abundance and stage composition of three dominant Antarctic copepods along 140°E in the Indian Sector of the Southern Ocean
- S7-3469 **Jörg Dutz, Jasmin Renz and Jürgen Alheit**
Dynamics of Baltic Sea zooplankton and their sensitivity to climate/physical forcing
- S7-3474 **Kate Willis, Finlo Cottier, Slawek Kwasniewski and Stig Falk-Petersen**
The impact of climate change on zooplankton in an Arctic fjord
- S7-3476 **Kate Willis, Finlo Cottier, Slawek Kwasniewski and Stig Falk-Petersen**
Long-term monitoring of zooplankton in an Arctic fjord using sediment traps
- S7-3480 **Ksenia N. Kosobokova and Natalia M. Pertzova**
How does the Arctic copepod *Calanus glacialis* cope with the thermal regime in the subarctic White Sea?
- S7-3482 **Jai Gopal Sharma, Reiji Masuda and Masaru Tanaka**
Development of a new and simple technique for the continuous culture of *Brachionus plicatilis*
- S7-3486 **Diego F. Figueroa**
The distribution and community structure of zooplankton in the Galapagos Islands
- S7-3497 **Delphine Beyrend-Dur, Sami Souissi, David Devreker, Gesche Winkler and Jiang-Shiou Hwang**
Salinity effects on the life cycle traits of two genetically divergent populations of *Eurytemora affinis* (Copepoda: Calanoida): a laboratory study
- S7-3498 **Delphine Beyrend-Dur, Sami Souissi, David Devreker, Juan-C. Molinero and Jiang-Shiou Hwang**
High frequency sampling of the copepods *Eurytemora affinis* and *Acartia tonsa* populations in the Seine estuary, France: tidal and seasonal effects
- S7-3499 **Sofiane M. Mahjoub, Orlane Anneville, Juan C. Molinero, Sami Souissi and Jiang-Shiou Hwang**
Foraging behaviour of the European whitefish *Coregonus lavaretus* larvae on copepods
- S7-3506 **Cecilie T.Å. Broms, Webjørn Melle and John K. Horne**
Seasonal ascent of *Calanus finmarchicus* as driving force for herring feeding migration
- S7-3527 **Eileen E. Hofmann, Eric N. Powell, John N. Kraeuter, John M. Klinck and V. Monica Bricelj**
Can hard clam larval survivorship explain recruitment failure in the Great South Bay: a modelling study
- S7-3533 **Kevin J. Flynn and Roger P. Harris**
Trophic interactions between diatoms, non-diatoms and zooplankton; why polyunsaturated aldehydes cannot be considered as diatom defence metabolites
- S7-3539 **Ulf Båmstedt**
Significance of variability in food and temperature on copepod survival, growth and reproduction
- S7-3549 **Hildur Petursdottir and Astthor Gislason**
Seasonal abundance of zooplankton south of Iceland – a multivariate approach
- S7-3558 **Sandra Jansen, Sabine Grabbert and Ulrich Bathmann**
Reproduction and development of the copepods *Rhincalanus gigas*, *Calanus simillimus* and *Pleuromamma robusta* during an iron induced phytoplankton bloom (EIFEX) in the Southern Ocean
- S7-3564 **Gabriela Ma. Esqueda-Escárcega and Sergio Hernández-Trujillo**
Fluctuations of the copepod community in Magdalena Bay, Baja California Sur, México

- S7-3566 **Leopoldo Llinás, Robert S. Pickart, Jeremy T. Mathis and Sharon L. Smith**
The effects of eddy transport on zooplankton biomass and community composition in the western Arctic
- S7-3568 **Tomoko Yoshiki, Banri Yamanoha, Tomohiko Kikuchi and Tatsuki Toda**
The effects of hydrostatic pressure on eggs of the calanoid copepod, *Calanus sinicus*
- S7-3574 **Sanae Chiba and David L. Mackas**
GLOBEC process studies of small-scale biology-physics interactions
- S7-3586 **Atsushi Tsuda, Hiroaki Saito and Hiromi Kasai**
Life histories of ontogenetically migrating copepods in the Sea of Okhotsk and the Oyashio region: a comparative study
- S7-3593 **Maria Isabel Criales-Hernandez, Ralf Schwamborn, Patricia Ayón, Michelle Graco, Hans-Jürgen Hirche and Matthias Wolff**
Vertical distribution and migration of nearshore and offshore zooplankton in relation to the oxygen minimum zone off central Peru
- S7-3596 **Patricia Ayón and Hans-Jürgen Hirche**
Reproduction of the copepod *Acartia tonsa* in the nearshore zone off Callao (Peru)
- S7-3606 **Takumi Nonomura, Ryuji J. Machida and Shuhei Nishida**
Vertical distribution of *Calanus sinicus* and *C. jashnovi* (Copepoda: Calanoida), based on genetic identification, in Sagami Bay, central Japan
- S7-3619 **Hiroshi Hattori, Makoto Sampei, Ryosuke Makabe, Hiroshi Sasaki, Mitsuo Fukuchi and Louis Fortier**
Ontogenetic migration of copepods obtained with an upward migrating swimmer trap in the Amundsen Gulf, Canadian Arctic in the CASES 2003-2004
- S7-3622 **Salvatore Mazzola, Angela Cuttitta, Bernardo Patti, Angelo Bonanno, Monica Di Nieri, Carlo Patti, Gualtiero Basilone, Alba Ruth Vergara Castaño, Salvatore Aronica and Giuseppa Buscaino**
Spatial patterns in larval species diversity in the Strait of Sicily (Central Mediterranean). Could they be linked to hydrographic features?
- S7-3624 **Patricia Kremer and Laurence P. Madin**
An Antarctic opportunist, *Salpa thompsoni*
- S7-3627 **Angela Cuttitta, Bernardo Patti, Angelo Bonanno, Carmela Cavalcante, Monica Di Nieri, Luca Caruana, Carlo Patti, Gualtiero Basilone, Salvatore Aronica, Giuseppa Buscaino and Salvatore Mazzola**
Summer ichthyoplankton assemblage structure in the Strait of Sicily in relation to the key hydrographic features
- S7-3634 **Ji-ho Seo and J.K. Choi**
The effect of suspended sediment from sand-bed on *Acartia hongii* (Copepoda: Calanoida) in Kyeonggi Bay, Republic of Korea
- S7-3656 **Epaminondas D. Christou, Antonia Giannakourou and Dimitris Georgopoulos**
Effect of a total solar eclipse event on the vertical distribution of zooplankton in the Mediterranean Sea
- S7-3659 **Erica J.H. Head and Pierre Pepin**
Seasonal cycles of *Calanus* spp. abundance at fixed time series stations on the Scotian and Newfoundland Shelves (1999-2005)
- S7-3668 **François Carlotti**
A synthesis of the biology and ecology of *Centropages typicus*
- S7-3672 **Tao Zuo and Rong Wang**
Zooplankton communities on the continental shelf of the Yellow Sea and the East China Sea

- S7-3673 **Tao Zuo and Rong Wang**
Autumn diurnal vertical distribution of copepods in the Yellow Sea and the East China Sea
- S7-3679 **Janna Peters, Jörg Dutz, Jasmin Renz and Wilhelm Hagen**
Life-cycles and feeding of predominant copepod species in the Bornholm Basin (Baltic Sea) as indicated by lipid dynamics
- S7-3680 **Keun-Hyung Choi and Wim J. Kimmerer**
Mating success and sex ratio and their consequences for population growth of copepods
- S7-3705 **François Carlotti**
Characteristic time-scales of pelagic copepod egg production
- S7-3714 **Tobias Kreibich, Eike Gentsch, Benjamin Hansen, Reinhard Saborowski, Wilhelm Hagen and Barbara Niehoff**
Adaptation of lipolytic enzyme pattern and response in the fatty acid composition of *Temora longicornis* females (Calanoida, Copepoda) due to different diets under laboratory conditions
- S7-3731 **Rubens M. Lopes, Hans G. Dam, George McManus and Salvador Gaeta**
Observations on egg production rates of *Clausocalanus furcatus* from a subtropical coastal area
- S7-3732 **Adriana R.M. Crété and Rubens M. Lopes**
Coupling of *Calanoides carinatus* production with South Atlantic Central Water intrusions off the southeastern Brazilian shelf
- S7-3734 **Anda Ikauniece, Vadims Jermakovs and Juris Aigars**
Forecasting the future for a cladoceran *Bosmina longispina*, Gulf of Riga, eastern Baltic Sea
- S7-3744 **Jörn O. Schmidt, Jasmin Renz and Jörg Dutz**
Vertical distribution and diel vertical migration of main copepod species in the Bornholm Basin (Baltic Sea)
- S7-3746 **Maria A. Chicharo, Luis Chicharo, Ana Faria, Ana Amaral and Pedro Morais**
Are *Engraulis encrasicolus* eggs and larvae declining in the Guadiana estuary? Results before and after the Alqueva dam construction
- S7-3750 **Maarten Boersma, Andrea Gerecht, Simon Dittami, Thomas Wichard, Georg Pohnert and Karen H. Wiltshire**
Diatom-copepod interactions: linking nutritional quality with possible toxicity

S8 Zooplankton biochemistry and physiology: practical and potential biotechnology applications

Co-convenors: Ann Bucklin (USA), Adrianna Ianora (Italy) and Kurt Tande (Norway)

Invited Speaker: Angelo Fontana (Institute of Biomolecular Chemistry, Italy)

Advanced methodologies are emerging that are strongly impacting research development in the marine sciences. Studies using microsatellite markers are now providing new understanding of genetic differentiation, phenotypic plasticity and identification of subpopulations that are shaping the future of zooplankton ecology research. Fluorescent molecular probes have facilitated studies on physiological processes regarding the reproduction, development, growth and mortality of zooplankton. There is also a growing interest in marine bioprospecting, i.e. search for bioactive compounds relevant for drug development and other product categories. Although few zooplankton groups have been commercially utilised historically for this purpose, there may be great scope for research in this field in the future. This theme session seeks contributions from practical and potential biotechnological applications in zooplankton within, but not restricted to, the above outlined areas.

Wednesday 30 May 2007 09:00 - 12:40

- 09:00 *Welcome by convenors*
- 09:05 **Angelo Fontana, Guido Cimino, Adele Cutignano and Giuliana d'Ippolito**
Chemodiversity and biopotential of planktonic organisms (S8-3707)
- 09:35 **Ann Bucklin, Robert M. Jennings, Brian D. Ortman, Lisa Nigro, Christopher J. Sweetman, Nancy J. Copley and Peter H. Wiebe**
DNA barcoding of marine zooplankton: a 'Rosetta Stone' for taxonomic and biodiversity studies (S8-3442)
- 09:55 **Jessica R. Frost, Charles A. Jacoby, Giseller Gust, Morten H. Nielsen, Robert W. Campbell and Michael A. St. John**
Behavioural and biochemical effects of hydrostatic pressure changes on *Acartia tonsa* (Dana, 1848) (Copepoda: Calanoida): a methodological approach (S8-3725)
- 10:15 **Ryuji J. Machida, Mutsumi Nishida and Shuhei Nishida**
Zooplankton community genomics (S8-3362)
- 10:35 *Tea / coffee break*
- 11:00 **Young-Mi Lee, Kyun-Woo Lee, Jung Soo Seo, Hyun Park, Il-Chan Kim, Heum Gi Park, Sheikh Raisuddin, In-Young Ahn and Jae-Seong Lee**
The sigma class glutathione S-transferase (GST-S) enhances resistance on oxidative stresses in the intertidal copepod *Tigriopus japonicus* (S8-3726)
- 11:20 **Lidia Yebra, Andrew G. Hirst and Santiago Hernández-León**
Quantifying *Calanus finmarchicus* growth and dormancy using AARS activity (S8-3341)
- 11:40 **Ted T. Packard and May Gómez**
Enzymatic regulation of metabolism in planktonic communities (S8-3453)
- 12:00 **Isabella Buttino, Ylenia Carotenuto, Giuseppe De Rosa, Francesco Esposito and Marialuisa Mazzella**
Effects of diatom aldehydes on copepod reproduction: use of giant liposomes encapsulated with decadienal (S8-3405)
- 12:20 **Adrianna Ianora, Giovanna Romano and Antonio Miralto**
Use of fluorescent probes in studies on copepod reproduction and development (S8-3404)

S8 Posters

- S8-3322 **Benni Winding Hansen**
Eggs from a calanoid copepod *Acartia tonsa* – tolerance to environmental stressors
- S8-3331 **Yuan-Shao Lin, Wen-Qing Cao and Shao-Jing Li**
Population genetic structure of a copepod, *Calanus sinicus* Brodsky
- S8-3340 **Lidia Yebra, Roger P. Harris, Erica J.H. Head, Igor Yashayaev, Les Harris and Andrew G. Hirst**
Seasonal mesoscale variability and zooplankton production in the Labrador Sea
- S8-3366 **Chi-Chi Liu, Yuan-Shao Lin, Wen-Qing Cao and Lu-Ping Fang**
Comparative studies of mitochondrial COI sequence between two *Acartia* species from Xiamen waters
- S8-3507 **Isabella Buttingo, Giovanni Sansone, Silvia Buono, Valentina Vitiello, Maria Gabriella Malzone, Cira Rico and Francesca Rinna**
Experimental intensive cultivation of the Mediterranean copepod *Temora stylifera* in a re-circulating system and their potential use as live food in aquaculture
- S8-3532 **María Delia Viñas, Ann Bucklin, Hans M. Verheye, José Guilherme F. Bersano, Sara Ceballos and Wanda Monteiro Ribas**
Taxonomic and phylogeographic comparisons of *Calanoides carinatus* (Copepoda, Calanoida, Calanidae) from the Atlantic Ocean (43°N - 47°S)
- S8-3637 **Ingrid Overrein, Turid Rustad, Jan O. Evjemo, Dag Altin and Jose R. Rainuzzo**
Seasonal- and post mortem changes in *Calanus finmarchicus*, with main emphasis on lipids
- S8-3641 **Peter H. Wiebe, Ann Bucklin, Laurence P. Madin, Martin V. Angel, Tracey Sutton, Francesc Pages and Russell R. Hopcroft**
Integrated at-sea morphological and molecular assessment of zooplankton biodiversity in the Northwestern Atlantic Ocean from the surface to 5000 m
- S8-3727 **Young-Mi Lee, Kyun-Woo Lee, Heum Gi Park and Jae-Seong Lee**
Mining of massive expressed sequence tags (ESTs) from the intertidal copepod *Tigriopus japonicus* using GS-20 sequencer
- S8-3728 **Dae-Sik Hwang, Kyoung-Soon Shin and Jae-Seong Lee**
High similarity of 16S rRNAs between two jellyfishes, *Aurelia aurita* and *Dactylometra quinquecirrha*
- S8-3730 **Dae-Sik Hwang, Young-Shil Kang, Kyoungsoon Shin and Jae-Seong Lee**
Mitochondrial genomes of two jellyfishes, *Aurelia aurita* and *Dactylometra quinquecirrha*
- S8-3784 **Leocadio Blanco-Bercial, A. Bucklin and F. Álvarez-Marqués**
Spatial population genetic structure and phylogeography of two species of the copepod genus *Clausocalanus*
- S8-3976 **Jan Ove Evjemo, Nils Tokle, Olav Vadstein and Yngvar Olsen**
Effect of the essential fatty acids DHA and EPA on egg production and hatching success of the marine copepod *Temora longicornis*

S9 Advances in image technologies and the application of image analysis to count and identify plankton

Co-convenors: Cabell Davis (USA) and Xabier Irigoien (Spain)

Invited speakers: Mark Benfield (Louisiana State University, USA) and Philippe Grosjean (Mons University, Belgium)

One of the main problems confronting plankton research is low sampling resolution, both spatial and temporal. Although it is widely recognised that the relevant scales for plankton are much smaller than those usually sampled, the work involved in plankton sample analysis has made it impossible to sample at very high resolution in most programmes. To some extent the lack of sampling capability has been resolved using simplified measurements such as Chl *a*, total biovolume, biomass (wet or dry weight) or more sophisticated systems providing size and number of particles (e.g. OPC). However, these methods have a common problem: they lack the ability to distinguish between different functional groups of plankton that we know have a very different roles in the ecosystem (e.g. diatoms vs flagellates, marine snow, or copepods vs appendicularia). In recent years several *in situ* and laboratory imaging systems have been developed. These systems are capable of obtaining relatively good resolution images at high sampling rates that would in theory allow quantification of the abundance of taxonomically well-resolved groups in the appropriate spatial and temporal scales. These systems have been confronted by a new problem, due to the huge amount of information (images) they produce, which is again impossible to analyse manually. New image analysis systems offer an advantage over other methods of counting/sizing: the images can be used for automated taxonomic identification using different recognition systems to identify at least major groups. Many sophisticated automatic recognition algorithms exist, and the research in this area is very active. The objective of this session is to present state of the art systems (imaging and analysis software) as well as examples of the results obtained using image analysis approaches to high resolution sampling.

Friday 1 June 2007 09:00 - 12:40

- 09:00 **Welcome by Convenors**
- 09:05 **Mark C. Benfield and Peter H. Wiebe**
From the OPC to the CCD (S9-3667)
- 09:30 **Philippe Grosjean and Kevin Denis**
The computer does the hard work: (semi)-automatic classification of zooplankton (S9-3299)
- 09:55 **Phil Culverhouse, R. Williams and Isabella Buttino**
Taxonomically driven recognition of features for visual categorisation of zooplankton (S9-3560)
- 10:15 **Nick Loomis, Jose A. Dominguez-Caballero, Weichang Li, Qiao Hu, Cabell Davis, Jerome Milgram and George Barbastathis**
A compact, low-power digital holographic imaging system for automated plankton taxonomical classification (S9-3411)
- 10:35 **Tea / coffee break**
- 11:00 **Angel Lopez-Urrutia, Jesus Cabal and Luis Valdés**
Estimating zooplankton production from images (S9-3654)
- 11:20 **Carin J. Ashjian**
Bridging the gap between biology and physics: the use of the Video Plankton Recorder to understand distributions and transport of plankton and particles in the Western Arctic (S9-3713)
- 11:40 **Lars Stemann, Marc Picheral, Harriet Paterson, Robert Kevin, Lionel Guidi, Gabriel Gorsky**
Biogeography of gelatinous macroplankton in the upper 1000 m depth inferred from the Underwater Video Profiler (S9-3546)
- 12:00 **Leonardo Castro, Arnoldo Valle-Levinson, Marcus Sobarzo, Cristian Chandia and Samuel Soto**
The ADCP-backscatter and the use of ZOOIMAGE for discriminating diel vertical migrating zooplankton (S9-3669)
- 12:20 **Robert W. Campbell and Morten H. Nielsen**
Meso- to small-scale distributions of plankton and marine snow in the southeastern North Sea in relation to fronts (S9-3661)

S9 Posters

- S9-3430 **Keiichiro Ide, Kazutaka Takahashi and Hiroaki Saito**
The use of FlowCAM for rapid shipboard analysis of grazing by copepods
- S9-3435 **Frank Gaardsted, Are Edvardsen and Kurt S. Tande**
Extracting zooplankton information from Laser Optical Plankton Counter (LOPC) data
- S9-3487 **Elvire Antajan, Ricco Rakotomalala, Stéphane Gasparini, Marc Picheral, Lars Stemmann and Gabriel Gorsky**
Automatic quantification and recognition of major zooplankton groups in a North Sea time series using the Zooscan imaging system
- S9-3501 **Nick Mortimer and J. Anthony Koslow**
PlanktonJ: an interactive tool for zooplankton measurement and image analysis
- S9-3518 **Pierre Joly, Stéphane Plourde and Xabier Irigoien**
A comparison of the performance of a new image analysis system (ZooImage) and the traditional taxonomist approach in the analysis of zooplankton samples from the Gulf of St. Lawrence, northwest Atlantic
- S9-3561 **Phil Culverhouse, R. Williams, Mark C. Benfield and Ioannis Psitsikas**
Pleione: a reference database of plankton images collected by automated imaging systems
- S9-3562 **Phil Culverhouse, R. Williams and Chris Gallienne**
Mesoplankton Image Analyser (MIA)
- S9-3580 **Cabell Davis and Qiao Hu**
Visual Plankton: automatic identification and visualisation of plankton taxa off-line or real-time
- S9-3591 **Dirk M. Mendedoht, Jan Schulz and Hans-Jürgen Hirche**
Imaging live zooplankton by Light frame On-sight Key species Investigation (LOKI)
- S9-3592 **Xabier Irigoien, Agurtzane Urtizbera, Aitor Albaina and Maria Santos**
Zooplankton spring distribution in the Bay of Biscay: biomass and size distribution using image analysis
- S9-3604 **Erhan Mutlu**
DVM dynamics of two mesozooplankton as inferred acoustically in the Black Sea
- S9-3670 **Joyce Mendez, Leonardo R. Castro, Samuel Soto and Luis Cubillos**
Larval prey field and invertebrate predators in the southernmost spawning zone of the anchoveta, *Engraulis ringens*, determined from ZOOIMAGE and GAM analyses
- S9-3678 **Gabriel Claramunt, Samuel Soto, Paola Moreno, Joyce Mendez, Karen Manríquez, Leonardo R. Castro, Pamela Hidalgo and Rubén V. Escribano**
Variability of zooplankton community structure and biomass in the coastal upwelling zone of the Chilean Humboldt Current as assessed by ZOOIMAGE analysis
- S9-3681 **Michael E. Sieracki, W.M. Balch, M.C. Benfield, A.R. Hansen, M.A. Mattar, S.J. Murtagh, C.H. Pilskaln, E.M. Riseman, H. Schultz, B. Tupper and P.E. Utgoff**
Software tools for automated recognition of plankton from digital images
- S9-3709 **Marc Picheral, Elvire Antajan, Stéphane Gasparini, Lars Stemmann, Seugmin Choe and Gaby Gorsky**
Digital archiving and processing of zooplankton samples with the Zooscan system
- S9-3737 **Pascal Lehette and Santiago Hernández-León**
Mesozooplankton biomass estimation from digitised images
- S9-3739 **Russ E. Davis, Mark D. Ohman and Jeff T. Sherman**
Autonomous ocean gliders as a platform for continuous zooplankton observations
- S9-3762 **Harry Nelson, Nicole J. Poulton and Scott Ellis**
Using a continuous imaging particle analyser (FlowCAM®) for the analysis and classification of zooplankton
- S9-3977 **Norman MacLeod**
A comparison between geometric morphometric and PSOM neural net approaches to automated species identification in planktonic foraminifera

S10 Analysis and synthesis: modelling zooplankton in aquatic ecosystems

Co-convenors: Daniel Grunbaum (USA) and Michio Kishi (Japan)

Invited speaker: Daniel Grunbaum (University of Washington, USA)

Zooplankton models have a long history and have made major contributions to our understanding of trophic impacts in marine ecosystems, giving us key quantitative insights into spatial processes such as vertical fluxes and temporal phenomena such as spring blooms. In the future, models of zooplankton dynamics will have rapidly expanding and increasingly central roles as tools for interpreting, integrating and extracting predictive insights from observations. Improving technology is resulting in an exponential growth of biological oceanography datasets that span spatial, temporal and organisational scales from organism-level genetics and physiology to basin-wide biomass distributions. At the same time, scientific and societal needs for quantitative understanding of ecological and evolutionary dynamics in the oceans are increasing in accuracy and scope. Translating better data into enhanced understanding will require new breadth and depth in zooplankton modelling approaches. We invite papers that advance spatial, temporal or organismal analysis of interactions among zooplankton and between zooplankton and other components of plankton communities, and of zooplankton dynamics in global and regional ecosystems. We especially welcome new, integrative applications of existing modelling approaches such as biomass-based (NPZ) models and individual-based models, and novel modelling techniques that promise to synthesize and reconcile diverse observations at multiple organisational levels. A more comprehensive understanding of the boundary current systems requires modelling approaches, although the data for model validation is often limited. This session will also provide consideration of observing system requirements and techniques for monitoring boundary current circulation and ecosystems, in particular the necessary combination of data and models.

Wednesday 30 May 2007 14:00 - 17:40

- 14:00 **Welcome by convenors**
- 14:05 **Daniel Grunbaum**
Expressing simplicity while implying complexity: increasing the biological information content of ocean biogeochemical models (S10-3745)
- 14:35 **Thomas J. Kunz, Alistair J. Hobday and Anthony J. Richardson**
Modelling climate change impacts on zooplankton in the Tasman Sea, southwest Pacific (S10-3583)
- 14:55 **Marcos Llope, Nils Chr. Stenseth, Ricardo Anadón, Lorenzo Ciannelli, Kung-Sik Chan, Dag Ø. Hjermann, Espen Bagøien and Geir Ottersen**
Seasonal plankton dynamics along a cross-shelf gradient off northern Spain (S10-3439)
- 15:15 **Vincenzo Botte, Maria Grazia Mazzocchi and Maurizio Ribera d'Alcalà**
Modelling the copepod-phytoplankton interactions in presence of chemical defenses (S10-3490)
- 15:35 **Tea / coffee break**
- 16:00 **Fabien Lombard, Jonathan Erez, Elisabeth Michel and Laurent Labeyrie**
Multispecies modelling approach to predict foraminifer growth, ecological niches and shell export to the sea floor (S10-3578)
- 16:20 **Eric N. Powell, Eileen E. Hofmann, John M. Klinck and Dennis Hedgecock**
A coupled genetics-growth model for *Crassostrea gigas* larvae (S10-3524)
- 16:40 **Harold P. Batchelder, Brie J. Lindsey, Enrique Curchitser and William T. Peterson**
Modelled growth and development of *Euphausia pacifica* in the Northern California Current (S10-3683)
- 17:00 **Michio J. Kishi and Takeshi Terui**
Population dynamics model of Copepoda (*Neocalanus cristatus*) in the northwestern subarctic Pacific (S10-3319)
- 17:20 **Frédéric Maps, Stéphane Plourde, Bruno Zakardjian and François J. Saucier**
Modelling the interactions between the hydrodynamics and the population dynamics of *Calanus finmarchicus* in the Gulf of St. Lawrence, eastern Canada: (1) The “*Calanus* circuit” (S10-3975)

S10 Posters

- S10-3300 **Geir Huse, Morten Skogen, Einar Svendsen and Knut Yngve Børsheim**
Zooplankton-phytoplankton interactions simulated by combining distinct modelling approaches in the Norwegian Sea
- S10-3385 **Shin-ichi Ito, Kenneth A. Rose, Naoki Yoshie, Bernard A. Megrey, Michio J. Kishi and Francisco E. Werner**
Evaluation of an automated calibration approach for calibrating the NEMURO nutrient-phytoplankton-zooplankton food web model
- S10-3495 **Gael Dur, Sami Souissi, David Devreker, Vincent Ginot, François G. Schmitt and Jiang-Shiou Hwang**
Individual-based experimental and modelling approach to study the effects of temperature and individual variability on the reproduction of the estuarine copepod *Eurytemora affinis*
- S10-3496 **Gael Dur, Sami Souissi, David Devreker, Vincent Ginot, François G. Schmitt and Jiang-Shiou Hwang**
Investigation of the influence of temperature on the estuarine copepod *Eurytemora affinis* population dynamics through a combination of an individual-based model and field observations
- S10-3510 **Qiao Hu, Cabell Davis and Colleen Petrik**
A simplified age-stage model for copepod population dynamics
- S10-3515 **Marco Uttieri, Daniela Cianelli, J. Rudi Strickler and Enrico Zambianchi**
Zooplankton encounters in uniform vs. patchy particle distributions
- S10-3516 **Todd D. O'Brien**
COPEPOD: an online plankton database and modeller's resource
- S10-3522 **Frédéric Maps, Stéphane Plourde, Bruno Zakardjian and François J. Saucier**
Modelling the interactions between the hydrodynamics and the population dynamics of *Calanus finmarchicus* in the Gulf of St. Lawrence, eastern Canada: (2) mechanistic formulation of the mortality, swimming behaviour and diapause processes
- S10-3577 **Fabien Lombard, Marc Picheral, Antoine Sciandra, Louis Legendre and Gabriel Gorsky**
Multispecies modelling approach to predict ecological niches and carbon export by appendicularians
- S10-3588 **Bettina A. Fach, Ralph Timmermann, Bettina Meyer, Dieter Wolf-Gladrow and Ulrich Bathmann**
Modelling Antarctic krill (*Euphausia superba*) development in the Lazarev Sea
- S10-3652 **Tim J. Cowles, Malinda Sutor, Amanda Whitmire, Kelly Benoit-Bird, Chris Wingard and Russ Desiderio**
Plankton layers: formation, persistence, and ecological consequences
- S10-3703 **Lionel Eisenhauer, François Carlotti and Albert Calbet**
Modelling the effect of constant and fluctuating food supply on egg production rates of *Acartia grani*
- S10-3751 **Kit Yu Karen Chan and Daniel Grünbaum**
Larval consumption of dissolved organic matter (DOM) and population viability of marine invertebrates in a changing ocean

W1 Temporal and regional responses of zooplankton to global warming: phenology and poleward displacement

Convenor: *Wulf Greve (Germany)*

The mean temperature of the biosphere is increasing on land and - after a lag-phase - in the oceans. The organisms of the sea - evolutionarily accustomed to a low level of annual and seasonal variance in temperature - respond to the global warming with changes in the seasonal timing and with lateral shifts of the range of distribution. Phenology, the science of the timing of recursive events in organism's life cycles, established in terrestrial sciences, will help to recognise temporal responses of zooplankton including fish and benthic larvae and to understand distributional change on a local and global scale. Community changes, the appearance of neozoa and the loss of even key species to regional biota can be understood as responses to climatic change, mismatch with their traditional environment and opening of their ecological niches elsewhere. The process of global warming-related community change has begun. In trying to observe, document and analyse it we can increase our understanding of the functioning of the pelagic ecosystem regarding this process as a large natural experiment. This workshop will address aspects of this natural experiment, new data, new approaches, and new syntheses.

Monday 28 May 2007 10:00 - 17:50

- 10:00 **Welcome by Convenor**
- 10:05 **Wulf Greve**
Climate effects on North Sea zooplankton (W1-3433)
- 10:35 **Sophie G. Pitois and Clive J. Fox**
Have climate induced changes in zooplankton communities led to poor conditions for larval fish growth? A test on cod larvae on the UK shelf (W1-3312)
- 10:55 **Rüdiger Voss, Jörn O. Schmidt and Dietrich Schnack**
Impacts of climate change on the Baltic zooplankton – fish larvae link: evidence for sprat (*Sprattus sprattus* L.) larval behaviour change influencing recruitment levels (W1-3347)
- 11:15 **Tea / coffee break**
- 11:30 **Leif Chr. Stige, Dmitry L. Lajus, Kung-Sik Chan, Sergey Timofeev and Nils Chr. Stenseth**
The combined effects of climate and fish on zooplankton abundance and distribution in the southern Barents Sea (W1-3676)
- 11:50 **Dag Slagstad, Ingrid Ellingsen and Are Edvardsen**
Effect of climatic change on the production and distribution of *Calanus finmarchicus* in the Norwegian and Barents Seas (W1-3742)
- 12:10 **Hans-Juergen Hirche, Anne Wesche, Karen H. Wiltshire and Wulf Greve**
What controls interannual variability of abundance and phenology of *Acartia clausi* in the southern North Sea? (W1-3589)
- 12:30 **Lunch**
- 14:20 **Sergey A. Piontkovski and Claudia Castellani**
Decline of zooplankton biomass in the tropical Atlantic Ocean (W1-3349)
- 14:40 **Sonia Batten**
Changes in the oceanic northeast Pacific plankton populations; what may happen in a warmer ocean (W1-3329)
- 15:00 **Martin Edwards and Gregory Beaugrand**
Spatial variability of marine climate change impacts in the North Atlantic (W1-3689)

- 15:20 **Juan-Carlos Molinero, Frédéric Ibanez, Sami Souissi, Priscilla Licandro, Emmanuelle Buecher, Serge Dallot and Paul Nival**
Northern hemisphere climate impact on Mediterranean zooplankton (W1-3741)
- 15:40 ***Tea / coffee break***
- 16:10 **Tamara Shiganova**
Arrival of Mediterranean species into the Black Sea is increasing (W1-3440)
- 16:30 **A.V. Temnykh, Y.A. Zagorodnyaya, V.V. Melnikov, V.N. Belokopytov and V.K. Moryakova**
The variability of the Black Sea zooplankton as a derivative of long term dynamics in the water hydrological structure (W1-3296)
- 16:50 ***Discussion***
- 17:40 ***Closing remarks***

W2 Zooplankton research in Asian countries: current status and future prospects

Co-convenors: Sun Song (P.R. China), Sanae Chiba (Japan) and Young-Shil Kang (Republic of Korea)

The Indian-Pacific region is a region of high zooplankton biodiversity, covering several high biological productivity areas and several important fishing grounds. Many Asian countries are developing countries, and they are facing the common issues: marine pollution, coastal destruction, overfishing, and marine aquaculture etc. These activities affect the coastal ecosystem more seriously than climate change, in turn, the marine ecosystems in this area are being influenced both by climate change and human activities. As zooplankton play vital roles in the aquatic ecosystem, it can be used as an indicator of ecosystem change. Zooplankton research in Asian countries has developed very rapidly in recent years, from primitive level studies in local waters to internationally collaborative projects in the open ocean. However, these are still weak compared to European and Northern American countries. The purpose of this workshop is to facilitate zooplankton research in Asian countries by presenting research activities, results, progress, main problems, strategies, surveys, standard methods, and main instruments. We aim to strengthen our cooperative research and long-term zooplankton survey, and establish a list of Asian zooplankton communities and a zooplankton data exchange system. Although several workshops, conferences and symposia have been carried out in the last 10 years in Japan, the Republic of Korea and China under the framework of GLOBEC, LME, HAB and PICES, we hope other Asian countries will participate in these activities.

Monday 28 May 2007 10:00 - 18:00

- 10:00 **Welcome by Convenors**
- 10:15 **Ramasamy Santhanam**
Current zooplankton production research in India (W2-2794)
- 10:35 **Young-Shil Kang and Seok-Hyun Youn**
Zooplankton in Korean waters (W2-3426)
- 10:55 **Mulyadi and Inneke F.M. Rumengan**
Zooplankton research in Indonesian waters (W2-3658)
- 11:15 **Tea / coffee break**
- 11:30 **Jun Nishikawa and Shuhei Nishida**
Mesozooplankton in the Sulu Sea and its adjacent waters with special reference to copepods (W2-3693)
- 11:50 **Riki Sato**
Experimental study of appendicularians (W2-3612)
- 12:10 **Mary Mar P. Noblazada and Wilfredo L. Campos**
Spatial distribution of chaetognaths along with oceanographic conditions off the northern Bicol Shelf, Philippines (Pacific Coast) (W2-3399)
- 12:30 **Lunch**
- 14:00 **Chetan A. Gaonkar, Venkat Krishnamurthy and Arga Chandrashekar Anil**
Zooplankton community structure in the ports of Mumbai, India: an account since the 1940s (W2-3286)
- 14:20 **Chih-hao Hsieh, Toshiyuki Ishikawa, Youichirou Sakai, Kanako Ishikawa and Michio Kumagai**
Long-term variation of trophic status and its impact on the diversity and abundance of zooplankton in Lake Biwa (W2-3402)
- 14:40 **Iskandar Mirabdullayev, Lola Abdullayeva and Ablatdiyn Musaev**
Succession of zooplankton in the Aral Sea (W2-3674)

- 15:00 **Ephrime Bicoy Metillo and Anelyn Lim Dapanas**
Monsoonal influence on the spatio-temporal patterns of zooplankton abundance and assemblage structure in Iligan Bay, northern Mindanao, Philippines (W2-3301)
- 15:20 **Nallamuthu Godhantaraman**
Seasonal variations in abundance, biomass and ecological significance of microzooplankton in tropical coastal marine waters, South India (W2-3267)
- 15:40 ***Tea / coffee break***
- 16:10 **Jinhui Wang, Yuanli Yang, Yawei Sun and Caicai Liu**
Response of zooplankton populations to eutrophication in the Changjiang Estuary: phosphate enrichment in mesocosms and in the field (W2-3600)
- 16:30 **Vijayalakshmi R. Nair**
Role of zooplankton in pollution monitoring: case studies along the west coast of India (W2-3467)
- 16:50 **Hina S. Baig, Saira Ishaq, M.M. Rabbani and S.M. Ali**
Variation in distribution of phyto- and zoo-plankton biomass during the NE-monsoonal period in coastal waters of Karachi, Pakistan (W2-3635)
- 17:10 ***Introduction of posters***
- 17:25 ***Discussion***
- 17:50 ***Closing remarks***

W2 Posters

- W2-3327 **Joepette J. Hermosilla and Filipina B. Sotto**
Distribution of ichthyoplankton relative to moon-induced tide inside and outside the marine sanctuaries of Cabilao Island, Bohol, Philippines
- W2-3344 **Rosamma Stephen, Honey U.K. Pillai, K.J. Jayalakshmi, P. Sabu and C.T. Achuthankutty**
Zooplankton study in Bay of Bengal, 1999-2005-changing perspectives
- W2-3363 **Ryota Nakajima, Teruaki Yoshida, B.H.R. Othman and Tatsuki Toda**
Quality and quantity of particulate organic matter and nutrition of zooplankton in a coral reef of Peninsular Malaysia
- W2-3400 **Naoki Nagai, Kazuaki Tadokoro, Kazunori Kuroda and Takashige Sugimoto**
Species-specific responses of three dominant chaetognaths to climate regime shifts in the Tsushima Warm Current of the Japan Sea during 1972-2002
- W2-3611 **Yuji Okazaki, Hideaki Nakata, Aida Sartimbul and Kou Nishiuchi**
Distribution and abundance of copepod nauplii in the southern East China Sea: implications for prey availability of jack mackerel (*Trachurus japonicus*) larvae
- W2-3621 **Honey U.K. Pillai, C.K. Shiju, S.U. Panampunnayil, Vijayalakshmi R. Nair and C.B. Lalitahambika Devi**
Community structure and diversity of zooplankton in the Mahatma Gandhi Marine National Park, Wandoor, South Andaman, Indian Ocean
- W2-3631 **Alexander V. Zavolokin, Natalya S. Kosenok and Igor I. Glebov**
Abundance, distribution and feeding habits of jellyfish in the upper epipelagical of the western Bering Sea
- W2-3632 **Samina Kidwai, Shahid Amjad, Naem Ahmed, Mohsin Tabrez and M.M. Rabbani**
Spatio-temporal variability in the ichthyolarvae and zooplankton in the tidally influenced creeks of the Indus delta, North Arabian Sea
- W2-3649 **Chang Rae Lee and Chul W. Park**
Vertical distribution and community properties of mesozooplankton in the Japan/East Sea

W3 Krill research: current status and its future

Co-convenors: *So Kawaguchi (Australia) and William T. Peterson (USA)*

Invited Speaker: *Stephen Nicol (Australian Antarctic Division, Australia)*

The significance of euphausiids in marine ecosystem has been recognised for centuries particularly because of their obvious importance in the diet of baleen whales and many fish. They are excellent experimental organisms because of their relatively large size and high survival rate in captivity. They are also an ideal model organism for studying interactions between environmental and organismal variability at a variety of scales ranging from short-term variation up to regime shifts. Recent advances in technology have increased the range of techniques that can be used for studies on krill biology and ecology, and the outcomes are now covering numerous research topics. The purpose of this workshop is to review current knowledge of krill biology, to highlight gaps and future areas for research, and to explore how the study of a range species of krill can further address general problems of the euphausiids (flux, biomass, recruitment, behaviour, growth and ageing, genetics).

Monday 28 May 2007 10:00 - 17:50

- 10:00 **Welcome by convenors**
- 10:05 **Stephen Nicol**
What is so special about krill? (W3-3314)
- 10:35 **Angus Atkinson, Volker Siegel, Evgeny A. Pakhomov Valerie J. Loeb, Robin M. Ross, Langdon B. Quetin, Eugene J. Murphy, Peter Rothery, Peter Fretwell and Andrew Fleming**
Understanding mechanisms for the success of Antarctic krill: an approach based on habitat risk and reward (W3-3512)
- 10:55 **Jonathan L. Watkins, Eugene J. Murphy, Philip N. Trathan, Michael P. Meredith, Sally E. Thorpe and Geraint A. Tarling**
The importance of advection in a productive Southern Ocean ecosystem (W3-3715)
- 11:15 **Tea / coffee break**
- 11:30 **Geraint A. Tarling and Janine Cuzin-Roudy**
Relationship of parasitism to life-cycle characteristics of *Euphausia superba* (W3-3475)
- 11:50 **Martin J. Cox, David A. Demer, Joe Warren, George Cutter and Andrew S. Brierley**
Characterising the three dimensional structure of Antarctic krill (*Euphausia superba*) swarms (W3-3513)
- 12:10 **Gareth L. Lawson, Peter H. Wiebe, Carin J. Ashjian, Christine A. Ribic, Erik W. Chapman, Ari S. Friedlaender and Deborah Thiele**
Antarctic krill aggregation structure and vertical migration in relation to features of the physical and biological environment (W3-3711)
- 12:30 **Erik W. Chapman, Eileen E. Hofmann and William R. Fraser**
Climate variability, Antarctic krill (*Euphausia superba*) spawning, and Adelie penguin (*Pygoscelis adeliae*) chick growth (W3-3706)
- 12:50 **Lunch**
- 14:00 **Valerie J. Loeb, Eileen E. Hofmann, John M. Klinck, Osmund Holm-Hansen and Warren B. White**
ENSO drives interannual variability of the Antarctic Peninsula pelagic marine ecosystem (W3-3572)
- 14:20 **C. Tracy Shaw, Leah R. Feinberg, Jaime Gómez-Gutiérrez and William T. Peterson**
Review of life history and ecology of *Euphausia pacifica* off Newport, OR, USA (W3-3529)

- 14:40 **Huilian Liu, Zhencheng Tao and Song Sun**
The distribution pattern, abundance and life cycle of *Euphausia pacifica* in the southern Yellow Sea (W3-3464)
- 15:00 **Jaime Gómez-Gutiérrez, Carlos J. Robinson, Jorge Del Angel-Rodríguez, Samuel Martínez-Gómez, Nelly Tremblay, Tania Zenteno-Savín, Carmen Rodríguez-Jaramillo, Karmina Arroyo Ramírez and Christian Zavala-Hernández**
Multidisciplinary study of the subtropical sac-spawning euphausiid *Nyctiphanes simplex* in the southern part of the California Current System and Gulf of California (W3-3275)
- 15:20 **Joseph J. Torres, Joel L. Bellucci and Joseph Donnelly**
Southern Ocean GLOBEC: overwintering metabolism in Antarctic zooplankton and micronekton (W3-3748)
- 15:40 **Tea / coffee break**
- 16:10 **Dorothea Stübing and Wilhelm Hagen**
Seasonal lipid dynamics of the Antarctic krill *Euphausia superba* in the Lazarev Sea (W3-3617)
- 16:30 **Bettina Meyer, Veronica L. Fuentes, Katrin Schmidt and Carsten Pape**
The importance of zooplankton as food source for larval Antarctic krill, *Euphausia superba* during winter (W3-3531)
- 16:50 **Toshihiro Yoshida, So Kawaguchi, Bettina Meyer, Jennifer Penschow and Gerry Nash**
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P

Plenary

29 May, 09:45 (Plenary-3738) Invited

Impacts of ocean acidification on marine zooplankton: knowns and unknowns

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Oceanic uptake of anthropogenic carbon dioxide (CO₂) changes the seawater chemistry and may have significant impacts on zooplankton. Increasing the amount of CO₂ dissolved in the ocean lowers the pH and decreases the carbonate ion concentration and the saturation states of aragonite and calcite, the major biogenic calcium carbonate minerals. Estimates of future CO₂ emissions indicate that atmospheric CO₂ levels could approach 800 ppm by the end of the century. Corresponding models for the oceans suggest that the average surface water pH will decrease by approximately 0.4 pH units and the carbonate ion concentration will decrease by as much as 48%, relative to preindustrial values. If current rates of CO₂ emissions continue, surface waters of high latitude regions will become undersaturated with respect to aragonite by the year 2100, and calcite undersaturation will follow. Calcifying zooplankton such as foraminifera, euthecosomatous pteropods, and planktonic larvae of benthic calcifiers (e.g. molluscs, echinoderms) will likely be directly impacted by ocean acidification. Evidence suggests that some non-calcifying zooplankton may also be sensitive to elevated pCO₂ conditions. If CO₂-sensitive species cannot adapt to changing seawater chemistry, then the vertical and latitudinal distributions of these zooplankton taxa are expected to shift. Because high resolution data of the baseline distributions of calcareous zooplankton are limited, changes that may occur within the next 50-100 years will be difficult to detect. The consequences of ocean acidification to productivity, food web interactions, and carbon and nutrient cycling are largely unknown, but may be significant for both planktonic and benthic ecosystems.

29 May, 11:00 (Plenary-3798) Invited

In hot water: zooplankton communities now and in the future

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I describe some of the theoretical and observed impacts of global warming on plankton, from the organism to the community level, and ultimately possible future impacts on marine ecosystems. I deliberately take a large-scale view and draw on evidence from the laboratory, time series and modelling studies. Direct effects of temperature on organism physiology have been described from laboratory studies and are likely to explain the observed earlier appearance in the field of crustacean, gelatinous and ichthyoplankton. Most physiological rates, however, do not accelerate indefinitely with temperature, but are generally adapted to an optimal thermal environment. Species distributions are sensitive to temperatures, both annually in response to climate indices, and also in the longer-term in response to ocean warming. Even more important than these direct effects of temperature on species are likely to be the indirect effects on communities. This is because temperature influences and is a proxy for water column stability, and thus nutrient enrichment and the degree of new production. This has profound implications for the abundance, size composition, diversity and the dependence upon recycled production of the entire community. This link between temperature and nutrient enrichment is not as clear in terrestrial systems, so the effect of global warming in marine systems may both be greater and more easily studied, at least on the broad scale. I conclude with examples of possible marine impacts of future climate change. By using output from global climate models under future greenhouse gas emission scenarios, researchers have explored effects of climate change on species distribution, on the abundance and composition of plankton communities, and on the implications for higher trophic levels.

29 May, 11:45 (Plenary-3401) Invited

The role of microzooplankton in a changing ocean

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Microzooplankton highlight as main grazers in most marine ecosystems on Earth, from ultra-oligotrophic areas to upwellings, where they outcompete copepods and other larger zooplankters. They are also important contributors to the diet of mesozooplankton (e.g. in oligotrophic ecosystems microzooplankton-associated carbon supply for copepods surpasses that of phytoplankton), and they have key roles as nutrient recyclers and CO₂ producers. This talk will summarise the present knowledge on the role of microzooplankton in the oceans, identifying its weak aspects, and suggesting lines of research to be reinforced. The talk will also describe the effects that human forcing and climate change may have on microzooplankton. It is out of question anthropogenic activities are directly influencing marine systems (e.g. eutrophication, overfishing, modification of the line shore, pollution, etc.). Human activities are also indirectly affecting the chemistry of the water by raising the atmospheric CO₂ concentration, which results in an acidification of the oceans. This compound and other chemicals generated by human activities may also likely be altering the climate by greenhouse effects, and therefore influencing the oceans. The results of these processes on the ecosystem, and specifically upon microzooplankton, are diverse and complex to interpret and predict. Here I will present some speculations on the fate of microzooplankton populations under different future hypothetical scenarios.

S1 Global comparisons of zooplankton time series

29 May, 14:05 (S1-3357) Invited

Plankton, from the last ice age to the year 3007

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Climate forcing of the environment and biota have been happening since time immemorial, human forcing only for the past 200 years or so. The paper considers, first, climatic changes over the past 30,000 years as indicated by plankton and how the changes have affected plankton. Only fossilizable zooplankton can be observed: principally foraminifera, radiolaria and pteropods, and their food which is represented by coccoliths, fossil diatoms and dinoflagellate cysts. The soft-bodied zooplankton species, especially copepods, which lived with them can only be inferred. Secondly, an attempt is made to predict how “human forcing” in the form of human-caused climate change is likely to affect marine ecosystems in the future. All plankton will inevitably be greatly affected by the habitat changes that global warming will bring. The Arctic Ocean and especially the Canadian Arctic Archipelago are considered. The effects that the probable complete disappearance of Arctic ice is likely to have on such habitat factors as ocean currents, temperature, thermocline, salinity, upwelling and nutrients are explored, and the consequent effects on zooplankton populations, especially those important to fisheries.

29 May, 14:35 (S1-3446)

Direct and indirect effects of climate on the zooplankton community of the Central Baltic Sea

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In recent decades the Baltic Sea underwent drastic climate-induced fluctuations in temperature and salinity. In particular, the frequent periods since the late 1980s with a positive NAO have affected the physical environment of the Baltic Sea, the largest brackish water body of the world ocean. Zooplankton is the key trophic level in the Central Baltic ecosystem, which usually reacts quickly to changes in the physical environment, and its components are thus reliable indicators of climate-related changes in the ecosystem. Here we present results of a study using a 45-year time series of data collected within an ongoing monitoring programme in the Central Baltic Sea. Data were analysed by various multivariate techniques including Principal Component Analysis and Chronological Clustering. Our analyses revealed pronounced regime-like changes in total biomass and zooplankton community composition directly related to the observed climatic and hydrographic variability. We additionally evaluated indirect effects of climate through bottom-up and top-down control mechanisms on zooplankton dynamics. While we observed no significant effect of phytoplankton on zooplankton fluctuations, we demonstrated a predation effect by the major planktivorous predator sprat (*Sprattus sprattus*), whose stock size increased in the 1990s possibly due to higher temperatures. Our study emphasizes the importance of considering both direct and indirect effects of climate on zooplankton dynamics.

29 May, 14:55 (S1-3603)

Zooplankton time series of the World Ocean: pilot results of a global comparison

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This study examines interannual zooplankton dynamics at global and basin scales across coastal and oceanic waters of the Pacific Ocean, the Atlantic Ocean and its enclosed seas (the Mediterranean, Black, Caspian and Aral seas). Total mesozooplankton biomass or abundance data was sampled at 23 sites which covered a broad range of geographic regions and ecological environments, were annually averaged and analysed in the form of time series.

The majority of these time series were twenty years or longer with samples starting as far back as the early 1950s. In general, the time series exhibited three obvious types of interannual trends (rising, declining or relatively stable over the years). A global or basin scale synchrony between interannual fluctuations was not obvious but correlation with ENSO and/or NAO characteristics were found in many sites. Initial results suggest that local atmospheric and water mass dynamics along with fluctuations of food availability dominant the interannual zooplankton dynamics and contribute noise that makes it difficult to isolate the effects of larger or longer term events.

29 May, 15:15 (S1-3544)

Comparison of copepod decadal variability in the coastal Ligurian and Tyrrhenian Seas (Mediterranean Sea)

Carmen **Garcia-Comas**^{1,2}, L. Stemmam¹, M.G. Mazzocchi², E. Antajan¹, G. Beaugrand³, F. Ibanez¹, M. Picheral¹, M. Ribera d'Alcalà² and G. Gorsky¹

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Climate-induced changes in water column temperature and other environmental parameters rapidly affect the lower levels of marine ecosystems. Zooplankton population changes are among the first indicators of regime shifts. In the western Mediterranean Sea, the longest ongoing coastal time-series are in the Bay of Villefranche, Ligurian Sea (weekly sampling since 1957), and in the Gulf of Naples, Tyrrhenian Sea (since 1984). Recently, long-term changes in the abundance of several copepod and salp target species have been detected in the Villefranche time-series and proposed to be linked to large scale climatic change in the North Atlantic. However, there is a lack of information regarding the zooplankton community as a whole, and regarding the spatial range of concomitant changes in the western Mediterranean Sea. In order to address these issues, we have re-processed both long-term time-series and analysed their decadal variability using the Zooscan imaging system. The Zooscan has provided us with standardised data on size and abundance for the whole mesozooplankton community, allowing in addition the automatic recognition of several taxonomic groups. The community size structure is used here as an aggregation criterion. Comparative analyses of seasonal and inter-annual patterns of the copepod community size structure from both sites will be discussed in relation with environmental conditions at local, regional and basin scale.

29 May, 16:00 (S1-3528)

The influence of ENSO events and the PDO on copepod biodiversity and community structure in the Northern California Current: is climate change a contributing factor?

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We analysed species composition in zooplankton samples collected at several stations across the continental shelf off central Oregon at biweekly intervals since 1996, and in samples collected at some of the same stations from 1969-1973, 1978, 1982, 1983 and 1990-1992. These samples span a 35 year period allowing us to compare copepod biodiversity and community composition between both negative and positive phases of the Pacific Decadal Oscillation (PDO), and several El Niño events. Biodiversity, as indexed by species richness (total number of copepod species in a sample), varies seasonally and is always higher during winter months and during large El Niño events, as a result of northward advection of coastal waters which brings to central Oregon a highly-diverse fauna with subtropical affinities. During summer months, upwelling dominates the hydrography of the coastal zone, and species richness is low due to the advection of subarctic coastal waters to central Oregon. Since 2002, species richness has increased dramatically, and is now 25% higher than values observed during the 1983 and 1997 El Niño events. Using cluster analysis and ordination, we show that dominance and community composition has changed markedly in the past four years: the Oregon upwelling zone now has unusually high diversity, unexplained by differences in upwelling strength, ENSO or the PDO. We suggest that the recent increases in biodiversity and changes in community structure are due to increased shoreward advection of oceanic waters into the Oregon coastal zone and increased stratification of coastal waters, due possibly to global warming.

29 May, 16:20 (S1-3573)

Transformation of zooplankton community in the western North Pacific with warming condition after the 1990s

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As both modelling and observational studies have evidenced a warming trend of the global ocean in recent decades, there is an increasing demand for a better understanding of regional marine ecosystem responses to the changing environment. We have been conducting a retrospective study in the western North Pacific using a 50 year zooplankton collection, Odate Collection. Functional and taxonomic level analyses of the Odate collection zooplankton revealed changes in ecosystem structure responding to the North Pacific decadal oscillation, that had never been detected by biomass-based retrospective studies in the past. Wintertime cooling and warming in the 1980s and 1990s, respectively, related to the Aleutian Low dynamics were conspicuous conditions over the western North Pacific, and we detected those conditions which influenced species and size composition, phenology, biogeography and biochemical properties of regional zooplankton. Toward the future goal of basin-scale to global comparison of marine ecosystem responses to global changes, this presentation will summarise the observed decadal changes in the zooplankton community in this region from various aspects, and suggest possible mechanisms linking climate to marine ecosystems. Particular interest is toward influences of the marked warming condition in the 1990s, which was considered to have contributed to an increase in secondary production in the subarctic western North Pacific, which has been known for its high seasonal biological production.

29 May, 16:40 (S1-3688)

Variability in zooplankton community indexes at two coastal areas of Peruvian coastal waters between 1994 and 2006

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The main objective of this study is to compare zooplankton community indexes of two different places of the Peruvian coastal waters for the period 1994 to 2006. Paita is located at 5°S and is influenced by the dynamics of the equatorial front, the encounter of warm and low salinity equatorial surface waters with upwelled cold coastal waters; while San José at 6°30'S is influenced by the oceanic front, the encounter of cold coastal waters with warm and high salinity subtropical surface waters. During El Niño the equatorial front displaces southward reaching the second place.

Quasi bimonthly subsurface sampling was conducted with a WP-2 net at four stations between 2 and 20 nautical miles offshore. Oceanographic variables such as temperature, salinity, oxygen and biotic variables including chlorophyll and phytoplankton were recorded. Species richness, diversity and evenness were also calculated. Temporal trends of some community parameters were significant ($\alpha = 0.05$). In Paita, total abundance increased while equitability decreased. In San José, total abundance decreased weakly, and also the evenness. In both places the Shannon diversity index showed similar trends. Changes in zooplankton abundance were associated with the vertical and horizontal temperature and oxygen gradient, while changes in equitability were associated with increasing dominance of two species *Acartia tonsa* (Paita) and *Paracalanus parvus* (San José). The different trends in both places are discussed in relation to variability of oceanographic variables, including the effect of El Niño.

29 May, 17:00 (S1-3567)

Long-term changes in abundance and community structure of copepods in the northern Benguela upwelling system off Namibia, 1950s-present

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A multi-decadal zooplankton time-series for a transect off Walvis Bay (23°S), Namibia in the northern Benguela Current system was reconstructed from a number of data sources. These included: (i) published literature for 1959 and 1972, (ii) retrospective analysis of samples collected during monthly ichthyoplankton surveys in the late 1970s and the 1980s, (iii) an unpublished manuscript for 1997, and (iv) ongoing analysis of samples collected during Namibia's current environmental monitoring programme since February 2000. Despite some methodological differences (especially with respect to sampling gear, mesh size, and sampling depth), data gaps and substantial interannual variability, there is evidence to suggest that, similar to the southern Benguela off South Africa, zooplankton in the northern Benguela has increased markedly over the past five decades. Coastal zooplankton biomass off Walvis Bay has increased by about one order of magnitude since 1959, and the total number of copepods has increased >5-fold over the past three decades. Long-term trends in the abundance of dominant copepod species (*Calanoides carinatus*, *Calanus* spp., *Centropages brachiatus*, *Metridia lucens*, *Oithona* spp., *Rhincalanus nasutus*) are examined and indicate decade-scale changes in community structure.

29 May, 17:20 (S1-3508)

The impact of climate change on long-term zooplankton distribution in the Gulf of Guinea upwelling region

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Understanding the causes of variation in zooplankton distribution is fundamental to prediction of future changes through ecosystem modelling. Long term changes in coastal zooplankton of Ghana, from 1969 to 1992 was investigated *viz a viz* the effects of local and remote hydrographic and climatic factors, i.e. sea surface temperature (SST), salinity, sea level pressure, wind field, and Southern Oscillation Index (SOI). Annual variation in zooplankton abundance was observed to be cyclical, with peaks occurring during the major upwelling season. Over the 24-year period, there was a downward trend in zooplankton biomass, and this was generally homogenous between the four hydrographic seasons (i.e. two periods of hydrographic stability alternating with a minor and major upwelling). Linear trend, applying least-squares method estimated the rate of decrease in zooplankton biomass as 6.33 ml per 1000 m³ per year. During the same period, there was significant increase in SST as well as salinity, sea level pressure and zonal wind stress. It is proposed that rising SST in relation to global climate change contributed to the decline in the dominant copepod species *Calanoides carinatus*, particularly during the major upwelling season. The study also found significant association between SOI and local sea level pressure, as well as a coincidence of low SOI values during 'low zooplankton production' years. This therefore, supports the linkage between local processes and global El Niño events.

S1

Posters

Poster S1-3257

Composition, abundance and diversity of zooplankton in Ennore creek, Tamilnadu, India

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The taxonomic composition, abundance and spatio-temporal distribution of zooplankton were analysed from monthly samples collected in Ennore Creek during July 2002 to March 2004. 57 zooplankton species belonging to 35 genera from groups, Copepoda (21), Rotifera (11), Tintinnid (21), Cladocera (1) and Ostracoda (3) were identified. The most common genera were, *Acartia*, *Oithona*, *Pseudodiaptomus*, *Tintinniopsis*, *Favella* and *Brachionus*. Copepod nauplii were more prominent during the post monsoon seasons. The abundance of copepods ($\leq 12,000$ ind/L) and rotifers ($\leq 35,000$ ind/L) peaked during the wet months (November, December and January) and pre-monsoon month (August). The zooplankton abundance and richness were consistently high at the creek mouth and low in the upper regions of the creek. Shannon-Weaver diversity (H') of zooplankton was high (1.8-2.4) during December and January and low (1.3-2.1) during the remaining months. The results suggest that the zooplankton diversity and abundance in Ennore creek seems to be governed by the seasons prevailing in this part of India and the spatial difference in plankton diversity could be related to the environmental degradation caused by industrial pollution. Another important factor that was observed during this study was a drastic increase in the surface water temperature of the creek which may be due to the coolant water release from the nearby thermal power plant close to station 2. The Shannon-Weaver diversity index showed a negative correlation with the temperature in all the three stations.

Poster S1-3295

Distribution and abundance of *Oikopleura* spp. in Kuwait Bay during 2003-2005

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Oikopleura spp. are abundant in Kuwait waters especially in Kuwait Bay, which is regarded as a reception area for land runoffs (mainly sewage). Sampling was conducted every three months for two years (June 2003 to June 2005) at three Kuwait Bay stations (K3, K6, and K10) using 64 μm mesh nets. *In situ* physicochemical parameters were measured by a CTD, where no significant difference was observed throughout the sampling period with respect to each month. The distribution and abundance of *Oikopleura* were assessed since it is the most abundant zooplankton after copepods and some fish larvae feed on it, especially solefish, which are common in Kuwait Bay and of commercial importance. In Kuwait waters, the number of *Oikopleura* is three times numerous than that in other parts of the Arabian Gulf and populations fluctuated throughout each year at all stations. The highest abundance occurred at station K6 in May 2004 and June 2005 while highest abundance of 2003 was recorded in September at station K10. June showed highest abundance in 2005 at all stations, but it was lower at K6 and K10 but not at K3 in 2003. As for December, there was a lower abundance in 2003 except for K3 when compared to 2004. As for September, K3 of 2004 was higher than that of 2003 but K6 and K10 of the later were higher. Generally, the lowest densities observed in winter. In addition, the total density of *Oikopleura* in 2003 was generally lower than that of the two successive years.

Poster S1-3317

Spatio-temporal distribution and ecological role of appendicularians off the La Plata River estuary (34-39°S, 52-58°W), southwestern Atlantic Ocean

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The discharges into the continental shelf of the La Plata River, the second largest of South America, enhance high levels of biological production in the near-shore marine ecosystem. Appendicularians, which are often implicated as mediators of carbon flux through the water column, graze on sub-micron colloids, lithogenic materials, cyanobacteria, bacterioplankton and nanoflagellates. We present results on the distribution pattern of these tunicates in relation to the water masses and their ecological role, which were obtained during 6 spring cruises (1993-1996, 2003-2004). The spatial distribution of salinity showed differences in the river discharges. During 1993, low salinity waters (<33.3 psu) were displaced as far as 38°S and appendicularian abundances reached up to 3000 ind m⁻³. *Oikopleura dioica* was the most abundant and its pellet production, estimated by combining field measurements and literature data, reached 66.58 gC.m⁻² d⁻¹. This value is considerably high when compared to those reported for other estuaries. During 1995, the river scarce outflow and the detection of mid-shelf waters (33.4-33.7 psu) at the mouth of the estuary were coincident with *O. fusiformis* and *Fritillaria borealis* occurrences. Both discharge anomalies may be associated with two climatologic events, El Niño and La Niña, registered in 1993 and 1995 respectively. In the other cruises, especially in 1996, not only was the main influence of the river extended to the south but it also was displaced offshore to the northeast. Therefore, the river's outflow variability is reflected on the species spatial distribution and *O. dioica* may contribute significantly to carbon cycling in the estuary.

Poster S1-3321

Zooplankton in the Irminger Basin: a comparison between 1963 and 2002 surveys, and the CPR time series

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Two large-scale zooplankton survey studies were conducted in the Irminger Basin, west of the Reykjanes Ridge, in 1963 and 2002 respectively (1963: the NORWESTLANT Survey, 2002: the NERC Marine Productivity Cruises). The two years being in opposite NAO phases. During the April to August periods of the two survey years, spatial patterns of relative abundance for a total 19 groups of zooplankton are compared. In spite of the challenges of comparing estimates obtained with different gear types and reporting methods, strong similarities in spatial patterns were determined for some species (including *Calanus* copepods). Across the Irminger Basin, CPR data for almost the same 19 groups of zooplankton were examined for the intervening period between the two surveys to describe the patterns and changes in plankton composition and succession for these groups. Some of the plankton groups in the Irminger Basin, such as *Oithona* spp. copepods appear resilient and always occur in high concentrations, while other groups have changed drastically in abundance and spatial distribution (e.g. harpacticoids) between 1963 and 2002. This paper addresses the broad temporal and spatial plankton distributions in the Irminger Basin during the period. The issues of interpreting plankton data from multiple samplers and sources are discussed.

Poster S1-3323

Changes in zooplankton and micronekton community structure induced by human action in the Senegal River estuary

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The Senegal River estuary extends along 50 km from the sea to the Diama dam. In October 2003, to reduce flooding in Saint-Louis city (16°N, 16°W), a narrow channel was dug downstream the town in the sandbar located along the river. The channel widened to a wide mouth one year later, whilst the natural mouth closed. Changes of estuarine zooplankton and micronekton were determined before (2003) and after the new mouth formation (2005) during time series studies carried out at stations differently subjected to continental and marine influences. Before and after the new river mouth opening, the seasonal variation constituted the main factor determining the structure and abundance of zooplanktonic and micronektonic communities which were much less abundant during the flood than during the dry season. A principal component analysis shows the major effect of the seasonality in 2005 as in 2003. Micronekton and zooplankton abundances were correlated with high salinities (dry season) and inversely correlated with high temperatures (flood). Plots of the sampling stations show the partition between 2003 and 2005 samples. Inside the set corresponding to 2003, the natural river mouth stations are well individualised. Inside the set corresponding to 2005, the new river mouth stations are close to mid-estuary stations whereas stations near the dam are more distant, showing the extent of marine influence. In 2005 there was a neat decrease in zooplankton abundance particularly marked near the dam during the dry season and a marked decrease of micronekton abundance near the new river mouth.

Poster S1-3343

Variability of zooplankton and calanoid copepod community in the eastern Arabian Sea, an evaluation

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This paper addresses the available information from three targeted programmes from 1960 onwards from the Arabian Sea one of the most productive marine environments. The biomass data of the International Indian Ocean Expedition (IIOE, 1960-65) showed the coasts of Somalia, Arabian Peninsula and the west coast of India to have very high zooplankton biomass. Under JGOFS (1992-1997) zooplankton production was estimated and is consolidated in Smith and Madhupratap (2005), although no attempt has been made to assess the variability of biomass, density and diversity over the years. The zooplankton collected during the summer monsoon along preset transects extending between 8-22°N and 64-78°E under the Marine Research on Living Resources of the EEZ of India (DOD funded project) formed the material for this study. The samples were collected from mixed layer using MPN. The transect at 10°N off Kochi sustained high biomass and is identified as a “zooplankton hotspot”. During the study period the average biomass varied from 0.10-0.16ml/m³ and the density of copepods ranged between 107-258/m³. Copepods being the most abundant zooplankton component are considered to give early signals of subtle climate variations. The density of *Temora turbinata*, the dominant calanoid species associated with upwelling has been considerably reduced. It is also intriguing that *Nannocalanus minor*, a widespread species during the IIOE is restricted during the present series. The changing trend in biomass and community structure of copepods are attributable to the changing hydrographic properties.

Poster S1-3384

Decadal scale variations in *Neocalanus* copepod biomass in the Oyashio and Kuroshio-Oyashio Transition waters of the western North Pacific

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Neocalanus is a key species investigating long-term variation in mesozooplankton community because they dominate the biomass in the subarctic North Pacific. Our Institute have collected mesozooplankton including the samples of A-line monitoring transect conducted by Fisheries Research Agency over longer than half a century, and the archive is called as Odate Collection. It will be a one of the largest mesozooplankton collection in the world ocean. We analysed the collection to clarify the decadal scale variations in three species of *Neocalanus* (*N. flemingeri*, *N. cristatus*, *N. plumchrus*) biomass in the Oyashio and Kuroshio-Oyashio Transition waters from 1960 to 2002. In the Oyashio waters, *N. cristatus* and *N. flemingeri* were relatively low from 1960s to 1980s and increased in the 1990s. On the other hand, biomass of the *N. plumchrus* was relatively high from the 1960s-1970s and decreased in the 1980s, and had very high value in the 1990s. In the Transition waters, biomass of the three species had high value in the early-mid 1960s and decreased after that. Biomass of *N. plumchrus* in the both waters and *N. flemingeri* and *N. cristatus* in the Transition waters had significant positive correlation with variation in phosphate concentration in the surface layer. The relationships suggested that change in phosphate concentration affected to the productivity of the *Neocalanus* copepods due to change the primary productivity. Phosphate concentration had bidecadal oscillation superimposed on the decreasing trends in the both waters. The oscillation and trend might be related to the 18.6 year oscillation caused by lunar nodal cycle and diminished water exchange between surface and subsurface, respectively.

Poster S1-3443

Latitudinal gradients in copepod community composition in the Northern California Current and the southern Gulf of Alaska during years of varying ocean conditions

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During summer from 1998 to present, zooplankton have been sampled by various research programmes from the central California Current north to the southern Gulf of Alaska, a distance of 2000 km. Comparisons among these programmes are of interest because there is a strong latitudinal gradient in ocean conditions among regions, particularly in the strength of coastal upwelling. Off California and southern Oregon upwelling is strong and occurs over most months of the year. Upwelling is less strong and highly seasonal off central and northern Oregon, relatively weak off Washington and Vancouver Island, and completely lacking off northern British Columbia and southeast Alaska. Due to these latitudinal gradients in hydrography, we expect to identify faunal boundary regions. Sampling intensity was highest during the summers of 2000 and 2002, so these years serve as our focal comparisons. Sufficient sampling was also carried out during the 1998 El Niño event and the warmer year of 2003 to allow for comparison of differences in climatic forcing and ecosystem response among regions. We examine copepod species density, species richness, distribution, and community composition and relate these to temperature, salinity, mixed layer depth, water column stratification, and chlorophyll-*a* concentration. We use multivariate ordination and cluster analysis to describe spatial and interannual relationships between copepods and differences in physical conditions as well as responses to different climatic conditions among contrasting years.

Poster S1-3444

Spatial and temporal variability of the copepod community along a monitoring transect in the northern Benguela during 2000-2006

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Zooplankton has been collected regularly along a 70 nautical mile-transect off Walvis Bay (23°S) since February 2000. Copepods were numerically the most abundant mesozooplankton. Their abundances increased at the beginning of the time-series reaching a peak in 2004 and declining sharply after that. Copepod abundance showed a seasonal cycle with abundances at their lowest during austral winter (May to August), increasing after the onset of upwelling in September and reaching highest values during summer (November to February). Strong interannual variability in seasonality and abundance, however, did occur throughout the time-series. The dominant calanoid copepod species were *Metridia lucens*, *Calanoides carinatus*, *Centropages brachiatus*, *Rhincalanus nasutus* and *Calanus* spp. *C. carinatus* occurred mainly on the shelf, with highest abundances during peak upwelling, whereas *M. lucens* was more evenly distributed along the entire transect with highest abundances occurring between October and February. *Calanus* spp. only appeared in high numbers since the summer of 2005/2006 and subsequently dominated the calanoid copepod community during almost every month of sampling. The spatial distribution along the transect varied greatly throughout the time-series. During the austral summers of 2001/2002 and 2003/2004 copepods were mainly concentrated in the shelf areas, whereas during all other years they were distributed along the entire transect. The observed temporal and spatial variability in copepod abundance and community structure will be discussed in relation to the hydrography.

Poster S1-3450

Changes in the chaetognath community along the Vancouver Island continental margin and in the subarctic NE Pacific

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Analyses of time series focused on either total zooplankton biomass, or selected copepod species groups have often found large decadal variability and trends. However, similar or larger signals are present for other taxa. One group especially sensitive to changing ocean climate and circulation are the chaetognaths (e.g. Russell 1935). We report large post-1990 changes in the dominance hierarchy of chaetognaths along the Vancouver Island continental shelf, slope, and adjoining deep ocean (the northern and upstream end of the California Current). Prior to the 1990s, samples were very strongly dominated by two species: *Parasagitta elegans* (found at all of our sampling locations) and *Eukrohnia hamata* (primarily seaward of the shelf break and in the deeper coastal inlets). A third species, *Pseudosagitta scrippsae* (historical distribution centred off California), was rare but often present at deep locations. Major alterations of this hierarchy began during the 1997-1998 El Niño, when *Parasagitta euneritica* (range similar to *P. scrippsae*) attained moderate to high abundance all along Vancouver Island. *P. euneritica* disappeared during the 1999-2002 cool interval, but reappeared in 2003, and essentially replaced *P. elegans* at shelf and slope stations from 2004 to spring of 2006. Following strong upwelling, *P. euneritica* declined (but not to zero) in summer 2006, while *P. elegans* increased (but not to prior dominance). Two additional southern-origin species also recently increased. *Mesosagitta minima* (circumglobal 40°N-40°S) appeared in 2004, and *Serratosagitta bierii* (oxygen-poor waters of the eastern tropical Pacific) in early spring of 2006. Intruding species first appear over the continental slope, probably carried by the winter Davidson Current, and spread both shoreward onto the shelf and seaward into the Alaska Gyre. Anomalies attenuate with seaward distance, remaining strong to about 100 km beyond the shelf break, and clearly detectable to about 400 km. In addition to association with alongshore flow over the slope, chaetognath anomalies are very strongly associated with recent ocean warming: during positive temperature anomalies the previously dominant taxa are largely replaced by warm water species from lower latitudes.

Poster S1-3465

Phenomenal changes in chaetognath community of the Andaman Sea, Indian Ocean

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The sea around Andaman Island is one of the prominent biodiversity hotspots in the Indian Ocean. This coral ecosystem with luxuriant fringing coral reefs supports a rich and diverse fauna. Comparative evaluation of zooplankton samples collected around the Andaman Seas during the North East (NE) monsoon period (November to February) of 1963, 1979 and 2005 shows glaring changes in the population density and community structure of Chaetognatha. In 1963 the average population of chaetognath was 20 m⁻³, which decreased to 7 m⁻³ in 1979 and further reduced to 4 m⁻³ in 2005. During 1963 chaetognaths were represented by 10 epipelagic species with predominance of *Sagitta enflata* and *S. pacifica*. Thirteen epipelagic species were found in the collections of 1979 and *S. enflata* continued to be the most abundant group and a few rare species encountered in the 1963 collections became abundant. Recent sampling around Andaman Seas in 2005 showed enhancement in the number of species to 18 (including 2 new species). Also, the community structure of chaetognaths showed drastic changes due to surfacing of meso and bathypelagic species like *Sagitta decipiens*, *S. lyra* and *Eukrohnia fowleri*. Though *Sagitta enflata* was the common species, *S. decipiens*, a mesopelagic species became dominant at 150-300 m depth in the water column. *Krohniitta pacifica*, *S. neglecta* and *S. regularis* became very common in the area. Such variability in the community structure of chaetognaths could be explained by physical factors. Recurrently occurring severe cyclones in the Bay of Bengal during the NE monsoon season and associated strong surface winds cause lateral stirring leading to upward movement of deep waters species.

Poster S1-3466

Temporal and spatial variability of *Oithona* spp. abundance and phenology in the North Atlantic, North Pacific and Southern Ocean using the CPR data

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The genus *Oithona* is considered the most ubiquitous and abundant copepod group in the world oceans. Although they generally make-up a lower proportion of the total copepod biomass, because of their high numerical abundance, preferential feeding for microzooplankton and motile preys, *Oithona* spp. plays an important role in microbial food webs and can provide a food source for other planktonic organisms. Thus, changes in *Oithona* spp. overall abundance and the timing of their annual maximum (i.e. phenology) can have important consequences for both energy flow within marine food webs and secondary production. Using the long term data (1954-2005) collected by the Continuous Plankton Recorder (CPR), the present study, investigates whether global climate warming may have affected the long term trends in *Oithona* spp. population abundance and phenology in relation to biotic and abiotic variables and over a wide latitudinal range and diverse oceanographic regions in the Atlantic, Pacific and Southern Ocean.

Poster S1-3509

Diversity, seasonal cycles and recruitment processes of zooplankton in coastal and oceanic waters in relation to environmental variability; a time series study at a standard section off western Norway

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Data on zooplankton abundance, chlorophyll, nutrients, temperature and salinity was collected from 1993 to 2006 at 17 stations on Svinøy standard section heading northwest from the Norwegian coast at about 62°N. Zooplankton was sampled by vertical net hauls from 200 m to the surface. Samples were fixed in formalin and analysed

taxonomically under the microscope. Samples for chlorophyll and nutrients were taken at standard depths, using a rosette sampler on a CTD, and analysed according to routine analytical procedures of the IMR. Coastal and oceanic Atlantic water masses showed distinct diversity and interannual variability. During recent years with warming, smaller and more abundant warm water taxa with a different phenology have been introduced in both water masses. Increased abundance of the warm water species, *Calanus helgolandicus*, relative to *C. finmarchicus* was observed after 1995. The major contributor to zooplankton biomass, *C. finmarchicus*, does not overwinter in coastal water. Comparative population dynamic studies and timing of seasonal cycles of Atlantic and coastal stocks of *C. finmarchicus* showed that spring production of *C. finmarchicus* in coastal water relies on advection of G0 from the oceanic stock. High recruits to parental stock ratio in coastal water indicates higher recruitment success in this water mass and lower winter survival. Long-term variability in phenology and abundance is related to seasonal dynamics of the phytoplankton, and to variability in climate and physical oceanography. Timing and magnitude of production of eggs and nauplii in Norwegian coastal waters is essential for recruitment success of cod and herring.

Poster S1-3514

SCOR WG-125: Global Comparisons of Zooplankton Time Series

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The SCOR Working Group on Global Comparisons of Zooplankton Time Series (WG-125) was formed to promote between-region comparisons of longer zooplankton time series from around the globe. With data contributions and participation from 12 countries, over twenty long term regional zooplankton time series have been identified, and data from these regions have been collated and prepared for further numerical analysis. Within many regions, substantial long term shifts in the zooplankton biomass, species abundance, community composition, and/or seasonal timing are already evident (factor of 5-100 for the "amount" time series, 0.1-0.2 years for the seasonal timing). Work has begun to compare these changes across and between regions, looking for evidence of temporal synchrony and large scale spatial teleconnection among the zooplankton time series and also with time series of climate and fishery indices. This work reviews the participants and time series of SCOR WG-125 and presents some of the initial results of our analyses.

Poster S1-3519

Zooplankton community description and comparison of seasonal population development for common species and groups, sampled weekly at time series sites on the Scottish east and west coasts

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Two Scottish coastal sites are sampled weekly for meso-zooplankton, phytoplankton, temperature, salinity and inorganic nutrients. The first site is 3 km offshore off Stonehaven on the east coast, sampled since January 1997, and the second is at a sea loch (Loch Ewe) on the northwest coast, sampled since April 2002. We describe here the zooplankton communities at these sites and the seasonal development of major species and groups against the background of environmental seasonality. We compare data from the two sites and consider the interannual variability in seasonal timing and abundance of key species.

Poster S1-3523

Plankton time series in the coastal upwelling off central-southern Chile (Station 18): driving forces on planktonic community structure

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Seasonal to inter-annual variability in coastal planktonic assemblages (abundance and biomass) is examined using data from the COPAS Center time series at Station 18 on the continental shelf in the upwelling ecosystem off Concepción, Chile (36° S). This fixed station is located within the highly productive zone subjected to seasonal wind-driven upwelling and river inputs. Nearly monthly sampling for autotrophic and heterotrophic pico-, nano- and micro-, meso- and macrozooplankton were undertaken (2002-2006). The analyses showed both periodical and stochastic signals in the dominance of species/functional groups and different degrees of correlation between biological components and environmental forcing. Picoplankton (bacterioplankton, *Synechococcus* spp. and photosynthetic picoeukaryotes) exhibit a strong seasonal variability not in phase with total chlorophyll-*a* concentration. Nanoplankton was mostly composed by autotrophic cells, concentrated in the upper 30 m with no seasonal differences in abundance/biomass though maximum values appeared during upwelling, along with maximum integrated (0-80 m) chlorophyll-*a* (total and the <20 µm fraction). Microplankton was also concentrated in the top 10 m depth, dominated by diatoms and making substantial contributions to total biomass during the upwelling season, with maxima (also dinoflagellates and tintinnids) in the austral summer, together with maxima in total chlorophyll-*a*. Nitrate limitation does not explain the strong seasonal signal in micro-phytoplankton dominance or the suppression of co-existing nano-phytoplankton during upwelling. Meso- and macrozooplankton showed a strong annual signal, associated with depth of the oxycline. Neither, biomass or taxa abundance showed any correlation with temperature or phytoplankton biomass, whereas C and N contents varied accordingly with changes in taxa. Greater C/N ratios occurred upon dominance of copepods and the average C content of zooplankton was 40%. The study provides baseline information to assess the impact of El Niño, or other large scale variability on the planktonic community of this upwelling system.

Poster S1-3534

ICES Working Group on Zooplankton Ecology

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The ICES Working Group on Zooplankton Ecology (WGZE) was established as a Study Group by the ICES Council in 1990. In 1994, ICES changed the status of the group into a Working Group, giving it a more permanent position within the ICES structure. Since then the group has met annually to discuss research activities and technical issues on micro-, meso-, and macroplankton, as well as benthic meroplanktonic larvae and ichthyoplankton. The group is the only single disciplinary international group working on zooplankton in the world, giving it a special position within the community of marine researchers. The products of its work include Laboratory and Sea-going Workshops, Taxonomic Workshops, The Zooplankton Methodology Manual, The Annual Plankton Status Report, ICES Zooplankton Taxonomic ID Sheets and advice to other ICES expert groups. The products have wide use both within and outside the ICES community. The poster is intended to advertise some of the activities of WGZE, and to encourage participation and collaboration.

Poster S1-3542

Long time series in the Gulf of Trieste (northern Adriatic Sea): *Penilia avirostris* vs copepod abundance

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The shallow, semi-enclosed Gulf of Trieste is the east-northernmost edge of the Adriatic Sea is highly dynamic (temperature ranges 6°C to > 2°C). Here the zooplankton community reflect the fluctuations of a few dominant copepod species such as *Acartia clausi*, *Temora* and *Oithona* and the only abundant cladoceran *Penilia avirostris*.

We reported a time series analysis from March 1986 to December 2006 data set on copepod and *P. avirostris* abundance collected on a monthly (or fortnightly) basis at a coastal site in the Gulf. Copepods dominate the community all year round with the exception of summer, when *P. avirostris* percentage increases up to more than 80% of total mesozooplankton community. Abundance maxima of *P. avirostris* almost regularly appeared between July and August, besides in the years affected by mucilage (which generally happens in June-July) when it was delayed until September. In the first period (1986-1991) copepod abundance never exceeded 20000 individuals m⁻³, whereas *P. avirostris* maxima were far below 10000 individuals m⁻³; afterward (1991-2002) peaks often largely exceeded 15000 individuals m⁻³, finally, since 2002, copepod peaks increased to reach a maximum of almost 40000 individuals m⁻³ (June 2002), whilst *P. avirostris* remained constant. Overall 3 distinct periods can be identified: 1986-1991 (low *P. avirostris*, high copepod abundances); 1991-2002 (low copepod, high *P. avirostris* abundances); 2002-2006 (higher copepod abundance).

Poster S1-3545

***Calanus finmarchicus* changes in the southern Norwegian Sea, 1990-2006**

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In the south-western Norwegian Sea two water masses dominate in the upper layers: cold water from the East Icelandic current, flowing from the north, and warmer Atlantic water from the southwest. In both water masses *Calanus finmarchicus* is the dominant copepod. Seasonal variability in temperature and salinity, chlorophyll *a*, and *C. finmarchicus* stage composition and abundance in these two water masses is presented. Monitoring of zooplankton in the southern Norwegian Sea has revealed significant changes in abundance, time of reproduction and seasonal development during the 1990-2006 period, which may be related to hydrographic changes. Prior to 2003, reproduction started significantly earlier in spring in the warm Atlantic water than in the colder East Icelandic Current Water (EICW). However, since 2003 the time of reproduction has changed in the EICW, and now occurs simultaneously in both water masses. Thus, the seasonal development in secondary production has changed significantly in the cold water mass in the south-western Norwegian Sea. This may have significant effects on annual secondary production and food potential for migratory pelagic fish in the area.

Poster S1-3548

Interannual variability in abundance and community structure of zooplankton south and north of Iceland in relation to environmental conditions in spring 1990-2006

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A 17-year zooplankton time series from two standard sections differing in hydrographical conditions (subarctic water north of Iceland, Atlantic water south of Iceland), was examined in relation to hydrography and phytoplankton dynamics, and large scale climatic changes in the North Atlantic Ocean (NAO). Both the long-term mean zooplankton biomass and abundance were higher south (~4.1 g dw m⁻² and ~160000 individuals m⁻²) than north of Iceland (~3.4 g dw m⁻² and ~120000 individuals m⁻²). Biomass and abundance fluctuated markedly between years with maxima every ~5-7 years. Copepods (mainly *Calanus finmarchicus* and *Oithona* spp.) dominated the zooplankton, comprising >60-70% of the plankton in most years. Among the copepods, *C. finmarchicus* was more abundant south of Iceland (~45%) than to the north (~35%). Abundance and community structure were related to environmental variables using regression and Canonical Correspondence Analyses (CCA). Temperature was the most important environmental variable in explaining the differences in species composition north and south of Iceland, with species like *Temora longicornis* and *Evadne nordmanni* being abundant to the south, and *Metridia longa* and *C. hyperboreus* to the north of Iceland. In both regions, the chlorophyll concentrations were negatively related to the abundance of *C. finmarchicus*, indicating a top-down control of primary production. Temperature was positively related to the abundance of *C. finmarchicus* north of Iceland, whereas no such relationship was found to the south, suggesting that advection of animals with warm currents from the south was important for the growth of the northern population. The CCA demonstrated a shift in community pattern north of Iceland in the mid-1990s related to major shifts in hydrographic conditions, whereas no such shift was observed in the more hydrographically stable waters south of Iceland.

Poster S1-3550

Trends of copepods from Peruvian northern zone – Humboldt Current System, from 1994 to 2005

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Zooplankton from two coastal zones in the northern of the Humboldt Current System (HCS), Paita (05°00'S) and San Jose (06°50'S) were studied, the first influenced by the Equatorial front and the second is generally influenced by Cold Coastal Waters (CCW). Samples were collected from four fixed stations at 5 to 20 nm with superficial horizontal hauls with WP-2 (330 µm) during 1994-2005. Physical oceanographic profiles (temperature, salinity and oxygen) were obtained. Copepods were dominant in both regions (>70%). Species such as *Acartia tonsa* and *Paracalanus parvus* were most important in terms of abundance and frequency. Relative abundance of *A. tonsa* and *P. parvus* were significant negatives ($p < 0.05$) correlated in Paita ($R^2 = -0.59$) and San José ($R^2 = -0.67$). Also both species showed a positive significant correlation with temperature ($R^2 = 0.26$ and $R^2 = 0.12$) and negative correlation with salinity ($R^2 = -0.23$ and $R^2 = -0.13$). *A. tonsa* decreases with low oxygen concentration and *P. parvus* takes advantage of it, increasing in abundance. At the same time several species changed their normal distribution and abundance during El Niño (EN) 1997-98 event, *Centropages furcatus*, *Subeucalanus mucronatus* and *Oncaea venusta* associated with high temperature and lower salinity (Equatorial Surface Waters -ESW), increasing dramatically in abundance, frequency and distribution besides *Centropages brachiatus* which is associated with CCW decreased during EN 97-98 and is related with La Niña 1998-99 period. Temporal variability and community structure of copepods in the two zones showed differences due to physical dynamics and water masses. San José is a strategic zone to detect changes at a scale longer than seasonal.

Poster S1-3551

Spatial and temporal variability in Scotian Shelf zooplankton communities

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Zooplankton are indicators of the response of marine ecosystems to environmental variability. The relationships between zooplankton communities on the Scotian Shelf and hydrographic and geographic regions of the Scotian Shelf in the 1990s and 2000s were described using complementary data sets, each resolving different space and time scales. The Atlantic Zone Monitoring Program (AZMP) sampled Scotian Shelf zooplankton from the whole water column twice per year at stations along three cross-shelf transects and semi-monthly at a fixed station on the inshore central shelf, while Continuous Plankton Recorder (CPR) samples were collected from near-surface waters approximately monthly on an along-shelf transect. Variability patterns were compared among these three data sets to identify robust spatial and interannual trends. Stations were clustered based on taxonomic composition, and spatial clusters were compared to hydrographic boundaries and bathymetry to determine whether temporal changes in community composition were driven by changes in water mass distributions on the shelf. This project identifies zooplankton community and abundance shifts that may affect fish recruitment in the northwest Atlantic and contributes to development of ecosystem-based fisheries management on the Scotian Shelf.

Poster S1-3559

Long-term and seasonal variability of abundance and stable N isotope signature in coastal copepods

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A long-term time-series is being carried out in the Gulf of Naples (Western Mediterranean Sea) since 1984 to track the dynamics of the coastal mesozooplankton along with environmental variability. Copepods dominate in terms of numbers and biomass at the sampling site and are characterised by the abundant occurrence of the small calanoids *Acartia clausi*, *Centropages typicus*, *Paracalanus parvus* and *Temora stylifera* through most of

the year. All together, these four species represent a dominant and stable component of the copepod assemblages throughout our time-series. In the last two decades, the group accounted for 48 ± 6 % of total copepod abundance on a mean annual basis. However, the single species show different interannual variability and different seasonal cycles with a typical succession of their major peaks of abundance from spring to autumn. The patterns of their time courses suggest specific adaptation to different environmental conditions, which likely lead to the partial separation of their temporal niches. In order to determine whether the temporal variability of populations might reflect in their trophic habits, we analysed the stable N isotope content of adult females of the four species through seasons (from March to October) and years (1984-2004). The results indicate significant differences in the specific isotopic signatures, both in the seasonal and in the long-term, suggesting some resource partitioning among the four coastal calanoids.

Poster S1-3571

A cooperative partnership with the fishing industry for long time series observing of zooplankton abundance and composition in the Gulf of Maine

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We report on a successful partnership for a cooperative, industry-based contribution to monitoring of the pelagic ecosystem in the Gulf of Maine. The need for long-term zooplankton and ichthyoplankton data collection in the Gulf of Maine becomes critical in light of the potential for change in climate at both the regional and global scale. It is increasingly important for the fishing industry as decisions about fishery management shift from a single or multi-species to an ecosystem-based approach. Here we describe the structure of the partnership and major results of a three year time series, between 2003-2005, of hydrographic and biological data from a fixed station at GoMOOS buoy "B" and on Jeffreys Ledge. This is the first recorded time series for the western Gulf of Maine showing both seasonal and interannual variability in phytoplankton and zooplankton biomass. It indicates a marked reduction of abundance of *Calanus finmarchicus*, a dominant Gulf of Maine planktonic copepod that is a primary prey for adult herring and the northern Right Whales, in 2004-2005, particularly in summer on Jeffreys Ledge. In addition to providing indicators of seasonal and interannual variations in abundance of plankton, the time series results serve fundamental data needs for coupled physical biological models investigating coupling between climate forcing, physical circulation and mixing, plankton production and recruitment processes in the western Gulf of Maine.

Poster S1-3610

Long-term changes in zooplankton community of the Black Sea: biological and climatic aspects

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Zooplankton abundance and species composition were analysed based on long-term investigations (1993, 1999-2006) in the NE Black Sea. STD-probes and zooplankton sampling were carried out along 80-100 mile transects off the Caucasian coast. The Black Sea is a quasi-enclosed basin with thin, 150-180 m, oxic layer; hence its ecosystem is sensitive to the influence of internal forcing. During last decades, the pelagic community experienced dramatic changes caused by successive invasions of two top-predators, ctenophores *Mnemiopsis leidyi* and *Beroe ovata* together with climatic changes and eutrophication. After the ecosystem collapse in the early 1990s, a stable increase in zooplankton biomass was observed in the NE Black Sea: from 4 g/m², to 11 g/m² and 26 g/m² in 1993, 1999 and 2006, respectively. In 1993, zooplankton was strongly dominated by *Calanus euxinus*. In 1999-2005, 80-90% of total mesozooplankton biomass were comprised of *C. euxinus*, *Acartia clausi* and *Parasagitta setosa*. Abundance of *Parasagitta* and *Acartia* showed dramatic year-to-year changes. There was no difference in *Calanus* biomass between 1993 and 1999; in 2000, it increased by a factor of 2.5 and further changes were insignificant. No correlation between zooplankton biomass and temperature of winter air and Cold Intermediate Layer (CIL) was observed in 1999-2005 ($R^2 < 0.1$). A significant correlation between biomass of upper-dwelling species and the surface Chl *a* concentration was found. Monovoltine species are more sensitive to predation control than multivoltine species. That is why the former group of species was more affected by *M. leidyi* invasion.

Poster S1-3613

Zooplankton data archaeology and rescue by universities in Japan

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Oceanographic data and information have been exchanged under the framework of the International Oceanographic Data and Information Exchange (IODE), which has been promoted by the Intergovernmental Oceanographic Commission (IOC) of UNESCO since 1961 in order to enhance marine research, exploration and development. Physical oceanographic data are well circulated and exchanged among IODE communities. However, marine biological data including marine plankton data available through the IODE network are very limited, although those data become more essential in studies on biogeochemical processes related to the issue of global change. With the above background, we initiated an activity to rescue historical marine plankton data that have been recorded in paper form and threatened to be lost from many university laboratories. As the first step of this initiative, we have compiled over 2000 data points of zooplankton observation on board research vessels of the University of Tokyo by digitising and applying a basic quality control procedure. The geographic coverage of the data extends not only across the Pacific Ocean but also to other oceans including Southern Ocean. Next, we have rescued zooplankton data in the Inland Sea and other coastal regions of Japan not yet in digital form. These data are available online through Japan Oceanographic Data Center (JODC). This initiative is a steady and important contribution to the global earth observation systems and the Global Oceanographic Data Archaeology and Rescue (GODAR) project by IOC/IODE.

Poster S1-3618

Inter-annual variations of zooplankton in the northern coastal Gulf of Alaska

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The Seward Line in the Northern Gulf of Alaska has been the focus of multidisciplinary sampling for the past 9 years. We report on the observed inter-annual variations in the zooplankton community and its relationship to climatic influences. Over the study period we have observed years favourable and unfavourable to the local zooplankton species (e.g. a 5 fold range in *Neocalanus plumchrus/flemingeri*), and observed the summer import of southern species during warm years (e.g. *Calanus pacificus*, *Mesocalanus tenuicornis*, *Paracalanus parvus*). Surprisingly, even some subarctic species (e.g. *Calanus marshallae*, *Limacina helicina*) appear to do better during many warmer springs. Differences in temperature, along with chlorophyll, drive growth and reproduction of the zooplankton. This has consequences for the annual progression of the *Neocalanus* populations that dominate the spring, and the smaller species, such as *Pseudocalanus*, that dominate the summer zooplankton communities.

Poster S1-3623

Changes in zooplankton community structure in the northern Benguela during 1978-1989

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Zooplankton was analysed from ichthyoplankton-directed samples collected monthly at nine stations along a transect (5 nautical miles extending up to 65 nautical miles offshore) at 23°S off Walvis Bay (Namibia) between 1978 and 1989. From this dataset, interannual variations of seasonal patterns of zooplankton community structure were studied, particularly during austral spring (upwelling season) and summer (warm and stratified water). The former season is characterised, in the coastal area, by high abundance and low diversity of zooplankton, and the predominance of *Calanoides carinatus*, whereas the latter season shows higher diversity and the presence of warm-water indicator species such as *Nannocalanus minor*, *Acartia tranteri* and *Temora turbinata*. The distribution of the most abundant species (*Calanoides carinatus*, *Metridia lucens*, *Centropages brachiatus* and *Rhincalanus*

nasutus) and their biogeographic role in the system are described. In 1984, a Benguela Niño occurred, which altered the zooplankton species composition and abundance in the area. Total copepod abundance during the ten-year study period appeared constant in spring, but summer abundances increased over time. Various taxa showed different patterns of abundance during different seasons; for instance, whereas the presence of *M. lucens* (characteristically more abundant at the shelf break) remained constant during the study period, *C. carinatus* (predominant in upwelled water inshore) was more abundant during the upwelling season and its presence, in summer, diminished over the years.

Poster S1-3646

Planktivorous predators as indicators of changes in zooplankton: importance of time-series on trophic ecology

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Secondary and some tertiary consumers (upper-trophic level predators) in marine ecosystems derive all or some of their carbon and energy needs from zooplankton, notably copepods and euphausiid crustaceans. Therefore, time series of the trophic ecology (e.g. diet composition, prey characteristics, etc.) of these organisms may reveal patterns of change in zooplankton communities across time and space. In the North Atlantic, North Pacific and Southern Ocean, a variety of time-series on many species, including marine birds, marine mammals, and fish have been developed which demonstrate changes in zooplankton on multiple time scales, from seasonal to interdecadal, and relative to secular climate change. Herein, we review and evaluate planktivorous predators as indicators of spatial and temporal changes in zooplankton species and communities. Challenges to predator-based sampling of zooplankton include prey and size selection, statistical verification, calibration of changes in zooplankton in the environment versus changes in diets, and mechanistic understanding. Benefits of predator-based sampling include sampling of difficult to monitor patchy organisms, complementarity with traditional net sampling programs, cost effectiveness, and implications for “top-down” control. We conclude that sampling zooplankton using predators can provide important information on difficult to study species, and is a logical step in ecosystem-based approaches to management.

Poster S1-3653

Long-term mesozooplankton variability in a Mediterranean coastal area, as influenced by trophic relationships and climate

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The interannual variability of mesozooplankton biomass, total abundance and community composition was studied over 20 years (1984-2004) in Saronikos Gulf (Aegean Sea, Eastern Mediterranean). This oligotrophic area is moderately affected by sewage effluents. Mesozooplankton samples were collected from two stations: one at 75 m depth, surveyed monthly or seasonally, and another at 15 m depth surveyed bi-weekly. A clear increasing trend of mesozooplankton biomass and total abundance was detected at both stations. Chlorophyll- α has shown a parallel decreasing tendency, although nutrients levels have increased due to the increase of sewage outflow volume. A long-term (1984-2004) increasing trend is apparent in the temperature record and the same was true for salinity during the last 10 years. It seems probable that mesozooplankton was grazing less successfully on the large phytoplankton biomass observed before 1994 when the sewage treatment method changed; the subsequent enhancement of consumer biomass could have cascading influences on lower levels, in spite of the nutrient availability. Changes in phytoplankton groups and/or size composition could account for the augmentation of the appendicularians, doliolids and cyclopoid copepods absolute and relative abundance, the later taxa being favoured also by temperature and a small increase in salinity. Our results suggest that the relative roles of trophic relationships and climate change should be considered in further detail in coastal areas affected by human activities.

Poster S1-3655

The mid-eighties regime shift and appendicularian abundance

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There is accumulating evidence suggesting that a regime shift occurred in the North Atlantic during the mid-eighties. This shift has been reported primarily from Continuous Plankton Recorder (CPR) data as a stepwise change in plankton abundance and copepod community structure. Here we analyse the CPR data for appendicularian abundance to show that a similar stepwise increase occurred in the abundance of appendicularians during the mid-eighties. Furthermore, we compare these results to data recorded by other zooplankton time series programmes to show that a similar abrupt increase in appendicularian abundance during the mid-early eighties has also been recorded in other areas. The fact that such a change occurred at locations so distant apart as Helgoland Roads in the North Sea or the White Sea in the Arctic suggests that these changes have a global origin. The strong dependence of appendicularian phenology with temperature points out to direct links to global climate change.

Poster S1-3657

A decade of sampling in the Bay of Biscay: what are the zooplankton time series telling us?

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The project "Studies on time series of oceanographic data" was established as a pilot project by the Instituto Español de Oceanografía (IEO) in 1991. After more than a decade, the project has grown to encompass a network of 20 sampling stations in 5 different transects at the N and NW coast of Spain: Vigo, Coruña, Cudillero, Gijón and Santander beginning in 1987, 1988, 1993, 2001, 1991, respectively. At each location a coastal-ocean gradient is sampled monthly for hydrography, nutrients and planktonic communities. We have used these data to set with statistical significance the range of variability of several environmental variables and biological communities and determined the rates and trends of warming due to the climate change as well as to describe some direct and indirect effects of the increase in temperature in the water column and in the pelagic ecology. The project had substantially contributed to get a deeper knowledge on planktonic communities and species and to produce baselines, climatologies and reference levels for the north coast of Spain, which allow us to do accurate evaluations on the effects of environmental perturbations on the ecosystem and forecast the expected recovering time. Examples of mesozooplankton dynamics and possible relationships with environmental properties are presented and discussed in the present study. We examine the biogeography of the region and the occurrence of the new coming species like *Temora stylifera*, together with the dynamics of mesozooplankton species and factors explaining most of the seasonal and interannual variability.

Poster S1-3671

Relationship of mesozooplankton and population variations of jellyfish (*Aurelia aurita*) in Masan Bay, Republic of Korea

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Masan Bay is a representative semi-enclosed bay in the Republic of Korea. Masan has been developed as a coastal industrial complex since the 1970s. There is a serious contamination from municipal and industrial sewage, due to the inflow of eight rivers around the area. However, the self-cleansing process of nature is retarded as the circulation of water is slow. As a result, eutrophication, phytoplankton bloom, and the formation of layer, which has a low level of oxygen, have occurred frequently and damaged the ecosystem. In addition, there has been often the presence of jellyfish in a large quantity during the summer.

This study investigated the temporal variation of jellyfish population and focused on the relationship between jellyfish and mesozooplankton communities, which are the prey of jellyfish, in Masan Bay from 2004 to 2006. The digestion time of jellyfish was measured using jellyfish's gut contents in the field and the lab. *Artemia*, which is a prey of jellyfish, was used in the laboratory. The biggest size of jellyfish was found in February, while ephyrae, which were 2-3 mm in diameter, were present from March to May in Masan Bay. An ephyra grew faster after May and became an adult by June. The size of adult jellyfish maintained until December. The population density of jellyfish reached 3000 inds/100m³ in March and April when ephyra appeared, whereas it decreased as the size of ephyra increased after April. However, the population density of jellyfish was still high (around 600 inds/100m³) in the summer of 2005. The abundance of mesozooplankton related inversely to the abundance of jellyfish. The gut contents of jellyfish were mainly copepods, while the seasonal variation of amount of gut contents was various. The digestion time was measured in the laboratory as an ingested prey (*Artemia*) disappeared from the stomach of jellyfish which took approximately 30-60 minutes. The presence of jellyfish in a massive quantity caused the decrease in the copepod population. This may trigger the phytoplankton bloom according to the top-down control as copepod is one of the major predators of phytoplankton. The occurrence of a harmful algal bloom may relate closely to the increase in the jellyfish population.

Poster S1-3691

10-year variations in biomass, production and ecological role of *Noctiluca scintillans* in the coastal waters of Sagami Bay, Japan

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The biomass and production of the large heterotrophic dinoflagellate *Noctiluca scintillans* were examined in the coastal waters of Sagami Bay, Japan from 1997 to 2006. In order to estimate the biomass of *N. scintillans*, the relationship between the cell volume and the carbon content was obtained as the logarithm equation, $C = 0.24 X \text{Log}_e V - 3.71$ ($n = 9$, $P < 0.01$), where C is the carbon content per single cell of *N. scintillans* ($\mu\text{g C cell}^{-1}$) and V is the cell volume ($\mu\text{m}^3 \text{cell}^{-1}$). The growth rates of *N. scintillans* (μ) fed *Dunaliella salina* were also measured in the laboratory under different chlorophyll *a* concentrations from 0.2 to 20 mg Chl. *a* m⁻³. The relationship between *N. scintillans* growth rate and chlorophyll *a* concentration could be approximated by a hyperbolic equation: $\mu = 0.21 - 0.03 \text{Chl. } a^{-1}$. The production of *N. scintillans* was estimated using this relationship and the measured biomass. The highest biomass was 294 mg C m⁻³ in May 2000. The biomass in 2000 was extremely high compared with other years. During the bloom period in spring, the biomass of *N. scintillans* overwhelmed the other-zooplankton biomass. The production of *N. scintillans* in 2000 reached 48 mg C m⁻³ d⁻¹. The production in the period was not only considerably higher than that of dominant copepods such as *Calanus sinicus*, *Paracalanus parvus* and *Acartia steueri*, but also the production was occupied the half of primary production; 83.5 mg C m⁻³ d⁻¹ in this study area. These considerations suggest that *N. scintillans* plays an important role in the carbon flux in the coastal waters of Sagami Bay.

Poster S1-3695

Decadal changes in hydrographic and ecological time-series in the Balearic Sea (western Mediterranean), identifying links between climate and zooplankton

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The seasonal and interannual abundance of main zooplankton groups are presented for a monitoring station of the Balearic Sea, where we investigate potential relationships between hydroclimatic variability and mesozooplankton. The results based on 10 year samples were collected every 10 days during the period from January 1994 to December 2003. The pattern of major zooplankton groups are defined, as well as the physico-chemical variables

which characterised the area. Almost all of groups exhibited annual cycles and recurrent patterns where the copepods, appendicularians and cladocerans were the most representative. Results indicate that ecological responses to hydrographic variability differ according to different life-histories of zooplankton groups. Although hydrographic patterns of temperature and salinity showed marked seasonal patterns, we observed that over the interannual scale such hydrographic patterns are driven by regional atmospheric forcing and ultimately related to the North Atlantic climate variability. Regarding zooplankton groups, both biomass and abundance strongly decrease during years of higher temperature records and lower ones of salinity. Subsequently, the temporal variability in the total abundance of zooplankton appears to be indicative of the southern spreading of the Northern Mediterranean Current, and therefore of meridional transport of water masses in the Balearic Sea. The relationship between the patterns of the main zooplankton groups and changes in the thermohaline regime in the context of the climate-oceanographic time-series are discussed.

Poster S1-3720

Zooplankton stable N isotopes as an index of climate variation in the NE Pacific

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We have analysed the long-term (>54 year) variability in zooplankton ¹⁵N/¹⁴N isotopes in two sectors of the California Current System (CCS): Southern California (Pt. Conception to the Mexican border) and Central California (centred on the Monterey Bay area), utilising the extraordinary CalCOFI zooplankton collection. We use zooplankton stable N isotopes to assess the spatial coherence of food web responses in these two geographically different, but interconnected regions of the CCS. We address the sensitivity of pelagic food web structure to climate forcing on multiple time scales: El Niño, multi-decadal variability, and the long-term warming trend. Toward this end we have focused on four zooplankton species: the particle-feeding copepods *Eucalanus californicus* and *Calanus pacificus* and the obligately carnivorous chaetognaths *Sagitta bierii* and *S. euneritica*, all of which were found in both regions in nearly all study years. Three of the four species exhibit an El Niño-related enrichment in heavy N in both geographic regions. The remaining species (*E. californicus*) does not respond in a consistent manner to El Niño and other interannual variations, but shows a secular decline in $\delta^{15}\text{N}$. We consider the possibility that a progressive deepening of this species' habitat, combined with a long-term change in NO₃ concentration in source waters for upwelling in the California Current, may be responsible for the observed changes.

Poster S1-3756

Euphausiid abundance trends in two Peruvian upwelling zones

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The main purpose of the present study was to show changes in euphausiid abundance observed from 1994 to 2005 in Paita (05°00'S) and San José (06°30'S). Euphausiids seem to be an important key species at Peruvian sea water as a the main food for hake, *Merluccius gayi* and as the second most abundant group in those zones. Bimonthly samples were carried out since 1994 to 2005 in these areas with sampling performed at the subsurface with a 300 micron WP-2 net. We found that in last 10 years euphausiids shows seasonal patterns in Paita, which are not seen in San José. It appears that the El Niño does not have any effect on euphausiid group. If we compare the abundances, euphausiids have increased their abundance in Paita which is the reverse of what has happened in San José where euphausiid abundances are less. The effect of physical parameters such as temperature, salinity and oxygen content on euphausiid abundance are discussed.

S2 Importance of zooplankton in biogeochemical cycles

29 May, 14:05 (S2-3717) Invited

Gelatinous grazers: an underestimated force in ocean carbon cycles

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The biological carbon cycle in the ocean begins with photosynthetic fixation of carbon dioxide into phytoplankton cells, which are consumed by a variety of grazers. While some grazers, particularly microzooplankton, respire and recycle the carbon near the surface, many larger metazoan grazers transport significant portions of ingested C to deeper ocean strata by vertical migration, as rapidly sinking faecal pellets, or both. Gelatinous grazers, particularly pelagic tunicates are often more effective in this transport than other kinds of zooplankton, due to their high feeding rates, large population sizes, and dense, rapidly sinking faecal pellets. Epipelagic salps can occur in huge populations over large areas, consuming and sedimenting tons of C daily from the surface to deeper waters. At midwater depths, salps are rare, but doliolids and appendicularians are often abundant, collecting food with internal or external filters and producing both faecal pellets and discarded mucous houses. Other gelatinous particle feeders, including planktonic holothurians, polychaete worms and pteropods, are even less well-known than the tunicates. The activity of these grazers has consequences both for the food supply to the deep sea and benthos, and for the removal of C from the ocean-atmosphere equilibrium. When faecal pellets sink deep into the bathypelagic zone the carbon they contain may be consumed and respired by deep-living organisms, but it will not be returned to surface waters for thousands of years, and effectively removes it from equilibrium with atmospheric CO₂. This natural sequestration of C by zooplankton has been occurring for millions of years.

29 May, 14:35 (S2-3479)

Functional groups and key species of the zooplankton as pivotal drivers of the biological pump in the Humboldt Current System off Chile

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The role of zooplankton in the vertical flux of particulates via faecal pellets (FP) has been studied during the last 10 years by using free-drifting and anchored sediment traps in coastal and oceanic areas of the Humboldt Current System (HCS) off Chile. Recognisable FP usually made up the bulk of the sedimented matter, accounting up to 76% of the average total organic carbon (POC) recorded in the HCS. Euphausiids seem to be the key drivers of the biological pump due to the production of large, fast-sinking faecal strings, accounting on average for 50% and 33% of total POC collected at shallow (100 m depth) and deep (2300 m depth) sediment traps along the HCS. Copepod, appendicularian, chaetognath, and protozoan faecal material made a minor contribution to vertical flux of POC in coastal and oceanic areas, however, appendicularian faecal pellets contributed significantly (~10%) of the CaCO₃ flux to the deep sea. This highlights the significance of appendicularian pellets because the sinking flux of CaCO₃ was ca. one order of magnitude higher than the POC flux, suggesting deep-water delivery of biogenic CaCO₃ is the main pathway for removing carbon from the upper-ocean biosphere in the HCS off Chile. Thus, faecal pellets may constitute a fast-sinking vehicle for the export of organic matter towards deeper layers when the dominant producers are euphausiids or may be largely recycled in near surface layers when the dominant producers are copepods. Sinking speeds of faecal pellets of different zooplanktonic groups were measured with average values of 100, 240 and 500 m d⁻¹ for copepods and appendicularians, chaetognaths and euphausiids, respectively. In general, only a minor fraction of the produced zooplankton faecal pellets are exported below the productive layer of the ocean, mainly due to mineralisation and utilisation processes exerted by bacteria and metazoans. However, the faecal material that exits the productive layer of the ocean before being recycled might constitute the main fuel of the POC pump in the HCS off Chile.

29 May, 14:55 (S2-3575)

Vertical flux of zooplankton products in an oligotrophic coastal ecosystem: importance of copepod carcasses and faecal pellets

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Vertical flux of zooplankton faecal pellets and carcasses was studied during and after a plankton bloom in an oligotrophic coastal area of the Western Mediterranean using a sediment trap. Zooplankton products retrieved from the trap constituted of faecal pellets (from copepods and macrozooplankton) and copepod carcasses; with a respective carbon flux of 0.05 to 2.69 mg C m⁻² d⁻¹ and 0.42 to 4.37 mgC m⁻² d⁻¹. Carcass carbon always exceeded total faecal pellet carbon, except when at the bloom beginning, due to a higher carbon contribution of macrozooplankton faecal pellets. During the peaks of mesozooplankton biomass, total faecal flux was essentially constituted by copepod faecal pellets (75-95% of the total faecal pellet numbers, 68-86% of the total faecal carbon flux), whereas before and after this period, copepod faecal pellet contribution was lower (40-50% of total pellet numbers, 9 to 12% of total faecal carbon flux). Copepod faecal carbon vertical flux was positively correlated with both mesozooplankton biomass and chlorophyll *a*. Carcass vertical flux was negatively related to mesozooplankton biomass, suggesting an increase in mortality rate. The estimated values of mortality rate are discussed. Because of the significant role of carcasses in shallow areas, we conclude that carcasses should be compared to faecal pellets in such areas.

29 May, 15:15 (S2-3451)

The importance of zooplankton in unravelling the ocean methane paradox

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Why is the world's upper ocean supersaturated with methane? We know it is, but don't fully understand why. Evidence suggests that a portion of this methane comes from *in situ* production in oxygenated waters, however, that contradicts all we know about methanogenesis; a strictly anaerobic process. If, there were anaerobic microsites, then it is possible that methanogenesis could occur within these sites. We hypothesise that marine zooplankton, their faecal material, and other sedimenting particles, represent these anaerobic microsites in oxygenated pelagic waters. We have now clearly identified methanogens within marine zooplankton faecal pellets and sedimenting particles. This, along with preliminary evidence showing elevated methane concentrations associated with these sites, has led to greater insights into how this anaerobic process may be actively occurring in pelagic waters. Interestingly, some of the methanogens identified are affiliated with the genus *Methanobus*, and these microbes are thought to utilise the climate feedback gas, dimethylsulphide (DMS). The main source of DMS is dimethylsulphoniopropionate (DMSP), a compatible solute produced by marine phytoplankton. It is likely that when zooplankton graze they consume at least some of the DMSP, which is then packaged into their faecal pellets, converted into DMS by microbial activity and subsequently used as a substrate for methanogenesis. Therefore, zooplankton faecal pellets could be instrumental sites both in the production of a greenhouse gas and the removal of climatic feedback gases, having consequences for our understanding of the role the oceans play in climate change. Preliminary data in support of this hypothesis will be presented.

29 May, 16:00 (S2-3547)

Zooplankton processing of sinking particle flux in the mesopelagic zone

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Mesopelagic zooplankton can affect the downward flux of particulate organic carbon (POC), and thus the biological pump, by consuming and remineralising sinking particles, repackaging them into faecal pellets, and by fragmenting them into slower- or non-sinking particles. We characterised the mesopelagic zooplankton community and sinking particle flux at the Hawaii Ocean Time series (HOT) station ALOHA in the subtropical Pacific and the Japanese times series site (K2) in the subarctic Pacific to determine the potential contribution of zooplankton to particle transformations. We estimated the contribution of mesopelagic zooplankton to remineralisation of sinking particles by comparing losses of sinking C measured by sediment traps with zooplankton metabolic requirements. We further investigated how zooplankton faecal pellet characteristics changed with depth in order to quantify the extent of particle repackaging by zooplankton. Zooplankton metabolic C requirements between 150-1000 m were higher at K2 than at ALOHA, and sinking POC flux was inadequate to meet the metabolic demand of mesopelagic zooplankton at either site. The latter suggests vertical migration plus carnivory supports a greater fraction of mesopelagic zooplankton C demand than does sinking POC. We also saw significant changes in types of faecal pellets with depth at both sites, indicative of midwater consumption and repackaging of sinking particles. These include changes in flux of larvacean, large copepod, and carnivore faecal pellets with depth. These results will help incorporate the role of zooplankton in predictive biogeochemical models, and have important implications for models of C export and sequestration in the deep sea.

29 May, 16:20 (S2-3685)

Downward carbon transport by diel vertical migration of *Metridia* spp. in the subarctic Pacific Ocean: respiratory and mortality fluxes

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Seasonal change of downward carbon transport due to respiration and mortality through diel vertical migration (DVM) in the calanoid copepods *Metridia* spp. was estimated in the Oyashio region, western subarctic Pacific during six cruises from June 2001 to June 2002. *Metridia pacifica* (CIV-CVI female) was an active migratory species throughout the year though its travel distance varied among seasons and stages. The annual mean biomass of *M. pacifica* which migrated between the surface and beneath the permanent halocline (150 m) was 502 mgC m⁻² d⁻¹ and was high during summer-winter (260-1300 mgC m⁻² d⁻¹) and low during spring (25-30 mgC m⁻² d⁻¹). Inorganic carbon respired at depth during daytime varied between 0.1 (April) and 13.2 mgC m⁻² d⁻¹ (August). Carbon transport due to mortality at depth was estimated on the basis of results of gut content analysis of myctophid fishes, and assumed daily mortality of 1%, and ranged from 0.001 (April) to 3.1 mgC m⁻² d⁻¹ (August and January). Secondly dominant migrant *M. okhotensis* was most active in spring, resulting in a flux of 2.3 mgC m⁻² d⁻¹ by respiration and 0.1 mgC m⁻² d⁻¹ by mortality. Overall annual carbon transport by DVM of *Metridia* spp. was estimated as 3.1 gC m⁻² year⁻¹, corresponding to 1.5% of annual primary production and 16% of particulate carbon flux at the halocline in the study site. Since DVM in *M. pacifica* is more active during the non-bloom season when gravitational flux of particulate matter is low, this species plays an important role in driving the biological pump efficiently in subarctic Pacific during summer-winter.

29 May, 16:40 (S2-3419)

Efficient transport of primary production to the mesopelagic layer by *Neocalanus plumchrus* in the subarctic Pacific

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There are several components to the biological pump, and each has its own flow rate and speed, pump-tube length, and transfer efficiency. Diatoms and coccolithophores are generally considered effective organic transporters, because they provide ballast (i.e. heavy Si and Ca frustules, respectively) for the sinking of particulate organic matter (POM). Most sinking POM is remineralised before reaching the bottom of the mesopelagic layer (ca. 1000 m), in which the oxygen minimum layer is situated. Zooplankton and micronekton are another component of the pump, transporting POM to depth by vertical migration behaviour. *Neocalanus* spp. are dominant copepods in the subarctic Pacific. They feed and grow in the epipelagic layer during spring and migrate down during late-spring and summer to 500-2000 m depth for mating and spawning. Unlike sinking particles, the biological pump driven by *Neocalanus* transports organic matter with low decay rate with depth to the mesopelagic layer. It is not well known, however, what role *Neocalanus* plays in the biological pump. During the iron-enrichment experiment in the subarctic Pacific (SEEDS-II), we tracked a tracer-marked water mass for 4 weeks and examined nitrate drawdown, and growth and downward migration of zooplankton. Downward migration of *N. plumchrus* transported 56 mmol N m⁻² from the surface mixed layer, corresponding to ca. 40% of new production during the experiment. Our finding shows that *Neocalanus* transports a significant portion of new production to the lower half of the mesopelagic layer in the subarctic Pacific.

29 May, 17:00 (S2-3416)

Absorption of organic carbon into copepods changes with phytoplankton concentration and species composition

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Copepods are key conveyors of organic carbon through the pelagic ecosystem during periods of high predation pressure. The absorption efficiency (AE) of carbon in the copepod gut determines the fate of ingested carbon and copepod AE may accordingly be an important parameter in the carbon flow from primary producers in the pelagic. Thus, absorbed carbon enters the classic food chain and becomes available to higher trophic levels, whereas egested carbon may enter the microbial loop. But despite its logical significance, our knowledge of the importance and variability of copepod AE is scarce. We investigated changes in copepod carbon AE due to phytoplankton diet. *Acartia tonsa* were fed *Dunaliella tertiolecta*, *Rhodomonas baltica*, and *Thalassiosira weissflogii*, and ingestion rates, carbon AEs as well as AEs of protein, lipids, and polysaccharides were measured. Carbon AEs varied significantly with both diet and phytoplankton concentration. AEs were significantly different on the three diets; highest on *D. tertiolecta* and lowest on *T. weissflogii*. AEs decreased from above 70% at low phytoplankton concentrations to a level at 50-60% at medium concentrations. Interestingly, carbon AEs increased to almost 80% at high concentrations on *D. tertiolecta*. The three phytoplankton species showed greatest differences in their content of protein and polysaccharides. Accordingly, the differences in carbon AEs were largely due to differences in the AE of these two macromolecules.

29 May, 17:20 (S2-3511)

Stoichiometry of zooplankton in the Baltic Sea: spatial and interspecific variation

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Changes in salinity and proceeding eutrophication have caused major changes in the Baltic Sea ecosystem during the last three decades. The phytoplankton community structure has shifted from a diverse community towards a simpler one, and marine copepods have been replaced by species favouring lower salinity and a more eutrophic environment. Zooplankton species differ in size, and some zooplankton species have a capacity to accumulate lipids. Therefore changes in the zooplankton community probably affect the amount and quality of food available for the higher trophic levels, including the commercially important planktivorous fish. We determined carbon (C), nitrogen (N) and phosphorus (P) composition of the most abundant zooplankton species in the main basins of the Baltic Sea in August 2002. In the Gulf of Finland and the Baltic Proper the spatial variation of species-specific C:N and C:P ratios were relatively stable, conforming with the stoichiometric theory. In the Bothnia Bay, where phytoplankton production is mostly phosphorus limited, *Limnocalanus macrurus* and *Bosmina longispina* had a relatively low C:N ratio and high N:P ratio. *Pseudocalanus acuspes* and *Limnocalanus macrurus*, that have lipid storage capacities, had a higher C:P ratio and higher variation in C:N ratio than the other species, regardless of study area. Overall, the zooplankton C:N:P ratios reflected both the differences between the areas (i.e. phytoplankton C:N:P ratios) and the species-specific differences in the lipid storage capacities. These results need to be taken into account when assessing the effects of historic changes in zooplankton species composition in the Baltic Sea.

S2

Posters

Poster S2-3265

Limitation of egg production in *Calanus finmarchicus* in the field: a stoichiometric analysisDaniel J. **Mayor**¹, T.R. Anderson², D.W. Pond³ and X. Irigoien⁴¹ Oceanlab, University of Aberdeen, Newburgh, Aberdeenshire AB41 6AA, UK. E-mail: dan.mayor@abdn.ac.uk² Ocean Modelling and Forecasting, National Oceanography Centre, Southampton, SO14 3ZH, UK.³ British Antarctic Survey, High Cross, Madingley Road, Cambridge CB3 0ET, UK.⁴ AZTI, Herrera Kaia Portualdea, Z/G, 20110 Gipuzkoa, Spain.

Egg production (growth) in marine copepods has been observed to correlate with both food quantity (bulk carbon, C) and also descriptors of food quality, including food nitrogen (N) and the polyunsaturated fatty acids 20:5(n-3) (EPA) and 22:6(n-3) (DHA). Consequently a consensus on the substrate that typically limits the growth of these animals has yet to be reached. Field experiments with *Calanus finmarchicus* were conducted in the Irminger Sea prior to the spring bloom to examine the biochemical limitation of their growth. The quantities of C, N, EPA and DHA invested in eggs were compared to the supply of these substrates from both maternal biomass and food ingested whilst feeding on natural plankton assemblages. Ratios of N:C, EPA:C and DHA:C in the ingested food and biomass utilised were compared to those in the eggs produced, and limiting substrates identified using simple stoichiometric theory. C and N, but not the fatty acids, were shown to be potentially limiting egg production, the relative strength of limitation of each depending on assumptions regarding utilisation efficiencies. Results highlight the importance of supplying N, in this instance primarily from maternal biomass, to egg production.

Poster S2-3339

Respiratory carbon flux by the diel vertical migration of the copepod *Metridia pacifica* in the subarctic Pacific OceanAtsushi **Yamaguchi**¹, K. Sasaoka², Y. Kamei², T. Rho³ and T. Ikeda¹¹ Laboratory of Marine Biology, Graduate School of Fisheries Sciences, Hokkaido University, 3-1-1 Minatomachi, Hakodate, Hokkaido 041-8611, Japan. E-mail: a-yama@fish.hokudai.ac.jp² T/S Oshoro-Maru, Faculty of Fisheries, Hokkaido University, 3-1-1 Minatomachi, Hakodate, Hokkaido 041-8611, Japan.³ Laboratory of Marine Bioresource and Environment Sensing, Graduate School of Fisheries Sciences, Hokkaido University, 3-1-1 Minatomachi, Hakodate, Hokkaido 041-8611, Japan.

Oxygen consumption rates and day/night abundance in the top 50 m water column of *Metridia pacifica* (adult females only) were determined at twelve stations in the subarctic Pacific and one station in the oceanic Bering Sea during summer of 2004. Assuming an assimilation efficiency (70%) and gross growth efficiency (30%), we calculated their night time ingestion in the top 50 m and daytime respiration in the layer >50 m at each station. The night time abundance of *M. pacifica* in the upper 50 m varied between 27 and 5422 inds. m⁻², and daytime abundance was zero across the stations. Daily migrating biomass of *M. pacifica* varied between 1 and 309 mg C m⁻². Oxygen consumption rate was 3.7-9.5 and 2.9-6.7 $\mu\text{l O}_2 \text{ ind}^{-1} \text{ day}^{-1}$ at *in situ* temperatures in the upper 50 m (6.4-14.2°C) and in the layer 50-200 m (2.8-9.5°C), respectively. Total night time ingestion by the females (0.04-11.04 mg C m⁻² day⁻¹) accounted to 0-2.4% of the local primary production. Total daytime respiration by the females in the layer >50 m (0.02-9.39 mg C m⁻² day⁻¹) corresponded to 0-10% of the POC flux down from the euphotic zone. Although our calculation is limited to the females of the single species, respiratory flux by migrant mesozooplankton as a whole in the subarctic Pacific appears to be comparable to that reported in subtropical and tropical waters.

Poster S2-3367

Studies on biological processes of the phosphorus turnover in surface water of Xiamen Harbour I: grazing of microzooplankton on phytoplankton

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In order to understand the role that microzooplankton play in the biogeochemical cycling of phosphorus, dilution experiments were performed *in situ* to examine the growth rates and grazing mortality rates of size-fractionated phytoplankton in Xiamen Harbour in March, May, August and November 2005. The growth rates of total phytoplankton in surface water ranged from 0.46 d⁻¹ to 1.44 d⁻¹, while microzooplankton grazing rates ranged from 0.12 d⁻¹ to 0.86 d⁻¹. Both reached maximum values in August and minimum values in March. The carbon flux consumed by microzooplankton was 19.25-965.40 µgC L⁻¹ d⁻¹, corresponding to 18.45%-243.18% of phytoplankton standing stocks and 31.71%-75.80% of potential primary productivity. Microzooplankton ingested more primary production from 0.45-20 µm phytoplankton than from 20-200 µm phytoplankton. The grazing pressure of microzooplankton on primary production produced by 0.45-20 µm and 20-200 µm phytoplankton was 82.38%-92.95% and 65.35%-71.41% respectively. The secondary production of microzooplankton ranged from 6-162 µgC L⁻¹ d⁻¹, which was 16.79%-32.04% of the carbon flux consumed by microzooplankton per day.

Poster S2-3369

Studies on biological processes of the phosphorus turnover in surface water of Xiamen Harbour II: species composition of copepods and feeding impact

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Species composition, abundance, and feeding activities of copepods on phytoplankton were estimated in Xiamen Harbour on four cruises in May, August, November 2005 and March 2006. 32 species of copepods were recognised, of which the dominant species (dominance index > 0.02) were *Bestiolina amoyensis*, *Paracalanus crassirostris*, *Paracalanus parvus*, *Acartia pacifica*, *Labidocera euchaeta* and *Centropages tenuiremis*. The grazing rates of 10 species of copepods were determined, *in situ*, by the gut fluorescence method. Gut pigment content ranged from 0.0483 to 4.1713 ng ind⁻¹, and grazing rates ranged from 1.68 to 145.36 ng d⁻¹ ind⁻¹. The feeding impacts of copepods on phytoplankton were 6948.38 ng d⁻¹ m⁻³ (in May), 97642.87 ng d⁻¹ m⁻³ (in August), 7902.16 ng d⁻¹ m⁻³ (in November) and 51629.99 ng d⁻¹ m⁻³ (in March). The annual average daily grazing rates of the copepod population on phytoplankton was 1.69% of phytoplankton standing stock. The daily grazing rate was highest in November (3.15% of phytoplankton standing stock) and lowest in August (0.06%).

Poster S2-3395

Distribution, feeding and remineralisation role of heterotrophic nanoflagellates in the East China Sea

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Heterotrophic nanoflagellates (HNF) are a key component of the microbial food web in the sea, due to their widespread distribution, and importance in growth, feeding, and metabolic nutrient regeneration of N and P. In the East China Sea, the distribution and role of HNF in feeding and remineralisation of nutrients were studied in the Fujian-Zhejiang alongshore waters (FZAW), Changjiang River diluted waters (CRDW), Taiwan Warm Current waters (TWCW), and Kuroshio waters (KW) from 1999 to 2006. The results show that: 1) the biomass of HNF was 5.45, 3.95, 2.68 and 0.47 µgC dm⁻³ in FZAW, CRDW, TWCW and KW, respectively; 2) the feeding rate of HNF on heterotrophic bacteria (and cyanobacteria) was 2.46 (3.26), 1.78 (2.37), 1.21 (1.60) and 0.21 (0.28) µgC dm⁻³ hr⁻¹, in the above waters, respectively; 3) with the assumption of a gross growth efficiency of 25%, the turnover rate of HNF in the above

waters was calculated as 14.2, 14.9, 12.4 and 12.1 hours, respectively; 4) with an ammonia secretion rate of $140 \mu\text{gN mg}^{-1} \text{hr}^{-1}$ (Wambeke, 1985) for HNF, the percentage of DIN secreted by HNF per day was estimated to be 15-80%, 7-20%, 20-50% and 15-30% of DIN in the above waters, respectively. Our results suggest an important role of HNF in nutrient remineralisation and regeneration in the study waters. This role, however, varied in the water bodies of different external nutrient supply condition, and varied with seasons in the nearshore waters, e.g. FZAW.

Poster S2-3408

Metabolism and elemental composition of four oncaeid copepods in the western subarctic Pacific

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The family Oncaeidae (Cyclopoida) is one of the most numerous groups in marine copepod communities, but our knowledge of their physiology and biochemistry is currently quite limited. We determined respiration rates at *in situ* temperature (3°C) and bodily elemental composition (carbon and nitrogen) of the four dominant oncaeid species (*Triconia borealis*, *T. canadensis*, *Oncaea grossa* and *O. parila*) in the western subarctic Pacific Ocean. Across the four oncaeid species, respiration rates were near proportional to the body dry weight (DW), ranging from 0.00099 to $0.0074 \mu\text{l O}_2 \text{ individual}^{-1} \text{h}^{-1}$. Carbon (C) and nitrogen (N) composition of the four oncaeid species were 48.8–57.1% of DW and 7.0–10.3% of DW, respectively, and the resultant C:N ratios were 4.8–8.3. These high C contents and C:N ratios reflect the large accumulation of lipids in their bodies. Respiration rates adjusted to a body size of 1 mg body N (i.e. adjusted metabolic rates, AMR) of the four oncaeid species ($0.85\text{--}1.39 \mu\text{l O}_2 (\text{mg body N})^{-0.843} \text{h}^{-1}$ at 3°C) were low and less than 20% those predicted from the global respiration model for epipelagic calanoid copepods. These results are discussed in the light of unique behavioural and feeding modes of oncaeid copepods.

Poster S2-3428

Micro- and mesozooplankton respiratory metabolism: comparison of simultaneous incubation experiments and ETS activity

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The assessment of respiration rates for the different zooplankton size-fractions by classical incubation experiments is extremely time and labour consuming. Enzymatic methods, such as ETS activity, overcome most of the experimental inconveniences, but ETS activity is a proxy for respiration; it gives potential respiration, not actual respiratory rates. It is analogous to the use of chlorophyll as a proxy for phytoplankton biomass, or the Lowry method as a proxy for protein – all proxy measurements needing standard curves. For this reason, the determination of robust relationships between ETS activity and experimentally measured respiratory rates for the different plankton components are essential. Here the relationships between potential and actual respiration rates of metazoan plankton have been studied by simultaneous incubation experiments and ETS measurements. The study focuses on two size classes of zooplankton, > 200 μm (mesoplankton) and 50-200 μm (microplankton). Both groups were obtained in offshore and coastal communities in the NW Mediterranean. The usefulness of these relations and their interest for a better understanding of global oceanic respiration are discussed.

Poster S2-3456

Sources of production to subsystems of the Seto Inland Sea, Japan

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An ecological treasure of Japan, the Seto Inland Sea (SIS), is linked to the Pacific Ocean and Sea of Japan, yet it also receives varying levels of organic/inorganic inputs from areas with intensive urban, industrial, and agricultural development. To determine the importance of terrestrial versus marine-derived production to the SIS, we measured carbon and nitrogen stable isotopes of particulate organic matter (POM) and zooplankton, and carbon isotopes of

dissolved organic (DOC) and inorganic carbon (DIC) from five major river systems draining into the SIS, six subsystems within the SIS, and the Pacific Ocean. Results showed that SIS $\delta^{13}\text{C}$ values closely resembled $\delta^{13}\text{C}$ of marine production, indicating that POM and zooplankton within the SIS were largely derived from a marine source. However, the relative influence of river and anthropogenic inputs to the SIS varied by subsystem. From spatial comparisons of $\delta^{15}\text{N}$ of POM and zooplankton, a distinct east-west separation of the SIS was observed, with eastern subsystems exhibiting high $\delta^{15}\text{N}$ values associated with river inputs from areas of heavy urban and industrial development (low salinity, high nitrate and phosphate, low dissolved oxygen). Patterns in $\delta^{13}\text{C}$ of POM also showed a similar east-west trend that was likely related to greater benthic-pelagic coupling and a predominance of diatom production. Zooplankton $\delta^{13}\text{C}$ values were more variable, but generally showed a similar trend of ^{13}C -enrichment relative to subsystem differences in primary production and benthic-pelagic coupling. The SIS therefore consists of subsystems that have unique biological characteristics due to terrestrial and marine inputs and benthic-pelagic coupling.

Poster S2-3468

Concentrations of trace elements in zooplankton off northeastern Japan

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Zooplankton samples were collected at about 50 m depth with a large ring net (160 cm mouth diameter, 0.5 mm mesh) in May, June, October 2005 and June 2006 at fixed stations off northeastern Japan. Concentrations of trace elements were determined in bulk samples or samples sorted by taxa: euphausiids, chaetognaths, copepods; *Neocalanus* spp., amphipods; *Themisto* spp. and *Cyphocaris* sp. The trace elements measured were Al, Ce, Co, Cs, Cu, Fe, Gd, La, Mn, Nd, Pr, Sr and Zn. Chaetognaths had relatively lower concentrations of Co and Sr, and higher concentration of Cs than other species. Two amphipods had higher concentration of Sr. These differences may reflect different biological processes in metabolism of these elements. Generally speaking, the concentrations of lanthanides along with Al and Mn did not differ greatly among the taxonomic groups. A good linear relationship on a log-log plot was observed between the concentration factors of the trace elements in zooplankton and the mean oceanic residence times calculated from mean dissolved river-water inputs. Our study would contribute to the understanding of the role of zooplankton in the marine biogeochemical cycle of the trace elements.

Poster S2-3477

Importance of expatriated boreal copepods in the Oyashio-Kuroshio mixed region

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Seasonal fluctuations of abundance, biomass, and population structure of boreal copepods were investigated by analysis of monthly zooplankton samples from the Oyashio-Kuroshio Mixed region of the western North Pacific Ocean. Hydrographical conditions were complicated as a cold and less saline water mass appeared in the surface layer from April to May and was covered with warm and saline waters thereafter. Although boreal copepods were a minor component by number of the zooplankton community above 1000 m, they composed more than 60% of the biomass throughout the year. These copepods were observed in the layers above 1000 m over the study period, but their abundance decreased between August and December. In the surface layer above 150 m, high abundance was limited to the period May through July. The most predominant species by number was *Metridia pacifica*, and by biomass was *Neocalanus cristatus*, with *Eucalanus bungii* making a secondary contribution. Seasonal population structure of each copepod species revealed that the timing of occurrence for younger copepodites, dormant stages, and adult specimens were comparable to those previously reported in the upstream Oyashio region. These results suggest that the boreal copepods that appeared in the study area are the expatriated animals transported downstream in the submerged Oyashio. Such expatriated biomass was estimated to be 2.1 to 24.0 gC m⁻² and was 137 times higher than the summer feeding of *S. nannochir* in the Oyashio-Kuroshio Mixed region. Biogeochemical importance of the expatriated boreal copepods will be discussed.

Poster S2-3520

Climate effects on zooplankton biomass, species composition, and cross-shelf delivery of carbon in a coastal upwelling system

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In coastal upwelling ecosystems, the export of biological production from nearshore to the deep ocean feeds the global carbon cycle and productivity of the oceanic ecosystem, while also playing an important role in zooplankton population dynamics. Typically, wind-driven Ekman transport has been considered the dominant mechanism of cross-shelf transport during upwelling, but more recently, mesoscale circulation features such as 'squirts,' filaments, and eddies are recognised as important contributors. Such dynamic features are common in the California Current System (CCS) and may persist several months, delivering large amounts of nearshore water and the associated biology to the deep sea. As part of the US GLOBEC Northeast Pacific Program, we are studying climate effects on zooplankton species composition, biomass, and distribution in conjunction with the timing and intensity of mesoscale circulation in the CCS. We use satellite altimetry to study interannual variability in circulation, and zooplankton collected off Oregon and northern California during summers 1998-2003 to study zooplankton variability. Our results indicate that climate effects on the cross-shelf transport of zooplankton biomass are a complex interaction of both circulation and population dynamics. Zooplankton biomass and the intensity of mesoscale circulation peaked in summer in most years, but the timing and amplitude of the peaks in energy and biomass varied interannually. In this presentation, we explore the complexities of ecosystem variability including changes in climate, circulation, and zooplankton species composition and biomass, all of which contribute to interannual variability in the transport of zooplankton biomass to deeper, offshore regions of the CCS.

Poster S2-3556

Fate of copepod faecal pellets during an iron induced phytoplankton bloom (EIFEX) in the Southern Ocean

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A combined examination of faecal pellet production in experiments and the analysis of the faecal pellet standing stock within the water column were carried out during the course of the European iron fertilization experiment (EIFEX) in the Southern Ocean in late summer, early autumn 2004. In response to the iron fertilization, a diatom bloom developed with chlorophyll *a* concentrations up to 3.1 $\mu\text{g Chl } a \text{ L}^{-1}$ inside the fertilised patch. Faecal pellet production experiments with the abundant copepods showed that faecal pellet volume and faecal pellet production increased with increasing chlorophyll *a* values. Faecal pellet carbon (FPC) standing stock increased inside the fertilised patch during the course of the experiment. At day 37 after fertilisation, FPC within the euphotic zone was 13 times higher than in the beginning of the fertilisation experiment, while the FPC increase at the out patch stations was only half of this. The turnover rate for faecal pellets within the euphotic zone was calculated based on a comparison between the expected and the actual faecal pellet abundance in the field and was determined to be 17-22 hours for the in patch stations. At depths beneath 150 m, only 1-7 % of the maximum FPC could be detected and the temporal evolution of biogenic silica within the euphotic zone indicates that most of the faecal pellets were recycled within the euphotic zone during EIFEX. Different possible mechanisms for and processes resulting in these findings will be discussed.

Poster S2-3633

Vertical distribution of suspended faecal pellets and production of copepod faecal pellets in the Ulleung Basin in the Japan/East Sea

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Vertical distribution of suspended faecal pellets (SFP) in water column and production rates of faecal pellets by copepod community was studied in the Ulleung Basin, Japan/East Sea in July 2005. An anticyclonic eddy existed in the centre of the basin. The eddy was stratified with a seasonal thermocline and in the centre of the eddy a

strong subsurface chlorophyll maximum was developed at 40-50 m depth. Experiments were performed at three stations: D1 (located at the shelf edge and outside of the eddy), D2 (at the periphery of the eddy), and D4 (inside the eddy). The mean standing stock of SFP in the upper 150 m was higher at D1 than at D2 and D4, showing highly positive correlation with mesozooplankton biomass. The SFP at D2 and D4 peaked at 30-50 m depth with no clear difference between the day and night sampling. The SFP in the water column, however, peaked at 100 m depth at D1, due to potential vertical migration of euphausiids and amphipods at dawn. The estimated production of faecal pellets by the copepod community was higher at D4 than D2, mainly due to the higher chlorophyll *a* concentration in the subsurface chlorophyll maximum layer. The production rate of faecal pellets by the copepod community was estimated as $9.16 \text{ mgC m}^{-3} \text{ day}^{-1}$ (or $1.83 \text{ gC m}^{-2} \text{ day}^{-1}$ in the upper 200 m). The major controlling factors for the variability of mesozooplankton faecal pellets are discussed in the context of the potential role of faecal pellets in carbon flux in the Ulleung Basin in summer.

Poster S2-3682

Mesozooplankton biomass and copepod growth rates in the Whitsunday Islands, Great Barrier Reef, Australia

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Size-fractionated mesozooplankton biomass, copepod growth rates (evaluated using the artificial cohort method) and nutrients in the water were measured in stations close to the coast and on the Great Barrier Reef (GBR). Chlorophyll levels were usually low ($\sim 0.35 \mu\text{g l}^{-1}$) and temperature very constant in the incubations ($21.3 \pm 0.7^\circ\text{C}$). Mean mesozooplankton biomass was low ($22.7 \text{ mg dry weight m}^{-3}$), and had no clear relationship with nutrient concentration. In 2005 there was no clear pattern of distribution of biomass, but in 2006 the contribution of smaller size fractions was higher closer to the coastline than on the GBR itself. Cyclopoid nauplii, mainly oithonids, were the most common copepod stages, present in all growth experiments, followed by calanoid nauplii. Harpacticoids, when present, were represented mainly by *Euterpina acutifrons* and nauplii of *Microsetella* sp., with growth rates usually similar to those of the cyclopoids. Calanoid nauplii had a larger range of growth rates than cyclopoids, but the total mean copepod growth rates were similar in both years (0.1 and 0.2 d^{-1}). The low copepod growth rates and zooplankton standing stock support the hypothesis of a food-limited community, as has been observed in previous studies in the GBR lagoon. This has implications for the role of mesozooplankton in carbon cycling and in the transformation of nutrients in the region.

Poster S2-3736

Carbon fluxes due to diel vertical migrant zooplankton during the late winter bloom in the Canary Islands waters

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Temporal variability of zooplankton vertical distribution (0-800 m) was studied at dawn, noon and night in a station located at 100 km to the North of Gran Canaria Island (Canary Islands) during March 2000. Zooplankton biomass (protein content), indices of feeding (gut fluorescence, GF) and indices of metabolism (electron transfer system activity, ETS) were measured at the end of a late winter bloom period. Two dense layers of organisms were clearly observed during the day, one above 200 m and the other at about 500 m, coincident with the deep scattering layer (DSL). A typical pattern of higher biomass in the shallower layers was displayed at night. Biomass in the 0-200 m layer remained high during the study period due to the combination of the influence of the late winter bloom, and a dust storm. Average ETS activity was almost two-fold higher above 200 m than at 200-800 m depth. The gut flux estimated ($1.26 \text{ mg C m}^{-2} \text{ d}^{-1}$) was similar to the values previously found in the Canary Island waters. This value represented 2.5% of the calculated passive particulate export production resulting from primary production. The active respiratory flux mediated by diel vertical migrants ($1.23\text{-}2.70 \text{ mg C m}^{-2} \text{ d}^{-1}$) was in the lower range of values reported for this area. This value represented only 5% of the calculated total passive particulate export production. These results agree with previous estimates and suggest that diel-migrants play a moderate role in the downward flux of carbon.

Poster S2-3754

Grazing impact of *Neocalanus* spp. compared to remainder mesozooplankton in the coastal and shelf water of the Gulf of Alaska

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Three species of large calanoid copepods, *Neocalanus flemingeri*, *N. plumchrus* and *N. cristatus*, dominate the springtime biomass of mesozooplankton in the entire subarctic Pacific. We compared the grazing impact of *Neocalanus* species on phytoplankton with grazing by the remainder of mesozooplankton community in the coastal and shelf waters of the Gulf of Alaska during spring and summer of 2003. *Neocalanus* spp. and the remainder mesozooplankton fed mainly on particles >20 µm in our investigations, and phytoplankton in the small size-fractions increased in the presence of mesozooplankton, possibly due to a trophic cascade resulting from mesozooplankton consumption of microzooplankton. *Neocalanus* spp. accounted for the majority of mesozooplankton biomass and herbivory in the shelf-break region during April-May. Their contribution to total mesozooplankton biomass and to herbivory was lower in the inner-shelf region and in the Prince William Sound (PWS) where diatom blooms occurred during the same time period. The biomass of other mesozooplankton (mostly small copepods) was seasonally and spatially invariable; it did not increase in summer after the descent of *Neocalanus* spp. from the surface layer. In spring, the combined grazing by *Neocalanus* spp. and other mesozooplankton consumed a large part of daily growth of phytoplankton larger than 20 µm in the outer-shelf region where chlorophyll *a* concentrations were low and phytoplankton community was dominated by pico- and nano-sized cells. In contrast, mesozooplankton consumed a negligible fraction of the greater than 20 µm daily phytoplankton production in the inner and mid-shelf regions where chlorophyll *a* concentrations were typically higher than 3 mg m⁻³. In summer without *Neocalanus* spp. in the surface layer, copepod grazing was a small proportion of phytoplankton production over the entire shelf. However, larvaceans consumed a significant portion of the phytoplankton biomass during summer.

Poster S2-3777

Krill faeces as a key vehicle of the downward particle flux in Southern Ocean

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A preliminary analysis of materials recovered from an Antarctic sediment trap was undertaken. The analysed samples were part of the year-round collections (from December 1999 to December 2000) obtained from two depths (678 m and 1678 m), south of Elephant Island, Antarctica. Sequential filtration through a series of sieves proved to be a simple, less destructive method to sort the trap material by origin. Zooplankton faeces dominated the upper trap material during summer. Most of the faeces of Antarctic krill could be retained by 180 µm mesh, and were by far the most significant contributor, reaching up to 60 % by mass. Smaller pellets of other origins were of much less importance. On the other hand, the lower trap material was dominated by a fraction that passed through a 32 µm mesh, and could not be attributed to zooplankton faeces. The krill faeces recovered from the trap included significantly more carbon and biogenic silica than in the finer sized fraction. The krill faeces contained broken cells of larger diatom species whereas the fine size fraction contained a greater proportion of less-damaged cells of smaller species. The density of krill faecal strings in the trap were lower than measured for fresh pellets of other euphausiid species but significantly high so that the pellets sink rapidly and reach the upper trap within a few days. The downward flux of carbon and biogenic silica mediated by krill faeces should be substantial. This suggests that the grazing pressure of krill, and the removal of diatom cells from the upper water column in particular, could be more intense than previously thought. It also implies that the abundance and the distribution of large grazers such as krill and salps can be critical in determining the downward carbon flux.

S3

The role of zooplankton in food webs: changes related to impacts of climate variability and human perturbation

1 June, 09:05 (S3-3576)

The relation of northern Baltic zooplankton to climatic forcing, eutrophication and clupeid stocks in 1979-2006: bottom-up regulation revisited

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We analysed FIMR and ICES data from Baltic Proper (BP), Gulf of Finland (GoF) and Gulf of Bothnia (GoB) during 1979-2006. Significant trends were observed in BP and GoF zooplankton. Neritic copepod *Pseudocalanus acuspes*, the preferred, high-energy food item of the Baltic herring, have decreased, whereas other copepods have increased. In GoB, which doesn't suffer from anoxic deep-water, preferred clupeid food items *Eurytemora* spp. and *Limnocalanus macrurus* increased. BP and GoF deep water (below halocline, 80 m) suffered a long stagnation period from 1978 to 1993. During this time, the average oxygen content decreased, and after a temporary relapse after the strong saline water inflow of 1993, declined to present low values. Dissolved oxygen in sub-halocline water has remained below 2ml/l since 1996 in BP. In BS and BB systems oxygen levels at deep water remain at 5-8ml/l. Abundance of herring +1 recruits from BP and GoF decreased, while sprat +1 recruits increased since the mid-1980s. Factors causing these changes are: 1) Climatic forcing through increased precipitation in the Baltic drainage area, a positive NAO index signifies increased river runoff, preventing saline inflow. 2) Anthropogenic eutrophication increases organic matter flux to deep bottoms, consuming oxygen. In BP and GoF abundance of herring recruits significantly positively correlates to *Pseudocalanus* biomass in the same, and two consecutive years. Sprat food gain is less dependent on *Pseudocalanus*, consisting of abundant copepod species. We discuss the effects of decreasing salinity and eutrophication induced oxygen deficiency to crustacean zooplankton in Baltic food webs, and cascading effects on clupeids.

1 June, 09:25 (S3-3767) Invited

The importance of zooplankton in reducing levels of atmospheric CO₂ via the biological pump

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Zooplankton play a key role in climate change through the transfer of large quantities of CO₂ to the deep ocean by a process known as the biological pump. Plankton composition is crucial as associated mineral material facilitates sinking of carbon rich debris and some taxa package faecal and detrital material. Ocean acidification may impact calcareous groups. Zooplankton have also been shown to be highly sensitive indicators of environmental change. Results will be presented to show that ocean temperature, circulation and planktonic ecosystems (using data from the Continuous Plankton Recorder, CPR survey) in the North Atlantic are changing rapidly in concert and that there is evidence to suggest that the changes are an ocean wide response to global warming with potential feedback effects. Given the importance of the oceans to the carbon cycle, even a minor change in the flux of carbon to the deep ocean would have a big impact increasing growth of atmospheric CO₂. We have virtually no understanding of the spatial and temporal variability in the efficiency of the biological pump for most of the world's ocean. Establishing new plankton monitoring programmes backed up by appropriate research to help understand processes is needed to address this gap in knowledge. There is little doubt within a global change context and the future of mankind that a potential acceleration in the growth of atmospheric carbon due to a reduction in the efficiency of the biological pump is a key issue for future research in zooplankton ecology.

1 June, 09:55 (S3-3264)

Sub-lethal effects of elevated CO₂ on *Calanus* spp.

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The partial pressure of carbon dioxide (CO₂) in our atmosphere has increased from 280 to 370 ppm in the past 200 years, causing the phenomenon known as 'ocean acidification'. Model predictions illustrate that further increases in CO₂ are inevitable, with 'worst-case' atmospheric concentrations potentially reaching up to 8000 ppm. The ecosystem-wide implications of CO₂-induced acidification remain poorly understood because almost nothing is known about how individual, key-stone species will be affected. A series of incubation studies with adult female *Calanus finmarchicus*, the predominant copepods in the North Atlantic and northern North Sea, were conducted to examine how their biology and ecology will be affected by the worst-case scenario CO₂ concentration. Rates of egg production and energy consumption were not significantly affected by elevated CO₂. Conversely, egg-hatching success was strongly affected, with a significantly higher proportion of the eggs remaining un-hatched after 72 hrs in the CO₂-enriched seawater. The implications of these data will be discussed.

1 June, 10:15 (S3-3478)

The effects of rising seawater CO₂ on marine zooplankton

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Increasing atmospheric CO₂ has been diffusing across the ocean surface, acidifying the whole neritic ocean, and thereby driving all marine organisms to live in lowering pH environments. The atmospheric CO₂ is projected to rise from the present level of 380 ppm to about 2,000 ppm in 300 years, resulting in a pH drop of 0.77 units. As calcification rate is known to decrease with increasing seawater CO₂, the future oceanic environment will likely impact on calcifying marine organisms. First, we present our studies on the CO₂ effects on zooplanktonic larval stage of the sea urchins *Hemicentrotus pulcherrimus* and *Echinometra mathaei* and the shellfish *Crassostrea gigas*. The synthesis of calcium carbonate spicules and shells of both pluteus larvae and veliger larvae was highly affected by increased seawater CO₂, suggesting a reduction of larval recruitment and population size of these organisms in the future ocean. Secondly, we present recent data on the long-term effects on two crustaceans (shrimp and copepod). Survival, growth and molting rate of the shrimp *Palaemon pacificus* were significantly affected when reared for 15 and 30 weeks in seawater equilibrated with air containing 1,000 and 1,900 ppm CO₂, respectively. In contrast, no significant effect on survival, growth and reproduction was observed when the copepod *Acartia tsuensis* was reared from egg to adult stage under 2,000 ppm CO₂ conditions. Thus, the ocean acidification may potentially alter the marine ecosystem through affecting essential constituents of the marine food web.

1 June, 11:00 (S3-3276)

Indirect effects of climate- and overfishing- induced zooplankton changes on ecosystem structure – regime shifts, trophic cascades and feedback loops in a simple ecosystem

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The central Baltic Sea is the largest brackish water body in the world ocean, containing a highly productive but low diversity ecosystem. Climate-induced changes in hydrography have recently resulted in an ecosystem regime shift with pronounced changes on all trophic levels. The most pronounced changes in the ecosystem have occurred in the zooplankton and the fish. In the zooplankton, dominance changed between the copepods *Pseudocalanus acuspes* and *Acartia* spp., a result of reduced salinities and increased temperatures. The change in hydrography also affected the reproductive success of the major fish species with the result of a change in dominance from the

piscivorous cod (*Gadus morhua*) to the planktivorous sprat (*Sprattus sprattus*). Here we show the linkage between the zooplankton and fish regime changes, specifically how the trends of the key copepod species contributed to the switch in dominance of the key fish species. We further demonstrate how overfishing amplified the climate-induced changes on both trophic levels, resulting in a species-level trophic cascade and a predator-to-prey loop from cod to sprat to *P. acuspes*, stabilising the new regime. Hence, our study demonstrates the multiple pathways on how climatic and anthropogenic pressures propagate through the food web, and especially the crucial role of zooplankton in mediating these ecosystem changes.

1 June, 11:20 (S3-3697)

Interannual variability in Southern Ocean ecosystems: impacts of climate-driven fluctuations in Scotia Sea food webs

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Determining how climate fluctuations affect ocean ecosystems requires an understanding of how biological and physical processes interact across a wide range of scales. Here we present analyses that show that El Niño Southern Oscillation related anomalies in sea surface temperature (SST) in the South Pacific sector of the Southern Ocean are propagated via the Antarctic Circumpolar Current into the South Atlantic, with warm anomalies in the southeast Pacific occurring a year prior to warm anomalies in the South Atlantic. We show that across the South Atlantic sector these changes in SST, and related fluctuations in winter sea ice extent, affect recruitment and dispersal of Antarctic krill (*Euphausia superba*). This variation in turn affects the breeding success of seabird and marine mammal predators that depend on krill as food. The fluctuations generate shifts in trophic interactions and energy flow, highlighting the importance of alternative pathways in maintaining food webs. Such propagating anomalies, mediated through physical and trophic interactions, are likely to be a major component of variation in oceanic ecosystems and affect responses to longer term change.

1 June, 11:40 (S3-3664)

Changes in mesozooplankton community structure in a highly stratified basin due to anthropogenic forcing

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During the last decades anthropogenic eutrophication has been identified as the key ecological problem for the Sea of Marmara. This forcing caused significant shifts in zooplankton community structure and the highly stratified basin became a *Cladocera* dominated system and pollution indicator species frequently constituted the major fraction of zooplankton biomass. This paper deals with the response of Marmara zooplankton to eutrophication. The eutrophication stress on zooplankton communities has been scaled by the trophic state index (TRIX) and compared to the spatial patterns in zooplankton community and distribution of pollution indicators. Results clearly pointed out the pollution based problems at İzmit and Gemlik bays. In addition to high total zooplankton abundance at these regions, well-known pollution indicators reach high values, replacing the niches of other species that compete under normal trophic conditions of the Sea of Marmara. *Penilia avirostris* was the dominant species in September 2005, while its abundance drastically dropped at İzmit and Gemlik bays and replaced by the pollution-tolerant *P. polyphemoides* that was either absent or represented by very low numbers at other stations. Similarly, *Acartia clausi* abundance also increased at the region vs. *Paracalanus parvus*, the dominant copepod species at the rest of the Sea of Marmara. The distribution of *Noctiluca scintillans* also provided a good separation of troubled regions. MDS analysis supported the spatial differentiation of zooplankton communities and western and more polluted eastern parts were well separated through a transect from the Strait of Istanbul to the south. The studies performed clearly depicted the influence of anthropogenic perturbation on zooplankton communities and therefore the importance of zooplankton studies in pollution monitoring.

1 June, 12:00 (S3-3473)

Ctenophores - invaders and their role in trophic dynamics of the planktonic community in the coastal regions off the Crimean coast of the Black Sea (Sevastopol Bay)

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The Black Sea is an impressive model of the damaging impact of invasive species on the ecosystem as a whole and on the planktonic community in particular. The introduction of the ctenophore *M. leidyi* in the late 1980s resulted in a dramatic decrease in both the abundance of some species and in biodiversity of the zooplankton community. Competition between *M. leidyi* and planktonic fish for zooplankton prey brought about a remarkable decline in the fish stock. The appearance of a new invader ctenophore *Beroe ovata*, a feeder on *Mnemiopsis* at the end of the 1990s caused further changes in the planktonic community. In our work we discuss the seasonal and inter-annual dynamics of the two introduced ctenophore species monitored along with meso- and microzooplankton in the inshore waters of the northern Black Sea from 2000 to 2006. The *B. ovata* appearance resulted in *M. leidyi* biomass sharply falling to extremely low values and shortening time of *M. leidyi* presence in plankton. The predatory pressure of *M. leidyi* on the meso- and microzooplankton communities (evaluated by undertaking both field and laboratory studies of the main physiological characteristics) decreased much in those years. *M. leidyi* population consumed daily from 1.9 ± 0.4 to $13.4 \pm 5.7\%$ of mesoplankton biomass while these values were as high as 30–40% when *B. ovata* was absent. Maximum daily grazing rate of microzooplankton biomass by *M. leidyi* larvae was as much as 40% in Sevastopol Bay in the years of high abundance. The consequence of *B. ovata* invasion was positive for the recovery of the Black Sea planktonic communities and the ecosystem as a whole.

1 June, 12:20 (S3-3540)

Predation and ecological impact of an introduced predatory cladoceran *Cercopagis pengoi* on native copepods in the Baltic Sea

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We studied the potential of an introduced species, the predatory cladoceran *Cercopagis pengoi*, to influence native zooplankton populations in the Baltic Sea. Feeding rates of different instars of *C. pengoi* on copepodites and adults of *Eurytemora affinis*, a dominant copepod species, were determined in feeding experiments. The feeding rates of *C. pengoi* varied from 0.7 to 4.8 prey predator⁻¹ d⁻¹, being significantly higher in older instars. Based on these experimental results and long-term zooplankton abundance data from the Gulf of Finland, we estimated the *in situ* predation on *E. affinis* and related it to the observed changes in the copepod stocks following *C. pengoi* invasion. The results imply that at its maximum population densities, *C. pengoi* would consume *E. affinis* at a rate of up to 10,550 copepods m⁻³ d⁻¹, exerting an additional predation pressure on copepods. This could explain the observed drastic decrease in *E. affinis* abundances especially in the eastern parts of the Gulf of Finland where *C. pengoi* has been most abundant. Such decline probably strengthens the food competition between planktivorous fish and mysids that feed on the same prey and increase the overall predation pressure on *E. affinis*, thus leading to its further decline. In the Baltic Sea, a collapse of this ecologically important species would cause major changes in virtually all trophic levels, because the food web structure is simple with only a few species of herbivorous zooplankton, planktivores and piscivores.

1 June, 14:00 (S3-3396)

Consequences of extensive aquaculture-structure removal: the relative importance of planktonic versus structure-related changes

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The removal of extensive oyster and finfish culture structures in a hypertrophic, semi-enclosed lagoon in southwestern Taiwan provided a “natural” experiment to test resulting changes in the food web. Many changes resulted in the lagoon ecosystem, including increased flushing, water clarity, dissolved oxygen, salinity, chlorophyll

a, gross production, and zooplankton, but decreased nutrients, periphyton, and dramatically reduced populations of bivalves, finfish, and jellyfish (*Aurelia aurita*). We examine changes in the ecosystem to determine whether they explain the near disappearance of jellyfish. Alternatively, removal of the aquaculture structures, which may have provided substrate for polyps of *A. aurita*, may be the primary cause. The relative importance of changes in top-down (consumers) versus bottom-up (nutrient inputs) forces in explaining the resulting ecosystem changes are also discussed.

1 June, 14:20 (S3-3597)

Indirect human impacts on an estuarine food web illustrate the false dichotomy of top-down and bottom-up

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During the last three decades, introductions of new species have caused the most striking anthropogenic perturbations to the northern San Francisco Estuary. Introduction of the clam *Corbula amurensis* in 1986 triggered changes in the food web that have been well-described in the literature. Since introduction of this clam the summer food web of the oligohaline zone is characterised by low primary productivity, feeding by copepods largely on ciliates, poor survival of copepod nauplii due to predation by clams, and reduced abundance of several fish species, particularly anchovies, formerly the dominant filter-feeders. Most remaining planktivores feed visually, so the low primary productivity is coupled with fewer predatory modes. This combination has apparently facilitated the numerical dominance of the small cyclopoid *Limnoithona tetraspina*, which is cryptic to visual planktivores and feeds on motile prey. In recent years, survival of nauplii of the calanoid copepod *Pseudodiaptomus forbesi* decreased to ~zero, and the consequent decline in abundance probably contributed to the crash of several fish species. Apparently *P. forbesi* is squeezed between losses of nauplii to clam predation and competition for food by clams and *L. tetraspina*, and maintains its population only through advection from an upstream refuge. This subtle pattern of linkages complicated the response of the ecosystem to species introductions. This scenario also illustrates the false dichotomy of “top-down” vs. “bottom-up” controls: in any ecosystem, food limitation and predatory effects together control the productivity and the species composition of the zooplankton, and higher trophic levels respond in ways that can be difficult to predict.

1 June, 14:40 (S3-3755)

Copepod resistance to toxic phytoplankton

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Toxic phytoplankton blooms are increasing in distribution, duration and intensity worldwide, presumably as a result of eutrophication. These blooms represent a selective force in zooplankton populations. Animals that are resistant to the deleterious effects of toxic phytoplankton should be selected for, leading to evolutionary changes in zooplankton populations. We have carried a series of studies dealing with the evolution of resistance of populations of the copepod *Acartia hudsonica* to the toxic dinoflagellates *Alexandrium tamarense* and *A. fundyense*. Here we will summarise these studies that have 1) experimentally demonstrated differential resistance of populations of *A. hudsonica* 2) The presence of different phenotypes of resistance within populations. We will briefly outline the consequences of resistance for the structure and function of planktonic food webs.

1 June, 15:00 (S3-3391)

***Euphausia mucronata* a central link in the Humboldt Current food web**

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Zooplankton and small pelagic fish are considered intermediate links in the transfer of photosynthetic production to higher trophic levels, a role mainly assumed by krill species in highly productive ecosystems. This work provides evidence suggesting a similar role for *E. mucronata* in the Humboldt Current System (HCS). *E. mucronata*, an indigenous species concentrated in the coastal upwelling belt, shows morpho-physiological adaptations to vertically migrate into the Oxygen Minimum Layer (OML). A herbivore in the mixed layer with high evacuation rates of ca. 2/h and high ingestion rates of ca. 300 ng Chl eq./ind.hr or ca 500 µgC/ind.d accounts for a significant impact on primary production (ca. 30%). Such impact is clearly supported by high densities in the pelagic (probably overlooked in fishery-oriented plankton surveys). *E. mucronata* amounted to ca. 50% of mesozooplankton wet weight in the coastal 60 miles belt of the HCS, and a dominant prey of fish and whales. Jack mackerel population alone accounted for ca. 30 million tonnes consumed a year according to stomach content analysis during fishing operation 1989-1991 off southern Chile 34-39°S. Estimations and implications of the predation pressure upon *E. mucronata* of several fish populations are examined according to commercial landings off Peru and central Chile. Alternative scenarios associated with regime shifts of small pelagic forms such as anchovy, sardine and jack mackerel and their predation or competitive pressure upon *E. mucronata* are examined with regard to food web structure under the assumption that euphausiids are a keystone link.

1 June, 15:20 (S3-3409)

Influence of chlorophyll and sea ice dynamics on the reproduction and recruitment of the Antarctic krill *Euphausia superba* in waters west of the Antarctic Peninsula (45-75°S, 50-80°W)

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The reproductive patterns and recruitment success of the Antarctic krill *Euphausia superba* were investigated in relation to chlorophyll distributions and sea ice dynamics in waters west of the Antarctic Peninsula during 2000/2001 and 2001/2002 as part of the Southern Ocean GLOBEC programme. The Antarctic Peninsula is warming relative to other regions of the Southern Ocean, potentially impacting on phytoplankton populations and consequently on krill, which in turn may have an effect on top predators such as whales, seals, and penguins. Climatological SeaWiFS chlorophyll data (1997-2004) showed that the Bellingshausen Sea and Marguerite Bay regions consistently had higher and more persistent chlorophyll concentrations than the more northern areas along the Antarctic Peninsula shelf and the western Scotia Sea. Net and high-frequency acoustic data revealed strong interannual variability in krill abundance and population structure. Unusually high krill reproduction in 2000/2001 coincided with widespread high positive chlorophyll anomalies and resulted in a relatively large juvenile recruitment during the following spring. Ice edge blooms were only a significant feature in the Bellingshausen Sea and, thus, were not likely to support krill reproduction in the northern Peninsula region. Differences in sea ice conditions in Marguerite Bay during spring and summer also probably contributed to the variable krill abundances observed. Winter sea ice cover was extensive during both seasons. Thus, above average chlorophyll concentrations and favourable sea ice conditions in coastal areas during spring and summer 2000/2001 likely supported the high densities of larval krill observed during fall in waters west of the Antarctic Peninsula.

1 June, 16:00 (S3-3565)

Pteropods in Southern Ocean ecosystems

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Southern Ocean zooplankton research has traditionally focused on the perceived key ecosystem components, predominantly Antarctic krill (*Euphausia superba*), but including several copepod species (e.g. *Calanoides acutus*, *Rhincalanus gigas*). More recently the tunicate *Salpa thompsoni* has been added to this list due to its seasonally high densities, high grazing rates, contribution to vertical flux, and southward range expansion in response to ocean warming. However, data on the majority Southern Ocean pelagic ecosystem components remain thin, despite being essential to our understanding of the ecological impacts of climate change. Until very recently Pteropoda, dominated by *Limacina* spp. and *Clio* spp., have largely been ignored in the Southern Ocean. Nevertheless, pteropods can be a major component of zooplankton biomass. Furthermore, pteropods have a measurable grazing impact and contribute significantly to the vertical flux of both organic (faecal pellets) and inorganic (aragonite shells) carbon. Orr *et al.*, 2005 (Nature 437/29) have drawn attention to changes in oceanic acidity, due to increasing levels of atmospheric CO₂, and its implications for pteropod survival. It is projected that Southern Ocean surface waters could become undersaturated with respect to aragonite by 2050. Major changes to the distribution of pteropods and their role in biological and carbonate pumps in the Southern Ocean may therefore occur within the next few decades. This highlights a need for focused research on this group. In this paper we review current knowledge on Antarctic pteropods focusing on their distribution, densities, and contribution to ecosystem processes, and assess knowledge gaps and directions for future research.

1 June, 16:20 (S3-3394)

Dominant zooplankton species shift in the Changjiang River estuary: possible causes

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Zooplankton in the Changjiang River estuary was investigated quarterly in 2004, the first year after the Three Gorges Reservoir was impounded to a water level of 135 m. Compared with zooplankton assemblages during 1955-56, 1985-86, and in 2002, evident dominant species shift was observed only in August. A tropical-subtropical copepod species *Temora turbinata* (Dana, 1849), recognised as seasonal and non-dominant in this area before 2003, became the most abundant zooplankton species in August 2004, while previous dominant species, such as *Calanus sinicus*, *Euchaeta concinna* and *Labidocera euchaeta*, decreased in density and appearing frequency. *T. turbinata* is perennially found and seasonally predominant in coastal and estuary areas in the south of China, such as both sides of the Taiwan Strait. It appears in the Changjiang River estuary in summer, in correspondence with northwards invasion of the Taiwan Warm Current. Our findings indicate that in summer 2004 the Changjiang River diluted water shrank its range and the Taiwan Warm Current occupied a larger area in both bottom and surface layers, comparing to long-term average. It is suggested that *T. turbinata* in Changjiang River estuary originates from south of the East China Sea, but reasons of its prosperity in this area remain unexplained. It may be another example of northward extension of warm-water species resulting from global warming, or effects of water control of the Three Gorges Reservoir in the estuarine ecosystem.

1 June, 16:40 (S3-3710)

Genetic analysis of Continuous Plankton Recorder (CPR) samples

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Genetic analysis of Continuous Plankton Recorder (CPR) samples is enabling greater taxonomic resolution and the study of plankton population structure. Here, we present some results from the genetic analysis of CPR samples collected in the North Sea and north-eastern Atlantic that reveal the impacts of climate on benthic-pelagic

coupling and the food web. We show that pronounced changes in the North Sea meroplankton are related to an increased abundance and spatial distribution of the larvae of the benthic echinoderm, *Echinocardium cordatum*. Key stages of reproduction in *E. cordatum*, gametogenesis and spawning, are influenced by winter and spring sea temperature (January-May). A stepwise increase in sea temperature after 1987, which has created warmer conditions earlier in the year, together with increased summer phytoplankton, may benefit the reproduction and survival of this benthic species. Competition between the larvae of *E. cordatum* and other holozooplankton taxa may now be altering the trophodynamics of the summer pelagic ecosystem. In the north-eastern Atlantic the genetic analysis of fish larvae sampled by the CPR has revealed an unprecedented increase in the abundance of juvenile snake pipefish, *Entelurus aequoreus* since 2002. We argue that increased sea surface temperatures in winter and spring when the eggs of *E. aequoreus*, which are brooded by the male, are developing and the young larvae are growing in the plankton are a likely cause. The increased abundance of this species in Atlantic and adjacent European seas already appears to be influencing the marine food web.

S3

Posters

Poster S3-2775

Zooplankton biodiversity relative to long-term ecological variations in the southeastern Mediterranean

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The construction of the High Dam on the River Nile caused a drastic drop of the amount of fresh water discharged to the southeastern Mediterranean during the Nile flood every year. As a consequence nutrient concentrations and phytoplankton production sharply decreased, followed by the long term disappearance of sardine shoals. A few years ago, the fertility of nearshore waters was restored due to the increase of nutrient load brought by discharged agricultural, domestic and industrial wastes. Phytoplankton production rose and relatively large amounts of sardines reappeared along the Egyptian coastal waters. However, the offshore waters are still lacking the high nutrient supply that used to reach them before the High Dam during the flood season. In addition, frequent variability in the quality and quantity of discharged wastes led to several changes in the environmental conditions along the southeastern Mediterranean coast during the past 50 years, reflected in serious changes in the water quality as well as the biotic components of the ecosystem. Zooplankton was influenced by such changes and experienced pronounced temporal and spatial variations in its species composition, biodiversity, seasonal production, relative abundance of the major groups and succession of the dominant species.

Poster S3-3238

Study on the role of zooplankton in the sturgeon food web

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The goal of this study was to calculate the best diet in Persian Sturgeon, *Acipenser persicus*, to increase production and survival of the larvae. Larvae were fed as follows: 1) *Artemia parthenogenetica* Instar I 100% (control treatment), 2) *A. parthenogenetica* 75%, *Brachionus plicatilis* (S- type) (Muller) 25%. 3) *A. parthenogenetica* 50%, *B. plicatilis* 75% and 4) *A. parthenogenetica* 25%, *B. plicatilis* 75%. The larvae were fed daily 25-30% of their body weight, six times during an 11 day period. Physico-chemical factors of water were analysed by correlation coefficient and comparisons between treatments were done by Duncan's test and two-way ANOVA. The results showed that in the first week, there was significant differences in weight increase at 5% level ($p < 0.05$). The results of the experiments showed the best growth was in the treatment No. 4, where the mean weight and growth was 41.1 ± 0.04 mg and 6.69%, respectively. We conclude that it is possible to raise *A. persicus* up to day 7 with a mixed diet of rotifer and *A. parthenogenetica*.

Poster S3-3239

Study of zooplankton populations effective in nutrition of *Acipenser stellatus* fingerlings

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In order to study the growth rate to stellate sturgeons, three earthen ponds were randomly selected. Two ponds were treated with 16 tons organic fertilizer and 40 kg *Daphnia*. The physical and chemical parameters of water and also the density of zooplankton and benthos were measured during the rearing period. On the basis of the statistical analysis conducted, no significant difference was observed in the physical factors of the water in the three ponds, but nitrite values were significantly different. Zooplankton productivity was dominated by *Daphnia magna* and *Daphnia pulex*, Cyclops and nauplii of Cyclops. *D. magna* and *D. pulex* were also the most abundant prey, followed by Cyclops and nauplii of Cyclops. Tubificidae and Chironomidae were occasional prey items.

The results of gastrosomatic index observations indicated a decrease in daily growth rate and condition factor with an increase in weight and length of the fingerlings, but this difference was not significant. The analysis of gut contents of the 120 fingerlings in the ponds treated with animal fertilizer and live-food indicated that 30 of the fingerlings were reared under good rearing conditions.

Poster S3-3247

A comparative account of the distribution of copepods in five estuaries along the northeast coast of Tamilnadu, India

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Plankton indicators are used in composite indexes of ecosystem health. Phytoplankton communities exhibit strong responses to eutrophication and the copepods are considered to be a prominent member of the primary consumers. A study of zooplankton was carried out in five estuaries along the northeast coast of Tamilnadu, from July 2002 to April 2005. Of the 75 zooplankton species recorded during the study, copepods constituted 29 species, followed by the microzooplankton group tintinnids (21 species). The abundance of copepod in Pulicat estuary was 38.6 ± 12.9 ind/L. *Acartia tonsa*, and *Oithona similis* were the dominant calanoids. The harpacticoid group was represented by three species *Euterpina acutifrons*, *Attheyella alaskansis* and *Bryocamptus hiemalis*. In Ennore creek the dominant calanoid copepods were *Pseudodiaptomus* sp. and *Oithona similis*. The harpacticoid group was represented by *Microsetella norvigicus* and *Euterpina acutifrons*. Cyclopoids were nearly absent. Only three species of copepods were present in the Cooum estuary. *Pseudodiaptomus* sp. was the dominant among them. Copepods were the second abundant group with 136 ± 85.5 ind/L next to the rotifers in Adyar estuary. They were represented by *Mesocyclops* sp., *Eucalanus* sp., *Euterpina acutifrons* and *Bryocamptus hiemalis*. The highest abundance of copepod was 356 ind/L during October 2002. Cyclopoids were equally represented in this estuary. The Muttukadu estuary had a copepod abundance of 178 ± 120 ind/L, which was the highest among the estuaries studied. *Oithona similis*, *Paracalanus parvus* and *Acartia tonsa* were more abundant in this estuary. Copepods and rotifers were more abundant during the monsoon compared to the other seasons.

Poster S3-3266

Seasonal and geographical variations in abundance, biomass, production rate and grazing impact of microzooplankton in eutrophic northern Hiroshima Bay, the Inland Sea of Japan

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In order to elucidate the ecological roles of microzooplankton in eutrophic northern Hiroshima Bay, the Inland Sea of Japan, we measured their abundance and biomass, and estimated their production rate and grazing impact, monthly from June 2000 to May 2001. There were remarkable seasonal variations in abundance and biomass of microzooplankton: being high in spring-summer and low in fall-winter. Over the study area and study period, tintinnids were overwhelmingly dominant in terms of abundance (mean: 71.4%), followed, in order, by copepod nauplii (14.4%) and naked ciliates (14.2%). In terms of biomass, tintinnids, copepod nauplii and naked ciliates accounted for 51.2, 29.8, and 19.0%, respectively. Geographically, the abundance and biomass of microzooplankton were highest at the innermost station and decreased offshore. Tintinnids occurred homogeneously over the area, whereas naked ciliates tended to occur more abundantly at inshore stations and copepod nauplii at offshore stations. The biomass of microzooplankton showed a significant positive relationship with chlorophyll *a* concentration (both total and <10 μm fraction) suggesting that microzooplankton growth is controlled by food supply. The grazing impact of microzooplankton, as expressed by daily removal of phytoplankton biomass, was lower at inshore stations (annual mean: 2.0%) than offshore stations (5.8%). These results demonstrated that in northern Hiroshima Bay, the trophodynamic role of microzooplankton as nanoplankton grazers is less important in the innermost highly eutrophic area compared to offshore less eutrophic area. Indirect effects of climate- and overfishing-induced zooplankton changes on ecosystem structure – regime shifts, trophic cascades and feedback loops in a simple ecosystem.

Poster S3-3285

Changes in zooplankton community related to environmental and anthropogenic influences in a subtropical lagoon

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Plankton samples were taken monthly in 21 stations in the San Ignacio-Navachiste-Macapule lagoon system, Mexico, from October 2002 to September 2003, in order to evaluate the zooplankton community structure changes associated to environmental variability and to possible anthropogenic effects. Forty-four zooplanktonic taxa were recorded along the year. Four groups constituted 91% of the total abundance; with copepods dominating (50%), followed by decapods, chaetognaths, and cladocerans. Changes in zooplankton composition were related to seasonal environmental conditions, but dominance of copepods and decapods was maintained throughout the year, with the exception of summer when the gelatinous component (medusae and cnidarians) was important. Principal factor analysis (PFA) identified four areas and one isolated station in function of the distribution of dominant groups: the first area, included stations with strong influence of neritic waters, high diversity, and copepods *Centropages furcatus*, *Labidocera trispinosa*, and *Corycaeus affinis*, cladocerans and chaetognaths broadly distributed. The second area was characterised by high plankton volumes (PV) and high concentrations of copepods typical of lagoon environments (*Acartia clausi* and *A. lilljeborgii*). In the Macapule area, predominance of *Paracalanus* and *Clausocalanus* and low PV was observed. Stations with a strong impact from sewage pollution formed the fourth area. This last area, and one isolated station were also characterised by the lowest α diversity, abundance, PV, but with highest values of chlorophyll-*a* throughout the year. Besides the spatial definition of these areas, this work points out the strong effects of sewage discharges on the zooplanktonic community in this lagoon system.

Poster S3-3307

Amphipods (hypheriidae) in the macroplankton community of the Antarctic waters (Pacific part of Antarctic, PPA)

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Pelagic amphipods dominate the number species and are an important link in Antarctic seas trophic chains, particularly for many fishes, seabirds and squids. We studied the Bransfield Strait in March-April 2002, an area known for very productive in krill fisheries. Zooplankton samples were collected in vertical tows (0-100 m) at 25 stations. In addition to amphipods, krill (*Euphausia superba* Dana) and salps (*Salpa thompsoni* Foxton) dominate the macroplankton. Of the three groups, amphipods have the greatest specific diversity (5 species), but the lowest abundance. All observed amphipod species are representative of Antarctic waters: *Parathemisto gaudichaudi* (Guerin), *Hyperia galba* (Montagu; Hyperieidae), *Primno macropa* (Guerin-Menville; Phrosinidae), *Cyllopus lucasii* (Bate; Vibiliidae) and *Scina* sp. (Scinidae). *P. gaudichaudi* and *P. macropa* constitute 92 % of the total amphipod biomass. Amphipod abundance ranged from 4 up to 63 m⁻³, but generally did not exceed 30 m⁻³. We distinguish two amphipods groups: “free” amphipods, which live in krill aggregations, are active predators and good swimmers, but scarce in numbers. Members of the second group live and feed within salps (*Parathemisto*) and medusae (*Hyperia*). One in ten salps was infected with amphipods. During this study, we observed a decrease of krill and an increase of salps, with salp biomass exceeding krill biomass by > 25 fold. Therefore abundance of amphipods associated with salps should have also increased. Because amphipods are nutritionally better than salps, they can potentially mitigate the negative effects of krill reduction for higher trophic levels.

Poster S3-3313

Causal analysis of HAB and zooplankton in the East China Sea

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Based on the data from eight oceanographic surveys in the nearshore of the East China Sea (121°-123°00'E, 27°-30°N) from March to June in 2005, a study was carried out to analyse the dynamics of zooplankton in harmful algal blooms (HAB). The change in water environment, especially temperature, caused a shift in the dominant species and a decrease in biomass. *Calanus sinicus* (Copepoda, Crustacea), a key zooplankton species of the East China Sea, strengthened its dominance from March to May, resulting in low species diversity during this period. In June, the dominance of *C. sinicus* decreased rapidly, the number of temperate water species decreased and warm water species increased; for example, *Sagitta enflata* and *Lucifer intermedius* developed their populations rapidly during this period. The increase in diversity was linked with the warm water species occurrence. There was a HAB event in the spring. In the investigated area, zooplankton biomass increased first when temperature rose and reinforcing from the Taiwan Warm Current, then the warm water species were replaced by the temperate water species, which resulted in a decrease in zooplankton biomass. The decrease in zooplankton biomass might have resulted in a relaxation of grazing, allowing the development of the HAB.

Poster S3-3342

Man-induced changes in trophic pathways of metazooplankton in the Senegal River estuary (West Africa)

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To minimise the flooding effects in Saint-Louis city (Senegal, 16°N, 16°W), a channel was dug in October 2003 in the sandbar along the Senegal River estuary. However, this management has completely disturbed the hydro dynamism of the estuary and has induced deep hydrological modifications. To test the effects of increased marine influence on the planktonic trophic pathway, gut fluorescence measurements and field experiments on zooplankton feeding and metabolism were performed in April 2006 at a station located near the new channel, allowing us to compare these results with the same study performed in May 2002. Before the creation of the channel, phytoplankton was dominated by picoplanktonic cells (83 to 94% of total numbers), and particulate organic carbon (1.2 to 2.7 mg l⁻¹), of which organic detritus accounted for 20-70%. The dominant zooplankton (Cirripede larvae, *Acartia clausi*, *Temora stylifera* and *Paracalanus* spp.) could not meet their metabolic requirement solely with ingestion of phytoplankton. They exerted a selective feeding upon heterotrophic nanoflagellates (HNF) and detritus to complete their energetic needs. In 2006, phytoplankton biomass was slightly more abundant (15 µg Chl a l⁻¹ vs 10 µg Chl a l⁻¹ in 2002), and nanoplankton more representative (50%). The dominant zooplankton, with the same taxa as in 2002, grazed mainly on nanophytoplankton and met their metabolic needs with autotrophic carbon. Then, if microbial and multifarious pathways were dominant for mesozooplankton before 2003, the opening of the channel, by allowing massive intrusion of upwelled marine water, enhanced nanophytoplankton and herbivorous pathway.

Poster S3-3353

Distribution and biomass of large jellyfish assemblages and association with oceanographic features in the Yellow Sea and northern East China Sea

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Temporal and spatial distribution, biomass and composition of large jellyfish assemblages were examined based on samples collected from bottom trawl field surveys in 2006 in the Yellow Sea (YS) and Northern East China Sea (NECS). *Stomolophus meleagris*, *Cyanea* spp., *Semaeostomeae* sp., *Aequorea* spp., *Aurelia aurita*, and

Pelagia noctiluca were registered. Among them, *S. meleagris* overwhelming other gelatinous species, formed jellyfish blooms and accounted for more than 90% of the catch in September. The total biomass of jellyfish assemblage varied from April to November, and the maximum biomass in YS was 10.5, 12000, 2065 kg/net-h in April, September, and November, respectively, and in NECS it was 500, 5000, 1500 kg/net-h in June, August, and October, respectively. Jellyfish biomass was usually higher in the tidal fronts (boundary of the Yellow Sea Bottom Cold Water (YSBCW)) than adjacent areas in September, where the high-density biomass ranged from about 2 to 12 ton/net-h (12 ton: equivalent to 25-100 indiv/100 m² at the surface water). The high-density areas usually shrank northward and toward the center accompanying the reduction of YSBCW from September to November in YS. As far as the distribution pattern, dominant species prefer to occur in the specific water mass in association with their adaptation. Based on data from 1999 to 2006, the possible causes resulting in jellyfish bloom of *S. meleagris* or *Cyanea* spp. in recent years will be discussed.

Poster S3-3361

Seasonal variations of the copepod community derived from the seasonal monsoon system in the southern East China Sea

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This study was carried out in the southern East China Sea (ECS) in December 2003, and February, June and August 2004. Waters in the southeastern ECS were occupied by the Kuroshio Current (KC) all year round. However, hydrographic conditions in the southwestern ECS were influenced by the China Coastal Current (CCC), the Kuroshio Branch Current (KBC), and the South China Sea Current (SCSC) which were controlled by the seasonal monsoon system. In this study, 141 species of copepods belonging to 54 genera and 27 families were identified. According to the result of cluster analysis, the species composition of copepods was divided into 3 groups, CCCG, SCSG and KG. The CCCG group was associated with the CCC. It had low values for Shannon's diversity, Simpson's evenness indices, and high copepod abundance. The dominant and indicator species in this group were *Calanus sinicus* and *Corycaeus (Ditrichocorycaeus)*. The SCSG group was associated with the SCSC, where dominant and indicator species were *Temora turbinata*, *Undinula vulgaris*, *Oncaea venusta* and *Canthocalanus pauper*. The KG group was found in the area where the KC intrudes year round. It had the lowest copepod abundance, and highest diversity and evenness among the 3 groups. Its dominant species were *Oncaea venusta*, *Acrocalanus gibber*, and *Paracalanus aculeatus*. There was no distinct indicator species in the KG group. Canonical correspondence analysis was used to correlate copepods to hydrographic conditions, and will be discussed.

Poster S3-3381

Seasonal and spatial changes in abundance, vertical distribution, grazing and egg production of dominant copepods in the Humboldt Current System off central Peru

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Zooplankton were collected at two stations during austral summer and winter 2006 off Callao (12°S), Peru, using stratified vertical multinet hauls. The copepod *Acartia tonsa* was the dominant species, except in winter at the offshore station, when *Centropages brachiatus* was dominant. *A. tonsa* showed an ontogenetic vertical distribution, with 94% of the adults in the upper 20 m, and copepodids and nauplii occupying deeper layers. At the offshore station, nanoflagellates were numerically dominant followed by dinoflagellates and diatoms (*Chaetoceros* spp., *Asterionellopsis glacialis*, *Dactyliosolen mediterraneus*), whereas nearshore diatoms ranked second in dominance and dinoflagellates third. Total ingestion rate was 69.8 to 85.4 cells copepod⁻¹ hour⁻¹ during summer and 20.8 to 45.1 cells copepod⁻¹ hour⁻¹ during winter. Both copepod species showed a strong selectivity for nanoflagellates and diatoms, but against dinoflagellates. Although most cells ingested by *A. tonsa* were nanoflagellates, in

terms of biomass (volume or carbon) diatoms were the most important group. In winter, ingestion rates were generally lower despite only slightly lower *in situ* phytoplankton concentrations. Similarly, egg production rates measured during the grazing incubations were considerably higher in summer (10.2 eggs female⁻¹ day⁻¹) than in winter (0.75 eggs female⁻¹ day⁻¹). Gelatinous zooplankton present in higher numbers in winter (especially at the offshore station) may have caused the strong reduction in *A. tonsa* abundance, and may have effected the ingestion and egg production rates observed. This study was supported by the EU FP6 project CENSOR.

Poster S3-3420

Impact of artificial eutrophication on coastal zooplankton communities: a comparative study of zooplankton communities receiving different human activities (fish and pearl oyster farming)

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One central problem in coastal marine waters is eutrophication due to anthropogenic nutrient loading. Japan has a long history of aquaculture, and such farming activities often cause environmental problems in Japanese coastal waters. To assess the impact of farming activities on coastal zooplankton communities, we conducted comparative studies at coastal marine waters, Uchiumi and Fukuura Bays, neighbouring but receiving different farming effects (pearl oyster and fish farmings) at Uwa Sea, east side of the Bungo Channel. Fukuura Bay is highly eutrophic due to fish farming and other activities while the trophic status of Uchiumi Bay is oligo-mesotrophic. Seasonal changes of zooplankton communities were monitored from May 2005 to May 2006. To include microzooplankton as well as mesozooplankton, a Van-Dorn sampler was used with a 40 µm-mesh net filtering. Coastal calanoid copepods, *Paracalanus* spp. and *Temora* spp., dominated zooplankton communities at both sites, but their abundances different with higher abundances at Uchiumi Bay. Species compositions of calanoid copepods were also different with more frequent appearances of larger species such as *Calanus* spp. and *Eucalanus* spp. at Uchiumi Bay. The densities of microzooplankton including rotifers, bivalve larvae, and appendicularians, were higher at Fukuura Bay, however. The impact of eutrophication on zooplankton community structure and overall impact on the function of planktonic food web in coastal marine waters were analysed and will be discussed.

Poster S3-3429

Distribution and population structure of the non-indigenous cladoceran *Evadne anonyx* in comparison with the native *Evadne nordmanni* in the north-eastern Baltic Sea

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The Ponto-Caspian predatory cladoceran *Evadne anonyx* G.O. Sars, 1897 was first recorded in the central Gulf of Finland in 1999 and in its eastern part in 2000. In the Gulf of Riga the first specimens were found in 2000. Distribution pattern and increase in population density in years 2000-2006 indicate successful establishment of this new invader in the Baltic Sea recently. *E. anonyx* and the native *E. nordmanni* Loven are present in mesozooplankton community from June to October. In annual scale, the abundance maximum of *E. anonyx* occurs later in the season than that of *E. nordmanni* (August and June, respectively). During the abundance peak of both species, parthenogenetic females were dominating in the population. The mean body length and height of *E. anonyx* were larger than those of *E. nordmanni*, both in case of males and females. Average parthenogenetic fecundity was higher for *E. anonyx* than for *E. nordmanni* while the gamogenetic fecundity for both species was similar (1-2 eggs per individual).

Poster S3-3432

Shifts in composition and community structure of pelagic copepods in the Gulf of Trieste (Northern Adriatic Sea)

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The present study intended to reveal seasonal, interannual and decadal oscillations in the composition and community structure of pelagic copepods in the Gulf of Trieste (Northern Adriatic Sea) in relation to some environmental factors (phytoplankton taxonomic structure, sea temperature, North Atlantic Oscillation). The study is based on mesozooplankton samples collected by a vertical WP2 net (200 µm) on a monthly basis from April 1970 to December 1980, and from January 1986 to December 2005 at one monitoring station (depth 21 m) in the Gulf. Dynamics pattern and trends of the most common calanoid, cyclopoid and harpacticoid copepods (22 species) on seasonal, annual and decadal time scale are illustrated by cluster analysis, time-series analyses, and analysis of variance (ANOVA). We report substantial shifts in the copepod community during the period 1970-2005. Small-sized species such as *Diaixis pygmoea*, *Euterpina acutifrons*, *Oncaea* sp., *Coryceus* sp. increased significantly during the 1990s. The total numerical abundance of copepods sharply shifted after 2001-2002 to the level exceeding the one observed in the 1980s. The mode of sea temperature revealed lowest values in February ($8.22 \pm 0.98^\circ\text{C}$) and maximum in August ($23.57 \pm 1.19^\circ\text{C}$). The average monthly temperature slightly increased from July to December during the period 2000-2005, especially compared to the 1970s. Temporal variability of copepod community in the coastal ecosystem of the Northern Adriatic Sea was found to correlate with the environmental factors, which might suggest a mutual effect of climatic changes, shift in phytoplankton structure, and possibly anthropogenic pressure too.

Poster S3-3438

Changes in ctenophore *Mnemiopsis leidyi* phenology and population dynamics linked to environmental variability and climate forcing in its recipient areas of the Southern Seas

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The native habitat of the ctenophore *Mnemiopsis leidyi* is the Atlantic American coast. In the 1980s it was introduced into the Black Sea and then spread to the Azov, Marmara and the Aegean Seas. In 1999 it was introduced into the Caspian and in 2005 it was found in the Adriatic, followed by the north-western European coast in 2006. Therefore an analysis of the factors which control its development is important for prediction of possible future expansions into new areas. *M. leidyi* has wide environmental tolerance and could become established in different environmental conditions. We analysed variability of *M. leidyi* morphological, ecological and physiological features in the Black, Azov, Caspian, and Aegean Seas as a response to the different environmental conditions (salinity, temperature, prey concentration) of these seas and climate shifts effect, including large-scale atmospheric forcing. The *M. leidyi* physiological features in different environments determine life cycle, which includes fecundity, reproduction time and duration, growth and size, pattern of distribution and finally predation rate on zoo- and ichthyoplankton. Interannual individual and population *M. leidyi* size, spatial distribution in spring, seasonal time of spreading from the Black Sea to the adjacent seas, and from the Southern Caspian to the north are controlled by SST, particularly by minimal winter SST, which are determined mostly by NAO and modified by EAWR indexes. *M. leidyi* effects on the Southern Seas ecosystems are different. The strongest impact was recorded in the productive Black, Azov and Caspian Seas. But the effect depends on population size, which is controlled by climate forcing.

Poster S3-3441

Grazing dynamics of *Calanus finmarchicus* and *Oithona similis* on the microplankton assemblage in the Irminger basin, North Atlantic

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Copepods can shape microplankton communities and affect the carbon flux through their grazing activities. Nevertheless, the factors determining the degree of omnivory and selective feeding by different copepod species and stages in the marine environment remains an open question. Here we compare the feeding rates and prey preferences of the adult females and nauplii of the calanoid *Calanus finmarchicus* and of the females of the cyclopoid *Oithona similis* on the spring and summer microplankton assemblage in the Irminger basin. Our results show that the feeding selection by the different copepod species and stages differed substantially and according to the type and relative concentration of the prey. These feeding strategies may reflect differences in the energetic and nutritional requirements of the different copepods. In addition, high predation rates on ciliates and negative selection on flagellates by all copepods may have contributed to the bloom of flagellates during spring and summer.

Poster S3-3445

Plankton production and the abundance and feeding of larval fish in contrasting El Niño and La Niña years at Australia's North West Cape

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Coastal seas adjacent to Australia's North West Cape are dynamic in terms of their physical oceanography. The first year of our study (1997/98, an El Niño year), was characterised by a weak Leeuwin Current, a thinner mixed layer and a higher frequency of upwelling events, resulting in periodically very high rates of primary production – up to 8 g C m⁻² d⁻¹. In 1998/99, (a La Niña year) a stronger Leeuwin current suppressed the tendency of the system to upwell and resulted in generally lower rates of primary production. In spite of these differences we were unable to demonstrate substantial differences between years in copepod secondary production rates, which were generally low (~13 mg C m⁻² d⁻¹). We suspect the cause of this anomaly is the highly pulsed nature of upwelling (and subsequent production events), a strongly advective physical environment and a domination of food web structure by microbial processes. Bongo net collections contained the larvae of 76 families of fishes, with a similar community composition in each year, though some families (e.g. Pomacentridae, Carangidae) showed differences in abundance. Most larvae preyed upon copepods, and individual families of fishes exhibited strong selection for particular taxa. Late stage larvae sampled with light traps were threefold higher in the La Niña year and differed markedly in community composition between years. Richest catches occurred at stations characterised by high mixing. Paradoxically, temperature rather than food was more important in determining the growth rate of at least one species of coral reef fish (*Pomacentrus coelestis*).

Poster S3-3463

Seasonal variability and production of zooplankton community of Razdol'naya River estuary (the Peter Great Bay, Sea of Japan/East Sea)

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Zooplankton in the Razdol'naya River estuary (depending on the tidal cycle) consists of freshwater, brackish, neritic and oceanic taxa. Peaks of biomass (more than 1 g/m³) and species diversity are usually observed during June and September. At this time estuarine copepods (*Sinocalanus tenellus*, *Eurytemora pacifica*, sometimes *Schmackeria*

inopina) are the most common species. The period of maximum number is April-May; it is connected with development of rotifers (*Synchaeta* sp., *Polyarthra dolichoptera*, etc.). Also the rotifers are indicators of organic pollution of the estuary (peaks of number up to some million ind./m³). In the winter, during a seasonal minimum of zooplankton, *Sinocalanus tenellus* and freshwater rotifers are dominant species. In spring, species diversity of planktonic animals increases with the addition of copepods (freshwater *Thermocyclops crassus*, *Th. asiaticus*, brackish *Sinocalanus tenellus*, *Schmackeria inopina*, *Eurytemora pacifica*, neritic - *Acartia clausi*, *Oithona similis*, *O. brevis*) and cladocerans (*Diaphanosoma dubium*, *Bosmina longirostris*, *Bosminopsis deitersi*). In summer rotifers are mainly represented by species from the genera *Brachionus*, *Keratella*, *Trichocerca*, *Hexarthra*, *Polyarthra*, *Filinia*. In autumn, the decrease of number of cladocerans and thermophilic rotifers (diapause stage) account for the reduction of species diversity and abundance of zooplankton. Three main groups form the biomass and production of zooplankton community (copepods, rotifers and cladocerans).

Poster S3-3484

Threshold dynamics in the regulation mechanism of central Baltic Sea zooplankton: causes, mechanisms and ecological implications

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During the last decades there has been an intense scientific debate to elucidate which are the driving factors on zooplankton variations in the Baltic Sea, variations that could also help explain the drastic inter-annual changes in growth of zooplankton-feeder clupeid fish. One theory suggests that zooplankton dynamics are regulated by abiotic conditions, whereas the other stresses the importance of predation by clupeid fish. Here we provide evidence that the two theories are not mutually exclusive, showing that zooplankton dynamics respond to either bottom-up or top-down forces depending on the dynamics of the Baltic major zooplanktivorous fish, the clupeid sprat (*Sprattus sprattus*). Zooplankton is regulated by climate-controlled hydrographic factors when sprat abundance is low, whereas it is driven by sprat predation pressure when sprat population exceeds a certain threshold. The discontinuous shift in the zooplankton mechanism of regulation is originally triggered by the change in the population of the main piscivore of the Baltic ecosystem, the cod (*Gadus morhua*), which strongly shapes sprat population. This study provides evidence thus of the existence of two alternative ecosystem configurations in the Baltic Sea, one cod-dominated and one sprat-dominated, characterised by different zooplankton communities and ecosystem functioning, whose establishment ultimately depends on the top-predator biomass. The two different mechanisms of zooplankton regulation could represent an example of alternative stable states maintained by different ecological attractors.

Poster S3-3503

Biomass, production rate and trophic roles of the net-zooplankton community across the environmental gradient in Yatsushiro Bay, Japan

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The geographical variations in biomass and production rate of net-zooplankton were studied across the environmental gradient in Yatsushiro Bay, Japan, monthly from May 2002 to April 2003. The bay is elongated and there are significant geographical variations in environmental conditions along the bay axis. Based on such environmental/hydrographical properties, the bay was divided into three, i.e. the inner (average depth, salinity and chlorophyll *a* concentration: 11 m, 31.8 psu, 6.5 µg l⁻¹, respectively), middle (30 m, 32.8 psu, 3.2 µg l⁻¹) and outer (43 m, 33.4 psu, 1.9 µg l⁻¹) regions. Net-zooplankton biomass was high in warm months and low in cold months, with annual average of 20.2, 38.8 and 16.4 mg C m⁻³ in the inner, middle and outer region, respectively. Copepods were the most important constituent (>70% of net-zooplankton) in all regions. The inner region was characterised by the dominance of *Oithona* spp. (primarily *O. davisae*) in summer and *Acartia* spp. (primarily *A. omorii*) in winter-spring, respectively. In the middle region, *Microsetella norvegica* dominated in summer-fall. In both

middle and outer regions, *Calanus sinicus* and *Eucalanus* spp. dominated in winter-spring and fall, respectively. The annual average net-zooplankton secondary production rate was 4.4, 7.5 and 3.9 mg C m⁻³ d⁻¹ in the inner, middle and outer regions, respectively. If the secondary producers depended entirely on phytoplankton for food, their carbon requirement was equivalent to 5.6, 19.7 and 16.9% of the phytoplankton biomass in respective regions. In Yatsushiro Bay, the trophic roles of net-zooplankton varied across the environmental gradient, and the trophic link between phytoplankton and secondary producers was loosest in the inner eutrophic region.

Poster S3-3504

Summer distribution and abundance of the invasive ctenophore *Mnemiopsis leidyi* (Agassiz A., 1865) in the Black Sea

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Introductions of invasive alien species (IAS) in the European Seas are historical processes, but IAS have escalated considerably nowadays as a result of globalisation and intensive human activity. Climate change further affects the spreading of IAS and sensitivity of aquatic ecosystems to novel species. Among the enclosed basins, the Black Sea is ranked as a highly invaded environment. IAS, together with anthropogenic eutrophication and overfishing emerged as key ecological issues for the Black Sea ecosystem health. The need for regional policies and transboundary approaches to deal with bioinvasions is a challenging theme for the Black Sea scientific community, to increase awareness and information on IAS issues. One of the invasive species with a great ecological impact on the Black Sea ecosystem is the ctenophore *Mnemiopsis leidyi* (Agassiz A., 1865). The present study is devoted to the summer distribution of *M. leidyi* after the coming of its predator *Beroe ovata* (phylum: Ctenophore) to the Black Sea. Data from areas (North-Eastern, Western, North-Western) with different trophic and hydrophysical conditions were used to reveal *M. leidyi* distributional shift along the gradients and to distinguish plankton community features among the regions and years (1998-2004). Higher ctenophore abundance was recorded in the North-Western and Western Black Sea (high trophic status) compared to the North-Eastern part. Long-term dynamics of the species displayed a huge variability due to the trophic relationship between *M. leidyi* - *B. ovata*, contributing to the recovery of the Black Sea plankton fauna.

Poster S3-3517

Can the Continuous Plankton Recorder (CPR) be used to infer sardine diet?

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Knowledge on the impact of climate variability in the diet of planktivorous fish is limited by the laborious work involved in stomach content analysis, impractical for large scale studies. Routine measurements of plankton such as the Continuous Plankton Recorder (CPR) survey provide valuable information of the temporal variation of phyto- and zooplankton prey availability for higher trophic levels. Sardines are a world-wide distributed and commercially important planktivorous fish, at the basis of the pelagic marine food web. Being predominantly non-selective filter-feeders, their diets closely correspond to the water plankton species and a significant relationship was recently found between *Sardina pilchardus* feeding intensity and remotely sensed chlorophyll *a*. Data of sardine stomach prey composition and CPR were obtained during 2003 for the same location off the west coast of Portugal, an area characterised by strong seasonality of plankton abundance and composition, mainly governed by upwelling events. Phyto- and zooplankton prey in sardine stomachs were identified to the lowest possible taxa and their numerical and volumetric abundance was registered, as well as their contribution to the prey carbon content. The seasonal variation of the abundance and composition of sardine diet was then compared to the abundance and composition of the water plankton obtained with the CPR at the same time and for the same area where the fish were collected, in order to evaluate if CPR data can be used to proxy sardine prey availability and diet composition at large temporal scales.

Poster S3-3526

A model of the growth and development of *Crassostrea virginica* larvae

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A biochemically-based model was developed to simulate the growth, development, and metamorphosis of larvae of the Eastern oyster, *Crassostrea virginica*. This model defines larvae in terms of their gross biochemical composition: protein, neutral lipid, polar lipid, carbohydrate, and ash content. The model includes parameterisations for larval filtration, ingestion, and respiration, which determine growth rate, and processes controlling larval mortality and metamorphosis. The initial biochemical content of the larva is determined by the composition of the egg. Simulations of larval growth and survival, that use environmental conditions from Chesapeake Bay, show that food quality and timing of food availability are the two factors that have the largest influence on larval survival. This suggests that changes in phytoplankton species assemblage and/or changes in environmental conditions, such as those that occur as a result of climate change, that affect the timing of phytoplankton blooms can potentially control *C. virginica* larval survival, which will affect recruitment to post-settlement populations.

Poster S3-3537

Long-term changes in North Atlantic zooplankton biomass

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New measures of zooplankton biomass have been derived from CPR samples in the North Atlantic from 1958 to 2005. The final aim was to investigate how the zooplankton standing stock had varied throughout the last decades, knowing that in different areas of the North Atlantic significant changes in the distribution of the dominant zooplankton species as well as the plankton assemblage have been observed. During the forty-five years of monitoring the contribution of the different groups (e.g. copepods, euphausiids, meroplankton larvae) to the total zooplankton biomass has been evaluated. The changes in the phenology of the biomass were also considered. The relationship between quantity, quality and seasonal timing of plankton and the poor fish recruitment seen in recent years in the North Sea are also discussed.

Poster S3-3541

Zooplankton fluctuations in the Gulf of Trieste (Northern Adriatic Sea): what is the role of small pelagic fish?

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The trophic link between zooplankton and planktivorous fish is a fundamental step for energy transfer from primary producers to higher trophic levels in marine ecosystems. As a consequence, fluctuations in zooplankton populations might be strongly related to predation (top-down control). This relationship is very difficult to demonstrate because of the complexity of food webs in many systems and few studies have attempted to explore this subject. A further difficulty is represented by the lack of simultaneous long time series of fish and its prey in the same area. Here we present a comparative analysis of long term (from January 1989 to December 2006) time series of zooplankton and landings of small pelagics in the Gulf of Trieste (Italy). In this area, anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*) represent the most abundant species among planktivorous fishes. The study of gut content of these species demonstrated that their diet is essentially based on copepods (in particular on the genus *Oncaea* and the species *Acartia clausi*, *Temora longicornis* and *Euterpina acutifrons*). Data concerning the diet of anchovy and sardine pointed out that only few species are involved in top-down mediation and time series analysis highlighted significant relationship between fish and their preys.

Poster S3-3554

Spatial distributions, community structure and trophic interactions of phytoplankton, micro- and mesozooplankton and planktivorous fish in the Gulf of Finland, Baltic Sea

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The brackish water Baltic Sea is one of the most thoroughly studied marine systems in the world. However, synoptic studies covering the whole pelagic ecosystem from primary producers to fish have rarely been attempted. We studied the distribution of cyanobacteria, phytoplankton, microzooplankton, mesozooplankton, and planktivorous fish, during 2-week cruises in summers of 2004-06 within a 70 x 170 nm sea area in the Gulf of Finland (GoF), northern Baltic. Application of two research vessels ensured intensive sampling of a wide range of biological, chemical and physical variables. Hydrography and planktonic species were sampled with traditional methods as well as continuously measuring devices. Primary and secondary productivities were studied with onboard measurements. The distribution of planktivorous fish (Baltic herring, sprat and three-spined sticklebacks) was determined with echosounding and trawling, and their stomach contents were analysed. Spatial analysis revealed how environmental variables affected the abundance and composition of the phyto- and zooplankton communities, and how these influenced the distribution and food consumption of the fish. The copepod species that are considered as preferred food for herring (*Pseudocalanus* spp. and *Temora longicornis*) increased westward with greater water depth and higher salinity. However, fish abundance was highest in the more limnic and eutrophic NE part of the study area, where the abundances of brackish water copepods (*Eurytemora affinis*) and cyanobacteria were the highest. This highlights the complexity of natural interactions in the field, and shows that hypotheses arising from laboratory results or long-term analyses may be rejected or reversed in a spatially oriented study.

Poster S3-3601

Has the Three Gorge Project influenced zooplankton and ichthyoplankton populations in the Changjiang estuary?

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The ecological survey of the Changjiang estuary before the Three Gorge Dam was constructed indicated the correlation of river flux with plankton abundance, especially the estuarine dominant species, and plankton community. Some environmental factors (such as salinity, nutrients and suspended sediments), which are correlated with plankton community composition and abundance will fluctuate with the river flux variation brought about by the Three Gorge Dam. To date there has been a slight increase of zooplankton abundance, with estuarine species shrinking and more warm pelagic species in Changjiang estuary being present in October. Further research has been started on account of the far-reaching influence in the Changjiang estuary after the Three Gorge Dam was built. Carnivorous zooplankton in Changjiang diluted water increased in recent years, the ichthyoplankton were also influenced by the change of habitat and fish population.

Poster S3-3643

Zooplankton production of estuarine systems of Primorye (Russia)

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Estuarine systems of Primorye have different zooplankton production, which are linked with the structure of the zooplankton community, with the orography of the reservoir, latitude and morphology. Freshwater and brackish groups of planktonic animals (Copepoda, Cladocera and Rotifera) have the highest production in estuaries of rivers with extended estuarine zone (Razdol'naya River and Artemovka River) and lakes or lagoon type. Brackish and sea neritic species of zooplankton (Copepoda) predominate in estuaries of rivers with average and short estuarine zone (Narva, Sukhodol, Kievka, Avvakumovka, etc.). Zooplankton

biomass is 1-2 orders of magnitude higher in the lower portion of estuaries than upstream or out to sea. The dominant biomass species in estuarine systems of Primorye are represented by Rotifera - *Synchaeta* sp., *Brachionus calyciflorus*, *Keratella quadrata*, *Filinia terminalis*, *Notolca acuminata*, *Polyarthra dolichoptera* (all freshwater), Cladocera - *Diaphanosoma dubium*, *Bosmina longirostris*, *Bosminopsis deitersi*, *Cydorus sphaericus* (all freshwater), Copepoda - *Thermocyclops asiaticus*, *T. crassus*, *Mesocyclops leuckarti*, *Diacyclops bicuspidatus* (freshwater), *Sinocalanus tenellus*, *Schmackeria inopina*, *Eurytemora pacifica*, *E. americana* (brackish), *Acartia clausi*, *A. longiremis*, *A. tumida*, *Pseudocalanus newmanni*, *Paracalanus parvus*, *Oithona similis*, *O. brevisrostris* (neritic).

Poster S3-3645

Night illumination-induced zooplankton community change and feeding, and weight increase of juvenile black seabream, *Acanthopagrus schlegeli*

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We examined whether night illumination can induce positive phototaxis of zooplankton and how juvenile black seabream, *Acanthopagrus schlegeli*, in netted cages respond to the zooplankton with respect to stomach contents and weight increase. Zooplankton abundance in open water near the fish rearing facility was much higher in most taxa under night illumination than that under natural conditions. Correspondingly, large benthic zooplankton (e.g. amphipods) were the most important diet for juvenile fishes reared in the netted cages that received artificial illumination, whereas two calanoid copepods (*Paracalanus parvus*, and *P. aculeatus*) were in the control cages that did not receive night illumination. Despite such contrast in diet composition, the fish weight was not significantly different. The juveniles in the control cages, however, showed much larger variation in both weight and body length, with some juveniles having grown little. These results indicated that there was severe competition among the juveniles for food resource and only some highly competitive ones gained significant weight, suggesting the juvenile black seabream overall grew better under night illumination.

Poster S3-3648

Occurrence of the ctenophore *Beroe ovata* in Narragansett Bay, Rhode Island, 2006

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An unusual occurrence of the ctenophore *Beroe ovata* was observed in Narragansett Bay, RI, USA in the summer/fall of 2006. This warm water species, which preys exclusively on other jellyfish, is usually distributed in waters off-shore of Narragansett Bay. We hypothesize that it was carried into the Bay by an on-shelf warm-water intrusion in July. We took advantage of this rare event to investigate the ecology of *B. ovata* in the region, including impacts on its primary prey, another ctenophore, *Mnemiopsis leidyi*. During August and September, the period coinciding with increasing abundance of *B. ovata*, *M. leidyi* declined from 810 to 1 ind. m⁻². In past years this has been a period during which *M. leidyi* increased or maintained high abundance. Also observed was the transfer of the endoparasitic anemone *Edwardsiella lineata* from its usual host (*M. leidyi*) to *B. ovata*, with an infection rate of 28%. Beginning in October the population of *B. ovata* declined from a high of 1.34 ind. m⁻², probably because of the shortage of prey and decreasing water temperatures. Continued study will be directed at determining whether *B. ovata* has a multi-year influence on *M. leidyi*, via depletion of *M. leidyi*'s over-wintering population. The infrequency of *B. ovata*'s appearances in Narragansett Bay indicates that the species cannot successfully colonise the region; however, it is possible that frequency of its appearances might be altered if climate change influences its transportation pathway into Narragansett Bay.

Poster S3-3662

Feeding of *Calanus finmarchicus* and *Metridia longa* females during the spring bloom in the St. Lawrence estuary, Canada: evidence from stable isotope analysis and trophic biomarkers

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Tropho-dynamic processes and interactions are most significant forces structuring marine communities. Feeding fuels all metabolic processes, and the physiological capability of an organism to exploit food resources is pivotal for the success of a species in its habitat. The feeding strategies of *Calanus finmarchicus* and *Metridia longa*, both dominant calanoid copepod species in the zooplankton community of the St. Lawrence, Canada, differ. *C. finmarchicus* is often considered herbivorous, and thus its reproduction mainly depends on the phytoplankton development, whereas *M. longa* is omnivorous. Detailed knowledge, however, on possible differences in feeding behaviour of the two species is lacking although such information is essential for understanding the functioning of the pelagic system. Therefore, the aim of this study was to elucidate the feeding of *C. finmarchicus* and *M. longa* during the spring bloom when both species reproduce at high rates. Weekly samples were taken from the end of May until mid August 2006 for analysing the fatty acid composition and stable isotope signatures of females of both species. Fatty acids can be used as trophic biomarkers for the ingestion of specific algae taxa. The analysis of nitrogen (¹⁵N/¹⁴N = δ15N) isotopes provides estimates of the trophic level since δ15N is typically enriched in the tissues of consumers. Based on these results, the trophic position of the two species during the spring bloom in the estuary of the St. Lawrence will be compared.

Poster S3-3686

A combined approach to understand trophic interactions between *Cercopagis pengoi* (Cladocera: Onychopoda) and mysids in the Gulf of Finland

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We applied a combined approach using (1) molecular markers, (2) feeding experiments, and (3) stable isotopes, to understand trophic interactions between native mysids, *Mysis mixta* and *M. relicta*, and a recent invader to the Baltic Sea, the cladoceran *Cercopagis pengoi*. Frequency of predation on *C. pengoi* assayed by molecular diet analysis of field-collected mysids varied between 5 and 43% depending on mysid size and species. Surprisingly, it was consistently higher in stomachs of juveniles than in adults and in *M. mixta* than in *M. relicta*. In feeding experiments, both mysid species ingested *C. pengoi* of a maximum of 16 prey mysid⁻¹ d⁻¹ and a specific consumption rate of 0.15 day⁻¹, similar to rates reported for predation on other prey species. Results of stable isotope analysis corroborate those of feeding experiments and molecular analysis and indicate higher contribution of *C. pengoi* to nutrition of juveniles and of *M. mixta*. These ontogenetic and interspecific differences in mysid predation on *C. pengoi* are likely to reflect differences related to their different migratory behaviour. Thus, despite its low relative abundance, *C. pengoi* is readily consumed by mysids; this may affect lower food web interactions and the nutrition of mysids in the invaded ecosystems.

Poster S3-3698

Factors affecting zooplankton long-term changes in the south-eastern Baltic Sea coastal ecosystems

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A statistical analysis of environmental and biological long-term data of the Gulf of Riga and Gulf of Finland was performed. Long-term changes (1973-2004) in the biomass of main zooplankton taxonomic groups were analysed for two different seasons in the Gulf of Riga. In spring shifts in *Acartia* and *Eurytemora* biomass

were observed since the late 1980s. *Limnocalanus* almost disappeared from May samples since the mid 1980s. *Bosmina* biomass was significantly higher during the 1989-2000 period. The decreasing tendency in *Acartia* and *Eurytemora* biomass in August samples was observed over the whole period. However, in the case of *Acartia*, it was statistically insignificant. Relatively low biomass of *Limnocalanus* was recorded in 1980s and 1990s, and it recovered again during 2000s. Extremely low values of biomass of *Bosmina* (since 1999) were found. Long-term changes in zooplankton community structure were tested against environmental and biological factors. The Gulf of Riga zooplankton community changes are significantly correlated with changes in herring abundance, recruitment level and also with decrease of herring average weight. The long-term zooplankton series of August (1963-2004) in Gulf of Finland showed significant decrease of *Centropages* in the western, *Limnocalanus* in the central, cladocerans and *Acartia* in the eastern part of Gulf, while the biomass of *Eurytemora* in the central part has been increasing as well as *Bosmina* in western part. The biomass of most dominant crustacean species is strongly dependent on salinity in the Gulf of Finland. Analysis from the Curonian Lagoon will be discussed.

Poster S3-3712

Meroplanktonic larvae in the marine food web - a combination of grazing experiments and stable isotope analyses at Helgoland Roads, North Sea

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Knowledge about the feeding behaviour and the importance of meroplanktonic larvae in the marine food web is rare, even though these larvae are, at times, more abundant than holoplanktonic organisms such as copepods. The aim of this study was to better understand the role of the meroplanktonic larvae as potential grazers in the food web of the North Sea at Helgoland Roads. Here, we present results from a combination of feeding experiments and $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ stable isotope analyses of abundant meroplanktonic larvae, i.e. *Liocarcinus* sp. and *Janicea conchilega*. Experiments and stable isotope sampling were conducted weekly from late April to August 2006. In the feeding experiments, the larvae were incubated for 8 hours in natural, 70 μm pre-screened seawater at ambient water temperature. Feeding rates were determined by measuring pigment concentrations in the incubation-water before and after the incubation. Stable isotope signatures were determined in abundant zooplankton groups and in the seston to monitor the long term feeding history. The experiments show that larvae fed upon phytoplankton at various rates. Also the results from stable isotope analysis point to feeding on lower trophic levels. In general, the stable isotope signatures in the larvae were approximately one trophic level above the signatures found in the seston throughout the time series. The trophic position of larvae of a single species did not change significantly with growth in summer. Differences in trophic levels were only found between taxa. Meroplanktonic larvae can play a major role as grazers in marine food webs.

Poster S3-3723

Impact of urbanisation and possible climate change on the welfare of a traditional fishery: a case study on the south-western coast of India

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Due to the presence of upwelling currents, the western coast of India has a well established fishing industry, which is an important economic activity in the region. Reduced strength of upwelling currents between 120° to 150° of latitude, coupled with sewage and effluents from urban centres have often resulted in algal blooms, more so during post monsoon with a result of anaerobic conditions, having a severe economic impact on the fishing sector. Global circulation models for this region have suggested no significant reduction in the rainfall, but a reduced number of rain days, implying higher flush out from the land with a potential for longer and more frequent formation of anaerobic conditions. The possible fallout of such eventuality is likely to manifest in the harvesting of 'Low Hanging Apple', but sanitary and phytosanitary measures under General Agreement on Agriculture of World Trade Organization would restrict its market only to Persian Gulf nations or for domestic consumption only instead of usual EU market. We would like to highlight these issues.

Poster S3-3743

Consequences of interannual variability in the trophic status of *Neocalanus plumchrus* in the Strait of Georgia, British Columbia

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The calanoid copepod *Neocalanus plumchrus* has traditionally dominated the biomass of the mesozooplankton community in the Strait of Georgia (SoG). In recent years, however, *N. plumchrus* biomass in the SoG has declined and in 2005, the population crashed. We have analysed the stable isotope signatures ($\delta^{13}\text{C}$ and $\delta^{15}\text{N}$) and fatty acids of *N. plumchrus* from 2001–2006 to assess whether changes in dietary quality are associated with this decline in biomass. This study constitutes one of the longest time series of fatty acid dynamics for calanoid copepods, and is one of the very few data sets available on fatty acid composition of coastal *Neocalanus* species. Our data show that between 2001 and 2006, *N. plumchrus* became increasingly herbivorous as evidenced by the rise of diatom markers (16:1n-7/16:00; 20:5n-3) and the decline of flagellate, carnivory and bacterial markers (22:6n-3, 18:1n-9, $\Sigma 15+17$) in fatty acid profiles. Stable isotope data generally support these trends. These changes coincide with a decline in the diversity of phytoplankton in the SoG, and an increased abundance of diatoms in surface waters. Combining these data with chemical, physical and biological data from the SoG, we present a conceptual model that explains how variability in diet composition and trophic position affects *N. plumchrus* population dynamics. We also discuss the potential impact that trophic variability of *N. plumchrus* may have on higher trophic levels in the SoG.

Poster S3-3747

Use of the Alqueva Dam to regulate planktonic assemblages in the Guadiana estuary: basis for sustainable water and ecosystem services management

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The phytoplankton and zooplankton assemblages in the Guadiana estuary (south Portugal) were compared in two contrasting hydrologic years characterised by high and low freshwater discharges. Changes in salinity, nutrients and turbidity, which were mainly due to changes in freshwater input, had an important influence on the structure of the planktonic assemblages. Nevertheless, coastal upwelling can also influence the productivity of the lower estuarine area during short periods both in winter and in summer. In 2000, a short-term freshwater pulse during May (average $126.5 \text{ m}^3 \text{ s}^{-1}$) was markedly beneficial; phytoplanktonic diversity increased, and this caused an increase in zooplanktonic diversity. As phyto-zooplankton coupling in these systems is an important regulator of processes in the trophic web, changes in the dominant groups can have consequences on water quality, especially on the occurrence of toxic plankton blooms. Modelling simulations indicate that a daily discharge of $50 \text{ m}^3 \text{ s}^{-1}$, every week during critical periods, such as summer/autumn, could be enough to avoid cyanobacteria blooms. Since freshwater “pulses” can be managed by operating the freshwater release from dams, understanding the relationships between the periodicity and magnitude of inflow pulse events and the estuarine ecosystem structure and healthy functioning is a crucial step towards the development of management modelling tools, as proposed in this study.

Poster S3-3753

Effects of elemental stoichiometric imbalance and prey size on cascading trophic interactions

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Human induced changes in coastal ecosystems include switches in phytoplankton cell size and nutrient loading. The latter can give rise to variations in the elemental composition of the phytoplankton. Both cell size and variable elemental composition of the phytoplankton are hypothesized to alter prey selectivity in copepods. Reduction

in cell size should lead to consumption of microzooplankton. Similarly when the stoichiometric imbalance (difference in elemental composition ratio) between phytoplankton and zooplankton increases, zooplankton should preferentially ingest microzooplankton. Both of these effects should lead to a strengthening of planktonic trophic cascades. We conducted field experiments to test these hypotheses. We employed path analysis to identify the strength of direct and indirect effects of copepod additions on the growth rates of lower trophic levels (ciliates, heterotrophic and autotrophic flagellates and bacteria). Experiments were conducted in March, June, August and September of 2004, in two regions of Long Island Sound that differed in nutrient loading. We were able to compare instances in which phytoplankton size was similar between times or regions, but the stoichiometric imbalance varied significantly, and vice versa. The results are consistent with the hypothesis that when large phytoplankton of adequate nutritional quality are available, they are directly grazed by copepods, and hence cascading trophic interactions are not pronounced. However, there was no support for the stoichiometric imbalance hypothesis. That is, when phytoplankton was large and stoichiometric imbalance was high, increasing copepod abundance had no effect on chlorophyll growth rate. Further work is required to test the stoichiometric imbalance hypothesis.

Poster S3-3757

Temporal variability of the first stages of *Euphausia mucronata* and its relation with oceanographic conditions off northern Perú (1994 –2006)

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Zooplankton samples were collected from August 1994 to December 2006 at four fixed stations located 5 to 20 nm offshore, off Paita (05°00'S), an upwelling area influenced by the Equatorial front with Equatorial Surface Waters (ESW), Tropical Surface Waters (TSW) and Coastal Cold Waters (CCW). Samples were collected at subsurface with a 330 micron WP-2 net for five minutes at three knots. For the measurement of water temperature, salinity and oxygen concentration, water samples were collected at pre-established depth levels (10, 25, 50, 75 and 100 m). The objective of this study is verify possible spatial and temporal variability influenced by oceanographic conditions on stages first of the euphausiids (calyptopis and furciliias). The stages of *Euphausia mucronata* like calyptopis was dominant with 70.6% while furciliias stage was 29.2% of *Euphausia mucronata*. Relative abundance of calyptopis and furciliias were negative correlated ($r^2 = 0.78$). Long-term trends were significant at $p = 0.05$ for several vertical and horizontal temperature and oxygen gradients. Euphausiid abundance increased from 1999 to 2000. Greater abundance was found at 15 nautical miles, and was related to oceanographic conditions. Spearman Correlation coefficients between furciliias and oceanographic parameters ($p < 0.05$) were: temperature ($r^2 = 0.20$), salinity ($r^2 = -0.22$), oxygen ($r^2 = 0.34$). In contrast, calyptopis was not correlated with oceanographic variables.

Poster S3-3811

Lethal and sublethal effects of PAHs on marine copepods

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The project PETROZOO is as a consequence of the catastrophe of the fuel cargo Prestige in Galician waters in 2002, which evidenced the lack of knowledge on the consequences of crude oil spills for the dynamics and functioning of marine planktonic food webs, and in special for zooplankton. Through this project, the effects of important components of the water-soluble fractions of fuel oils (polycyclic aromatic hydrocarbons, PAHs) on marine copepods have been studied. We determined lethal and sublethal responses of different developmental stages of the marine copepods *Paracartia (Acartia) grani* and *Oithona davisae* to single and mixtures of PAHs. The sublethal effects studied included narcosis, and detriments on feeding, egg production and egg viability rates. This poster highlights the major results of this study and their ecological implications.

Poster S3-4022

Can zooplankton escape predation in turbid water?

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Algae-induced turbidity has increased considerably during the last decades in the Baltic Sea. Due to increasing eutrophication, certain phytoplankton species and cyanobacteria form large blooms. Studies have shown that turbidity may provide shelter for small fish against predators. Few studies have been done to reveal whether also zooplankton may use turbidity to escape predators, such as small fish or mysid shrimps. We performed short-term laboratory experiments, where we fed mysid shrimps and small planktivorous fish with different zooplankton prey in turbid and clear water. Here we present the results on copepods' and daphnids' ability to avoid predation in turbid water. We show that the calanoid copepod *Acartia bifilosa* was fed significantly less by mysid shrimps and pike larvae in turbid water, caused by cyanobacteria. In a comparison between the calanoid copepod *Eurytemora affinis* and the water flea *Daphnia longispina*, it was shown that the copepods were significantly more efficient in avoiding predation by pike larvae. Our results suggest that the copepod populations may get a competitive advantage in turbid water in comparison to daphnids. Further, zooplankton may benefit from seeking shelter and migrating towards blooms or turbid water. Previously, it has been shown that copepod survival is high, but fecundity decreases in toxic cyanobacteria blooms. Hence, we hypothesize that the survival benefits of associating with dense albeit toxic blooms may override the relatively minor impact of toxicity on copepod fecundity.

S4 Mortality impacts on the ontogeny and productivity of zooplankton

1 June, 13:50 (S4-3448) Invited

Variation in phytoplankton food quality and effects on plankton community structure and functioning

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Food quality determines the interaction strength between zooplankton and their food. Here, I will discuss two chemical-mediated mechanisms that affect phytoplankton food quality: inducible defences and biological stoichiometry. Inducible defences allow phytoplankton species to alter their edibility in response to zooplankton cues, such as information chemicals. Infochemical-induced defences can be very effective (e.g. toxicity), but even small changes in edibility already create a dynamic heterogeneity within single phytoplankton species. This heterogeneity may stabilise population dynamics and therefore prevent (stochastic) species extinctions. Furthermore, inducible defences alter the strength of trophic cascades, which may cause pelagic food webs to respond differently to enrichment. Biological stoichiometry analyses trophic interactions from the balance between energy (carbon) and nutrients. A high carbon to nutrient ratio in the food is generally unfavourable for zooplankton, and may even cause (deterministic) extinction of species above a certain threshold elemental ratio (TER). This does not only happen with decreasing nutrient levels, but also when carbon levels go up. Rising aquatic CO₂ levels thus alter the carbon:nutrient ratio in algae, which lowers zooplankton productivity. When the phytoplankton is near the TER, increasing CO₂ levels may cause extinction of the herbivorous zooplankton, which in turn may lead to a cascade of extinctions in higher-level consumers. Both chemical-mediated mechanisms show that even slight changes in food quality already have important effects on the structure and functioning of simple plankton communities. This adds a new perspective on the structure and behaviour of the more complex ecosystems that we observe in nature.

1 June, 14:20 (S4-3288)

Parental phytoplankton diets indirectly induce variable mortality rates in copepods

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Different causes are evoked to explain traits of temporal and spatial zooplankton population changes. However, mortality estimates are scarce because of sampling difficulties in the field. Tools, or models, permitting the evaluation of mortality rates during ontogenic development of copepods in relation to predation, cannibalism, parasites, diseases, senescence, or advection and diffusion do not exist, or present several problems. Thus, it is difficult to know which of these biotic or abiotic causal agents influence mortality. A decadal survey conducted with several calanoid copepods, using standard methods, revealed that mortality rates vary from 0 to 100% during the pre- and post-natal phases, including oocyte maturation and early developmental life stages (egg to copepodite). Results showed that this type of mortality is related to a reproductive failure induced by parental diets. They further showed that symptoms observed under laboratory conditions are the same in the field. Phytoplankton species in copepod diets strongly determine the reproductive capacity of males and females, as well as the fitness of the offspring. Identification of phytoplankton inducing sterility, fecundity decrease, hatching inhibition and malformation of larvae has been partially achieved. However, determination of the causal chemical agents in the algae is at its infancy. In addition to instantaneous mortality, it is hypothesized that parental diets affect the health condition of the offspring, including starvation, decreased effectiveness of their immune system, malformation of appendages and abnormal swimming behaviour. Indirectly, these physiological symptoms can favour secondary mortality due to parasitism and/or predation.

1 June, 14:40 (S4-3582)

Effects of a recently introduced toxic dinoflagellate on grazing rates, egg production and survivorship of marine copepods

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Copepods that graze on toxic phytoplankton can manifest a variety of responses, ranging from no measurable effect to severe reactions including progressive paralysis. The onset of such physiological stress in copepods means that they can stop or decrease feeding, which, in turn, affects their egg production rates and survival. There is some evidence that grazers that have not co-evolved with a toxic phytoplankton will not eat them, leading to unpredictable food web dynamics if exotic species are introduced. *Gymnodinium catenatum*, a toxic dinoflagellate that produces paralytic shellfish toxins, was introduced into Tasmanian waters about 30 years ago. Since that time it has exhibited sporadic though substantial blooms. Local copepods, including *Centropages australiensis*, *Acartia tranteri* and *Paracalanus indicus*, do appear to ingest *G. catenatum*, but there is little direct evidence about actual grazing rates and the impacts, if any, of the toxins on copepod health. We have conducted controlled experiments to examine the impacts of feeding on toxic and non-toxic strains of *G. catenatum* on the grazing rates, egg production rates and survivorship of developmental stages of these three copepod species that are often dominant in temperate Australian coastal waters. At the same time measurements have been made on the degree of toxicity of both the prey and the grazers to assess the potential of the copepods to act as vectors of the toxins to higher trophic levels.

1 June, 15:00 (S4-3359)

Zooplankton mortality events in Antarctic coastal areas: a relation with global change?

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During the years 2002 and 2003 a complete zooplankton study was carried out in Potter Cove (King George -25 de Mayo Island, South Shetlands, Antarctica). On several occasions during the summer season, high numbers of diverse zooplankters (mainly krill and salps) were found dead along the coastline. To study these events, animals were sampled along 30 m transects on the beach during several mortality events and the specimens identified and quantified. Results were further related to environmental variables, such as salinity and particulate matter concentration in the water column. Our results indicate that these variables could play a significant role in relation to these massive zooplankton mortality events. Both the decrease in salinity and increases in the amounts of particulate material are processes linked to glacier melting. This is one of the effects of global climate warming on Antarctic coastal ecosystems that is expected to increase in the near future, with an impact on zooplankton as well as on the rest of the food web that depends on them.

1 June, 15:20 (S4-3587)

Estimations of development and mortality rates of ontogenetically migrating copepods in the SF6 labelled water mass during iron-enrichment experiments

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Water mass movement introduces serious errors for the estimation of development and mortality rates of free-living organisms. Labelling of a water mass by the inert tracer sulfur hexafluoride (SF6) and sequential sampling must be one of the best ways to examine these rates. SERIES and SEEDS II were mesoscale iron-enrichment

experiments in the eastern and western subarctic Pacific, having relatively long observation periods (about a month). We carried out zooplankton sampling at an interval of a few days inside and outside the iron patch and estimated the copepodite stage composition and abundance for dominant copepod species (*Neocalanus plumchrus* and *Eucalanus bungii*) throughout the observation period. In SERIES, the observation period agreed with the growth period of *E. bungii*. The predominant copepodite stages were C2 and C3, and we could clearly observe a progression of copepodite stages in the patch. A simple regression between averaged copepodite stage and time suggested stage duration was 11 and 26 days, inside and outside the iron-patch, respectively. We also observed a significant increase of first copepodites in the patch, suggesting a lowered mortality rate during the egg and nauplius stages caused by an increase of an alternative food source (diatom bloom). In SEEDS II, the observation period coincided with the development season of *N. plumchrus* and newly recruited *E. bungii*. A simple calculation suggested that stage durations of *N. plumchrus* were 8.1 and 8.3 days, inside and outside the patch, respectively. A preliminary estimation of mortality and growth rates using a stage-structured model suggested very low mortality rate inside the patch (0.00 d^{-1}) compare to the outside (0.044 d^{-1}).

1 June, 16:00 (S4-3345)

A comparison of four techniques for estimating stage-specific mortality rates of copepods

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We used simulated population data and field data for the calanoid copepod (*Clausocalanus furcatus*) to compare different techniques for estimating stage-specific mortality rates. The simulated copepod population was generated from a stage-structured population model, and the field data were net and bottle samples taken every 12 hours from 18 March - 6 April and from 15 May - 9 June, 2003 at an offshore petroleum platform in the northern Gulf of Mexico. Mortality rates were estimated using the horizontal life table (HLT) method, vertical life table (VLT) method, quadratic programming method (QPM), and an inverse matrix method (IMM) using a stage-structured population model combined with parameter estimation based upon a nonlinear Gauss-Marquardt-Levenburg algorithm. When applied to a simulated population with known mortality rates, the QPM and IMM recovered the known rates, while the HLT and VLT methods generated estimates different from the known rates. When applied to the field data, the four methods produced different estimates. The HLT and VLT methods had the disadvantage of producing negative mortality estimates, while the QPM likely overestimated mortality rates. The IMM method generally performed the best, and generated instantaneous egg mortality rates of 1.30 d^{-1} in March-April and 1.60 d^{-1} in May-June, rates of $0.02\text{--}0.18 \text{ d}^{-1}$ for nauplii I-VI and copepodite I-V, and rates of 0.37 d^{-1} in March-April and 0.32 d^{-1} in May-June for the adult stage. Further simulation experiments indicated that when variability was imposed on the stage-specific abundance data, the QPM method was more likely to overestimate mortality rates.

1 June, 16:20 (S4-3488)

Predation by the myctophid *Benthosema glaciale* on copepods of the genus *Calanus* in the Labrador Sea

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The biomass and number of *Benthosema glaciale* in the Labrador Sea make it the most important planktivorous fish in the region. This study reports on two surveys of the Labrador Sea during the summer of 2006, in which we use regional plankton surveys and hydroacoustic estimates of fish abundance to assess the impact of *B. glaciale* on *Calanus* spp. copepods. *Benthosema glaciale* occurs primarily at depths of 400-600 m, where the temperature is 4°C , but 10-25% of the population migrates to the surface at night to feed. Stomach content analysis reveals that *Calanus finmarchicus*, *C. glacialis*, *C. hyperboreus*, along with *Eucheata* spp. are the dominant prey of myctophids. Vulnerability, estimated from the relative occurrence in the guts and the water column, indicates that adult *C. finmarchicus* and *C. glacialis* are the preferred prey. An observations-based bioenergetic model combined with the vulnerability estimates is used to determine the potential impact of *B. glaciale* on the copepod community. Although the confidence intervals on the predicted mortality rates are large, the decrease in abundance of *C. finmarchicus* in the Labrador Sea during the summer, along with a truncated stage structure with few adults, relative to the adjacent continental shelf suggests that *B. glaciale* plays a significant role in the population dynamics of calanoid copepods in the region.

1 June, 16:40 (S4-3724)

Effects of mediocre diets on reproductive fitness of a common copepod

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Different phytoplankton diets affect copepod population growth and mortality in very different manners. It is well reported that egg mortality in nature due to maternal diet can be great at times, but in spite of numerous efforts of trying to understand how food type can control egg quality the underlying reasons are still poorly understood. This paper reports results from an intensive laboratory study on the reproductive success of the copepod *Temora longicornis* fed mixtures of diets of mediocre nutritional quality from variety of groups of non toxic autotrophs. The phytoplankton used was selected based on their fatty acid composition, where all types had one or more of the essential fatty acids missing or in low concentrations. The idea is to use variable availability of essential dietary elements to understand their importance in controlling viability of eggs. Preliminary results show that under food limited conditions, food quality in terms of specific fatty acids can affect viability of eggs, while egg production rates are more affected by ingested carbon. The complicated outcome of the experiments forms a basis for a model that predicts the nutritional requirements for successful reproductive fitness.

S4

Posters

Poster S4-3407

Stage-specific mortality of calanoid copepods in the southern North SeaChristian Möllmann¹, J. Renz², J. Dutz³, J. Peters⁴, H.-J. Hirche² and A. Temming¹¹ Institute of Hydrobiology and Fishery Science, University of Hamburg, Olbersweg 24, D-22767 Hamburg, Germany. E-mail: christian.moellmann@uni-hamburg.de² Alfred Wegener Institute Foundation for Polar and Marine Research, Postfach 12 0161, D-27515 Bremerhaven, Germany.³ Baltic Sea Research Institute, Seestrasse 15, D-18119 Rostock, Germany.⁴ University of Bremen, Postfach 33 0440, D-28334 Bremen, Germany.

The calanoid copepods *Acartia clausi*, *Temora longicornis* and *Pseudocalanus elongatus* are important members of the mesozooplankton community in the southern North Sea. These small-bodied calanoids vary in characteristic life history traits, e.g. reproductive mode (broadcast vs. sac spawners) and overwintering strategy (resting egg production vs. continuous reproduction). Further, the horizontal distribution of the copepods varies according to their preferences for hydrographic variables, i.e. temperature and salinity, their resulting vertical distribution and the prevailing circulation pattern. These copepod species are thus exposed to different environments with potentially varying predator fields and different mortality rates. Research on these key members of the North Sea food web has, as for most zooplankton species, mainly concentrated on reproductive and growth characteristics. Mortality rates based on field sampling are rare due to the inherent difficulties in the estimation procedure. We used the Vertical Life Table approach to estimate stage-specific mortality rates for *A. clausi*, *T. longicornis* and *P. elongatus* using stage-resolved abundance and egg production data sampled during the field campaign of the GLOBEC-Germany programme in the southern North Sea (7 cruises between February and October 2004). Temperature-dependent developmental times needed for the mortality estimation were based on literature-derived relationships and measured moulting rates. By contrasting the different species we investigate the importance of causal agents of mortality rates, e.g. physical parameters, food availability and predator abundance.

Poster S4-3472

Mesozooplankton assemblages and the life cycles, hibernation and production estimates of copepods at Potter Cove (King George Island) and Marguerite Bay (Antarctic Peninsula)

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Epipelagic mesozooplankton was studied at the maritime Antarctic Potter Cove (King George Island, Bransfield Strait) and compared with the high Antarctic Marguerite Bay (Antarctic Peninsula, Bellingshausen Sea) in the south Atlantic part of the Southern Ocean during 2 years of continuous sampling. At both stations assemblages were dominated by copepods, with up to 90% *Oithona similis*, *Oncaea curvata* and *Ctenocalanus citer* - all 3 most abundant species showing continuous reproduction. *Calanus propinquus* hibernates with late copepodids until June in a physiologically active state in upper water layers. Seasonal variation in abundance and population structure of *Oithona similis*, *Oncaea curvata*, *Ctenocalanus citer* and *Metridia gerlachei* indicate a better nutritional situation in the Potter Cove throughout the year. Maintenance of stable stage distributions at the expense of high juvenile mortalities seemed to be characteristic for the overwintering strategy of most copepods studied here. Prosome length of *Oithona similis* females indicate a change of generations for both areas in early summer and late autumn. Minimum generation time in *O. similis*, calculated on the basis of population structure and the assumption of an isochronal development was 4.4-4.8 months from egg to adult (stage duration 11.5-12.5 days; egg development 6 days); the same procedure revealed a minimum generation time of 5.7-6.4 months (stage duration 15-17 days, egg development 6 days) for *Ctenocalanus citer* from Marguerite Bay. The production of *Oithona similis* was estimated from population structure, rate of development, instar weights, and carbon analysis. Double logarithmic linear regressions for conversions of length to carbon weight show a high weight scatter. Minimum daily growth rates of *O. similis* were estimated as 1.8% body weight, providing an annual P/B ratio of 9.2 for Potter Cove and of 8.5 for Marguerite Bay. For *O. similis*, the mean annual population biomass in the epipelagic at Potter Cove was 230 mg C m⁻², with a minimum estimate of annual production of 2.12 g C m⁻², and 195 mg C m⁻² population biomass with a minimum annual production estimate of 1.65 g C m⁻² at Marguerite Bay. Since P/B ratios tend to be negatively correlated with body weight and considering the wide Antarctic distribution of the species, the production of *O. similis* with an intermediate area mean of 0.75 g C m⁻² will be a minimum estimate for *O. similis* production in coastal areas of the Southern Ocean.

Poster S4-3543

Mortality rate in eggs and early naupliar stages of *Calanus* spp. and *Metridia longa*: opposite effects of cannibalism/predation and phytoplankton biomass and their role in the control of population dynamics in sub-arctic and arctic ecosystems

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Density-dependent mortality in eggs and naupliar stages of *Calanus finmarchicus* driven by cannibalism exerted by C6f during the pre-bloom period potentially limit the development of the cohort to early copepodids. Here, we present mortality rates in eggs and early naupliar stages of *Calanus finmarchicus*, *C. glacialis* and *Metridia longa* in the sub-arctic Gulf of St. Lawrence (GSL) and the arctic North Water Polynya (NOW). Giving the nature of the sampling, mortality was estimated using the Vertical Life Table approach based on population *in situ* egg production rate, abundance of naupliar stages and temperature-dependent development time. In the GSL, daily mortality rate in egg and N1-2 of *C. finmarchicus* and *M. longa* was positively correlated to the abundance of C6f and temperature and inversely related to phytoplankton biomass, while in NOW, mortality rate in early stages of *C. glacialis* and *M. longa* was mostly related to abundance of C6f. These variables explained up to 70% of the variability in these early stages mortality rates, suggesting a relaxation of cannibalism/predation pressure during the phytoplankton bloom, allowing the recruitment to older development stages. Using a 1-D stage-based model of *C. finmarchicus* in the GSL, we compare the impact on the population dynamics of a new mechanistic formulation of mortality in eggs and early naupliar stages based on *in situ* abundance of C6f and phytoplankton biomass with existing deterministic mortality functions. This new mortality formulation could represent a significant breakthrough in the modelling of *Calanus* and *Metridia* species populations across their domain.

Poster S4-3555

Extremely high reproduction but low biomass — mortality of the copepod *Acartia tonsa* during a *Skeletonema costatum* bloom

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Abundance, mortality and egg production of the small calanoid copepod *Acartia tonsa* were studied during an intense summer phytoplankton bloom consisting of the diatom *Skeletonema costatum* in a hyper-eutrophic Danish estuary. Egg production ranged from 30-65 eggs female⁻¹ d⁻¹ and egg hatching was >90%, yet the abundance of copepods remained low (1-3 nauplii l⁻¹, 0.3-1.5 copepodites l⁻¹) for a period of 9 days. Mortality ranged from 18% d⁻¹ for nauplii, 16% for C1, up to 70% for C2 and C3, then declining for older stages. Despite a mono-culture of the potentially toxic diatom *S. costatum*, nauplii as a group showed the lowest mortality among stages. The vertical distribution of the different stages of copepodites in relation to the depth range of mussel beds suggest in particular for C2 and C3 a strong predation effect by *Mytilus edulis* at depths of 5-10 m.

Poster S4-3699

Escape ability of copepods - 3-D high-speed video observations

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How fast can zooplankton actually escape from predators? This is crucial to estimating their mortality, as well as behaviour such as feeding, migration, dispersion or accumulation. However, swimming of zooplankton has been difficult to see because they are too small and move too quickly to record; thus, there still exists wide room

to look into this problem. Here I show observations on the jumping of copepods recorded by a pair of high-speed video cameras, each capable of recording synchronized images of 512x480 pixels at a rate of 250 frames/s with exposure time of 100~200 μ s. Horizontal axes of the cameras were at 90° to one another. While viewing a copepod freely swimming in a cubic chamber of (80 mm)³, images were recorded for ~8 s. From each pair of 2-D images, a 3-D coordinate of the animal was obtained. With this system, one can measure the true speed of swimming and jumping. For *Euchaeta elongata*, a large and powerful species of copepod, I observed an escape swimming of ~1,000 mm/s in an adult of 5 mm in body length. Reynolds number of this motion was accordingly calculated to reach a few thousands, far away from the viscous world. Even a single kick in ~20 ms can accelerate an individual from zero to a top speed, but the legs' recovery stroke significantly decelerates the body. Such jerky motions of 10 strokes in 0.2 s displaced the animal by 60 mm, with an average speed of ~300 mm/s.

Poster S4-3718

Spatial domains of increased mortality of *Calanus pacificus* within the California Current System

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The Vertical Life Table method (Aksnes and Ohman, 1996) was used to estimate patterns of mortality of late developmental stages of *Calanus pacificus* in the southern sector of the California Current System (CalCOFI region). The stage-specific copepod enumerations utilised in this study were published by the late M.M. Mullin or by G.A. Rebstock, based on samples taken on 7 CalCOFI cruises (3 spring, 4 late autumn-early winter). Stage ratios were available from 9-52 stations per cruise. The durations of copepodid stages IV and V were described as a continuous function of both food concentration and temperature from a re-analysis of Vidal's (1980) experimental rearing of *Calanus pacificus*. This function was combined with *in situ* vertical profiles of temperature and chlorophyll *a* concentration to estimate stage durations in the field and solve for the instantaneous mortality rates of two stage pairs: CV/adult females and CV/adult males. Male mortality rates averaged 2-3 times higher than corresponding female mortality rates. There was no significant difference between seasons (spring vs. late autumn) in either male or female mortality rates. However, there was a consistent spatial pattern of higher mortality rates of both males and females in the inshore region relative to the offshore region ($P < 0.05$). This inshore increase in mortality rates is inversely related to food limitation, but directly correlated with an index of abundance of zooplanktivorous fishes obtained from the CalCOFI ichthyoplankton series (a fishery-independent data source). Elevated predation risk may mitigate the inferred benefits to zooplankton of increased food supply.

Poster S4-3735

The interplay between growth and mortality during the late winter bloom in subtropical waters

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The development of mesozooplankton biomass during the late winter bloom in subtropical waters was studied around the Canary Islands. A clear periodicity related to the moon cycle was found. The bloom showed a succession of increasing peaks as mixing progressed during winter. The absence of diel vertical migrants in the upper layers during the illuminated phase of the moon cycle decreased the predatory pressure upon epipelagic zooplankton allowing them to grow. The decrease in mesozooplankton biomass coincided with the dark phase of each moon cycle and was related to the predatory pressure exerted by diel vertical migrants, which reached the shallower layers preying upon epipelagic zooplankton. Biomass was significantly greater during the second quarter of the moon cycle, and decreased dramatically after the full moon. The development of the late winter bloom in these boundary areas of the ocean is driven by the interplay between growth and mortality due to predation. Biomass was predictable using a simple model taking growth as constant and mortality proportional to moon illumination. The structure of the food web in the euphotic zone was different depending on the presence or not of mesozooplankton, promoting important consequences for the transport of carbon to the mesopelagic zone in these large areas of the ocean.

S5 Zooplankton functional groups in ecosystems

31 May, 09:05 (S5-3609) Invited

An aspect of functional groups of zooplankton in oceanic ecosystems

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Identification of function of zooplankton in oceanic ecosystems is difficult and classification of functional groups is not simple, even if this aspect is limited to their feeding habitat. Zooplankton usually complete their whole life history in the same water body, during which their body size changes from small to adult size. They always coexist with phytoplankton of similar size and nutritional composition to themselves. Therefore, most zooplankton feed on a mixture of phyto- and zooplankton and so called 'ecological cannibalism' easily occurs among them. To predict structural change of the ecosystems or species alternation under changing environment, knowledge about the length and mode of the life history is essential. When we predict a change at the level of fish populations, we must take possible change in structure of whole food webs into account. These all make identification and classification of zooplankton functional groups extremely complex. Since the current Census of Marine Life Program indicates that there may be millions of unknown species in the ocean, to construct an ecosystem model involving every existing species is almost impossible. To involve as many as functional groups into the model is right but not always practical nor better. The controversy about 'right' or 'better' will arise among people with different philosophies. Since one can easily fall into self-conceit under such a situation, continuous discussion among the people is important.

31 May, 09:35 (S5-3569)

Classification of zooplankton life history strategies

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Life history and reproductive strategies, morphology, and feeding niche are all likely to affect how well individual zooplankton species can exploit and persist in changing ocean environments. Examples of potentially important factors include: presence/absence of seasonal dormancy, generation length, trophic level (herbivory vs. omnivory vs. carnivory), fecundity vs. body size, broadcast vs. brooding of eggs, depth distribution, and the degree to which morphology and trophic niche are stage/age dependent. We use multivariate ordination and clustering of these traits to group taxa into strategist guilds (as done by King and McFarlane, 2003 for marine fishes), and then examine the extent to which seasonal and interannual changes in abundance map onto guild-membership.

31 May, 09:55 (S5-3740)

Climate and gelatinous carnivores in semi-closed, small-oceans: the NW Mediterranean case study

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Pelagic gelatinous carnivores are of particular interest because of their potential effect on the population size of mesozooplankton, fish eggs and larvae. High abundances of gelatinous carnivores may channel the flow of energy away from fish and therefore drastically affect the ratio fish:primary production. Here we investigate potential connections between the population size of gelatinous carnivores and climate variability in the Northwestern

Mediterranean. The species investigated belong to three main groups: Hydromedusae, Siphonophores and Ctenophores. The approach used is based on a downscaling model through which the interannual variability of large- and meso-scale climate variables in the Northwestern Mediterranean region was related to the abundance of gelatinous carnivores. The results show that modifications in the hydrological regime, i.e. water temperature and low water column mixing, that are ultimately mediated by climate variability may shift abundances of these populations but also affect their seasonal peak. It is then suggested that gelatinous carnivores integrate the climate related changes in the northwestern Mediterranean, and therefore a substantial part of their variance may be forecast according to climate variability. Overall, our study contributes towards forecasting the abundance changes in gelatinous carnivores in the Mediterranean Sea since it reveals patterns that have been elusive so far, and suggests underlying mechanisms linking climate and the population size of these organisms.

31 May, 10:15 (S5-3282)

Community structure and trace elements in zooplankton in Sunderban mangrove wetland, northeast Bay of Bengal, India

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Copepods, by their sheer abundance and diversity, form the dominant group of the zooplankton community constituting 73.0 - 96.4% of the total biomass. Copepods show a bimodal type of distribution with maximum abundance during the high saline premonsoon period. Out of 32 genera and 54 copepod species, calanoids are represented by 17 genera and 37 species, cyclopoids by 7 genera and 9 species, and harpacticoids by 8 genera each having a single species. During the monsoon months, a good assemblage of oligohaline species e.g., *Acartiella keralensis*, *Neodiantomus strigilipes*, *Pseudodiantomus binghami*, *Halicyclops tenuispina*, *Mesocyclops* sp., and *Cyclops* sp., was observed. The positive correlation between any two pairs among the families Paracalanidae, Pontellidae, Eucalanidae, Oithonidae and Laophontidae provides evidence that these families combine to form a group by themselves while the families Acartiidae and Pseudodiantomidae showed negative correlations with other families. Significant correlation coefficient (r) values have been obtained among some zooplankters, salinity and pH. A positive and highly significant partial correlation between the perennial chaetognath *Sagitta bedoti* and salinity, eliminating the effect of water temperature, suggests that this species is greatly influenced by the salinity gradient. The frequency of mature chaetognaths (stage III) was noticeably smaller in comparison to the juveniles (stage I), which might be due to their presence in the deeper layers. Wide variations of trace elements (Fe, Mn, Zn, Cu, Co, Ni, Se) in diverse group of zooplankters were recorded which may be due to the combination of factors affecting the uptake rate of these metals. An in-depth biomonitoring is recommended to establish the studied biota as bioindicator species.

31 May, 11:00 (S5-3418)

Biological responses to oceanic climate variability off Oregon and Washington, USA in three calanoid copepods: *Acartia tonsa*, *Calanus pacificus* and *Paracalanus parvus*

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Recent studies have demonstrated the feasibility of using zooplankton taxa as an early indicator of ecosystem response to seasonal and large scale environmental changes in the Northeast Pacific. Copepod biodiversity and community structure can be useful indicators of climate variability, but also lower trophic level indicators of the relative health of an ecosystem. Using data from a ten year time series, we will examine three “warm water” species that have inhabited the Oregon continental shelf ecosystem: *Acartia tonsa*, *Calanus pacificus*, and *Paracalanus parvus*. We will take into account the specific parameters of these individual species (ontogeny, egg production, temperature/salinity tolerance, etc.) in order to explore which species are the most sensitive indicators of specific environmental conditions. We will also explore the opposite: whether any of these species have the potential to be more opportunistic in a wider range of environmental variability are therefore more spatially

and temporally broad. Such fine-scale information is essential for biological modelling with precise forecasting of both local and event-scale climate forced ecological events as the goal. We will compare plankton net data collected from multiple surveys off of the Oregon and Washington continental margins, from 42° to 48°N latitude. Data on individual copepod species will be compared with large-scale climate data (PDO and upwelling data) and the matching physical data from the corresponding cruises.

31 May, 11:20 (S5-3388)

Dominant zooplankton shift in the Strait of Georgia: an educated guess on the trophic implications and the probable biophysical context

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Temperate pelagic environments have a high biological production that is also localised in time. Such biological production is often dependent on a few key species that control biomass flow. Their trophic pathways are linked to zooplankton species, clupeoid species and major pelagic fish. In the North Pacific key organisms are the copepod *Neocalanus plumchrus*, the herring and the salmon. Within this geographic region the Strait of Georgia (SG) shares this trophic pathway. Typically in the SG this path develops during the spring phytoplankton bloom, followed by a massive population growth of *N. plumchrus* that dominates zooplankton biomass, on which salmon and other fish species feed. A second production peak occurs during the summer, other copepod species and the euphausiid *Euphausia pacifica* account for the bulk of zooplankton biomass during this season. Nevertheless, in 1997 the dominance in community structure shifted from the key species *N. plumchrus* and *E. pacifica* to the amphipods *Parathemisto pacifica* and *Cyphocaris challengeri*. Analyses of this information, along with results on feeding habits of substitute species, indicates the need to reassess the ecological role of small copepod species such as *Pseudocalanus minutus*, *Oithona similis* and *Oncaea borealis*, in the biological production of the Strait of Georgia.

31 May, 11:40 (S5-3398)

Spatial and seasonal variations in distribution and abundance of net zooplankton functional groups on the continental shelf of the Yellow Sea

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Spatial and seasonal changes in distribution and abundance of net zooplankton functional groups (ZFGs) were studied in the south of Yellow Sea (SYS) during 2000-2005. Five key ZFGs were defined: (a) Medusae, (b) Chaetognaths, (c) macrozooplankton, (d) mesozooplankton, (e) microzooplankton. The most important ZFGs in the Yellow Sea were macrozooplankton and mesozooplankton, and the Yellow Sea Cold Water Mass plays a vital role in the distribution and abundance of the main ZFGs. In SYS, Chaetognaths were more abundant predators than Medusae because of their high abundance, especially in the centre and northern part of SYS in autumn/winter. In March, microzooplankton was the important functional group because of high biomass and occurrence of abundant fish larvae, and that the replacement of function could not occur between macrozooplankton and mesozooplankton, mesozooplankton and microzooplankton. While in May, macrozooplankton, mesozooplankton and microzooplankton were all important functional groups, and the replacement could be processed between mesozooplankton and microzooplankton. In summer (June, July and August), microzooplankton was the primary functional group, and could displace mesozooplankton absolutely, in addition, macrozooplankton was also the important functional group. In autumn (October, November), macrozooplankton was the main functional group, microzooplankton taking the second place, and macrozooplankton and microzooplankton could replace the function of mesozooplankton. In winter (January), the biomass of every functional group was very low, but results indicated that macrozooplankton could replace mesozooplankton, and mesozooplankton could displace microzooplankton partially.

31 May, 12:00 (S5-3335)

Modern status of zooplankton in the northwest Japan Sea

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The total biomass of zooplankton in the shelf zone and in the deep-water area in the northwest part of the Japan Sea in the spring-summer period 2002-2006 has decreased on average by a factor of 1.5 in comparison with the 1990s. It has been shown that spring processes in the planktonic community began to be observed later than in the 1990s. A high concentration of net phytoplankton was observed in April - May, which was 2-3 times higher than in the previous decade and the peak did not coincide with the spring peak of zooplankton. In this connection dominant species of copepods, amphipods, euphausiids and chaetognaths were also observed 1-1.5 months later. Therefore the dimensional structure of the plankton in the spring 2002-2006 was characterised by an extraordinarily low share of the small-size fraction (animals with body size less than 2 mm) - from 7% up to 33% of the total biomass. The high contribution of large-size (greater than 3.5 mm) fraction is abnormal, from 50% up to 86% usually dominating over late summer until late autumn. The specific structure of the planktonic community, in general, has not undergone significant interannual changes, but the share of the seven dominant species, usually exceeding 65%, both in the spring and in the summer 2002-2006 has increased by 10-12%. Thus the total biomass of minor species of zooplankton during the last ten years has not changed. Therefore a reduction of the total biomass of zooplankton has taken place primarily due to a reduction in the dominant species, (*Neocalanus plumchrus*, *Neocalanus cristatus*, *Metridia pacifica*, *Oithona similis* and *Themisto japonica*), but also Chaetognaths, whose share has gone down 1.5 times, and is proportional to the downturn of the total zooplankton biomass.

31 May, 12:20 (S5-3332)

North-south comparisons of plankton communities in the Okhotsk Sea

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Interannual comparisons of zooplankton communities were carried out in the northern and southern parts of Okhotsk Sea based upon hydrographic and biological data for the period 1997-2005. The results show that in the northern part of the Okhotsk Sea zooplankton productivity is higher compared to the southern part. This is due to the regional differences in composition and P/B efficiency of the zooplankton communities, as well as to the influence of hydrological conditions. For example zooplankton abundance and productivity in the northeastern and northwestern Okhotsk Sea is influenced by interannual hydrological differences, resulting in either decreased or increased extent of sea ice cover as well as the synoptic situation. The years 2000 and 2001 may be referred to as years of "cold" type, due to the significant extent of ice cover. Based on ice cover extent, the years of 2004 and 2005 can be referred to as "warm" years due to the decreased extent of ice cover. "Cold" and "warm" years did not differ significantly in terms of scale of the zooplankton biomass. However, in the northeast Okhotsk Sea zooplankton abundance increased during the "cold" years. The different years differed significantly in the taxonomic structure of macroplankton community. The biomass of copepods increased in the warm years but biomass of *Sagitta* increased in cold years in the northern Okhotsk Sea. All these parameters have an influence on the production of the zooplankton community. The total zooplankton community production in the northeastern and northwestern Okhotsk Sea is approximately the same in cold years. Production of the zooplankton community was much higher in the northwestern Okhotsk Sea during warm years.

S5

Posters

Poster S5-2767

Bioecological observations of epipelagic zooplankton in Sharm El-Sheikh, Red Sea

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The dynamics of the zooplankton community and associated ecological conditions were studied seasonally in the epipelagic zone of the Sharm El-Sheikh region in the Red Sea. The physico-chemical characteristics of the water column demonstrated pronounced seasonal variations. Water temperature decreased within the upper 100 m by 2.1°C in most seasons and by 7.7°C in summer. The water column appeared to be well aerated with more or less homogeneous vertical distribution of dissolved oxygen, except for relatively low values in the deep layer in spring. The nutritional conditions classified the study area as oligotrophic, whereas the reactive phosphate and dissolved inorganic nitrogen fluctuated between undetectable levels to a maximum of 0.7 µM for both nutrients. In contrast, concentrations of silicate were on some occasions comparatively high in the deep layer (6.5 µM). Relative to these conditions phytoplankton production was generally low. The zooplankton community was represented by 69 species only, mainly copepods, with generally low standing crop (annual average of 4250 individuals m⁻³). The maximum zooplankton abundance was often found in the uppermost layer (0-25 m) in most seasons, but in spring abundance was greatest in the deeper layer (25-50 m). There were different seasonal patterns of vertical distribution of the dominant species. Sixteen bathypelagic species were reported in the epipelagic plankton of the Red Sea, three species as new records, and twenty nine species as newly transferred from the southern part to the northern part of the Red Sea and to the Gulf of Aqaba. Other species were considered to be immigrants from the Mediterranean Sea southward to the Red Sea.

Poster S5-3277

Zooplankton biomass along the Jordanian and Israeli sections of the Gulf of Aqaba, Red Sea

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The objective of work is to examine the variations in the surface zooplankton biomass on a temporal scale of 2 months to 1 year and on a spatial scale of 1 to 10 kms. In addition, zooplankton biomass was examined in term of time and space, vertical cross shore- offshore profile, using existing approaches in a new way. The results indicate significant variations in zooplankton biomass between months, but no major variation between stations. The most important size fractions, contributing to the total biomass in the Gulf of Aqaba, are those of 200-500 µm and >1000 µm. No spatial relationship between zooplankton biomass and either temperature, chl-*a* concentration or nutrients was apparent. Meanwhile, changes in zooplankton biomass co-varied with changes in surface chl *a* concentration measured from the pier of the Underwater Observatory. The biomass obtained from the three different stations shows that biomass tends to increase at the upper water interval compared to the lower one. However, the monthly average of zooplankton biomass at each sampling station shows that the biomass decreased towards the offshore water.

Poster S5-3279

Recent zooplankton research from the Caribbean and Atlantic coasts of Venezuela

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The study of community structure of coastal zooplankton contributes to knowledge and environmental resource management. Results are presented on the taxonomic composition, density and biomass of zooplankton in the National Parks Morrocoy, Mochima, and Los Roques Archipelago; Gulf of Paria, Serpent's Mouth, and Atlantic

front. The latter region was divided in three zones: littoral, neritic, and oceanic. Additionally temporal comparisons are presented between these different environments. Copepods dominated in Morrocoy, Mochima (upwelling and non-upwelling seasons), and the Atlantic front in equal proportion (72%) of the total holoplanktonic taxa present. In the Gulf of Paria, copepods represented 50%, in the Atlantic Front of the Orinoco Delta 63%, and in the Los Roques Archipelago 74-76%. Total zooplankton abundance and biomass in Morrocoy were classified in three large groups: (1) environments with high densities found close to urban centres and tourist areas; (2) intermediate densities located between the coastal and oceanic zones; and (3) environments with low densities having oceanic influence. In contrast to previous studies higher abundance and biomass were recorded towards the oceanic part in the Atlantic front. Abundance and biomass were greater in the Gulf of Paria during the rainy season, and in Serpent's Mouth, north of the neritic zone and oceanic part, during the dry season. This seems to depend on the river flow in the Atlantic front of Orinoco Delta, indicating high mixing processes.

Poster S5-3292

Upwelling index and zooplankton dynamics in Mochima Bay, Venezuela

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Upwelling events in Mochima Bay represent an important contribution to the environmental and productivity dynamics of the zooplankton community. Daily changes in the vertical distribution of zooplankton composition and abundance (individuals/m³), and environmental variables (transparency and temperature) were measured with a 170 µm mesh plankton net during upwelling (February) and non-upwelling (November) by stratified and paired sampling taken randomly during a 12 day (consecutive) period at the mouth of the bay, from a stratified water column between 0 and 60 m. Data analysed by Principal Components Analysis (PCA) showed considerable variation in zooplankton abundance between the two sampling periods, with values ranging between 468 and 6,147 ind/m³ in nonupwelling, and 1,646 and 33,196 ind/m³ in upwelling. Greater windspeed occurred during January-April and minimum in July-November, the upwelling index showed larger variation with low winds (124 y 866 m³ seg⁻¹, 100 m) and was higher during upwelling (984 y 1913 m³ seg⁻¹, 100 m). PCA showed a negative correlation between temperature and transparency. Zooplankton abundance was negatively correlated with temperature and transparency pointing to upwelling influence. In both periods zooplankton showed strong interdaily temporal changes as Lasker's events, i.e. pulse wise. Most important oceanic and deep-water zooplankton species were *Scolecithrix danae*, *Euchaeta spinosa* and *Euaetideus giesbrechti*.

Poster S5-3306

Seasonal variability of the biological state of krill (*Euphausia superba* Dana, 1852) in the coastal waters of the Argentina Islands (Antarctic)

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The Ukraine began to conduct independent hydrobiological research in the Antarctic in 1996. The Ukrainian Antarctic Station (UAS) "Akademik Vernadsky" (formerly the British Station "Faraday") was the site of this research, on Galindez Island, 65°15'S, 64°16'W. Galindez Island lies to west of the Antarctic Peninsula in the Argentina Islands archipelago. This region is an area of interaction between South American and Antarctic water masses and is characterised by high biological production. Biodiversity is high with large numbers of seabirds (24 species) and mammals (8 species). Associated with this area of high biological productivity is the southern border of distribution and reproduction of key bird species, Gentoo Penguins *Pygoscelis papua* (Forst.) and Adelie Penguins *Pygoscelis adeliae* (Hombr. A. Jacquin). The development of life in Argentine Islands region is defined by the quantitative distribution of Antarctic krill. Therefore knowledge of the state of the krill population (size-sexual structure, reproductive cycle) is necessary for understanding the biological processes in the region. Studies of the state of krill were conducted during the Antarctic year (2002-2003) at station "Akademik Vernadsky".

“Antarctic krill” is an aggregate of 11 euphausiid species, which live to the south of the 60th parallel. Only one species *Euphausia superba* Dana, 1852 dominates in terms of number, biomass and distribution. In coastal waters of the Argentina Island this species is the food of the numerous representatives of the highest trophic levels. Many indigenous species (Weddell seals, terns, Adelie penguins, snow petrels) feed intensively on these crustaceans. Two euphausiid species were found in coastal waters of the Argentina Islands, *E. triacantha* and the predatory species *Thysanoessa macrura*. Krill is present in coastal waters of the Argentina Islands throughout the year. The krill population is comprised of two groupings which differ in size-sexual structure, behaviour and other biological characteristics. Solitary (“dissipated”) krill, which do not form aggregations comprise the reproductive part of a population. Usually they are large, mature individuals, which live along the ice edge or around old icebergs. “Aggregation” krill forms the dense aggregations and is comprised of single-sized (even-aged) individuals. The size-sexual structure of krill varies during the year. In the Antarctic spring (November-December) “solitary” krill occurs in shallow water, juvenile or maturing animals with a length no more than 26 mm. Large mature krill form the aggregations. In the Antarctic autumn (April-May) and in winter the basis of the aggregations is the shallow preadolescent individuals. The blended aggregations are characteristic of the Antarctic summer. The number of krill in the aggregations makes ranges from 4 to 11 individuals/m³, and the average biomass changes from 480 mg/m³ in the spring to 2000 mg/m³ in the autumn. The number of “solitary” krill during the year is practically constant, 2-4 individuals/m². The stomachs are filled during the year. Krill feeds mainly phytoplankton. Only in the spring (September-October), is the role of detritus components in the diet of krill significant. Thus, coastal waters of the Argentina Islands are area of reproduction and weight increase for krill. Significant resources of krill ensure the existence of numerous seabirds and mammals in these waters.

Poster S5-3308

Zooplankton assemblage and water mass distribution off the northwest African coast

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One of the main oceanographic features of waters off the Northwest African coast is the boundary between North Atlantic Central Waters (NACW) and the South Atlantic Central Waters (SACW), which occurs near Cab Blanc. Location of this boundary can be well defined on the basis of oceanographic surveys. Multivariate statistical analysis of temperature and salinity data, which had been obtained during eight cruises in the Moroccan and Mauritanian EEZs between 1994-2005, was applied to reveal spatial variation of the boundary in the upper layer. The main reasons for the boundary shifts are dynamic factors, such as the intensity of the North Branch of the Equatorial Counter Current (NECC) and Canary Current (CC). These were shown from TOPEX/POSEIDON satellite altimetry data. Variations of sea level anomaly (SLA) in the coastal region and location of the boundary between NACW and SACW are coherent. Investigations on zooplankton in the coastal waters off Mauritania, which have been conducted in the summer periods of 1998-2004, have shown significant variability of zooplankton biomass, distribution and species diversity. Despite the fact that upwelling intensity had been decreasing, abundance and biomass of zooplankton increased in the summer periods of 1998-2004. Analysis of zooplankton assemblages reveals pronounced increases in the percentage of the species, which usually occur in Senegal and Guinea waters. At the same time the boundary between NACW and SACW has been shifting to the north. This indicates an intensification of the NECC. Thus the southern species abundance on the Mauritania shelf can be attributed to the northward advection of SACW.

Poster S5-3318

Seasonal changes in the species composition of mesozooplankton in the Beagle Channel, southern tip of South America

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The Beagle Channel (54°50'S, 66°50'-69°W) is an area of great interest due to the mixing of Atlantic, Pacific and Antarctic waters. However, little information is available on zooplankton distribution patterns in this area. Therefore, this work aims to study the diversity and seasonal changes of the mesozooplankton community in the

channel. Twelve coastal stations were sampled during spring, summer and autumn (November 2005, March 2006 and June 2006 respectively), and surface temperature, salinity and chlorophyll-*a* concentration were measured. Salinity was higher during spring and summer (21.7-32.0 and 23.9-31.6 psu respectively) than in autumn (30.3-31.7 psu) due to continental runoff, ice melting from glaciers and precipitation. Temperatures ranged between 7.5-10.3°C in spring-summer and between 4.8-6.8°C in autumn. The highest chlorophyll-*a* concentration was observed in spring (mean 1.23 ± 0.74 mg m⁻³) coinciding with the maximum density of copepods and appendicularians. Copepod assemblages were mainly composed of *Acartia tonsa*, *Oithona similis*, *Ctenocalanus citer*, *Drepanopus forcipatus*, *Calanus australis*, *Centropages brachiatus*, *Clausocalanus brevipes* and *Oncaea curvata*. Among appendicularians, the euryhaline and cosmopolitan *Fritillaria borealis* and *Oikopleura dioica* were the most abundant, although *O. fusiformis* was also recorded. During summer, the cold water cladocerans *Podon leuckarti* and *Evadne nordmanni* were abundant. The subantarctic chaetognath *Sagitta tasmanica* and the circumpolar amphipod *Themisto gaudichaudii* were found mainly in autumn. A high abundance of meroplanktonic larvae occurred in spring, suggesting a strong plankton-benthos coupling during this season.

Poster S5-3330

Zooplankton dynamics in the near water of the Yangtze estuary

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To study the zooplankton composition, population dynamics, dominant population distribution and community diversity in the Yangtze estuary, oceanographic surveys were carried out seasonally from May, 2004 to February, 2005, during which a total of 50 zooplankton species were identified (excluding larvae and juvenile zooplankton, fish eggs and larval fish). Although there were obviously seasonal species composition dynamics, crustaceans were the dominant zooplanktons. Furthermore a strong tidal influence was also observed. The abundance of freshwater and eurythermal-oligohaline communities was rather low. The most abundant communities were composed of oligohaline-neritic and brackish-water species. The mean biomass of zooplankton was 117.72 mg/m³, the seasonal dynamics were distinct, but there were no obviously differences between high and low tides, while mean diet biomass were 106.16 mg/m³, the value of high tide was lower than that of low tide. Ten dominant species were observed throughout four seasons, but only *Sinocalanus sinensis* was a dominant species in all four seasons, while *Labidocera euchaeta* and *Tortanus vermiculus* were dominant communities during three seasons. There were obvious seasonal variations. The Shannon-Weiner index (H') was below 2 throughout four seasons. This showed that the zooplankton communities were vulnerable, especially in winter, when the mean value of H' was less than 1; the evenness and richness indices were rather low, so the zooplankton communities were fairly uneven, dominant species were distinct and communities were instable. This indicates that the research area was not a good place for zooplankton to thrive in the winter.

Poster S5-3376

Gelatinous zooplankton off the Argentinian continental shelf: winter distribution, estimated biomass and significance for the pelagic community

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Beyond their seasonal fluctuations in abundance, numbers of gelatinous zooplankton seem to be increasing in ocean ecosystems. There are, nevertheless, few historical data to support this perception. Furthermore, their contribution to the production of pelagic environments remains uncertain. Distribution, abundance and biomass of jellyfish were studied using 152 samples (MWT net) off the Argentinian Continental Shelf (39-50°S; 61-34°W) in winter of 1998. Multivariate analyses were applied to investigate gelatinous zooplankton community structure and their relationship with water masses. We found 11 species of gelatinous zooplankton. Their distribution patterns were related to the distribution of water masses. The most abundant species were *Pegea confederata* and

Calycopsis sp. (0.002 ind./m³). Jellyfish biomass was dominated by *Periphylla periphylla* reaching 39% (13.9 mg/m³) of the wet weight (ww), 38.7% (0.5 mg/m³) of the dry weight (dw) and 33.6% (0.01 mg/m³) of the organic carbon content. Biomass of the pelagic community was dominated by jellyfish reaching up to 66.3% of the ww (35.5 mg/m³). In terms of dry weight and organic carbon, however, the pelagic environment was dominated by non-gelatinous species which represented 75.8% of the dry weight (3.8 mg/m³) and 97.9% of the organic carbon (1.8 mg/m³). These results suggest that gelatinous zooplankton could play an important role in the pelagic ecosystem as carnivorous or filtering species. However, in winter of 1998, they would not have contributed significantly to the pelagic standing stock. The historical data presented in this work provides a baseline for testing possible increases in jellyfish abundance.

Poster S5-3434

Influence of the Columbia River (USA) plume on zooplankton abundance, distribution and size structure over the continental shelf

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Surveys of zooplankton distribution and abundance were conducted off the Oregon and Washington coast (USA), near the outflow of the Columbia River, as part of the River Influence on Shelf Ecosystems (RISE) project. During July 2004, June 2005 and June 2006, a Laser Optical Plankton Counter (LOPC), CTD and fluorometer attached to a Triaxus tow body acquired a comprehensive data set of physical and biological parameters within the vicinity of the Columbia River plume. Results of the surveys provide new information on the influence of a large river plume on zooplankton at temporal and spatial scales relevant to many physical and biological processes (i.e. hours to days, metres to kilometres). Plankton were clearly influenced by physical and biological processes associated with the river plume. On small time and spatial scales, layered aggregations of zooplankton were vertically displaced 5-30 m by internal waves propagating away from the plume front. Across larger spatial scales, zooplankton concentrate directly beneath the plume waters and were often 2-5x greater in abundance and biovolume compared to surrounding waters. The magnitude and location of higher zooplankton abundance and biovolume will be discussed in relation to how physical and biological interactions associated with the Columbia River plume influence coastal biological processes.

Poster S5-3494

Effects of water temperature, light, and prey organisms on growth of the heterotrophic dinoflagellate *Gyrodinium dominans* (Dinophyceae)

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Heterotrophic dinoflagellates are one of the important groups to control populations of photosynthetic phytoplankton in coastal waters. The heterotrophic dinoflagellates *Noctiluca scintillans* and *Protoberidinium* are the most representative species as diatom grazer worldwide but other species is not well studied since their cell size is small (less than 100 µm). Of these, the genus *Gyrodinium* (Dinophyceae) sometimes shows active grazing impact on diatoms and phytoflagellates in nature. Particularly, *Gyrodinium dominans* Hulbert frequently occurs in photosynthetic dinoflagellate blooms and contributes to the cessation of these blooms due to its high predation impact. In studying how environmental factors control the population dynamics of *G. dominans*, the influence of water temperature, light regime, and prey species on growth, and grazing were examined in laboratory culture. Growth of *G. dominans* was observed over the range from 15 to 30°C and a maximum was observed from 25 to 32.5°C (2.1-2.4 divisions/day) and the species did not show any growth below 12.5°C. *G. dominans* clearly showed a light-dependent predation since no growth was observed in dark conditions. Twelve species of prey were studied in growth experiments. *G. dominans* showed higher growth rates when fed the small size (5 to 20 µm diameter) and solitary prey. No growth occurred when fed the two dinoflagellates *Cochlodinium polykrikoides* (28-34 µm) and *Alexandrium catenella* (24-37 µm).

Poster S5-3502

Growth, respiration and food requirement of the giant jellyfish *Nemopilema nomurai* (Scyphozoa: Rhizostomeae)

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The massive bloom of the giant jellyfish *Nemopilema nomurai* has been occurring almost every year since 2002 in the Sea of Japan, causing severe damages to local fisheries. It is important to understand the impact of the blooming medusae on the food web dynamics. We investigated the growth and respiration rates of *N. nomurai* in order to estimate its food requirement in the field. The growth rates were determined for larval medusae fed with sufficient *Artemia* nauplii and young/adult medusae caught by set-nets and seine-nets in the Sea of Japan from July 2005 to January 2006. The former grew from 1-day old ephyra of 9.0×10^{-4} g wet weight (WW) to 48-day old juvenile of 29 g WW, with rapid growth rate of 0.21 d^{-1} . The mean body weight of the latter was 3.4 kg WW in July and increased to 70 kg WW in October, with the growth rate of 0.033 d^{-1} during the period. The medusa weight was constant until November and thereafter decreased to 46 kg WW in January. We also measured the respiration rate (R, mg O₂ medusa⁻¹ d⁻¹) of *N. nomurai* from 0.8 to 7.8 kg WW, which was expressed by $R = 457 \text{ WW}^{0.88}$. These growth and respiration parameter enabled us to estimate the food requirement of *N. nomurai* in the field. For example, a medusa of 30 kg WW in September requires food of 11.0 g C d^{-1} (6% of medusa body C), for which it clears 1,100 m³ of seawater per day.

Poster S5-3525

The effect of sampling preference and environmental conditions on the foraging success of oligotrophic copepod populations: a modelling study

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A stochastic, object-oriented Lagrangian model has been applied to investigate how sampling preferences and environmental factors affect copepod foraging success. The model simulates distinct foraging behaviours for three tropical species: *Clausocalanus furcatus*, *Paracalanus aculeatus*, and *Oithona plumifera*. Thus through emergent behaviour derived from its application, this model can illuminate aspects of copepod grazing that are difficult to characterise with current observational capacities. Previously, results from this model demonstrated that their diverse foraging behaviours help to maintain copepod species diversity within oligotrophic regimes (i.e., Hutchinson's paradox). Here, these findings are extended through three experiment sets that investigate the impact of: 1) alteration of prey perception that shifts the size range of grazed cells; 2) applying observed oligotrophic prey spectra from all levels of the euphotic zone; and 3) applying an order of magnitude range of randomising (i.e., turbulent) velocities. Thus these experiments can distinguish foraging rates over a range of growth stages and provide insight into how grazing success is impacted by natural variations in prey size distributions that reflect distinct environments within an oligotrophic water column and turbulence-induced modification of predator-prey encounter rate. In addition, these modelled encounter rates are contrasted against theoretically derived rates, which underscores the role foraging behaviour plays in obtaining nutritional requirements.

Poster S5-3535

Stable isotopes and trophic structure of pelagic copepods in the tropical eastern Pacific Ocean

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The main ecological role of pelagic copepods is the transfer of energy from the primary producers to higher trophic levels in the food web. In this study we analyse the trophic structure of the pelagic copepod community in the tropical eastern Pacific Ocean. Zooplankton samples were obtained on two oceanographic cruises from August to

December, 2003 onboard the NOAA's David Starr Jordan and MacArthur II oceanographic vessels. Samples were collected by double oblique tows of a bongo net. 96 zooplankton samples were analysed, and 94 copepod species belonging to the orders Calanoida, Cyclopoida, Harpacticoida and Poecilostomatoida were identified. From those 96 species, twelve were the most dominant in terms of abundance and occurrence (~80%). Stable isotope ratios of ^{13}C and ^{15}N were measured in samples from 20-200 individuals of these dominant species. The results show a consistent latitudinal gradient in ^{15}N values among species, with high ^{15}N enrichment in samples from the northern zone of the study area. The enrichment of ^{13}C isotopes shows a longitudinal gradient with isotopic values decreasing from the coast to the open ocean. We conclude that the trophic position of some copepods could be redefined since species previously identified as carnivores showed a more omnivorous diet. *Pleuromamma robusta* was recognised as the species with the highest trophic position in the copepod community, its ^{15}N enrichment value being higher than those reported for other groups of zooplankton, such as Chaetognaths.

Poster S5-3553

Seasonal variations in abundance and biomass of the scyphomedusa *Aurelia aurita* and its predation impact on mesozooplankton in a brackish-water lake, Japan

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Seasonal variations in abundance, biomass and gut contents of *Aurelia aurita* medusae together with mesozooplankton were investigated in a brackish-water lake, Honjo District (area: 16.2 km², average depth: 5.1 m), Japan, from June 2005 to August 2006. The medusae occurred abundantly (> 0.18 medusae m⁻³) from June to November, with average abundance and biomass of 0.6 medusae m⁻³ and 64.2 mg C m⁻³, respectively. Abundance of medusae was low from December to their increase in June. Mesozooplankton biomass fluctuated from 1.3 to 150 mg C m⁻³ (average: 60 mg C m⁻³) unrelated to the variation in medusae biomass. The medusae fed on mesozooplankton almost non-selectively, and mainly ingested the small copepod *Oithona davisae* and bivalve veliger larvae, both accounting for 52-99% of the gastric pouch contents. The medusae population ingestion rate on mesozooplankton varied from 0.1 to 14 mg C m⁻³ d⁻¹ for the period from June to November, with the highest and average ingestion rates corresponding to 27.6 and 7.1% of the mesozooplankton biomass per day, respectively. Consequently, *A. aurita* medusae are key components of the zooplankton community and exert significant predation pressure on mesozooplankton in this brackish-water lake in summer to fall.

Poster S5-3614

Microzooplankton as a food source for the Pacific oyster *Crassostrea gigas*: seasonal variation in the gut contents and food availability

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Biomass of microzooplankton is often equivalent to that of mesozooplankton in coastal waters. The size of microzooplankton (generally < 200 μm) and the slower swimming speed compared to larger zooplankton are thought to be favourable for bivalve feeding, suggesting that microzooplankton is an available food source for bivalves. In our present study, seasonal occurrence of microzooplankton in the gut of the Pacific oyster *Crassostrea gigas* was investigated. As a result, loricae of tintinnid ciliates, dinoflagellates, copepod nauplii, bivalve larvae and rotifers were observed in the gut contents of the oysters. Monthly variation in abundance of tintinnids in the oyster's guts generally corresponded to their abundance in the surrounding seawater. However, the abundance of tintinnids in the gut contents decreased at a high concentration of chlorophyll-*a* or high densities of aloricate ciliates in the seawater even when tintinnid ciliates were abundant. Significant correlation between tintinnid ciliates in the gut contents and in the seawater was observed, although the metazoan in the gut contents did not show significant relationships with the abundance in the seawater. In laboratory experiments, oysters actively fed on ciliates labelled with the stable isotope nitrogen (^{15}N). After oysters fed on the ciliates, the nitrogen stable isotope ratio of the oyster meat was significantly higher in comparison with control oysters, suggesting that oysters assimilate the nitrogen of the ciliates into their body meat. These results suggest that microzooplankton is an important food source for oysters when phytoplankton is not abundant.

Poster S5-3638

A role of planktonic Crustacea in the food of Myctophidae

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Myctophidae or lantern fishes are the most numerous mesopelagic fishes. They are small-sized fishes (2.5-30.0 cm). The majority lead a pelagic life and belong to the macroplankton. Their food includes small-sized Crustacea in particular Copepoda and Euphausiacea. The nutrition of 6 species of Myctophidae from the Arabian Sea was investigated. In the Northern Arabian Sea, except for Copepoda and Euphausiacea, the percentage of Ostracoda was great. Crustacea contributed 80% (*Benthoosema fibulatum*) up to 99% (*Hygophum proximum*). In the food of *Diaphus arabicus* and *H. proximum* (maximum SL about 4 cm), Copepoda predominated over Euphausiacea. In the food of *B. fibulatum* and *Diaphus thiollierei* (maximum SL about 10 cm) Euphausiacea predominated over Copepoda. In the food of *D. arabicus* and *D. thillierei* Ostracoda dominated. In the South Arabian Sea *Diaphus perspicillatus* with standard lengths less than 2.5 cm feed mainly on Copepoda. Individuals with SL more than 2.5 cm eat mainly Euphausiacea. Thus Crustacea make up about 95 % of the myctophid ration in the Arabian Sea.

Poster S5-3644

Role of heterotrophic dinoflagellates in the fate of ice algal production released into the water column under fast ice near Syowa Station, Antarctica

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To understand the fate of ice algal diatoms released from sea ice, we investigated the abundance of diatoms and heterotrophic dinoflagellates in the water column and sinking diatom flux under the fast ice near Syowa Station, Antarctica during austral summer 2005/06. Diatoms showed a clear declining phase after rapid increase in the water column due to the release by ice melting. Among diatom assemblages, *Porosira pseudodenticulata* and *Pseudo-nitzschia turgiduloides* were abundant in the water column but low in sinking diatom flux, while *Fragilariopsis kerguelensis* and *Thalassiosira australis* were scarce in the water column but important in the flux. The former two would maintain their populations in the surface layer rather than sink to the bottom. Sinking loss was not the main factor in the diatom decline because it accounted for only 21% of the decrease in the water column. Heterotrophic dinoflagellates and naked ciliates, which were always dominant among the heterotrophic populations, exceeded diatoms in biomass during the declining phase of diatoms. Microscopic analysis revealed that heterotrophic dinoflagellates ingested large amounts of diatoms but naked ciliates hardly did, suggesting that heterotrophic dinoflagellates had few competitors for diatoms. The presence of the diatom species that maintain their populations in the surface layer and absence of potential competitors for diatoms would enhance the importance of heterotrophic dinoflagellates as diatom grazers. These results suggest that large amount of diatom carbon produced at the undersurface of the ice remains in the water column through feeding by heterotrophic dinoflagellates rather than sinking to the bottom.

Poster S5-3650

Biogeography of appendicularians in the North Pacific Ocean

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Appendicularians are typical filter-feeders which effectively ingest less than 1 μm food particles in the ocean. However, little is known of their ecology and importance in biogeochemical cycles in the oceanic ocean. During the last decade, we have analysed the distributional patterns of appendicularians in the North Pacific Ocean to evaluate their ecological role in the oceanic ecosystems. Sampling was carried out by vertical hauls with

NORPAC nets (45 cm diameter, 0.33 mm mesh) along various north-south transects, such as the 155°E, 165°E, 170°E, 175.5°E, 180°, 165°W, and 145°W meridians mostly between 35° and 55°N. Appendicularian abundance showed a bottleneck shape distribution in the transitional domain. The species composition was slightly different between the west and east regions within the transitional and subtropical domains. These differences might be due to the differences in the lower trophic structure of the surface current systems in the North Pacific Ocean.

Poster S5-3663

Succession of ultra fine particle feeders: the role of environmental variability

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Anthropogenic perturbations have caused significant alterations in the ecosystem of the highly stratified Marmara basin within the last three decades. One of the most significant changes is the dominance of cladocerans, comprising the major fraction of zooplankton for over 60% of the three year long monthly observations. This change is very important, since cladocerans are known to play a less important role in marine ecosystem compared to copepods. The mesotrophic regions of the Sea of Marmara are dominated by *Penilia avirostris* in summer and suppress the population development of other thermophilic ultra fine particle feeders, such as *Oikopleura dioica* and *Paracalanus parvus*. Multiple correspondence analysis results indicated that high abundance of *P. avirostris* was strongly associated with the high temperature-low chlorophyll *a* (~1 mg/L) period, while the other species increased their abundances at moderate temperatures. The succession of dominant ultra particle feeders therefore differed from neighbouring seas. *O. dioica*, which is known as a strictly thermophilic species, increased its abundance in late spring and October-November periods, before and after the *P. avirostris* dominance from May to September-October. *P. parvus*, on the other hand, increased following *O. dioica* in November. However, in August 2000, this succession pattern was interrupted, following a strong vertical mixing, as inferred from a decrease in temperature and an increase in salinity and chlorophyll *a*. The hydrographic processes broke down the dominance of cladocera in summer and *Acartia clausi*, supported by ~5 times higher chlorophyll *a* than in other years. This immediately increased abundance and restrained the abundance of ultra fine particle feeders, thus indicating a major difference in particle size of abundant prey (>70 µm). These results are evidence of alterations in the seasonal succession and hence the size spectrum of phytoplankton due to eutrophication stress and hydrographic variability.

Poster S5-3687

Effects of taxonomic resolution on estimates of plankton food web structure in the epipelagic equatorial Pacific

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Most natural plankton communities have complex and hierarchical food web structure. The extent of the complexity and hierarchical structure can be expressed by some food web indices such as average food chain length to each heterotrophic component in the particular food web. However, it is known that food web indices sometimes reflect the way of grouping organisms in the food web, but not the intrinsic characters of the food web structure. This presentation will show how taxonomic resolution in grouping food web components can affect apparent characteristics of the food web structure in the plankton community in the 0-200 m water column in the Equatorial Pacific. Food web and carbon flow in the plankton community studied were estimated from size-dependent predation, carbon transfer between trophic levels and size-biomass measurements in 5 independent field observations. The study community was firstly separated into 10 different functional groups (pico-, nano- and micro-phytoplankton; bacteria; heterotrophic nanoflagellates; heterotrophic dinoflagellates; ciliates; nauplii; copepods; and chaetognaths) and 20 size classes. Then, as the taxonomic resolution defining the functional groups become finer, food web structure and average food chain length to whole copepod community were re-estimated one by one. This result suggests that estimated food chain length to the copepod community is highly dependent on the way of grouping organisms in the food web, which does not largely change the estimated carbon budgets of the copepod community.

Poster S5-3700

Ecological niches in an almost homogeneous environment: deep-sea copepods in Polar Seas

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Deep-sea copepods of the calanoid families Euchaetidae and Aetideidae are important components of pelagic ecosystems in polar seas. Still enigmatic is the high biodiversity of these copepods in meso- and bathypelagic zones. The objective of this presentation is to characterise the ecological niches of closely related species in the almost homogeneous environment of the deep-sea pelagic realm. Vertical distribution patterns as well as trophic biomarkers (i.e. fatty acids and the stable isotope ratio $^{15}\text{N}/^{14}\text{N}$) were analysed in co-occurring species of both families in order to elucidate species-specific differences in diet spectra and spatial niche. Congeners usually showed a vertical partitioning of the water column, while different genera of both families often occurred sympatrically. However, the depth ranges of some closely related species considerably overlapped. Within families, the stable isotopic ratio $^{15}\text{N}/^{14}\text{N}$ generally increased with depth, indicating highest trophic levels in bathypelagic species. In Antarctic *Paraeuchaeta* spp., the isotopic ratio doubled from mesopelagic *P. antarctica* (4.8) to bathypelagic *P. farrani* (9.5). Arctic representatives of *Paraeuchaeta* apparently deviated from this general pattern with higher ratios of 9.3 in mesopelagic *P. norvegica* than in bathypelagic *P. barbata* (6.5). Here, herbivorous copepods diapausing at great depth seem to provide a shortcut between surface primary production and the meso- and bathypelagic zooplankton community. Biomarkers typical of *Calanus* (i.e. 20:1 and 22:1 fatty acids and alcohols) were found in high amounts of up to 20% of total fatty acids even in deep-living *Paraeuchaeta* species. Interspecific and ontogenetic trends in trophic niches will be presented in detail.

Poster S5-3704

A comparison of OPC-derived zooplankton size structure in different marine ecosystems

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Since 1999, a laboratory Optical Plankton Counter OPC (Herman, 1988) was used to count and size mesozooplankton (from 200 μm to 2 mm) from various types of pelagic ecosystem: oligotrophic (South Pacific gyre, Gulf of Guinea, south western and eastern Mediterranean sea), mesotrophic (Kerguelen plateau, Gulf of Lion) and eutrophic (Bay of Biscay), and for two annual time series in the Arcachon Bay and Marseille Bay. One advantage of this new automatic system is that it quickly provides size spectra from which both, zooplankton abundance and biovolume can be estimated. From our various campaigns, we made comparisons of biomasses and abundances derived from the OPC with those obtained from direct measurements. The slopes of the zooplankton size spectra from these different areas are compared to the environmental characteristics of production, as well as linkages with diversity indices. The use of zooplankton size spectra as descriptors of the structure and dynamics of the zooplankton component in these ecosystems is discussed.

Poster S5-3708

The trophic importance of gelatinous carnivorous zooplankton in an upwelling area of the Humboldt Current System (36°S)

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There is scarce information regarding the role of gelatinous carnivorous zooplankton in pelagic food webs of upwelling areas of the Humboldt Current System (HCS) off Chile. For instance, the potential predatory impact of dominant carnivorous species on copepod communities is still unknown. Here, we present the seasonal distribution of most abundant species of gelatinous carnivorous zooplankton throughout an annual cycle between 2004 and

2005, in relation to physical/biological oceanographic conditions. In addition, we evaluate the predation impact of two species of the numerically dominant siphonophores (*Muggiaea atlantica* and *Sphaeronectes gracilis*) on the small copepod communities. Mean values for predation rates were 5.3 and 11.4 cop siph⁻¹ d⁻¹ for *M. atlantica* and *S. gracilis*, respectively. Predation impact of these siphonophores species and the dominant ctenophore *Pleurobrachia bachei* involved a removal of ~10% and ~14% of the secondary production of small copepods daily in the autumn-winter season. Taking into account that highest predation impact of gelatinous carnivorous matches with the period of lowest primary and secondary production, and the main spawning season for pelagic fishes such as Peruvian anchovy *Engraulis ringens*, both potential predation on their early stages and competition for similar food resources (e.g. adult and larval stages of small copepods), might be a relevant factor to be considered in fish recruitment studies. We discuss the significance of gelatinous carnivorous zooplankton in pelagic food webs of upwelling areas in the Humboldt Current System.

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Poster S5-3759

Species composition and distribution of fish eggs and larvae in Vietnam Sea waters

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This report is based on data on fish eggs and larvae collected from 18 surveys of the Research Institute for Marine Fisheries (RIMF) in Vietnam sea waters, from 07°00'–21°00'N and 103°30'–110°00'E. Fish eggs and larvae samples were collected with two types of net surface and vertical. Total fish eggs and larvae were 165,750 and 52,290, respectively. A total of 110 species from 75 families were identified. For fish eggs the dominant families are Clupeidae, Cynoglossidae, Engraulidae, Synodontidae and Trichiuridae. For larval fish the dominant families are Bregmacerostidae, Callionymidae, Carangidae, Clupeidae, Engraulidae, Gobiidae, Leiognathidae, Mullidae, Sciaenidae and Teraponidae. Fish eggs and larval abundance in the inshore, estuary and around islands was higher than that offshore. In the Gulf of Tonkin, fish eggs and larval abundance were higher than that in the central area. In the south-west season, fish egg and larval abundance in the Gulf of Tonkin and the central area were higher than that in north-east season. However, in the South-West area fish egg and larval abundance were not different in the two seasons.

Poster S5-3769

An integrated approach to the study of very nearshore larval fish assemblages in the Arrábida Marine Park (Portugal)

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In temperate regions little is known about the composition and small scale patterns of distribution of larval fish assemblages in very nearshore waters, where sampling methods traditionally used to investigate spatial patterns of plankton distribution are difficult to use. The use of towed nets may give a biased view of the assemblages given that some larvae are able to avoid the nets. Therefore, the use of different sampling methodologies is best suited to understand both the species composition and the distribution patterns of the assemblages. We investigated a very nearshore ichthyoplankton assemblage in the Arrábida Marine Park (Portugal) during the spring-summer period using different methods. Diurnal assemblages were collected using sub-surface and bottom trawls using a net attached to an underwater scooter. We also collected larvae at night with a light-trap and subsurface trawls. Assemblages were composed mainly of larvae of shore fish species. Larvae collected with nets were mainly in the pre-flexion stage, but more developed larvae were collected with the scooter and light-traps. During daylight, surface samples had higher numbers of taxa than those collected with the scooter but lower larval density. Surface samples collected at night had a significantly higher larval density than those collected during the day, possibly indicating nightly hatching for some species. The most abundant larvae in the light-traps (Gobiesocidae) were caught in all developmental stages and were almost absent from the surface and scooter samples. This may indicate that larvae of these species might be able to avoid the nets and/or to settle very early in development.

Poster S5-3783

Feeding of carnivorous zooplankton in West Greenland waters

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Today, the West Greenland marine ecosystem sustains fisheries which contribute 95% of Greenland's total export value. Knowledge about the marine food webs that supports these rich resources is essential to manage the economically important fisheries resources in a sustainable manner. Important and common predatory groups, such as the chaetognaths and carnivorous copepods are particularly understudied in the Arctic. The aim of the present talk is to contribute to a better knowledge about carnivorous zooplankton, their trophic role in the arctic pelagic ecosystem, with emphasis on their predation on *Calanus* spp. The diet and vertical and horizontal distribution of the carnivorous copepods and chaetognaths were investigated in west Greenland waters during the Arctic spring. Feeding by the carnivorous copepod *Pareuchaeta norvegica* was assessed by measuring egestion of faecal pellets and the chaetognaths were analysed for gut contents. Simultaneously, prey composition and vertical distribution were determined and used to estimate predation pressure and selective feeding. *P. norvegica* was at all times restricted to the deeper parts of the water column while the chaetognath *Sagitta elegans* was found at all depths.

Poster S5-4023

Epipelagic copepods in the Andaman Sea, with 10 new records in Thailand

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The epipelagic copepods in Andaman Sea were studied from January to June 2006. Copepod samples were collected at 75 stations from 7 marine national parks: Chang, Phayam, Surin, Similan, PhiPhi, Phuket and Ardang Rawi Islands and Chao Mai Bay, by horizontal hauling with a conical 0.6 m diameter plankton net of 330 µm mesh size. Five environmental parameters were also investigated. Ninety species in 31 genera were recorded; 63 species are new records for the Andaman Sea. Ten species are new records for Thai waters: *Centropages calaninus* (Dana), *Centropages elongatus* Giesbrecht, *Labidocera pectinata* Thompson and Scott, *Miracia efferata* Dana, *Pontella fera* Dana, *Pontella spinipes* (Giesbrecht), *Pontella securifer* Brady, *Pontellopsis armata* (Giesbrecht), *Saphirella tropica* Wolfenden and *Sapphirina opalina-darwinii* Dana. The most diverse group was calanoid copepods (59 species), followed by poecilostomatoid copepods (23 species). The majority were rare and offshore species occurring at high water salinity (34-35 psu) e.g. *Temora discaudata* (Giesbrecht), *Temora stylifera* (Dana) and *Oithona* spp. The most dominant species were *Acartia amboinensis* Carl and *Acrocalanus gibber* Giesbrecht. Subdominant were brackish species: *Canthocalanus pauper* (Giesbrecht), *Centropages furcatus* (Dana), *Labidocera minuta* Giesbrecht and *Subeucalanus subcrassus* (Giesbrecht) that frequently occurred in this area.

S6

Microbial loop vs classical short food chains: implications for appraisal of food web efficiency and productivity

31 May, 09:05 (S6-3719) Invited

From primary production to mesozooplankton: trophic transfers through microbial food webs

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According to classical food-chain concepts, the size structure of pelagic primary producers strongly impacts the efficiency of carbon and energy transfer to higher-level consumers through its effect on trophic pathway length. In theory, at least, virtually all primary production is available to mesozooplankton in systems dominated by large phytoplankton, but multiple levels of protistan consumers drop transfer efficiencies by one or more orders of magnitude in pico-phytoplankton dominated systems. In nature, however, the variability of production fluxes to mesozooplankton is not nearly as extreme as these theoretical scenarios. This presentation will examine potential explanations for the discrepancy between prediction and observation: 1) that microzooplankton utilisation of primary production is significant in all systems; 2) that large phytoplankton systems generally lack strong coupling between production and grazing processes, and 3) that microbially dominated systems have subtle efficiency enhancing attributes, such as mixotrophy or size-distributed grazing. In addition to comparing system characteristics on regional and annual bases, initial results will be presented from experiments designed to provide instantaneous estimates of trophic coupling in systems with evolving community structure.

31 May, 09:35 (S6-3538)

The Baltic Sea as a natural ecosystem to study the significance of the phytoplankton/ bacterioplankton production ratio for pelagic food web efficiency

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The annual production of bacterioplankton (BP) remains almost the same in a north-south gradient from 66°N to 54°N in the Baltic Sea, whereas the phytoplankton production (PP) increases by a factor of ten. This strong gradient in PP/BP ratio is supposed to be the major factor causing diverging production conditions higher up in the food web. In accordance, the mesozooplankton biomass shows a strong increase from north to south. Further support is given from two contrasting experimental systems in the lab, with strong dominance of respectively bacterial production and phytoplankton production, generating an eleven-fold higher food web efficiency (up to mesozooplankton) in the latter system. This is mainly explained by an effect of longer food chain in the bacterial-based system. Up-to-date climate models propose increased temperature, more precipitation, and more extreme weather conditions in northern Europe. As secondary effects in the Baltic Sea such changes would probably cause a deepening of the pycnocline, increased river-bound addition of allochthonous dissolved organic carbon (ADOC), including humic substances, all factors that would benefit bacterial production and decrease phytoplankton production. We thus propose a long-term trend of decreased PP/PB ratio in the whole Baltic Sea, and thereby also a reduced food web efficiency, with deteriorated production of both mesozooplankton and fish. This will be most dramatic in the Baltic proper, where the phytoplankton production has hitherto been as high as in coastal waters of the North Sea.

31 May, 09:55 (S6-3311)

Microbial loop vs short food chains: what do mesozooplankton enzymatic indices tell us about differences in food web efficiency and productivity?

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A cruise carried out in year 2000 offered a first opportunity to simultaneously implement measurements of the activities of three enzymes in mesozooplankton samples collected at a regional scale on the continental shelf of the Bay of Biscay, NE Atlantic. These metabolic descriptors aim at characterising the assimilation rate of proteins by the activity of digestive endopeptidase trypsin, and of carbohydrates by pyruvate kinase (PK). The third enzyme studied, aspartate transcarbamylase (ATC), is devoted to an overall assessment of mesozooplankton productivity. The region is subject to influences of various strong physical driving forces, which directly affect the prime structure of the pelagic food web. In particular, the phytoplankton biomass distribution expressed these different influences: diatoms dominated in nutrient enriched coastal water; picoplankton were dominant in the northern central part, where nutrients were exhausted, whereas nanoplankton were stimulated at the shelf break, where there was an input of nutrients by internal waves. These and other results on bacteria, POC distribution etc., point out different local microbial food web functioning. The living matter produced was characterised by the quality and quantity of the smallest prey items that were available to higher trophic levels. Variations in enzyme activities may be quite in accordance with expected results, but may also show discrepancies from generally accepted relationships which are supposed to govern the functioning of pelagic food webs.

31 May, 10:15 (S6-3489)

The effect of temperature and food on zooplankton gross growth efficiency

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Gross growth efficiency (GGE) is the percentage of consumed biomass that is converted by an organism to new biomass. GGE is important in describing the flow and partitioning of material and energy in organisms and biological communities and has been used to predict material availability to higher trophic levels using simple to complex food web models. These models, however, commonly assume a constant GGE for all zooplankton taxa, with no temperature dependence. We present results following the compilation of global data across important pelagic taxa including bacteria, nano/microflagellates, dinoflagellates, ciliates, rotifers, cladocerans, copepods, ctenophores and scyphozoans. Although seven taxa had similar GGE values, ciliates achieved significantly lower values than nearly all other taxa. Meanwhile nano/microflagellates had a mean GGE at least 50% greater than all other taxa. Our study is the first to explicitly describe the relationships between GGE and both food concentration and temperature. Although bacteria and copepods displayed significant, negative relationships between GGE and temperature, other taxa showed a positive relationship (ciliates, dinoflagellates, ctenophores, scyphozoans and cladocerans), while the remainder had no relationship. GGE was positively associated with food concentration within scyphozoans and cladocerans, with no relationship in all other taxa. These relationships are subsequently used to construct simple ecosystem models to determine relative biomass/production distribution of different components of a food web. Differences in mean values and effect of temperature on GGE between taxa are likely to affect the flow of material through the planktonic food web, and need to be taken into account to increase ecosystem model accuracy.

31 May, 11:00 (S6-3500)

Classical food webs and the microbial loop off Western Australia: test of a new method to simultaneously estimate micro- and mesozooplankton grazing impacts

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Bottle incubation experiments are widely used in mesozooplankton grazing studies. However, prey suspensions typically contain several trophic levels, such as phyto- and microzooplankton, and experiments often yield low or negative mesozooplankton grazing estimates when the release of microzooplankton grazing pressure outweighs copepod grazing on the phytoplankton. Simultaneously conducted microzooplankton dilution experiments can correct for the effects of microzooplankton grazing, but this requires a second set of experiments. We propose a method based on an expansion of the Frost (1972) equations to estimate from the same experiment the parameters for phytoplankton growth, micro- and mesozooplankton grazing on the phytoplankton, and mesozooplankton predation on the microzooplankton. In 2003 and 2004 we conducted shipboard mesozooplankton grazing and microzooplankton dilution experiments seasonally at three locations off Perth, Australia: a coastal lagoon (10 m depth), mid-shelf (100 m depth) and offshore Leeuwin Current (1000 m depth). The mesozooplankton grazing experiments were based on manipulation of the density of natural assemblages of the mesozooplankton grazers to assess their impact on natural phytoplankton and heterotrophic protist assemblages. We hypothesized that an onshore-offshore gradient in productivity would lead to a gradient in the relative importance of the microbial and classical food webs. In this paper we test this hypothesis and compare estimates of primary production and microzooplankton grazing obtained from direct measurements and our modified Frost model.

31 May, 11:20 (S6-3701)

Low grazing pressure and high egg production by copepods in a productive estuarine lagoon

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We evaluated the coupling between primary production (PP), copepod grazing and egg production rates (EPR) at daily and seasonal time-scales in Laguna de Rocha, a highly productive and shallow brackish lagoon on the South Atlantic. Nano and microphytoplankton were represented by few taxa, while the copepod *Acartia tonsa* strongly dominated the mesozooplankton. PP correlated with phytoplankton biomass (as chlorophyll-*a*) and both varied widely between days and seasons, with maxima of 19 $\mu\text{g Chl L}^{-1}$ and 473 $\text{mg C m}^{-2} \text{d}^{-1}$ in January 2005, respectively, and minima of 2.8 $\mu\text{gChl L}^{-1}$ (September 2004) and 19 $\text{mg C m}^{-2} \text{d}^{-1}$ (April 2005). The fraction of PP removed by copepods (grazing pressure, GP) was consistently low between < 0.1 and ca. 3%, and tended to decline with PP. EPR by *A. tonsa* was generally high (range 11.6 to 100 eggs female⁻¹ d⁻¹) but did not show a clear relationship with PP; instead, estimated secondary production ($\mu\text{g C m}^{-2} \text{d}^{-1}$) was best explained by combined temperature, biomass, PP and individual ingestion rates. The herbivory index (range 0.05 to 1) suggested that production by *A. tonsa* relied heavily on consumption of microzooplankton, pointing to a strong link between microbial and grazer pathways. Concurrent estimates of microzooplankton grazing at several dates during the same period showed that this size-fraction consumed between 41 and $> 100\%$ of the daily PP. Higher importance of micrograzers and the tendency for copepod GP to decline with PP at system scale appear consistent with the global scale pattern arising from comparison of widely diverse marine ecosystems.

May 31, 11:40 (S6-3454)

Food web structure and carbon flows in a river-influenced and non-river influenced continental shelf at the coastal upwelling area off Central Chile (36°S): importance of mixotrophy and omnivory

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Classical and microbial pathways remain as a useful dichotomy for distinguishing the several fates of primary production in aquatic ecosystems. In most of our idealised concepts of food web, we tend to separate profoundly between the photosynthetic and the heterotrophic organisms in the predatory food web. This division is not necessarily adequate descriptions of reality since there are known organisms able to combine nutrition types, and complicate our traditional view about aquatic food webs. One complicating factor that is receiving increasing attention is the influence of 'mixotrophs', organisms that defy traditional trophic classification concepts by both photosynthesizing and grazing. In addition, 'omnivory', the consumption of resources from more than one trophic level, is a widespread behaviour among planktonic organisms. Evidence for shifting trophic roles of various types of planktonic organisms and multiple levels of feeding interactions within mixotrophs and omnivorous components, which typically have been regarded as a single trophic level have increased during the last decade. By using field and experimental approaches, we propose to elucidate the potential role of 'mixotrophy' and 'omnivory' to the carbon flows in a river-influenced and non-river influenced continental shelf off Central Chile. Primary production, bacterial production, autotrophic, heterotrophic and mixotrophic biomasses, as well as, measurements of grazing by nanoflagellates, microzooplankton, and mesozooplankton are conducted under contrasting conditions during spring and winter. Ongoing food web analysis of the spring condition during coastal upwelling events, and under the influence of the river discharge will be discussed, as well as, the implications of mixotrophy and omnivory in the structure and ecosystem functioning.

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31 May, 12:00 (S6-3414)

***Neocalanus* and the lower trophic levels of the subarctic Pacific Ocean**

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The eastern subarctic Pacific Ocean is an iron limited, HNLC system dominated by small phytoplankton, with chlorophyll concentrations typically about 0.3 µg l⁻¹. Microzooplankton consume most of the phytoplankton production. Mixed layer mesozooplankton in spring are dominated by the large copepods *Neocalanus flemingeri* and *N. plumchrus* and their diet consists of phytoplankton and microzooplankton. This is neither a classical food chain nor a microbial loop. Recent experimental data from the Gulf of Alaska have quantified the major trophic pathways. *Neocalanus* feeds almost entirely on phytoplankton and microzooplankton >20 µm although some smaller microzooplankton are also consumed. Large microzooplankton (>20 µm) feed on small microzooplankton (<20 µm), and large and small phytoplankton. Small microzooplankton (<20 µm) feed primarily on small phytoplankton (<5 µm). *Neocalanus* appear to (a) contribute significantly to the control of large diatoms under iron limited (slow) growth rates, and (b) control the large microzooplankton (>20 µm) and some of the smaller microzooplankton (< 20µm). *Neocalanus* consumption of microzooplankton grazers results in a net enhancement to the growth of small cells (a cascade effect). The net result is that *Neocalanus* drives the system towards small cell dominance. Under iron-replete conditions however, the growth of large phytoplankton is enhanced and escapes grazer control and trophic pathways from large diatoms to *Neocalanus*, and large diatoms to large microzooplankton to *Neocalanus*, are enhanced. This food web contains elements of both top-down and bottom-up controls, and it changes with iron events (bottom-up) and *Neocalanus* abundance (top-down).

31 May, 12:20 (S6-3770)

Parasitic fungi may bridge the gap between inedible algae and zooplankton

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The efficiency with which biomass and energy are transferred from primary produce to grazer is highly variable in lakes and oceans, and the two trophic levels can even become uncoupled. This is especially true when large inedible species dominate the phytoplankton. Our study shows that parasitic fungi (chytrids) which infect large diatoms (*Asterionella*) may bridge the gap between primary producer and grazer. Diatoms form large spring blooms in lakes and oceans, providing fuel for higher trophic levels at the start of the growing season. Some of the bloom diatoms, however, are not grazed by filter feeding zooplankton like *Daphnia* due to their large size. Furthermore, some diatoms are known to inhibit the reproduction of copepods because of their toxins. In life table experiments using the large diatom *Asterionella formosa* as food, the growth and survival of zooplankton (*Daphnia*, *Eudiaptomus*) increased significantly in treatments where a chytrid was present. Chytrids take up energy and nutrients from their host and produce abundant zoospores, which are released into the water. These zoospores are excellent food for zooplankton, both in terms of size (shape) and quality (PUFAs and cholesterol). By grazing on the zoospores, zooplankton acquired important supplementary nutrients and were able to grow in the presence of inedible diatom. This provides new insights into the role of parasitic fungi in aquatic food webs, where they improve zooplankton production and enhance the efficiency.

S6

Posters

Poster S6-3284**Pigment-specific rates of phytoplankton growth and microzooplankton grazing in a subtropical lagoon**Ricardo **Palomares-García**¹, J. Bustillos-Guzmán² and D. Lopez-Cortés²¹ Centro Interdisciplinario de Ciencias Marinas, Departamento de Plancton y Ecología Marina, Ave. IPN s/n, Col. Playa Palo de Santa Rita, A.P. 592, La Paz, Baja California Sur, C.P. 23096, México. E-mail: rpalomar@ipn.mx² Centro de Investigaciones Biológicas del Noroeste, A.P. 128, C.P. 23090, La Paz, Baja California Sur, México.

Phytoplankton growth and microzooplankton grazing rates were evaluated in one station in Bahía Concepción, located in the middle region of the Gulf of California, México. We used high performance liquid chromatography (HPLC) estimations of phytoplankton pigment signatures to evaluate the annual variation of taxon-specific grazing and growth rates obtained with the dilution technique. Chlorophyll-*a* (Chl-*a*) concentrations varied widely (0.34–3.32 mg L⁻¹) and showed two maxima, during late spring and autumn, associated with the transition between mixed and stratified conditions. Phytoplankton growth rates varied seasonally with the lowest rates during summer (range: 0.01–2.55 day⁻¹ for Chl-*a*; 0.00–3.84 day⁻¹ for Chl-*b*; 0.26–3.29 day⁻¹ for fucoxanthin; 0.00–6.27 day⁻¹ for peridinin; 0.00–4.35 day⁻¹ for zeaxanthin). Microzooplankton grazing was an important loss process (range: 0.0–1.89 day⁻¹ for Chl-*a*; 0.00–3.12 day⁻¹ for Chl-*b*; 0.26–3.29 day⁻¹ for fucoxanthin; 0.00–2.03 day⁻¹ for peridinin; 0.00–3.51 day⁻¹ for zeaxanthin). Average grazing rates accounted for 68–89% of estimated average phytoplankton pigment-specific growth rates. The analysis of pigment signatures indicates that diatoms and dinoflagellates were the dominant groups, and contrary to expectation for typical subtropical lagoons, the specific growth rates in Bahía Concepción showed a pronounced seasonal variability, linked to transitional hydrographic conditions. Our results indicate a close coupling between the community microzooplankton grazing and phytoplankton growth rates, without selective feeding behaviour. These results suggest that microzooplankton play a critical role in and may significantly modify the availability and efficiency of transfer of energy to higher trophic levels.

Poster S6-3370**Effects of turbulence on clearance and ingestion rates of metazoan microzooplankton feeding on a natural microplanktonic community**R. **Almeda**, M. Alcaraz, F. Peters, E. Romero and A. Sabata

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The changes induced by small-scale turbulence on the grazing rates of metazoan microzooplankton on the different components of a natural microplankton community were studied by laboratory experiments. Eight, 15-L Perspex cylindrical microcosms containing coastal water were incubated during three days under controlled temperature, light and turbulence conditions. In four of the microcosms the metazoans had been excluded by reverse-flow filtration through 50 µm mesh (m- microcosms). In the remaining four microcosms the “*in situ*” community of metazoan microzooplankton (50-150 µm size organisms) had been concentrated three times, also by reverse-flow filtration (M- microcosms). Four microcosms, two duplicates from each trophic manipulation, were maintained in still conditions (S- microcosms), whereas the remaining four microcosms were subjected to the turbulence generated by vertically oscillating grids ($\epsilon = 0.055 \text{ cm}^2 \text{ s}^{-3}$, T- microcosms). The grazing rates were estimated by comparing the changes occurred along the incubation in the microplankton community of SM, Sm, TM and Tm microcosms. Turbulence enhanced clearance and ingestion rates of metazoan microzooplankton. This community, dominated by meroplanktonic invertebrate larvae, exerted a strong trophic impact on ciliates, flagellates and especially on dinoflagellates. Similarly, the microcosms under turbulence illustrate clear examples of trophic cascade effects.

Poster S6-3371

Role of metazoan microzooplankton in marine food webs: trophic impact and feeding performance

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We conducted twelve grazing experiments with the coastal Northwest Mediterranean metazoan microzooplankton community throughout an annual cycle, from September 2005 to September 2006. We expected to find very contrasting composition and abundance of both the metazoan microzooplankton and their prey. The experimental setup consisted of 24 hour incubations of natural sea water and aliquots of increasing concentrations of metazoan microzooplankton (50-200 μm) as predators. Here we present data on ingestion rates, grazing impact, and daily rations. We discuss the direct and indirect influences of metazoan microzooplankton on lower levels of the food web in order to better understand the role of this poorly studied compartment of zooplankton in marine ecosystems.

Poster S6-3455

The dynamics of microbial and herbivorous food webs in a coastal sea with special reference to physical events

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This presentation summarises our studies on the dynamics of microbial and herbivorous food webs in Uchiumi Bay, the Uwa Sea, Japan. There are two major physical events in the bay: bottom intrusion and intrusion of warm, oligotrophic surface water from Kuroshio Current, a phenomenon called kyucho. The bottom intrusion, which occurs mainly in summer, consists of deep, cold, nutrient-rich water that flows just over the continental shelf, serving as the major nutrient input to the bay. The dominant production during most of the year is probably defined to the microbial food web, where abundant heterotrophic bacteria are consumed by nanoflagellates. However, blooms of diatoms and eukaryotic picophytoplankton promoted by the nutrient inputs of the bottom intrusion have been observed in the bay. Thus, due to the occurrence of the bottom intrusions, the dominant biological matter cycling in the sea may be changed by a shift of the dominant food linkages from a microbial food web to a herbivorous food web. In accordance with this, high abundance of herbivorous copepods was found during the bottom intrusion, suggesting more dominance of the herbivorous food web. In situations with kyucho, high abundances of *Prochlorococcus* and *Synechococcus* are advected into the bay. *Synechococcus* is mainly consumed by nanoflagellates, and its abundance is in a quasi steady-state system with grazing losses compensated by growth. The abundant *Prochlorococcus* is consumed by both nanoflagellates and microzooplankton such as ciliates, and their grazing is one of the important loss processes for the cyanobacteria in the bay.

Poster S6-3459

Estimating *Calanus sinicus* grazing rate on phytoplankton and microzooplankton communities in the harmful algal bloom area of the East China Sea

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A new approach was used, which combines the techniques in Frost's grazing experiments and Landry's dilution experiments, in order to estimate the grazing rate of mesozooplankton on phytoplankton and microzooplankton. The study was carried out in April - June 2005 at six typical stations in the East China Sea, where red tides occur with high frequency. We studied changes in phytoplankton and microzooplankton community structure, *in situ* grazing rates of mesozooplankton on phytoplankton and microzooplankton, food composition of *Calanus*

sinicus, and microzooplankton grazing pressure on phytoplankton. The average phytoplankton species-specific growth rate was $2.0 \pm 1.3 \text{ d}^{-1}$, while the average species-specific growth rate of microzooplankton was $0.5 \pm 0.8 \text{ d}^{-1}$. The average grazing rate of *C. sinicus* on phytoplankton was $53 \pm 154 \text{ cells ind}^{-1} \text{ d}^{-1}$, corresponding to $326 \pm 575 \text{ ng C ind}^{-1} \text{ d}^{-1}$. *C. sinicus* was grazing heavily on some species of harmful algal, such as *Karenia mikimotoi*, *Pseudo-nitzschia delicatissima*, *Pseudo-nitzschia pungens*, *Chaetoceros curvisetus*, *Scrippsiella trichoidea* and *Prorocentrum dentatum*. The average species-specific grazing rate of *C. sinicus* on microzooplankton was $3.8 \pm 6.0 \text{ ind. ind}^{-1} \text{ d}^{-1}$, with the highest grazing rate for dominant prey species, such as *Codonellopsis mobilis*, *Favella campanula*, *Tintinnopsis beroidea* and *Strombidium sulcatum*. The total consumption of microzooplankton carbon by *C. sinicus* was on average $35.4 \pm 40.1 \text{ ng C ind}^{-1} \text{ d}^{-1}$. These results showed that the food composition of *C. sinicus* was usually dominated by phytoplankton, which contributed on average by $77.3 \pm 19.2 \%$ of the total food content. The grazing rate of mesozooplankton on phytoplankton was on average $2.2 \pm 1.6 \text{ ng C L}^{-1} \text{ d}^{-1}$, while the corresponding figure for microzooplankton was $2801 \pm 4198 \text{ ng C L}^{-1} \text{ d}^{-1}$. Our results show that microzooplankton were the main grazers on phytoplankton, accounting for 95-100 % (average $97.9 \pm 2.3 \%$) of the total grazing pressure, with mesozooplankton mainly affecting phytoplankton indirectly through their grazing on microzooplankton.

Poster S6-3481

Phytoplankton carbon flux in a highly stratified Chilean fjord: the role of zooplankton in the pelagic food web

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Southern fjords of Chile are marine systems where waters from freshwater and marine origins meet, generating haline fronts characterised by their strong horizontal and vertical gradients. A study was carried out to assess the spring-summer carbon budget in the pelagic food web, contrasting the direct effects of cladocerans and calanoid copepods on the pelagic food web to determine the existence of a general pelagic pattern that may be related or a consequence of haline vertical stratification in a fjord. Our results showed relatively high primary production during spring and summer periods. The relatively high phytoplankton downward export/production rate at this productive area was a consequence of the dominance of large-sized phytoplankton cells. The vertical salinity distribution through the fjord clearly confirmed the presence of a two-layer water column: a 5 m surface layer with a salinity in the range 5-20, below which there is a typical oceanic water with a salinity in the range 20-33. Feeding experiments with the calanoid copepod *Calanus chilensis* and the cladoceran *Podon* sp., and information on the vertical flux of particulate matter, showed that these were the main significant processes fuelling carbon throughout the pelagic food web in the fjord.

Poster S6-3483

Microzooplankton grazing in La Paz Bay 2003-2004

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Phytoplankton growth rates and grazing impact by microzooplankton were estimated from dilution experiments during autumn and winter 2003 and summer 2004 in La Paz Bay. The grazing impact of microzooplankton in autumn corresponds to an instantaneous mortality range of 0.18-0.91 d^{-1} and the range corresponding to grazing impact was 90-104% of phytoplankton standing stock per day. In winter the grazing of microzooplankton was between 0 and 0.30 d^{-1} ; the grazing impact was 88 to 98% of phytoplankton standing stock per day. In summer the grazing rate was between 0.05 and 0.07 d^{-1} , and the mortality of phytoplankton was close to 100% d^{-1} . The phytoplankton growth coefficient range was 0.33-0.83 d^{-1} in autumn, in winter was 0.02-0.56 d^{-1} , and in summer 0.05-0.07 d^{-1} . Phytoplankton grazing dropped 70% and 94% during winter and summer, respectively,

compared to autumn. The apparent growth coefficient of phytoplankton was 53% lower in winter compared to autumn; in summer, the phytoplankton grazing and its growth coefficient were lower than in autumn by 90%. The overall phytoplankton consumption by zooplankton fluctuated from 88-104%. The relationship between growth rates and mortality rates due to grazing were balanced throughout the period studied, with microzooplankton consumption on average accounting for close to 100% of phytoplankton growth, which suggests that the impact of grazing on phytoplankton can be high and produces a significant removal of primary production in Bahía de La Paz.

Poster S6-3491

Temporal variability in plankton food web structure and trophodynamics in Sagami Bay, Japan

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The plankton food web structure and trophodynamics, based on abundance, biomass, production rate and food requirement of pico- (<2 μm), nano- (2–20 μm), micro- (20–200 μm) and mesoplankton (>200 μm , mainly copepods) at the 0–10 m layers were investigated in the neritic area of Sagami Bay, Kanagawa, Japan, from January 2002 to December 2005. The 0–10 m depth-integrated biomass was 226–8388 (mean 1229) mg C m^{-2} , and phytoplankton, bacteria, microzooplankton and copepods constituted 65.6 % (<20 μm : 32.1%; >20 μm : 33.4%), 14.9%, 14.7% and 4.8% of the mean total plankton biomass, respectively. Primary production (PP) determined by ^{13}C *in situ* incubation ranged from 0 to 1321 $\mu\text{g C L}^{-1} \text{ day}^{-1}$, corresponding to 0.01–3.89 $\text{g C m}^{-2} \text{ day}^{-1}$. The depth-integrated production rate of bacteria, heterotrophic nano-flagellates (HNF), microzooplankton (MZ), copepod secondary (CSP) and tertiary producers (CTP) was estimated to be 0.004–0.25, 0.002–0.32, 0.005–0.44, 0.001–0.02 and 0.0002–0.007 $\text{g C m}^{-2} \text{ day}^{-1}$, respectively. Transfer efficiency from PP to secondary producers (MZ+CSP) and CTP was 0.31–96.5% (mean: 8.4%) and 0.012–5.7 % (mean: 0.17%), respectively. The depth-integrated food requirement by HNF, MZ, CSP and CTP was estimated to be 0.005–0.79, 0.01–0.96, 0.002–0.08, and 0.0004–0.02 $\text{g C m}^{-2} \text{ day}^{-1}$. Based on the production rate and food requirement during the study period, the microbial food chain was the main route of carbon flow from PP to CTP rather than the classical food chain, although the importance of these two food chains could vary seasonally.

Poster S6-3493

Plankton food web structure and trophodynamics in Sagami Bay, Japan, in spring–summer 2006

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Abundance, biomass, production rate and food requirements of pico- (<2 μm), nano- (2–20 μm), micro- (20–200 μm) and mesoplankton (>200 μm) were measured fortnightly from April to September 2006 in the neritic area of Sagami Bay, Kanagawa, Japan. The pico-, nano-, and microplankton samples were collected at 0, 10, 20, 30, 40 and 50 m depth. Mesozooplankton samples were collected by vertical tows from the bottom (ca. 55 m) to the surface using a 200 μm -mesh plankton net. Primary production (PP) determined by ^{13}C *in situ* incubation for 24 hours was 0.17–1.01 $\text{g C m}^{-2} \text{ day}^{-1}$. The depth-integrated production rate of bacteria, heterotrophic nano-flagellates (HNF), microzooplankton (MZ), mesozooplankton secondary and tertiary producers (MesoZSP and MesoZTP, respectively) was estimated to be 0.037–0.111, 0.010–0.234, 0.077–0.226, 0.020–0.204 and 0.0042–0.025 $\text{g C m}^{-2} \text{ d}^{-1}$, respectively. Transfer efficiency from PP to secondary producers (MZ+ MesoZSP) and MesoZTP was 15.0–101.2% (average = 47.5%) and 0.9–10.0% (average = 3.0%), respectively. The depth-integrated food requirement by HNF, MZ, MesoZSP and MesoZTP was 5.5–151.8% (average = 52.3%), 24.0–254.6% (average = 87.2%), 6.8–105.2% (average = 43.2%), and 2.4–28.6% (average = 8.3%) of PP, respectively. The results suggest that primary production could not fully balance these food requirements. The microbial food chain was usually most important for the carbon flow to higher trophic levels during the study period, but a shift to dominance of a classical food chain with high abundance and production of cladocerans occurred in the beginning of August.

Poster S6-3584

Trophic coupling of *Synechococcus* and nanoflagellates in a bay of the Uwa Sea, Japan

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The cyanobacterium *Synechococcus* is widely distributed as the principal components of phytoplankton biomass in the world's oceans, comprising the most important part of marine primary production. However, we still cannot define the main grazers of the cyanobacterium, although we know that nanoflagellates are potential grazers of *Synechococcus*. We here report from monthly investigations on the vertical abundances of *Synechococcus* and nanoflagellates in Uchiumi Bay, Japan, from October 2003 to May 2006 in order to define the trophic relationship between them. Mean abundances of *Synechococcus* and nanoflagellates in the water column (0–50 m depth) varied from 4.7×10^2 to 5.8×10^5 cells ml⁻¹ and from 7.5×10 to 1.8×10^3 cells ml⁻¹, respectively, and high abundances were found during summer. There was no significant correlation between abundance of *Synechococcus* and abundance of nanoflagellates ($p > 0.05$). However, in 17 months out of 32, we could detect nanoflagellate cells which contained *Synechococcus* cells within their food vacuoles. In addition, the abundance ratios of *Synechococcus* to bacteria in the months when we found ingestion of *Synechococcus* by nanoflagellates were significantly higher than those when no ingestion was found (Mann-Whitney test, $p < 0.05$). Further, there was a significant positive correlation between mean abundance of heterotrophic bacteria and that of nanoflagellates for the whole study period ($p < 0.05$), suggesting a close trophic linkage between these two microorganism groups. We propose that the main food item for nanoflagellates in the bay is heterotrophic bacteria, and that *Synechococcus* serve as foods for nanoflagellates only when the cyanobacterial abundance is very high compared to the bacteria abundance.

Poster S6-3594

First estimate of copepod grazing on the tintinnid *Stenosemella nivalis* in the Gulf of Trieste (northern Adriatic Sea)

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The tintinnid *Stenosemella nivalis* is a typical component of the microzooplankton community in the Gulf of Trieste (northern Adriatic Sea), with abundances rarely exceeding 400 tintinnids l⁻¹. Analyses on a large data set (1986-1990, 1998-2005) of monthly samples revealed a winter-early spring presence, more regular in the 1980s in comparison with the last period. In February 2000 we recorded the maximum abundance of *S. nivalis* of 3084 tintinnids l⁻¹. In this occasion we carried out a grazing experiment incubating adult specimens of the calanoid copepods *Acartia clausi* and *Calanus helgolandicus* in natural surface seawater from the Gulf of Trieste. The microplankton fraction was almost entirely constituted by the diatom *Skeletonema costatum*, which accounted for 98% on carbon basis, corresponding to 280 $\mu\text{g C l}^{-1}$. The diet of the copepods was mainly this diatom. However, copepods selectively preyed upon the less abundant tintinnid, with a relatively high grazing rate of 68 tintinnids copepod⁻¹ day⁻¹ (*A. clausi*) respectively 224 tintinnids copepod⁻¹ day⁻¹ (*C. helgolandicus*).

Poster S6-3629

Temporal variations in microplankton species composition off the central Oregon coast (2001-2005) and its influence on copepod population structure and biomass

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Recent laboratory studies have shown several diatom species to induce low hatching success and abnormal naupliar development in certain copepod species through the production of abortifacient aldehydes. Field studies on the negative effects of such diatom species on the reproductive success of planktonic copepods however are few. Here we present results of an analysis of seasonal, annual and inter-annual variations in microplankton community composition at station NH05 along the Newport Hydrographic Line (44°40'N) Oregon, and examine the extent to

which this acts as a control for copepod species diversity and biomass. Surface water samples were collected on a bi-weekly basis between 2001 and 2005 and analysed microscopically for relative abundances of diatom species known to produce abortifacient aldehydes. Abundances of domoic acid producing diatom species from the genus *Pseudo-nitzschia* and both auto- and hetero-trophic dinoflagellates were also generated. All microplankton data was then compared with simultaneous data on copepod species diversity and biomass and regression analyses used to elucidate the effects of each microplankton species group on copepod egg production, naupliar survival and recruitment. These data were then examined in the context of basin-scale climatological events, namely the Pacific Decadal and El Niño Southern Oscillations, to assess the possible bottom up effects such forcing may have on microplankton species composition and copepod population structure and biomass.

Poster S6-3636

Contribution of planktonic protozoa to *Acartia hongii* diets in Kyeonggi Bay, Yellow Sea

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In order to understand the grazing effects of copepods in a plankton food web, grazing experiments were conducted with *Acartia hongii*, the dominating planktonic copepod in Kyeonggi Bay, Yellow Sea. In the laboratory, *Acartia hongii* were fed on equi-proportional mixtures of planktonic ciliates (*Rimostrombidium orientalis*, *Tintinnopsis angustior* and *Favella* sp.), and the dinoflagellate *Heterocapsa triquetra* or diatoms (*Skeletonema costatum* and *Thalassiosira* sp.). In the field experiments, *Acartia hongii* was fed on natural microplankton assemblage from Kyeonggi Bay. In the laboratory, ingestion rate of *A. hongii* on planktonic ciliates and phytoplankton increased in proportion to prey abundance. When *A. hongii* was fed ciliates and phytoplankton, the ingestion rate of *A. hongii* on ciliates tended to increase with increased ratio of ciliate: phytoplankton carbon. In the field, ingestion rates of *A. hongii* on planktonic protozoa were higher than those of phytoplankton, except during periods with phytoplankton bloom. The highest ingestion rate of *A. hongii* on protozoa was observed when autotrophic flagellates dominated. Of the total carbon ingested by *A. hongii*, planktonic protozoa contributed from 1.5 to 83% in the laboratory experiments, and from 3 to 90% in the field experiments. The results suggest that protozooplankton is an important component of the diet of *A. hongii* outside the phytoplankton bloom periods. The population dynamics of planktonic protozoa could therefore be significantly influenced by predation of the copepods in Kyeonggi Bay.

Poster S6-3640

Reproductive responses of copepod species in the Chilean northern upwelling system: the role of the nanoplankton fraction

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The significance of nanoplankton food for the diet and reproduction of copepods is relatively unknown for the Chilean upwelling system. While several copepod species are omnivorous, the efficiency by which they can use nanoplankton food for reproduction has rarely been studied in nature. During the summer campaign 2006 of CENSOR WP-2 project, a series of experiments with *Acartia tonsa* and *Centropages brachiatus* fed on natural nanoplankton were carried out in two upwelling zones off Chilean northern: Mejillones Bay (23°S) and Chipana Bay (21°S). Copepod incubations were followed by periods of 48 hours at 15 ± 1°C. Nanoplankton biomass and composition were established through epifluorescence microscopy techniques. The reproductive efficiency displayed by both species with the supplied food, was studied by mean the egg production rate (EPR), faecal pellet production rate (FPPR), ingestion rate (IR) and gross efficiency on egg production (GEEP). Six protist groups were identified and the food concentration was < 30 µg L⁻¹. EPR varied between 0.3 and 0.5 µg C female⁻¹ d⁻¹; FPPR varied between 0.10 and 0.20 µg C female⁻¹ d⁻¹; IR varied between 0.06 and 0.13 µg C female⁻¹ d⁻¹ and GEEP always was > 60%. Despite the narrow dietary offer and low food concentration covered, these results showed that more than 50% of ingested carbon was invested in egg production and the nanoplanktonic diet was efficiently used by both copepod species, revealing a high metabolic plasticity to cope with a strongly variable food supply in this upwelling zone.

Poster S6-3647

Possible controls on the abundance of planktonic ciliates in a bay of the Uwa Sea

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The seasonal vertical distribution of planktonic ciliates was studied in Uchiumi Bay of the Uwa Sea, Japan, from 2001 to 2006. There were cyclic patterns of thermal stratification between May and September and high chlorophyll *a* concentrations due to diatom blooms from March to June, when the ciliate abundance also was high. Dominant ciliate taxa in the bay were oligotrichous *Strombidium*, *Strobilidium*, *Lohmanniella*, and loricate *Tintinnopsis*. The abundance of heterotrophic bacteria and pico-cyanobacteria were usually high during the stratified period, the former one also during the diatom blooms. The seasonal cycle in nanoflagellate abundance varied from year to year. Pearson correlation analyses for the data between 2001 and 2005 showed significant positive correlations ($p < 0.01$) between concentration of chlorophyll *a* and abundance of heterotrophic bacteria, between abundances of heterotrophic bacteria and nanoflagellates, and between abundances nanoflagellates and each dominant ciliate taxon. Significant positive correlations were also found between abundances of heterotrophic bacteria and *Strombidium* ciliates, and between abundances of heterotrophic bacteria and *Strobilidium* ciliates. Thus, we define a transfer from phytoplankton primary production to ciliates via bacterial production, grazing on heterotrophic bacteria by nanoflagellates and predation on nanoflagellates by ciliates in Uchiumi Bay.

Poster S6-3696

Spatio-temporal and ecological role of microzooplankton in the central and eastern Arabian Sea

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Energy transfer from lower to higher trophic levels still remains a matter of concern even after major international programmes such as JGOFS and GLOBEC. Microzooplankton are capable of consuming a significant portion of daily primary production and form a considerable portion of larval fish food. In this study the role of microzooplankton in marine food web is explored with special reference to the eastern Arabian Sea where a switch over from conventional to microbial food web takes place seasonally, which ultimately results in sustaining the invariable mesozooplankton biomass “Arabian Sea paradox”. The Arabian Sea is unique due to monsoonal reversals leading to temporal variations in physical and chemical regimes, which in turn affect biological processes. Upwelling along the western and eastern boundaries during the southwest monsoon result in higher productivity along with open ocean upwelling. During the Northeast monsoon convective mixing and deepening of the mixed layer in the northern Arabian Sea causes increased primary production. During the spring intermonsoon, a transition period between northeast and southwest monsoon, the entire Arabian Sea becomes highly stratified and oligotrophic. Phytoplankton, bacteria, microzooplankton and mesozooplankton were studied during these seasons. Microzooplankton abundance and carbon biomass during intermonsoon were higher when phytoplankton biomass was the lowest. Overall, higher biomass of microzooplankton occurred in the coastal region than in the open ocean and had seasonal shifts. Analyses of microzooplankton along with other biological parameters suggests that they are nutritionally facultative and may feed on phytoplankton, bacteria or detritus depending on the available food. Their predominant source a food seems to be phytoplankton during southwest and northeast monsoon seasons but bacteria during spring intermonsoon. The seasonal average carbon biomass of microzooplankton accounted for 23-50% of the total living carbon in the pelagics, which at times even exceeded that of mesozooplankton, indicating that the microzooplankton play a key role in the food web. Further, microzooplankton role in the ‘microbial loop’ in the stratified, low-chlorophyll waters of the Arabian Sea during the spring intermonsoon period which, along with the uniformly high productivity during the northeast and southwest monsoon, provides explanation to the “Arabian Sea Paradox”. The microzooplankton abundance and community composition differed between the estuary (Zuari) and the open sea. Average seasonal abundance of microzooplankton during the Zuari estuary was much higher than in the open waters. Ciliates dominated the coastal and estuarine waters while, heterotrophic dinoflagellates were more common in open waters. Within the estuary, salinity was the dominant controlling factor and microzooplankton abundances were generally correlated with phytoplankton abundance. Further, the microzooplankton biomass formed a large carbon pool in the Zuari estuary, and accounted for 24-40% of the living carbon. In the Zuari estuary, the living carbon biomass of phytoplankton, bacteria and heterotrophic nanoflagellates appeared to be insufficient to sustain observed standing stock of microzooplankton during post and premonsoon. Thus non-living particulate carbon, i.e. detritus, may be important in the nutrition of microzooplankton during these seasons, with a transfer efficiency of 2.8% from primary to tertiary production.

S7 Environmental and other constraints on zooplankton behaviour, life histories and demography

30 May, 09:05 (S7-3368) Invited

Phenotypic variability in life history traits: is intra-population variability important for zooplankton dynamics?

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We address the question to what degree quantitative life history traits, such as body size and development time, vary within and between zooplankton populations, and if this variability matters for our understanding of their population dynamics on ecological time scales. Four approaches are applied: (1) a comparison of field and lab-reared copepod populations with respect to the degree of variability in body length and width, where it is assumed that the field population consists of individuals with potentially different environmental histories and thus should display higher variability than a lab-reared population that was kept under constant conditions over several generations. (2) To estimate heritability of these traits, artificial selection on body size in both directions was exerted on a lab population of *Acartia tonsa* over a number of generations. (3) About 50 individuals were reared individually from egg to adulthood and their development rates compared with their siblings, both within and between offspring from several females. (4) Finally, the body sizes, egg production and development rates obtained from the experiments are implemented into an individual-based model (IBM) to test for a possible effect on population dynamics on the scale of one to multiple generations. The implications for current methods in zooplankton field sampling, such as spatial and temporal frequency, replicates, etc. are discussed.

30 May, 09:35 (S7-3639)

Linkage between Antarctic krill (*Euphausia superba*) and primary production

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One of the goals in the analysis of the time-series data collected by the Palmer Long-Term Ecological Research (LTER) programme west of the Antarctic Peninsula (64°S to 69°S) between 1993 and 2004 has been to compare patterns in time and space variability and to investigate linkages among multiple ecosystem parameters and functions. Each January about 50 stations within a 400 km (alongshore) by 200 km (on/offshore) grid were surveyed; the long-term, multi-disciplinary data set created is a strong analytical tool. Within this epipelagic ecosystem, Antarctic krill (*Euphausia superba*) is one of the abundant macro-zooplanktonic grazers. Analysis of the long-term mean spatial distribution (climatology) and the differences between the climatology and a specific year (anomaly) revealed that the climatologies for Antarctic krill and primary production are similar, with a strong on/off shore gradient and a moderate alongshore gradient. Both the level of annual primary production and the abundance of Antarctic krill were highly cyclical. Inspection of the anomalies showed that there was a 1-year lag in the cycles, with positive anomalies in primary production followed by positive anomalies in abundance of Antarctic krill the following year. The process underlying the time/space linkage appears to be food-limitation in reproduction in Antarctic krill. Discussion about the role of winter sea ice in survival of the young-of-the-year has been ongoing for decades, but the role that variability in reproductive effort plays in overall recruitment success deserves greater attention.

30 May, 09:55 (S7-3375)

Multiscale patchiness of *Calanus finmarchicus* in an oceanic environment

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Three-dimensional data on hydrography, chlorophyll *a* concentration and zooplankton abundance were collected in an oceanic area (10,000 km²) of the NE Norwegian Sea (70°N, 13°E) in spring 2003 by semiautomatic sampling with a towed vehicle equipped with an optical plankton counter. Data from the semiautomatic sampling device were carefully calibrated with water samples and net samples from the area. Developmental stages of *C. finmarchicus* were highly patchy in distribution, both in the horizontal plane and along the vertical depth axis. Furthermore, young developmental stages were clearly separated from older copepodites. In order to analyse the effect of hydrography and chlorophyll *a* concentration (food) on distribution patterns, the size of the patches was measured and a 3D multiscale analysis of the data was performed. The importance of hydrography and food availability differed among different scales with copepodite behaviour being important on small scales.

30 May, 10:15 (S7-3585)

The impact of macrozoobenthos on the benthic life stage of zooplankton

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Long-lived resting stages form an integral part of zooplankton life cycles. Dormant eggs accumulate on the seafloor and in the sediment where they are subject to various benthic processes. The presentation will summarise several recent studies of effects of functionally different epi- and infaunal zoobenthic species on zooplankton benthic eggs in the Baltic Sea. Epifaunal benthic mysids (*Mysis* spp.) as well as sediment-dwelling mobile amphipods (*Monoporeia affinis*) and semi-mobile bivalves (*Macoma balthica*) were observed to feed on or reduce the number of cladoceran benthic eggs in sediment. In contrast, deep-burrowing polychaetes (*Marenzelleria* spp.) did not affect the number or vertical distribution of cladoceran eggs. Besides predatory effects, the bivalves buried eggs into deeper sediment strata, which prevents hatching. In addition, the bivalves and the amphipods also significantly increased the mortality rates of benthic eggs of copepods and rotifers. Both the bivalves and the amphipods suppressed the emergence of copepods, cladocerans, and rotifers from benthic eggs, but, in general, the bivalves had a more adverse effect than the amphipods. Video clips of the bivalves preying upon zooplankton hatchlings will be shown. Overall, copepods were less severely affected than cladocerans and rotifers, and in copepods, diapause eggs were less susceptible than subitaneous eggs. The results demonstrate that both epi- and infauna substantially influence the viability and hatching of zooplankton benthic eggs and may affect the dynamics of their pelagic populations.

30 May, 11:00 (S7-3536)

Eat, glow and die: predation by nocturnal fish on zooplankton which graze on bioluminescent bacteria

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The Burglar Alarm Hypothesis suggests that bioluminescence is advantageous for unicellular plankton as it increases the predation risk of zooplankton attempting to graze on it. The hypothesis has been corroborated by experiments focusing on the luminescence generated by motions of zooplankters in dinoflagellate-rich waters, rather than the glow generated after the ingestion of bioluminescent cells. Our experiment was designed to test the latter mechanism. It was carried out in a large, recirculating flume inhabited with *Apogon annularis*, a nocturnal, zooplanktivorous coral-reef fish. The fish's functional response is light dependent with zero prey detection in complete darkness. Glow was induced in brine shrimps (*Artemia salina*) after feeding them for 10 sec on cultured

Photobacterium leiognathi, a bioluminescent bacterium isolated from local waters. Microscopic examination showed that the source of light in the glowing *Artemia* was inside the digestive tract. Ten *Artemia* were put in the flume and allowed to drift past the fish 2-3 times at 6 cm/s in complete darkness. Almost all the glowing *Artemia* were consumed by the fish, whereas non-glowing *Artemia* were rarely captured, and only when drifting directly toward the fish's mouth. Infra-red video recording indicated that the fish detected the glowing prey from a distance greatly exceeding its reactive distance under saturating light. The bioluminescence produced by zooplankton freshly collected at sea, including krill, was insufficient to be detected by the fish except if artificially fed on glowing *P. leiognathi*. Our results suggest that zooplankton experiences a strong selection against grazing on glowing nanoplankton.

30 May, 11:20 (S7-3470)

Effects of turbulent flow fields on fish predation and mating success of *Pseudodiaptomus annandalei* (Copepoda: Calanoida)

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The fitness of an organism depends in part upon (1) its efficiency at escaping from predators and (2) its probability of effective mate encounters. We tested the abilities of copepods in these respects under various hydromechanical disturbance regimes. The calanoid copepod *Pseudodiaptomus annandalei* was used as an experimental model. We studied its escape response to predatory attacks by larvae of the orange-spotted grouper, *Epinephelus coioides*, and we studied its mating success under calm and turbulent conditions both day and night. At night we used infrared sensitive cameras to observe mating behaviour. The effect of turbulence intensity on copepod behaviour was studied by increasing the strength of air bubbling (600, 1200 and 1800 ml per min). The detection of predators, measured by the escape reaction of the copepods, was significantly higher in calm waters than in turbulent waters. Under calm conditions *P. annandalei* was able to escape by darting away from fish larvae at speeds of up to 143 body lengths per second, whereas under turbulent conditions escape speeds decreased and responses habituated. Regardless of external hydromechanical disturbances, the removal of copepods by fish larvae was more than an order of magnitude higher during day than at night. Differences between turbulent flow and calm water in the vulnerability of copepods to fish predation were not significant at night. The probability of mating success in turbulent flow fields is inversely related to the strength of flow, as well as to the level of turbulence. Our results indicate that the strengths of turbulent flow fields greatly influence not only larval fish predation on copepods, but it also decreases the mating success of the copepods themselves.

30 May, 11:40 (S7-3625)

Phenologic patterns result in an optimal window for survival of Atlantic cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) larvae on Georges Bank

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Changing climate and global depletion of fish stocks have added urgency to the century old quest to understand the factors controlling fish production. The leading hypotheses advanced to explain the large (orders of magnitude) inter-annual variability in recruitment emphasise rapid growth and a match to prey production in the first weeks after hatching when larvae drift as part of the plankton community. Here we show for two important North Atlantic ground fish (Atlantic cod, *Gadus morhua* and haddock, *Melanogrammus aeglefinus*) that seasonal patterns in the weight-specific growth (G) and the instantaneous mortality (M) rates of young larvae combine in some years to yield a window of opportunity when M falls below G within days after hatching and cohort biomass increases rapidly leading to potentially high recruitment. Contrary to expectations, this window occurs early in the seasonal production cycle (February-March) when water temperatures are near

their annual minimum, fish larvae and their zooplankton prey are relatively scarce, and G is low. Later, faster-growing cohorts are rapidly lost to a suite of vertebrate and invertebrate predators, whose abundance, metabolism and consumption increase with temperature. Both species appear to follow Pope *et al.*'s (1994) 'optimal fish strategy' in a size-structured, seasonally-forced ecosystem, hatching in advance of the seasonal prey wave to stay ahead of the predator wave for as long as possible before passing through at the largest practical size, thereby minimising predation mortality. Other factors being equal, an early and prolonged spring bloom should favour production of a strong year class.

30 May, 12:00 (S7-3620)

Life strategies of dominant Antarctic calanoid copepods in late winter/early spring

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The life cycles of Antarctic copepods are all well timed to the distinct annual periodicity in primary production. However, our knowledge in particular of the transition time from winter to spring is not yet complete and studies especially on physiological and biochemical adaptations are extremely rare. In September–October 2006 we studied the life strategies of calanoid copepods in the Scotia and Weddell Seas. The investigations included the vertical distribution, age structure, feeding, respiration, excretion, lipids, C:N and ion regulation. In September, a winter situation was encountered with a maximum in abundance at greater depths: the bulk of the copepod *Calanoides acutus* was concentrated below 1000 m and CV dominated. The specimens showed no or very low ingestion as well as very low respiration and excretion rates indicative of overwintering conditions. In contrast, *Calanus propinquus* occurred in upper waters and was clearly feeding. Six weeks later, in mid October, a spring bloom had developed in the Scotia Sea and *C. acutus* had left the winter quarters at depth and returned to the highly productive surface. Experiments revealed high ingestion, respiration and excretion rates. Interestingly, both *C. acutus* and *Rhincalanus gigas* had large amounts of ammonium in the haemolymph. This phenomenon was not detected in the other copepod species studied. The significance of these findings will be discussed with respect to the life strategies of the species and relationships to environmental parameters.

30 May, 12:20 (S7-3642)

Population structure and reproduction of the chaetognath *Eukrohnia hamata* in the Canada Basin, Arctic Ocean

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Population size structure, vertical distribution and parameters of reproduction of the chaetognath *Eukrohnia hamata* were studied in the Canada Basin of the Arctic Ocean during the summer of 2005. Analysis was based on stratified zooplankton collections covering the depth range from 3000 m to the surface. Individual length ranged from 2.5 to 38 mm. Younger juvenile specimens <10 mm comprised ~80% of the population, while specimens >20 mm contributed only 5%. Size of the mature specimens, carrying 2 ovoid egg-sacs within the marsupium, varied between 27 and 36 mm. The chaetognath was encountered throughout the Arctic surface water layer and Atlantic water down to 1000 m depth, but not deeper. Specimens with eggs and embryos in the marsupium, and the smallest young specimens of 2.5–3 mm, were found mostly between 500 and 750 m depths. Juveniles of 4–10 mm length showed a clear preference for the layer between 100 and 500 m suggesting the upward ontogenetic migration of the growing specimens to strata with richer prey densities. Number of eggs and embryos in egg sacs of mature specimens varied from 50 to 137 with a maximum of 266 eggs and embryos per specimen. Embryonic development was examined and documented from the egg stage to hatching for the first time.

30 May, 14:00 (S7-3570)

Control of *Calanus finmarchicus* dormancy patterns in the northwest Atlantic: the Lipid Accumulation Window hypothesis

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We seek to develop for inclusion in population dynamics modelling a mechanistic understanding of dormancy in the life cycle of *Calanus finmarchicus*. We compiled *Calanus* life cycle and environmental data sets, including ambient water temperature, food availability (measured as mean chlorophyll *a* concentration in the surface water column), photoperiod and life stage abundance cycles, across six regions in the NW Atlantic spanning 9 degrees of latitude. We used as proxies for dormancy entry and exit the proportion of stage CV (year day when the CV proportion is at one half of its climatological maximum proportion) and the proportion of adult females (year-day when adult females reach 10% of the population), respectively. Our first results show that no single observed environmental cue explains the range of dormancy patterns; rather, dormancy entry and emergence occur over a broad range of times, both among years and regions. We propose a “Lipid-Accumulation Window (LAW)” hypothesis, in which dormancy entry and exit involves interaction of multiple environmental factors with the copepod’s physiological responses, including lipid accumulation and development rates. We postulate that an individual enters dormancy when it has accumulated $\geq 50\%$ of its dry weight as lipid by the end of stage CV; if this condition is not met, it continues molting to adult. The lipid accumulation rate is dependent on ambient temperature and food availability. There is, therefore, a seasonal window of conditions that will allow dormancy. We are testing this hypothesis using individual based models against the observed data.

30 May, 14:20 (S7-3595)

Capital and income breeding as reproductive strategies in zooplankton

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Seasonality in food availability and predation risk strongly shapes zooplankton life histories. The seasonal cycle may cause time constraints on development, and therefore marked seasonality in the value of an egg. Phenology and life-history adaptations of later stages are expected to reflect such constraints. Some species prepare for reproduction by storing resources in advance, a reproductive strategy referred to as capital breeding. Capital breeders can, due to their stores, reproduce at times and places where food is unavailable, but where offspring value is potentially high. Others rely on concurrent food availability for reproduction, a strategy referred to as income breeding. High latitude zooplankton, and particularly copepods, offer a variety of examples along the capital-income breeder continuum. We discuss pros and cons of capital and income breeding and present general predictions motivated by a life history model of the Southern Ocean copepod *Calanoides acutus*. Our model predicts optimal life-history traits such as allocation of resources between growth and reproduction, timing of diapause, and breeding through income or capital pathways. The model is detailed on the individual states (somatic structure and energy reserves) and the model finds optimal life histories for all possible state combinations by dynamic programming. We show how capital breeding is used to shift breeding ahead of the feeding season, at a time when the value of an egg is high (developmental time constraint and predation risk reduced). The state-dependent model predicts that only parts of the population should be capable of, or will benefit from, early capital breeding.

30 May, 14:40 (S7-3607)

Life histories of *Calanus sinicus* and *Calanus jashnovi* (Copepoda: Calanoida) in the 1000 m water column of Sagami Bay, central Japan

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Seasonal changes in abundance, development and vertical distribution of *Calanus sinicus* and *C. jashnovi* were investigated in Sagami Bay, central Japan on the basis of monthly stratified sampling in the 1000 m water column from May 2002 to January 2004. *Calanus sinicus* showed a biphasic life history at copepodite stage 5 (C5). All copepodite stages of *C. sinicus* occurred in the 0-200 m stratum throughout the year, with seasonal and annual variation in abundance. At the same time, some C5 showed a diapause below 200 m from spring to autumn. Integrated individual numbers of the diapausing C5 per m⁻² in the 200-1000 m stratum were 2640-3728 (average 3040) in May-June, 5792 in July, 3872-6112 (average 5355) in September-October, and 0-368 (average 135) in November-February. Thus, the population built up in the stratum below 200 m from spring to summer, was constant during autumn, and emerged from diapause and matured in early winter. *Calanus jashnovi* showed a diapause at C5 in the stratum below 400 m during May to January and did not show a biphasic life history like that of *C. sinicus*. Female and male C6 of *C. jashnovi* appeared in the 200-400 m stratum in February, and then a new generation of C5 and C4 was observed at 0-200 m in March. However, since the other early copepodite stages did not occur in any season, *C. jashnovi* probably does not complete its life cycle in Sagami Bay.

30 May, 15:00 (S7-3733)

Comparative ecology of *Calanoides carinatus* and *Calanus agulhensis* in the southern Benguela and Agulhas Bank ecosystems

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Calanoides carinatus and *Calanus agulhensis* are similarly sized species that dominate the copepod biomass of the southern Benguela and adjacent Agulhas Bank ecosystems off South Africa respectively. *Calanoides carinatus*, a typical upwelling species, is largely concentrated on the West Coast, which is characterised by wind-induced coastal upwelling from spring through to autumn. Highest densities of *C. agulhensis* occur on the central Agulhas Bank, a triangular extension of the southern continental shelf, which has a seasonal structure typical of temperate continental shelf systems. Both species are present year-round and display considerable overlap in distribution. However, the separation of their core areas suggests that there are fundamental differences between the two species that make them better suited to their respective areas of dominance, and allow them to maintain life-cycle closure there. Physical and environmental disparities between their core habitats present a number of key hypotheses to be tested: that *C. carinatus* and *C. agulhensis* (1) have different thermal preferences or tolerances, (2) have different dietary requirements in terms of food abundance, size and/or type, (3) are adapted to different scales of temporal variability of food availability, and (4) have different vertical migratory behaviour and/or population retention mechanisms. Data from laboratory- and ship-based experiments, diel vertical migration studies, and extensive sampling over 13 years are used to test these hypotheses.

30 May, 15:20 (S7-3485)

Chasing all kinds: heterospecific mating, reproductive isolation and population dynamics in planktonic marine copepods

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Marine zooplanktonic species often co-occur in the water column with closely related congeners, and distinguishing conspecific from heterospecific potential mates is an important component of reproductive success for pelagic organisms. Through laboratory experiments on the copepod species *Centropages typicus*, *Centropages hamatus*,

Temora longicornis, and *Temora stylifera* we demonstrate that diffusible chemical pheromones, which are known to play an important role in copepod mate finding, are not used for species discrimination in these species. Males are able to detect and track pheromone trails of females of not only the congeneric species but also across genera (*Centropages* – *Temora*). Furthermore, males will attempt to mate with heterospecific, congeneric females at comparable frequencies to conspecific females. In order to determine whether heterospecific mating attempts are common in natural populations, we calculate encounter rates of hetero- and conspecific combinations of *Centropages* females and males by combining laboratory measurements of copepod motility with field observations of adult abundances. Our results indicate that although temporal isolation may be an important contributor to reproductive isolation for *Centropages* species, at times when the species co-occur males may encounter and attempt to mate with heterospecific females at rates up to 9 females day⁻¹. Heterospecific mating attempts may be relatively common in planktonic copepod populations.

30 May, 16:00 (S7-3505)

Seasonal changes in food quantity and quality for the development and egg production of the common North Sea copepods *Temora longicornis* and *Pseudocalanus elongatus*

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Copepod population dynamics and production in the sea are largely determined by temperature and food environment. In a bioassay approach, we evaluated the food quantity and quality over a seasonal cycle for the growth and egg production of the common North Sea copepods *Temora longicornis* and *Pseudocalanus elongatus*. Seston was sampled from December to October from a well-mixed water column of Marsdiep (Dutch Wadden Sea), and fed to cultured copepods at a constant temperature of 15°C, thus excluding seasonal effects of temperature and copepod condition. In addition to copepod egg production and juvenile development, we measured the chlorophyll-*a*, POC: PON, fatty acid and sterol composition of the seston. The egg production of both copepods was low when feeding with seston collected in winter, but increased to high values with the seston from the spring bloom in March-April, coinciding with the highest seasonal concentrations of PUFAs and sterols. However, whereas *T. longicornis* egg production correlated with the concentration of polyunsaturated fatty acids and sterols, *P. elongatus* egg production appeared to be connected to seston PON concentration. The juveniles of both species were able to complete their development only in March, whereas during all other months the development ceased in early copepodite stages. Our results show a 3-fold difference in egg production due to the seasonal changes in food conditions, and suggest that only abundant high quality food allows juvenile copepods to develop into maturity.

30 May, 16:20 (S7-3360)

Effect of temperature on egg development time and hatching success of three congeneric Acartiid species (Copepoda: Calanoida) from the Straits of Malacca

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Development time and hatching success are presented for eggs of three congeneric Acartiid copepods, *Acartia spinicauda*, *A. erythraea* and *A. pacifica*, from the Straits of Malacca (Malaysia). Development time was observed from the time spawned to hatching of eggs as nauplius stage I at six temperatures (10, 14, 18, 22, 27 and 31°C). Development times of the three species were significantly related to incubation temperature and each fitted to a Bełehradek's function. Hatching success at temperatures from 14-31°C was on average 61 ± 26, 78 ± 8 and 87 ± 8% for *A. erythraea*, *A. pacifica* and *A. spinicauda*, respectively. The copepods' eurythermic hatching success may be characteristic of coastal species which experience frequent temperature fluctuations. Egg development times of *A. erythraea*, *A. pacifica* and *A. spinicauda* are $D=294(T-4.47)^{-2.05}$, $D=894(T+1.94)^{-2.05}$ and $D=352(T-4.30)^{-2.05}$, respectively. Similar Bełehradek's function is suggested to reflect the habitat distribution of *A. erythraea* and *A. spinicauda* which primarily inhabit tropical and sub-tropical waters while a lower 'biological zero' is reflective

of *A. pacifica* distribution which can extend to temperate regions as far as Posvet and Amur gulfs (Sea of Japan). Egg development times observed in this study are compared with findings from previous studies performed on other *Acartia* species and from other copepod genera. Estimation of egg development time and hatching success is an important first step to empirically determining generation duration and population dynamics of the plankton in the tropical coastal waters of the Straits of Malacca.

30 May, 16:40 (S7-3304)

Predicting development times in marine copepods using an optimal life-history approach

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Strong inter-specific patterns are found in the development times (e.g. egg hatch times and egg-to-adult times) of marine and freshwater ectotherms across global temperature gradients. The metabolic theory of ecology hypothesizes that these patterns are largely driven by activation energy and rates of chemical reactions in organisms. Another school regards development times as evolvable and adaptable, with development time an 'optimal solution'; a trade-off between the benefits of achieving larger size with longer development (which allows higher fecundity rates) and the costs of having reduced survival with greater periods spent before achieving reproductive age. Although such approaches have been used to predict development time, generally these are at local or regional level, and often based on single species. Here we develop an optimal model to predict egg-to-adult times in marine copepods. Two measures of population fitness (r and R_0) are used, parameterised using laboratory and field data, and finally tested against global data sets on development. Our predictions match the patterns in nature well. Our results suggest that as the relative forces on organisms change (e.g. mortality rates), shifts should be seen in development rates. Predation in the pelagic environments is a profound driver of morphology, behaviour and demography of zooplankton. Patterns found in rate processes can provide an insight into the evolutionary forces such as predation that shape these animals.

30 May, 17:00 (S7-3377)

***Pseudocalanus* species in the Baltic Sea and North Sea: comparative field studies on the life cycles of congener species in adjacent waters**

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Distribution patterns and vital rates of congeneric copepod species often differ considerably in response to their physical and biological environment. We have compared the distribution, body size, egg production rate, stage duration and number of generations of *Pseudocalanus elongatus* from the North Sea and *P. acuspes* from the adjacent Baltic Sea. We conducted experiments on population dynamics of the two *Pseudocalanus* species during two intensive field studies in the framework of the German GLOBEC project and found remarkable differences in the life histories of these morphologically extremely similar species. The life cycle of *P. elongatus* in the southern North Sea is characterised by a reproduction peak during the phytoplankton bloom between March and May with rates up to 9 eggs female⁻¹ d⁻¹. Moulting rates are highest in spring, predicting stage durations well in the range of laboratory investigations at food saturation. Four to five generations per year can be distinguished by differences in female size. In contrast, *P. acuspes* from the central Baltic Sea shows egg production rates only 1/3 as great, with a peak in April/May. Its moulting rates are extremely low, and the predicted stage durations are 3-5 times longer than those of congeners. A life cycle with only 1 strong annual generation and potential minor cohorts during summer might reflect an adaptation to life in high latitudes. The results for species-specific differences in the life cycles of the *Pseudocalanus* congeners are discussed in light of biotic interactions and the specific physical environment of the two ecosystems.

30 May, 17:20 (S7-3412)

The impact of hydrographic parameters on the vertical and spatial distribution of calanoid copepod species on the shelf off SW Sulawesi (Indonesia)

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The coastal waters of southwest Sulawesi are characterised by an extensive shallow shelf covered with coral reefs and islands of the Spermonde Archipelago. The species composition and abundance of the calanoid copepods within this area were examined in relation to hydrography, nutrient concentrations and phytoplankton biomass. Sampling was carried out along four cross-shelf transects across the archipelago. Zooplankton was collected at each station from 3-4 depth layers in the upper 30 m during day by a vertically towed Apstein net (200 µm). At all stations the majority of copepods were encountered below 10 m where the diversity was highest. In total, we have identified 71 calanoid copepod species. The number of species decreased from the offshore waters (23-30 species) to the coast (12-16 species). The species composition changed considerably from the near shore (15-40 m water depth) to offshore stations (>100 m). At the coastal stations mainly neritic species occurred (*Acartia erythraea*, *Metacalanus aurivilli*, *Pseudodiaptomus aurivilli*, *Temora turbinata*, *Tortanus gracilis*) while at the offshore stations more oceanic species were found (e.g. *Clausocalanus* spp., *Canthocalanus pauper*, *Cosmocalanus darwini*, *Rhincalanus rostrifrons*, *Subeucalanus subcrassus*, *Candacia* spp., *Euchaeta media*, *Temora discaudata*, *Scolecithrix danae*). The most abundant taxa at all stations were species of the *Paracalanidae* and especially the genus *Paracalanus*. The results will be discussed in relation to various environmental parameters such as temperature, salinity, nutrients and phytoplankton composition.

30 May, 17:40 (S7-3437)

Zooplankton distribution in the sewage polluted coastal waters of Thoothukudi coast, Gulf of Mannar, southeast coast of India

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Thoothukudi coast is a part of the Gulf of Mannar in India, and the entire Gulf of Mannar has been declared as the first Marine Biosphere Reserve not only in India but also in all of Southeast Asia. It has also been declared a National Marine Park. The Gulf of Mannar is known to have its diversified fishery resources such as pearl oyster (*Pinctada fucata*), sacred chank (*Xancus pyrum*), coral reefs, seagrass beds, seaweeds, *Amphioxus* sp., balanoglossus (*Ptychodera fluva*) and sea cow (*Dugong* sp.). At present this coast is polluted due to urbanisation and industrialisation in general and particularly by the discharge of domestic sewage. Keeping this in view, the present investigation of the influence of sewage on the zooplankton species distribution and biomass, with reference to environmental characteristics, was made during August 2004 - July 2005 at two stations: Station 1, a coastal site receiving sewage, and Station 2 at another coastal site not influenced by sewage. The recorded zooplankton species diversity in terms of species number during the period of study ranged between 11 and 22 and 22 and 40 at Stations 1 and 2, respectively. While the zooplankton density varied between 42,000 and 202,000 individuals/m³ at Station 1, the zooplankton density varied between 112,000 and 339,000 individuals/m³ at Station 2. The minimum and the maximum densities of zooplankton were recorded, respectively, during May 2005 and October 2005 at Station 1 and during August 2004 and May 2005 at station 2. The total numbers of zooplankton species recorded during the study were 41 at Station 1 and 67 at Station 2. The influence of the physicochemical characteristics of the study areas on the distribution of zooplankton will be discussed in detail.

S7

Posters

Poster S7-3262

Effect of photoperiod on the egg production of *Neodiaptomus satanas* (Calanoida: Copepoda)

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The calanoid *Neodiaptomus satanas* was reared in the laboratory to assess the impact of photoperiod exposure on egg production and to assess whether day length acts as a proximate factor for the production of diapausing eggs and subitaneous eggs in laboratory conditions. *N. satanas* produces diapausing eggs in all conditions but subitaneous eggs are only produced under 12L:12D and 14L:12D light regimes. In *N. satanas* only the short day photoperiod (10L: 14D) induced the diapause egg production. When day length exceeds 12h *N. satanas* produced subitaneous eggs. The results suggest that the type of egg produced by *N. satanas* was affected primarily by photoperiod.

Poster S7-3271

Diminishing density and diversity of copepods in the semi-enclosed docks of Mumbai Port, west coast of India

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Ports and harbours are areas of intense human activities. Periodic dredging and disposal of waste in the harbour environment alter its physical and chemical properties. Constructions to provide dock facilities result in enclosed and semi enclosed water bodies, the biology of which has received little attention. The present study examines the physical properties, water quality, relative dominance and diversity of planktonic copepods from 29 locations within the Mumbai Port. The stations cover major docks, minor docks and bunders during postmonsoon (November 1996) and premonsoon (May 1997) periods. The copepod communities in these enclosed and semi-secluded water bodies are considered and are compared with the populations at 13 stations in the open ocean area adjacent to Mumbai Port, a natural harbour. The average percentage contribution of copepods to zooplankton was 57.5% in the open ocean, while in the docks it was 88.3%. The average population density of copepods in the open ocean (12506/100 m³) was 7 times higher than that of the docks (1744/100 m³). In the open ocean 23 species occurred during premonsoon with *Acartia spinicauda* and *Acrocalanus* sp. as the main contributors. During postmonsoon, 22 species were obtained and *Acartia spinicauda* and *Canthocalanus pauper* dominated. The density was low in the docks with minimum values during post monsoon. The number of species recorded at Indira, Victoria and Princess docks were respectively 13, 9 and 10 during premonsoon and 6, 6 and 9 during postmonsoon. *Pseudodiaptomus sewelli*, *Paracalanus aculeatus*, *Acrocalanus longicornis*, *Pseudodiaptomus serricaudatus* and *Onacea* sp. were the main components in the docks. In the Sasson dock located at the harbour entrance, 17 species were present during premonsoon but only 7 species were recorded during postmonsoon. Statistical interpretation for niche breadth and for differential factor groups of species was also attempted. The study showed a reduction in density and diversity of copepod population in the docks as compared to the open ocean. Limited flushing within the docks could be an adverse factor controlling the copepod community, so that only the tolerant species like *Pseudodiaptomus* spp. flourish.

Poster S7-3283

Reproductive cycles of dominant calanoid copepods in a subtropical lagoon

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The seasonal cycles of reproduction of the dominant copepods *Acartia clausi*, *Acartia lilljeborgii*, *Paracalanus parvus*, *Centropages furcatus*, and *Labidocera trispinosa*, were studied at Bahía Magdalena, México. Egg production rate, clutch size and prosome length were compared with temperature, chlorophyll *a* concentration,

and small plankton volume during an annual cycle (June 2000 to May 2001). The water column showed mixed vertical distribution of temperature and chlorophyll *a* concentrations throughout the year. Both variables, along with plankton volumes showed a strong seasonal variation. Mean sea surface temperature reached higher values during summer (25.8°C) and minimum values in spring (15.3°C), chlorophyll *a* showed two maxima, one in early summer, and one during spring. Maximum plankton volumes were recorded during early spring. Each copepod species responded differently to the seasonal environmental change. The larger egg production values were registered when maximum population size of dominant species (*A. lilljeborgii* during summer-autumn, and *A. clausi* and *P. parvus* at the end of winter and in spring) occurred. Non-resident species were restricted to a particular season of the year (summer-fall in *C. furcatus*), or showed no seasonal preference (*L. trispinosa*). On average, the specific growth rate by egg production (EPR) during the 2000-2001 was suboptimal; however, maximum individual egg production values recorded were higher than the maximum egg production values recorded during previous studies in this bay. Sea surface temperature variation and food availability were the most important environmental factors affecting the production cycle of copepods in Bahía Madalena.

Poster S7-3310

Spatial variations in zooplankton diversity in composite wastewater

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Zooplanktonic such as Cladocera, Copepoda, Rotifera and Ostracoda are cosmopolitan in their clean freshwater habitats and are also found in toxic industrial and municipal wastewaters. The current study on zooplanktonic groups was done at five selected sites in Storm Water Flow (SWF) channel, Dry Weather Flow (DWF) channel, and a tannery wastewater stabilising pond located at the east Calcutta wetlands, a Ramsar site. The study revealed 3 species of Cladocera, 2 species of Copepoda, 15 species of Rotifera, and 2 species of Ostracoda. The copepod *Mesocyclops leuckartii* was found in all the five sites, rotifers *Asplanchna brightwelli*, *Brachionus angularis*, *B. calyciflorus* and Cladocera *Ceriodaphnia cornuta* were found in four sites. Site wise variation in dominance, diversity, evenness and richness were calculated. Site 1 a fish pond that stabilised composite wastewater showed the maximum species richness having 17 species, while site 2 SWF wastewater carrying canal showed only 4 species. The calculated Jack 1 values of sites 1 to 5 were 21.78, 3.77, 18.63, 12.5, and 16.95 respectively. Shannon-Wiener species diversity index (H') values were almost similar for all the three relatively less polluted sites viz, Site 1 (1.959), site 4 (2.010), site 5 (2.047). However, at highly polluted sites 2 and 3, H' values were calculated of 1.336 and 0.984, respectively. Simpson's Dominance index (D_{simp}) was maximum at site 3 (0.618), indicating maximum dominance. The situation at site 5 was the opposite and dominance was minimum (0.1680) while diversity was maximum. Discussion will focus on the role of the zooplankton community in amelioration of wastewater pollution.

Poster S7-3315

Regulation of diapause in the copepod *Calanus finmarchicus*

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The copepod *Calanus finmarchicus* is a vital component of the pelagic food web in North Atlantic and peripheral ecosystems. Its life cycle involves a dormant overwintering phase (known as diapause), which often occurs at great depth. At the onset of diapause, development is suppressed and the animals sink out of the surface waters. They remain at depth until the termination of diapause the following year, when individuals migrate back to the surface. The cues for diapause entry and exit remain unknown, as do the cellular mechanisms associated with the induction and termination of diapause. The lipid-based hormone methyl farnesoate (MF), the crustacean version of juvenile hormone III (a multifunctional hormone linked with diapause in insects), has been proposed to act as a possible cellular cue for diapause induction, but MF has never been identified in a copepod. Using material from the North Atlantic and Loch Etive, a Scottish sea loch, we aim to test the association of MF with diapause induction by isolating an enzyme (farnesoic acid O-methyl transferase or FAMTase) that catalyses methylation of farnesoic acid to biosynthesize MF. We will isolate FAMTase from *Calanus* using molecular techniques, and then measure expression of the enzyme, and thus the production of MF through life events such as diapause. If the mechanisms driving diapause entry/exit can be elucidated, then progress could be made towards understanding likely consequences for this vital developmental stage of environmental changes such as warming and freshening. This in turn could inform future ecosystem management plans.

Poster S7-3320

Seasonal patterns of abundance, egg production and egg viability of the calanoid copepods *Calanus helgolandicus* and *Calanus finmarchicus* at a station off the north-western North Sea coast

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Two *Calanus* copepod species (*C. finmarchicus* and *C. helgolandicus*) co-occur at a monitoring site, sampled weekly since 1997, 3 km offshore of Stonehaven on the Scottish east coast (<http://www.frs-scotland.gov.uk/>). The former species is an Arctic boreal copepod shown to have been retreating north in response to ocean climate change, while the southern congener *C. helgolandicus* has expanded its range into these areas. We have investigated the contrasting seasonal occurrence and reproductive success of these species at our sampling site. Females have been incubated at field temperatures to determine egg production since 2003, while egg viability was determined from hatching success of the incubated eggs. Copepodite stage abundances, enumerated since 2000, were supplemented during 2003-2004 with counts of naupliar stages and gonad maturity analysis of females. Strong seasonality was evident, with peak *C. finmarchicus* abundance, reproduction and egg viability in the spring and summer, prior to the majority of the population entering its over-wintering resting state in autumn. By contrast *C. helgolandicus*, though present all year, were most fecund and abundant in summer and autumn. For both species egg viability was highly variable throughout the year, with *C. helgolandicus* eggs generally more viable in late summer and autumn. Egg production and hatching success are examined in relation to observed seasonal abundance and to environmental conditions. Results are discussed in relation to the implications of changes in the abundances and seasonal dominance of these copepods in the ecosystem.

Poster S7-3337

Impact of *Botryococcus braunii* blooms on the zooplankton of Paoay Lake

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Blooms of the colonial green alga *Botryococcus braunii* have been widely known to have toxic effects on a variety of aquatic organisms and have caused fish deaths. Zooplankton are also greatly affected by such harmful algal blooms and exhibit varying levels of tolerance and susceptibility to the toxic effects of *B. braunii*. In this study, a five month monitoring was done of the abundance and distribution of *B. braunii* in Paoay Lake. Plankton samples were taken from the surface and deep layers of the lake from 4 sampling sites. Data on the density (colonies /L) of *B. braunii* were found using Pearson coefficients to be correlated with zooplankton species diversity (H') and richness (DMG) at those sites. The data revealed an increase in the density of *B. braunii* from an average of 9,670 Col. /L in May to 24,656 Col. /L in June. This slightly decreased to 23,085 Col. /L. in July. The highest recorded density was 44,732 Col./L in the waters surrounding Baranggay Nagbacalan during July. In total, there were 31 species of zooplankton present in the lake, with the rotifer *Keratella procurva* being the most abundant. A remarkable increase in the abundance of *B. braunii* at the 4 sampling sites was observed from May to June. This was associated with a decrease in the density of zooplankton and an alteration in the composition of zooplankton assemblages. On the whole, the species diversity and richness of zooplankton were lower when the abundance of *B. braunii* was elevated in the lake. The study suggests that both the composition and the abundance of zooplankton in Paoay Lake were negatively affected by the occurrence of *B. braunii* and possibly caused by the toxic effects from this green alga.

Poster S7-3358

Reproductive responses of *Calanus sinicus* to food availability in Jiaozhou Bay, China

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Egg production rate (EPR), egg hatching success (HS) and effects of starvation on a calanoid copepod, *Calanus sinicus*, were measured from March to July in Jiaozhou Bay, China. A diatom dominated bloom was well developed inside the bay at the beginning of this study on 14 March, with the chlorophyll *a* concentration reaching

14 mg m⁻³. Phytoplankton had decreased in the following cruise on 20 March, and then increased again to a second peak in May/June. Females were reproductively mature and spawning throughout the study period. EPRs ranged from 5.2 to 42.5 eggs female⁻¹ d⁻¹. The highest EPR was found during the diatom bloom in March, while the lowest was found in July. EPRs were positively correlated with chlorophyll *a* concentration, but there was no correlation with temperature. Except for the significantly lower values (50%) observed during the diatom bloom, HS was generally high (>75%). Egg production gradually ceased within 3-5 days and the percentage of females with mature gonads decreased greatly after shorter, experimental starvation (1 week). The oil storage was also partly consumed and the gonad materials were almost exhausted under long-term starvation (2 weeks). All the starvation effects were more evident at higher temperature. After feeding excess food for 2-3 days, however, the starved females resumed spawning, which suggests that food plays a key role in determining the reproduction of *C. sinicus* during its production season in Jiaozhou Bay.

Poster S7-3365

Diversity of ichthyoplankton with reference to seasonal variation in the Arabian Sea

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Distribution of fish larvae serves as a valuable aid in resource assessment. Ichthyoplankton surveys during various seasons help to indicate shifts in the spawning of different species. This study includes the physico-chemical parameters in different seasons, the dominance and diversity of fish larvae collected from May 1998 to June 2002 from 8°N to 22°N latitude and 66°E to 77°E longitude, covering the Arabian Sea during spring intermonsoon, summer monsoon, fall intermonsoon and winter monsoon (JGOFS). The numerical abundance of fish larvae was maximum (63%) in summer monsoon and minimum in fall intermonsoon (7.9%). Areas of high density were the notable features of the summer monsoon. The larvae were mostly myctophids (35.6%), clupeids (19.96%), phosichthyids (9.95%), gobiids (9.66%), scombrids (6.71%), bregmacerotids (5.07%) and carangids (3.23%). We attempt to correlate the present data with the results of the International Indian Ocean Expedition (1960-1965).

Poster S7-3382

Combining time series data with spatial variability to study population dynamics of the large-sized calanoid copepod, *Rhincalanus nasutus*, off central/southern Chile

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Rhincalanus nasutus (Copepoda: calanoida) is a widely distributed species in the upwelling zone off central and southern Chile. Little is known about its life cycle or population dynamics in this highly productive ecosystem. We have used monthly time series data from Station 18 (36°S) over the shelf, seasonal data from Station 40 in the offshore, and two large-scale oceanographic surveys carried out in the spring of 2004 and 2005 to assess the species annual life cycle, its seasonal and interannual variability and its mesoscale spatial distribution. All life stages were studied and stage-specific biomass was estimated. The population reached maximal abundances during the spring-summer period at Station 18, suggesting rapid growth under intense upwelling conditions. By late summer and early fall the population exhibited low abundances. The combination of data from the shelf and offshore stations, and the distributions observed in the large-scale grids indicates much of the temporal variability results from changes in spatial distributional patterns. Because of its large body size and abundance, this species may contribute substantially to zooplankton biomass and the carbon budget in the upwelling zone.

Poster S7-3383

Copepod growth dynamics in detail; challenging the limits of carbon analysis

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Great intellectual and observational energy has gone to evaluating the mechanics of copepod growth and development. We have measures of stage duration, size at different stages and egg-biomass production. We have statistical and theoretical models. Yet, we do not have so clear a picture of growth dynamics as Steve Sulkin and

Klaus Anger have developed for crab larvae. Copepods almost certainly develop in the same fashion as crab zoeae, with growth rate strongly modulated by an individual's phase within its molt cycle. Initial growth is rapid for 40 to 60% of the molt-to-molt interval, producing about 80% of biomass growth for the stage. Then it slows, as does feeding rate, at a point Sulkin and Anger term the Point of Reserve Saturation (PRS). The physiology after PRS is hormonally switched to concentrate upon preparations for molting. Withdrawal of food at PRS does not prevent the next molt; it proceeds on schedule leading to reduced size at the next stage. Unlike zoeae, it is difficult to obtain groups of copepodites developing and molting closely in phase. Nevertheless, somebody can investigate the copepod pattern by determining exact age within stage using (1) frequent digital photography to catch exact specimen molt timing and by (2) measuring single-specimen biomass by refinements in carbon content determinations that are quite feasible but not commercially available. The consequences of molt phase 'growth cycling' for ecological interpretation of activity and size, of feeding and growth rates will be addressed.

Poster S7-3387

Alternative pathways of larval development of Humboldt Current krill, *Euphausia mucronata*

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The larval series, pathways of development and growth rates of *E. mucronata*, have been studied from field samples and rearing experiments. A fixed number of 3 stages in the calyptopis phase are followed by a variable number of furcilia stages and forms. Furcilia forms were grouped in 7 stages based on development of pleopods and telson spines. Development ended in the juvenile phase with 5 pairs of setose pleopods (5"), 1 terminal spine (1t) and 2 posterolateral spines (2pl) on the telson. The frequency of occurrence of furcilia forms in the field and examination of exuviae in rearing experiments allowed for the identification of variable pathways of development. For furcilia 1 to furcilia 3 there were two numerically dominant pathways of pleopod development in the field and one different dominant pathway in the laboratory. Alternative pathways involve skipping or not an extra molt. For furcilia 3 to furcilia 7, there was a common dominant pathway of telson development for field and reared animals. The intermolt period (mean=4d, range=4-6d) was consistent with that of most euphausiids. Growth factor (stage-to-stage length ratio) was higher for C1 to F1 (1.28-1.60) than for furcilia stages (1.00-1.30). Larvae following the direct-short pathway, had more morphological change/molting and required less time to reach the juvenile phase than larvae on indirect pathways. Since short or long pathways are associated with optimal to poor environments, respectively, ontogenic variability in morphology, pathways and growth may be interpreted as an adaptive strategy of euphausiid species to spatially and temporally variable environments, such as the Humboldt Current.

Poster S7-3403

Effects of water masses and seasonal monsoons on the distribution of siphonophores in Taiwanese waters

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The Taiwanese waters of the western North Pacific Ocean have high oceanographic complexity, characterised by the succession of at least 3 water masses, seasonal monsoons, and high zooplankton diversity. Based on collections during a winter and a summer cruise in 2003-4, 73 species of siphonophores were recognised from 33 stations in Taiwanese waters. Siphonophore abundance did not differ significantly between summer and winter, but species richness was higher in winter than summer. Cluster analysis of hydrography distinguished 3 water masses in winter - the Kuroshio Current (KC), the China Coastal Current (CCC), and the Transition zone (TZ), and two water masses in summer - KC + South China Sea Waters (SCSW), and Taiwan Strait waters (TSW) + East China Sea waters (ECSW). The abundance and species richness of zooplankton were always higher in the TZ, while the CCC showed higher abundance but lower species richness as compared with the KC in winter. In summer, the TSW+ECSW had higher abundance and lower species richness as compared with

KC+SCSW. The distribution of siphonophores showed clear association with water masses, having higher abundance and lower species richness in the CCC, and lower abundance and higher species diversity in the KC. The relationships between siphonophore abundance and environmental variables also were analysed. Our results suggest that the TZ and KC may enrich the species diversity in Taiwanese waters, while the CCC may bring higher zooplankton abundance into northwestern Taiwanese waters. The succession of these water masses, as influenced by seasonal monsoons, may be important in determining the abundance and diversity of siphonophore assemblages.

Poster S7-3406

Vertical distribution of species of Eucalanidae (Copepoda: Calanoida) in the Arabian Sea

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The numerical abundance and vertical distribution (0-1300 m) of 7 eucalanid species (Copepoda: Calanoida) were studied in the Arabian Sea based on zooplankton samples collected in the US JGOFS expeditions in 1994-95. The investigated species can be subdivided into two groups based on the patterns of vertical distribution in relation to the oxygen concentration. Representatives of the first group, small-sized eucalanids - *Subeucalanus mucronatus*, *S. pileatus*, *S. subcrassus* and *S. subtenuis* - occurred above the upper boundary of the oxygen minimum zone (OMZ) within the layer 0-150 m. The core of the *S. pileatus* population was situated in the upper 50 m, above the oxycline. The closely-related species, *S. subtenuis* and *S. mucronatus*, showed distinctive vertical segregation within the inhabited layer: the former was concentrated mostly above, and the latter - within the permanent oxycline. Representatives of the second group, large-sized eucalanids - *Eucalanus elongatus*, *Pareucalanus attenuatus* s.l. and *S. crassus* - were distributed throughout the layer 0-1300 m. Within the OMZ, only pre-adults (C4 and C5) and females of *E. elongatus*, *P. attenuatus* s.l. and *S. crassus* were present. It is hypothesized that specimens present within OMZ were diapausing. The investigated species showed no pronounced diurnal migrations. First and second copepodite stages (C1 and C2) of all the species were collected in the upper 100 m, indicating spawning occurred within the sub-surface layer. *Subeucalanus subtenuis*, *S. pileatus* and *S. mucronatus* were numerically dominant, constituting nearly 80% of the total eucalanid number.

Poster S7-3415

Diel vertical distribution of zooplankton as constrained by the upper boundary of the oxygen minimum zone at the coastal upwelling region off northern Chile

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A shallow (<50 m) oxygen minimum zone (OMZ) is a prominent feature in the coastal zone off northern Chile. The zooplankton community must cope with this oxygen-deficient water. We have found from day/night stratified Multinet samples taken during the ZOMEI cruise (October 2005, northern Chile) that the whole zooplankton community is mainly comprised by copepods (>50%), with many species whose vertical distribution and diel migration appears to be restricted to the upper 50 m layer where there are strong vertical gradients in temperature, salinity and dissolved oxygen. Few species seem able to inhabit the OMZ either temporarily or permanently. Calanoid copepods, such as *Paracalanus parvus*, *Acartia tonsa*, *Eucalanus inermis* and *Centropages brachiatus* were the dominant species at two study sites. Short-term variability in oceanographic conditions was considered to determine the extent to which populations can perform vertical movements given the OMZ constraint. A negative relationship between numerical abundance and the number of species became evident when comparing sampling sites. The OMZ system may impose major ecological consequences for the zooplankton community in this upwelling region.

Poster S7-3417

Growth of *Euphausia pacifica* and *Thysanoessa spinifera* in the coastal NE Pacific

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Euphausia pacifica and *Thysanoessa spinifera* are the two dominant species of euphausiids in the coastal northeast Pacific. This is a dynamic environment, with seasonally strong upwelling and associated phytoplankton blooms. Instantaneous growth rate (IGR) experiments on these two species were conducted using animals collected off the coasts of Oregon, Washington and Northern California throughout 2001-2006. This time period encompasses some distinctly different oceanographic conditions with 2001, 2002 and 2006 being relatively cold and productive years, while 2003-2005 were warmer and less productive. IGR experiments determine change in length and intermolt period (IMP) and allow us to calculate growth in length in mm per day. Positive growth ranged from 0 to 0.9 mm per day. Negative growth occurred during all seasons, usually in larger animals of both species. Negative growth observed during the reproductive season may be a result of reproductive activity rather than of poor environmental conditions. Individual growth tended to decrease as animals got larger but was highly variable. There was no clear relationship between growth and surface chl concentration or water depth.

Poster S7-3421

Day-night differences in zooplankton biomass in the eastern tropical Pacific

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According to our recent results in the eastern tropical Pacific (ETPac), no night-day differences in near surface (0-200m) zooplankton biomass have been found during summer or winter cruises. Trying to better understand these results and considering the special features of this wide area, we examined historical data to determine whether these differences were real or just the consequence of limited or too variable data. Historical data from the EASTROPAC cruises and other cruises were utilised. An ANOVA comparing night and day zooplankton volumes obtained with a 330 µm mesh net, showed significant differences. A multiple-way ANOVA comparing seasons or bimesters showed significant differences. However, even where significant differences were found, large areas of the ETPac show night/day zooplankton volume ratios close to 1. These are areas characterised in general by a shallow oxygen minimum layer (40 -100 m) in which oxygen is lower than 1 ml/l. They cover a wide area in the northern hemisphere between 5 to 15°N and around the Costa Rica Dome. A smaller set of sample data obtained with a 505 µm mesh net also showed significant differences. It is hypothesized that low oxygen limits the vertical migration of zooplankton. Zooplankton biomass data from the entrance of the Gulf of California were also examined; they showed no-significant difference between day and night, although with a limited number of samples. A comparison with the California Current zooplankton volume data from the CalCOFI programme was performed. Tridimensional analysis showed different characteristics for the California Current and higher night/day ratios. The implications for trophic relationships of no night-day difference in zooplankton biomass are discussed.

Poster S7-3424

The effect of temperature on the development of the copepod *Eucalanus bungii* reared in the laboratory

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Eucalanus bungii is a large grazing copepod predominant in the subarctic Pacific Ocean. Mature females of *E. bungii* were caught at Site H in the Oyashio region in March 2006 and brought back to the land laboratory to obtain eggs for observations of the effect of temperature on its development. As food, a mixture of phytoplankton

(*Prorocentrum* sp., *Phaeodactylum tricornerutum*, *Chaetoceros gracilis* and *Isochrysis* sp.) was provided *ad libitum*. At 5 graded temperatures between 2.5 and 10°C, time to egg hatching decreased with the increase of temperature from 4.3 to 2.2 days, and naupliar development time, decreased from 53 to 23 days. Egg hatching success (57-77%) was not affected by the temperature. For copepodid stages, mortality increased suddenly beyond C4: among 57 C1 specimens 11 reached C5 and only 2 reached C6. The effect of temperature on the development time of each copepodid stage was expressed as Bélehraděk function, and the results are compared with those of wild populations of this species in the Oyashio region.

Poster S7-3425

Relationship between seasonal occurrences of planktonic population and types of diapausing eggs in *Acartia steueri* from three geographically different sites in Sagami Bay, Japan

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Seasonal disappearances of planktonic populations are well known phenomena in coastal marine copepods. Diapausing eggs do not hatch during a few weeks to month (Type 1) and survive unfavourable seasons. Recently, diapausing eggs that hatch sporadically after a few days from spawning to several weeks (Type 2) are reported from some species including *Acartia steueri*, but we do not have enough information about relationships between seasonal occurrence of planktonic populations and this type of diapausing eggs. In this study, seasonal variation of abundance and hatching pattern of diapausing eggs were determined for *A. steueri* collected from three sites in Sagami Bay, Japan: the ports at Manazuru, Kawana and Ohse. We obtained data to explain the relationship between seasonal occurrences of planktonic populations and types of diapausing eggs. In Manazuru Port, *A. steueri* occurred during the sampling period and hatching of diapausing eggs incubated at field temperature occurred six days after spawning (Type 2). On the other hand, in Kawana and Ohse Ports, *A. steueri* disappeared from water column during summer and hatching of diapausing eggs incubated at field temperatures occurred later than at Manazuru Port (after 20 and 25 days from spawning in Kawana and Ohse Ports, respectively: Type 1). These results imply that the two types of hatching pattern in diapausing eggs would control the seasonal occurrence of planktonic populations differently. Producing diapausing eggs that have different hatching patterns depending on region may be advantageous for *A. steueri* to maintain populations under different habitat conditions.

Poster S7-3427

How does molting affect reproductive and feeding activities of *Euphausia pacifica*?

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The relationships among molting, reproductive processes and feeding activity were examined for *Euphausia pacifica*. Euphausiids were collected with a cylindrical-conical net (mouth diameter of 1.3 m and mesh size of 0.45 mm) obliquely hauled from 500 m depth at 30 stations in the sea area off northeastern Japan from 2-10 October, 2000. The mean percentage of molting individuals was 15.6%, 13.6% and 24.7% for day, night and at dawn, respectively without significant differences. In males, the percentage of molting individuals was fairly constant, ranging from 12.1 to 14.9% among various maturity stages without significant differences. In females, however, the percentage was significantly different among maturity stages. Molt percentage was higher than expected for IIB and lower than expected in IIID females. The contribution of molting individuals was the least, 6.9%, in females of maturity stage IIID. The result strongly suggests that IIID females molt less frequently, about

half as often as less mature females or all stages of males. The mean stomach fullness, based on ratings from 0 to 4, was significantly different among molt stages: 2.17, 3.59 and 3.77 for molt, post-molt and pre-molt individuals, respectively. The mean stomach fullness of each molt stage also differed significantly between time periods. Therefore, feeding activity of molting individuals is considerably restricted compared with non-molting ones, but even molting ones showed an intrinsic feeding rhythm.

Poster S7-3431

What do interannual changes of zooplankton tell us about long-term trends?

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Investigation of long-term trends in mesozooplankton (e.g. due to climate change) is usually based on monitoring data sets or on comparisons among data collected from time to time in the same region. Many times the second method is used, because long-term data are lacking. The aim of our study was to affirm how big changes may be seen from year to year, and to consider whether observed changes are really indicators of long-term trends or not. The Baltic is a semi-enclosed brackish sea situated in the temperate region (northern Europe). The most important factors influencing its pelagic fauna are salinity (decreasing from Danish Straits – the link with the North Sea - to the northeast and from the bottom to the surface) and temperature (characterised by seasonality). We used for comparison summer periods of three consecutive years 1998-2000. Mesozooplankton samples were collected from the Gulf of Gdansk (southern Baltic). The material was prepared and analysed according to HELCOM methodology. The number of zooplankton was comparatively high. We observed some differences not only in the following years but the following months as well, both in numbers of particular taxa and in general tendency of its increase or decrease. Strong quality and quantity changes of zooplankton were visible from month to month of particular years and also between the same calendar months in different years. Based on three years of observations, we confirm an important direct influence of hydro-meteorological conditions (especially temperature) on the variability of zooplankton from year to year, and we recommend to compare data very carefully.

Poster S7-3436

What determines the success of *Sagitta enflata* as a major zooplankton predator in the Humboldt Current System?

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This study is based on 3-years of monthly zooplankton sampling at a fixed point off Concepción (36°S) Chile. Reproduction of the chaetognath, *Sagitta enflata*, and its predation pressure upon zooplankton standing stock were assessed. Prior to net tows, water temperature, conductivity and oxygen were measured with a CTDO profiler and microzooplankton samples were collected, in order to account for prey available for *S. enflata* offspring. All *S. enflata* specimens were measured and assigned to a maturity stage, and ingested prey were identified up to species level. *Sagitta enflata* accounted on average for 60% of total chaetognath abundance. The number of prey per chaetognath was highly variable during the whole period. It was lowest during upwelling events due to the rise of oxygen depleted water, with low removal rates of copepod standing stock (0 to 7% d⁻¹), whereas above 4 ml O₂ L⁻¹ the removal rate increased exponentially up to 43% d⁻¹. High removal rates are achieved by juvenile *S. enflata* that dominated between 45 and 60 days after reproduction. The sexual maturation process occurred during spring and summer once the phytoplankton bloom was established. The appearance of mature chaetognaths was coupled with an intensification of predation pressure upon *Calanus chilensis*, which might be essential for the maintenance of growth of chaetognath eggs by allowing higher lipid content, as compared to others copepod prey potentially available, such as *Paracalanus parvus*, *Centropages* sp., *Acartia tonsa* and *Oithona* sp. Once *S. enflata* reproduces and the phytoplankton bloom reduces in intensity, many nauplii were available for *S. enflata* offspring. Adequate adjustment between prey life cycle and *S. enflata* reproduction and spawning would be one of the main factors determining the dominance of these organisms in a highly heterogeneous habitat such as the coastal upwelling zone of the Humboldt Current.

Poster S7-3447

The timing and location of spawning for the euphausiids *Euphausia pacifica* and *Thysanoessa spinifera* off the Oregon coast, USA

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Euphausia pacifica and *Thysanoessa spinifera* are the dominant euphausiid species in the upwelling region off Newport, Oregon (USA). Our 10-year time series (1996-2005) of biweekly sampling shows peaks in eggs occurring from late February through early November with a great deal of interannual and cross-shelf variability. We are striving to explain the spawning patterns that we observe and to determine the cues for euphausiid spawning in our study area. Euphausiid egg density is poorly correlated with chlorophyll concentrations and surface temperature measured at the time of the net tows. This, along with the laboratory observation of a median 5 day interbrood period, suggests that there are unknown lag periods between upwelling events, phytoplankton blooms, and euphausiid spawning. We gain greater insight into the phenology of euphausiid spawning through the study of adult euphausiid densities (available from 2001 onward). Though adults were most abundant near the shelf break and beyond, their infrequent appearances at our inner shelf stations correspond well with peaks in egg density on the shelf. Despite consistently high concentrations of adults at our shelf break station, peaks in egg density are no higher than are found over the shelf. Continuous datasets (temperature and currents from a mooring on our transect line, wind data and the Bakun upwelling index) from the area are used to try to account for time lags and to understand the mechanisms that bring adults into shelf waters to spawn.

Poster S7-3460

Spatio-temporal variability in abundance and stage composition of three dominant Antarctic copepods along 140°E in the Indian sector of the Southern Ocean

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The large Antarctic, herbivorous copepods *Calanoides acutus*, *Calanus propinquus*, and *Rhincalanus gigas* are the dominant species in the Antarctic zooplankton. The objective of this study was to highlight major seasonal differences in their abundance and stage composition in the Indian sector of the Southern Ocean, in order to discuss the relationships among their life cycles, environmental conditions and the retreat of the sea-ice. Data for this study were collected during the time-series observations conducted on RSV *Aurora Australis* in November 2001, *Hakuho Maru* in January 2002, RV *Tangaroa* in February 2002, and the icebreaker *Shirase* in March 2002 along a transect on 140°E between 61 and 66°S. The 140°E area is characterised by an extremely narrow seasonal ice zone. The distributions of *C. acutus*, *C. propinquus*, and *R. gigas* are separated on a biogeographic scale, and further by the timing of their development. *Calanoides acutus* is the first to ascend to the surface in spring and the first to descend to deeper water layers in autumn, followed by *C. propinquus* and then by *R. gigas*. According to the asynchronous development hypothesis, *C. acutus* should occur during the period of active development in a more advanced state than *C. propinquus*, while *R. gigas* would lag behind both of the others. In order to evaluate the life cycle of each species, it is therefore necessary to examine all three copepods simultaneously. Dynamics of sea-ice condition likely also influence their life cycles.

Poster S7-3469

Dynamics of Baltic Sea zooplankton and their sensitivity to climate/physical forcing

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Long-term investigations in the Baltic Sea have documented large inter-annual fluctuations in the standing stock of dominant copepod species that are potentially linked to climate variability. While the biomass variation of *Pseudocalanus* sp. has largely been related to reduced salt water inflows and physiological constraints on reproduction,

controlling mechanisms for the surface dwelling species *Acartia* spp. and *Temora longicornis* are ambiguous. Since the several species of the genus *Acartia* occurring in the Baltic Sea are generally not separated in long term studies, discrepancies in the apparent effects the hydrographical control may also result from the failure to separate species with different ecological preferences regarding temperature and salinity. In the presentation, we will summarise results from a GLOBEC Germany field campaign conducted to study the spatio-temporal dynamics and stage composition of standing stocks of *T. longicornis*, *A. biflosa* and *A. longiremis* in the southern Baltic Sea in 2002/2003. The variations in standing stocks are compared to the seasonal variation of the reproductive success and dynamics of resting eggs in the sediment. While the recruitment of the *Acartia* species in spring depends strongly on the emergence of nauplii from resting eggs, egg production of the individuals surviving the winter is the source for the first generation in *Temora longicornis*. The life cycle strategies of the different species are compared with regard to their sensitivity to physical forcing and in view of the relevance of phenology for the interpretation of long-term variations in standing stocks.

Poster S7-3474

The impact of climate change on zooplankton in an Arctic fjord

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Kongsfjorden is a glacial fjord on the northwest coast of Spitsbergen in the Svalbard archipelago that is influenced by water masses of Atlantic, Arctic and glacial origin. The effects of climate change are already apparent in Svalbard, with considerably reduced sea ice cover in Kongsfjorden during the winter of 2005/06 and water temperatures ~2°C above average. Intrusions of Arctic and Atlantic water masses into the fjord are usually restricted to the spring and summer months, with a density front at the fjord entrance preventing water mass intrusions from the shelf in winter. However, in February 2006, there was an intrusion of Atlantic water into the fjord, which raised water temperatures by several degrees and altered the composition of the fjord's winter zooplankton community. A sediment trap deployed at a depth of 100 m on a long-term hydrographic mooring in the outer basin of Kongsfjorden has provided us with the first winter zooplankton time-series in the fjord. The trap was deployed from September 2005 to May 2006. The Arctic species *Metridia longa* dominated the trap samples prior to the influx of Atlantic water in February. Copepods introduced during this anomalous advection event included late stages of *Calanus finmarchicus*, *Calanus glacialis*, *Calanus hyperboreus* and *Paraeuchaeta norvegica*. The early introduction of these species into the fjord, and thus increased copepod biomass relative to typical winter conditions with no advection, has implications for utilisation of the spring phytoplankton bloom and pelagic-benthic coupling in the fjord.

Poster S7-3476

Long-term monitoring of zooplankton in an Arctic fjord using sediment traps

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Continuous zooplankton time-series are difficult to obtain in the Arctic using standard zooplankton sampling methods due to the often adverse conditions experienced. The Scottish Association for Marine Science (SAMS) and the Norwegian Polar Institute (NPI) have been maintaining a long-term hydrographic/biological mooring in the outer basin of Kongsfjorden, Svalbard, to study exchange processes in the fjord. A sediment trap deployed on the mooring from April to September 2002 has, for the first time, demonstrated the close relationship between water mass advection and changes in zooplankton community composition in the fjord. Three phases in zooplankton community composition were identified in 2002, with intrusions of Arctic water and then Atlantic water marking the abrupt transition points between phases. Sediment traps have also provided the first winter zooplankton time-series in the fjord, with traps deployed at two depths (100 and 200 m) in the outer basin for nine months from September 2005 to May 2006. Winter 2005/06 was unusually warm in Svalbard, with reduced sea ice cover, water temperatures ~2°C above average, and an anomalous intrusion of Atlantic water into Kongsfjorden in February. The intrusion of Atlantic water altered the fjord's winter zooplankton community, with the introduction of late stages of *Calanus finmarchicus*, *Calanus glacialis*, *Calanus hyperboreus* and *Paraeuchaeta norvegica*. Under normal winter conditions, zooplankton from the shelf are not advected into the fjord until the spring and summer months.

Poster S7-3480

How does the Arctic copepod *Calanus glacialis* cope with the thermal regime in the subarctic White Sea?

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The arctic copepod *Calanus glacialis* is one of the dominant components of the zooplankton community of the subarctic White Sea. This population is a relict of the glacial period isolated at present from the main part of the species distributional area. The specific thermal regime of the White Sea, with pronounced summer warming of the 50 m upper water layer up to 12-15°C, has a strong effect on the species life cycle and patterns of its seasonal/ontogenetic vertical migration. Most of the year *C. glacialis* resides in the water mass below 50 m depth, where temperature remains negative throughout the year. The time favourable for reproduction and growth in productive surface waters is restricted to a short period between the ice melt (May) and the summer temperature rise (July). Warming of the upper layers up to 5°C then induces reproductive dormancy in females, with further warming forcing the downward migration of the population into the colder deep layers. The high abundance of the *C. glacialis* population in the White Sea indicates that this arctic species is able to cope with the seasonal surface warming, and should continue to do so provided the cold water “refuge” at depth is maintained. Our observations suggest that *C. glacialis* could be more tolerant of Arctic warming than it is usually believed.

Poster S7-3482

Development of a new and simple technique for the continuous culture of *Brachionus plicatilis*

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The importance of the rotifer *Brachionus plicatilis* is well recognised. Various culture techniques have been adopted for the production of this important live food organism. In Japan, a mixture of freshwater and sea water is usually used for its continuous culture. In the production cycle of *B. plicatilis*, 20, 40 and 60% water is exchanged on days 2, 3 and 4, respectively. On day 5, a fresh culture is started with 100% new water. Rotifers are fed with *Chlorella* spp. A mat used for removal of settled organic debris is cleaned every day. The density of rotifers is maintained around 400-500 organisms/l to achieve sustainable production. In the present study, an attempt has been made to simplify the labour-intensive production of the live food. *Brachionus plicatilis* were cultured in 100 l plastic, cylindrical tanks using 100% sea water without exchange of water in between. Culture tanks were cleaned on day 5 and were filled with 100% fresh sea water. The culture was continued for 2 months. *Chlorella* spp. was used as food (@200/ml, twice daily). Water quality parameters like temperature, salinity, conductivity and dissolved oxygen were monitored regularly. The mat was cleaned every other day. A steady production of *B. plicatilis* was obtained throughout the culture period. Their number ranged from 512 to 1027 ml⁻¹, without any culture crashes. Application of this method may simplify the production of this important live food organism.

Poster S7-3486

The distribution and community structure of zooplankton in the Galapagos Islands

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The Galapagos Islands have unique physical attributes that contribute to their considerable diversity of marine life. At the base of this biota are the phytoplankton and zooplankton. Previous scientific studies in the islands have neglected this smaller flora and fauna. Research in this area is essential to the understanding of the Galapagos marine environment. I am determining the community structure and distribution of zooplankton over the Galapagos platform. Over 200 zooplankton samples were taken from 72 stations across the archipelago. There

were a total of seven sampling cruises between September 2004 and July 2005. Because of their large numbers in the samples, species identification has focused mainly on copepods. Over 121 species of copepods have been identified. Species richness is high across all samples, and distributional patterns and species composition are related to the distinct climate zones and the bathymetry of the islands. The zooplankton data acquired give insight about the composition of the lower trophic levels in these regions, and they provide a baseline analysis of the zooplankton community that can be compared with future studies. This will be essential for assessing the response of the zooplankton community to climatic variations or management policies in the islands. Results have already changed the current understanding of the global distribution of several species of zooplankton.

Poster S7-3497

Salinity effects on the life cycle traits of two genetically divergent populations of *Eurytemora affinis* (Copepoda: Calanoida): a laboratory study

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The calanoid *Eurytemora affinis* is one of the most abundant copepod species in many estuaries in the Northern Hemisphere. Whilst *E. affinis* populations are often morphologically (i.e. taxonomy) indistinguishable, the species complex is composed of genetically distinct clades, representing divergent evolutionary histories. The most distant clades, genetically and morphologically (i.e. phylogenetically), are transatlantic clades: North American and European (Lee, 2000. *Evolution* 54(6), 2014-2027). To determine whether the genetic variations might contribute to physiological differences within this copepod species complex, we tested some life cycle traits of two populations of *E. affinis* under 3 salinities (5, 15 and 25 psu) at only one temperature, 10°C, and under food satiation. Common experiments applied to both populations were based on an individual approach. We compared the life cycle strategies of populations reared under culture conditions (>10 generations) from St. Lawrence salt marshes (Canada) and from the Seine estuary (France). The life cycle study revealed important differences in the salinity tolerance between the populations. Although the St. Lawrence individuals developed and reproduced quite well under all salinities studied, Seine individuals exhibit high mortality during development under highest salinity. The clutch size (eggs/clutch) was on average two times higher for St. Lawrence females compared to Seine females. Regardless of salinity, the longevity of St. Lawrence adults was about 2-fold higher than the longevity of Seine adults. It is assumed that such differences could be due to genetic and morphological differences resulting from divergent evolution. These results confirm that the use of egg production parameters for the same species from the literature may be erroneous. Different experimental protocols may introduce several biases in estimating copepod egg production, which also affects values in the literature. Our results show that the reproductive longevity of copepods is a crucial parameter in estimating total egg production of copepods. Our hypotheses will be tested in the future by increasing the range of experimental temperatures and by using other estuarine copepod species (i.e. *Acartia*, *Pseudodiaptomus*).

Poster S7-3498

High frequency sampling of the copepods *Eurytemora affinis* and *Acartia tonsa* populations in the Seine estuary, France: tidal and seasonal effects

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The copepod *Eurytemora affinis* plays a key role in the food web of many estuaries in the Northern Hemisphere as in the Seine estuary, France. This copepod dominated the estuarine zooplankton through the year in 1996 and exhibited very high abundances during spring season (>190 000 ind.m⁻³). It was necessary to understand the population dynamics of *E. affinis* at different scales (spatial and temporal) to identify the effects of a single or a

combination of external factors (i.e. salinity, temperature, food, etc.). Within the framework of a multidisciplinary project aiming at understanding the life cycle strategies of *E. affinis* in the Seine estuary, several high-frequency sampling cruises were realised during 2005. At the tidal scale, the results obtained confirmed the maintenance of the population of *E. affinis* within the oligohaline zone. At the annual scale, *E. affinis* population decreases drastically during summer and was replaced by the population of another copepod *Acartia tonsa*. This later species seems to be well adapted to high temperatures observed in the Seine estuary. Moreover, our sampling strategy based on Eulerian techniques (fixed station) was always realised in the same position near the mouth of the estuary. Consequently the optimal salinity range for *E. affinis* (around 5) was under sampled. Although these slight sampling biases, the dominance of *Acartia* sp. during summer was previously documented in the Seine estuary and also on other European estuaries. We suggest that the summer season is a critical period in the life cycle strategy of *E. affinis* in the Seine estuary (and other similar estuaries). In order to test these hypotheses the effects of high temperatures (>20°C) on the life cycle traits of *E. affinis* and *A. tonsa* from the Seine estuary should be studied experimentally.

Poster S7-3499

Foraging behaviour of the European whitefish *Coregonus lavaretus* larvae on copepods

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Successful fish recruitment relies not only on adult spawning stocks and physical processes, but also on the availability of prey. Indeed, feeding success is a key factor for larval growth and survival. However, feeding success is highly determined by the small-scale processes occurring during the predator-prey interaction. Comparing the feeding responses of larval fish to different environments (marine, brackish and lacustrine) in different latitudes (temperate and tropical) can give us insight about the mechanisms regulating the energy transfer from a lower to a higher consumer level. In this framework we studied the European whitefish (*Coregonus lavaretus*) of a sub-alpine lake. We investigated the predatory behaviour of three wild *C. lavaretus* larvae collected from Lake Annecy (France), fed upon zooplankton primarily composed by copepods. A preliminary set of 57 predator-prey events were recorded and analysed using image processing software. The successful predatory sequence of this species consists of: the encounter, the pursuit, the fixation, the attack, and the capture. While attacking its prey the European whitefish larvae exhibits an "S" shaped posture and moves only a few mm toward its prey to engulf it. Average attack speed was $27 \pm 10.6 \text{ mms}^{-1}$ and capture success ratio (capture/attack) was 0.26. The implications of the feeding responses of the larval *C. lavaretus* for its energetic balance are considered. Particularly, the potential consequences of zooplankton community structure on larval growth are discussed.

Poster S7-3506

Seasonal ascent of *Calanus finmarchicus* as driving force for herring feeding migration

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The seasonal development of *Calanus finmarchicus* was studied in relation to the physical environment and phytoplankton bloom dynamics in the Norwegian Sea. Additionally, the feeding migration of Norwegian spring spawning herring was studied in relation to prey abundance and environmental factors that may affect their feeding migration. The surveys were spatially and temporally designed to include the seasonal production cycle of plankton and the feeding migration of Norwegian spring spawning herring, carried out on a basin-scale from March to August 1995. Variations in the timing of *C. finmarchicus* seasonal development within and between water masses were linked to the phytoplankton development, both following a path of delayed seasonal development toward the west and north. This path coincides with the clockwise feeding migration pattern of herring. Herring abundance was positively associated with the overwintering population of *C. finmarchicus*. We suggest that spatial gradients and temporal dynamics of the seasonal ascent of the *C. finmarchicus* overwintering generation

provide stimuli for and affect the feeding migration of herring. Herring predation on the overwintering population of *C. finmarchicus* was estimated at 9% of the production of older stages of *C. finmarchicus*. The distribution of the overwintering generation of *C. finmarchicus* seems important for the direction of the herring migration, but the effect of predation by herring on the population of *C. finmarchicus* may be limited.

Poster S7-3527

Can hard clam larval survivorship explain recruitment failure in the Great South Bay: A modelling study

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A biochemically-based model was developed to simulate the growth, development, and metamorphosis of hard clam (*Mercenaria mercenaria*) larvae. Larvae are simulated in terms of protein, neutral lipid, polar lipid, carbohydrate, and ash content. Initial biochemical content of the larva is determined by egg composition and changes in content occurs as the larva grows and in response to the biochemical composition of available food. Simulations that used environmental conditions from Great South Bay, Long Island, showed that variations in temperature and food quantity produce small changes in overall larval survivorship relative to that obtained from average conditions. The largest decrease in larval survivorship resulted from variations in the quality of food available to the larva. Reductions in food lipid content resulted in lowest larval survival rate. These results suggest that potential changes in food quality during the past decade may contribute factor to the present low recruitment rates of hard clam larvae in Great South Bay.

Poster S7-3533

Trophic interactions between diatoms, non-diatoms and zooplankton; why polyunsaturated aldehydes cannot be considered as diatom defence metabolites

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The interactions among diatoms, non-diatoms, protozooplankton and copepods were considered using multi-nutrient models, including an age/stage resolving description of copepod demography. The model shows the stoichiometric implications of grazing on different phytoplankton prey growing under combinations of light, N and Si limitation. It also incorporates a prey-selectivity function capable of switching between food items of varying quality. The results show clearly that the production of polyunsaturated aldehydes, or other stage-impacting toxins, should not be considered to provide a defence for the organisms (diatoms) associated with their production. This does not necessarily imply that on occasion such toxins may not have a negative impact on copepod growth (depending on copepod demography and predator-prey matching). However, other interactions between the plankton may in part compensate for any short term impacts at the levels of both phytoplankton growth and copepod growth. While evolutionary pressure over the long term may be expected to select for copepods that avoid diatoms, such pressure is at least as likely to stem from the poor nutritional value of such a diet, when phytoplankton are nutrient deprived, as from the production of any toxins during their consumption.

Poster S7-3539

Significance of variability in food and temperature on copepod survival, growth and reproduction

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The calanoid copepods *Acartia clausi*, *Pseudocalanus* sp., and *Temora longicornisi*, and the cyclopoid copepod *Oithona similis* from Norwegian coastal waters were used to study inter-specific differences in starvation sustainability. *Acartia clausi* was also used to study effects of variable temperature on growth, stage-specific size

and variable food level on egg production. Finally, the effect of variable food level on growth and stage-specific size of *Acartia tonsa* was studied. *Pseudocalanus* sp. showed a steady mortality rate during starvation of around 3.7 % d⁻¹ over the whole experimental period of 26 days, whereas *O. similis* showed a high (7.0 % d⁻¹) mortality rate over the first 12 days, thereafter reducing to 0.6 % d⁻¹. Both *A. clausi* and *T. longicornis* showed three phases in their mortality response to starvation. *Acartia clausi* showed an initial mortality rate of 2.0 % d⁻¹ over the first six days, followed by high mortality (8.4 % d⁻¹) between days 7 and 15, thereafter reduced mortality (1.7 % d⁻¹). *Temora longicornis* had an initial period of 8 days with a mortality of 2.9 % d⁻¹, followed by an intermittent period (days 9-19) when the mortality was high (6.7 % d⁻¹), and ending with low mortality (0.9 % d⁻¹). *Acartia clausi* nauplius I and II (NI and NII), held at saturated food condition in three temperature treatments over 10 days, 12.5°C, 10/15°C (12h/12h), and 15°C, reached on average one development stage further at 15°C compared to the two other treatment groups. Warmer temperatures tended to have a negative effect on the individual size of the last two nauplius stages, whereas there was a positive correlation between individual size and temperature in the CI and CII that developed. Adult female *A. clausi* held at 11°C with *Rhodomonas baltica* as food in three different treatments, 75 ug C l⁻¹, 0/150 ug C l⁻¹ (24h/24h), and 150 ug C l⁻¹, showed highest egg production in the high food condition, and lowest with 75 ug C l⁻¹. However, after some days delay the fluctuating food condition gave the same egg production as the high food condition. Variable (0/150 ug C l⁻¹) food condition in *A. tonsa* resulted in a lower average stage (stage 6.3, where NI = 1; CVI = 12) than at 75 and 150 ug C l⁻¹ (stage 7.3 for both) after 10 days from start (stage 4.1). Average naupliar size did not differ between treatments whereas average copepodite size was larger for 150 ug C l⁻¹ than for the other two treatments. The results illustrate how environmental variability may influence survival, development and growth in different ways for different copepod species, thereby contributing to the species succession in zooplankton communities.

Poster S7-3549

Seasonal abundance of zooplankton south of Iceland – a multivariate approach

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Seasonal variations in zooplankton abundance and composition, as well as life history of some common zooplankton species, were studied in relation to hydrography and chlorophyll *a* between February 1997 and March 1998. The sampling was carried out at two stations south of Iceland near the main spawning grounds of several commercially important fish species. Abundance of zooplankton was low during winter, peaked in June/July (~1.000.000 individuals m⁻²) and remained relatively high until August. A total of 63 species and taxonomic groups were identified in the samples. In general, copepods dominated the zooplankton (65%-95%). *Temora longicornis*, *Oithona* spp. and *Calanus finmarchicus* were the most abundant species (~ 30%, 22%, 15% of the total zooplankton, respectively). Less important groups were *Evadne nordmanni* (~7%), *Pseudocalanus* spp. (~4%), Copepoda nauplii (~3%) and *Microcalanus* spp. (~3%). Canonical correspondence analysis (CCA) was used to relate seasonal change in community structure to environmental variables. A clear seasonal cycle in species composition was revealed. Chlorophyll *a* was found to be the most important environmental variable in explaining the species composition, followed by temperature and salinity. The CCA further demonstrated a separation between early summer species (i.e. *E. nordmanni* and *Podon leuckarti*) primarily associated with phytoplankton, late summer species (i.e. *T. longicornis* and *Acartia* spp.) closely correlated to temperature and winter species with *Scolecithricella minor* and *Metridia* spp. being relatively abundant.

Poster S7-3558

Reproduction and development of the copepods *Rhincalanus gigas*, *Calanus simillimus* and *Pleuromamma robusta* during an iron-induced phytoplankton bloom (EIFEX) in the Southern Ocean

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The Southern Ocean is characterised by low temperatures and a short growth season for primary producers, potentially limiting zooplankton growth and reproduction. However, the association of spawning events with phytoplankton concentration is not yet clearly demonstrated. Egg production experiments were performed with

the three dominant copepod species *Rhincalanus gigas*, *Calanus simillimus* and *Pleuromamma robusta* during the European iron fertilization experiment (EIFEX) over a period of approximately five weeks. In response to the iron fertilization, a diatom bloom developed with chlorophyll *a* concentrations up to 3.1 $\mu\text{g Chl } a \text{ L}^{-1}$. *Rhincalanus gigas* showed a clear response to increasing chlorophyll *a* concentrations and the total egg production of the *R. gigas* population was highest just after the peak of the bloom at day 30 after fertilization. The average production was 50 eggs female⁻¹ day⁻¹. The percentage of egg producing females increased from about 0 to 90% during the course of the experiment. The results are supported by the maturation of the gonads determined by means of microscopy, which reflected the response to enhanced chlorophyll concentrations. The egg and naupliar abundances reflected this response as well, and increasing animal concentrations were determined inside the fertilised patch during the course of EIFEX. While the egg production rate of *C. simillimus* was nearly the same inside and outside the fertilized area, *P. robusta* did not produce eggs in the experimental incubations regardless of the environmental situation. The results from the egg production experiments will be discussed in relation to the development and abundance changes of the copepod species in the field.

Poster S7-3564

Fluctuations of the copepod community in Magdalena Bay, Baja California Sur, México

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The objective of this paper was to study the variability of the copepods between 1997-98 and 2000-2001 to distinguish trends in the copepod community in the Magdalena Bay. 105 copepod species were identified and accounted. The copepod diversity index fluctuated between 0.8 and 3.2 bits/ind and the higher values were related to SST anomalies ranked 2-4°C. The abundance of copepods showed a maximum in April 1998 (> 1·106 ind·100 m⁻³) and lower values in both November 1997-98 and 2000-01 (~ 30,000 ind·100 m⁻³). Highest abundance concentration was recorded at chlorophyll *a* concentrations between 1.5 to 2.5 mg m⁻³. Eleven species determined the community structure, and *Acartia clausi*, *Paracalanus aculeatus* and *Paracalanus parvus*, were the most frequent and abundant species. *A. clausi* ranked 7-88% relative abundance and 94% occurrence; a negative trend of *A. clausi* abundance was observed along the period related to the SST. The relation between *A. clausi* density and chlorophyll *a* concentration no showed significant relationship, despite of had positive correlation. Seasonal cycle of abundance of copepoda and the dominant species is proposed.

Poster S7-3566

The effects of eddy transport on zooplankton biomass and community composition in the western Arctic

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In September 2004, we identified an anticyclonic, cold-core eddy in the Chukchi Sea and conducted a survey of its physical, chemical and biological properties. The eddy, located over the continental slope north of the Chukchi Shelf in the western Arctic, had a radius of ~8 km and was centred over a bottom depth of ~160 m. The core of the eddy was composed of water of Pacific origin as suggested by its physical and chemical properties and by the presence of copepods from the North Pacific Ocean (*Neocalanus flemingeri* and *Metridia pacifica*). Vertical distributions of zooplankton were associated with the physical structure of the water column. For most taxa, concentrations in the eddy core were elevated compared to waters of similar density in the basin. Higher abundances of *Metridia longa*, *Oithona similis*, *Oncaea* and *Pseudocalanus* within the eddy appear to be related to a combination of aggregation behaviours and retention mechanisms, and underline the important role of eddies in shelf-basin exchanges. An important exception was *Calanus glacialis* which had high concentrations above the eddy core. Our observations suggest that although the eddies found in the western Arctic are relatively small, their impact on the biological community in terms of mediating transport from the Arctic shelves into the basin interior can be significant. Alterations in the extent and timing of these key mesoscale processes could alter food webs and drive large ecosystem changes.

Poster S7-3568

The effects of hydrostatic pressure on eggs of the calanoid copepod, *Calanus sinicus*

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The effects of hydrostatic pressure on egg development of *Calanus sinicus* were examined. Egg development was observed under six temperatures (5, 8, 10, 15, 20 and 25 °C) and four pressures (1, 5, 10 and 100 atm). Egg development time was not affected by hydrostatic pressure. However, the egg hatching success significantly decreased with increasing pressure conditions. Most of the nauplii hatching under high pressure (10, 50, and 100 atm) were deformed and apoptotic cell degradation was detected in these abnormal nauplii. Eggs of *C. sinicus* did not tolerate even 10 atm, which is the pressure at 100 m depth. Although the lowest temperature tolerated by *C. sinicus* eggs is lower than 5°C as tested in the laboratory, the northern limit of distribution of *C. sinicus* is the Oyashio front, where mean annual maximum temperature at 20-30 m depth is 13.0±1.0 °C. Egg development time of *C. sinicus* at 13°C is estimated as 1.21 days by the Bělehrádek's function ($D=53.4(T+0.86)^{-1.44}$; where D is the development time in days and T is temperature in °C). Considering that egg sinking rate may be 70 m day⁻¹, and that the spawning depth could be about 20 m, the egg hatching depth would be approximately 100 m (=10 atm). These data suggest that eggs of *C. sinicus* would not survive in the Oyashio region. The effect of hydrostatic pressure should be considered as a factor controlling zooplankton distribution as well as temperature.

Poster S7-3574

GLOBEC process studies of small-scale biology-physics interactions

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Identification and understanding of multi-scale, key physical-biological interactions in determining ecosystem structure and secondary production are one of the major goals of GLOBEC. This presentation will review the status of small-scale process studies, which have been accomplished and enhanced within GLOBEC and/or projects relevant to GLOBEC research objectives. We classified the small scale into the two levels: (1) micro-scale physical processes including isotropic turbulence and dissipation (spatial scale: 1 mm to 1 m both vertically and horizontally, temporal scale: 1 sec to 1 hour), and (2) upper-ocean mixed-layer and pycnocline processes (spatial scale: 1-20 m vertical and up to 20 km horizontal, temporal scale: 20-30 seconds to 1 year). While the majority of experimental studies on micro-scale processes have been done as part of GLOBEC-like, rather than within GLOBEC studies, processes of patchiness formation at small to mesoscale by individual responses to physical cues have been actively investigated by various GLOBEC projects, through field observations based on newly innovated high-resolution 3-D observation systems and development of IBMs. These accomplishments have successfully advanced our understanding of the link between small and meso-scale physical-biological processes.

Poster S7-3586

Life histories of ontogenetically migrating copepods in the Sea of Okhotsk and the Oyashio region: a comparative study

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Ontogenetically migrating copepods (*Neocalanus plumchrus*, *N. flemingeri*, *N. cristatus* and *Eucalanus bungii*) are abundantly distributed throughout the subarctic North Pacific including marginal seas, and they contribute as an important food source for higher trophic level animals and as transporters of organic matter to the ocean interior.

Previous studies showed that their life history features, such as timing of development and vertical segregation of *Neocalanus* copepods, are relatively similar between eastern and western subarctic gyres, but that those of *E. bungii* are locally variable. We investigated the life cycles and vertical distribution of these copepods in the southwestern Sea of Okhotsk based on seasonal sampling. The timing of development in the surface layer for these copepods in the Sea of Okhotsk was later than in the Oyshio region, and the seasonal overlap in development among the species was greater. In contrast, the vertical distributions during the growing period extended to deeper layers with stronger segregation by species. In conclusion, the productive season is later and shorter in the Sea of Okhotsk due to fast-ice formation, and the seasonal segregation in utilisation of surface layers is replaced by vertical segregation among the sympatric, ontogenetically migrating copepods.

Poster S7-3593

Vertical distribution and migration of nearshore and offshore zooplankton in relation to the oxygen minimum zone off central Peru

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Vertical distribution and Diel Vertical Migration (DVM) of the zooplankton community were studied nearshore and offshore at two stations off central Peru (12°02.03 S, 77° W) in April 2006. Zooplankton was collected at 5 depth strata by vertical hauls with a Multinet (300 µm) every 3 hours for 24 hours. Oceanographic data were collected and chlorophyll was estimated after each haul. The dominant species nearshore were *Acartia tonsa* (74.2%), larvae of the polychaete *Magelona* sp. (6.4%) and *Centropages brachiatus* (3.3%). *Acartia tonsa* (54%) and *Eucalanus inermis* (20%) were dominant offshore. Significant positive correlations between vertical distribution and temperature and oxygen were observed for all taxa, except for adults of *Acartia tonsa*, copepodites of *A. tonsa* and copepod nauplii, for which no significant correlations were found. Cypris larvae of barnacles and *Discinichia lamellosa* larvae (Brachiopoda) showed positive correlations with salinity. The zooplankton community was concentrated in the upper layers, indicating a strong constraint by the oxycline. However, some taxa, such as *Magelona* sp. larvae (nearshore) and *Eucalanus inermis* (offshore) apparently performed DVM down to anoxic layers. Other taxa, such as *A. tonsa* (nearshore), showed ontogenetic vertical migration, the adults being located in the upper 20 m, and copepodites and nauplii occupying deeper layers. We discuss changes in zooplankton composition at onshore vs. offshore stations which occurred over 24 hours in relation to the oxygen minimum zone.

Poster S7-3596

Reproduction of the copepod *Acartia tonsa* in the nearshore zone off Callao (Peru)

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The annual reproductive cycle of *Acartia tonsa*, the dominant copepod in the nearshore zone of the central Peruvian coast, was studied from November 2005 to December 2006 with 2 or 3 samplings per month off Callao (9 m water depth). Females were collected with a WP-2 net and oceanographic data and phytoplankton samples were collected simultaneously. Seventy females were separated and incubated in cell wells for 24 hours. After counting the eggs they were incubated for another 24 hours to measure the egg viability. Clutch size ranged from 1 to 41 eggs female⁻¹ d⁻¹ (mean 9 eggs female⁻¹ d⁻¹); egg production rate was between 0.9 to 12.6 eggs female⁻¹ d⁻¹. The maximum value was obtained in February and was probably related to higher temperatures. Egg viability varied from 3.4 to 100%; the lowest values were found between April and May, coincident with very low values of oxygen content in the surface layer. The effect of phytoplankton composition and environmental conditions on egg production is discussed.

Poster S7-3606

Vertical distribution of *Calanus sinicus* and *C. jashnovi* (Copepoda: Calanoida), based on genetic identification, in Sagami Bay, central Japan

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Genetic differentiation among *Calanus sinicus* collected from Sagami Bay, central Japan, adjacent to the Kuroshio Current, *Calanus jashnovi* from the Kuroshio Extension region and *Calanus pacificus* from the Oyashio region were examined for mitochondrial srRNA and nuclear ITS I and ITS II genes, using adult females (C6) which are morphologically distinguishable. The highest levels of genetic differentiation among species were observed at srRNA, followed by ITS I and ITS II. The intraspecific genetic distance of srRNA within *C. sinicus* (0.000-0.002) was lower than the interspecific genetic distance (0.119-0.149), indicating that DNA sequences of these gene loci are consistent with the morphological differences among species, providing a basis for identification of immature specimens. Vertical distribution of *Calanus* species throughout all copepodite stages was investigated in Sagami Bay in May 2006, based on stratified sampling in the upper 1000 m. On the basis of the genetic markers, 22 individuals analysed were allocated into *C. sinicus* or *C. jashnovi* that were also distinguished by the prosome length (PL). Most individuals of *C. sinicus* were found in the 0-50 m layer; however, C5 of *C. sinicus* of ca. 2000 µm PL were also observed below 200 m. While C5 of *C. jashnovi* of ca. 2500 µm PL were distributed below 600 m, the other stages of *C. jashnovi* were almost absent throughout the water column. These data suggest that *C. sinicus* and *C. jashnovi* are able to diapause at C5.

Poster S7-3619

Ontogenetic migration of copepods obtained with an upward migrating swimmer trap in the Amundsen Gulf, Canadian Arctic in the CASES 2003-2004

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An upward-migrating swimmer trap (UST) which can collect sequentially 12 samples of zooplankton moving upward was deployed at 100 m above the bottom of the central part to the Amundsen Gulf for 280 days from October 2003 to July 2004 as part of the CASES 03-04 Project. The UST was used to observe the ontogenetic vertical migration of copepods. The upward migrating zooplankton were obtained every 15 days other than the first two periods. A seasonal change in migration was apparently observed in adult *Calanus hyperboreus*, the upward flux rates (ind/m²/d) of which were low before January and high in January-March. The maximum rate of upward flux was observed during April. Just after that peak flux of adults, nauplii of *C. hyperboreus* became the major migrants. The primary observation suggested that ontogenetic upward migration began in January and lasted until April, with maximum upward flux toward the end. Changes in reproduction and development of the new generation occurred in early May. The timing of the upward migration seems to be earlier than that observed in the subarctic.

Poster S7-3622

Spatial patterns in larval species diversity in the Strait of Sicily (Central Mediterranean). Could they be linked to hydrographic features?

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The present study represents an attempt to test the hypothesis that the hydrodynamics of the Strait of Sicily would affect the distribution and biodiversity of species of larval fish. A multidisciplinary data set was collected during an oceanographic survey accomplished on board O/V "Urania" in summer 2003. Plankton samples and

hydrological data were used. Among the fish larvae a total of 38 families and 59 species were recognised in the biological samples. The results show that larval assemblages seem to be mainly linked to bathymetric areas, and that the main circulation features have limited effects on the reported assemblages. Specifically, two main assemblages were identified, roughly representing coastal areas and offshore regions. Offshore stations are characterised by a quite uniform presence of mesopelagic and bathypelagic larvae, with *Cyclothone braueri* as the most abundant species, and generally these stations have higher diversity levels. Coastal stations are dominated by gobidae, clupeidae and thunnidae, together with larvae of demersal species in shallower regions. Interestingly, the Cape Passero area, identified as a retention area for fish larval stages in previous studies, is characterised by high diversity indices and high larval abundances.

Poster S7-3624

An Antarctic opportunist, *Salpa thompsoni*

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Studies over the past several years have established the importance of sea ice to the life history of Antarctic krill. Concurrently, studies near the Antarctic Peninsula (AMLR) have shown an inverse correlation between “krill years” and “salp years” in the shelf waters of that region, also implicating the importance of ice cover. Historical data of macro-zooplankton in the same region show an overall decrease in krill and increase in salps over the past several decades. As with several other *Salpa* species, *S. thompsoni*, the dominant salp of the Southern Ocean, is capable of forming “blooms” and dominating the zooplankton biomass over large geographic areas. These blooms are the result of the seasonal population growth of the salps. Our study quantifies both the somatic and reproductive growth of *S. thompsoni* in an attempt to better understand the population dynamics of this pelagic opportunist. We measured somatic growth rates $>0.10 \text{ d}^{-1}$ for small aggregates and 0.07 d^{-1} for newly released solitaries. During the early summer, reproductively mature solitaries were carried about 800 embryonic aggregates apportioned among 3 blocks. These high rates demonstrate the salp’s potential for rapid population growth during favourable conditions, adapting it to boom-bust population dynamics on an annual cycle. Although the diet of salps is similar to that of krill, there are marked differences in both life history and composition (for salps only about 0.2 % of the live weight is carbon). The impact of decreased krill and increased salps on higher trophic levels is not currently known.

Poster S7-3627

Summer ichthyoplankton assemblage structure in the Strait of Sicily in relation to the key hydrographic features

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The ichthyoplankton in the waters of Strait of Sicily have been studied during summer from 1998 to 2006. Data from these collections were used to examine spatial and temporal pattern in species assemblages in order to analyse annual variations in ichthyoplankton density, species composition and assemblage diversity and to relate observations to oceanographic conditions in the waters of the Central Mediterranean Sea. Species composition and distribution pattern of ichthyoplankton are mainly influenced by some key hydrographic features. We demonstrate that summer ichthyoplankton assemblages is fundamentally linked to variations in macro- and meso-scale topography and suggest that these intrinsic associations may be modified by spatial and temporal variations in local hydrographic conditions.

Poster S7-3634

The effect of suspended sediment from sand-bed on *Acartia hongii* (Copepoda: Calanoida) in Kyeonggi Bay, Republic of Korea

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The effects of suspended sediment (SS) on *Acartia hongii* were investigated at surface water in Kyeonggi Bay, Republic of Korea, in October, November, December, 2005 and February, 2006. For this purpose, we carried out field experiments using SS pumped up into the surface layer from the sand bed by dredge boat and laboratory experiments using pre-treated fine clay added to the seawater samples. The abundance of *A. hongii* slightly decreased just after sand pumping from the sea-bed due to the high concentration of SS, while abundance of *A. hongii* at a distance from pumping site was similar to that before sand pumping. *Acartia hongii* abundance slightly decreased just after pumping but it recovered within four hours around the pumping area. Abundance of *A. hongii* showed significant correlations with overall mesozooplankton abundance and SS concentration. High SS in the ocean had a momentary influence on *A. hongii*. In laboratory experiments, growth rate (G), ingestion rate (I) and egg production rate (EPr) of *A. hongii* were negatively related to SS, and the relationships were described by the equations $G=0.099e-0.210SS$ ($r^2=0.83$, $p<0.05$), $I=-0.136SS + 1.809$ ($r^2=0.67$, $p<0.05$), $EPr=-1.024SS + 24.81$ ($r^2=0.85$, $p<0.05$). However, the mortality (M) of *A. hongii* was positively related to SS and the relationship was described by the equation $M=4.261e^{0.191SS}$ ($r^2=0.86$, $p<0.05$).

Poster S7-3656

Effect of a total solar eclipse event on the vertical distribution of zooplankton in the Mediterranean Sea

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The possible effect of a total solar eclipse on marine zooplankton was investigated at a fixed station (depth 210 m) close to Kastelorizo Island (Eastern Mediterranean). The abundance and vertical distribution of microzooplankton (ciliates) and mesozooplankton in the water column was recorded before, during, and after the eclipse, during a 7 hour period. For microzooplankton, 7 replicates of water samples were taken every 10 m in the 0-100 m layer. For mesozooplankton, 6 replicates of samples were collected from several layers (0-10 m, 10-20 m, 20-50 m, 50-100 m, 100-200 m) with a WP-2 net (200 μ m mesh size). Vertical profiles of temperature, salinity, turbidity and light were also recorded. The ciliate community responded to the rapid decrease in light intensity during the eclipse, adopting their night-time behaviour. It was clear that ciliates showed a non-random distribution and tended to accumulate at 30 m depth before and after the eclipse, with a vertical spreading in the water column during totality. The mesozooplankton community showed some high abundances close to surface which may be explained by migratory behaviour. The magnitude and the importance of these responses are discussed.

Poster S7-3659

Seasonal cycles of *Calanus* spp. abundance at fixed time series stations on the Scotian and Newfoundland Shelves (1999-2005)

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Zooplankton have been collected in vertical net hauls from bottom to surface at approximately monthly intervals outside Halifax (Station HL2) and St. John's (Station 27) harbours since 1999. *Calanus finmarchicus*, *Calanus glacialis* and *Calanus hyperboreus* are important contributors to the zooplankton biomass, with *C.*

finmarchicus usually most abundant. At HL2, *C. finmarchicus* reproduction is earlier (spring) and occurs over a shorter period than at Station 27, where young stages (CI-CIII) show a peak in abundance in summer but are present year-round, except during March and April. At both sites the spring bloom peak is in April, and while it is short-lived at HL2, it generally persists into May at Station 27. Egg-laying starts before the spring bloom at both sites and the timing of the appearance of the CIs is probably controlled by temperature. *Calanus glacialis* are more abundant at Stn 27 than at HL2, while the opposite is true for *C. hyperboreus*. *Calanus glacialis* and *C. hyperboreus* abundances peak in April at HL2, and in May or June, respectively, at Station 27, and both species are absent for much of the year. This and the stage structures of the populations suggest that egg-laying occurred elsewhere. The observed seasonal cycles reflect the influence of advection at the sampling sites.

Poster S7-3668

A synthesis of the biology and ecology of *Centropages typicus*

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A synthesis of 9 papers recently published in a special issue of Progress in Oceanography and reviewing the current knowledge and understanding of the biology and ecology of *Centropages typicus* obtained over the last 30 years, is presented. Thirty researchers contributed to this special issue. *Centropages typicus* is a temperate calanoid copepod with a wide range of distribution in the North Atlantic and adjacent shelf seas and in the northern region of the Mediterranean Sea. The review covers the characteristic of behaviour, feeding, metabolism, growth and development, and reproduction and explains the temporal and spatial distributions of this species in Mediterranean Sea and in the North Atlantic shelf areas. The amount of knowledge converges to explain why *Centropages typicus* is such a successful copepod species in these coastal areas. The review also points out which future directions of research are needed to better quantify its role in the trophic food chain of pelagic coastal ecosystems.

Poster S7-3672

Zooplankton communities on the continental shelf of the Yellow Sea and the East China Sea

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Zooplankton communities of the continental shelf of the Yellow Sea (YS) and East China Sea (ECS) were classified based on net plankton samples collected in autumn 2000 and spring 2001. A total of 210 species with more than two occurrences were identified. There were 112 common species in both seasons. The most common species in autumn were *Sagitta nageae*, *Calanus sinicus*, *Sagitta enflata* and *Euchaeta concinna*, parts of an average abundance of 6,018 individuals m⁻². Spring dominants were *C. sinicus*, *Sagitta crassa*, *S. nageae*, *Paracalanus parvus* and *Euphausia pacifica*, all occurring at over 75% of the stations investigated, parts of an average abundance of 9,271 individuals m⁻². *Calanus sinicus* accounted for 87 of total abundance in spring. Multivariate analysis delineated five communities: (i) YS neritic community with representative species *Labidocera euchaeta*, *Centropages abdominalis*; (ii) the YS central community with representative species *Themisto gracilipes*; (iii) YS and ECS mixed water community; (iv) ECS inshore mixed water community (v) ECS offshore mixed water community with representative species *Rhincalanus rostrifrons* and *Pterosagitta draco*. Temperature and salinity were more important in effects upon zooplankton communities of the continental shelf than were chlorophyll *a* or nutrient elements.

Poster S7-3673

Autumn diurnal vertical distribution of copepods in the Yellow Sea and the East China Sea

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Diurnal vertical structure of copepod species diversity and biomass were investigated in the Yellow Sea (YS) and the East China Sea (ECS) based on time series of plankton net samples from four stations with different hydrographic conditions, i.e. an inshore station (S1) with low salinity YS surface water, an offshore station (S2) with YS cold water and strong thermocline, a shallow and low salinity station (S3) near the Yangtze estuary, and an offshore station (S4) near the ECS shelf edge. A total of 69 species were identified. *Calanus sinicus* was dominant at S1 and S2, comprising 67% and 85% of the total copepod biomass, respectively. *Calanus sinicus*, *Paracalanus aculeatus*, *Euchaeta concinna*, *Euchaeta plana* were dominant at S3, and *P. aculeatus*, *Eucalanus subcrassus*, *Undinular vulgaris*, *E. plana* at S4. Most species at S1, S3 and S4 had similar, normal diurnal vertical migrations, ascending around midnight and descending in the daytime, although they differed in the scope of their migrations. No significant migration was observed at S2, where species retained their positions below or above the thermocline all day and all night. *Calanus sinicus* and *Oithona* sp. were collected in deeper layers within the YS cold water. The small species *Paracalanus* sp., *Acartia* sp. and some tropic species, e.g. *E. plana*, occurred mostly in the upper water layer. The thermocline had stronger effects on copepod vertical distributions in the YS and ECS in autumn than did salinity, chl *a* or species diets.

Poster S7-3679

Life-cycles and feeding of predominant copepod species in the Bornholm Basin (Baltic Sea) as indicated by lipid dynamics

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Life-cycles and trophodynamics of the predominant copepod species *Pseudocalanus acuspes*, *Temora longicornis* and *Acartia longiremis* in the Bornholm Basin (Baltic Sea) were investigated during monthly field work in 2002 and 2003 as part of the German GLOBEC project and are discussed in respect to copepod distribution and stage structure. Lipid accumulation for overwintering started in early summer for *P. acuspes* in copepodite stages IV and V with high amounts of wax esters, whereas *T. longicornis* females did not switch from reproduction to lipid anabolism (triacylglycerols) before late autumn. This arrest in development and reproduction apparently represented an “active diapause” of both species. Lipid stores of *A. longiremis* females were not elevated during winter, suggesting that most females may not survive the winter season and that resting eggs might be an important source for population recruitment in the following year. According to fatty acid (FA) markers in storage lipids, distinct interspecific and interseasonal differences could be identified. Lipids of *T. longicornis* contained indicators for herbivory, with diatom- and dinoflagellate-signals increasing in times of high egg production and lipid accumulation. *A. longiremis* selected strongly against diatoms at all times, which was most likely a consequence of ambush feeding on large motile prey. A remarkable characteristic in the FA patterns of the copepods consisted in the relatively parallel seasonal progression of 18:1(n-9) with times of peak ciliate biomass in the seston. This reflects an occasionally high relevance of ciliates in the pelagic food web of the Baltic Sea.

Poster S7-3680

Mating success and sex ratio and their consequences for population growth of copepods

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Mating behaviour of the copepods has been an important subject of behavioural ecology of zooplankton. Yet, little is known about how mating success translates into population growth, and how sex ratio alters the population growth despite much information available as to what environmental factors may alter the copepod sex ratio.

We combined experimental measurements of mating success of two estuarine copepods (*Acartia hudsonica* and *Eurytemora affinis*) with a model of mating probability to determine mate search parameters. We then incorporated the estimated mate search volume into a population model incorporating sex ratio to examine population growth. The search volume of *E. affinis* ($4.7 \pm 0.6 \text{ L h}^{-1}$) was substantially greater than that of *A. hudsonica* ($0.16 \pm 0.02 \text{ L h}^{-1}$). This difference may be due to the more efficient search by male *E. affinis* which are tracing a sex pheromone produced by females, than that of *A. hudsonica* males searching for females only through hydromechanical signals. In addition, *E. affinis* males become ready to mate in a shorter time (0.9 ± 0.1 hours) than *A. hudsonica* males (6.6 ± 0.4 hours). Consequently, the critical density of the *E. affinis* population (0.01 individuals m^{-3}) was substantially lower than that of *A. hudsonica* (0.1 individuals m^{-3}). Copepod population growth rate depends on interactions among mating probability, sex ratio, reproductive rate of mated females, and mortality. For a given dependence of mating probability on density (which may be species-specific), higher reproductive rate or survival allows a lower density to support positive growth.

Poster S7-3705

Characteristic time-scales of pelagic copepod egg production

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Egg production is an essential process for the population dynamics of copepods, as it represents the recruitment of new offspring. For decades, zooplanktonologists have used it as an index of copepod population production. Here we review the different parameters affecting egg production and particularly their time scales from small-scale patchiness to diurnal rhythm up to seasonal and decadal variations. Comparison of egg production rates should be established from protocols specifying a set of environmental parameters and female characteristics.

Poster S7-3714

Adaptation of lipolytic enzyme pattern and response in the fatty acid composition of *Temora longicornis* females (Calanoida, Copepoda) due to different diets under laboratory conditions

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Temora longicornis, a calanoid copepod with low energy reserves and high metabolic requirements, is a key species in the North Sea zooplankton community. Since the North Sea is characterised by high seasonal variation in food quality, the digestive system of *T. longicornis* must respond fast to use different food sources efficiently. Lipids play a major role in studies of copepod feeding, because (1) they are an important energy source, and (2) different diets can be traced by specific dietary fatty acids. Information, however, on the capacity of the lipid metabolism to adapt to changing food is scarce. Therefore, we have studied the fatty acid composition and lipolytic enzyme patterns of *T. longicornis* in relation to food supply. Adult females were incubated for three days, feeding either upon the diatom *Thalassiosira weissflogii* or upon the heterotrophic dinoflagellate *Oxyrrhis marina*. The enzyme patterns of single females were identified by SDS-PAGE using a fluorescent substrate for lipases/esterases at the start and the end of the experiments. The fatty acid compositions were analysed by gas chromatography. In females fed with *T. weissflogii* the portion of the fatty acids 16:2(n-4) and 16:3(n-4) increased by a factor of 2.5 and 6.3, respectively. The portion of 22:6(n-3) doubled in individuals fed with *O. marina*. This shows that the dietary fatty acids have been digested and incorporated in the copepod's lipids within three days. In both groups, new enzyme bands (30 to 100 kDa) appeared, indicating a high adaptive capacity of the lipolytic enzyme complex to different diets.

Poster S7-3731

Observations on egg production rates of *Clausocalanus furcatus* from a subtropical coastal area

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We analysed egg production rates of the dominant tropical copepod *Clausocalanus furcatus* off the Rio de Janeiro coast (Brazil) during winter 2001 and summer 2002. The study area is subjected to bottom intrusions of cold and nutrient-rich South Atlantic Central Water (SACW), eventually leading to upwelling episodes under favourable wind conditions. Our main objective was to verify whether egg production and hatching in this species were influenced by SACW intrusions. We carried out experiments at 9 stations on each cruise by incubating individual females in natural seawater for 24 hours, then allowing the produced eggs to hatch for another 24 hours. *Clausocalanus furcatus* remained virtually restricted to the upper mixed layer, where chlorophyll *a* concentrations were relatively low ($1 \mu\text{g L}^{-1}$), staying above the SACW located below the thermocline. Mean egg production rates were usually low, ranging from 0.1 to 13 eggs female d^{-1} , with a grand mean of 5 ± 9 eggs female d^{-1} in both cruises. Maximum egg production by individual females reached 63 eggs female d^{-1} . Hatching success was low ($< 30\%$) for most replicates and experiments, probably as a result of too short incubation times. Correlation between egg production rate and chlorophyll was relatively weak ($r^2 = 0.32$), suggesting that copepods were either exposed to a diluted food environment or that other food items predominated in the females' diet. We explore the latter possibility by comparing the observed egg production rates with vertical profiles of microzooplankton abundance and biomass obtained from the same stations.

Poster S7-3732

Coupling of *Calanoides carinatus* production with South Atlantic Central Water intrusions off the southeastern Brazilian shelf

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Stage-specific biomass and secondary production of *Calanoides carinatus* were estimated on the southeastern Brazilian shelf using different regression approaches (Huntley-Lopez, Hirst-Lampitt, and Hirst-Bunker methods). Since *C. carinatus* is a major component of the zooplankton community in coastal upwelling systems, we hypothesized its abundance and production would increase during intrusions of the South Atlantic Central Water (SACW), which are more frequent and extensive in summer. SACW intrusions cause a system shift from warmer ($> 22^\circ\text{C}$), oligotrophic ($\text{Chl } a < 1 \mu\text{g L}^{-1}$) water to colder ($< 20^\circ\text{C}$), mesotrophic ($\text{Chl } a \sim 6 \mu\text{g L}^{-1}$) conditions. All copepodite stages (CI-CVI) occurred at high abundance during summer, while few individuals appeared in winter. Copepodite V and females dominated in summer and winter, respectively. Biomass was higher at coastal stations (bathymetry < 100 m) than in intermediate (100-200 m) and outer shelf (> 200 m) stations. Early development stages (CI and CII) occurred mainly above 20 m, while the average depth of CVs and adults was at 60-80 m, with intermediate stages between. Mean depth-integrated secondary production rates varied from 1 to 153 $\text{mg C m}^{-2} \text{d}^{-1}$ (figures from the Huntley-Lopez model), with higher values in summer and at coastal stations, following biomass distribution patterns. Estimates from the Hirst-Lampitt and Hirst-Bunker methods corresponded to 15 and 37.5% of the Huntley-Lopez model output, respectively. Overall, these rates corresponded to an average of 0.4 to 2.8% of primary production during summer, and were similar to those encountered in other South Atlantic upwelling systems.

Poster S7-3734

Forecasting the future for the cladoceran *Bosmina longispina* in the Gulf of Riga, eastern Baltic Sea

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The cladoceran *Bosmina longispina* is a key summer zooplankton species in the Gulf of Riga, making up to 50% of the total biomass and thus being involved in nutrient regeneration and various food webs. Its reproductive success, and consequently *Bosmina* abundance, depends on water temperature, stratification regime and upon the bottom conditions, as the cladoceran life cycle includes a resting egg stage. Global climate change is expected to

raise the water temperature and decrease the salinity in the Gulf of Riga due to higher river runoff, which will also lead to higher nutrient content and turbidity. The aim of this study was to identify the present state of conditions for the *Bosmina* resting eggs in the field and to find the reasons for the horizontal and vertical distribution patterns of eggs in the Gulf. *Bosmina* resting eggs were collected by sampling the sediment at stations chosen to represent the major sediment types and oxygen conditions in the Gulf. The results are expected to provide basic information for at least hypothetical forecasts regarding the cladoceran community dynamics in the course of further climatic fluctuations.

Poster S7-3744

Vertical distribution and diel vertical migration of main copepod species in the Bornholm Basin (Baltic Sea)

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Vertical distribution and diel vertical migration (DVM) of copepods are widely studied topics in zooplankton behavioural research. We present results from two intense field studies in June 2001 and April, July, August and November 2002 for the Central Baltic Sea. Stage-specific data were obtained for the five major calanoid copepod species in this area (*Pseudocalanus acuspes*, *Acartia bifilosa*, *Acartia longiremis*, *Centropages hamatus*, *Temora longicornisi*) and for one cyclopoid species (*Oithona similis*). Samples were taken with conventional multiple opening-closing nets, deployed repeatedly to account for horizontal patchiness in the distribution. Concurrently measured hydrography, fluorescence and fish distribution were used to explain the observed distribution and migration patterns. Overall, the copepods could be separated into two groups with distinctly different vertical distribution patterns. Both *Acartia* species, *C. hamatus* and *T. longicornis* inhabited the upper water layers, within which *T. longicornis* performed a diel vertical migration in the summer months, staying in midwater during the day and moving upwards at night. *Pseudocalanus acuspes* and *O. similis* dwelled deeper, in and under the halocline. However, *P. acuspes* showed an ontogenetic vertical migration, with the younger stages dwelling less deep than the older stages. All species showed seasonal differences in their vertical distribution. To analyse the differences between the day and the night distributions, we used a statistic introduced by Beet *et al.* (2003) for zooplankton DVM.

Poster S7-3746

Are *Engraulis encrasicolus* eggs and larvae declining in the Guadiana estuary? Results before and after the Alqueva dam construction

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Studies of plankton dynamics in estuarine and coastal areas often neglect the role of freshwater inflow and runoff. However, it was the beginning of the operation of the Alqueva Dam, in February 2002, that by doubling the volume of water already stored above the Guadiana river dams was responsible for changes in the ecosystems downstream. The decrease in freshwater discharge and nutrient loading affects the primary productivity of the estuary and coastal zone and hence influences the trophic structure and ecosystem sustainability in these areas. Data from *Engraulis encrasicolus* eggs and larvae collected in contrasting hydrologic years characterised by high and low freshwater discharges, before and after the Alqueva dam construction, were analysed. Changes in salinity, nutrients and turbidity, which were mainly due to changes in freshwater input, had an important influence on the structure of the planktonic assemblages. A general decline of productivity of the estuary was registered from chlorophyll measurements. Nevertheless, coastal upwelling can also influence the productivity of the lower estuarine area during short periods both in winter and in summer. Short-term freshwater pulses during spring also enhanced production. As phyto-zooplankton coupling in these systems is an important regulator of processes in the trophic web, changes in the dominant groups can have consequences for upper levels. The results show decreasing importance of this estuary as a spawning ground for anchovy. Also, increased importance was registered of other species such as *Pomatochistus microps* and *Pomatochistus minutus*, with

benthic eggs, from which hatch advanced larvae not so dependent on zooplankton production as are anchovies. The nutritional condition of anchovy larvae was in general lower than that of gobiid species. Since freshwater “pulses” can be managed by regulating the freshwater release from hydrotechnical structures, understanding the relationships between the periodicity and magnitude of inflow pulse events and the estuarine ecosystem structure and healthy functioning is a crucial step towards the development of management tools to support the maintenance of production and fishing grounds. Only continued monitoring can help to distinguish between climate effects and dam effects.

Poster S7-3750

Diatom-copepod interactions: linking nutritional quality with possible toxicity

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The interaction between copepods and their food sources has been under intense scrutiny for many years. Especially the usefulness of diatoms as food has been questioned in recent years, as several authors have shown that copepods when feeding on a diatom diet produce eggs that do not hatch, and in several cases also produce fewer eggs. Polyunsaturated aldehydes produced when the algal cell is damaged have been invoked as an explanation for these observations, although nutritional deficiencies of single diatom diets have also been used as an explanation for the observed effects. Here we present experiments carried out to coalesce nutritional and toxicity aspects of copepod-diatom interactions. We investigated under which circumstances diatoms produce the highest quantities of polyunsaturated aldehydes, and fed those diatoms to the copepod *Temora longicornisi*. At the same time, we carried out experiments aimed to tease apart the effects of toxicity of the aldehydes and nutritional imbalances present in diatoms.

S8 Zooplankton biochemistry and physiology: practical and potential biotechnology applications

30 May, 09:05 (S8-3707) Invited

Chemodiversity and biopotential of planktonic organisms

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Secondary metabolism is regarded as the pool of biochemical transformations specific to a single or restricted number of species. The end products of this cellular activity, generically known as secondary metabolites or natural products, play crucial roles in eco-physiological processes and may also have applications of human interest. Considering man's millenary interest for these molecules, there is a long tradition of studies on secondary products and enzymes from terrestrial sources. By comparison, the sea has scarcely been explored, even though marine organisms have developed unique metabolic processes that do not have similar counterparts in terrestrial habitats due to the severe life conditions at sea. Of the thousands of marine metabolites described in the literature, the majority originate from macroorganisms (macroalgae, coelenterates, echinoderms and sponges) living in coastal and shallow-water sites which are easily accessible from land. Chemistry and biochemistry of other organisms and habitats have been poorly investigated even if, with recent advances in genetic and molecular techniques, marine microorganisms, including phyto- and zooplankton, are now being explored as a potential source of cultivable and renewable bioactive products. Secondary metabolites and biopolymers of marine organisms are currently being screened, extracted and economically produced for use in medicine, cosmetology, aquaculture, functional human food and other biotechnological areas. Difficulties in culturing these organisms on a large scale, together with the fact that many products of interest are prone to chemical, thermal, or photo-oxidative damage, account for the existing gap between basic scientific information and their applicability to marketable products.

In this communication we will show a few examples, some of which already available in the literature, of chemical investigations of plankton secondary metabolites and enzymes of biotechnological interest. The examples illustrate the extraordinary capability of these species to create new chemistry through unprecedented enzymatic activities, shedding light on the possible eco-physiological function of these metabolites in marine organisms. In the spirit of the symposium, the contribution will concern technical aspects and methodologies used to carry out these investigations, with emphasis on zooplankton.

30 May, 09:35 (S8-3442)

DNA barcoding of marine zooplankton: a 'Rosetta Stone' for taxonomic and biodiversity studies

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The marine holozooplankton assemblage includes ~7,000 described species in 15 phyla. Taxonomic analysis of samples is time-consuming and identification of difficult taxa often requires the attention of experts. As part of a global survey of biodiversity, the Census of Marine Zooplankton (CMarZ) has determined DNA barcodes (i.e. sequences for short regions of DNA that discriminate species) for more than 1,500 zooplankton species and seeks to barcode all described species by 2010. The growing database of DNA barcodes will serve the function of a 'Rosetta Stone' for the zooplankton community, by associating a diagnostic DNA sequence with identified specimens and thus providing a new key to the cumulative knowledge of taxonomic experts. The DNA barcode database can be used to identify individual specimens and to identify species in unsorted samples. In the not-too-distant future, DNA barcodes will be used to fabricate DNA microarrays for use in automated taxonomic analysis of known species in zooplankton samples, thus freeing experts to focus on the identification and description of new species. Eventually, DNA microarrays may be used in remote and autonomous applications for characterisation of species diversity and biogeography throughout the world oceans.

30 May, 09:55 (S8-3725)

Behavioural and biochemical effects of hydrostatic pressure changes on *Acartia tonsa* (Dana, 1848) (Copepoda: Calanoida): a methodological approach

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Hydrostatic pressure, like temperature, is a pervasive physical influence in the environment of any aquatic animal. Many animals make daily vertical migrations of several hundred meters during which they can experience considerable changes in pressure, temperature and salinity. Since many zooplankters move between areas rich in food and areas with less food, migrations also may be influenced by recent feeding behaviour. Investigations of vertical migration at intermediate scales (centimetres and minutes) are still in their infancy and data are scarce. Although the overall biological effects of pressure remain uncertain, controlled laboratory studies indicate that animals will respond by swimming upward or downward. In addition to questions about the influences of feeding history, temperature and salinity, artifacts arising from pressure changes that differ in magnitude from those experienced *in situ* raise methodological concerns. The effects of differing temperatures, salinities, presence of food, and pressure changes on the calanoid copepod, *Acartia tonsa*, were investigated in a 10-bar pressure apparatus consisting of a vertical glass cylinder measuring 16 cm in diameter and 45 cm in height. Parameters measured include swimming behaviour, vertical distribution and changes in biochemical composition (carbohydrates, fatty acids and proteins). The results of this study contribute to an understanding of the biology of *A. tonsa* and act as a guide for the design of future experiments with other zooplankters.

30 May, 10:15 (S8-3362)

Zooplankton community genomics

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Impacts of human activities on the environment are of growing concern to society, with biodiversity disturbance being one of the most important issues. However, our understanding of biodiversity, especially in the ocean ecosystem, is very limited and difficult to assess with the current available information. In this context, we need further detailed information to evaluate biodiversity changes in the ocean ecosystem with accurate species identification, recognition of population structure, and genetic diversity. In this respect, we are carrying out an experiment called “Zooplankton community genomics”. We focus on zooplankton, because they occupy a vital role in the pelagic realm of the world ocean ecosystem since they transfer energy and matter produced by unicellular algae to higher trophic levels. They are known to occur in all marine habitats, throughout the vertical and horizontal pelagic realms. Despite such importance of zooplankton in the ocean ecosystem, it is difficult to understand their comprehensive biodiversity, because of fragility, rarity, small size, and systematic complexity of many taxa. We are currently applying molecular genetic techniques to answer this question.

30 May, 11:00 (S8-3726)

The sigma class glutathione S-transferase (GST-S) enhances resistance on oxidative stresses in the intertidal copepod *Tigriopus japonicus*

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We cloned and sequenced full-length cDNA of a novel sigma class glutathione S-transferase (GST-S) from the intertidal copepod *Tigriopus japonicus* Mori. The full-length cDNA of *Tigriopus* GST-S was 1,136 bp in length containing an open reading frame (ORF) of 651 bp that encoded 217 amino acid residues. The recombinant *Tigriopus* GST-S was highly expressed in transformed *Escherichia coli*. The kinetic properties and effects of pH

and temperature on *Tigriopus* GST-S were also studied along with enzyme activity and inhibition assay with known inhibitors. The expression of GST-S was studied using real-time RT-PCR in response to exposure to oxidative stress-inducing agents, hydrogen peroxide (H₂O₂) and metals (Cu, Mn). It was observed that H₂O₂ (2 mM) exposure down-regulated its expression at the initial stage but there was recovery shortly afterwards. In the case of heavy metals there was a concentration-dependent increase in *Tigriopus* GST-S gene expression. These results suggest that *Tigriopus* GST-S may play a conserved functional role in *T. japonicus* against oxidative stress. These findings provide a better understanding of cellular protection mechanisms against environmental stresses including oxidative stress in this ecologically-relevant marine copepod species.

30 May, 11:20 (S8-3341)

Quantifying *Calanus finmarchicus* growth and dormancy using AARS activity

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Between May 1998 and June 2004, we obtained growth rates of the copepod *Calanus finmarchicus* at different locations across the North Atlantic. Copepods were incubated for 2 to 9 days, and fed either with natural food assemblages or cultured algae. We measured both somatic weight-specific growth rates (measured as protein change) and aminoacyl-tRNA synthetases (AARS) activity. We found a highly significant relationship between AARS activity and growth in protein content ($R^2 = 0.55$, $p < 0.001$). Significant AARS activity also occurred when growth was negative, the relationship predicting an AARS activity level ≤ 8.33 nmPPi·mg protein⁻¹·h⁻¹ when somatic growth is zero. This is because AARS activity is expected even when growth is negative, due to the continued protein turnover in the cells. The AARS method allows, for the first time, the study of protein metabolism in overwintering *Calanus finmarchicus*. Our results show that overwintering copepods had significantly lower values of AARS activity than non-diapausing animals ($t = -3.51$, $p < 0.002$). The AARS method opens the possibility to better understand physiology dynamics of deep water organisms (e.g. the beginning and end of diapause).

30 May, 11:40 (S8-3453)

Enzymatic regulation of metabolism in planktonic communities

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Oxygen consumption (R) is caused by enzymatic activity of the respiratory electron transport system (ETS) and not by organism size, mass, surface area, or bio-volume. ETS is ubiquitous in zooplankton. It is the enzyme system that ultimately oxidizes the products of food digestion, makes cellular energy currency, ATP, and consumes oxygen. Current hypotheses concerning respiration are based on empirically observed allometric relationships between R and organism size, mass (M), surface area, or bio-volume. The most accepted version is $R = K_1 M^{3/4}$, where K_1 is a constant. We argue that, for zooplankton, an algorithm based on respiratory ETS activity is more consistent with the cause of respiration. In effect we argue that $R = f(\text{ETS})$. Our point is that, although mass and its related parameters are statistically related to respiration, the first principle cause of respiration, is the enzyme system that controls oxygen consumption. Mass, itself, or size have no first-principles basis for their association with respiration. Consequently we propose to bypass these parameters completely and build a model for respiration on ETS activity, itself. ETS is regulated by temperature (T) and specific reactants (S) that sustain the oxidation-reduction reactions connected to oxygen consumption. The kinetics of this thermal-substrate regulation are described by Michaelis-Menten and Arrhenius equations. We argue that using the following equation,

$$R = A_{\text{ETS}} S (e^{E_a/RT_g}) / (K_m + S)$$

one can calculate respiration. In this equation E_a is the Arrhenius activation energy, R_g is the gas constant, and A_{ETS} , the ETS activity.

30 May, 12:00 (S8-3405)

Effects of diatom aldehydes on copepod reproduction: use of giant liposomes encapsulated with decadienal

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Several studies have shown that some diatoms contain linear poly-unsaturated aldehydes that strongly reduce copepod egg viability. These effects have been observed using classical feeding experiments or by incubating embryos in known concentrations of pure molecules or using the algae *Prorocentrum minimum* as live carrier cells. In the present study, we used giant liposomes encapsulated with decadienal as delivery system to study the effect of this molecule on egg production, egg hatching success, faecal pellet production and adult survival of *Temora stylifera* and *Calanus helgolandicus* copepods. Results show that egg hatching success of *T. stylifera* fed decadienal encapsulated-liposomes at a concentration of 3 ng/ml was reduced by about 50% after 3 days, and 40% after 8 days. Egg hatching success of *C. helgolandicus* fed decadienal encapsulated-liposomes at a concentration of 2.3 ng/ml was also reduced by about 40% after 8 days. Considering an ingestion rate of 0.14 ml/hour, as calculated in a previous paper using ³H cholesterol labelled liposomes, we estimated an uptake of 0.42 ng decadienal per hour per copepod. This concentration, which affected egg hatching success in both copepod species, is much lower than that theoretically calculated by exposing females with decadienal dissolved in sea water. Our results open new questions on how and when a natural diatom bloom can affect copepod reproduction at sea.

30 May, 12:20 (S8-3404)

Use of fluorescent probes in studies on copepod reproduction and development

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Fluorescent probes are common analytical tools in life sciences and biotechnology for labelling nucleic acids, proteins and other bio-molecules. In copepods, they have been used as markers to study the internal anatomy of the reproductive system, as well as to distinguish between fertilised and unfertilised eggs, viable and dead eggs, and other physiological processes regarding developmental status and fitness. Here we discuss the use of several of these probes, including HOESCHT 3342, SYTOX green and deoxynucleotidyl-transferase-mediated dUTP nick-end labelling (TUNEL), that we are currently using in field studies to assess hatching success and abnormal development in the copepod *Calanus helgolandicus* during a toxic aldehyde-producing bloom of the diatom *Skeletonema marinoi* (formerly *S. costatum*) in the North Adriatic Sea. We show that these probes do not only reveal apoptosis and cell death in malformed eggs and nauplii, but also in apparently normal ones that may be compromised due to internal lesions which are not visible with common microscopic techniques. Our study would provide a useful and rapid tool for the assessment of embryonic and naupliar physiological mortality in the field where such rates are poorly known. We also discuss the potential use of new probes such as MitoTracker® (Molecular Probes) to specifically stain mitochondria and 4-amino-methylamino-2',7'-diuorourescein diacetate (DAF-FM) to follow the activity of the signal molecule nitric oxide in order to better study the mechanisms of action of bioactive molecules involved in apoptosis and cell death in copepods.

S8

Posters

Poster S8-3322**Eggs from a calanoid copepod *Acartia tonsa* – tolerance to environmental stressors**Benni Winding **Hansen**

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Eggs from free spawning calanoid copepods are classified as subitaneous or resting eggs. Subitaneous eggs are ready to hatch whereas resting eggs exhibit arrested development. Resting eggs reach the often anoxic and sulphidic sediment. They are categorised as 1) quiescent eggs; subitaneous eggs that enter arrested development if environmental factors are unfavourable, but resume hatchability as soon as the environment becomes favourable, 2) diapause eggs, that no matter what the prevailing environmental conditions are, require a refractory phase to be able to hatch. Hatching time as well as hatching success of subitaneous eggs is strongly temperature dependent within 6-24°C. Eggs cultivated at 6°C contain certain small peptides suggesting the possible presence of heat shock protein synthesis. The oxygen consumption of subitaneous eggs has a Q_{10} of 2.51 ± 0.15 . The effect of temperature on oxygen consumption rate is far less important than the prolonged development time when calculating the energy consumed during embryogenesis. Subitaneous eggs enter arrested development when exposed to low salinity (<10 psu) and energy consumption seems related to ion regulation. Subitaneous eggs also enter arrested development under anoxia and retain 40% hatchability even after one year. These eggs can also tolerate sulphide exposure and enter arrested development. No significant effect of sulphide $\leq 250 \mu\text{mol l}^{-1}$ is observed during ≤ 60 d. However, at a longer time scale viability decreases significantly. Sulphide penetrates the egg shell and with time the eggs are adversely affected and degenerate. We hypothesize that an unknown detoxification mechanism against sulphide is present causing this energy expenditure.

Poster S8-3331**Population genetic structure of a copepod, *Calanus sinicus* Brodsky**Yuan-Shao **Lin**, W.-Q. Cao and S.-J. Li

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Calanus sinicus is not only a dominant copepod that is widely distributed in the Seas of China but also provides a wide size spectrum of food to local commercial pelagic fish stocks. Based on forty-four mtCOI sequences of *Calanus sinicus* collected from Bohai Sea, Yellow Sea and Zhe-Min coastal current zones, nucleotide diversity was $Pi = 0.00313$ and hypotype diversity was $h = 0.8742$. By calculating nucleotide and hypotype diversity, the gene flow of *Calanus sinicus* within the Seas of China was $Fst = 0.01913$, $Nm = 12.82$; $Gst = 0.03342$, $Nm = 7.23$. The result revealed that *Calanus sinicus* has a population with high gene flow. There was no population differentiation found in the Seas of China using Chi-square and PM (permutation) tests with P value > 0.05 (no significant). It is concluded that population genetic diversity of *Calanus sinicus* is relatively poor both in nucleotide and hypotype, and the copepod lacks gene divergence for ecological evolution. The complicated circular current system in the Seas of China may be a key factor which drives *Calanus sinicus* dispersal and determines population distribution patterns. Water temperature may play another important role in survival, growth, and reproduction. In contrast, salinity, the available food supply, depth, etc. may provide a suitable habitat for this copepod.

Poster S8-3340**Seasonal mesoscale variability and zooplankton production in the Labrador Sea**Lidia **Yebra**^{1,2}, R.P. Harris¹, E.J.H. Head³, I. Yashayaev³, L. Harris³ and A.G. Hirst⁴¹ Plymouth Marine Laboratory, Prospect Place, Plymouth PL1 3DH, UK. E-mail: lyebra@icm.csic.es² Institut de Ciències del Mar (CSIC), Passeig Marítim de la Barceloneta, 37-49, Barcelona 08003, Spain.³ Ocean Sciences Division, Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, NS, B2Y 2A4, Canada.⁴ British Antarctic Survey, High Cross, Madingley Road, Cambridge CB3 0ET, UK.

Surface distribution (0-100 m) of zooplankton biomass and specific aminoacyl-tRNA synthetase (AARS) activity, as a proxy of structural growth, were studied during winter 2002 and spring 2004 in the Labrador Sea. Hydrography in the area was complex, showing marked fronts between both shelves and the basin. Results show

that the presence of both cyclonic and anticyclonic eddies affected mesozooplankton biomass and AARS activities distribution. *Calanus* was the most abundant genus in the in the study area. We found three species: *C. glacialis* was restricted to shelves' cold waters while *C. hyperboreus* and *C. finmarchicus* had a widespread distribution from Canada to Greenland. We also present an insight on *Calanus finmarchicus* later stages (CV-CVI) protein metabolism at different depths.

Poster S8-3366

Comparative studies of mitochondrial COI sequence between two *Acartia* species from Xiamen waters

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Acartia spinicauda and *A. pacifica* are sibling species of the southeast coast of China. Taxonomic discrimination of these two species relies on subtle morphological characteristics. They are different in seasonal distribution, but appear together at the end of spring and autumn. The most bewildering thing is that female individuals have intermediate forms. For this study, the molecular population genetic diversity of *A. spinicauda* and *A. pacifica* was described based on DNA sequence variation for a 709 base pair region of the mitochondrial COI gene. Samples of the two *Acartia* species were collected from Xiamen waters from May to October 2004 (15 individuals total). Since the average genetic distance of *A. spinicauda* and *A. pacifica* is 15.6% based on the 709 bps in mtCOI fragment, we conclude that they are different species. Both *Acartia* species show high population genetic diversity (nucleotide diversity of *A. spinicauda*, $Pi=0.0155$, *A. pacifica*, $Pi=0.0126$) in this variable estuarine environment. We also found two kinds of intermediate forms between these two species, and defined their taxonomic status: intermediate form 1 is *A. spinicauda* and there is no difference between intermediate form 2 and *A. pacifica* in mtCOI sequence. As a result, we bring forward a new morphological taxonomic method to distinguish the two types of *Acartia* species and their intermediate forms.

Poster S8-3507

Experimental intensive cultivation of the Mediterranean copepod *Temora stylifera* in a re-circulating system and their potential use as live food in aquaculture

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Artemia nauplii are commonly used in aquaculture as food for fish larvae. However, in the last few years their cost has increased due to depletion of natural resources. In terms of size or biochemical composition, *Artemia* nauplii are not always adequate as food for fish larvae. Although copepods represent an important natural food for many fish larvae they are rarely used in aquaculture. The aim of this project is to set up a system for the intensive production of a Mediterranean calanoid copepod, *Temora stylifera*, and to use nauplii and copepodids as live nutriment for fish larvae. The re-circulating system consists of two 500 litre tanks to rear adult males and females and two 200 litre tanks to collect nauplii. Different uni and pluri-microalgal diets have been tested in order to maximise egg production rate and hatching success. In addition, algae with high fatty acid contents were used to improve the nutritional value of nauplii and copepodids. Unialgal diets, *Prorocentrum minimum* and *Isochrysis galbana*, were provided at a mean carbon concentration of 1 mg C/l. In the pluri-microalgal diets, *P. minimum* was still supplied at 1 mg C/l, whereas *I. galbana* and *T. suecica* were furnished as enrichment food at high concentrations based on the size ratio of *P. minimum* and these algae. At present, the best results in terms of egg production (31.76 ± 16.8 eggs/female/day) and hatching success (75.36%) were obtained with a mixed diet of *P. minimum* and *I. galbana*.

Poster S8-3532

Taxonomic and phylogeographic comparisons of *Calanoides carinatus* (Copepoda, Calanoida, Calanidae) from the Atlantic Ocean (43°N-47°S)

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Calanoides carinatus inhabits the Atlantic and Indo-Pacific oceans and the Mediterranean Sea. In highly productive areas this species may dominate the copepod biomass and occupy a pivotal position in fisheries food webs. Despite the ecological importance of this species, its taxonomic status and biogeographic range are not certain. An international collaborative project, the *Calanoides carinatus* ZooGene Project (CCZP), was designed during the 3rd International Zooplankton Production Symposium (Gijón, Spain) to examine population genetic variation of *C. carinatus* across its biogeographic range in the Atlantic Ocean. Samples were collected from populations of the western (off Brazil and Argentina) and eastern South Atlantic Ocean (off South Africa) as well as the eastern North Atlantic Ocean (off Spain). Ten individuals were sequenced from each region for a ~700 base-pair region of the mitochondrial cytochrome oxidase I (mtCOI) gene. Molecular phylogeographic analysis indicated that *C. carinatus* of the western S. Atlantic were genetically cohesive. Since the type locality of the species is near the Brazilian collections, we conclude that these populations are indeed *C. carinatus*, *sensu stricto*. Opposite, specimens from the eastern Atlantic differed from the western Atlantic samples by 21% for mtCOI sequence. The eastern Atlantic form was genetically similar (~2% mtCOI sequence differences) from Spain to Africa. These results are consistent with the designation of two different species from the western and eastern boundaries of the Atlantic Ocean. The geographical distribution of *C. carinatus* should thus be considered to include only the western boundary of the South Atlantic Ocean.

Poster S8-3637

Seasonal- and post mortem changes in *Calanus finmarchicus*, with main emphasis on lipids

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Fisheries are now reaching limits for sustainable catches worldwide. However, interest for marine lipids is increasing due to a growing awareness of the health benefits of these lipids. Accordingly, the interest for harvesting lower trophic levels is increasing. *Calanus finmarchicus* is one of the major copepod species in the North Atlantic Ocean which is currently being considered for possible exploitation for its lipid reserves. Seasonal variations in lipid content in *C. finmarchicus* are mainly due to an increase in the wax ester fraction. However, differences are also found in phospholipid content. The fatty acid composition in the polar lipid fraction is on the other hand stable, both as a function of season and between other investigated copepod species. In *C. finmarchicus* sampled throughout the year, DHA (22:6n-3) and EPA (20:5n-3) contributed with 40.8% (± 5.4) and 20.8% (± 3.3) of the identified fatty acids in the polar lipid fraction, respectively. When individual phospholipids were investigated at different seasons, higher levels of DHA were found in phosphatidylethanolamine (57.3% ± 0.7) compared to in the phosphatidylcholine (37.8% ± 1.6). However, phospholipids as well as proteins are rapidly broken down post mortem due to high enzymatic activity. Phospholipases (PLA₂) and proteolytic activity have been investigated. The effect of temperature for stabilisation procedures on the various lipid fractions will be discussed.

Poster S8-3641

Integrated at-sea morphological and molecular assessment of zooplankton biodiversity in the northwestern Atlantic Ocean from the surface to 5000 m

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Zooplankton from northwestern Atlantic tropical/subtropical waters were sampled at five stations from the surface to 5000 m. Environmental data and zooplankton samples were collected with a 102 m opening/closing MOCNESS trawl with 335 µm mesh nets from 5000 to 1000 m. Two smaller MOCNESS sampled the upper 1000 m. Ring net and water bottle casts, and blue-water SCUBA diving were also conducted. A team of taxonomic experts using traditional morphological approaches analysed samples at sea and provided identified specimens for determination of DNA barcodes for species recognition. Over 500 species were identified; >1000 specimens were placed in a queue for barcoding; 87 species were barcoded at sea. For several taxonomic groups, a significant fraction of the region's known species were collected and identified (i.e. 65 ostracod species were identified of the 140 known species for the Atlantic Ocean were collected, plus at least six undescribed species, and the first DNA barcode for a planktonic ostracod was obtained). Also identified were >40 molluscs, >100 species of cnidarians, several hundred species of copepods, and >100 species of fish. At least 12-15 new species will be described from this effort. The deployment of specially-designed trawls to sample large volumes for small zooplankton is essential to provide an accurate assessment of species diversity at great depths. This study yielded preliminary confirmation of high species diversity and low species abundances in the deep sea. Below 1000 m, even rare species may have huge population sizes and play a critical role in the dynamics of deep-sea environments.

Poster S8-3727

Mining of massive expressed sequence tags (ESTs) from the intertidal copepod *Tigriopus japonicus* using GS-20 sequencer

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To get a massive amount of information of expressed sequence tags (ESTs) from a copepod, we used a GS-20 sequencer after making blunt-end cDNAs from the intertidal copepod *Tigriopus japonicus*. After two runs of the GS-20 sequencer, we got approximately 40 Mb of cDNA information of this species. This information represents expression profiles including functional genes along with structural genes. Of the functional genes, several groups of important genes were appeared for maintaining the intact balance of the life of the copepod. These genes consisted of antioxidative genes, DNA repair genes, heat shock protein genes, mutation-related genes. This kind of approach would be very useful to obtain molecular information of non-model organisms such as copepods. We here discuss the potential use and their application in molecular and environmental investigations using copepods.

Poster S8-3728

High similarity of 16S rRNAs between two jellyfishes, *Aurelia aurita* and *Dactylometra quinquecirrha*

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To obtain genetic information from two jellyfishes *Aurelia aurita* and *Dactylometra quinquecirrha*, we amplified 16S rRNAs and sequenced 503 bp. After comparison of the two species, we found 4 bp of differences between both jellyfish. This result shows that these jellyfishes do not have a big difference in nucleotide sequences, even though they are different species. This also indicates that we need to get more sequence information to identify the species, especially in early developmental stages.

Poster S8-3730

Mitochondrial genomes of two jellyfishes, *Aurelia aurita* and *Dactylometra quinquecirrha*

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To get complete mitochondrial genomes from two jellyfishes, *Aurelia aurita* and *Dactylometra quinquecirrha*, we designed 14 conserved primer sets for amplifying the protein-coding region, 16S and 12S rRNAs. After amplification of these regions by polymerase chain reaction, we cloned them to pCR2.1 TA cloning vector for further analysis. Currently, we have sequenced 8 kb and 6 kb of two jellyfishes, *A. aurita* and *D. quinquecirrha*, respectively. These results may be applicable to designing the new markers to identify blooming-causing organisms, especially in early stages of development, and also be applicable to designing the specific primer sets for amplifying the complete mitogenome for other cryptic species of jellyfishes which is currently lacking.

Poster S8-3784

Spatial population genetic structure and phylogeography of two species of the copepod genus *Clausocalanus*

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The copepod genus *Clausocalanus* includes widespread species that occur in every ocean and can be very abundant (and sometimes numerically dominant) in many places. Despite their overlapping distributions, the species are ecologically, biogeographically, and genetically distinct. The present study focuses on two species: the circumglobally distributed *C. arcuicornis* and the biantitropical *C. lividus*. DNA sequences for a portion of mitochondrial cytochrome oxidase I (mtCOI) were determined for individuals of different populations of each species. Multiple analytical approaches were carried out in order to analyse phylogeographic patterns and genetic population structure for both species. The results showed high haplotype diversity for both species, especially *C. arcuicornis*, and a lack of intermediate haplotypes. An hierarchical Analysis of Molecular Variation (AMOVA) revealed differences in population genetic structure between the two species: *C. arcuicornis* primarily exhibited variation within populations, whereas *C. lividus* primarily had variation among populations. Cluster analysis of F_{st} values between pairs of conspecific populations clearly showed differing patterns of genetic diversity for the two species. Phylogeographic analysis of spatial patterns of mtCOI haplotypes provided evidence of gene flow patterns, with differences between *C. arcuicornis* and *C. lividus* likely resulting from their biogeographical distributions.

Poster S8-3976

Effect of the essential fatty acids DHA and EPA on egg production and hatching success of the marine copepod *Temora longicornis*

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In marine ecology the link between phytoplankton and copepods has been a major issue for many decades. So far diatoms have been considered as the principal components of planktonic copepod diets. Recent studies have shown that heterotrophic protists and dinoflagellates can be important food sources for copepods and the hatching success seems to be more closely correlated with biomass of heterotrophic protists and dinoflagellates than with diatoms. The diatom-copepod link, which was believed to be the predominant food chain, is most likely, a part of a more complicated planktonic food web. The calanoid copepod *Temora longicornis* and the food (seston <

200 µm, grouped into diatoms, dinoflagellates and ciliates) were sampled in the Trondheimsfjord, central Norway, successively during one year. Egg production and hatching success of adult females were measured post harvest in the laboratory together with essential fatty acids (EFA) in the food. The dominant EFA in the seston samples were DHA (22:6n-3) and EPA (20:5n-3).

In spring the seston samples were dominated by diatoms and contained relatively low amounts of DHA (DHA/EPA ratio; 0.3 - 0.7) whereas dinoflagellates and ciliates dominated during summer and fall contain higher amounts of DHA (DHA/EPA ratio; 1.9 - 2.7). The changes in the DHA content had a significant effect on the egg production and hatching success of *T. longicornis*. The quantitative and percent DHA contents of the food was significantly related to egg production but no such relationship were observed for the quantitative or percent content of EPA.

S9 Advances in image technologies and the application of image analysis to count and identify plankton

1 June, 09:05 (S9-3667) Invited

From the OPC to the CCD

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Remote sensing of plankton and their environment is essential to the future ocean observation systems designed to portray their distribution and abundance world-wide. The ability to remotely sense physical and biological properties of the oceans has made great strides over the past several decades and is constantly being refined. The resultant proliferation of new sensors and instruments is particularly apparent in the realm of plankton ecology. An ever-increasing diversity of imaging systems is providing oceanographers with new insights into the structure and function of planktonic ecosystems on scales ranging from millimetres through ocean basins. Early attempts to use film cameras in conjunction with nets gave rise to stand-alone, analog video camera systems. Advances in imaging sensor, fibre-optic telemetry, microprocessor, and illumination technologies have now made it possible to construct sophisticated plankton imaging systems capable of revealing minute details of planktonic organisms and their distributions. The coupling of low cost and low power imaging systems with towed, moored, and autonomous platforms will revolutionise the way in which plankton data are acquired and utilised. This presentation will summarise the diversity, potential, and challenges associated with planktonic imaging systems.

1 June, 09:30 (S9-3299) Invited

The computer does the hard work: (semi)-automatic classification of zooplankton

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Manual enumeration and measurement of zooplankton has always been a bottleneck in plankton studies. With the advances in numeric imaging systems, both *in situ* and for the analysis of traditional plankton net samples in the laboratory, new opportunities appear to automate plankton analysis using computers. Whatever the initial images and whatever the purpose of the analyses, the scheme is always the same: (1) images are analysed and particles are identified (segmented), (2) various features are extracted, (3) a small subsample is manually identified to make a training set, (4) a classifier is trained to recognise these particles, and (5) that classifier is finally used to identify all plankters in the series. Even if this scheme is well-known and successfully applied to various machine vision applications (for instance, face recognition, car numberplate identification), its application to plankton is challenging due to the extreme variability of planktonic organisms. Several recent studies show, however, that current algorithms can separate 20-30 taxa or more, with a success level of about 75-80%. This is enough for many ecological studies, and a good starting point for other applications. Given the common framework and current performances of such systems, we propose a free software, called ZooImage (<http://www.sciviews.org/zooimage/>), tailored for such analyses. It is both a highly customisable toolbox to build actual applications, and a complete environment ready to routinely analyse plankton digital images. Its mode of operation ranges from completely automatic analysis to semi-automatic support for taxonomists and operators working with plankton digital images. It is not a proprietary system, but a project aiming to be developed collaboratively by the scientific community (e.g., the "RAPID" SCOR working group for automatic visual plankton identification). The main benefit expected from such a collaboration is a coherent environment to analyse numerous plankton images whatever their origin, and without unnecessary duplication of the development effort across separate and incompatible projects.

1 June, 09:55 (S9-3560)

Taxonomically driven recognition of features for visual categorisation of zooplankton

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Taxonomic identification of zooplankton to species can require careful inspection of specimens under a microscope. Recent developments in machine vision systems offer automatic recognition of zooplankton to group or occasionally to genera. It is desirable, from an ecological and biodiversity viewpoint, to improve this taxonomic resolution to species. Unfortunately, pattern recognition algorithms utilised at present, do not directly use taxonomic features of specimens for identification. A more scattergun approach is used, where the machine extracts all low level features it can. These features are then correlated through a training process to achieve acceptable recognition rates. Discrimination of species is not possible unless the morphological differences between genera are profound. We are currently developing a hybrid knowledge-based system that uses features identified by taxonomic experts in a top-down model fitting process to bottom-up camera derived images. Initially, we are using high resolution 3-D confocal images of the calanoid copepod *Temora stylifera* to extract features and to match these to the model described in Culverhouse *et al.*, 2006. Techniques are being developed for feature location and identification on lower resolution optical images derived from laboratory microscope and *in situ* automated systems. The proposed steps for this new taxonomically oriented recognition system will be outlined and progress presented.

1 June, 10:15 (S9-3411)

A compact, low-power digital holographic imaging system for automated plankton taxonomical classification

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Digital holographic imaging (DHI) records three-dimensional information about plankton located throughout a large sample volume. Holograms captured by a digital detector array are computationally reconstructed to yield high-resolution images of plankton, which then can be utilised in automated taxonomic classification algorithms. We have developed a lens-less DHI camera system that uses a high space bandwidth-product (SBP) camera and compact optics. The system reveals morphological details, enabling greater taxonomic resolution, along with object size, 3D position and orientation. The high SBP camera improves sample volumes to 500 mL per exposure while maintaining resolutions down to 9 microns and allowing objects ranging from 100 µm to 5 mm. A laser diode with fibre coupling reduces overall size and power consumption, making the system suitable for deployments on autonomous vehicles. A new focus metric computed in the Fourier domain makes locating plankton a near-real-time process, an order of magnitude faster than previous methods. Variations include using a spherical reference wave to magnify small objects (with 3 µm resolution) without using lenses or by using a 4*f* optical arrangement to magnify images by a set factor. The system has been tested in the laboratory and shipboard with numerous samples including copepods, diatoms, brine shrimp, small nekton, *Phaeocystis* colonies, and *Trichodesmium*.

1 June, 11:00 (S9-3654)

Estimating zooplankton production from images

Angel **López-Urrutia**, J. Cabal and L. Valdés

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It's been a couple of decades now since Huntley and Boyd (1984) suggested that high resolution zooplankton production estimates could be obtained from a combination of automated techniques to count zooplankton and equations to estimate individual production from temperature. Since then, there have been significant advances in the development of models to describe the dependence of zooplankton physiology on temperature, body size, resource availability, and life history strategies. There have been few attempts, however, to use the advances in

imaging technologies to take advantage of these improved models for estimating zooplankton production. In order to obtain such zooplankton production estimates, accurate estimation of organism size, biomass, and life history strategy should be principal objectives of image analysis systems. Using a time series of zooplankton in the southern Bay of Biscay we evaluate the ability of image analysis methods to measure zooplankton abundance and biomass and to obtain a classification of zooplankton into functional groups that have distinctive life history strategies and physiological rates. We compare the results with taxonomic counts and biomass estimates obtained by traditional methods, finding relatively good agreement between both methodologies. Our results suggest that a combination of physiological models and automated sample analysis can provide high resolution estimates of zooplankton production.

1 June, 11:20 (S9-3713)

Bridging the gap between biology and physics: the use of the Video Plankton Recorder to understand distributions and transport of plankton and particles in the Western Arctic

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Use of imaging systems such as the Video Plankton Recorder (VPR) has increased our understanding of the role of physical characteristics (e.g., hydrographic structure, circulation) in determining the horizontal and vertical distribution of plankton and particulate material. Such imaging systems are particularly useful because taxonomically specific biological data is obtained at spatial and temporal scales comparable to physical measurements. The VPR has been used effectively to describe such associations in multiple ocean regions, including the Japan Sea, the Arctic, and the Antarctic. A series of cruises was conducted in the Western Arctic (Chukchi, Beaufort Seas) in spring-summer of 2002-2004 to describe the exchange of plankton and particles via physical processes across the shelf-basin boundary and across and along submarine canyons using high vertical and horizontal resolution VPR data coupled to physical data. Extremely sharp boundaries between water types and plankton/particle compositions were observed in both the horizontal and vertical, especially in the canyons. Transport across the shelf-basin boundary varied between year and season, with mesoscale physical processes at the shelf break and associated with the submarine canyons being most important in influencing the direction and magnitude of that transport. Here some highlights of these studies are presented, focusing in particular on the synthesis of biological and physical data, on high resolution vertical and horizontal distributions, and on the new insights that have been obtained using the VPR.

1 June, 11:40 (S9-3546)

Biogeography of gelatinous macroplankton in the upper 1000 m depth inferred from the Underwater Video Profiler

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Deep and mid-water gelatinous zooplankton fauna is insufficiently known because they have been poorly sampled, but they may play important trophic roles in mesopelagic communities. *In situ* imaging systems or manned vehicles have been used to monitor their distribution in various oceans and seas. However, the use of disparate and rarely available instruments makes it difficult to compare data from different regions. Since 2001, we have used the Underwater Video Profiler (UVP) in different ocean basins (in the tropical Pacific, along the Atlantic ridge, Indian Ocean, Mediterranean Sea) to analyse the vertical distribution of organisms and particles in the upper kilometre of the water column. Fifteen morphotypes of gelatinous animals have been recognised in most of the profiles: lobate and cydippid ctenophores, siphonophores, hydrozoan and scyphozoan medusae (including three sub-groups, *Aeginura grimaldi*, *Aglantha* sp. and other), oikopleurid appendicularians, salps, chaetognaths, colonial and solitary radiolarians and crustaceans. The depth zonation patterns of these groups in relation with the physical (temperature, salinity and local hydrodynamic) and biological (fluorescence, marine snow) properties of the water column in the different basins will be presented.

1 June, 12:00 (S9-3669)

The ADCP-backscatter and the use of ZOOIMAGE for discriminating diel vertical migrating zooplankton

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Acoustic Doppler Current Profiler (ADCP) provides information on currents and on the presence of particles in the water column along with their fluctuations on short time and fine-space scales. Use of ADCP backscatter data to study plankton behaviour, however, has not been widely done, although the technology has been in use for over a decade. We utilised ADCP backscatter data to study vertical migration patterns of zooplankton in the upwelling areas off Concepción, Chile during 4 daily cycles in summer and winter. Along with hourly ADCP measurements throughout the day, zooplankton samples were collected at 2 hour intervals from 5 strata day and night. Zooplankton samples were analysed utilising ZOOIMAGE. ADCP-backscatter correspond to particles larger than 3.5 mm. Accordingly, from the ZOOIMAGE output, we separated, identified and quantified items larger and smaller than 4 mm. Separately, from the original zooplankton samples, we quantified *Euphausia mucronata*, the largest and dominant euphausiid in the area, which we expected to be responsible for the diel changes in vertical distribution of backscatter. Our ADCP-backscatter results show a very clear pattern of diel vertical movements of particles. Manual sorting and identification of euphausiids also revealed a clear pattern of DVM concordant with the backscatter. However, ZOOIMAGE analyses allowed identification of euphausiids and also other zooplankters that carried out vertical displacements, some concordant with the backscatter and others undetected in it. ZOOIMAGE therefore, represents a fast and very useful tool to complement ADCP backscatter in the study of displacement of plankton in the water column.

1 June, 12:20 (S9-3661)

Meso- to small-scale distributions of plankton and marine snow in the southeastern North Sea in relation to fronts

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The distributions of phytoplankton, zooplankton and marine snow, and their relation to the physical environment (temperature, salinity, turbidity and *in situ* mixing) were observed with *in situ* (Video Plankton Recorder) and shipboard (ADCP) instruments in the Southeast North Sea during early and late summer, 2005. Images were discriminated with a semi-automated machine vision technique: a neural network/support vector machine dual classifier. The pelagic ecosystem shifted from a diatom-dominated one in early summer (late May), to *Noctiluca*/marine snow aggregates in late summer (July). Transects across a persistent tidal front in the German Bight and the estuarine front at the mouth of the Elbe River showed a close correspondence between biological features and physical ones. Aggregation of the very abundant *Noctiluca scintillans* and the presence of marine snow were also related to shear rates in the upper water column.

S9

Posters

Poster S9-3430

The use of FlowCAM for rapid shipboard analysis of grazing by copepods

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FlowCAM is developed for the *in situ* monitoring of plankton communities in aquatic environments. In this study, the utility and problems for the use of FlowCAM to analysis of grazing by copepods on shipboard were addressed comparing with the traditional analysis (chl-analysis and microscopy). Grazing experiments (bottle incubation) of *Neocalanus cristatus* and *Metridia pacifica* were conducted in the Oyashio region, western subarctic Pacific. For both species, clearance rates for each size class of particles calculated from the FlowCAM were approximately consistent with those from microscopy. Meanwhile, clearance rates based on chlorophyll *a* were lower than the rates calculated from the FlowCAM except for the case of spring bloom, due to a high contribution of microzooplankton in the copepods' diet. Based on images and fluorescence intensities of each particle obtained by the FlowCAM, size-specific fluorescence intensity was calculated as an index to distinguish phytoplankton from microzooplankton, and this index was confirmed to allow an adequate estimation of relative contribution of the phytoplankton and microzooplankton. One of the problems for digital image analysis occurred when images of particles were taken at an unsuitable angle for identification. Also, small particles (< 5 μm) were difficult to identify due to the low image resolution. Despite of these nuisances, the FlowCAM appears to be a valuable tool for the study of zooplankton grazing on different size of phyto- and microzooplankton without time-consuming processing.

Poster S9-3435

Extracting zooplankton information from Laser Optical Plankton Counter (LOPC) data

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Because of its high sampling efficiency of large quantities of size based zooplankton data, the Optical Plankton Counter (OPC) represents a major step forward in marine environment monitoring. The number of published works based on OPC data is steadily increasing, and new process studies and knowledge of coupled physical-biological processes emerge from studies where this platform has been used. There are however limitations in the measurement capabilities of the OPC. For instance, at high plankton densities it is difficult to separate individual particles, resulting in multiple particles being counted as one. Another problem is the lack of direct measurements of flow through the OPC. An improved version, the Laser OPC (LOPC), has recently been launched to resolve the limitations of the original OPC and also to provide further zooplankton identification capabilities. One of the main new features is the possibility to measure shape profiles of plankton larger than 1.5 mm (equivalent spherical diameter). Not very much work has been carried out to test and develop tools to categorise organisms and thereby enable us to identify major organism groups in the data sets. This work is a contribution towards developing tools to characterise and identify zooplankton by LOPC.

Poster S9-3487

Automatic quantification and recognition of major zooplankton groups in a North Sea time series using the Zooscan imaging system

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Seasonal variation of the mesozooplankton from Belgian coastal waters, North Sea, collected in 2001 was analysed using the Zooscan imaging system. This system is composed of the Zooscan hardware for image acquisition and of a free dedicated software package for image processing, feature extraction and automatic plankton recognition.

From the 33 digitised samples, 58541 objects were automatically counted, sized and characterised. A learning set of 3900 manually identified objects was constructed and divided into 16 groups: 4 non-biologic (detritus, etc.), and 12 biologic groups that included *Coscinodiscus* spp., *Noctiluca*, calanoid, cyclopoid and harpacticoid copepods, chaetognaths, appendicularians, fish eggs, large crustaceans, other zooplankton and multiple objects. The analysis was performed on coastal samples, containing high amount of detritic material, and without the separation of overlapping objects (multiples). We decided not to exclude any object from the learning set. Furthermore, an independent test set containing 1634 randomly chosen objects in the whole data series was used to determine the accuracy rate of the classifiers. Seven machine-learning methods were compared using multiclass and binary class (one vs. all) approaches. Results concerning automatic recognition accuracy vs. microscopic determination and counting will be presented and the relationships between the seasonal patterns of different functional groups will be discussed.

Poster S9-3501

PlanktonJ: an interactive tool for zooplankton measurement and image analysis

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Recent advances in counting, measuring and identifying zooplankton using automated and semi-automated image analysis systems provide opportunities to rapidly analyse samples for their size spectra and biomass by major taxa. However estimates of biovolume from existing systems often exhibit substantial variability and error due to thresholding problems. For example, a copepod's appendages may be included in the ellipse fitted to its body outline; decreasing the threshold may lead to loss of gelatinous organisms. Validating machine-based measurements is often tedious and difficult. We present PlanktonJ, a system developed using ZooImage and ImageJ, which improves the accuracy and reliability of zooplankton measurements and allows users to interact with zooplankton measurements in a fast and efficient manner. Adaptive thresholding removes appendages from ellipses fitted to the body outline, significantly improving the regression between manual and automated measurements. Quality-control metrics that estimate the proportion of an organism inside and outside a fitted ellipse enable automated detection of problematic measurements. Comparison of fixed and adaptive thresholds for organisms also provides information on body structure and taxonomy, which can be used in classification. Images can be rapidly classified, sorted, and visualised, along with their measurements, for further validation. PlanktonJ is based on open-source software and can be used in conjunction with existing tools such as ZooImage.

Poster S9-3518

A comparison of the performance of a new image analysis system (ZooImage) and the traditional taxonomist approach in the analysis of zooplankton samples from the Gulf of St. Lawrence, northwest Atlantic

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In recent years, some laboratory imaging systems have been developed with the ultimate goal of developing an automated approach of analysing zooplankton samples. In this study, we evaluate the performance of the ZooImage software in estimating both zooplankton species composition and biomass in samples collected and analysed by taxonomists as part of the Atlantic Zonal Monitoring Program (AZMP) conducted by the Department of Fisheries and Oceans Canada in the northwest Atlantic. The ability of ZooImage to identify different groups of species (functional groups), species, and developmental stages is evaluated using training sets built with either (1) specimens of most species pre-identified by taxonomists (high taxonomic resolution), or (2) with 'vignettes' extracted from scanned images of zooplankton samples (low taxonomic resolution). Abundance of the different 'categories' are compared with corresponding AZMP data and an evaluation of the performance of the software in identifying the different groups/species is performed based on different scanning parameters such as resolution (dpi) and colours (grey and red). Size frequency distributions of the Equivalent Spherical Diameter (ESD) of all 'vignettes' extracted from a given sample is combined with a general relationship of ESD and biomass in zooplankton to derive biomass. These biomass results then are directly compared with biomass data obtained from the AZMP protocol. Considering the on-going rapid evolution of sophisticated automatic recognition algorithms, this automated approach with ZooImage represents a great potential in the future.

Poster S9-3561

Pleione: a reference database of plankton images collected by automated imaging systems

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Automated plankton image labelling instruments need validated training data. The process of validation requires the efforts of a plankton expert, either taxonomist or ecologist. It can be difficult or impossible for systems developers to gain access to, or request, taxonomists to label their data. This difficulty is highlighted using our Mesoplankton Image Analyser (MIA), which can image up to 30,000 particles in a 250 ml water sample. Luckily, only subsets of these are needed to be identified for training. To build systems that can handle in excess of 2,000 species, a large scale facility is required to provide the validated reference image data sets needed for training and assessing performance. The Pleione project is a web-based database that handles uploading of images from providers and offers sets of images to validators for labelling. Pleione uses the ITIS taxonomy resource for labels. It also automatically assesses the repeatability of expert labellers contributing to the database. Over time, several experts will label each image in the database and the consensus of opinion of these experts is stored with each image, allowing Bayesian methods to be applied to label certainty. The principles of operation of Pleione will be described and examples given.

Poster S9-3562

Mesoplankton Image Analyser (MIA)

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A new laboratory instrument is described for imaging and analysis of mesozooplankton. It integrates a high-speed line scan camera for in-flow image acquisition with automatic specimen labelling software. The image acquisition system of the Mesoplankton Image Analyser (MIA) comprises a near-infra-red light source, flow cell, lens and camera, which is interfaced to a high-speed dual processor computer with 2GB of local memory. System throughput is approximately 375 ml per hour, ensuring in a 24 hour period, 6.75L of water can be analysed at a camera resolution of one micron. Automatic analysis and labelling of specimens is completed internally within the instrument using developed software. Software has been developed to successfully discriminate mesozooplankton using advanced pattern recognition methods. The processing by the software is invariant to specimen rotation and translation in the field of view. It is also partially invariant to scale, allowing up to 10% variation in specimen size. The categoriser uses a committee of six Support Vector Machines (SVMs), one for each channel, and outputs a vote for each category. Votes can be combined either by a simple majority or by application of a naïve Bayes rule that normalises each channel 'expert' by its training. Training the MIA software on mesozooplankton species is a lengthy process, but high quality images have been obtained of Euphausiids, Salps, Cladocera, Decapoda, Tunicate, Tintinnids and a range of Copepods. The combined camera and software will enable *in situ* non-invasive identification of marine plankton, (phytoplankton, micro and mesozooplankton). Performance data will be presented.

Poster S9-3580

Visual Plankton: automatic identification and visualisation of plankton taxa off-line or real-time

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An overview of the Video Plankton Recorder's automatic plankton identification and visualisation system (Visual Plankton) will be presented. Visual Plankton is specifically designed to work with the VPR system and includes a graphical user interface (GUI) that comprises five main steps: 1) Calibration, 2) ROI extraction, 3) Classifier Training, 4) Classification, and 5) Data Visualisation. The programme is used for real-time automated

identification and visualisation of plankton abundance patterns at sea as well as off-line post-processing of video files collected using the autonomous VPR. The software, written as Matlab m-files, is public domain and available via internet download. Although Visual Plankton is specifically designed for the VPR system, the algorithms for focus detection, feature extraction, and classification are generic and available for incorporation into other image analysis software packages. This software uses a dual classification method with correction to accurately determine abundance of both dominant and less dominant taxa. The image volume of the VPR is discussed, and it is shown to be sufficient for common taxa in shelf and oceanic environments and yields equivalent or better estimates of abundance of major taxa than typical analyses using plankton nets, for robust and delicate plankton. Examples of data from various marine habitats will be presented, including a recent transect across the Caribbean Sea.

Poster S9-3591

Imaging live zooplankton by Light frame On-sight Key species Investigation (LOKI)

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Various approaches exist to overcome the limitations set by conventional net sampling of zooplankton. Optical *in situ* imaging systems are promising tools; but most approaches only allow distinction between major taxa and provide image qualities that make finer taxonomic identification and precise gauging of the sampled volume impossible. Especially in neritic zones with small species and high particle densities, the usability of these systems is constrained. We describe a new approach with alternative illumination devices. LOKI consists of a submersible unit that is connected with the surface by a two-conductor cable. In the underwater unit Areas of Interest (AOI) are extracted in real time from the images and stored together with readings from various sensors. Image acquisition and operation are performed on live video by using a CameraLink™ interface. Basic AOI segmentation is performed by threshold logic and contour tracing algorithms merging unassociated parts of images. A complete TCP/IP signal is modulated onto the power line and allows communicating with the underwater unit via inter- or intranet. Onboard images are gauged for geometrical and higher dimensional characteristics. Readings are stored with the environmental and image data in an extendible backend database. The database allows investigating the appearance of single specimens in relation to any parameter by structured query language (SQL). The software frontend allows simple visualising of imaged objects, extracted picture properties and environmental parameters. An adapted interface executes the SQL statements for the most common queries and can be performed in an expert mode. Examples of *in situ* tows will be presented.

Poster S9-3592

Zooplankton spring distribution in the Bay of Biscay: biomass and size distribution using image analysis

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Zooplankton samples collected during high resolution surveys (3.15 nautical miles) in the Bay of Biscay (43.32°N to 46.12°N and 1.29°W to 4.31°W) from 1998 to 2006 in spring have been analysed using ZooImage. Recurrent patterns appear from year to year. In terms of biomass higher values for small individuals (< 1 mm ECD) are found in the coastal areas. However, the higher biomasses of large individuals (> 1 mm ECD) are found at the shelf-break. This is reflected in the slope of the zooplankton size spectra, which shows flatter slopes in the shelfbreak and oceanic areas. This work reflects the potential of ZooImage to reanalyse stored collections of samples.

Poster S9-3604

DVM dynamics of two mesozooplankton as inferred acoustically in the Black Sea

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Swimming trajectories from enhanced acoustical images of copepods, *Calanus euxinus*, Hulsemann, and chaetognaths, *Sagitta setosa*, Muller, in the Black Sea were obtained using an echosounder operating at 120 and 200 kHz and an acoustic Doppler current profiler (ADCP) operating at 150 kHz. These species were acoustically discriminated with respect to vertical migration and swimming speed, dissolved oxygen (DO) concentration, and

timing of migrations. Taking the minimum background noise threshold and detection limit of acoustical frequencies into account, the concentration layer of *S. setosa* was acoustically identified by observing their diel migrational pattern during different months in the Black Sea. *Sagitta setosa* showed different patterns in time depending on their generation time and stage composition. During the cold season, when their population consisted mainly of adult individuals, their daytime maximum concentration layer coexisted with that of *C. euxinus* in the OMZ. In the warm season, when immature individuals (juveniles) comprised more than 60% of the population, their maximum concentration layer stayed in the oxycline. In July and September, detectable individuals of the new generation did not migrate during the day and stayed in subsurface water. *Calanus euxinus* started accelerating upon entering the oxycline, while *S. setosa* accelerated only after entering well-oxygenated subsurface water. This feature distinguishes *S. setosa* from *C. euxinus*. *Sagitta setosa* completed its migration within 4 hours.

Poster S9-3670

Larval prey field and invertebrate predators in the southernmost spawning zone of the anchoveta, *Engraulis ringens*, determined from ZOOIMAGE and GAM analyses

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The southernmost anchoveta stock along the Humboldt Current spawns in winter, a season of reduced primary production, higher turbulence, and colder seawater temperature. With a very coastal distribution, nuclei of maximum egg and larval abundance repeat yearly in the same localities. To assess why these spawning localities are utilised for spawning and nursery, we studied the potential larval prey field and invertebrate predator distributions along the distribution of the southern stock during the winter spawning season 2005. Zooplankton samples (CalVET, Bongo) and CTD data were obtained in the egg surveys for stock assessment (Daily Egg Production Method). Zooplankton was analysed utilising ZOOIMAGE to identify and quantify the most common potential larval food items (small and large copepods; appendicularia) and the most common potential invertebrate egg and larval predators (euphausiids, siphonophores, chaetognaths, medusae and ctenophores). GAMS were utilised to assess relationships between hydrographic data, potential food items, potential invertebrate predators and the egg and larval distributions. Except for chaetognaths, no significant relationships were observed between predator groups and anchoveta egg and larval distributions. Potential predators occurred in relatively low numbers. Similarly, no relationship was observed between the food items and egg and larval distributions. Our results suggest that the low number of potential predators probably do not have a large impact on egg and larvae through direct predation. However, their impact might become important eventually as they also prey on the larval food items, especially during dates of stronger turbulence when the food items are more dispersed in the water column.

Poster S9-3678

Variability of zooplankton community structure and biomass in the coastal upwelling zone of the Chilean Humboldt Current as assessed by ZOOIMAGE analysis

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Coastal upwelling systems exhibit strong spatial and temporal variability in plankton distribution. In order to examine such variability and its association with upwelling variation, we applied ZooImage analysis to zooplankton samples obtained at two upwelling sites off Chile, Iquique area (18-26°S) and Concepción area (34-37°S). Samples obtained in the last 5 years covered coastal and oceanic zones (at variable spatial resolution) and intra-seasonal to inter-annual variation using Calvet, Bongo and Tucker Trawl nets. Some sets of samples were also analysed by traditional methods. The complete analysis allowed us to make comparisons between sampling methods and between analytical methods, as well as to examine the spatial distribution of zooplankton biomass and taxa over the continental slope and in oceanic areas. Temporally, upwelling is strongly seasonal off Concepción,

whereas in Iquique upwelling is intermittent year-round. Zooplankton biomass and taxa, mostly represented by calanoid copepods and euphausiids, may respond to this upwelling variability as revealed by correlation with oceanographic variables most linked to upwelling, such as surface temperature, dissolved oxygen, and depth of the oxygen minimum zone. We concluded that the ZooImage software may offer a highly valuable analytical tool to assess and understand plankton variability in the coastal zone of highly productive upwelling systems.

Poster S9-3681

Software tools for automated recognition of plankton from digital images

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The ocean is vastly under-sampled relative to critical ecological questions that remain open. To understand ocean ecosystems better information is needed about plankton and marine particle distributions. There has been a rapid development of various kinds of plankton imaging instruments to increase sampling for ecological and biogeochemical studies. These instruments are used in surveys of particular regions, and are being mounted on various automated platforms (moorings, floats, and vehicles) as part of coastal and oceanic observing systems. They produce large numbers of digital images that require automated classification. Automated classifiers need optimised image feature selection and extraction, expert-identified training sets, and accurate classification algorithms. Current methods yield classification accuracies around 70-80% on typical many-class problems (ca. 20+ plankton/particle types). Software tools are needed that enable taxonomic and ecological experts to interact with large digital image sets and efficiently extract biologically and ecologically relevant information about plankton and particle populations. Human interactive methods and statistical approaches are needed to deal with the subset of images that are not reliably classified. We are building open-source software tools to improve the creation of unbiased and optimal training image sets and facilitate optimisation of automated classification approaches. These software tools will enable new studies to increase our understanding of marine ecosystem structure and function.

Poster S9-3709

Digital archiving and processing of zooplankton samples with the Zooscan system

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It is now acknowledged that long term zooplankton series provide useful information for examining climate-ecosystem interactions. Especially important are the large-scale comparisons of zooplankton time series. Sample collections in jars that have never or, partially been analysed exist worldwide but their retrospective analysis is a very time consuming and laborious task. One solution is the digitisation of samples for archiving and subsequent processing. Although the resolution of global digitised zooplankton images is lower than the image obtained using a microscope, this technique is essential for large sample sets. Archiving of high resolution raw images of long time series may save fragile samples in jars and facilitate their share and study by the scientific community. The digital image preserves a precise representation of the organisms, allowing their measurement, enumeration and identification. The ZOOSCAN (Grosjean *et al.*, 2004) and its dedicated software (Zooprocess) is a specialised system that performs this task. The instrument is built according to the safety regulations for the laboratory environment and it allows going beyond biomass to assess plankton compositional information. It allows the comparison of distant series due to its ability to calibrate the parameters of image acquisition from different Zooscans. Digitised images can be easily examined by experts using Internet and the results can be put in a readily accessible format for different databases. While machine-learning techniques only allows the main groups to be recognised, a semi manual technique allows a quick and more detailed taxonomic identification. The Zooscan hardware and Zooprocess software will be presented and results discussed.

Poster S9-3737

Mesozooplankton biomass estimation from digitised images

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The measurement of mesozooplankton biomass in the ocean requires the use of analytical procedures that cause the destruction of samples or, by contrast, the development of methods to estimate biomass from optical systems using appropriate conversion factors. The conversion of the area recorded by an optical counter or a camera was suggested as a suitable method to estimate total biomass by converting the digitised area of an organism into individual biomass and summing up the individual biomass. In this study, crustacean mesozooplankton from subtropical waters were analysed. Direct individual dry weight of the most common groups and body area by digitised image analysis were obtained. Relationships between individual dry weight and body area agreed with other measurements of biomass obtained in a previous study in Antarctic waters, suggesting a universal regression for these organisms. Gelatinous mesozooplankton from subtropical and Antarctic waters were also sampled and processed for body area and biomass. As expected, differences between these two planktonic groups (crustacean and gelatinous) were highly significant. Transparent gelatinous organisms have a lower dry weight per unit area. Therefore, to estimate biomass from digitised images pattern recognition methods that can distinguish at least between crustaceans and gelatinous forms are required.

Poster S9-3739

Autonomous ocean gliders as a platform for continuous zooplankton observations

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New approaches are needed to sample zooplankton continuously over extended geographic areas, in order to resolve the mechanisms underlying zooplankton responses to climate and other sources of ocean variability. While a variety of optical, acoustical, and direct zooplankton sampling devices currently exist, present modes of instrument deployment have serious limitations. Shiptime is expensive and shipboard sampling with nets, pumps, profilers, or towed bodies is typically spatially restricted. Moorings resolve temporal, but not spatial variations. Conventional AUV's often have restricted endurance. Improvements in deployment platforms are needed to significantly expand temporal and spatial characteristics of zooplankton sampling devices. Here we describe the use of Spray gliders, designed and built in the Instrument Development Group at Scripps, as a platform for deployment of instruments for zooplankton acoustic backscatter, CTD, and chlorophyll fluorescence. With this particular payload, the glider has an endurance of approximately 90 days, at which time it is remotely navigated close to shore and recovered with a small skiff. Two Spray gliders are currently sampling the southern sector of the California Current from nearshore to ca. 500 km from the coast. Data from vertical profiles to a depth of 500 m are telemetered via the Iridium satellite network immediately upon completion of each dive. Full two-way communications permit remotely-guided adaptive sampling in response to unexpected phenomena. Other instruments will be accommodated in the future.

Poster S9-3762

Using a continuous imaging particle analyser (FlowCAM®) for the analysis and classification of zooplankton

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Monitoring the health of marine and freshwater systems and tracking environmental change requires a knowledge and understanding of the system's phytoplankton and zooplankton communities. A major drawback of plankton monitoring using microscopy for identification and enumeration from samples is the amount of time required for preparation and analysis. Determining zooplankton abundance, size classification, or group classification is

important when identifying the dominate primary producers in an aquatic system. Here we present data from a continuous imaging particle analyser (FlowCAM®) that uses proprietary VisualSpreadsheet™ software to automatically detect, image and enumerate zooplankton in real-time. The FlowCAM is now being used for monitoring of microorganisms and particles in both marine and freshwater systems. A laser interacts with a high resolution digital camera to capture images and data of a passing particle or organism. Image data from a sample or batch of samples can be analysed by the FlowCAM, and the user is provided with data that includes cell counts, size data (length, width, area, ESD). The software also has the ability to process the digital images for automatic classification through the use of user-generated libraries and image recognition capabilities. An overview of the technology will be given, including a review of the image parameters that are collected and used by the image recognition algorithm for image analysis, 'pattern matching' and classification.

Poster S9-3977

A comparison between geometric morphometric and PSOM neural net approaches to automated species identification in planktonic foraminifera

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At present two generalized analytic approaches are considered relevant to the problem of automated taxon identification: morphometric systems based on some form of linear or non-linear discriminant analysis (LDA), and artificial neural networks (ANN). Both approaches have been employed in a variety of systematic and ecological contexts. In this investigation, digital images of seven modern planktonic foraminiferal species were used to compare and contrast these approaches in terms of accuracy, generality, speed, and scalability. Results demonstrate that both approaches can yield sets of discriminant models that are over ninety per cent accurate for small datasets. With increased sample size ANNs yielded superior accuracies. Performance of distance and landmark-based LDA systems was enhanced substantially through application of generalised least-squares superposition methods that normalise morphometric data for variations in position, size, and orientation. Nevertheless, this approach is practically limited to the detailed analysis of relatively small numbers of species by a variety of factors, including the complexity of basis morphologies, data collection rate, and sample dependencies. An ANN variant based on the concept of a plastic self-organising map (PSOM), combined with an n-tuple classifier, was found to be marginally less accurate than linear LDA, but far more flexible, much faster, and more robust to sample dependencies. Moreover, the PSOM-ANN approach can analyse either image-based or true morphometric data yielding comparable results. Both LDA and PSOM-ANN approaches are considered useful within their own analytic domains and both can be usefully combined to compensate for their complementary deficiencies.

S10 Analysis and synthesis: modelling zooplankton in aquatic ecosystems

30 May, 14:05 (S10-3745) Invited

Expressing simplicity while implying complexity: increasing the biological information content of ocean biogeochemical models

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Modellers of biological dynamics in the oceans face a dilemma: from a biological perspective, the diversity of marine organisms potentially relevant to large-scale biogeochemical processes is large and growing rapidly. Many of these organisms have multiple modes of interaction and their distributions are highly variable across a wide range of space and time scales. These biological observations seem to require models with fine resolution of time, space, taxonomy and organismal condition. From a modelling perspective, however, a useful ocean biology model must have parameters that can be determined, computational requirements that can be met, and output that can be understood and interpreted to yield biological insights. In practice, these constraints are met only for models with a small number of biological variables. Each variable then is “shorthand” for a broad biological group (such as “diatoms” or “microplankton”) whose members may be dissimilar in their interactions with the environment and with other groups. Mismatches in complexity between biological dynamics and feasible models can be reduced if biological variables can implicitly contain information about processes that cannot be described explicitly. Scaling analyses for deriving simple approximations to complicated dynamics have been developed in the mathematical, computational, and physical sciences but have yet to be widely applied to enhancing the information content of ocean biology models. In this talk, I will use spatial and temporal variability in plankton distributions to illustrate how these approximation methods may enhance our ability to incorporate and interpret biological mechanisms into large-scale models.

30 May, 14:35 (S10-3583)

Modelling climate change impacts on zooplankton in the Tasman Sea, southwest Pacific

Thomas J. Kunz¹, A.J. Hobday¹ and A.J. Richardson²

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Climate models project that one of the fastest rates of ocean warming in the Southern Hemisphere will occur in the Tasman Sea, due to enhanced southward penetration of the East Australian Current. Such warming and the associated enhancement of water column stratification are likely to fundamentally change the phytoplankton and zooplankton communities in the region, with implications for higher trophic levels. Here, we develop a simple nutrient-phytoplankton-zooplankton (NPZ) model for the region. We force this model with output from a suite of global climate models and from a range of emission scenarios to investigate how future ocean warming and stratification in the Tasman Sea will impact phytoplankton and zooplankton. We find that climate change alters the composition, and production of phytoplankton and zooplankton by influencing nutrient availability and also via temperature effects. Prey fields generated from the NPZ model are used to qualitatively assess the impacts of climate change on the timing and abundance of prey of major small pelagic fish and larger predatory fish such as tuna.

30 May, 14:55 (S10-3439)

Seasonal plankton dynamics along a cross-shelf gradient off northern Spain

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The development of population models able to reproduce the dynamics of zooplankton is a central issue when trying to understand how a changing environment would affect zooplankton in the future. Using 10 years of monthly data on phytoplankton and zooplankton abundance in the Bay of Biscay from the IEO's RADIALES time-series programme, we built non-parametric Generalized Additive Models (GAMs) able to reproduce the dynamics of plankton on the basis of environmental factors (nutrients, temperature, upwelling and photoperiod). We found that the interaction between these two plankton components is approximately linear, whereas the effects of environmental factors are non-linear. With the inclusion of the environmental variability, the main seasonal and inter-annual dynamic patterns observed within the studied plankton assemblage indicate the prevalence of bottom-up regulatory control. The statistically deduced models were used to simulate the dynamics of the phytoplankton and zooplankton. A good agreement between observations and simulations was obtained, especially for zooplankton. We are presently developing spatio-temporal GAM models for the North Sea based on the Continuous Plankton Recorder database.

30 May, 15:15 (S10-3490)

Modelling copepod-phytoplankton interactions in presence of chemical defenses

Vincenzo Botte, M.G. Mazzocchi and Maurizio Ribera d'Alcalà

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Recent laboratory and field studies have provided convincing evidence that some species of phytoplankton produce chemicals harmful to copepod reproduction and survival. The impact of these substances on the population dynamics of the grazers in nature has still to be properly quantified. More importantly, their role as a defense mechanism giving selective advantage to the producers, while being a reasonable hypothesis, is still to be proven. We will present the results of numerical simulations based on an Individual Based Model of one or two grazers and several phytoplankters. We considered prey types that compete for resources, have different nutritional requirements and defensive properties, and correspondingly differ in metabolic costs. Copepods may be either selective or unselective feeders, and develop through different stages of their life cycle, which in the model are compacted to seven. The numerical model is zero-dimensional and Object-Oriented: each organism is modelled as an object that contains the information that pertains to that organism. Development of single organisms, their interaction with the environment and prey-predator interactions are modelled in terms of the flow of nutrients among the several components of the system, so as to keep constant the global pool. The goal of the study is to determine conditions under which a chemical defense produced by a single individual is advantageous for its survival, relative to other cells of the same species or of other species. The answer will shed light on factors necessary for proliferation of chemical defensive substances sufficient to depress grazing pressure.

30 May, 16:00 (S10-3578)

Multispecies modelling approach to predict foraminifera growth, ecological niches and shell export to the sea floor

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An ecophysiological model reproducing the growth of different foraminifera species as a function of environmental parameters has been developed for paleoceanographic reconstructions. This model estimates growth through the main physiological rates of foraminifera (nutrition, respiration, and symbiotic photosynthesis). The influence of light availability and temperature on respiration, photosynthesis and growth were calibrated using new experimental

observations and the literature. Notably, we measured respiration of recently-captured foraminifera to better understand the influence of temperature on respiration and photosynthesis. The influence of food concentration (on a Chl *a* basis) was calibrated in regard to field observations. This model is now calibrated for the species *Neogloboquadrina pachyderma* (dextral and sinistral forms), *Neogloboquadrina dutertrei*, *Globigerina bulloides*, *Globigerinoides ruber*, *Globigerinoides sacculifer*, *Globigerinella siphonifera* and *Orbulina universa*. Using annual mean Sea Surface Temperature (SST), light availability and Chl *a* data from MODIS satellite, the model predicts the dominant foraminiferan species in over 576 field observations worldwide with efficiency higher than 60%. This model makes possible prediction of foraminiferan fluxes observed in sediment traps, and enhances interpretation of paleoceanographic information from fossil records.

30 May, 16:20 (S10-3524)

A coupled genetics-growth model for *Crassostrea gigas* larvae

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Survival and recruitment of marine bivalve larvae represent the interplay of environmental, biological, and physiological processes. The genetic characteristics of individuals provide a substantial role in the response of populations to exogenous and endogenous forces. This study describes the first genetically-based model developed for larvae of a marine bivalve species, *Crassostrea gigas*, which is coupled to a traditional model that describes larval growth and development. The coupling between the genetics and larval growth models allows mapping of physiological function to specific genotypes. Explicit inclusion of genetic structure allows a mechanistic understanding of variability in larval growth, survival and recruitment. The coupled individual-based genetics-growth model simulates changes in population genotype as a function of the number of parents and their genotypes. As a result of adult reproduction, each larva receives a specific genotype which is provided a level of fitness, where fitness is expressed in terms of the variation in assimilation efficiency. The larval growth model then allows prediction of the likelihood of survival for individual genotypes. Simulations show that the average fitness of a *C. gigas* population increases from an initial random distribution of genes, because less fit individuals do not survive. Additional simulations provide insights into the genetic basis for larval survival.

30 May, 16:40 (S10-3683)

Modelled growth and development of *Euphausia pacifica* in the Northern California Current

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Surveys of physical and biological conditions of the central Oregon (USA) coast were conducted by US GLOBEC in June and August of 2000 and 2002. Chlorophyll concentrations in 2002 were significantly higher than in 2000 over much of the shelf, but especially over the Heceta Bank region, where local retention occurs and permits accumulation of phytoplankton biomass. Euphausiid distributions and abundances were estimated from acoustic surveys, while net tows provided information on the vertical and horizontal distribution and abundances of the larval stages of *Euphausia pacifica*. *E. pacifica* larvae are often most abundant over Oregon continental shelf waters, whereas adults are more common along and seaward of the shelf break. Retention of euphausiid individuals (and populations) nearshore and to the north is an ecological problem for this species off Oregon, where the summertime southward winds cause coastal upwelling and offshore and southward surface transport. Northward transport of individuals could occur in the very nearshore during upwelling relaxations, or at depth (100-400 m) over the slope in the northward flowing California Undercurrent. We used an individual-based model to examine the population dynamics, distribution and growth and development of *Euphausia pacifica*. Development and growth were decoupled for this modelling. Development (progression in life stage) was determined by temperature using a Belehrádek relationship. Growth (increment in individual weight) was determined primarily by food availability. This allowed for development (stage progression) to occur even when food was scarce, resulting in declining individual sizes (negative growth). Observations from off Oregon suggest that euphausiid

growth is negative during some periods. The individual-based model is coupled using particle tracking to physical circulations from a 3-D ROMS simulation, that is forced by observed wind forcing and boundary conditions specified from a coarser, larger-scale model. We explore the influence of different euphausiid behaviours—including passive transport, fixed-depth transport, and ontogenetically (or size-based) diel vertical migration superimposed on physical transports - on retention, growth and development.

30 May, 17:00 (S10-3319)

Population dynamics model of Copepoda (*Neocalanus cristatus*) in the northwestern subarctic Pacific

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A population dynamics model (PDM) for *Neocalanus cristatus*, which is the dominant large copepod in the northwestern subarctic Pacific, was developed to simulate the increase of production with developmental stages and the transfer of production by vertical migration. The PDM was coupled with a lower trophic level ecosystem model, NEMURO (Northern Pacific Ecosystem Model used for Regional Oceanography, developed by PICES), by replacing the large-zooplankton component (ZooL) in NEMURO with the PDM. Ecological effects in the coupled model were compared to those in the original NEMURO. In the simulations, the annual cycle of copepodite stages began during the spring bloom, followed by a decrease in biomass during summer, then by migration of *Neocalanus* to deeper layers where they diapaused during autumn and winter, and finally ended with egg production in winter. The PDM successfully described the annual life cycle of *Neocalanus*. During early copepodite stages (during the spring bloom), they grazed small-phytoplankton (PhyS), without consuming large-phytoplankton (PhyL). Therefore, PhyL biomass increased greatly in spring. In summer, during the last copepodite stage, they began to prey mostly on PhyL, causing a decrease in PhyL biomass, while PhyS biomass increased. Production by PhyL remained higher than that of PhyS because predatory pressure by *Neocalanus* gradually weakened as the last copepodite stage near the surface approached its end in summer. These simulations suggest that, in addition to *Neocalanus*, we should include PDMs for the other large copepods that consume PhyL during summer, in order to reproduce the lower trophic ecosystems in the northwestern sub-arctic Pacific.

30 May, 17:20 (S10-3975)

Modelling the interactions between the hydrodynamics and the population dynamics of *Calanus finmarchicus* in the Gulf of St. Lawrence, eastern Canada: (1) The “*Calanus* circuit”

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We used numerical models to heuristically address the interactions between the population dynamics of *Calanus finmarchicus* and the hydrodynamics of the St. Lawrence system. The Gulf of St. Lawrence (GSL) is a large semi-enclosed sea which represents the southernmost limit of the northern Atlantic seasonal sea-ice cover. Its general cyclonic circulation is driven mainly by the seasonality of the freshwater discharge from the St. Lawrence River, and by variations in the synoptic meteorological systems. This dynamic system sustains a productive pelagic ecosystem whose dominant zooplankton species is the copepod *C. finmarchicus*. We coupled a stage-based population dynamics model of *C. finmarchicus*, representing the average properties of the population in regards of swimming behaviour, development, mortality and birth rates, to an eddy-permitting resolution 3D regional circulation model driven by realistic high and low frequency atmospheric, hydrologic and oceanic forcing (tides, storms, formation and melting of sea-ice, etc.). The distribution and abundance patterns simulated for the year 1999 were found to be highly sensitive to the migration behaviour owing to the strong vertical shears of the circulation. In the western GSL, nychthemeral migration behaviour was essential for the year-round presence of a *C. finmarchicus* population in the strongly advective Lower Estuary. Seasonal colonisation of the southwestern Magdalen Shallows was also heavily affected by the swimming behaviour. This study identified for the first time the “*Calanus* circuit” in the GSL, consisting of hydrodynamic features separated in space and time but linked together by the swimming behaviour of *C. finmarchicus*.

S10

Posters

Poster S10-3300

Zooplankton-phytoplankton interactions simulated by combining distinct modelling approaches in the Norwegian SeaGeir **Huse**, M. Skogen, E. Svendsen and K.Y. Børsheim

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Zooplankton are usually modelled individually, whereas phytoplankton models are typically based on biomass concentrations. We have combined these approaches specifically to address interactions between zooplankton and phytoplankton. *Calanus finmarchicus* is the dominant herbivorous mesozooplankton in the Norwegian Sea and has the potential for strongly impacting the population dynamics of phytoplankton. We present a novel individual-based *Calanus* model with simulated evolution of behavioural traits, including vertical migration strategies and timing of ontogenetic migrations. The results show that the simulated *Calanus* population is able to remain viable in the Norwegian Sea basin over hundreds of years and evolves a life history that resembles the observed life history of *C. finmarchicus*. The model predicts a higher abundance of *C. finmarchicus* in the southern part of the Norwegian Sea and along the Norwegian shelf than is generally observed in the field. Phytoplankton biomass was simulated by a newly developed model, based on a ROMS physical model and a modified NORWECOM model for phytoplankton, and linked with the zooplankton model. We show that linking *Calanus* grazing to phytoplankton mortality has a profound effect on the population dynamics of phytoplankton, compared with the constant mortality parameter implementation previously applied in NORWECOM. Most notably the phytoplankton bloom is prolonged and the primary production increases. Examples from simulating climatically quite different years demonstrate a significant bottom up regulation of the *Calanus* production and distribution, which may affect recruitment, growth, and migration pattern of planktivorous fish such as herring.

Poster S10-3385

Evaluation of an automated calibration approach for calibrating the NEMURO nutrient-phytoplankton-zooplankton food web modelShin-ichi **Ito**¹, K.A. Rose², N. Yoshie¹, B.A. Megrey³, M.J. Kishi^{4,5} and F.E. Werner⁶¹ Tohoku National Fisheries Research Institute, FRA, 3-27-5 Shinjima-cho, Shiogama, Miyagi 985-0001, Japan. E-mail: goito@affrc.go.jp² Department of Oceanography and Coastal Sciences, Louisiana State University, Baton Rouge, LA 70803, USA.³ National Marine Fisheries Service, Alaska Fisheries Science Center, 7600 Sandpoint Way NE, Seattle, WA 98115-0070, USA.⁴ Faculty of Fisheries Sciences, Hokkaido University, N13 W8, Sapporo, Hokkaido 060-0813, Japan.⁵ Ecosystem Change Research Program, Frontier Research Center for Global Change, 3173-25, Showa-machi, Kanazawa-ku, Yokohama, Kanagawa 236-0001, Japan.⁶ Department of Marine Sciences, University of North Carolina, Chapel Hill, NC 27599-3300, USA.

Automated calibration software PEST (Model-Independent Parameter Estimation) was applied to the NEMURO (North Pacific Ecosystem Model for Understanding Regional Oceanography) nutrient-phytoplankton-zooplankton food web model, as an alternative to the usual *ad-hoc* calibration. Prior to applying PEST to field data situations, several twin experiments were conducted to evaluate the performance of PEST. In the twin experiments, the model predictions were used as virtual observations and then PEST was used with arbitrary starting parameter values to determine if PEST could recover the original parameter values. First, a twin experiment was conducted that included vertical ontogenetic migration of large zooplankton. In this case, PEST failed to find the original parameter values. In NEMURO, large zooplankton are defined to appear in the surface in spring and disappear in autumn. Thus, the simulated system has two different states depending on the presence or absence of large zooplankton. This instantaneous discontinuity in the state of the simulated system created estimation problems for PEST. Experiments without ontogenetic migration successfully recovered model parameters. Therefore, the simplest way to apply PEST calibration to NEMURO is to exclude ontogenetic migration from the model. Another approach would be to separate the season into two distinct periods, reflecting presence and absence of large zooplankton, and to apply PEST to each period individually. However, this later approach is not guaranteed to provide the same values for parameters that are not directly related to large zooplankton across the two periods.

Poster S10-3495

Individual-based experimental and modelling approach to study the effects of temperature and individual variability on the reproduction of the estuarine copepod *Eurytemora affinis*

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The daily egg production rate of copepods is a key parameter for estimating their specific production in the field. The effects of external factors (e.g. temperature, food) on copepod egg production are well-documented in the literature. Most studies have targeted free-spawning copepods using field observations and incubation techniques. Numerical approaches rarely been used to test the representation of egg bearing copepod reproductive processes, and to estimate daily egg production. We developed an individual based model based on a realistic representation of reproduction of an egg-bearing copepod. The model was calibrated using an extensive set of laboratory and field data for the estuarine copepod *Eurytemora affinis*. The key parameters of the model are: adult female longevity; clutch size; and spawning interval, which changes depending on oocyte maturation and latency time required by a female after hatching to produce a new egg sac. Embryonic development, hatching success and development of early naupliar stages are also represented in the model. The effects of temperature variation on the average values of these processes are introduced. Use of a generic platform (MOBIDYC) based on multi-agent systems enabled us to represent the individual variability of all the processes mentioned above. The model was applied separately to two previously published experimental approaches: incubation protocol and individual based experiments. The model correctly reproduced the egg production rate estimated in individual-based experiments, under different temperature and salinity conditions. However, model results differed from results of the incubation protocol. These differences may reflect biases this method can introduce into estimates of daily egg production of egg-carrying copepods. The proposed model can be easily generalised to other egg-bearing copepods (i.e. *Pseudodiaptomus* sp.).

Poster S10-3496

Investigation of the influence of temperature on the estuarine copepod *Eurytemora affinis* population dynamics through a combination of an individual-based model and field observations

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The calanoid copepod *Eurytemora affinis* is by far the dominant zooplankton species in most North American and European estuaries. Particularly in the Seine estuary in France, this copepod dominates the estuarine zooplankton throughout the year. A recurrent pattern observed in the Seine estuary shows a major peak of the *E. affinis* population during spring (April-May), and a secondary less-dense peak during autumn. The increase of population abundance results from high reproduction, that is enhanced by increases in temperature and favourable food conditions. Field observations suggest the apparent optimal temperature for *E. affinis* population in the Seine-estuary was around 15°C. However, our experimental observations suggested egg production was high at temperatures from 18°C to 20°C. To understand the complex patterns of recruitment and population growth in this population, we developed an individual-based model for this species. The main forcing factor in this model is temperature. Calibration of all demographic processes (residence time in all developmental stages, and reproduction) and the representation of the individual variability are based primarily on our experimental data. We show here the potential of the multi-agent system platform MOBIDYC in building, calibrating and performing several numerical experiments without hard encoding. The results obtained with a first simulation over three years emphasise the significance of temperature as a key process for shaping the seasonality of the species. Although temperature has the most important effects on the population dynamics of this species, other factors (food, predation, photoperiod, etc.) could also be directly or indirectly responsible for observed patterns. We used the model to simulate combinations of these factors, and assess their consequences for population dynamics of *E. affinis* in the Seine estuary. We qualitatively compare the results of these simulations to observed patterns in this population.

Poster S10-3510

A simplified age-stage model for copepod population dynamics

Qiao Hu, Cabell **Davis** and C. Petrik

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Coupled biological-physical models are becoming increasingly used in aquatic ecology. These models are highly valued because they provide insights into complex dynamics that are difficult to obtain from other methods. These numerical models however typically have large numbers of grid points and therefore require a simplified biological model. A particular interest has been the incorporation of concentration-based copepod population dynamics into 3D physical transport models. A well known problem with simplified structured copepod population models is “numerical diffusion”. This problem is due to insufficient resolution of the population structure on the time-scale of temporal forcing, leading to artificially short generation times. To overcome this problem, copepod population models have been developed that contain numerous age-classes within each life stage, but this increased age-stage structure results in a large number of state variables that must be carried in the coupled physical-biological model, causing computational and memory limitations. We present a new method in which we track the mean-age of each life stage. A probability model was developed to simulate the molting process. This method effectively prevents numerical diffusion without the need for including age-classes within each life stage. This simplification enables the use of more accurate concentration-based copepod models in complex biological-physical models. We also discuss other aspects of copepod modelling, including correct use of the formula for molting rate, comparison of different probability density functions for simulating the molting process, and temperature and mortality effects on copepod population dynamics.

Poster S10-3515

Zooplankton encounters in uniform vs. patchy particle distributions

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Zooplankton encounter rates are dependent on both sensory and swimming performance of the organism. In this work, we focus our attention on the relationship between swimming complexity and the number of realised encounters in case of uniformly or patchily distributed particles. To this end, we simulated different swimming behaviours, each representative of a specific motion rule and characterised by a typical value of fractal dimension, and calculated the associated number of encounters. We show that the encounter efficiency is critically dependent on the degree of convolutedness of swimming tracks, as well as on particle distribution patterns. We interpret our results in terms of optimal foraging strategies, and provide new insights for the understanding of behavioural adaptations in zooplankton.

Poster S10-3516

COPEPOD: an online plankton database and modeller’s resource

Todd D. **O’Brien**

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The Coastal & Oceanic Plankton Ecology, Production & Observation Database (COPEPOD) is an online database of zooplankton biomass and composition data collected by cruises, projects, and institutes from around the world. COPEPOD’s online data content ranges from surveys and process studies to time series, each presented via searchable indices and detailed content summaries. In addition to its huge collection of raw data sets, COPEPOD features gridded value fields and regional compilations offered at a variety of spatial and temporal resolutions. COPEPOD strives to become a better resource for modellers, working to create new products and features to help with model skill assessment and development. This work reviews previous uses of COPEPOD data and presents new data products currently in development.

COPEPOD is available online at: <http://www.st.nmfs.noaa.gov/plankton>.

Poster S10-3522

Modelling the interactions between the hydrodynamics and the population dynamics of *Calanus finmarchicus* in the Gulf of St. Lawrence, eastern Canada: (2) mechanistic formulation of the mortality, swimming behaviour and diapause processes

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We used numerical models to address the interactions between the population dynamics of *C. finmarchicus* and the physical realm in the St. Lawrence system. The Gulf of St. Lawrence (GSL) is a large semi-enclosed sea that represents the southernmost limit of the northern Atlantic seasonal sea-ice cover. Its general cyclonic circulation is driven mainly by the seasonality of the freshwater discharge from the St. Lawrence River, and by variations in the synoptic meteorological systems. It sustains a productive pelagic ecosystem whose dominant zooplankton species is the copepod *Calanus finmarchicus*. In a first approach, we coupled a deterministic stage-based population dynamics model of *C. finmarchicus*, representing the average properties of the population regarding swimming behaviour, development, mortality and birth rates, to an eddy-permitting resolution 3D regional circulation model driven by realistic atmospheric, hydrologic and oceanic forcing. The distribution and abundance patterns simulated were found to be highly sensitive to migration behaviour, owing to the strong vertical shears of the circulation, and to the mortality term parameterisation. In a second approach, we elaborated a stage-structured population biomass model to explore mechanistic formulations of stage-specific swimming behaviour, growth and mortality rates, and of the diapause process. The switch from constant biological parameters to functions of environmental variables enabled this model to predict population responses to environmental variability in specific regions. These model predictions agreed well with observations from the GSL system in 1999 and 2000.

Poster S10-3577

Multi-species modelling approach to predict ecological niches and carbon export by appendicularians

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An ecophysiological model representing food consumption, growth and production of particles during the life cycle of an appendicularian was calibrated for the four most common appendicularian species: *Oikopleura dioica*, *O. longicauda*, *O. fusiformis* and *O. rufescens*. Using this model, we calculated growth rates and predicted the dominant species as a function of environmental conditions. This approach was validated on two different datasets. First, we used the model to reproduce the seasonal distributions of different species observed in Villefranche-sur-mer bay as a function of temperature. Using Sea Surface Temperature (SST) and chl *a* data from the MODIS satellite, the model predicted the dominant appendicularian species over 487 field observations worldwide with 62.6% accuracy. Second, we applied the model to *in situ* observations performed with the Underwater Video Profiler during the POMME programme in the North-Eastern Atlantic in 2001, to predict the particle consumption, growth, respiration, and production of faecal pellets and discarded houses by the appendicularian population. At high appendicularian densities (135 ind m⁻³), the population grazed daily only 0.63% of the total particulate carbon concentration. Only 21% of the grazed particles carbon was used for growth, whereas 14 and 65% were released as respiration and detritus, respectively. Nevertheless, the model shows that in two of the four sampled stations, the integrated mass of detritus produced by the appendicularian population equalled or exceeded the carbon flux recorded at 200 m depth in sediment traps. This indicates that the disaggregation and recycling rates of these particles during their sedimentation to deeper layers may be extremely high.

Poster S10-3588

Modelling Antarctic krill (*Euphausia superba*) development in the Lazarev Sea

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Physiological data on Antarctic krill (*Euphausia superba*) from three LAKRIS cruises in the Lazarev Sea were synthesized to develop a biochemical model of krill that accounts for food quality, in addition to food availability, over the course of the year. It defines krill in terms of their protein, neutral lipid, polar lipid, carbohydrate and chitin content and tracks krill weight separately from length. The model includes parameterisations of filtration, ingestion, and metabolic processes, which determine krill growth. The model was developed to investigate environmental and biological factors controlling growth and development of Antarctic krill, focusing on their ability to survive times with low food concentration such as during austral winter. Model results show that lipid metabolism plays a major role in surviving low food conditions, but as another survival strategy the use of alternative food sources (omnivory) is shown to also be important. Implications of these survival strategies for krill populations in the Lazarev Sea and possible connection with other areas are discussed by way of combining the biochemical model with output from a finite element model of Southern Ocean hydrography and biochemistry (FESOM).

Poster S10-3652

Plankton layers: formation, persistence, and ecological consequences

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Spatial and temporal patterns of plankton layer formation and persistence now have been examined in considerable detail in the coastal Northeast Pacific Ocean. These plankton layers are often less than 1 m thick and may persist for many hours. We have found thin layers during studies conducted over the continental shelf of Oregon (USA) during the summers of 1997, 1998, 2001, and 2004, and in Monterey Bay, California (USA) during the summers of 2005 and 2006. Each study included time-series of vertical profiling that defined hydrographic and bio-optical characteristics of the water column at centimetre vertical scales. The 2005 and 2006 studies included high-resolution vertical assessment of zooplankton using bio-acoustics, and the 2001 and 2006 studies used a zooplankton pumping system to obtain vertical patterns. Each study also included assessment of small-scale vertical gradients in horizontal velocity to evaluate the role of advection and shear in forming and maintaining plankton layers. Our results indicate that vertical structure and position of thin bio-optical and bio-acoustical layers is correlated with vertical gradients in horizontal velocity and local maxima in density stratification, and large changes in zooplankton population composition can occur on vertical scales of a few metres. Persistence of plankton layers, and their ecological importance, is a complex function of stratification, local mixing, and plankton behaviour. We will discuss these extensive field observations in the context of a resource utilisation model that evaluates the importance of persistent plankton layers in the ecological dynamics of the upper ocean.

Poster S10-3703

Modelling the effect of constant and fluctuating food supply on egg production rates of *Acartia grani*

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We present a mathematical model of the individual energetic budget of *Acartia grani* with four state variables: gut contents, nutrients in the internal body fluid, structural body weight and gonad weight. Physiological functions and parameters come from an exhaustive literature review on *Acartia* species. Experimental results on the egg production of *A. grani* under various food fluctuations of 6, 12, 24 and 48 hours, and starvation of 4, 5 and 6 days are used to test the model. Simulation results are in good agreement with the results. Three different patterns in

egg production response are observed: food fluctuations with frequencies below 12 hours have no effect on egg production; food fluctuations of 12 hours to 5 days induce synchronous egg production fluctuations; beyond 5 days the strong physiological changes induced by long starvation durations create delays in the responses to food replenishment. Different experimental protocols for complementary experiments are proposed to test some of the model results.

Poster S10-3751

Larval consumption of dissolved organic matter (DOM) and population viability of marine invertebrates in a changing ocean

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Dissolved organic matter (DOM) is the largest reservoir of reduced carbon in the world and yet its availability is spatially and temporally heterogeneous. In coastal regions, high DOM concentration is often associated with conditions unfavourable for larval development (e.g. excessive temperature or high pollutant level). Food limitation and temperature strongly affect larval development rates, which in turn affect survivorship, settlement success and ultimately the distribution and viability of adult populations of marine invertebrates. In contrast to the traditional view of mesozooplankton as DOM producers, recent studies suggest that some marine invertebrate larvae absorb significant amounts of DOM. Furthermore, this DOM may be required for larval growth. Hence, changes in availability of DOM are likely to affect the sustainability of some adult marine invertebrate populations, especially those that are already endangered. In the coastal northeast Pacific, surface waters with high DOM from riverine inputs are predicted to shrink and warm significantly due to global climate change. This study aims to quantify the ability of marine invertebrate larvae to use swimming behaviour to exploit near-surface DOM while minimising negative thermal effects. Using the critically endangered northern abalone (*Haliotis kamtschatkana*) as a model organism, larval behavioural responses to vertically structured laboratory DOM distributions will first be quantified using video tracking. The effects of elevated water temperature on behaviour will also be investigated in subsequent studies. These individual movement data are crucial in developing population-level models to aid the design of conservation, management and restoration strategies.

W1 Temporal and regional responses of zooplankton to global warming: phenology and poleward displacement

28 May, 10:05 (W1-3433)

Climate effects on North Sea zooplankton

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The end of the last century is characterised by a rise in seawater temperature by 1.4°C in 30 years in the North Sea, eastern part of the North Atlantic. During this period and till today zooplankton samples have been taken near its only offshore island Helgoland at a frequency of every other workday. Thereby it was possible to register the dynamics of 400 zooplankton populations. These were influenced by NAO variations, by nutrient supply changes and by further external and internal forcing. In the analysis of the observations it was possible to separate out phenological and numeric alterations. Holoplankton and meroplankton show population specific responses to temperature changes. The start of season (SOS) is ahead of time in many but not all species, so is the middle of season (MOS). The end of season (EOS) varies most, so does the resulting length of season (LOS). This can be seen as long term phenological population changes and as a function of the phenological timing and the preceding winter temperatures. Such observations are made in hydrozoa, ctenophora, crustaceans, echinodermata, appendicularians, fish and other. Based on these results the prediction of phenological timing is possible. The operative online plankton prognosis is available on the web since 2004. Beyond temperature based phenological changes the lateral displacement of zooplankton populations can be observed. Examples are *Muggiaea atlantica*, *Doliolum nationalis* and *Penilia avirostrius* in the North Sea.

28 May, 10:35 (W1-3312)

Have climate induced changes in zooplankton communities led to poor conditions for larval fish growth? A test on cod larvae on the UK shelf

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Climate effects have been shown to be at least partly responsible for the reorganisation in the plankton ecosystem on the shelf seas of NW Europe over the last 50 years. Most fish larvae feed primarily on zooplankton, so changes in zooplankton quantity, quality and seasonal timing have been hypothesized to be a key factor affecting their survival. To investigate this we have implemented a 1-dimensional trophodynamic growth model of cod larvae for the waters around the UK covering the period 1960 to 2003. Larval growth is modelled as the difference between the amount of food absorbed by the larva and its various metabolic costs. Prey availability is based upon the biomass and size of available preys (i.e. adults and nauplii copepods and cladocerans) taken from the Continuous Plankton Recorder dataset. Temperature and wind forcing are also taken into account. Results suggest that observed changes in plankton community structure may have had less impact than previously suggested. This is because changes in prey availability may be compensated for by increased temperatures resulting in little overall impact on potential larval growth. Stock recovery, at least in the short term is likely to be more dependent upon conserving the year classes recruited to allow spawning stock biomass to rebuild. If as our model suggests, the larvae are still able to survive in the changing environment, reduction in fishing on the adults is needed to allow the stock to recover.

28 May, 10:55 (W1-3347)

Impacts of climate change on the Baltic zooplankton – fish larvae link: evidence for sprat (*Sprattus sprattus* L.) larval behaviour change influencing recruitment levels

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Larval distribution and diurnal migration behaviour of Baltic sprat (*Sprattus sprattus* L.), presently the dominating commercial fish stock in the Baltic Sea and of high ecological importance, were investigated in the period 1998-2002 and a decade earlier, in 1989 and 1990. Comparison of the results of both periods lead to the hypothesis that changes in prey abundance, related to an increase in surface temperature, triggered a change in the diel vertical migration behaviour. In 1989 and 1990 sprat larvae migrated to the surface at night, while they stayed at 30-50 m depth during day-time. In 1998-2002 sprat larvae showed no signs of diel vertical migration. They stayed the whole day in the warmer, near surface waters. This behavioural change happened concurrently to a more general change in the Baltic ecosystem. Near surface temperatures increased since the 1990s and the major prey organism (*Acartia* spp.) of Baltic sprat larvae increased in abundance, with a more pronounced aggregation in the surface waters. Under the changed conditions sprat larvae should benefit from staying in surface waters as they experience higher ambient temperatures and higher growth rates. When food supply is sufficient, this results in better survival. On the other hand, the risk for starvation is enhanced, due to increased standard metabolic costs. The observed change in vertical distribution patterns of sprat larvae might therefore have contributed to the generally higher but also more variable recruitment in Baltic sprat in the last decade.

28 May, 11:30 (W1-3676)

The combined effects of climate and fish on zooplankton abundance and distribution in the southern Barents Sea

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† S. Timofeev tragically died before the presented work was completed.

It is well established that the abundance and distribution of zooplankton in the Barents Sea is influenced by grazing by capelin as well as by climatic factors. However, how these factors interact is less clear. We here explore the combined effects of capelin and climate (the North Atlantic Oscillation) on interannual variability in zooplankton biomass along two inshore-offshore transects in the Barents Sea (19°20'–33°30' E; 69°30'–74°30' N). The two transects were sampled biannually in spring (May) and summer (June-July) 1959-1993. The data are analysed using Generalized Additive Mixed Models, which allow the estimation of location-specific effects of the explanatory variables and the linear or nonlinear (e.g. threshold-dependent) interaction between these variables. We thus quantify the effects of capelin and climate, the spatial and temporal variation in these effects, and the possible interaction between the effects.

28 May, 11:50 (W1-3742)

Effect of climatic change on the production and distribution of *Calanus finmarchicus* in the Norwegian and Barents Seas

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The effect of global warming on high latitude marine ecosystems may be an increase in the overall production, as a response to the temperature increase. However, structural changes are also likely to take place which make any prediction less reliable, unless models include structural information. Here, we present results from a 3D coupled

hydrodynamic and ecological model study of the Nordic Seas. Atmospheric forcing is taken from a global climate model (ECHAM4/OPYC) with a downscaled region covering the Norwegian and Barents Seas to a resolution of 1/6°. The IPCC's B2 scenario is used as CO₂ input. The presentation will focus on the effect of increased ocean temperature, less ice in the northern Barents Sea, growth, development and distribution of *Calanus finmarchicus*. The *Calanus* component of the ecosystem model is represented by a stage structured model enabling simulation of the live cycle, its interaction with the climatic change and variability. Two time slices (1990-1999 and 2050-2059) are compared.

28 May, 12:10 (W1-3589)

What controls interannual variability of abundance and phenology of *Acartia clausi* in the southern North Sea?

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While most time series analysis deal with interannual variability of abundance, little is known on interannual changes in phenology. The copepod *Acartia clausi* is an important component of the zooplankton community in the southern North Sea, where it contributes ca. 25% of the biomass. Interannual variability in abundance together with female size and the timing of growth and reproduction were recorded during seven years at Helgoland Roads (southern North Sea) and related to phytoplankton biomass and composition, temperature and salinity. The annual life cycle is characterised by an active growth period between end of spring and late summer. Large annual and interannual differences were observed in the life cycle parameters, but no clear relationship was found to time series of environmental parameters. The use of prosome length measurements for phenological investigations is demonstrated. The effect of the expected increased sea surface temperature and changes in the timing of phytoplankton development on the population dynamics and the role of a female diapause in this species are discussed.

28 May, 14:20 (W1-3349)

Decline of zooplankton biomass in the tropical Atlantic Ocean

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A number of investigators have reported gradual changes of zooplankton communities taking place in the northern latitudes of the Atlantic Ocean probably in response to climate change. In comparison with the northern latitudes, the tropical Atlantic Ocean has been much less studied. Until recently, no studies have been made of variations of zooplankton communities on climatic scale in this region. Through data mining in the archives, retrospective literature analysis, and personal contacts with data holders, we have assembled data from 43 expeditions in the tropical zone, over the past 50 years. The most abundant measurements available at present time are data on integrated mesozooplankton biomass from the upper 100 or 200 m. We selected samples collected by nets with approximately the same mesh size (178-200 µm). Most of the data (over 80%) were available in the form of wet weight biomass. All biomass values (977 measurements) sampled within the tropical zone were annually averaged and distributed over sampling years, covering the range of years from 1950 through to 2000. The interannual time series obtained was subjected to regression analysis. Changes in mesozooplankton biomass over the years show a pronounced declining trend, with almost 10 fold drop of the total wet mesozooplankton biomass, from the 1950s to 2000. We compare this trend with the reported long-term tendencies of atmospheric characteristics, thermo-saline characteristics and productivity of the tropical ocean.

28 May, 14:40 (W1-3329)

Changes in the oceanic northeast Pacific plankton populations; what may happen in a warmer ocean

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The Continuous Plankton Recorder has been sampling the northeast Pacific on a routine basis since 2000. Although this is a relatively short time series still, climate variability within that time has caused noticeable related changes in the plankton. The earlier part of the time series followed the 1999 La Niña and conditions were cool, but conditions between 2003 and 2005 were anomalously warm. Oceanic zooplankton have responded to this warming in several ways that are discernible in CPR data. The seasonal cycle of mesozooplankton biomass in the eastern Gulf of Alaska has shifted earlier in the spring by a few weeks (sampling resolution is too coarse to be more accurate). The copepod *Neocalanus plumchrus/flemingeri* is largely responsible as it makes up a high proportion of the spring surface biomass and stage-based determinations have shown an earlier maximum in warmer years across much of the northeast Pacific, spanning nearly 20 degrees of latitude. Summer copepod populations are more diverse than in spring, although lower in biomass. The northwards extension of southern taxa in the summer correlates with surface temperature and in warmer years southern taxa are found further north than in cooler years. These findings support the importance of monitoring the open ocean particularly as it is an important foraging ground for large fish, birds and mammals. Higher trophic levels may time their reproduction or migration to coincide with the abundance of particular prey which may be of a different composition and/or lower abundance at a particular time in warmer conditions.

28 May, 15:00 (W1-3689)

Spatial variability of marine climate change impacts in the North Atlantic

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There is an accumulating body of evidence to suggest that many marine ecosystems in the North Atlantic, both physically and biologically are responding to changes in regional climate caused predominately by the warming of air and sea surface temperatures (SST) and to a varying degree by the modification of oceanic currents, precipitation regimes and wind patterns. The biological manifestations of rising SST and oceanographic changes have variously taken the form of biogeographical, phenological, physiological and community changes. For example, during the last 40 years there has been a northerly movement of warmer water plankton by 10° latitude in the north-east Atlantic and a similar retreat of colder water plankton to the north. This geographical movement is much more pronounced than any documented terrestrial study, presumably due to advective processes playing an important role. Other research has shown that the plankton community in the North Sea has responded to changes in SST by adjusting their seasonality (in some cases a shift in seasonal cycles of over six weeks has been detected), but more importantly the response to climate warming varied between different functional groups and trophic levels, leading to mismatch. Therefore, while it has been documented that marine ecosystems in certain regions of the Atlantic have undergone some conspicuous changes over the last few decades it is not known whether this is a pan-oceanic homogenous response. Using these two most prominent responses and/or indicative signals of pelagic ecosystems to hydro-climatic change, changes in species phenology and the biogeographical movement of populations, we attempt to identify vulnerable regional areas in terms of particularly rapid and marked change.

28 May, 15:20 (W1-3741)

Northern Hemisphere climate impact on Mediterranean zooplankton

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Considered as a model for many open ocean processes, the Mediterranean Sea is a particularly interesting zone to investigate the impact of climate on zooplankton communities. In this study we examined the effects of the Northern Hemisphere climate variability on the population size of zooplankton functional groups: crustacean zooplankton, gelatinous carnivores and gelatinous microfilters over the period 1966 to late 1990s. We show that extreme events in the long-term variability of these functional groups were tightly linked to climatic changes of the North Atlantic sector. The large-scale climate forcing has altered the pelagic food web dynamics through changes in biological interactions, competition and predation, leading to extreme events (bursts/collapses) in zooplankton communities, and consequently to a major change circa 1987. The recurrence of extreme events during the 1980s in the studied zooplankton functional groups suggest a shift in the functioning of the pelagic ecosystem. The environmental modifications and the results reported here are therefore indicators of a regime change pointing to a more regeneration-dominated system in the study area. We suggest a chain of mechanisms whereby climate variability modified the long-term dynamics of the studied trophic groups in the Northwestern Mediterranean.

28 May, 16:10 (W1-3440)

Arrival of Mediterranean species into the Black Sea is increasing

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Since last century due to increasing human activities first shipping intensity high numbers of alien species have established in the Black Sea, all together 152 species, which belong to different taxonomical groups. In addition, global warming facilitates the increase population of thermophilic species and their northward expansion from the Mediterranean. Until recently Mediterranean species have been recorded temporally or permanently mainly in the near-Bosporus region. Therefore, they are usually not regarded as established alien species. The currents via the Bosporus Strait delivered 59 species of holozooplankton, 37 species of phytoplankton, 51 benthic species, 23 species of macrophytes. But selected Mediterranean species of phyto- and zooplankton were found also off northwestern coasts even in the 1960s. At present, this process is still going on and numbers of penetrated and even established species far from Bosporus greatly increase during last years. Some species were represented by a few specimens; others are increasing their density, such as copepod *Oithona brevicornis*, amphipod *Microprotopus maculatus* off the Crimea, three fish species, two of them may be regarded as established species - the golden goby *Gobius auratus* and the centracant *Centracanthus cirrus*, which became a commercial species off Romania. During the last years other groups of species of Indo-Pacific origin appeared in the Black Sea. The probably also arrived from the Mediterranean where they penetrated as Lessepsian migrants, their further destiny is unknown. The possible reason of this process is a higher temperature since 1995 in the Black Sea, which could stimulate penetration and establishment of Mediterranean and even lessepsian migrants that were never observed before.

28 May, 16:30 (W1-3296)

The variability of the Black Sea zooplankton as a derivative of long term dynamics in the water hydrological structure

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The investigation of climatic variation influence on the inter-year dynamics of the Black Sea plankton composition was examined qualitatively and quantitatively. Data from other relevant articles, computer data bases on biology and hydrology (Ocean Base NATO TU-Black sea project: 195 cruises, 17,877 stations) and the result of the authors own studies in the Sevastopol region were used in the investigation. It has been shown, that variability of the Black Sea plankton numerical indices are connected with the long term variability in the water masses hydrological structure. Dynamics in long term climate variation leads to changes in the zooplankton dominating groups. With high positive magnitudes in the North Atlantic Oscillation (NAO) the warm water species dominate. With negative magnitudes, the cold water species and eurythermic forms dominate. Due to this the total biomass of the fodder zooplankton in the Black Sea has increased. Periods of high positive NAO are characterised with intensive phytoplankton development and a decrease in abundance and biomass of the fodder zooplankton. Periods of long negative NAO lead to a warming of the Cold Intermediate Layer (CIL), a lowering of iso-oxygens at 100-120 m depth and to an increase of zooplankton biomass.

W2 Zooplankton research in Asian countries: current status and future prospects

28 May, 10:15 (W2-2794)

Current zooplankton production research in India

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The east and west coasts of India are known for their zooplankton. The ongoing research in marine zooplankton of India is primarily basic in nature and applied research is uncommon. In these coastal waters of India, current zooplankton research is mainly on diversity, qualitative and quantitative composition, distribution, diel vertical migration, biochemical composition, and zooplankton-phytoplankton interrelationships. The author has more than 35 years of experience with the marine zooplankton of India and has studied the species composition and biomass of zooplankton in the southeast coast of India. He has also planned applied research on topics such as: bacteria associated with zooplankton; pharmaceutical properties of zooplankton; nutritional characteristics of jellyfish (to serve as human food); zooplankton indicators of sewage and industrial pollution; zooplankton associated with coral reefs; and culture of zooplankton species to serve as live food for aquaculture. The results of current research and methodologies to be followed for future applied zooplankton research will be discussed in detail.

28 May, 10:35 (W2-3426)

Zooplankton in Korean waters

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We review the results obtained during the past several decades on the spatial and temporal variations of major zooplankton assemblages and biomass, zooplankton indicator species of specific water masses, and decadal changes in zooplankton communities in Korean waters. Additionally, we briefly discuss zooplankton process studies and their importance to fisheries. Copepods were the most dominant group of zooplankton in Korean waters, followed by chaetognaths, siphonophores, euphausiids, cladocerans, appendicularians and amphipods in order of decrease. Zooplankton biomass showed two peaks in April-June and October with geographical variations, and was higher in the coastal area than in the offshore area. In particular, zooplankton biomass was high in the frontal area compared with the other areas. Some calanoid copepods were indicator species of oceanic warm-water and were therefore closely associated with the extension of the Tsushima Warm Current. Their distribution indicated that the Tsushima Warm Current occupied the offshore area between Jeju Island and the Korea Strait in February and April and extended to the southern-offshore area of the East/Japan Sea in August and October. Long-term changes in zooplankton biomass and abundance were investigated to understand and predict the impact of climatic change on the marine ecosystem. Zooplankton biomass increased since the early 1990s and changes in the composition of major zooplankton groups have been observed. Long-term changes in geographic distribution have also been observed. Studies of zooplankton production and of zooplankton impacts on the fisheries have been very limited in Korean waters. Of coastal neritic calanoid species, egg production and life history of *Acartia* spp. and *Calanus sinicus* have been examined. On the other hand, it has been shown that zooplankton biomass and composition affects the squid and mackerel fisheries. Such results clearly suggest future research directions in Korean waters. Especially, we need to understand population level processes on appropriate spatio-temporal scales with focus on understanding productivity. An ecosystem level approach should also be adopted to understand the function of zooplankton in the marine ecosystem. Currently, we are concerned about the abruptly increasing jellyfish populations, changing zooplankton species diversity, and the impact of climatic change on the zooplankton production and composition.

28 May, 10:55 (W2-3658)

Zooplankton research in Indonesian waters

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The earliest studies of zooplankton in Indonesian waters, including those from historical expeditions and local faunal studies by individual scientists or research groups, focused primarily on taxonomy. Later, study of fish eggs, larvae and copepods in relation to water properties in the Java Sea was initiated by Delsman (1921-1939). Recent studies by Mulyadi (1994-2006) have listed about 300 species, 55 new records and 11 new species of copepods. Production-oriented studies have also been carried out by several research projects. The influence of monsoonal oceanographic conditions on zooplankton production in the Banda and Arafuru Seas was investigated by cooperative research between Indonesia and the Netherlands during the Snellius II Expeditions (1984-1985). These studies indicated that zooplankton biomass in the east-monsoon (upwelling period) was twice that seen during the west-monsoon (downwelling period). Other cooperative studies such as the Baruna Jaya Expedition I (1964) found higher abundances of zooplankton in the Java Sea than in the Indian Ocean. A similar pattern of temporal zooplankton distribution around the Seribu Islands and in Jakarta Bay has been found by the Research Center for Oceanography. Zooplankton abundance and biomass data (1970-1985), including data from the Snellius II Expeditions, are available in an online database. Studies of zooplankton abundance and diversity in North Sulawesi waters, and pollution issues comparing zooplankton baseline data of 1996 with recent data of 2004 in that region, are also reviewed. Some constraints in taxonomic studies due to a lack of taxonomic skills and poor facilities need to be addressed for future expansion of this zooplankton database.

28 May, 11:30 (W2-3693)

Mesozooplankton in the Sulu Sea and its adjacent waters with special reference to copepods

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The Sulu Sea (SS) is located in the western equatorial Pacific and is a semi-enclosed basin, rimmed by sills shallower than ca. 400 m. This sea has homogeneous and unusually warm (ca. 10°C) water from the mesopelagic zone to the sea bottom, while the adjacent Celebes Sea and the South China Sea show more 'normal' oceanic conditions. Under these contrasting settings, the relationships between vertical water-column structure and biomass, biodiversity and patterns of vertical distribution of mesozooplankton were examined. The total mesozooplankton biomass in the mesopelagic layer, the degree of exponential decrease in their biomass and abundance with depth, the vertical distribution patterns of higher taxonomic groups, and community structure analysis using a dissimilarity index applied to higher taxa, all indicated no significant differences between the seas. This suggests that warm mesopelagic water in the SS does not drastically influence the mesozooplankton standing stocks, vertical distribution patterns and the community structure at the higher taxonomic levels. However, the composition of copepods was markedly different in the calanoid families between the SS and the Celebes Sea, with dominance of Eucalanidae, Metridinidae, and Lucicutiidae in the layer of lower dissolved oxygen in the SS. Reduced abundance in the dominant genera such as *Euchaeta*, *Mormonilla*, and *Conaea* was also observed in the SS. Among the > 300 species identified, 5 possible new species were found only in the mesopelagic water of the SS, suggesting the existence of unique communities at lower taxonomic levels (genera and/or species) in the SS.

28 May, 11:50 (W2-3612)

Experimental study of appendicularians

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Appendicularians are common pelagic tunicates in the world oceans. This group has received increasing attention because of its significant contribution to the vertical flux of organic matter; their mucus houses are a major origin of marine snow. Appendicularians have a fast growth rate, and a high grazing rate. Most of the ecological studies

of appendicularians have been done by marine biologists in European and Northern American countries. In Asian countries, although some excellent work has been done especially on taxonomy and geographical distribution, physiological or ecological studies of appendicularians in this region are still rare. In this presentation, I will introduce my laboratory and field work on measurements of growth, clearance and house production rates of appendicularians, demonstrate their importance in marine ecosystems of this region, and discuss future work needed to further understand this unique group of pelagic organisms.

28 May, 12:10 (W2-3399)

Spatial distribution of chaetognaths along with oceanographic conditions off the northern Bicol Shelf, Philippines (Pacific Coast)

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The composition, abundance and distribution of chaetognaths off the northern Bicol Shelf, Philippines (Pacific Coast) were analysed from 31 stations perpendicular to the coast. Samples were collected on board the M/V DA-BFAR from April 1-11, 2001. Corresponding data on the main hydrologic features of the surveyed area were used to relate species occurrence with water masses. Stations grids were laid out to examine the possible heterogeneity in hydrographic conditions. Twenty six species of 5 genera of chaetognaths were identified, and –in order of relative abundance were: *Sagitta enflata*, *S. neglecta*, *S. serratodentata*, *S. bipunctata*, *S. ferox*, *S. bedoti*, *S. oceanica*, *S. robusta*, *S. minima*, *S. pacifica*, *S. decipiens*, *S. hexaptera*, *S. johorensis*, *S. macrocephala*, *S. regularis*, *S. tasmanica*, *S. nagae*, *Pterosagitta draco*, *S. pulchra*, *S. bedfordii*, *Krohnitta pacifica*, *K. subtilis*, *Eukronia fowleri*, *S. septata*, *S. setosa*, and *Spadella* sp, excluding the unknown *Sagitta* sp. and *Sagitta* juvenile. *Sagitta enflata* was the most abundant and frequent species in all stations analysed and comprised 41.88% of the total specimens. Most of the lowest diversity values were distributed in the areas directly affected by or adjacent to upwelling. Highest dominance was observed in station located within the upwelling zones. The occurrence of mesopelagic, mesobathypelagic and bathypelagic species (*S. decipiens*, *S. serratodentata*, *S. macrocephala*, *S. minima*, *Krohnitta subtilis*, *K. pacifica* and *Eukronia fowleri*) in samples collected from the upper layer of water could be explained by vertical transport affected by the upwelling, in which deep-living organisms are carried to the epipelagic layer.

28 May, 14:00 (W2-3286)

Zooplankton community structure in the ports of Mumbai, India: an account since the 1940s

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Mumbai is the second largest coastal city in the world and is India's premier port. The census report of 2001 suggests that the population of Mumbai increased from 4 million in 1960 to 7.7 million in 1971 and is projected to be between 18.3 million and 22.4 million by 2011. This has led to an unprecedented increase in human and industrial activities, resulting in generation of over 2485 million litres of wastewater per day and exerting enormous pressure on the adjacent marine environment, including harbour waters. Nutrient concentrations, especially nitrate, have increased gradually over the years with a simultaneous decrease in dissolved oxygen. Apart from receiving local sewage and industrial waste, the harbour is also subject, by ship ballast water, to inoculation of non-native waters containing a wide range of pollutants and biota. In order to evaluate the impact of these activities on the surrounding environment and to elucidate the possible changes in the community structure of zooplankton in Mumbai harbour, 14 stations were selected in and around the area and samples were collected during three different periods between 2001 and 2002. The results are compared with the records available from the 1940s. The copepods *Canthocalanus* sp., *Paracalanus nanus*, *Cosmocalanus* sp., *Euterpina acutifrons*, *Nannocalanus minor*, *Nannocalanus* sp. and *Tortanus* sp. were not reported in the earlier studies but were observed in the present investigation. Purely herbivorous forms like *Nannocalanus minor*, *Paracalanus*

sp. and *Temora discaudata* were less abundant during the pre-monsoon sampling, because of reduced diatom concentrations. In contrast, increased abundance of some carnivorous and omnivorous forms during the same period can be related to the changes in food web dynamics. There was also a change in species composition, biomass and abundance between the two post-monsoons. Possible causes for these variations could be the differences in rainfall during the two sampling years. The study area is a tropical mesotrophic environment influenced by southwest monsoons and the two post-monsoon seasons differed with respect to length and intensity of the preceding monsoons. The anthropogenic contribution to these variations and subsequent responses in ecosystem functioning and food web dynamics are the key issues which will be addressed during this presentation.

28 May, 14:20 (W2-3402)

Long-term variation of trophic status and its impact on the diversity and abundance of zooplankton in Lake Biwa

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We investigated the trophic status of Lake Biwa and its effects on the diversity and abundance of zooplankton. Lake Biwa, the largest lake of Japan, is one of a few lakes in the world that has undergone eutrophication, due to urbanisation, that has later been successfully mitigated. Using time series data from 1962 to 2005, we found that the intensity of eutrophication (based on total phosphorus concentration) in Lake Biwa increased rapidly in the late 1960s and then decreased in the late 1980s. Phytoplankton concentration followed the trend of total phosphorus relatively well. The enhanced total phosphorus and thus phytoplankton concentration from the late 1960s to middle 1980s resulted in high abundance of herbivorous zooplankton (e.g. *Daphnia* and rotifers). An apparent increased species diversity in zooplankton during this period was likely due to sampling effects. Curiously, the abundance of carnivorous zooplankton did not follow the same course of eutrophication and mitigation. The fluctuations of carnivorous zooplankton may be affected by both bottom-up (food) and top-down (predators) controls.

28 May, 14:40 (W2-3674)

Succession of zooplankton in the Aral Sea

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Until the 1970s (salinity 10), the composition of zooplankton in the Aral Sea was stable, comprising over 40 pelagic species. A drop in the inflow of the rivers and growing salinisation of the waters of the Aral Sea caused a rapid decrease in the biodiversity of zooplankton in the 1970s. By 1976, the species composition became stable as the average salinity of the Aral Sea reached 14. Later, a gradual decrease in the zooplankton diversity took place. By 1997, when the salinity reached 50, the former dominant, *Calanipeda aquaedulcis*, had vanished from the plankton, and *Moina salina* and *Artemia parthenogenetica* had emerged. Since 2000, *Artemia* has been dominant in the Aral Sea zooplankton. In the last five years (salinity 60-110), four species have represented permanent elements of the Aral Sea zooplankton: *Hexarthra fennica*, *Artemia parthenogenetica*, *Cletocamptus retrogressus* and larvae *Chironomus salinus*. However, sharp fluctuations in water inflow into the shallow east Big Aral in recent years resulted in sharp changes in the structure and composition of the zooplankton. So for example, a rapid decline in the mineralisation of water in east Big Aral Sea (from 100 to 70) in Autumn 2005 - Spring 2006 resulted in a sharp increase in the abundance and biomass of zooplankton and the re-appearance of such species as *Brachionus plicatilis*, *M. salina*, *Arctodiaptomus salinus*, and *Apocyclops dengizicus*, which had not been recorded in the Big Aral in the previous few years.

28 May, 15:00 (W2-3301)

Monsoonal influence on the spatio-temporal patterns of zooplankton abundance and assemblage structure in Iligan Bay, northern Mindanao, Philippines

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We conducted a one year sampling at two fixed stations and a systematic sampling of physico-chemical factors and zooplankton in the upper 25 m surface layer across a 24 station grid in Iligan Bay to determine whether the assemblage structure and abundance of zooplankton differ between months and stations, and to establish correlations between zooplankton parameters and physico-chemical factors. Abundance was estimated by stereomicroscopy, and assemblage structure analysed using multivariate and univariate routines available in the E-PRIMER v.5 software. Abundance across stations and between months was higher during months coinciding with the southwest monsoon. Bay-wide and year round assemblages were similar in terms of taxonomic composition and dominant taxa (>67% of the total abundance: calanoid copepods, copepod nauplii and copepodites, and tintinnids). Change in assemblage structure was largely attributed to shifting in ranks of taxa (bivalve veligers, ostracods, gastropod veligers, fish eggs, larvaceans, chaetognaths, and cyclopoid copepods) that contribute <7% relative abundance. Bay-wide assemblages consist of high, moderate, and low levels in relative abundance, and taxonomic richness and diversity. Very crucial assemblages are those that had low diversity and abundance in the southeastern sector of the bay during the northeast monsoon and those with low diversity but high abundance in the southwestern sector during the SW monsoon. The former assemblages could be associated with areas with severe pollution stress while the latter with a possible micro-upwelling event. Salinity, temperature, and total dissolved phosphorus and nitrogen were weakly correlated with zooplankton spatio-temporal variations, but contrasting monsoons and associated hydrodynamic processes are also important in structuring zooplankton assemblages in Iligan Bay.

28 May, 15:20 (W2-3267)

Seasonal variations in abundance, biomass and ecological significance of microzooplankton in tropical coastal marine waters, South India

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Seasonal variations in taxonomic composition, abundance, biomass and ecological significance of microzooplankton were investigated in the plankton-rich, tropical, Vellar estuarine system, a unique coastal marine ecosystem in South India. Samples were collected monthly from April 1988 to March 1993. A total of 82 species of microzooplankton, consisting of naked ciliates, tintinnid ciliates, rotifers, copepod nauplii and early stages of mesozooplankton, were identified. Tintinnid ciliates overwhelmingly dominated the microzooplankton community both in terms of species diversity (mean 65%) and abundance (mean 68%). The population abundance, biomass and species diversity showed strong seasonal variations, being highest in summer and lowest in the monsoon season. The overall mean abundance (3.8 fold) and biomass (3.2 fold) were higher in summer than in the monsoon season. Significant positive correlations were observed between the abundance of microzooplankton, temperature and salinity, and between the biomass of microzooplankton and chlorophyll *a* concentration. Because of the relationships between microzooplankton and environmental factors, their grazing activity may also show similar seasonal variation. Overall, the results showed that environmental gradients and quality and quantity of food exert a major influence on the abundance and biomass of microzooplankton in this environmentally complex, coastal ecosystem.

28 May, 16:10 (W2-3600)

Response of zooplankton populations to eutrophication in the Changjiang Estuary: phosphate enrichment in mesocosms and in the field

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Because the Changjiang drainage area has experienced rapid urbanisation and project development (e.g. Three Gorges Dam and Water Transferring Project), its estuary has become the most eutrophic marine area in China. Direct and distinct effects have been observed such as the readjustment of river flux among seasons, decreases

in turbidity and dissolved oxygen, and a continuous decrease of nitrogen and silicate since 2003. In contrast, phosphorous has tended to increase in the last decades. What effects have these changes had on the ecology? There has been an increase in the frequency, spatial extent and intensity of harmful algal blooms. Fluctuations in zooplankton abundance and species composition are described from a field study (1990s - present) and from phosphate enrichment experiments conducted in two mesocosms. Top down effects of carnivorous medusa and chaetognath were not considered important. In both phosphate enrichment experiments and the field study there were steady increases in the abundance of zooplankton that corresponded to increases in abundance of phytoplankton and bacteria. In addition, there was a decrease of zooplankton biodiversity and decreased variation of community structure.

28 May, 16:30 (W2-3467)

Role of zooplankton in pollution monitoring: case studies along the west coast of India

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The most characteristic feature of zooplankton is its variability over space and time. Because of such inherent variability, it has been debated whether zooplankton can be used as an index to evaluate the impact of pollution. Environmental impact assessment studies conducted during 1990-1999 along the west coast of India indicate that a systematic evaluation of variations within the zooplankton can provide reliable information on pollution stress. Alterations in biomass and abundance of zooplankton beyond the natural fluctuations provide clues to unfavourable water quality. Variations in zooplankton biomass and abundance in a polluted creek are much greater than those observed in an unpolluted area. Species diversity and community structure of groups like copepods and chaetognaths give reliable indices of pollution load. Copepod species like *Acartia spinicauda*, *Bestiolina similis*, *Paracalanus crassirostris*, and *Canthocalanus pauper* are tolerant to pollution stress. Chaetognaths, very sensitive to environmental stress, showed increased population density and species diversity in the clean environment. Morphological changes in the chaetognath species *Sagitta bedoti* were observed in highly polluted environments. In the polluted creeks of Mumbai, the ratio between carnivores and herbivores increased to 40% compared to the normal 10%. Trophic conversion efficiency of 10% is also not attained in polluted environments. Concentrations of Cu and Zn in major groups of zooplankton were relatively low in the offshore area compared to the polluted creek environment. In general, these observations suggest that the deleterious effects of pollutants need to be evaluated quantitatively as well as qualitatively.

28 May, 16:50 (W2-3635)

Variation in distribution of phyto- and zoo-plankton biomass during the NE-monsoonal period in coastal waters of Karachi, Pakistan

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Human population in coastal areas has been increasing drastically over the last few decades and the coastal areas of Southeast Asian countries are considered to be one of the highly populated areas of the world. Associated developments have adverse effects on coastal marine life. The present study deals with the distribution pattern of phytoplankton and zooplankton communities and the anthropogenic impacts on their distribution, by evaluating the biomass of the plankton collected from coastal waters of Karachi, Pakistan. Variation in the diversity and distribution of plankton was observed during the NE-monsoonal period. Characteristically, a decrease in biomass of large centric diatoms and zooplankton groups like amphipods and ostracods was observed. The relationship with recent oil spills in the area is discussed with special reference to ecological parameters.

W2

Posters

Poster W2-3327

Distribution of ichthyoplankton relative to moon-induced tide inside and outside the marine sanctuaries of Cabilao Island, Bohol, Philippines

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The establishment of marine sanctuaries in the Philippines is often based on high coral cover with the associated genetic diversity of its communities. However, this is not sufficient to support the full potential of marine sanctuaries to the local fishery. Local currents may account for the variations in ichthyoplankton density that comprise the potential settlers inside the sanctuary. Variation in ichthyoplankton density inside and outside the marine sanctuaries of Cabilao Island was attributed to a dilution gradient, which was high in the up-current station and decreased with increasing distance downstream. During the new and full moon, the spring flood tide intensified the advection of ichthyoplankton inshore. However, the strength and duration of the tide during these lunar periods promote further advection downstream, especially if the cohorts are composed of pre-flexion stage larvae. Generally, flexion and post-flexion stage larvae appear to resist advection and remain in the up-current region of the island. During the new moon, the absence of visual cues promotes disorientation and most ichthyoplankton are advected downstream. During the last quarter, when ichthyoplankton were most abundant and tides were minimal, downstream advection was reduced and a high density of ichthyoplankton was observed in the up-current region of the island. It is recommended that a sanctuary should also be established in the up-current region of Cabilao Island because of the high density of ichthyoplankton during flood tides. This sanctuary will serve as a refuge for ichthyoplankton that were transported inshore during the flood tide and as a potential source of fish larvae downstream.

Poster W2-3344

Zooplankton study in Bay of Bengal, 1999-2005-changing perspectives

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The Bay of Bengal (BOB), a part of the Indian Ocean, is landlocked in the north and connected to the Pacific through the Malayan and Australian seaways. Recurring cyclones and the recent devastating Indian Ocean Tsunami of 2004 have brought much scientific attention to this Large Marine Ecosystem (LME). The zooplankton investigation carried out between 11-22°N and 80-96°E from 1999-2005 presents a better scope to analyse plankton production in relation to these episodic events. The samples for this study, along with hydrographical parameters, were collected from the mixed layer and the thermocline layer using a MPN sampler. The cyclones enhanced nutrient enrichment and primary production. This paper highlights the impact of these events on zooplankton. The biomass and density were high at the coastal stations off Chennai (13°50'N and 80°50'E). The average biomass decreased from 0.135ml/m³ before the tsunami to 0.09ml/m³ immediately after the tsunami. Similarly the density decreased from 284/m³ prior to the tsunami to 126/m³ after. A shift in the community structure of major herbivorous species was evident after the tsunami. Mesopelagic species like *Lophothrix frontalis*, *Haloptilus spiniceps*, *Pachos punctatum*, *Mormonilla phasma* and *Conaea rapax* were observed in the samples taken after the tsunami, suggesting the intrusion of deep water species to the upper strata. In contrast, the super cyclone of October 1999 triggered high primary production followed by an increase in zooplankton biomass and density. The biological changes are discussed in relation to changes in physical and chemical parameters.

Poster W2-3363

Quality and quantity of particulate organic matter and nutrition of zooplankton in a coral reef of Peninsular Malaysia

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In order to understand trophic structure of the coral reef pelagic ecosystem, qualitative and quantitative studies of size-fractionated zooplankton and particulate organic matter (POM) as food for the zooplankton were conducted in a coral reef of Tioman Island, off the east coast of Peninsular Malaysia. Sampling was done in August and October 2004 and February and June 2005. Zooplankton were sorted into three size-fractions (100-200 μm , 200-335 μm , and 335-2000 μm) and their carbon contents and taxonomic compositions were examined. POM was also sorted into three size-fractions (0.7-3 μm , 3-35 μm , and 35-100 μm) and their carbon contents and chlorophyll *a* concentrations were measured. The largest zooplankton size-class (355-2000 μm) was dominant among the three size-fractions of zooplankton during all the study periods (more than 50%). Total POM (0.7-100 μm) concentration was about 180 mg C m⁻³. The smallest size-fraction (0.7-3 μm) was dominant among the three size-fractions of POM. The contribution of each size-fraction (0.7-3 μm , 3-35 μm , and 35-100 μm) to the total POM was 54%, 31%, and 15%, respectively. The phytoplankton contribution of each fraction to the POM was very low (less than 8%). As a result, the contribution of detritus was high and detritus may compensate for the low standing stock of phytoplankton and form the main food for the zooplankton community in our study areas.

Poster W2-3400

Species-specific responses of three dominant chaetognaths to climate regime shifts in the Tsushima Warm Current of the Japan Sea during 1972-2002

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Using zooplankton samples collected between 1972 and 2002 along the PM transect in the Japan Sea, an attempt was made to understand how three dominant chaetognath species - *Sagitta minima*, *S. nagae* and *S. enflata* - in the upper 150 m water column are responding to inter-annual variations of atmospheric signals and oceanic effects in the Tsushima Warm Current water. The inter-annual abundance of chaetognath species fluctuated in response to warm or cool water temperature. Species-specific responses of chaetognaths to climate forcing via water temperature were ascertained by studying inter-annual linkages among climate-ocean-ecosystem elements in the years before and after climate regime shifts. Among the ocean-atmosphere interaction parameters, the winter monsoon was the most crucial for driving the climate-ocean-ecosystem of the Japan Sea. The climate regime shift during 1976/77 was characterised by anomalously cold water induced by a strong winter monsoon. The next climate regime shift (1988/89) brought a warm water anomaly. This was due to retention of warm water formed in winter by a weak winter monsoon and by increased transport in the Tsushima Warm Current. Chaetognath abundance and species numbers decreased during the colder regime and increased during the warmer regime. Chaetognaths responded to water mass properties (especially temperature) in a species-specific manner, notable by variation in abundance, species numbers and switching of dominant species. Thus, chaetognath species could be a useful indicator of water masses, climate events, and ecosystem health in the Japan Sea.

Poster W2-3611

Distribution and abundance of copepod nauplii in the southern East China Sea: implications for prey availability of jack mackerel (*Trachurus japonicus*) larvae

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Copepod nauplii are well-known as the most important prey item for larval fish at the first feeding stage. In the southern East China Sea (ECS), a large spawning ground of jack mackerel (*Trachurus japonicus*) has recently been found, and larval survival during the period of transport from this spawning ground along the shelf edge could be critical for recruitment. In this regard, we have investigated distribution of copepod nauplii in this region during the main spawning period (from February to March) in 2003-2006. Nauplii densities in 2003 were significantly higher than the other years along the shelf edge, the major transport pathway of jack mackerel larvae (with SST of 20-23°C). The frequency of sampling stations with prey density higher than 10 nauplii l⁻¹ was also high in 2003. Nauplii densities showed significant positive correlations with chlorophyll *a* concentrations for all years. Egg production rates for *Paracalanus*, one of the most abundant copepods in the southern ECS, were estimated from temperature and chlorophyll *a* concentration and were positively correlated with nauplii densities at lower SST (15-18°C). However, this analytical model could not fully explain the annual difference in nauplii distribution and abundance. This may possibly be due to the difference in dominant species of the adult copepods: broadcasters such as *Paracalanus* in the shelf region and sac spawners in the shelf edge and offshore regions.

Poster W2-3621

Community structure and diversity of zooplankton in the Mahatma Gandhi Marine National Park, Wandoor, South Andaman, Indian Ocean

Honey U.K. **Pillai**, C.K. Shiju, S.U. Panampunnayil, V.R. Nair and C.B. Lalitahambika Devi

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The tsunami of December 2004 caused extensive damage to the coastal regions of southern Andaman and the Nicobar Islands. The Mahatma Gandhi Marine National Park at Wandoor was hard hit by the tsunami and the coral reefs and other habitats were extensively damaged. Community structure and diversity of zooplankton in relation to environmental parameters of Mahatma Gandhi Marine National Park were studied during the winter monsoon (WM; February, 2005) and inter monsoon (IM, May, 2005) periods. Though the variation in zooplankton biomass between the two seasons was negligible (WM - average 7.94; IM - 6.95 ml/100m³), the population density was significantly lower during the winter monsoon (WM- average 16018; IM - 28704 no./100m³). Copepods formed the dominant group (77-81%) during both seasons whereas other groups showed variation in dominance rank. The copepod community was represented by 43 and 33 species during the winter and inter monsoon respectively. A total of 8 species of Chaetognath were observed during WM and 5 species during IM of which *Sagitta enflata*, and *S. neglecta* were the most abundant. Abundance and species diversity of other major groups will also be discussed. In general the area supported a moderately rich zooplankton community.

Poster W2-3631

Abundance, distribution and feeding habits of jellyfish in the upper epipelagic of the western Bering Sea

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We examined the biomass, distribution and feeding habits of jellyfish in the upper epipelagic zone of the western part of the Bering Sea. Data were from trawl surveys conducted in summer and fall 2002-2006. The total biomass of jellyfish increased from 1770-3226 kg km⁻² in summer to 1859-4214 kg km⁻² in fall. The scyphomedusa

Chrysaora melanaster and the hydromedusa *Aequorea* sp. dominated the jellyfish biomass (59–99%). Distribution of these dominant species showed different patterns. *Aequorea* sp. was concentrated in the deepwater regions. *Chrysaora melanaster* occurred in all parts of the western Bering Sea and was most abundant in the shelf near Anadir Bay. In fall 2006, most medusae fed on zooplankton (copepods, euphausiids, amphipods, pteropods, chaetognaths, ostracods, and larvae decapods). A high proportion of the *Chrysaora melanaster* diet was comprised of larval squid and fish (*Stenobrachius leucopsarus*).

Poster W2-3632

Spatio-temporal variability in the ichthyolarvae and zooplankton in the tidally influenced creeks of the Indus delta, North Arabian Sea

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The Indus delta and adjacent waters over the continental shelf are traditional fishing grounds and *per se* support 60% of all fishing activities in Pakistani waters. The entire north Arabian Sea experiences wind and water circulation reversal during the southeast and northwest monsoon periods and the deltaic creeks of the Indus are strongly tidal. The water currents in the creeks and coastal area are generally strong and variable, influenced by a complex of the tides and the monsoonal variability. Furthermore, the close proximity of Karachi, Pakistan's largest port city, to some Indus delta creeks makes these highly vulnerable to the city's growing population and coastal development. In light of such dynamic and diverse conditions, the present study looks at both natural and anthropogenic influences on the species composition and abundance of fish larvae and zooplankton in the Korangi creek and its offshoot, Gizri creek. A simple conceptual model describes the forces determining the distribution pattern of overall zooplankton productivity in the creeks over the two monsoons.

Poster W2-3649

Vertical distribution and community properties of mesozooplankton in the Japan/East Sea

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Mesozooplankton community was studied in the Japan/East Sea. First, the pattern of vertical distribution and diel vertical migration (DVM), if any, was examined with time dependent vertically stratified samples. Then community properties of mesozooplankton in the three distinctive areas, the Korea Strait, the frequently upwelling area and the frontal zone, were investigated. In vertical distribution of mesozooplankton, most taxa have their preferred depth zones of distribution, usually surface area. However, two major components of mesozooplankton, *Metridia pacifica* and *Scolecithricella minor*, showed normal DVM patterns, even in the strongly thermal stratified area. Distribution pattern of mesozooplankton showed that the number of taxa appeared was the most abundant in the Korea Strait and southwestern area (the upwelling area), but decreased northward area (the frontal zone). On the other hand, averaged zooplankton abundance increased northward area. Seawater temperature and salinity were very important environmental factors in the study area. However, their influences were rather time accumulated and in a large scales. Our results suggest that food resources seemed to be more important than seawater temperature and salinity when viewed within a relatively small area and as a snap shot.

W3 Krill research: current status and its future

28 May, 10:05 (W3-3314) Invited

What is so special about krill?

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Krill are found throughout the pelagic ocean and occupy a variety of niches and in some ocean areas they can become dominant members of the pelagic community. There are a number of features that make krill unusual both as crustaceans and as oceanic animals. They are of a particular size that gives them a measure of independence from the local physical environment and recent research suggests that they may, in fact, significantly affect oceanic structure. Many are schooling species achieving densities within schools that are amongst the highest observed in the ocean and the biomass achieved within individual schools reaches levels rarely exceeded by any other animal aggregation on Earth. Their aggregating habit matched to their high requirement for food results in them having a marked effect on the other inhabitants of the pelagic zone. In turn they are vital prey for many vertebrate and invertebrate species. Some vertebrates are almost obligate krill feeders and the largest animal that has ever lived attains spectacular growth and development rates on a diet of krill. The unique properties of krill are now attracting industrial attention and plans are afoot for the development of major industries based on their nutritional and chemical attributes.

28 May, 10:35 (W3-3512)

Mechanisms for the high total production of Antarctic krill

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Antarctic krill can maintain a massive biomass across the Southern Ocean, despite suffering predation of $>100 \times 10^6$ tonnes per year. How they achieve this is still unclear - estimates of their production, for example, tend to be low compared to those for predation loss. This talk is aimed to stimulate discussion on how we can reconcile two fundamentally different ways of looking at krill - from the perspectives of top-down or bottom-up control. We have synthesized data on krill, their predators, food and environment for a circumpolar view on the mechanisms behind their high production. Krill biology is being interpreted increasingly in relation to continental shelves and slopes. However we find that 87% of the summer population lives over deep ocean waters (>2000 m water depth). This great reservoir of oceanic krill provides one of the keys to its success. Its low average density, patchiness and vast habitat area provide an effective refuge from predation, allowing a high biomass to be sustained. The trade-off for oceanic life is lower food concentrations and thus sub-optimal growth. However, we calculate that on average across the whole Southern Ocean, krill can still quadruple in mass over summer. This reflects first their ability to grow fast at moderate oceanic food concentrations and second, their ability to maintain populations in sectors with enhanced food, avoiding oligotrophic areas. These key facets of krill biology are interlinked and yield a total annual production of at least 380×10^6 tonnes, well in excess of minimum consumption estimates.

28 May, 10:55 (W3-3715)

The importance of advection in a productive Southern Ocean ecosystem

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The South Georgia region is one of the most productive parts of the Southern Ocean. Here Antarctic krill are abundant and support large colonies of top predators as well as a commercial fishery. South Georgia is positioned within the Antarctic Circumpolar Current and so krill found here are likely to have been carried into the region with the prevailing large-scale current regime. To understand how such a marine ecosystem functions it is important to consider the role of advection in transporting krill through the regional ecosystem. We present data from cruises, Lagrangian drifters and models to look at potential transport pathways into and out of the South Georgia region. Focusing on a 10,000 km² meso-scale area at the northwest of South Georgia we link advection rates, acoustically estimated biomass of krill, measurements of krill growth and estimates of krill consumption by key predators to determine the relative importance of advection and local production in determining the biomass of krill in the South Georgia area. We show that advection across all spatial scales (from basin scale transport to meso-scale inertial oscillations), plays a pivotal role in the function of the South Georgia ecosystem.

28 May, 11:30 (W3-3475)

Relationship of parasitism to life-cycle characteristics of *Euphausia superba*

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Of all sources of natural mortality on krill populations, parasitism is one of the least studied and least understood. Parasitic infestations can devastate entire swarms of adult krill, a hazard of high transmission rates between many individuals in close proximity. Many host-parasite relationships show closely coupled life-cycles. We examined the relationship between parasitic load and krill development during the reproductive season across a number of years in the Scotia Sea. Our study focused on the external suctorian parasite *Ephelota* sp. Although non-lethal, high levels of suctorian infestation indicate a wider susceptibility of krill to parasitism, since many parasites enter through the cuticle. Krill sex, maturity, moult stage, body length and relative age (for which eye-diameter was used as a proxy) were compared to infestation levels. We found moult stage to be an important determinant of suctorian parasitic load, with two thirds of the population being infested prior to moult but very few after. Krill maintain a comparatively high adult moult rate but its selective advantage is unclear. Our results show that a high moulting frequency is effective at controlling parasitism. Krill age was also important, with the oldest males having the most suctorians, including relatively numerous reproductive bodies. The decreasing capacity of ageing krill to moult frequently is responsible for increased suctorian colonisation. Lengthy inter-moult periods are also a requirement of the parasite to complete its own life cycle, suggesting a long host-parasite co-evolution. Parameterising parasitism within krill life-cycle models, particularly with regards to natural lifespan, will be discussed.

28 May, 11:50 (W3-3513)

Characterising the three dimensional structure of Antarctic krill (*Euphausia superba*) swarms

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Antarctic krill (*Euphausia superba*) form dense aggregations or swarms. Quantifying the distribution, morphology and internal density structure of these swarms is an important step towards improving our understanding of krill behaviour and predator-prey interactions. Conventional vertical-looking single beam echosounders however do

not provide a 3D view. In January 2006 a 200 KHz multi-beam echosounder (Simrad, SM20) was deployed from a 5.7 m zodiac inflatable boat to observe krill swarms in the nearshore environment at Cape Shirreff, Livingston Island, Antarctica (62°30'S, 60°40'W). Data were collected in a line transect survey totalling 250 km in length in water depths from 30 to 150 m. The 120° across-transect arc sampled by the multi-beam revealed that krill form complex swarms that cannot be approximated by simple shapes. During daylight, krill swarms were seen to extend to within 5 m of the surface, the minimum range at which the SM20 could detect krill. This has implications for krill biomass estimation, since conventional hull-mounted echosounder transducers cannot observe shallow water depths. The magnitude of this bias has been investigated using 2D distance sampling techniques. A generalised additive model was used to explore the interaction between krill swarms and predators and showed that swarms exhibit different shapes in the vicinity of predators.

28 May, 12:10 (W3-3711)

Antarctic krill aggregation structure and vertical migration in relation to features of the physical and biological environment

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The Antarctic krill (*Euphausia superba*) is known for its formation of highly cohesive aggregations and is a strong swimmer capable of overcoming relatively strong currents. It therefore represents an attractive species for the study of how active behaviours interact with physical oceanographic processes and the presence of predators and prey to generate patchiness in the distributions of zooplankton. We examined the morphology, internal composition, and vertical position of individual krill aggregations in relation to a variety of concurrent measurements of the physical and biological environment. Acoustic, video, environmental, and predator data were collected during fall and winter surveys west of the Antarctic Peninsula, as part of the US Southern Ocean GLOBEC programme. Methods were developed and verified for identifying krill aggregations in the acoustic record, and then estimating the length, abundance, and biomass of constituent members. Application of these methods demonstrated strong variability in aggregation characteristics. There was little association between the characteristics of individual aggregations and the mean length of krill estimated acoustically, and thus little evidence for size-related changes in aggregative behaviour. The observed patterns of variability in aggregation characteristics between day and night, regions of high versus low food availability, and in the presence or absence of predators, together reinforced the conclusion that aggregation and diel vertical migration represent strategies to avoid visual predators, while allowing the krill access to shallowly-distributed food resources. In particular, abundant crabeater seals may have the strongest influence on krill behaviour, rather than the relatively rare whale and smaller penguin predators.

28 May, 12:30 (W3-3706)

Climate variability, Antarctic krill (*Euphausia superba*) spawning, and Adelie penguin (*Pygoscelis adeliae*) chick growth

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Factors that control variability in energy-density of Antarctic krill (*Euphausia superba*) populations, and the consequences of this variability on chick growth and fledging weight of Adelie penguins (*Pygoscelis adeliae*) was investigated. An individual-based energetics model describing the growth of penguin chicks from hatching to fledging was used in this study. In the model, lipid content as a function of sex/maturity stage and season (julian date) was used to calculate the energy-density of krill ingested by chicks. Model simulations tested the influence of variability in krill demography, length-at-maturity, and the timing of spawning on krill population energy-

density and penguin fledging weights. Of the parameters included in simulations, variability in the timing of krill spawning had the greatest influence on predicted fledging weights, as fledging weights dropped from 3.92 kg to 3.42 kg when peak spawning was shifted from 6 December to 6 March. The timing of Antarctic krill spawning is influenced by the timing and distribution of phytoplankton blooms, which is mediated by characteristics of the seasonal pack-ice. Off the WAP, krill spawning is delayed by an early ice-retreat. Recent warming has shifted the timing of sea-ice retreat to earlier in the summer, which may alter the timing of krill spawning in this region. This may have important implications for species, such as the Adelie penguin, that time their breeding to coincide with a period of high prey-availability and energy-density, and have a limited capacity to shift their breeding behaviour in response to short-term trends in environmental variability.

28 May, 14:00 (W3-3572)

ENSO drives interannual variability of the Antarctic Peninsula pelagic marine ecosystem

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The Drake Passage region off the West Antarctic Peninsula is a major source of Antarctic krill (*Euphausia superba*) for the entire Southern Ocean. This also is the domain where El Niño-Southern Oscillation (ENSO) variability in the tropics imposes its signature on climate variability in the Southern Ocean via meridional atmospheric teleconnections, the “Antarctic Dipole”. This study utilises data collected in the South Shetland-Elephant Island area for 27 years, 1980 through 2006, to describe ecological response to interannual climate variability over seven-to-eight ENSO cycles. Here we find interannual variations of elevated chlorophyll-*a* (Chl-*a*) and copepod concentrations and early krill spawning seasonality with increased reproductive and recruitment success that fluctuate in phase with poleward displacement of the Southern ACC Front (SACCF) and Southern Boundary of the Antarctic Circumpolar Current (SBACC) and retracted sea ice extent during the previous winter, variables that fluctuate in phase with La Niña in the eastern equatorial Pacific Ocean. El Niño conditions, in contrast, produce reduced copepod numbers, increased abundance of the salps *Salpa thompsoni* and *Ihlea racovitzai* and low krill reproductive success and recruitment, all with subsequent impacts on the pelagic marine ecosystem. We explain this in terms of the importance of climate variability on the krill-based food web and its implications for krill fishery management.

28 May, 14:20 (W3-3529)

Review of life history and ecology of *Euphausia pacifica* off Newport, OR, USA

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We have studied *Euphausia pacifica* off Newport, OR since 1996 using data from a biweekly sampling programme. Experiments on growth rates and egg production of *E. pacifica* began in 2000. We also conducted two long-term laboratory experiments on *E. pacifica*: 1) development from egg to adult, and 2) egg production by individual females from two different geographical areas. *E. pacifica* often had multiple instars at the same developmental stage, and 58% of the animals skipped one developmental stage between FIII-juvenile. Animals that skipped a stage developed to the juvenile stage significantly faster than those that did not (20.5d and 27.1d, respectively). Measurements of growth using several methods (IGR experiments, cohort analysis and long-term laboratory observations) were consistent and showed that individual growth rates for adults were highly variable but were typically $\leq \pm 0.02$ mm/d. Seasonality of spawning was determined by the presence of eggs in preserved samples. The spawning season for *E. pacifica* in our study area was generally March-October, consistent with the upwelling season when phytoplankton blooms occur. Comparison of *E. pacifica* brood sizes from several regions indicates that animals off Newport, OR had higher average brood sizes (152 eggs/brood) than those in Puget Sound, WA (96 eggs/brood) or Toyama Bay, Japan (113 eggs/brood). A long-term laboratory

study of spawning by females from Santa Barbara (SB), California and Heceta Bank (HB), Oregon showed that both groups had similar average brood sizes (HB=102 eggs/brood, SB=116 eggs/brood) but the SB animals had a significantly shorter median interbrood period (HB=5d, SB=4d).

28 May, 14:40 (W3-3464)

The distribution pattern, abundance and life cycle of *Euphausia pacifica* in the southern Yellow Sea

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The distribution, abundance and life cycle of *Euphausia pacifica*, and their relationship to the environmental factors in the southern Yellow Sea were analysed and studied by using monthly samples and environmental factors obtained at 90 stations in 1959 and those obtained since 2002. Results on *E. pacifica* stage-specific analyses show that *E. pacifica* population is usually distributed east of 121°E in the southern Yellow Sea, and each stage was present all year round, except some early larval stages that were absent in the samples for a few months. The distribution and abundance of *E. pacifica* differed spatially, seasonally and stage-specifically. As for the whole population, its abundance and distribution pattern were mainly influenced by one or two, or more of the most abundant stages. The ratio of female to male ranged from 0.31-0.64, averaged 0.49 in 1959. Although spawning and larval recruitment of *E. pacifica* happened throughout the year, there were two obvious spawning seasons in the southern Yellow Sea, one prominent from March to July, and another but much reduced from November to December. This coincided with the copulated adult/female abundance, which showed a high peak during March to July, and a low peak from November to December. The peaks of larval recruitment and the spawning seasons indicate there would be two generations of *E. pacifica* in a year in the southern Yellow Sea. The results of analysis on relationship between the distribution, abundance and environmental factors are also included in this paper.

28 May, 15:00 (W3-3275)

Multidisciplinary study of the subtropical sac-spawning euphausiid *Nyctiphanes simplex* in the southern part of the California Current System and Gulf of California

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Nyctiphanes simplex is the most prominent euphausiid from the neritic region along the west coast of Baja California peninsula and Gulf of California, Mexico. We studied the reproductive biology (histology, brood size, interbrood period, lipid composition), embryonic development time, molting rates, high resolution vertical and horizontal distribution (hydroacoustic), and endoparasitology from five oceanographic cruises (March 2004-December 2006). *N. simplex* attains first maturity at ~9 mm length (>60 days, recognised by a pale pink coloured ovary), is a synchronous partial spawner (histological evidence) that produces and spawns one batch of oöcytes (<105 embryos fem⁻¹) every 7-15 days (previously assumed as 30 days). Life-span fecundity is 600-1200 eggs fem⁻¹ (6 months, 12-24 ovigerous sacs, average BS 50 eggs fem⁻¹). Embryonic development is delayed <3 days (16°C, hatching as nauplius) and embryos are released from the ovigerous sac as metanauplius (~5 days after spawning). Instantaneous growth rates (IGR) indicate higher growth rates in spring and summer. Although no body growth or even negative IGR was commonly observed throughout the year, average negative IGR were recorded in November-December at both sides of the peninsula. Dense *N. simplex* swarms (~74 tons day⁻¹) invade shallower bay environments (Bahía Magdalena, ~30 m depth) transported by intense tidal currents. Species composition and total biomass (hydroacoustic) was estimated in the GC (November-December). A novel Apostome ciliate species of the genus *Collinia* infects and kills *N. simplex* (third known endoparasitoid ciliate species infecting euphausiids) and its life cycle and ecophysiology (lipid utilisation and activity of oxidative stress enzymes) were investigated.

28 May, 15:20 (W3-3748)

Southern Ocean GLOBEC: overwintering metabolism in Antarctic zooplankton and micronekton

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Overwintering *Euphausia superba* (and other herbivorous and omnivorous pelagic Crustacea) are faced with an energy shortfall due to the loss of their phytoplankton food source, a result of the vanishingly low chlorophyll biomass typical of the Antarctic water column during the fall and winter. Two strategies that are widely exploited to overcome food deprivation in overwintering species are the use of an energy depot as a source of fuel and a reduction in the need for fuel by reducing metabolic demand. The present study was designed to test the hypothesis that *Euphausia superba* and other micronektonic/mesozooplanktonic species reduce metabolic demand as part of their overwintering strategy. Krill and copepods were captured in a Tucker trawl designed for gentle handling of specimens on four GLOBEC cruises to the Western Antarctic Peninsula (WAP) shelf, two in the austral fall (April-May) and the others in the austral winter (July-August). Specimens were rapidly sorted into cold (0°C) filtered seawater and allowed to adjust to laboratory conditions for a minimum of 4 hours. They were then placed in sealed, water-jacketed vessels filled with filtered (0.45 µ) seawater and allowed to deplete the oxygen to intermediate levels of dissolved oxygen (80 mm Hg) at a temperature of 0°C. Oxygen consumption was continuously recorded with Clark polarographic electrodes. In *E. superba*, no differences were observed in oxygen consumption between the fall and winter seasons. The equation for the line describing metabolism vs mass in fall-winter WAP shelf animals was $Y (\mu\text{l O}_2 \text{ individual}^{-1} \text{ h}^{-1}) = 0.310 X (\text{mass (mg)})^{0.772}$, $r^2=0.754$. WAP shelf fall-winter krill had a metabolic rate about 60% of that of summer animals captured in the Weddell Sea ($Y (\mu\text{l O}_2 \text{ individual}^{-1} \text{ h}^{-1}) = 0.514 X (\text{mass (mg)})^{0.792}$, $r^2=0.9650$) suggesting a profound drop in metabolic rate during the winter. Despite the observed dramatically reduced metabolism in fall-winter, WAP shelf krill showed a higher winter rate than *E. superba* captured in the Weddell Sea ($Y = 0.213 X^{0.807}$, $r^2=0.970$). The drop in metabolic rate during the dark season was mirrored in the activities of the intermediary metabolic enzymes citrate synthase (CS) and malate dehydrogenase (MDH). The dominant copepod *Calanoides acutus*, a diapausing species, showed a slightly different pattern. It also showed a profound drop in metabolism from summer to fall, but exhibited a continuing downward trend from fall to winter. The drop in metabolism (about 50% from summer to winter) was reflected in the drop of CS and MDH activities (50% to 75% drop from summer to winter). No significant changes were observed in the activities of CS and MDH from fall to winter in either the neritic euphausiid *Euphausia crystallorophias* or the ubiquitous *Thysanoessa macrura*. Overwintering strategies vary considerably within and between crustacean taxa, particularly the use of reduced metabolism

28 May, 16:10 (W3-3617)

Seasonal lipid dynamics of the Antarctic krill *Euphausia superba* in the Lazarev Sea

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Most ecological and biochemical information about the Antarctic krill *Euphausia superba* is derived from the extensively studied region around the Antarctic Peninsula. The Lazarev Sea is characterised by a lower abundance and krill life cycle differs in various aspects, such as shorter maximum lengths. Here we present a comprehensive seasonal data set on the lipid dynamics of various developmental and reproductive stages of *E. superba* in the Lazarev Sea. Total lipid content of postlarval krill varied markedly with maximum levels in late autumn (up to 50% of dry mass (DM)), slowly decreasing values in July and August (25-40% DM), down to minimum levels in late spring/early summer ($\geq 5\%$ DM). During the reproductive period in summer, the individual variability of lipid content among adult krill was most pronounced. The lipid class composition varied accordingly with highest storage lipid levels in autumn and winter. Triacylglycerols (TAG) were the most abundant neutral lipids and phosphatidylcholine was the predominant lipid class throughout the year. Furciliae were present in all sampling periods. In autumn, their lipid content increased steadily with development, whereas in winter the relationship between lipid content and stage was not as evident. *E. superba* eggs contained approximately 60% lipid, dominated by TAG. During embryonic development, lipid content decreased in freshly hatched nauplii, and further in the non-feeding calyptopis larvae (5% DM). Lipid dynamics will be discussed with regard to life cycle characteristics and compared with respective data from different Antarctic regions.

28 May, 16:30 (W3-3531)

The importance of zooplankton as food source for larval Antarctic krill, *Euphausia superba* during winter

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Feeding rates of larval krill on phytoplankton and specific zooplankton species as well as metabolic rates were measured during two cruises with RV Polarstern in early autumn and mid-winter in the Lazarev Sea. The zooplankton organism used for the feeding experiments were *Oithona* sp., *Microcalanus* sp., *Ctenocalanus* sp., and copepodid stages of *Calanus propinquus*, *Calanoides acutus*, *Metridia gerlachei*, *Rhincalanus gigas*. Oxygen uptake rates in furcilia larvae during winter ranged between 0.2 and 0.6 $\mu\text{l O}_2 \text{ ind.}^{-1} \text{ h}^{-1}$, similar to values measured in late summer and early autumn. In contrast, the ammonium production in winter more than doubled, compared to rates measured during the other seasons (winter: 0.02 - 0.08, late summer, autumn: 0.002-0.04 $\mu\text{g NH}_4 \text{ ind.}^{-1} \text{ h}^{-1}$). This results in low O:N ratios, indicating a preference for heterotrophic diet. Furcilia larvae showed a much lower response to increasing phytoplankton concentration in winter than in austral autumn. The ingestion rates on natural phytoplankton mixture derived from incubation experiments ranged between 0.02 and 0.3 $\mu\text{g C ind.}^{-1} \text{ h}^{-1}$ and were similar to ingestion rates derived from gut pigment measurements (0.08 to 0.4 $\mu\text{g C ind.}^{-1} \text{ h}^{-1}$). The results from these studies will be discussed in relation to the metabolic demands of larval krill.

28 May, 16:50 (W3-3608)

Structural changes in the digestive glands of larval Antarctic krill (*Euphausia superba*) through starvation

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Antarctic krill (*Euphausia superba*: hereafter krill) plays a key role in the Southern Ocean ecosystems. Studies on its larval ecology are important since population size of krill is mainly determined by their survival rates during their early life stages. Larval krill have low lipid reserves and thus might not be able to tolerate long starvation periods as the post larval stages. The knowledge of starvation resistance of larval krill and when they reach their 'Point of no Return' (PNR) is important to understanding larval survival, development and ultimately recruitment. The PNR is the time after which a larva loses its capability to recover from their nutritional stress. After passing the PNR, starved and subsequently fed larvae are unable to recover from the effects of prolonged starvation. The most characteristic effects of starvation can be seen in ultrastructural changes in the digestive system, particularly in the R (resorptive)-cells. This study demonstrate for the first time histological changes of digestive cells (B-, F-, R-cells) after 5, 10, 15, 20 and 25 days of starvation to estimate the PNR in larval krill.

28 May, 17:10 (W3-3729)

The biochemical estimation of age in krill: laboratory calibration and field comparisons

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Euphausiids play a key role in the marine ecosystem as a link between primary producers and top predators. Understanding their demographic structure is an essential tool to assess growth and recruitment as well as determine how changes in environmental condition might alter their condition and distribution. Since age determination of crustaceans cannot be accomplished using traditional approaches, we evaluated the potential of biochemical

products of tissue metabolism (termed lipofuscins) to determine the demographic structure of Euphausiids in field collections. Lipofuscin was extracted from neural tissues (eye and eye-stalk), quantified using their fluorescent intensity, and normalised to protein content to allow comparisons across animal sizes. Age calibration of lipofuscin accumulation was accomplished using *Euphausia pacifica* eggs collected in the field and reared in the laboratory for over 1 year. Lipofuscin content extracted from neural tissues of laboratory-reared animals was well correlated with the chronological age of animals. Field populations contained variable levels of lipofuscin dependant on size. Based on comparison with laboratory accumulation rates, sub-adults and adults in the Northeast Pacific were older than 100 days and younger than 1 year based on lipofuscin age estimation. Comparative measures of the Antarctic krill, *E. superba*, showed much higher lipofuscin levels, suggesting a much longer lifespan than that of the temperate species, *E. pacifica*. These regional comparisons suggest that biochemical indices allow a practical approach to estimate population age structure, and combined with other measures can provide estimates of vital rates (i.e. longevity, mortality, growth) for krill populations in dynamic environments.

28 May, 17:30 (W3-3352)

Making krill behave in the aquarium

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Antarctic krill (hereafter, krill) exhibit complex social behaviour and are an active migratory species. However, when their population movements are dealt with at regional or local scales, they tend to be regarded as passive particles drifting in ocean currents. This causes a major dilemma when scientists try to make sense between observational evidences and ecosystem modelling. Conducting aquarium studies is one of the avenues to try understanding their behaviour, which helps us predict how they are behaving in the ocean environments, although there are many issues to overcome to condition/adjust the aquarium system to successfully carry out sensible observations. Although a single study on schooling behaviour using Antarctic krill held for a short-term in an aquarium system setup on the Antarctic continent has been reported in the past, it has never been replicated. In the research aquarium at the Australian Government Antarctic Division, we have been keeping Antarctic krill for research purposes and recently succeeded in inducing breeding and schooling. Water quality, adequate feeding conditions, temperature, stable light environment, and suitable tank arrangements were the keys to the success. This major achievement opens up whole new opportunities for studying various aspects of krill behaviour. In our presentation, we will give an overview of our aquarium system and introduce some of our recent research activities.

W3

Posters

Poster W3-3298

Using GIS and remote sensing data for analysis and forecast of fishery conditions in Atlantic Antarctic area

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The pelagic ecosystem of the Atlantic Antarctic area is one of the most productive zones in the world's ocean. Management of this zone is one of the important tasks in fishery oceanography. Efficiency of investigations is gaining with the use of geographic informational system (GIS) and remote sensing data from satellites. Complex analysis of retrospective, satellite and cruise data now allow one to show relationship between abiotic processes and time-spatial distribution of fishery species. In this article we show an example of using retrospective data surveys gathered by AtlantNIRO (Atlantic Research Institute of Fisheries and Oceanography), monthly satellite data of SST, SLP and ice concentration between 70° to 5°W and 50° to 70°S area from 1981 to 2005. We chose Antarctic krill (*Euphausia superba* Dana) as an indicator of environmental changes.

Poster W3-3334

The role of lipids in winter survival of Antarctic zooplankton

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Two species of adult Antarctic krill, *Euphausia superba* and *E. crystallorophias*, and two species of adult Antarctic copepods, *Pareuchaeta antarctica* and *Calanoides acutus*, were collected and analysed for total lipid and lipid classes to understand the role of lipids in overwintering survival of Antarctic zooplankton. We estimated the lipid utilisation rates of Antarctic zooplankton during winter based on the differences of total lipid content in organisms collected from Marguerite Bay in fall and winter. This estimate indicates that *C. acutus* utilise the least amount of lipid (237 µg lipid/g DW/day), mainly as triacylglycerols, among investigated zooplankton because low energy requirement for *C. acutus* during winter diapause. In contrast, *P. antarctica* utilised the most amount of lipid (1600 µg lipid/g DW/day), mainly as wax esters, due to their continual active behaviour during winter. Estimated lipid utilisation rates for *E. superba* and *E. crystallorophias* were 633 and 1174 µg lipid/g DW/day, respectively. Of particular interest was that both krill species utilised typical storage lipids (triacylglycerol for *E. superba* and wax ester for *E. crystallorophias*) as well as membrane lipids (phospholipids), demonstrating that structural phospholipids can also serve as energy stores in Antarctic krill. Combining other studies of metabolic rates with the contribution of lipids for *E. superba* suggests that lipids contribute only 20% of energy requirement needed to maintain the metabolic activity of *E. superba* during winter. Therefore, *E. superba* is less dependent on lipid reserves than other zooplankton, and must depend on additional strategies (i.e., body shrinkage, etc.) to survive during winter.

Poster W3-3336

Temperature effects on growth and reproduction of Antarctic krill

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Antarctic krill (*Euphausia superba*) is a keystone species of the Antarctic marine ecosystem, but it is also attracting increasing interests as a target for commercial fishing. Understanding characteristics of krill life history parameters, especially growth and reproduction, are the essential part of developing an adequate management

regime for its fishery. These parameters are heavily affected by environmental conditions such as temperature and food availability, but it is not possible to delineate and understand the relative magnitudes of these effects by solely relying on field experiments. A long-term experiment extending 12 months is currently underway in an artificially controlled environment, with krill incubated in tanks subjected to varying temperature regimes (-1°C, 1°C and 3°C) to understand the effect of temperature on growth. Physiological parameters including lipid analysis, oxygen consumption, and excretion and feeding rates are also monitored to understand the *in situ* effect of temperature on growth and reproduction. Within the temperature range of -1°C to 3°C, there was a simple increasing trend in their growth rates and earlier maturity with increasing temperature, despite some suggestions of an optimal temperature at 0.5°C from field observations (Atkinson *et al.*, 2006). These results will be further discussed in relation to their physiological conditions and energy budget.

Poster W3-3338

The early development and life history characteristics of *Thysanoessa inspinata* and *T. longipes* in the Oyashio region, western subarctic Pacific Ocean

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Although euphausiids, *Euphausia pacifica*, *Thysanoessa inspinata* and *T. longipes* predominate in the Oyashio region, little research has been carried out on the life history of the latter two species. We analysed the size structure and maturity composition of *T. inspinata* and *T. longipes* using seasonal field samples collected at a station (Site H) in the Oyashio region from August 2002 to August 2003. Samplings were undertaken using Bongo-nets from 1000 m to the surface. Judging from the occurrence of gravid females, the major spawning season was May-August for *T. inspinata* and March-May for *T. longipes*. The longevity of both species was estimated as 2-3 years. In addition to the analysis of the field samples, laboratory-rearing experiments on eggs and hatched larvae revealed that the development time from an egg through to metanauplius via nauplius I and II at 3°C was 14-16 days for *T. inspinata*, and 14 days for *T. longipes*. Between-species differences in the morphology of eggs and nauplii were not noticeable, except for the greater body size of *T. longipes* than that of *T. inspinata*.

Poster W3-3350

Significant presence of subarctic euphausiids off Baja California during the summers of 2002 and 2005

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The species *Euphausia pacifica* and *Thysanoessa spinifera* are conspicuous elements in the northern portion of the California Current and subarctic regions. Although both are part of the transition zone assemblage, their presence off Baja California is typically low compared to other species such as *Nematoscelis difficilis* and *Thysanoessa gregaria*. The distribution of *E. pacifica* usually reach their southern limit in Punta Eugenia (28°N), but in July 2002 and July 2005 it was observed towards south to this latitude. The presence of the neritic *T. spinifera* (considered as a relict in Baja California since the collapse caused by El Niño 1958) increased in both summers of 2002 and 2005. Captures of this species were particularly high in central Baja California. Most of the collected specimens were furciliae and juveniles, but a substantial amount of adults occurred around Vizcaino Bay. Other species were also very abundant in the summer of 2005, recording up to 350 ind m⁻³ for *Nytiphanes simplex* inside Vizcaino Bay, 36 ind m⁻³ for *Euphausia pacifica* off Ensenada (32°N) and 8 ind m⁻³ for *Euphausia recurva* in one offshore station. Those values surpassed any other previously recorded for these species during the period 1997-1999. These observations attain a higher relevance when they are compared to the shortage of krill during 2005 in northern regions of the California Current, producing the reproductive failure of krill-eating birds. The Baja California region was a refuge for temperate species during summer 2005, though the re-colonisation by *T. spinifera* appeared to begin before as was observed in summer 2002.

Poster W3-3351

Changes in krill composition during the 1997-1999 ENSO cycle in Baja California waters

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We analysed changes in euphausiid species composition off the Baja California western coast during El Niño 1997-1998 and La Niña in 1998-1999. Total euphausiids were abundant in the climax of both climatic events, decreasing during the transition phase from warm to cool conditions. Despite a considerable reduction of temperate species during El Niño peak, *Euphausia eximia* and other tropical species showed a remarkable increase, maintaining high abundance of euphausiids in the region. The subtropical *Nyctiphanes simplex* presented a decreasing tendency from January 1998 to January 1999. Further, the intense activity of coastal upwelling in April 1999 promoted a strong increase of this species (from a geometric mean of 16 to 772 ind/1000 m³). Thus, the response of *N. simplex* during the ENSO was more typical of a temperate species in Baja California waters, contrasting with their presence associated to warm water advection in northern locations of the California Current. A similar rebound during April 1999 was observed in other transition zone species (*Nematoscelis difficilis*, *Euphausia pacifica*, *Thysanoessa gregaria* and *Euphausia gibboides*). The subarctic *Thysanoessa spinifera* was virtually absent during the study period, appearing only in one sample during October 1998 and two in April 1999.

Poster W3-3386

Taxonomy and distribution of euphausiids of the south eastern Pacific off Peru and Chile

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Despite outstanding recent reviews of euphausiids encompassing their taxonomy, distribution, biology and ecology, background information is still scarce for some regions of the world ocean. The aim of this study is to compile unpublished and published knowledge on the euphausiids collected between 1958-1974, in several expeditions (MARCHILE I, MARCHILE V, MARCHILE VI, PIQUERO III, HERO 73-2, KRILL), which surveyed the Pacific between 3°S latitude and ca. 60°S and east of 80°W. The area covers the Humboldt Current, the subantarctic, and the austral Chilean fjords. The fauna accounted for 42 epi-, meso- and bathypelagic species, (ca. 50% of known Euphausiacea of the world), belonging to genera *Bentheuphausia* (1), *Thysanopoda* (8), *Nyctiphanes* (1), *Euphausia* (18), *Thysanoessa* (2), *Nematoscelis* (4), *Nematobrachion* (2) and *Stylocheiron* (6). Distribution ranges of several species are extended to new localities, and examined in a biogeographic context. A consistent zonation was found between pelagic (fish and other mesozooplankton) and littoral biotas and they are associated with the distribution of water masses and particularly with the latitudinal extension of the Oxygen Minimum Layer off Peru and Chile. The hydrographic characteristics of the subantarctic region off Patagonia and the fjords are examined as sites of particular adaptations and eventual speciation of colonising euphausiids. The vertical distribution and diel migration of species in the Humboldt Current showed that most euphausiids survived and even took feeding advantages of migrating into severe oxygen depleted waters (e.g. *Euphausia mucronata*). Feeding plasticity of euphausiids during diel migration is also suggested for *E. vallentini* in the Patagonian fjords.

Poster W3-3389

Vertical diel migration and feeding of *Euphausia vallentini* within southern Chilean fjords

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Euphausia vallentini is a vertical migrator in open ocean waters. It enters the Chilean fjords from the open subantarctic ocean through shallow sills and it becomes a most abundant zooplankton there. What are the biological adaptations of *E. vallentini* to such a distinct, enclosed and occasionally shallow environment? A

leading objective was to determine its ability to alter daily its depth range in order to avoid contact with shallow depths, or to maintain its vertical migratory range for dietary advantages. Multiple opening-closing nets sampled the water column in basins of various depths along the Strait of Magellan. Plant pigments from the stomachs of fresh samples, along with on board experiments of evacuation rates allowed for characterisation of day and night diet and for estimation of ingestion and consumption rates. Food items were microscopically counted in vertical day and night samples. *E. valleritini* migrated between the surface at night and 100-200 m in daytime. Surface night dwellers had higher chlorophyll *a* content in the stomachs than deep daytime dwellers. Stomach content, ingestion rates and consumption rates of phytoplankton were higher at night than in daytime, and accounted for by an impact of 0.17% upon phytoplankton biomass. Diet composition changed: dinoflagellates, tintinnids and diatoms occurred in high abundances in the stomach content at night, while polychaetes dominated in daytime. Diet switch in *E. valleritini* imply unique adaptations to take advantage of both pelagic and demersal environments, which could explain its high abundances and high frequencies of encounter within the southern Chilean fjords.

Poster W3-3390

Vertical distribution and diel migration of euphausiids in the Oxygen Minimum Layer of the Humboldt Current

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Severe depletion of oxygen limits the vertical migration of most pelagic animals. A permanent Oxygen Minimum Layer (OML) occurring along the 4°S to 42°S latitudinal range of the Humboldt Current System (HCS) did not exclude euphausiids as evidenced from stratified bongo net tows off Peru and Chile. Seven strong migrants dwelled in the OML in daytime: *Euphausia mucronata*, *E. lamelligera*, *E. eximia*, *E. tenera*, *E. distinguenda*, *Nematoscelis gracilis*, *N. megalops*, and three short distant migrants crossed the oxycline and reached the upper part of the OML in daytime: *Nyctiphanes simplex*, *Stylocheiron affine*, *Thysanoessa gregaria*. An interspecific vertical pattern was identified in the HCS: one carnivore occupant of the mixed layer and oxycline (*Thysanoessa* sp. or *Stylocheiron* sp.), a strong migrant omnivore at the core of the OML (*E. mucronata* or *E. lamelligera*) and one carnivore, at the lower depths of the OML (*N. megalops* or *N. gracilis*). The diel migration of euphausiids is described as a discontinuous process characterised by a rapid upward displacement, a long shallow residence at night, a slow downward movement and a long deep residence in daytime. Species specific differences were also found in the timing and depth layering of migratory cycle, e.g. the beginning and duration of the ascent, the descent, and residence in shallow and deep layers. These differential patterns in vertical migration behaviour when coupled to specific diet and feeding rhythms suggest some level of niche separation such that resources are shared and competition reduced.

Poster W3-3393

Studies on the distribution and life history of euphausiids in the western North Pacific

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Euphausiids often have a large abundance and play a key role in marine ecosystems. In the coastal area of northeast Japan, euphausiids (mainly *Euphausia pacifica*) are not only a prey item of fishery species (e.g. saury, walleye pollock) but also fishery resources. Therefore, previous studies on the ecology of euphausiids around northeast Japan concentrated on the continental shelf and its adjacent area. On the other hand, although euphausiids are widely distributed in oceanic waters, only a small amount of research has been conducted in offshore areas of northeast Japan. In this study, the distribution and life history of euphausiids in an offshore area has been investigated. We obtained seasonal data (May, July, November and March) at five stations along the A-line (a fixed transect from Oyashio to Kuroshio-Oyashio transition region) using 1 m² MOCNESS (0.33 mm mesh size at 8 discrete depths: 0-50, 50-100, 100-150, 150-200, 200-300, 300-500, 500-750, 750-1000 m), BONGO net (0.33 mm mesh size with 0.6 m diameter) and MOHT (1.59 mm mesh size with a mouth area of 5 m²). The BONGO net and MOHT were towed from depth of ca. 500 m to the surface. All net tows were conducted in both day and night at the each station. We mainly analysed diurnal and ontogenetic vertical migrations and seasonal variation of horizontal distribution of *E. pacifica*. These results have implications not only with respect to the euphausiids ecology in Oyashio and the transition region, but also could provide important biological parameters for ecological model (e.g. NEMURO).

Poster W3-3422

Euphausiid distribution and hydrography in the entrance of the Sea of Cortés during summer

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Zooplankton samples obtained with a bongo net during summer in the entrance of the Sea of Cortés, were utilised to study euphausiid distribution. Four transects were followed in relation to water masses. No significant differences was found between day and night abundances, neither for adults nor for larvae, however richness of species was higher during the night. Dominant species was the neritic species *Euphausia lamelligera*, followed by *Euphausia eximia*, *E. tenera*, and *E. distinguenda*. Species with affinity with the California Current warm section were found in the stations corresponding to open water of the California Current, dominated by *Euphausia eximia* and *E. tenera*, this last one seem to be a transition species. *E. lamelligera*, *E. diomedea* and *E. distinguenda* were the species with affinity with the north-equatorial current and the oxygen minimum. The transect from Cabo San Lucas to Socorro Island was the one with higher larval abundance, which is apparently a result of the frontal zone between the California Current and Gulf of California waters. High POM was found in coincidence with high concentrations of krill at certain stations specially those where fronts were clearly present, like Cabo San Lucas and in transition areas. When stations were separated by water masses, we found a good affinity with their corresponding water mass for groups of species, in some frontal stations mixing of species showed the mixing of water masses.

Poster W3-3423

Morphology and lipids in *Thysanoessa macrura* from the southern part of the Indian Ocean: spatial and sex differences

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Samples obtained during the FIBEX cruise, during Antarctic summer, were utilised to study the morphology of *Thysanoessa macrura* and its biochemical composition; animals were preserved by freezing. Former work showed that this species has an ontogenetic morphological differentiation and that adults have high lipid content (Färber-Lorda, 1990, 1991). Females had higher lipid content (~7% wet weight) than males (1.51%) and juveniles (2.97%) and a significant difference was found between males, females and juveniles. Lipid content in *T. macrura* showed a steep exponential regression with carapace length. Measurements of the second thoracopod showed an increase of its length with size, thus it is hypothesized that after a certain size animals will be able to feed on other zooplankton which will help in the accumulation of lipids. It is surprising to find such great differences between females, males and juveniles in the same area and during the same season. A significant regression was found between total length and thoracopod length and between thoracopod length and dactylus length. Other characteristics of the species indicate that they are more predators and capture their prey with their long thoracopods. This species was found in alternate stations with *Euphausia superba* in the southern part of the Indian Ocean.

Poster W3-3530

The importance of Antarctic krill *Euphausia superba* as a food source for the Antarctic fish *Nothothenia coriiceps*, in Potter Cove, King George Island

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The Antarctic krill, *Euphausia superba*, plays a central role in the Antarctic trophic web, and is considered the preferred food item for many fishes. The importance of Antarctic krill *Euphausia superba* as food source for the dominant inshore demersal fish in Potter Cove (Antarctica), *Nothothenia coriiceps*, was studied by analysing the

stomach content of males and females of *N. coriiceps* during the austral spring and summer (November 2002 to January 2003). Surface krill net samples were studied simultaneously in the area in order to compare them with the amounts and sizes of *E. superba* found in the stomachs of the fishes. Our results show a strong correlation between the number and sizes of krill in the water column and in the stomach contents of *N. coriiceps*. In one opportunity, in the stomach content of the *N. coriiceps* females high amounts of krill were found when the number of krill in the water column was lowest. This could be explained by the fact that females probably also feed near the bottom: after a storm event, a large number of krill were washed ashore allowing *N. coriiceps* to feed near the bottom on krill sedimented.

Poster W3-3552

Spatial distribution and larval development of *Euphausia pacifica* in the Yellow Sea in spring and autumn

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The spatial distribution and larval development of *Euphausia pacifica* Hansen in the Yellow Sea were studied based on vertical haul samples during spring and autumn (April and November), 2006. In spring, adults were abundant in two patch areas, and their abundances were obviously related to chlorophyll *a* concentrations, but not to temperature and salinity. The maximum abundance of eggs and larvae were 22550 and 5931 ind.m⁻², respectively. Eggs, larvae and adults swarmed in different areas. In autumn, the adults abundance was significantly correlated with the sea bottom temperature and were mainly distributed in Yellow Sea Cold Water Mass (YSCWM). Adults were much more abundant in autumn than in spring, with the highest value of 2650 ind.m⁻² in autumn and 183 ind.m⁻² in spring, while, eggs or larvae were rarely found in YSCWM. Diel vertical migration (DVM) was found both in spring and autumn. Adult *E. pacifica* would ascend to middle-surface layer at 18:00 and go down to the bottom at 6:00 h. There were geographical variations in larval development pathways in *E. pacifica*. The dominant development pathways in the Yellow Sea can be expressed as follow: Calyptopis III, 0'7 or 1'7, 3'1"7 or 1'4"7, 5"7, 5"5, 5"3, 5"1. According to the incubation experiments *in situ*, the developmental times of *E. pacifica* in 4, 12, 15°C were 16.1, 5.23, 5.6 d.

Poster W3-3557

Hydrochemical parameters of the mass krill concentrations in the Atlantic sector of the Southern Ocean

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The distribution of hydrochemical elements in the Atlantic sector of the Southern Ocean is analysed in this study as an index of geographical position of the Southern Boundary of the Antarctic Circumpolar Current (SBACC), being the northern border of the mass krill concentrations. It is established that hydrochemical elements (especially concentration of dissolved silicon) and ratio of silicon to phosphorus (Si/P) are natural indicators of water masses of various modifications. While in the waters of Antarctic Circumpolar Current (ACC) the content of dissolved silicon fluctuates between 5 and 40 gm-at/l, in the high-latitude waters its content is about 60-120 gm-at/l. As a rule, the ratio Si/P in ACC waters does not exceed 20, and in the high-latitude waters it is above 35. The required zone of maximum gradients of the hydrochemical elements where Si/P is within the range 20-35 is an area of the mass krill concentrations. The knowledge of the SBACC position can be used for monitoring of krill stocks in the fishing areas of the Southern Ocean.

Poster W3-3581

Seasonal and inter-annual fluctuations in adult and juvenile *Euphausia pacifica* and *Thysanoessa spinifera* abundance for the years 1998 through 2006 in the Northern California Current

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Recent discussions concerning the potential establishment of a krill fishery in the northern California Current has highlighted a need for a krill based biomass estimate for euphausiids. Understanding the annual and seasonal variability in abundances as well as the distribution of *Euphausia pacifica* and *Thysanoessa spinifera* and how these species respond to climatic changes is necessary in order to make fisheries management decisions. By combining multiple scientific sampling projects we have produced coast-wide charts showing the distribution of euphausiids in the night time vertical net samples from 1998 through 2006. We analysed these samples for adult and juvenile *E. pacifica* and *T. spinifera* combining these stages to give us an overall biomass estimate. Though the majority of adult and juvenile biomass was found near the shelf break, both species exhibited wide fluctuations in distribution patterns depending on the yearly oceanographic conditions. The years 1998 (El Niño) and 2005 showed depressed abundances, good years from 2000-2002, and an exceptionally good year in 2006. These results will contribute to the development of a standing stock biomass estimate for *E. pacifica* and *T. spinifera* and future modelling of biomass estimates.

Poster W3-3602

Quantitative distribution of euphausiids in relation to the environmental conditions in the East China Sea and seasonal variation in the Changjiang Estuary

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Quantitative distribution of the euphausiids in the East China Sea was studied based on zooplankton samples collected during 3 summer cruises in 2002, 2003 and 2006. 9 species were found including *Euphausia diomedea*, *Euphausia mutica*, *Euphausia nana*, *Euphausia pacifica*, *Nematoscelis gracilis*, *Pseudeuphausia latifrons*, *Pseudeuphausia sinica*, *Stylocheiron affine*, *Stylocheiron carinatum*, *Stylocheiron microphthalma*. Among them *P. sinica*, *E. nana* and *P. latifrons* were dominant. *Pseudeuphausia sinica* was widespread in the East China Sea with high abundance in Zhejiang coast (41.5 ind m⁻³) and Changjiang estuary (86.67 ind m⁻³), with the seasonal variation showing: summer > autumn > spring > winter. *Pseudeuphausia latifrons* was the dominant species distributed in south part of the East China Sea and was dominant in the outer-shelf waters but the high abundance center was in near-shore sea area. The other 6 species were rare. Most of them were warm water species with exceptions of *E. nana* and *E. pacifica*. There were 7 species of euphausiids based on the investigation of 21 cruises during 1997 and 2006, with more species and higher abundance in summer. *Pseudeuphausia sinica* was found all year around in Changjiang estuary. The seasonal variation of abundance and population of euphausiids in Changjiang Estuary was analysed with the flux and environmental conditions such as salinity, turbidity, dissolved oxygen and chlorophyll *a*.

Poster W3-3605

Temporal changes in euphausiid distribution and abundance in North Atlantic cold-core rings in relation to the surrounding waters

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The species composition of euphausiids was investigated in relationship to the hydrographic conditions in the North Atlantic cold-core rings (CCR) and adjacent waters to elucidate species succession in evolving water masses. Using data, dating back to the 1970s, from as many CCRs as possible and selecting typical cases where

no major physical perturbations occurred, a general pattern of euphausiid succession and change in vertical distribution in rings with time was obtained. This pattern was related to the general distribution of euphausiids in the northwestern North Atlantic Ocean, aiming at providing basic information on probable response of North Atlantic marine ecosystem to global warming. CCR populations can be characterised by high species number, but intermediate evenness between the slope water and northern Sargasso Sea. In CCRs, only a limited number of species were dominant even if there were more species present in rings as old as 9-12 months than in the northern Sargasso Sea. In rings older than 9 months, euphausiids showed two peaks in their vertical distribution: a shallow daytime peak at about 400 m and a night time peak in the upper 100 m consisting of warm-water species and a deeper persistent peak at 800 m or deeper. This shallow peak in CCRs is shallower than that in the surrounding northern Sargasso Sea, and the deep peak is rarely observed in these waters.

Poster W3-3665

Immunochemistry as an ecological tool: diet analysis of formalin-preserved Antarctic krill (*Euphausia superba*) from the western Antarctic Peninsula

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Global climate change has the potential to alter phytoplankton community composition in Antarctic waters. Such change will likely impact the survival, growth and reproduction of Antarctic krill, *Euphausia superba*. The level of impact will depend, in part, on the degree of selectivity of krill for particular types of phytoplankton and other food resources. But exactly what do krill eat? The natural diet of *Euphausia superba* remains a topic of active research. One promising method of diet analysis is immunochemistry. Our previous immunochemical studies were restricted to frozen samples. Here, we apply modified immunochemical methods to analyse the diets of formalin-preserved krill from the Palmer Long-term Ecological Research grid along the western Antarctic Peninsula. We compare results between formalin-preserved and frozen samples to verify the efficacy of the technique for formalin-preserved specimens. We also explore the extent to which krill consume the prymnesiophyte *Phaeocystis*, comparing these results to previous studies that suggest krill selectively consume diatoms over *Phaeocystis*. Finally, we discuss the promise and pitfalls of using immunochemical techniques to study the feeding ecology of krill collected and preserved in formalin throughout the Antarctic over the past several decades.

Poster W3-3677

Utility of common dietary methods for *Euphausia superba* and *Meganctiphanes norvegica*

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Studies on species feeding behaviour and diet are crucial to our understanding of ecosystems, and stomach content analyses have a long history. However, for krill, food items have often been counted in a semi-quantitative way only and differences in their size have not been considered. Here we analysed the diet of two euphausiids, *Meganctiphanes norvegica* and *Euphausia superba*, and evaluated the importance of different food items on basis of their total volume in the stomach. For *E. superba*, the study covers different seasons and a range of environments. In addition, stomach content results were compared to fatty acids and stable isotopes in simultaneously sampled tissue, and krill nutrition was related to their *in situ* growth rates. Even though pelagic algae were often the most numerous food item both species have been found to exploit protozoan and even benthic material, while feeding on copepods seems only to important in *M. norvegica*. In the Scotia Sea, we found krill swarms with empty or full stomachs during both winter and summer, suggesting that *E. superba* find suitable food even in ice-free water in mid-winter, but can suffer food shortage in summer. Fatty acid and stable isotope analyses draw our attention to a food source, which cannot be encountered in the stomach - athecate heterotrophic dinoflagellates. Krill were able to sustain medium growth rates when feeding on these flagellates even when Chl-*a* concentrations were low. However, highest krill growth rates were found during a diatom bloom and coincided with a mixed diet.

Poster W3-3684

Characterising krill aggregations and linking them to some environmental factors in Southern Ocean: relevant to other krill-bearing marine ecosystem studies?

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Euphausiids, often a key trophic link in marine food webs around the globe, form near-monospecific aggregations in epipelagic zones. Hence, formation and dispersion of these aggregations are subject to a range of environmental conditions. Hydroacoustic techniques have been used extensively to determine krill biomass and also offer a tool to investigate various aspects of their ecology. In this study, we examined morphological characteristics of Antarctic krill aggregations using a scientific echosounder (38 and 120 kHz) in the Southern Ocean. Based on the dB difference ($2\text{dB} < \text{Sv}_{120-38} < 16\text{dB}$) between mean backscattering strength (Sv) at 120 and 38 kHz, krill aggregations were delineated. Krill swarms were categorised into a number of groups by physical dimension, and the frequency of occurrence was calculated. We also extracted various parameters such as $\text{Sv}_{\text{mean}}/\text{Sv}_{\text{max}}$, the depth, and the spacing between aggregations, and examined these in relation to hydrography, sea ice distribution, and chlorophyll level and so on. Krill seem to form well-separated, dense aggregations close to the ice edge, and these tend to turn into layers that are more diffuse and interweaving in offshore waters. This may represent a response to a spectrum in food condition, from concentrated, pulsed to more dilute, well-spread supplies. In the Southern Ocean, this range corresponds to 'sea ice to open water'. A similar spectrum in terms of food condition, or at least part of the spectrum, may apply in other krill-bearing marine ecosystems.

Poster W3-3694

Distribution and community structure of euphausiids in the Southern Ocean along the 140°E meridian during the austral summer 2001/2002

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The abundance, biomass, diversity and community structure of euphausiids in the Southern Ocean along the 140°E meridian between latitudes 47°-65°S were examined by RMT8 during the 2001/2002 summer. Both total abundance and biomass were much higher to the southern part of the Southern boundary of the Polar Front (PF-S) located in 60-61°S than in the northern part, corresponding with higher chlorophyll concentrations. The ranges of biomass and abundance values were similar to those reported 18 years ago. Twelve species were collected, and clear horizontal distribution patterns enabled the classification of each species into one of 3 different types: species occurring only at stations north of the PF, species occurring in a broad distribution from south of the PF-S to the south of the Southern Boundary (SB) of the Antarctic Circumpolar Current, and species occurring only south of the SB. The latitudinal zonation in occurrence and peak abundance were evident for all species. Hierarchical cluster analysis by species and station resulted in the 2 distinct communities of euphausiids: community I comprised the stations north of the PF where both euphausiid abundance and biomass were relatively low and 2 species, *Thysanopoda acutifrons* and *Thysanoëssa gregaria* dominated, community II comprised the southern 5 stations where abundance and biomass were high and *Euphausia frigida*, *E. superba* and *Thysanoëssa macrura* were numerically dominant. Among the 5 oceanographic fronts within the research area, the PF (either south or north) appears to be the most important biogeographical boundary separating abundance, biomass, and the community structure of euphausiids.

Poster W3-3702

Krill size/maturity distribution underlies niche separation of their avian and mammalian predators

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During summer months Antarctic krill (*Euphausia superba*) in the Antarctic Peninsula region demonstrate distribution patterns and seasonal migrations that reflect their size, age and maturity. Small one year old juveniles exhibit extreme patchiness, are located closest to the continent with greatest concentrations in Southern Bransfield

Strait; large reproductively mature adults generally occur offshore in Drake Passage and over the northern shelves of the South Shetland Islands; intermediate immature and small mature stages are typically located in between the smaller and larger krill. All size/maturity categories demonstrate onshore migration with the advancing season. These krill distribution patterns are reflected by the distributions and feeding activities of their avian and mammalian predators. A variety of Albatross and Petrel species typically are concentrated in oceanic regions near the outer shelf break coincidental with spawning adult krill. Humpback whales occur in greatest numbers and exhibit coordinated feeding activity in parts of Bransfield Strait coincidental with concentrations of juvenile krill. Stomach and scat analyses of Chinstrap Penguins and Fur Seals occupying breeding colonies on the South Shetland Islands indicate that they are feeding primarily on intermediate and large sized krill in adjacent waters. These distribution attributes combined with the foraging and breeding behaviour of the predators suggests a probable niche separation of krill resources.

Poster W3-3796

Rotating mechanism of a transducer to measure target strength (TS) pattern of small aquatic organisms

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The information of target strength (TS) is indispensable for acoustic estimation of the important small aquatic organisms. A system was developed to achieve precise measurement of TS pattern by using a stepping motor. By using this system, TS patterns of several kinds of aquatic organisms were measured with the controlled method. In order to measure the directivity of TS, relative aspect of a suspended target against a transducer was changed step by step using a rotated actuator. A single step angle of this system is 1.0 degree. The distinct character of this system is that the developed rotating mechanisms are installed with a stepping motor together with an absolute encoder. The precision of rotation angle is currently been evaluated.

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