Report of the Working Group on Zooplankton Ecology (WGZE)

26–29 March 2007

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Contents

Executive summary

Highlights

- In the North Atlantic, significant changes have occurred in the abundance, distribution, community structure and population dynamics of zooplankton and phytoplankton, mainly reflecting changes in regional climate, caused predominately by the warming of air and sea surface temperatures (Sections 5.1, 6.1, 6.2, 6.3).

- The changes in the zooplankton and phytoplankton communities that are at the bottom of the marine pelagic food-web, affect higher trophic levels, as the synchrony between predator and prey (match-mismatch) plays an important role (bottom-up control of the marine pelagic environment) in the successful recruitment of top predators, such as fish and sea birds (Sections 5.3, 6.1 and 6.2).

- The poor recruitment of several fish of commercial interest and the low seabird breeding productivity recorded in recent years in some regions are associated with changes in plankton biomass and in the seasonal timing of plankton production (Sections 6.1 and 6.2).

The WGZE encourages microzooplankton to be included in time series monitoring within the ICES area (ToR b).

In reviewing the ICES Annual Plankton Status Report (ToR a), various plankton trends and changes were noted (some of which are taken up in the OSPAR Climate Request, see following paragraph). Important additions and improvements to the report are planned.

Recognizing that interaction is needed between scientists working in the field and modellers (ToR d), the group will combine with ICES WGPBI in a one day joint session during its next annual meeting.

When considering phenological changes (ToR f), several examples were mentioned. (e.g. *Acartia* sp., *Temora longicornis*, *Pleurobracia pileus*, echinoderm larvae in the North Sea). Phenology is already included in the ICES Annual Plankton Status Report and should be expanded.

Considering the OSPAR Climate Request (ToRs m, l), the following evidence was provided of changes in the plankton in relation to hydroclimatic changes:

- The NAO has been rising over the past 30 years, as have the surface waters of the European Continental shelf. This has caused extensive changes in the planktonic compartment of the marine ecosystem affecting plankton production, biodiversity, species distribution which has had effects on fisheries production and other marine life (e.g. fish larvae, seabirds).

- In North Sea, the population of the previously dominant zooplankton species (the cold water *Calanus finmarchicus*) have decreased in biomass by 70%, between the 1960s and the post 1990s. Warm-water species have moved northwards to replace the species but their biomass is not as abundant.

- A shift in the distribution of many plankton and fish species by more than 10° latitude northward has been recorded in the OSPAR area over the past thirty years.

- The seasonal timing of phyto- and zooplankton production also altered in response to recent climate changes. This has consequences for plankton predator species, including fish, whose life cycles are timed in order to make use of seasonal production of particular prey species.

- In the North Sea and around the British Isles, considerable increase in phytoplankton biomass has been recorded since the mid-1980s.

- In the North Sea functional changes in the phytoplankton community have been recorded in recent decades, with an increase of dinoflagellates and a decrease of diatoms abundance in response to warmer sea waters.

- In the North Sea, warmer conditions earlier in the year together with increased phytoplankton abundance since the late 1980s, has determined the significant increase of meroplankton, in particular echinoderm larvae of *Echinocardium cordatum*. This change in the food-web structure, due to the competitive exclusion of the holozooplankton (i.e. permanently plankton species) by the meroplankton, may significantly diminish the transfer of energy towards top pelagic predators (e.g. fish) while increasing the same transfer towards the benthic component.

- Future warming is likely to alter the geographical distribution of primary and secondary pelagic production, affecting oxygen production, carbon sequestration and biogeochemical cycling. These changes may place additional stress on already-depleted fish stocks as well as have consequences for mammal and seabird populations.

Several examples of introduced species were noted from both sides of the North Atlantic, most notably *Mnemiopsis leydi* that has been observed in the Baltic Sea, the Kattegat and the North Sea, and has extended to waters off Bergen (Tor e).

Arrangements for the planning of the 'Joint WGZE/CIESM Workshop to compare Zooplankton Ecology and Methodologies between the Mediterranean and the North Atlantic (WKZEM)' (Co-Chairs: A. Gislason, Iceland, and G. Gorsky, France), adopted by ICES in 2006, are progressing well (ToR c). It was decided that the workshop be held in Heraklion, Crete, Greece in the second half of October 2008.

In reviewing the development of web-based taxonomic training (ToR g), the group noted that one such initiative is already underway in the Marine Laboratory in Aberdeen.

WGZE reviewed the progress and prospects for they European Census of Marine Life Project (EuroCoML) (ToR h). The WGZE is willing to collaborate, expand partnerships and formulated some future contributions (e.g. providing an inventory of samples and activities, samples for genetic analysis, taxonomic expertise).

WGZE reviewed the progress in the formation of a new WGPE to replace the disbanded in 2006, and noted with concern that limited progress had been made (ToR k). The group strongly recommends that a new WG on Phytoplankton and Microbial Ecology be formed by ICES, and is willing to contribute.

The group was presented with an overview of the Basin programme (Basin-scale Analysis, Synthesis and Integration initiative), which seeks to foster a co-ordinated joint US, Canadian and EU research programme in the North Atlantic basin.

A Baltic Sea mini session was held during the last day of the meeting. Abstracts are included in the report.

A summary of the Terms of Reference for the 2006 meeting is given in Section 1 of the Report. All ToRs were met.

The ICES WGZE proposes to meet next time from 31 March to 3 April 2008 in the University of Montpellier, Montpellier, France.

1   Opening of the meeting

The ICES Working Group on Zooplankton Ecology (WGZE) met at Hotel Gutenbergs, Riga, Latvia from 26–29 March 2007 at the kind invitation of Solvita Strake from the Institute of Aquatic Ecology, Riga. The meeting was attended by 30 scientist representing 14 countries (Annex 1).

Astthor Gislason (Chair) opened the meeting at 11:00 and welcomed the attending scientists. This was followed by a round of introductions and a welcome and comments on the housekeeping arrangements from Solvita Strake, the host.

2   Adoption of the agenda

The agenda for the WGZE meeting (Annex 2) followed the Terms of Reference adopted as a resolution by the ICES 2006 Annual Science Conference and Statutory Meeting. The agenda was reviewed and last minute adjustments were discussed. Thereafter, the agenda was adopted. WGZE will report by 1 May 2007 for the attention of the Oceanography Committee, ACE and ACME. The Terms of Reference for this meeting are to:

a)   update the ICES Plankton Status Report;

b)   review the role of microzooplankton, including metazoans, in marine food web;

c)   compare the zooplankton ecology of the North Atlantic and the Mediterranean;

d)   review the use of numerical methods in exploring and predicting long-term plankton variability in relation to climate;

e)   review and consider the impact on zooplankton communities of introduced or disappearing species;

f)   consider rate process studies and zooplankton phenology in association with time-series monitoring;

g)   consider the development of web-based taxonomic training and the promotion of the ICES WGZE to a wider community;

h)   review and consider species biodiversity in zooplankton from coastal zones to oceanic deep sea: progress and prospects for the European Census of Marine Life Project (EuroCoML);

i)   discuss and report on quality assurance and control guidelines for sampling and analytical practices for zooplankton;

j)   provide expert knowledge and guidance to ICES Data Centre (possibly via sub-group) on a continuous basis;

k)   take part in the intersessional work led by PGPYME in developing the mission and draft resolutions for a new working group related to phytoplankton and microbial ecology;

l)   assess and report on changes in the distribution, population abundance and condition of zooplankton in the OSPAR maritime area in relation to changes in hydrodynamics and sea temperature (further details on the interpretation and handling of this ToR will be provided by ACE);

m)   assess and report on changes in the distribution, population abundance and condition of phytoplankton in the OSPAR maritime area in relation to changes in hydrodynamics and sea temperature (further details on the interpretation and handling of this ToR will be provided by ACE).

After introducing the ToRs and the Agenda, the Chair draw the attention of the group to a recent letter from Harald Loeng, Chair of the Consultative Committee (ConC) (December 2006), expressing concern as to how to determine the main findings of the expert groups. One way at achieving this would be that WG members to try to be specific and to identify highlights and unusual events related to the ToRs. The Chair encouraged the WG members to

keep this in mind during the meeting and try to identify highlights related to the ToRs dealt with. Astthor went on to draw the attention of the group to another letter, this one from Paul L Connolly (Chair of MCAP), sent to all members of the ICES community (Dec 2006) with information on on-going reforming of the ICES Advisory Structure, and encouraging the whole ICES community to take part in the process. Astthor encouraged the WGZE members to consider Connolly's letter and take part in the reforming process.

The Chair then went through the list of Actions that arose during the last meeting of the group (ICES 2006a). Most of these were carried out intersessionally, while a few have not been fulfilled yet. Thus, the group has not as yet succeeded in including data from Russia in the Plankton Status Report, although the Russian ICES delegates have been contacted. It is a continuing aim to include more data from the North Atlantic in the Report than are presently there. As a starter, metadata should be included. WGZE will continue pursuing this issue.

3   Data management issues

(Lead: Peter Wiebe, Rapporteur: Priscilla Licandro)

3.1   Discuss and report on quality assurance and control guidelines for sampling and analytical practices for zooplankton (ToR i)

3.2   Provide expert knowledge and guidance to ICES Data Centre (possibly via sub-group) on a continuous basis (ToR j)

The discussion opened with remarks from the Chair explaining that the ToR was given to the group by ICES, in response to a memorandum of understanding with OSPAR and HELCOM. They asked ICES for advice as to quality assurance of biological measurements. ToR j, on the other hand, is a reiteration of a request from the ICES Data Centre. For our last meeting they gave us exactly the same ToR. The WGZE responded by forming a subgroup with Peter Wiebe, Todd O'Brien, and Steve Hay as members. The idea was that they should work intersessionally and thus be able to respond quickly to demands from the ICES data centre and others. Astthor said that the group had already received one request from Marilynn Sørensen, the ICES data manager and responded to it. So the system with a Data Management Sub-group seems to be functioning quite well.

The proceedings then proceeded with a presentation of background information by Peter Wiebe, based on the STGQAB 2007 Report (ICES, 2007). The ICES/OSPAR/HELCOM Steering Group on Quality Assurance of Biological Measurements (STGQAB) met on the 13-15 February 2007 in Copenhagen (ICES 2007) to review the HELCOM COMBINE Manual (Cooperative Monitoring in the Baltic Marine Environment – COMBINE, http://sea.helcom.fi/Monas/CombineManual2/CombineHome.htm).

The STGQAB reviewed the manual, updates, and amendments that were prepared and the general reorganization of chapters and annexes that were proposed. One important recommendation was to invite ICES Working Groups to look on the proposed changes, particularly on chapter 8 and Annex 4 (recommendations nos. 7, 8, 9 and 20).

The STGQAB recommended also that the Zooplankton Expert Network group (ZEN), in collaboration with WGZE, revise the text and the content of the Zooplankton guideline, providing a draft for the next meeting of STGQAB in 2008 (see Agenda Item 7 and ANNEX 11 in STGQAB Report 2007).

The STGQAB, for example, felt that Chapter 8 in the HELCOM COMBINE manual, "Quality Assurance", should be revised and clarified. The estimation of errors at the different stages of

sampling and counting procedure should be assessed as well as the range of maximum and minimum values. The sources of errors should also be listed.

STGQAB further proposed a new structure of the HELCOM COMBINE guidelines part C, with a subchapter (C.4.3.4) on mesozooplankton (Annex 7, STGQAB Report, 2007).

STGQAB has already recommended to HELCOM to consider changing the status of zooplankton as a mandatory variable in the MON-PRO scheme HELCOM MONAS and MON-PRO (STGQAB report 2006).

These and other recommendations from STGQAB 2006 were not considered by the HELCOM MONAS 9/2006 meeting. P. Wiebe and WGZE members stated that it is important that zooplankton become a mandatory variable not only for HELCOM MONAS, but also in relation to OSPAR and the EU.

The STGQAB will meet next in Copenhagen (5–7 February 2008). Inputs of WGZE are requested in relation to the following Tors:

c) Review the outcome of the HELCOM ZEN;
d) Review and propose on updated guideline for Zooplankton biomass determination in the HELCOM COMBINE guideline.

After P. Wiebe's introduction, a discussion followed on the revision of the HELCOM Manual. It was felt that in particular the sections on abundance (Subchapter 6.1) and biomass (Subchapter 6.2) needed to be reviewed by WGZE.

A discussion then took place related to Annex 11 in the STGQAB-2007-Report. A few notes: In determining carbon biomass it is important to submit how zooplankton length is measured and how this information is converted to carbon. Species specific regression length equations have been used to determine carbon biomass of target copepod and cladoceran species. The species specific regression coefficients a and b are indicated in Table 2 in the Report. Steve Hay recommended whenever possible, to indicate the average length of the species that was to be used for the regression calculation in Table 2. He also noted a likely error in the table, i.e. that the species *Temora longicornis* indicated in Table 2 should probably be *E. affinis*. Steve Hay emphasized the importance of also including length of the different stages of target species for which carbon biomass conversion factors are indicated in Table 3. There was general consensus in the group on this. Indicating lengths of species is worth the effort, because this information may reduce the error when deriving the biomass with regression-length equations. WGZE suggests whenever possible that the measuring of species length and carbon biomass be made at the same time, so that more basic calibration data are made available to the scientific community.

Wulf Greve said that it is fundamental to know the variance associated with carbon conversion factors. The WGZE agrees and suggested adding variance or another indication of variability to Tables 2 and 3.

Ioanna Siokou argued that some small copepods as *Clausocalanus* and *Ctenocalanus* are difficult to distinguish to genus or species. Thus, it may prove difficult to calculate carbon conversion factors for these species.

P. Wiebe suggested making a list of recommendations to consider when measuring / deriving carbon biomass measurements.

Piotr Margoński, who was at the ZEN meeting, said that ZEN seeks mainly to improve the calculation of biomass thus diminishing the variability due to the use of wet weight.

Catherine Johnson said that sometimes there are not the resources to measure carbon biomass and that in these cases other measurements of biomass (e.g. wet weight, volume) may be done. She said that such measurements would still be valuable as supplementary information.

Cabell Davis asked about the scientific questions asked in relation to the data. He also stressed the importance of deriving carbon biomass for large zooplankton and microzooplankton as this information is important in a modelling perspective. In answer to this, Steve Hay noted that WGZE had been asked to provide advice on mesozooplankton biomass in relation to the eutrophication issue.

Another point raised by P. Wiebe is the request of Marilynn Sørensen, ICES Data manager, on providing guidance about the definition for zooplankton 'sampled volume' and 'flow volume'. Peter said that Todd O'Brien had answered back indicating that there were two ways of doing this, either using 'exact volume' (i.e. a fairly precise measured value provided by a flow meter, pump meter, or bottle graduation) or 'estimated volume' (i.e. a roughly estimated value from net dimensions and towing distance). The working group strongly recommended use of a flowmeter to measure volume filtered by a net and not estimates based on net dimensions and towing distance. It was emphasized that use of a flowmeter required frequent calibration of the flow meter. The methods of quantitative net towing for zooplankton have been available for many years and the recent ICES Zooplankton Methodology Manual provides details about their implementation.

4 Microzooplankton

4.1 Review the role of microzooplankton, including metazoans, in marine food web (ToR b)

(Lead: Roger Harris, Rapporteur: Delphine Bonnet)

Roger Harris gave an overview on what organisms compose microzooplankton and what are their roles in the marine pelagic food web. It was recognized that this was a large subject and a very broad ToR.

Microzooplankton constitutes a significant component of the plankton community in many marine environments. They are of small size and have higher weight-specific growth rate than larger metazoans. They are important phytoplankton grazers capable of exploiting pico- and nanoplankton. Microzooplankton can be in turn eaten by larger metazoans. There is a lack of proper methodology for their collection, and because of their role in the marine food web (microbial loop), they are important to study.

What are they?

Microzooplankton mainly comprise protozoa and metazoa <200μm. This size division is practical (but artificial). The major taxa of the nanozooplankton (2–20μm) are heterotrophic dinoflagellates, ciliates and heterotrophic dinoflagellates while ciliates and heterotrophic dinoflagellates are the main components of microzooplankton (20–200μm). Copepod eggs and nauplii are also part of the microzooplankton. The size spectra of phytoplanktonic organisms overlaps with microzooplankton as it is usually considered that large phytoplankton cells are >5μm while small cells are <5μm.

What is their role?

In some cases microzooplankton contribute to primary production, as some organisms are able to retain functional chloroplasts and therefore to produce organic matter from photosynthesis (mixotrophy). They have also a major role in nutrient cycling. Microzooplankton grazing is a

major source of phytoplankton and bacterial mortality. The grazing impact by protozoa in pelagic ecosystems can be quite high. For example, in the Atlantic, it can be up to 100% of the daily primary production (Gifford *et al.*, 1995). They can be in turn the prey of higher trophic level like mesozooplankton for example. Several examples of copepod diets were presented: *Acartia tonsa, Neocalanus plumchrus* in the Pacific (Gifford, 1993), *Calanus finmarchicus* on George Bank at different seasons, *Oithona* in the Irminger Sea grazing on ciliates (Castellani *et al.* 2005), *Calanus finmarchicus* nauplii on the Irminger Sea (Irigoien *et al.*, 2003), cannibalism of *C. helgolandicus* feeding on its eggs and the consequences on mortality (Bonnet *et al.*, 2004).

The chemical composition of microzooplankton shows low C/N ratios compared to phytoplankton. They are more rich in N, and so represent a good food. They contain lots of lipids. A literature review presented the significant effects of microzooplankton diet on consumers. There are studies showing enhanced survival, increased reproduction and growth rate of consumers when part of the diet. The main mesozooplankton taxa feeding on microzooplankton are decapod larvae, fish larvae and crustaceans.

How to study them?

There are several methods which have been developed and a good treatment and recommendations are presented in the Chapter 5 of the ICES Zooplankton Methodology Manual (Gifford and Caron 2000). Lugol and Gluteraldehyde are the main preservatives/fixatives used. Enumeration is commonly done by inverted and/or epifluorescence microscopy. Advances in image analysis techniques are now opening a new field for counts and identification (FlowCAM). The fine mesh size used for collecting net samples of more robust microzooplankton, varies according to the users: 68, 64, 53, 40 μm mesh have all been or are currently used by members of the WGZE. There is no homogeneity in the net and mesh size used for collection, but collection is always carried out with very short tows (to prevent clogging of the net). Pumps have also been used (Georges Bank, Peter Wiebe).

Identification

Attention was drawn to the site hosted by Liverpool University: http:// www.liv.ac.uk/ciliate/. This has a valuable 'User friendly guide to coastal planktonic ciliates' developed by David Montagnes.

Distribution

Ciliates distribute in different kinds of way and not much is known about it. An example of the UK GLOBEC programme was presented relative to a study in the Irminger Sea. Fifty ciliate species in the study area, with one dominant species *Strombidium* sp. on the Greenland Shelf and a different one *Myrionecta rubra* (mixotroph), dominating in the open ocean basin.

Why microzooplankton relevant for the WGZE?

Time series. There are not many microzooplankton time series. In the 1980s, some data were collected by Victor Smetacek in the Kiel Bight with very good spatial resolution. David Montagnes has published annual cycle of heterotrophic ciliates for a couple of years in the Gulf of Maine. Microzooplankton has been sampled at station L4 (Western English Channel) since 2002 showing large interannual differences in ciliate abundances (Lugol fixed samples). A recent paper on tintinnid ciliates seasonal cycle off Naples (Modigh and Castaldo, 2002) has been published. The time series off Naples started in 1996 and most of the microzooplankton biomass is composed by ciliates.

Major characteristics about the datasets available. Most of the datasets aim to study water quality, and are not really connected with getting a better understanding of the marine food web functioning. There is not much linkage between micro- and mesozooplankton (monitoring or studies are independent).Most of the sampling sites are lakes or estuaries. The data are not on line for most of these monitoring programmes.

Data from the CPR. Microzooplankton is also collected by the CPR. They monitored only the tintinnids. Post 1996, all Tintinnids were counted as Total Tintinnids. From 1996, 5 genera of Tintinnids are counted separately.

Conclusions

- WGZE should include both micro and mesozooplankton experts;
- Microzooplankton make a good link with phytoplankton within ICES (similar methods);
- Microzooplankton methodology is well defined in the Zooplankton Methodology Manual;
- We should encourage microzooplankton time series and monitoring within the ICES area.

Open Discussion

The open discussion then developed in three directions:

i) The limitation of sampling methods and the possible improvements;

ii) Considering if the WGZE should invite some microzooplankton experts to be part of the working group and should we get a ToR or a theme session during the future meetings?

iii) Recommendations to OSPAR.

i) The limitation of sampling methods and the possible improvements

Steve Hay opened the discussion underlying that the main problem with microzooplankton comes from the way of sampling. People counting eggs and nauplii use nets while people counting ciliates use bottles, and there are too few eggs or nauplii in the bottle volume The WGZE should point out there is a gap between 100 and 200μm for which we do not have data. This is the part for the copepod life- cycle where the mortality is the highest and is an important gap in getting meaningful abundances. Collecting samples with a fine mesh net is difficult as the net tends to clog up very quickly. Steve said that he is looking for a very accurate flowmeter able to measure the volume filtered by a very fine mesh net. He explained that microzooplankton and phytoplankton are not homogeneously distributed in the water column so if you sample with a bottle at one depth you can miss a whole population. In Aberdeen, they are using a pump system down to 45m and it is working very well. However the risk of the organisms being smashed on the filter still remains. They are waiting for a holographic imagery system to be developed.

Ioanna Siokou thinks that finer mesh sizes should be used. Indeed, a lot of small species are missing from the counts as they are not well captured by the nets (for example: *Oithona, Oncaea, Microsetella*). When using a 63μm mesh net instead of a 200μm mesh net, she noticed that the total zooplankton abundance is 4 times higher. Steve Hay answered that 200μm mesh nets have been chosen because nets were clogging up too fast with fine mesh. Peter Wiebe underlined that high abundance of tintinnids are measured well below 100m. There is therefore a real limitation in the sampling techniques.

In the Baltic, workers are using a 100μm mesh net. They count both nauplii and rotifers and the people working on phytoplankton include the protozoa in their counts. Cabell Davis

mentioned that some of the protozoa are not microzooplankton but mesozooplankton. He gave the example of the radiolarians in the Sargasso Sea. They can stick together and can actually predate on copepods. They are difficult to sample and to identify.

Luis Valdes suggested that maybe we should put together time series of fine mesh net samples. Luis and Roger both have data at their stations for fine mesh samples. Luis showed a slide of the long term datasets of Gijon. Vertical profiles of total Chla and microzooplankton abundance until 100m depth (total abundance from the bottle, filtered on a fine mesh) match very well.

Delphine Bonnet mentioned that the same difficulties in proper sampling strategy and devices also exist at the other end of the zooplankton size spectra for the gelatinous plankton. Steve Hay mentioned that he has a 350μm mesh net of 1m diameter collected every week off Aberdeen, but none of the samples have been processed yet. Priscilla Licandro followed on, underlining the lack of expertise in gelatinous taxonomy. There is a need to improve the knowledge. Steve Hay agreed. He says that gelatinous zooplankton is a relatively easy group to learn because there are only few species. Peter Wiebe reminded us that Pat Kremer was once in the WGZE group and was working on gelatinous plankton.

Some species disintegrate in formalin but not all of them. For example, appendicularians, siphonophores, salps, doliolids, jellyfish are well preserved. *Bolinopsis* is one of the exceptions.

It was agreed that the WGZE should address the question of both micro- and macrozooplankton.

Cabell Davis told about the FlowCAM which uses Optical techniques for counts and identification of microzooplankton. With this sampling device, most of the organisms are stuck to particles and aggregated so it is difficult to count them by optical measurements. Steve Hay underlined that there are problems in interpreting data from the FlowCAM. Roger Harris reported that at PML they have successfully used the FlowCAM for a study on Tintinnids, but the competition with phytoplankton particles on the size spectra studied can makes the data analysis difficult. However Peter Wiebe mentioned that Mike Sieracki has a time series in the Gulf of Maine using the FlowCAM.

ii) Considering if the WGZE should invite some microzooplankton experts to be part of the working group and should we get a ToR or a theme session during the future meetings?

Cabell Davis suggested that there is a need to identify why we are part of the WGZE group. JGOFS and GLOBEC are integrative group, ICES WGZE should stay focused on mesozooplankton only.

Do we want to get microzooplankton experts on board? If yes, we need another ToR to encourage people to come in and to attract people. Maybe we should put it in the Agenda for the next meeting? However, if the new phytoplankton group will be working on phytoplankton and microbial ecology, we do not want to overlap.

Luis Valdes questioned whether we should continue with this topic at the next meeting or organise a theme session. Members agreed to have ToRs or a theme session for the next joint meeting with the CIESM in October.

It was felt significant to this discussion, that a workshop was held in Copenhagen in June 2005 organised by Jeff Runge and Öivind Fiksen: Workshop on the Impact of Zooplankton on Cod Abundance and production, WKIZC (ICES 2005). Microzooplankton was a big point of this workshop, so we need to go back to the report. Eilif Gaard reported about this workshop at the WGZE meeting in Villefranche in 2006. (ICES 2006a).

The WGZE should point out there is a gap between 100 and 200μm for which we do not have data. This is the part for the copepod lifecycle where the mortality is the highest, so it is very important.

iii) Recommendations to OSPAR

We should come up with recommendations for OSPAR on micro-, meso- and macrozooplankton.

Wulf Greve mentioned that the size range of zooplankton studied needs to be increased and we need to take into account the seasonal aspect, especially when considering eutrophication.

Peter Wiebe reminded us that in the Water Framework Directive, there is no mention of zooplankton, but those directives could be looked at so that we will not be starting from scratch.

5 ICES plankton Status Report

5.1 Update the ICES Plankton Status Report (ToR a)

(Lead: Luis Valdes, Rapporteur: Mark Benfield)

The ICES WGZE started in 2000 to monitor the plankton abundance in the ICES area. The material presented under this item is presented in the annual Summary Plankton Status Report in the ICES area (ICES 2006b). Reported results are significant observations and trends based on a wide range of time-series sampling programmes. Efforts are in hand to expand the report, to include phytoplankton and elementary physics and to facilitate comparative analyses and setting monitoring standards and recommendations.

Luis Valdés began by presenting a summary of the history of the zooplankton status report, the first was developed in 2001 based on discussions that started in 1997. Initially the reports were an annex to the Working Group report. Reports were published as annexes annually from 2001-2004. Subsequently the status report was published as an ICES Cooperative Research Report in 2005 and 2006. Over time the report has become more complex, increasing in length from 18 to near 50 pages. At the same time it includes a broad range of data and topics in the discussion. For example, it now includes zooplankton, data on phytoplankton and temperature, plus a geographical overview of the North Atlantic by latitude and the relationship with temperature. The most recent versions included phenology and temperature data. There are ten ICES countries that contribute data to the zooplankton status report.

It was remarked that the Status report should cover two objectives: (1) to provide ICES with an overview of the zooplankton status in the North Atlantic; and (2) offer an interesting scientific product.

Topics for discussion in this year's report were presented. Luis felt that we shouldn't duplicate the discussion of the previous year's report, though it was later pointed out that we should maintain some continuity by including at least a brief summary discussion of the major topics in prior report discussions.

One potential new topic for inclusion in this year report is the relationship between stratification of the water column and zooplankton abundance/biomass. An example, data from Spain were presented. When there is no stratification, the growing season for zooplankton is extended through most of the year. Strong stratification leads to abbreviated periods for growth. If members can provide temperature data from 0–100 m at 1 m vertical intervals, plots could be produced for other regions in the next report and see if this pattern is the same at both, temperate and boreal regions.

Discussion of this topic included whether we understood the mechanisms behind the relationship between stratification and the duration of zooplankton growth. A suggestion was made to add nutrient data since this is likely the factor responding to changes in stratification. Luis felt that adding nutrient data at this point might be too complicated. Salinity was viewed as another important variable. At present the stratification index is based on the standard deviation of temperature observations from the upper 100 m. Luis was quite willing to use salinity data in conjunction with temperature and develop an index based on density. Webjörn Melle commented that in the Norwegian Sea, strong stratification tended to be associated with a high annual zooplankton biomass, which could be an interesting difference between boreal and temperate regions. Not all areas have worked up the temperature data. For example, the FRS (Scotland) has surface and bottom temperature but may not have the CTD data in a form that could be used in the same manner as the Spanish example.

A second potential topic was inclusion of more taxonomically explicit data. Roger Harris mentioned that the table of dominant species might become interesting as the time series gets longer. In some time-series, meroplankton are important and in others, they are not. Comparisons of dominants among stations could be done. While we are probably not ready to do this in the forthcoming report, it could be done for future reports. Species data from the Gulf of Maine should be available and ECOMON and MARMAP surveys from the National Marine Fisheries Service could be used to extract most abundant species. John Hare would be a likely point of contact with whom Todd O'Brien could work to extract necessary data. There is also the Halifax to New Jersey CPR line. We should be able to add data from the NW Atlantic to the next report. Regarding taxonomic comparisons Luis showed a similarity plot based on correlation among taxonomic composition by different regions. It showed clear separation among tropical and subtropical/temperate regions.

Peter Wiebe stated that one of the underlying assumptions of comparing taxonomic composition among regions is that similar protocols were used to collect, count, stage and identify organisms. We might consider some intercalibration methodology. Sigrid gave an example of a Red Sea study that compared counts and identifications, which had highly unsatisfactory agreement between two experts. Steve Hay pointed out the need to include voucher specimens from any sorting and analysis.

Wulf Greve mentioned that we had not really discussed the abundance shift patterns. The composition of the communities may be related to changes in temperature. We should consider discussing this. When winter populations disappear, there is a sharp shift in community composition. In the Helgoland Region, there has not been a real winter recently. In 2006 the abundance of small copepods was all time low. This example was from one location (Helgoland Roads) but it would be interesting to know whether similar patterns are prevalent in other parts of the ICES region.

Roger Harris thought that one practical thing we could do is to try and advance the taxonomic lists for the time series areas. If we can extend the species data for each time series, we may be able to focus on certain (possibly dominant) species. The importance of rare or low abundance species should not be overlooked particularly in a context of climate change. If we are running a monitoring programme for the whole ICES area, are we capable of detecting new species or changes in rare species? We know that there are indicator species of particular water masses. There are now species appearing in water masses that were not present 30 years ago. We need to determine what the indicator species are for each region. It may also be useful to consider not only the frequency but also the relative importance of each species in a community.

Additional information needed is biodiversity. A biodiversity index might be a useful means of assessing change. This is of course, biased by the taxonomic capabilities of each region. The CPR data have shown quite interesting changes in echinoderm larvae in the North Sea. Perhaps we should consider groups at this level rather than all the taxonomically more explicit

data. Another issue is that the National Marine Fisheries Service sends their data to the Polish Plankton Sorting Centre. They count many species but not all. Thus these data may not be useful for rare or less abundant taxa.

The discussion was ended by summarizing the needs for this years and future reports:

a) We have to bring more ICES countries to contribute to the Status Report. Russia is a clear candidate as we know that there is a time-series from the Vistula Lagoon. Russian data from the Barents Sea and the Norwegian Sea may also be available. We should check if there may be data from the Russian Institute of Oceanography (e.g. Prof. Vinogradov; ask also via Kurt Tande).

b) We will enlarge the area covered by the Status Report to the Mediterranean Sea. In fact we have approached our colleagues of CIESM in some occasions, and at the last meeting Gaby Gorsky and other researches from the Western Mediterranean Sea offered to send data. There may be also data available from Grecian studies in the Mediterranean. There is also another time series from Trieste.

c) We should include more data for the top ten species. It may be premature to fully implement this in this year report. However, we could include a section describing the needs for more taxonomically explicit data and perhaps summarize what level of taxonomic resolution is presently available in each time series.

d) We should keep at least one paragraph discussing previous topics. It can be brief and each year we can focus on a new topic for the discussion.

e) A new topic for this report could be the relationship between stratification and abundance. This will depend on the availability of CTD data at 1m intervals from 0–100 m and time resolution of a minimum of 1 sample per month.

5.2 Review the use of numerical methods in exploring and predicting long–term plankton variability in relation to climate (ToR d)

(Lead: Cabell Davis, Rapporteur: Mark Benfield)

Background: Time-series studies on zooplankton long term-trends and their relationships with climate indices (e.g. NAO, Gulf Stream north wall index) and global warming suggest that important changes may occur in zooplankton processes and community structure as a result of climate change. By taking account of advances in statistical and biophysical modelling approaches we seek to elucidate the links between climate change and long term zooplankton variability.

The presentation began with an overview of available statistical methods for time-series analyses: 1) Principal Components Analysis (PCA); 2) Correlation Analysis and Random Effects Meta-analysis; 3) Autoregressive Analysis; and 4) Other Methods (Power Spectral Analysis; Continuous Wavelet Transforms, General Additive Models, New Hybrid Models). Power Spectral Analysis estimates dominant time scales of variation. Continuous Wavelet Transforms partition data series into different frequency components as functions of time. General Additive Models quantify the relationship between variables but don't account for autocorrelation. New Hybrid Methods do not yet appear to have been used but would use vector autoregressive models with GAMs to account for autocorrelation. It might also be possible to incorporate population models into these techniques to extract vital rates.

A SCOR Working Group (WG125) 'Global Comparisons of Zooplankton Time-Series' exists. They are currently in a data analysis mode, and a usable database will be available soon. The next meeting of this group will precede the Hiroshima meeting. One of their products is to be a toolbox for time-series analysis. Priscilla Licandro pointed out that there is now a freely available time-series package from France called (PASTECS: Package for Analysis of Space-Time Ecological Series) written in R. PASTECS is available: http://www.sciviews.org/pastecs.

Cabell Davis continued with an introduction of mechanistic modelling, through an example from the GLOBEC Northwest Atlantic Georges Bank Programme. A brief overview of the programme was presented including the programme rationale (to understand biological/physical mechanisms controlling recruitment in cod and haddock and their dominant copepod prey), the physical setting and species, the field sampling from 1995–1999, and the main results of the programme. It was found that low-salinity intrusions into this region were associated with increases in phytoplankton (chlorophyll), copepods, and larval fish growth and survival. The low salinity water was found, using oxygen isotope ratios, to come from the Labrador Sea and is hypothesized to come from the increasingly melting Arctic region. A 3D physical-biological model of the ocean basin and the GB/GOM region is being developed and used to quantify the circulation and biological dynamics. The biological model includes NPZD dynamics to generate 3D phytoplankton and microzooplankton fields over multiple years as a function of regional and external forcing. Concentration-based (Eulerian) copepod population modelling is being used to model dominant copepod species patterns, using the NPZD phytoplankton and microzooplankton fields as food. An individual based larval fish model by Greg Lough, Cisco Werner, and Larry Buckley is being used to simulate larval cod and haddock growth and survival given the copepod fields generated by the model. This model will be run for the 5 GLOBEC years, but will subsequently be run from 1970– present day to examine long term trends in the physics and biology. This work demonstrates how simple NPZD and species population models can be coupled with flow field models and rate processes to understand community responses to environmental change over long time periods. An example of a very high resolution flow model using an unstructured grid (Chen) was provided. Such a model would be of use to zooplankton ecologists by providing a detailed 3D flow field within which the copepods are transported. Results from the basin-scale model Yamanaka *et al* (NEMURO.FISH) were presented to show how large-scale models can be run over multiple decades to look at the effect of decadal oscillations in climate on ecosystems.

In reference to a recent talk by Charles Hannah, Cabell said that ecological analysis might be said to include a combination of approaches: Empiricists, Reductionist Modellers, and Holistic Modellers. Empiricists, by definition are data driven. They focus on identifying the patterns in the observations using statistical approaches. Reductionist modellers are mechanism driven. They believe that given enough mechanism detail, the emergent properties of a system will emerge from the noise. Holistic Modellers attempt to find the laws that give rise to emergent properties without simulating the details.

An interesting way of representing the relationships between models, data, and reality can be summarized in Figure 5.2.1 (modified from D. Lynch's presentation at the GLOBEC Pan Regional Meeting, 27–30 November 2006 in Boulder, Colorado, USA).
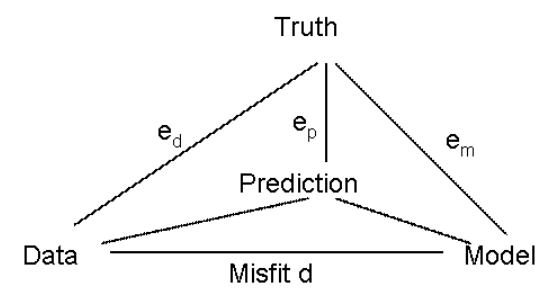
Figure 5.2.1. Relationships between models, data, and reality (modified from D. Lynch presentation at the GLOBEC Pan Regional Meeting in Boulder, CO).

A discussion of how this group feels about working with models followed the presentation. Wulf Greve felt that it was important to keep track of the changes in prediction. Rather than simply develop new models, we need to keep track of the changes in prediction that the

models provide as they evolve. The product is a prediction, and the goal is continually-improved prediction capability. Hindcasting from statistical models is certainly possible but one requires mechanisms for forecasting.

Catherine Johnson said that Ken Denman had a philosophy that you start with the data, and see how far off your predictions are from the data, and iterate the process. This led to a discussion of validation. How many of these models include a validation? Apparently this is being taken more and more seriously by the modelling community. Reference to Friedrichs *et al.* (in press) and to Dennis McGillicuddy's Model Skill Assessment Workshop was made regarding evidence for increased validation efforts. Friedrichs *et al.* (in press) found that as models increase in complexity, model misfit didn't change much. How might these types of models be included in the plankton status report?

Davis suggested it would be fruitful to combine with Charles Hannah's Working Group on Physical Biological Interactions (WGPBI) to explore how we might use our data and their models to elucidate mechanisms explaining our observed variation. Often the modellers are asking questions that cannot be covered by our data. For example: rate processes over a broad range of environmental conditions. These needs have not apparently reached our community because there has been a decline in simple experimental investigations to elucidate these rates. We also need to understand the frequently subtle and complex relationships between the individual zooplankton and its environment. Without an understanding of these mechanisms, it is extremely difficult to include factors such as temperature and food supply in a model of *Calanus* growth. It was decided that Astthor will pursue potential joint meeting with WGPBI next year.

5.3 Consider rate process studies and zooplankton phenology in association with time-series monitoring (ToR f)

(Lead: Wulf Greve and Astthor Gislason, Rapporteur: Mark Benfield)

Astthor Gislason gave the background for rate process studies involving zooplankton, saying that the idea that WGZE organise a workshop on biochemical and molecular methods to measure rate processes in zooplankton had been on our agenda every year since first proposed in 2002 (for a history of the idea within WGZE see ICES 2006a). The WGZE has been trying to push the idea to conclusion for several years now, together with the original proposers (Santiago Hernandes-Leon, Lutz Postel, and Rob Campbell). This is proofing to be a very complicated task, requiring among other things sophisticated facilities. When asking about the progress of the Workshop idea recently, Astthor received an e-mail answer from Lutz informing of limited or no progress. In response to the limited progress made, Astthor proposed that we do not once more put up a ToR on this, but let the idea rest. This does not have to mean that we cannot take this up on a later occasion. The group agreed that the issue be handled in this way, and that the Workshop idea be put on ice for now.

Wulf Greve introduced the session on phenology. Phenology can provide a powerful tool for understanding the status of species, communities and ecosystems in a changing environment. For example, the timing of spring production and the length of the productive season may change as a consequence of a changing climate. Zooplankton is – for one thing – a very good indicator of phenological change in the sea. The marine system so far has no phenological observation system, but should be initiated.

Phenology is the study of the timing of recurring events in nature (seasonal events). Obviously there are links to climate change as temperature affects life history events. The objectives of phenological research are: (1) to determine the sensitivity of life history to temperature; (2) record phenological trends and possible causes; (3) determine the functional relationships of phenophases with current (weather) and preceding (climate) temperature (utilizing NAO

indices); (4) determine the seasonality of populations; and (4) analysis of the match/mismatch for population dynamics.

Marine plankton phenophases are determined on the basis of changes in abundance either by cumulative sums or integers. Seasonality uses the differences in the end of season (EOS) and start of season (SOS) to determine length of season (LOS). An example was provided from the Helgoland Time Series of the week of the start of season of the arrival of *Pleurobrachia pileus* as a function of temperature. Another example showed how the SOS, MOS, EOS are occurring earlier for *Acartia* spp. and *Temora longicornis* (Greve *et al.* 2001) For *Acartia*, the LOS is getting slightly lower, while for *T. longicornis*, the LOS is expanding. Another example based on the work of Edwards and Richardson (2004) showed changes in the timing of spring bloom for different species of phytoplankton. Changes in the echinoderm peak based on CPR data from the central North Sea indicated that it is occurring progressively earlier with time.

Existing phenology networks are all terrestrial: European Phenology Network (EPN), USA National Phenological Network (USA NPN), UK Phenology Network (Nature's Calendar) Germany has the Phänologie im Deutschen Wetterdienst.

Climate history is really temperature history and organisms are very good indictors of changes in temperature. OSPAR/HELCOM should be encouraged to treat ecologically indicative species by:

a) determining the sensitivity of life history to temperature;

b) recording phenological trends and possible causes;

c) determining the functional relationships of phenophases with current (weather) and preceding (climate) temperature;

d) determining the seasonality of populations to focus inter-annual comparisons;

e) analyzing the role of match/mismatch for population dynamics;

f) initiating a phenological network for the European seas; and

g) providing public consultancy by phenological predictions.

Phenology is already a part of the Zooplankton Status Report and should be expanded. Wulf pointed out that he is approaching retirement and urged others to continue the work. One of the weaknesses of many time-series is their relatively coarse temporal sampling frequency. This makes it difficult to resolve changes on shorter time scales. Weekly sampling is desirable but the patterns found in Helgoland may be clearer than in other areas such as Stonehaven (e.g. sampling by Hay's group). If we are to urge zooplankton to be a mandatory monitoring element in OSPAR/HELCOM and other programmes, this will be critical for establishing phenological time series. Establishing a network, even a limited one, for phenological observations is going to be expensive but potentially very useful.

One issue that was raised was that if we have a lack of observed phenology in the presence of environmental forcing. How important is phenotypical plasticity in responding to changes in temperature? Another issue was that since most of our time-series don't have sampling at frequencies of weeks or days, can data on stage structure taken at the same time each year, be used to determine some phenological change? The answer to that is that it might be possible to assess some degree of interannual variability if one has a good mechanistic model of development and responses to temperature.

6 Changes in distribution of species in relation to climate change (including OSPAR Climate Request)

(Lead: Astthor Gislason and Priscilla Licandro, Rapporteur: Cabell Davis)

The session was preceded by an interesting talk by Bärbel Müller-Karulis of the Latvian Institute of Aquatic Ecology entitled: 'Climate-induced ecosystem regime shifts in the Baltic Sea' by Christian Möllmann (University of Hamburg) and Bärbel Müller-Karulis (Latvian Institue of Aquatic Ecology). Results were presented from the ICES Integrated assessment working group of the Baltic Sea and dealt with principal component analysis of long term time series from this region. The analysis demonstrated different regimes within the considered period (mid-70s to 2005), with major changes in ecosystem structure (regime shifts) being detected at the end of the 1980s.

After this presentation, the session began with an introduction by the Chair to ToRs i), m), and e) which dealt with changes in distribution of plankton in relation to climate change. In particular, ToRs i) and m dealt with the request from OSPAR for WGZE to report on the effects of climate change on zooplankton and phytoplankton, respectively.

The OSPAR climate request was for the WGZE: 'To prepare an assessment of what is known of the changes in the distribution and abundance of marine species in the OSPAR maritime area in relation to changes in hydrodynamics and sea temperature. The assessment should look at ecologically indicative species, including the threatened and declining species identified by OSPAR, for which adequate time series data exist, in order to assess to what extent there have been changes in distribution, population and condition of species going beyond what might have been expected from natural. The aim is to prepare an overview of as a major contribution towards JAMP ('Joint Analytical Model Programme') Product BA-3 and material that can be included in the Quality Status Report in 2010'.

This request was interpreted by ACE, ACME, and OSPAR to include: 1) ecologically indicative species, i.e., species that show responses to hydrodynamics and temperature on the spatial and temporal scales given below; 2) species that OSPAR have listed as threatened and declining; 3) only changes that can be attributed directly or indirectly to human activities; 4) the spatial coverage includes the OSPAR area on scales ≥100 km, and smaller scales may also be included provided that the changes are exceptionally severe; 5) temporal coverage includes the last 50 years with an emphasis on the last 10–20 years. The OSPAR request is for a short referenced report of about 5 pages of text and about 5–10 figures.

Astthor said that the report is to be prepared by the WGZE for the Working Group on Ecosystem Effects of Fishing Activities (WGECO) and should be submitted to them by April 7, 2007. WGECO then will meet on 11–18 April 2007 to review reports from all the EG groups given this task and will develop a response. The WGECO will report to ACE on 15 May 2007, and ACE then will process the WGECO report and submit it to OSPAR. In October 2007, the OSPAR working group on Marine protected areas, Species and Habitats (MASH) will provide feedback to OSPAR on the advice from ACE. Late in 2007, OSPAR will assign ToRs to EGs for 2008 that will focus on development of final products for the OSPAR Quality Status Report. By May 2008, ACE will produce the final response to OSPAR.

The WGZE will contribute to OSPAR's request, given the above requirements and time frame. Essentially, the request is to provide an assessment of the changes in distribution and abundance of marine species in relation to changes in hydrodynamics in the OSPAR area with emphasis on threatened or declining species.

Astthor pointed out that the WGZE can meet the request, in terms of plankton, by providing an overview of conditions in different regions, collating and discussing the findings, and preparing a draft report.

An overview and introduction to the problem was provided by Astthor and Pricilla, followed by a group discussion of plankton in each region, and a subsequent draft outline of a report,

which was prepared by Pricilla and presented to the WGZE and vetted by them on Wednesday morning.

Astthor explained the geographic extent of the OSPAR region (Figure 5.2.2) which includes the North-East Atlantic, extending westward to the east coast of Greenland, east to the continental North Sea coast, south to the Straits of Gibraltar and north to the North Pole. The region does not include the Baltic Sea and the Belts or the Mediterranean Sea and its dependent seas.
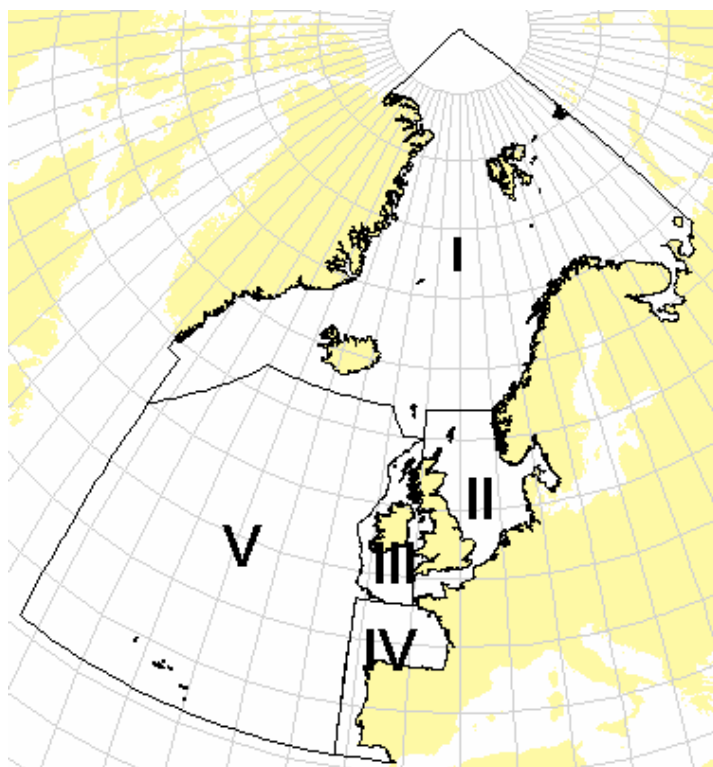
Figure 5.2.2: Map showing the OSPAR Maritime Area with division into subregions

An initial OSPAR list of threatened and/or declining species and habitats adopted by OSPAR in 2003 included the following numbers of species: 5 invertebrates, 5 birds, 13 fish, 2 reptiles, 4 mammals. It also included 14 habitats. In 2004, 2 fish species and 4 habitats were added. The list does not include phytoplankton or zooplankton.

6.1 Assess and report on changes in the distribution, population abundance and condition of phytoplankton in the OSPAR maritime area in relation to changes in hydrodynamics and sea temperature (ToR m)

Astthor and Priscilla presented an overview of changes in the distribution and abundance of phytoplankton in the North Atlantic as based on the scientific literature to address ToR m).

Phytoplankton Biomass — The CPR phytoplankton color index (PCI) has been shown to be a good index of phytoplankton biomass when compared with SeaWifs data (Raitsos *et al*. 2005). The PCI from 1948–95 revealed an increase in Central North Sea and Central NE Atlantic since mid 1980s but a decrease in the PCI in the Northern NE Atlantic during the same period (Reid *et al*, 1998). The SST had a similar trend and was influenced by NAO through air temperature (Reid *et al*. 1998, Edwards *et al*. 2001). Strong correlations have been found between the PCI and the NAO index, and a general increase in PCI was found in the southern North Sea from 1960–1995 (Edwards, 2000). Long-term trends were found in the relationship

between PCI and NAO, but the correlations were not strong (Barton *et al.* 2003). Using a random effects meta-analysis on CPR PCI data and SST, Richardson and Schoeman (2004) found that in colder, nutrient-rich regions, where turbulence is strong, an increase in SST led to increased stratification and increased PCI. By contrast, in warmer stratified regions with lower nutrients, an increase in SST led to increased stratification, and reduced nutrients and phytoplankton. Over the whole NE Atlantic, Edwards *et al* (2006) found a distinct increase in PCI from 1946–2004.

Phytoplankton Species — An example of a northerly shift in phytoplankton species was presented. The dinoflagellate *Ceratium trichoceros* distribution from the CPR data revealed a distinct increase in abundance in the CPR sampling region when comparing data before and after 1970 (Edinburgh Oceanographic Laboratory, 1973; Barnard *et al.*, 2004; Hays *et al.*, 2005). General eutrophication of the North Sea as evidenced by CPR estimated abundance increases in harmful algal species (Edwards *et al* 2006). *Prorocentrum* spp. increased throughout the North Sea while *Noctiluca* spp increased in the southern North Sea. *Ceratium furca* and *Dinophysis* spp. increased along the Norwegian coast.

6.2 Assess and report on changes in the distribution, population abundance and condition of zooplankton in the OSPAR maritime area in relation to changes in hydrodynamics and sea temperature. (further details on the interpretation and handling of this ToR will be provided by ACE) (ToR i)

A discussion of zooplankton then followed to address ToR i). In general, it was agreed by the WGZE that there is substantial evidence that zooplankton distributions are being strongly impacted by climate change. The WGZE therefore strongly recommends that zooplankton monitoring be an essential component of OSPAR sampling protocols.

Effects of climate on zooplankton and their consequences for marine food webs are clear. Beaugrand *et al.* (2003) showed from CPR data and cod catch data in the North Sea that a decreasing abundance of *Calanus finmarchicus* and concomitant shift toward the warmer water *Calanus helgolandicus*, was clearly associated with a reduction in cod recruitment. This study demonstrated the critical importance of zooplankton in the marine food web, fisheries yields, and their sensitivity to climate change. Likewise, Corten (2000) showed that the distribution of herring depends on the persistence of suitable food organisms, in particular abundance of *Calanus finmarchicus*. Using PCA, Beaugrand and Reid (2003) found strong relationships between NAO, SST, phytoplankton, *Calanus finmarchicus*, and salmon. Sims and Reid (2002) found parallel declines in *Calanus* and Basking sharks. Sea birds are strongly impacted by the abundance of sand eels which in turn is determined by abundance of zooplankton and phytoplankton (Frederiksen *et al.*, 2006).

Planque and Froementin (1996) found a strong relationship between *Calanus finmarchicus* and NAO from 1958–1995, but the correlation was not as strong after 1996 (Planque and Reid, 1998; Pershing *et al.*, 2004). Beaugrand *et al.* (2002) found a decrease in abundance of cold-water and arctic zooplankton species and an increase in warmer water ones in the NE Atlantic and N Sea.

In analyzing CPR data from the North Sea between 1960 and 2003, Hays *et al* (2005) observed a clear decrease in abundance of *Calanus finmarchicus*, an increase in *C. helgolandicus*, and a marked overall decrease in both species combined. Over the whole NE Atlantic, Edwards *et al* (2006) found a distinct decrease in copepod abundance from 1946–2004. In addition to copepods, phenological studies of invertebrate larvae (decapods and echinoderms) in the North Sea reveal a clear trend toward earlier seasonal peaks in abundance, indicating the effects of a warming environment. There have also been clear shifts in

community structure in the North Sea, from a low-diversity boreal community during the late 1970s to a higher-diversity warmer water community during the 1990s to present day.

The above information was to be used as a basis for a draft outline of the WGZE report to OSPAR. It was agreed that the outline would be prepared by Priscilla Licandro and presented to the WGZE on Wednesday morning.

During the first hour of the morning session (Wednesday 28 March), Priscilla Licandro presented an outline of the WGZE answer to the OSPAR Request based on previous day's discussions. The outline was approved by the group with some ammendments. The finalized document ('Report on the Assessment of Changes in the Distribution and Abundance of Plankton in the OSPAR Maritime Area') was sent to WGECO (Working Group on Ecosystem Effects of Fishing Activities) 10 April, and is attached as Annex 3.

6.3 Review and consider the impact on zooplankton communities of introduced or disappearing species (ToR e)

The final ToR addressed in the Tuesday afternoon session dealt with introduced or disappearing zooplankton species in the ICES area. Unlike ToRs i) and m), ToR e) was not restricted to the OSPAR region.

A distinction was made between introduced species and those species simply increasing in an area. The former are caused directly by humans via transport such as ballast water exchange.

It was noted that there is an increasing prevalence of the cladoceran *Penilia avirostris*, in the North Sea (Johns *et al*., 2005). The copepod species *Acartia omorii* was introduced through ballast discharge, while other species may have increased by natural processes including: 1) *Muggiaea atlantica* (Siphonophora) in the German Bight, 2) *Temora stylifera* (Copepoda) off the Spanish coast, 3) *Neocalanus cristatus* (Copepoda) in the North Sea.

Also in the more northern areas changes have been taking place. In the East Icelandic Current, to the north of the Faroes, for instance, a marked reduction in the abundance of the arctic copepod species *Calanus hyperboreus* has been observed, probably because of increased temperatures in the area. In the same area, a shift in the timing of the reproduction *of Calanus finmarchicu*s towards earlier reproduction, has also been observed.

Mysid and polychaete species have increased in the Gulf of St. Lawrence N America. Exponential growth of the hyperiid amphipod, *Themisto libilule*, has occurred in Gulf of St Lawrence.

The ctenophore *Mnemiopsis leydi*, which is native to the waters off the US east coast, from where it was introduced to the Black Sea in the 1980's by ballast water, has recently been recorded from the the Baltic Sea, the Kattegat and the North Sea, and has extended to waters off Bergen. *Mnemiopsis* is voracious and reduces fisheries yields. It is now becoming a problem in the Caspian sea. *Beroe cucumis* is a predator of *Mnemiopsis* in the North Sea, while *Beroe ovata* is its predator in the Black Sea. *Mnemiopsis* may become a big problem in the Baltic Sea. There has been a marked decline in fisheries yields in the Black Sea since the introduction of *Mnemiopsis*. In the Aegean sea *Mnemiopsis* is not a problem at present.

A number of species have increased in the North Sea including: *Calocalanus sp, Calocalanus, eucalanus, Clytemnestra scutellata, Corycaeus anglicus, Eucalanus, Mesocalanus tenuicornis, Neocalanus sp, Phaenna spinifera, Phronima sedentaria, Sapphriina stellata, Scottocalanus securifrons, Tharybis macrophtalma*.

Invasive species in the Baltic Sea (list provided by Juha Flinkman) are given in Table 6.3.1.

Table 6.3.1. Invasive species in the Baltic (list provided by Juha Flinkman)

SPECIES OR GROUP	OBSERVED	ORIGIN
Early invasive species		
Barnacle (*Balanus improvisus*)	1840's	North America
Aquatic plant (*Elodea canadensis*)	1870's	North America
Peregrine cockle (*Potamopyrgus antipodarum*)	1880's	New Zealand
Amphipod (*Coroophium curvispinum*)	1920–30's	Ponto-Caspia
Copepod (*Acartia tonsa*)	1930's	North America
Polychaete worm (*Polydora redeki*)	1960's	Western Europe
Gammarid amphipod (*Gammarus tigrinus*)	1975	North America
Recent invasive species		
Polychaete worm (*Marezelleria viridis*)	1985–1990	North America
Mysid (*Hemimysis anomala*)	1992	Ponto-Caspia
Cladoceran (*Cercopagis pengoi*)	1992	Ponto-Caspia
Zebra mussle (*Dreissena polymorpha*)	1995 (1820's?)	Ponto-Caspia

In general, there were 'natural' increases in non-indigenous species through such factors as warming climatic conditions. There also were truly invasive species introduced through ballast water exchange. In either case, the species and communities of zooplankton in the N Atlantic have a large influence on both upper and lower trophic levels and are being strikingly impacted by human activity. The continued monitoring and analysis of these populations is critical for proper understanding of fisheries yields and global carbon cycling.

7   Joint meeting with CIESM in 2008

7.1   Compare the zooplankton ecology of the North Atlantic and the Mediterranean (ToR c)

(Lead: Astthor Gislason and Ioanna Siokou-Frangou, Rapporteur: Steve Hay)

The group was introduced to the subject by the Chair, who reminded us that the WGZE had discussed this issue at previous meetings, notably the last in Villefranche 2006. Also the idea of collaboration with CIESM in a comparison between North Atlantic and Mediterranean plankton ecology had been raised in 2005. For marine ecosystems the need for comparisons and syntheses in plankton research is high. These must consider effects of climate change, eutrophication, pollution, harvesting, species introductions etc, and so the need is there for ecosystem approaches to both research and the provision of data and advice to management and policy groups. Making comparisons between contrasting and similar systems is a practical and useful approach. This process requires a coordinated approach, which also brings benefits from harmonisation of methods and approaches.

The WGZE has precedents for such collaborations in having met with PICES in Hawaii in 2000 and with WGPE in Bergen in 2001. The joint workshop - 'A Joint WGZE/CIESM Workshop to compare Zooplankton Ecology and Methodologies between the Mediterranean and the North Atlantic (WKZEM) (Co-Chairs: A. Gislason, Iceland, and G. Gorsky, France) to be held in October 2008' - was proposed in 2006 to ICES OCC and accepted by ICES Council in October 2006.

The WGZE discussed various aspects of plankton comparisons that could be made. It was noted that there are species in common between the North Atlantic fauna and that of the Mediterranean. Opportunity for local plankton researchers and modellers will be extended to consider greater latitudinal variations in phenology and in species functional and adaptive

responses to environmental variables across different systems. One paper has recently been published by a group including WGZE members. This paper compares the ecology of the eastern temperate Atlantic's ubiquitous copepod *Calanus helgolandicus* across the latitudinal gradient from the Mediterranean to Norway; other work on *Centropages typicus* is being set up. The Mediterranean has various different basins and areas which can be compared at a range of scales with the open Atlantic, and shelf seas such as the North Sea, Irish Sea and Baltic, down to estuaries and semi-enclosed sea areas.

The group was given an interesting presentation The Mediterranean Sea Zooplankton characteristics and perspectives: by Ioanna Siokou-Frangou and representing M. L. Fernandez, G. Gorsky and the CIESM MedZoo group. She described the broad status of the Mediterranean Ecosystems and species and gave insights into the current status and some results of major plankton research projects in the Mediterranean including MedZoo. Ioanna demonstrated the oceanography and plankton diversity in the region, highlighting some problem areas and showing the group some fascinating insights into some CIESM members' research.

The MedZoo (Mediterranean Zooplankton) group was organized in Barcelona in 2004 by the CIESM Zooplankton Indicator program. With a particular focus on time series data and monitoring work (approx 18 current and historical stations/datasets and several prospective sites), the objectives of MedZoo include:

- Establishment of a Mediterranean zooplankton expert's network, largely through regional or bilateral collaborations;
- Harmonization of sample treatments: both manual and automatic (i.e. ZOOSCAN and Image analysis systems) for enhanced comparative studies;
- Sample and data archiving (where possible in digital form).

MedZoo has a strong collaboration with SESAME (Southern European Seas: Assessing and Modelling Ecosystem changes). Most of the MedZoo scientists are also partners in SESAME; SESAME's goal is 'to assess and predict changes in the Mediterranean and Black Sea ecosystems and their ability to provide key goods and services'. The Black Sea being a strong example of how zooplankton dynamics and interactions with the influences of eutrophication, introduced species, climate changes and fish harvesting pressures, have resulted in dramatic ecosystem changes. Some specific aims in SESAME are the 'Identification of the major regime shifts in ecosystems that occurred during the last 50 years in the Black and Mediterranean Seas. Also, ecological models will be validated and upgraded using existing and new observations'. The MedZoo group also has links with other scientists and zooplankton experts in ICES areas through EU and other national research projects, examples include EUROCEANS and MARBEF.

The Mediterranean Sea is warm temperate - subtropical, almost a 'mini-ocean', with oligotrophic to ultra-oligotrophic regions, with average depth of around 1500m and having, few large rivers, several deep basins bounded by mostly narrow shelf regions. Surface salinity is 36.2 - 39 and temperature is 15 - 26 West - East and 13.5 - 14.9 in deeper areas from 200 - 1000m. Circulation is generally anticyclonic with several gyres (cyclonic and anticyclonic), fronts and areas of eddy formation and known regions of intermediate and deep water formation. Several studies have shown the links between climate and hydrography, so with plankton community and species dynamics.

Planktonic fauna of Atlantic origin do still exchange with the western Mediterranean; thus for copepod species 710 Atlantic species compares with 526 in the Mediterranean. Due to the Gibraltar sill (300m), there are no true bathypelagic fauna in the Mediterranean Sea, rather a deep expansion of mesopelagic species, with a prevalence of small and medium size species such as *Clausocalanus, Oncaea* and *Oithona*. In places there are some boreal relict species

such as *Temora longicornis* and *Pseudocalanus elongatus*. There are introductions such as from the Red sea (Lessepsian migrants), with several copepods and others such as the scyphomedusae *Rhopilema nomadica*, which interferes with fishing and tourism. Tourism has also been badly affected by periodic swarms of the oceanic jellyfish *Pelagia noctiluca* blooming into coastal seas and resort areas; blooms that appear favoured by high temperatures and dry conditions and which may exert significant controls on secondary producer dynamics at times.

Like the ICES WGZE the MedZoo group has a strong interest in modern data management and analysis issues and links with for example the PANGEA data centre. The WGZE was told that members of CIESM and MedZoo have had several meetings in which they have pre-prepared for particular presentations of work that have lead to notable publications. Thus they are keen to meet with WGZE, and to be prepared sufficiently in advance with, themes, agenda, data and collaborations, to better make a productive meeting. However, on the question of where and when, both groups' projects and associated cruises meant that there will be limitations as to when to get together with a WGZE/CIESM workshop.

After some discussion and consultation it was decided that the best time to hold this workshop would be latter half of October 2008 and that the place should be Heraklion, Crete, Greece. The group foresees that the workshop will be attended by c 60 scientists and that it will last for 4 days with oral presentations, working sessions, discussions and a short (half a day) field trip. Deliverables from the workshop would include a report in the ICES Cooperative Research Report Series and papers in peer reviewed scientific journals.

The following tentative agenda was proposed (as based on the resolution proposed and adopted by ICES in 2006). However, this is still very preliminary as it has to be discussed further both within and among the WGZE and CIESM scientists:

- Review and consider comparison of zooplankton ecology of the CIESM and the ICES areas;
- Overview of on-going time series programmes;
- Harmonization of methods, overview of experimental work;
- Appearance or disappearance of species vs. global warming;
- Autecology of key species.

8   Zooplankton taxonomic skills

8.1   Consider the development of web-based taxonomic training and the promotion of the ICES WGZE to a wider community (ToR g)

(Lead: Priscilla Licandro, Rapporteur: Webjörn Melle)

Priscilla Licandro introduced the working group to the subject by reviewing The ICES Crustacean Zooplankton Taxonomic workshop that was hosted by Sir Alister Hardy Foundation for Ocean Science (SAHFOS) under the auspices of MARBEF, Plymouth, 20–23 June 2006 (http://192.171.163.165/Event_taxonomic_wkshp_index.htm).

Steve Hay informed about the Scottish initiative to build a Planktonic species list website. The objectives are to build: A flexible system that allows various pieces of information to be stored at different taxonomic levels while maintaining a searchable structure. A system that is flexible, expandable, easy to search and easy to edit. The system can be expanded with information about genetics, rates, etc. The expectation is that this will be useful for plankton ecologists, teaching and outreach. SAHFOS will be asked to host the website which is to be finished in 2007. The working group expressed concern regarding the unsecured status of

many taxonomic data series (see EUROCEAN calls for Data rescue and data transformation activities: http://www.eurocean.org/).

Tone Falkenhaug informed about the MARBEF taxonomic training course, 'The Identification of marine macrozooplankton and (micro)nekton', to be held in Espeland Marine Biological Station, University of Bergen, Norway, 4–15 June 2007. The course will use MAR-ECO pelagic samples from the northern Mid-Atlantic Ridge collected on stations along the Mid-Atlantic Ridge from Iceland to the Azores (0-3000 m,). The following taxonomic groups will be addressed (lecturers in brackets): Amphipoda. (Georgyi Vinogradov), Euphausiids, (Alistair Lindley), Chaetognatha (Annelies Pierrot-Bults), Cephalopoda (Uwe Piatkowski), Mesopelagic fishes (Filipe Porteiro), curation of collections and barcoding (Endre Willassen).

Piot Margonski informed the group about the 'Baltic Sea Intercalibration of zooplankton analysis' (Ring Test). As an outcome of the First HELCOM MONAS Zooplankton Monitoring Expert Workshop in Warnemuende in March 2005, it was strongly recommended to organise an intercalibration exercise for zooplankton analysis in 2006. The Expert Group considered this as a basic activity of quality assurance. All zooplankton laboratories which contribute data to the joint HELCOM database were contacted and asked to participate. The Zooplankton Monitoring Expert Group recommended organising the activity jointly with the Baltic Sea Regional Project (BSRP) Lead Laboratory on Zooplankton and Ichthyoplankton to guarantee a joint quality level for interactive utilisation of data in the Baltic Sea area. The test was supervised by the Federal Environmental Agency of Germany (UBA). Samples were collected at one station located in the Gotland Deep during the Second HELCOM MONAS Zooplankton Monitoring Expert Workshop onboard of R/V Aranda in August 2006. Test samples were prepared at the Sea Fisheries Institute in Gdynia and then sent to UBA for distribution among participants. Results from the ring test are not available now, but will be soon.

Astthor told the group, that Dr Alistair Lindley has decided to step down as the Editor for the ICES Identification Leaflets for Plankton in September 2007. Astthor asked the members of group to consider people who would be interested in taking over the task. The WGZE needs to present a nomination resolution at the ASC in Helsinki for a new editor. In recent years, there have been no new leaflets although some are in preparation (ICES CM, 2006/Pub:04). The editorship is an important role not only for ICES but for the entire scientific community because the leaflets are used throughout the world. It would be important for the nominee to be active researcher, capable of looking at the leaflets with a critical eye, and who could be an advocate on behalf of ICES capable of attracting revisions or new contributions. Astthor said that there was a modest honorarium attached with the position. The working group acknowledged the good work done by Dr. Lindley.

There were no proposals made as to a new editor. Astthor urged the group members to involve in the search for a successor. It was decided that the WGZE would work on this intersessionally and that the WGZE members should look around for prospective editors in their respective labs and institutions and try to find a new editor. The aim is to present a nomination resolution for a new editor at the ASC in Helsinki in September 2007.

9 Census of Marine Life

9.1 Review and consider species biodiversity in zooplankton from coastal zones to oceanic deep sea: progress and prospects for the European Census of Marine Life Project (EuroCoML) (ToR h)

(Lead: Peter Wiebe, Rapporteur: Arno Pollumae)

Peter opened the discussion by giving an overview of the European Census of Marine Life Project (EuroCoML). The EuroCoML headquarters are based at the Scottish Association for Marine Science, with Professor Graham Shimmield as its Chairman and Dr Bhavani Narayanaswamy as the Project Officer. EuroCoML is a Regional Implementation Committee for the global Census of Marine Life project (CoML).

EuroCoMarL's aims are to:

- expand partnerships and coordination with relevant European programmes and organisations also in tandem with the general growth of the CoML;
- increase European participation in several particular CoML projects where untapped potential remains;
- improve marine taxonomy and species data in the European region;
- improve biodiversity and ecosystem information for applied resource management in waters where European nations hold major influence.

EuroCoMarL European Projects are:

- Environmental Modulation of Biodiversity Ecosystem Dynamics (EMBED) that focuses on coastal biodiversity.
- European Biogeographic Information System (EurOBIS), that has been developed within the MarBEF network and acts as the European node of OBIS. This distributed system to present biogeographic information will integrate individual datasets on marine organisms into one large consolidated database.
- Alien Invasive Species Workshop that was held in Oostende, Belgium, 10–11 March 2006.
- European Tracking of Predators in the Atlantic (EUTOPIA) seeks to describe and understand the movements and behaviour of marine vertebrates in relation to environment.

EuroCoML currently includes no zooplankton projects. The call for WORKSHOPS is now closed, so that the avenue of adding new projects is not available. WGZE should consider adding a project to be proposed to the EuroCoML Executive Committee that focuses on zooplankton. One question is whether MARBEF can help with the organizing and planning. Carlo Heip leads MARBEF and is also on the EuroCoML Executive Committee.

Peter then went on to describe the Census of Marine Zooplankton (CoMarZ), which is an ocean realm field project of CoML CoMarZ is addressing the overarching question: 'what are the patterns of zooplankton biodiversity throughout the world ocean, and how are they generated and maintained?'

For decades humans have mapped the oceans, charted the currents and faunal boundaries, and defined biogeographical provinces. The voyage of the HMS Challenger (1873 – 1876) was one of the earliest attempts to record global patterns of biological, chemical, and physical properties in the oceans. Our current understanding of global patterns of pelagic biodiversity results from decades of work by oceanographers, ecologists, and taxonomists. CoMarZ has established regional centres for scientific leadership, planning and implementation of field

activities, and fund rising. Three project offices have been established: in N. America (USA – Ann Bucklin), Europe (Germany – Sigrid Schiel), and Asia (Japan – Shuhei Nishida). The CoMarZ Steering Group reflects the project's geographic, taxonomic, and disciplinary diversity. The Steering Group guides the scientific and technical development; and ensures close coordination with other CoMarL field projects.

CoMarZ Goal is a taxonomically comprehensive, global-scale census of marine plankton, to produce accurate and complete information on species diversity, biomass, biogeographic distribution, and other individual and aggregate characters. CoMarZ seeks to analyse the ~6,800 described species – and likely discover at least this many new species – of marine metazoan and protozoan zooplankton by 2010.

One of CoMarZ approaches are DNA-based technologies (barcodes and phylogeny). DNA is particularly useful to study animal plankton, because the organisms are frequently rare, fragile, and/or small. Evolutionarily-conserved body plans for some groups (e.g., copepods) makes morphological identification difficult and mistakes likely. Many species are widespread or circumglobal, and DNA can be used to evaluate taxonomic significance of geographic variation. DNA-based species identification will speed analysis of samples for known species.

Comprehensive databases of DNA barcodes for zooplankton will provide a useful means of identifying known species and suggesting the presence of cryptic, unknown, or undescribed species. Only species for which barcodes are already present in the database can be reliably identified using barcodes. Rapid species detection may eventually be done using region- and taxon-specific DNA microarrays. Lab-on-a-chip miniaturization and automation may allow remote species detection from oceanographic platforms.

Peter Wiebe then described some CoMarZ Cooperating Projects. During 2005-2007, >25 field sampling efforts yielded zooplankton samples and environmental data for CoMarZ, either from ships of opportunity or dedicated cruises. Peter mentioned that in April 2006, a CoMarZ cruise took place to collect zooplankton and fish from the deepest waters of the NW Atlantic. Another cruise of opportunity for CoMarZ will be on the Polarstern in autumn 2007.

There is a CoMarZ Data Serving System (http://www.cmarz.org) with two components: 1) environmental and other information about collections and cruises; and 2) species pages.

A Network of people (Zooplankton taxonomists, ecologists, oceanographers, researchers, students, technical staff, and others who are committed to working toward the goal of completing a global biodiversity of holozooplankton by 2010) provide samples for the CoMarZ taxonomy work. The taxonomist Network will confirm the identification of species, collaborate on global surveys, prepare inventories of species and prepare a bibliography. Taxonomic experts provide information for the creation of species pages in their respective area of expertise.

After Peter's introduction, a discussion took place. There was consensus that WGZE should seek to collaborate with EuroCoML and CoMarZ, expand partnerships, and formulate future contributions.

As to techniques based on DNA analyses, Cabell S. Davis noted, that first results from DNA abundance analyses are now becoming available.

Tone Falkenhaug mentioned, that maybe it's too late to start cooperation with EuroCoML, since the project ends in 2010. Peter: Peter answered that all project objectives will not be concluded by 2010 and there will surely be some further actions.

Roger Harris asked about cooperation between CoMarZ Data Serving System Species pages part and the web-based database Steve Hay presented earlier. Interoperability is desirable in this case, and the best solution is if one database can communicate with the other.

Further discussion was about availability of samples for DNA analyses. There was common agreement, that there are plenty of samples but main problem is in manpower, since the samples need to be sorted first.

Steve Hay noted that an inventory of samples and activities be created and made available for CoML.

At the end of the discussion, it was decided, that Sigrid Schiel will contact EuroCoML and inquire what kind of cooperation are they expecting from WGZE. Sigrid Schiel will also send a file with an inventory of zooplankton specialists and their expertise, to be updated.

10   New Phytoplankton Working Group

10.1   Take part in the intersessional work led by PGPYME in developing the mission and draft resolutions for a new working group related to phytoplankton and microbial ecology (ToR k)

(Lead: Luis Valdes, Rapporteur: Steve Hay)

The group was informed that ICES had dissolved the WGPE due to lack of commitment, and was seeking through a Planning Group on Phytoplankton and Microbial Ecology (PGPYME), lead by John Steele, Franciscus Colijn, and Ted Smayda, to form a new ICES Working Group on Phytoplankton and Microbial Ecology (to start 2008) (OCC report 2006). The advice from OCC is that the Chairs of the PGPYME correspond with the WGPBI, WGZE, WGHABD, and WGRP to develop a firm proposal for the mission of the group, including a proposal for Chair, initial ToRs, date and venue, and supporting information

The OCC committee had also noted the comments from various groups that the demise of the WGPE was unfortunate and calling for its re-formation in some form. In particular, the Workshop on Time Series Data Relevant to Eutrophication and Ecological Quality Objectives (WKEUT) recommends that ICES continue to support a working group on phytoplankton ecology, particularly a group to deal with phytoplankton ecological processes. Inclusion of expertise on long term data sets in this WG is also recommended. Further, given the ecosystem relevance of long-term time series, the WKEUT recommends the collaboration of phytoplankton scientists with those dealing with higher trophic levels. This includes convening joint ICES workshops and symposia, and dealing with issues such as top-down and bottom-up effects and regime shifts, etc (ICES, 2006c)

It was noted that the WGZE had strongly supported the need for the WGPE in the past. In fact, the two groups had had a joint meeting earlier (in Bergen 2001; ICES, 2001). However the WGZE had resisted the suggestion that WGZE become an overall plankton group and take on WGPE Terms of Reference. This case had been argued to the OCC and they had agreed (For our arguments for this position see Annex 3 in ICES 2006a).

So having heard the background, the group began to discuss the ToR. It quite soon became apparent that the PGPYME group had not progressed very far with their deliberations, or at least had not communicated much to WGZE as yet. The major point raised was that a newly formulated WGPE should include Phytoplankton and Microbial Ecology in its title and expertise. This reflects the close links between these disciplines and the need for a new more integrated WG approach, which would serve also to reflect the increasing importance and awareness of microbial ecology being as fundamental as phytoplankton in marine systems. This was noted especially by the WGZE which was aware that proto- and microzooplankton were research areas which were not well represented in their own ranks; yet it was agreed very important and likely areas for interaction between WGZE and any future WG on Phytoplankton and Microbial Ecology.

Further discussion proved that there were two difficulties for the WGZE. Firstly, since none present were expert in these fields, it was not easy for the group to just come up with suggestions for names to lead or participate in a new WG without more thought and reference to contacts and colleagues 'back home'. Secondly, given the current situation and the widened remit for a new WG, the WGZE felt that it should not at this point spend time suggesting Terms of Reference for a new group. This should be a job for the OCC, the PGPYME and those experts who they could encourage to initiate and participate in a new group. The WGZE agreed that members would contact Luis Valdes with their individual suggestions for Chair and candidate members of a new Study or Working Group. In the meantime Luis would contact John Steele and PGPYME to discuss their progress. It was noted that there was really quite a short time to get such a new group off the ground, but that perhaps a workshop at the 2007 ASC might advertise and provide an opportunity for interested researchers to come together to discuss issues and to form a group.

Finally it was reiterated by the WGZE that, given the calls and policy directives for more integrated working and an ecosystem approach, The WGZE again strongly recommends that a new WG on Phytoplankton and Microbial Ecology is formed by ICES. It is not really possible for WGZE and many others in ICES and elsewhere to address many of the important issues in marine ecology or marine system management and policy without reference to such expertise and their associated data.

11   Report on the Basin programme

(Lead: Peter Wiebe, Rapporteur: Roger Harris)

Peter Wiebe introduced the current status of the BASIN, Basin-scale Analysis, Synthesis and Integration, initiative, which seeks to foster a co-coordinated joint US, Canadian and EU research programme in the North Atlantic basin. In his introduction he noted that BASIN had very much developed out of some of the data networking activities encouraged by the WGZE. It was highly relevant to the interests of the WGZE.

The justification for the BASIN programme is the scale of influence of global change and the added value of co-coordinating the scientific activities of the EU and North American countries to assess, predict, and mitigate the impact of climate and anthropogenic forcing on marine ecosystems and services of the North Atlantic. A crucial step towards such a co-coordinated approach is the development of an implementation plan whereby jointly funded international projects can be supported. The development of such a plan is the first key goal of BASIN. The second goal of BASIN is to develop an integrated basin scale North Atlantic science plan. The BASIN programme will seek to:

- understand and simulate the population structure and dynamics of broadly distributed, and trophically and biogeochemically important plankton and fish species in the North Atlantic ocean;
- resolve the impacts of climate variability on marine ecosystems and the feedbacks to the climate system, and to develop understanding;
- develop models that will advance ocean management.

Support for BASIN, to hold four meetings in 2007, has been provided by the US NSF and the EU 6th Framework Specific Support Action (SSA) (Sub-Priority 1.1.6.3). The scale of influence of global change and the added value of coordinating the scientific activities of the EU and North American countries to assess, predict, and mitigate the effects on marine ecosystems of the North Atlantic and their services is the justification for the development of the SSA.

These workshops will build on the actions identified in the 2005 BASIN Workshop in Reykjavik jointly funded by NSF and EUR-OCEANS. Full details of the outcome of the Reykjavik meeting can be found in the report (Wiebe, P.H., R.P. Harris, M.A. St. John, F.E. Werner and B. de Young. (Eds.). 2007. BASIN. Basin-scale Analysis, Synthesis, and INtegration. GLOBEC Report 23 and U.S. GLOBEC Report 20. 1–56pp).
http://www.globec.org/structure/multinational/basin/BASINweb.pdf

The development of the programme goals began at a meeting held in Hamburg in January 2007 and will continue at a second meeting to be held at the beginning of May in North Carolina. These meetings involve open discussion in working groups with experts from both the EU and North America. The approach taken towards the development of a science plan for BASIN begins with:

- The assessment of the status of climate-related ecosystem research in the North Atlantic Basin and associated shelf seas;
- Identification of the gaps in systematic observations and process understanding of atmospheric and oceanic parameters;
- Identification of the potential for consolidation of long-term observations from EU and international databases for modelling and prediction.

The BASIN science plan will focus on resolving the natural variability, potential impacts and feedbacks of global change on the structure, function, and dynamics of ecosystems. The programme will also seek to improve the understanding of marine ecosystem functioning. Improved understanding and modelling will be applied to the development of new and improved approaches to ecosystem-based management. BASIN will contribute significantly to the Global Earth Observation System of Systems (GEOSS) 10-Year Implementation Plan via the development of comprehensive, coordinated, and sustained observations of the earth system, improved monitoring of the state of the earth, increased understanding of earth processes, and enhanced prediction.

The report, from the Hamburg meeting, can be found at:
http://web.pml.ac.uk/globec/structure/multinational/basin/Reports/Hamburg_MeetingRpt.pdf

The report summarizes the activities and discussions from the first of four BASIN meetings to be held during 2007. These meetings are supported by the EU Specific Support Action BASIN and the NSF. The purpose of this European meeting was to start the process leading to the development of a Science Plan that would enable the integration and advancement of observation, monitoring, and prediction of ecosystems of the North Atlantic basin and shelf seas in order to assess the impact of climate variability and change on their processes. A number of questions for potential further development were identified during the Hamburg Workshop. These include:

- How will climate change, as manifested through changes in, e.g., temperature, stratification, transport, etc., influence the phenology of features such as the spring bloom, the flux of carbon to the deep ocean, and interactions between trophic levels? How do these dynamics differ from the shelf to the open basin? What are the potential feedbacks to climate?
- Has the harvesting of resources such as fish stocks resulted in a restructuring of marine ecosystems? How do these changes in ecosystem structure influence the sequestering of carbon in the deep ocean and on the continental shelves as well as the resilience of these ecosystems?
- How are the populations of phytoplankton, zooplankton, and icthyoplankton influenced by the present large-scale basin circulation and what is the influence of changes of the oceanic and atmospheric climate on their population dynamics?
- How do the overwintering strategies of organisms, involving both vertical and horizontal migration, lead to the observed patterns of community structure?

The second BASIN SSA Workshop will be held at Chapel Hill, North Carolina, 1–3 May, 2007.

The goal is to build upon previous and ongoing research in the North Atlantic, integrating and synthesizing the results of these programmes, thus determining the mechanisms that link zooplankton, fish, ocean biogeochemistry, climate and environment at ocean basin scales. The Hamburg meeting had primary input from European participants, with limited representation of North American scientists. The Chapel Hill meeting will build on the Hamburg results with greater representation from North Americans than from Europeans.

1) Assess and report on the status of climate-related ecosystem research in the North Atlantic basin and associated shelf seas (from Georges Bank to the Barents Sea and the North Sea shelf) conducted intensively over the past decade particularly through national GLOBEC programmes (US, Canada, UK, Germany), GLOBEC related projects (ICES, Mare Cognitum), and EU projects, particularly ICOS and TASC.

2) Identify and document gaps in systematic observations and understanding of atmospheric and oceanic parameters, necessary to improve forecasting of ecosystems in the North Atlantic and associated shelves.

3) Identify via the development of a meta-database the potential for consolidation of long-term observations from North American, EU and other international databases for the modelling and in particular prediction of the dynamics of North Atlantic and associated shelf ecosystems and their services (biogeochemical and exploited resources).

4) Consider the feasibility of producing a science plan for the future development a BASIN research programme on:

- Resolving the natural variability, potential impacts and feedbacks of global change on the structure, function, and dynamics of the ecosystems of the North Atlantic Basin and associated shelf seas;

- Improving the understanding of marine ecosystem functioning in North Atlantic Basin and associated shelf seas;

- Developing ecosystem based management strategies that incorporate the effects of global change and hence contribute to the sustainable use of the marine resources of the North Atlantic Basin and associated shelf seas.

This will be an open meeting and interested scientists are welcome to participate at their own expense, with total attendance capped at 40 participants.

Further information, documents, and news of the development of the BASIN programme can be found at:

http://web.pml.ac.uk/globec/structure/multinational/basin/Reports/Hamburg_MeetingRpt.pdf

12   Zooplankton studies in the Baltic

Lead: Piotr Margonski, Rapporteur: Juha Flinkman

During the Baltic Sea Mini Session, the following ten presentations were provided:

1) 'Short overview of Baltic Sea activities' by Piotr Margoński;

2) 'National Research Programme: Climate Change Impact on the Water Environment of Latvia' by Andris Andrushaitis;

3) 'Trying to find out more (about marine mesozooplankton)' by Anda Ikauniece;

4) 'Baseline Port Surveys for Invasive Marine Species in the North-Eastern Baltic Sea' by Solvita Strake;

5) 'Monitoring of zooplankton in the SE Baltic' by Natalja Demereckiene;

6) 'Zooplankton in the South-East Baltic' by Julia Polunina;

7) 'Hydrological regimes instability and climate changes influence on zooplankton community of open parts of the Baltic Sea and the Gulf of Finland' by Larisa Litvinchuk;

8) 'Recent newcomers in zooplankton of Estonian coastal areas' by Arno Põllumäe;

9) 'Zooplankton monitoring as it is carried out by FIMR' by Juha Flinkman;

10) 'Sea Fisheries Institute zooplankton activities' by Piotr Margoński.

1. Short overview of Baltic Sea zooplankton activities (Piotr Margoński)

Piotr gave an overview of the most important international actions undertaken by Baltic zooplankton scientists. Those carried out by the HELCOM MONAS Zooplankton Expert Network include regular workshops, gear intercomparison (WP-2 nets: 60 μm, 100 μm, 200 μm; Juday net 90 μm), ring test, improving the biomass equivalents for the mesozooplankton (carbon mass conversion factors), and the problem of *Mnemiopsis* in the Baltic Sea. There are also numerous 'ICES related' activities: ICES/BSRP Workshop on Recruitment Processes of Baltic Sea herring stocks (27 February to 2 March 2007, Hamburg, Germany), ICES/HELCOM Working Group on Integrated Assessments of the Baltic Sea (12–16 March 2007, Hamburg, Germany), In-Ex-Fish Project: Incorporating extrinsic drivers into fisheries management (FP6- 022710). In each of these cases zooplankton data are useful explanatory variables. Many of activities mentioned above are supported by the GEF funded Baltic Sea Regional Project. One of the key goals of this project is searching for successful indicators of eutrophication and productivity.

2. National Research Programme: Climate Change Impact on the Water Environment of Latvia (Andris Andrushaitis)

In June 2006 environmental research was adopted as one of Latvia's nine research priorities. The National Research Programme 'Climate Change Impact on Water Environment of Latvia' started later in the same year. The programme's general tasks are to 1) assess possible climate change impacts on the quality of inland waters of Latvia, their availability, flood and drought risk; 2) facilitate adaptation of the drainage basin management and secure protection and sustainable use of water resources, and to forecast possible climate change impact on the physical regime, coastal dynamics, bio-geo-chemical regime, and ecosystems of the Baltic Sea; 3) to facilitate protection of marine environmental quality, biological diversity, and sustainable use of its resources and services. The programme consists of nine mutually interlinked work packages, three of which address specific marine issues: coastal processes, bio-geo-chemistry, and marine ecosystems, while one focuses on the links between science and policy. Partners are three universities and several research institutions, among them the two major national centres of marine research: Latvian Institute of Aquatic Ecology and Latvian Fish Resource Agency. Importantly, Latvia's national research programme will serve as a platform to secure participation in the future Joint Baltic Sea Research Programme (BONUS). More information on the National Research Programme is available at www.kalme.daba.lv , and on BONUS - at www.bolusportal.org.

3. Trying to find out more (about marine mesozooplankton) (Anda Ikauniece)

Anda Ikauniece presented a short description of the main issues related to zooplankton monitoring carried out by the Latvian Institute of Aquatic Ecology. The monitoring part has been dominating for almost 15 years; therefore not much basic research has been carried out at the Institute.

Zooplankton monitoring in its present form started in 1993 in both Latvian marine areas, the southern Gulf of Riga and the Eastern Baltic Proper. Some stations at the coastal zone of the Gulf have been monitored since 1980. Zooplankton monitoring is always fulfilled as a part of

integrated marine environmental monitoring, so basic physical, chemical and hydrobiological parameters are available.

A few examples of interesting findings of the monitoring activities:

1) A dramatic decrease of the calanoid copepod *Limnocalanus macrurus* abundance was observed, beginning in early 1980's. This species is the biggest copepod in the Gulf, and it prefers oxygen rich and cold waters, and inhabits the deeper parts of the Gulf. The reasons for the decline are not quite clear as no correlations were found with oxygen content or water temperature. Besides, none of the abiotic factors showed any drastic changes. Most likely, the decrease can be explained by the combined effect of several factors, including predation, eutrophication and warmer winters. A factor in this, may also be the higher nutrient content together with relatively warm winters that affect the species composition of spring phytoplankton, switching from diatom dominated to larger role of dinoflagellates, which are not favourable food for *L. macrurus* development and growth.

2) An interesting feature has been noticed in the diel vertical migration of *Limnocalanus* in the Bothnian Bay (Northern Baltic Sea). The animals migrated towards surface during daytime and descended at night thus having an opposite directions to those most commonly observed and described in the literature. Copepods obviously try to avoid the predation by mysids abundant in this area and therefore use a different migration pattern to avoid predators.

3) A small cladoceran species *Bosmina longispina* is one of the dominant zooplankter in summer in the Gulf of Riga and also known for its large interannual variations in abundance. The variability is most likely influenced both by conditions in the sediments, and even more by the abundance of the invasive predatory cladoceran *Cercopagis pengoi*.

4. Baseline Port Surveys for Invasive Marine Species in the North-Eastern Baltic Sea (Solvita Strake)

Biological invasions have resulted in comparably large-scale ecological changes and economic damage worldwide. The examples of invasions in the 1980's and 1990's in the NE Baltic have shown that successful exotics may render previously stable systems unbalanced and unpredictable and may severely affect biological diversity in the area.

Taking into the account the importance of shipping in the introduction of new species and also for the economy, biological investigations in port areas are of utmost importance. Still, in several port areas of the eastern Baltic Sea, biological data are very incomplete and scarce, or are even missing. Development and implementation of a special regional action plan for prevention and control of alien species introductions into this area is needed and should be carried out at international level.

Considering the above mentioned knowledge and the present status, i.e. total lack of information on planktonic, benthic and epifaunal composition in the Latvian ports (ports of Liepaja, Ventspils and Riga), the project 'Identification and distribution the invasive species at the ports of Northeastern Baltic Sea' funded by Phare Cross Border Co-operation Programme was initiated. The main objectives of the project were: 1) investigation the distribution and population dynamics of the planktonic and benthic including invasive species in relation to spatio-temporal dynamics of the key environmental parameters; 2) assessing the risk of alien aquatic organisms in the high-risk areas for biological invasion in the north-eastern part of the Baltic Sea.

5. Monitoring of zooplankton in the SE Baltic (Natalja Demereckiene)

Analysis of zooplankton data in spring from the Southeastern Baltic Sea revealed long-term variations in relative abundances of different zooplankton taxa. The relative abundance of

copepods decreased while that of rotifers increased. An increase in trophity was observed as the abundance of copepods decreased and the abundance of rotifers and cladocerans increased.

In summer of 2002 and 2005, cladocerans in the Southeastern Baltic made 80–65 % of the total zooplankton abundance. In 2003, the rotifers made 65 % of the total zooplankton abundance. Data shows that the process of trophity has been going on.

6. Zooplankton in the South-East Baltic (Julia Polunina)

Julia Polunina told us about investigations being carried out in the north-eastern part of the Vistula Lagoon (1996–2006) and the southern part of the Curonian Lagoon (2001–2006) and the south-eastern part of the Baltic Sea (2001–2003).

In the *Curonian Lagoon* summer zooplankton consisted of 63 species. Comparisons of our data with data from 1930s (Schmidt-Ries, 1940) revealed: 1) increase of large crustaceans of and decrease of rotifers, forming the complex of dominant species; 2) increase in average body size of crustacean species; 3) increase in size of food items for the species in the dominant complex. These changes in zooplankton communities indicate significant qualitative changes in zooplankton feeding resources in the Curonian lagoon, in particular with the increase of total concentration of suspended matter, and the proportion of organic matter and large-sized organic particles in suspended matter.

In the *costal zone of the south-eastern Sea (Kaliningrad region)* the zooplankton consisted of 30 species. Species of brackish-water complex (*Acartia, Synchaeta*) predominated during the study period. We recorded the mass development of the eurytermic and euryhaline species *Acartia*, the presence of Ponto-Caspian species *Ceropagis pengoi* and the total absence of stenotermic and stenohaline species *Pseudocalanus elongatus* and *Oithonia similes*. The abundance of warm-water zooplankton species was higher during 2001–2003 than in the 1980's. This change was possibly mediated through changes of the North Sea inflows and water temperature increase in the open area of the Baltic since mid-1990s.

In the *Vistula Lagoon* 66 species of zooplankton were observed. Specific hydrology of the lagoon allows the mass development of populations consisting of a few species. Only *Eurytemora affinis* can be a dominant species in the lagoon (more than 50 % of biomass). In the seasonal dynamics of zooplankton abundance and biomass, two peaks were observed, the former in May and the latter in August. The zooplankton abundance sharply decreased in the Lagoon in the end of June. Thus the feeding resources for zooplankton were sufficient in June. The main controlling factor of zooplankton abundance is the herring fry.

Ceropagis pengoi was first recorded in the Vistula lagoon in August 1999, and has since been present annually in the zooplankton in the whole Lagoon. A significant decrease of filter-feeding cladocerans and copepod nauplii has been observed during *C. pengoi* mass development in the Lagoon. These crustaceans are considered as important food source of *C. pengoi.*

On the whole, the species composition of zooplankton in the Vistula Lagoon changed somewhat during 1980s: the decrease of number of freshwater species and increase of number of brackish-water species (for example: *Acartia tonsa*, *C. pengoi*) was noticeable, in comparison with date 1930s. However, the dominant species complex did not change. It indicates that feeding resources for zooplankton have not changed significantly during last century in the Vistula lagoon.

7. Hydrological regimes instability and climate changes influence on zooplankton community of open parts of the Baltic Sea and the Gulf of Finland (Larisa Litvinchuk)

Material for this study was collected on cruises of the r/v Stockmann from 2004–2006. Increasing water salinity after salt water flows influenced on zooplankton community of the Baltic Sea. In 2004, the highest zooplankton density was registered at the border between the Gulf of Finland and the Baltic Proper reflecting increasing abundance of small rotifers. The density peak of the rotifers did not depend on chlorophyll *a* concentration nor surface temperature.

During summer of 2004, euryhaline marine zooplankton Baltic species have been spreading into all parts of the Gulf of Finland (with the exception of the Neva Bay). In 2005 and 2006, only freshwater and brackish water zooplankton species dominated in the Gulf of Finland. Two copepod species, formerly common for the Baltic Sea, were no longer observed in the Baltic Sea.

Three species of predaceous cladocerans and two benthic species that have meroplanktonic larvae, have invaded the Baltic Sea. In the Gulf of Finland from 2004 to 2006, *Cercopagis pengoi*, *Dreissena veligers* and *Marenzelleria* larvae were the most abundant among all invaded species. In the near future, the list of zooplankton species of the Gulf of Finland may increase due to invasion of four podonid species and one cercopagid species. These polyphemoids (in exception of one northern Atlantic species) inhabit fresh- and brackish water parts of the Ponto-Caspian basin, similar to other recent Baltic invaders.

8. *Cercopagis pengoi, Maeotias marginata, Evadne anonyx* – recent newcomers in zooplankton of Estonian coastal areas (Arno Põllumäe)

Cercopagis pengoi is one of the most studied invasive species during recent years in the Baltic Sea. It was first found in Estonia and in the Baltic in Gulf of Finland and Gulf of Riga 1992. This Ponto-Caspic species also gets publicity in nonescientific press because it can clog fishing nets. The main changes after the invasion is a decrease in the abundance of native cladocerans. A shift in the timing of population development of *Eubosmina maritima* in the Gulf of Riga has also occurred; after the invasion, populations have disappeared from the zooplankton community several weeks earlier than before the invasion.In the trophic web, *C. pengoi* has taken a position between the mesozooplankton and planktivorous fish.*Maeotias marginata* is the only hydromedusa in Estonian waters. It was first found in West-Estonian Archipelago in 1999. Only a few records of this species are made since in same area. It is never very abundant and occurs only in late summer during the blooms of native *Aurelia aurita.*

Another ponto-caspic predatory cladoceran *Evadne anonyx* was first recorded in Baltic Sea in 2000. As this species can easy be misidentified as native *E. nordmanni*, the exact time of invasion is yet unknown and has to be confirmed by reanalyzing old samples.

9. Zooplankton monitoring as it is carried out by FIMR (Juha Flinkman)

Finnish Institute of Marine Research has carried out zooplankton monitoring as part of HELCOM Combine monitoring programme since 1979. Stations span Northern Baltic Proper down to Gotland Island, Gulf of Finland, and the Åland Sea – Gulf of Bothnia complex.

Analysis of this monitoring data shows significant trends, which however are different between sub-areas. In the Baltic Proper and Gulf of Finland, neritic copepod *Pseudocalanus acuspes* decreased, whereas other copepods, including species such as *Temora longicornis* that are favored by planktivorous fish, increased in abundance and biomass. Surprisingly, marine cladocerans *Evadne, Podon and Pleopsis* decreased as well.

In the Gulf of Bothnia system the development was somewhat different. In general, an increase in most groups could be detected, also in those much favored by planktivorous fish. This was especially evident in the Bothnian Sea.

These changes are probably caused mostly by abiotic factors. In Baltic Proper and Gulf of Finland, the most important forcing factors are decrease in salinity, and increasing volume of poor- or anoxic deep water. The Gulf of Bothnia is separated from the Baltic Proper by Salpausselkä sill south of Åland islands, which prevents the saline deep water from entering. This protects the area from the effects of anoxic deep water, but the general trend of increasing zooplankton biomass can be interpreted as a sign of general eutrophication in its early stages.

FIMR has also experimented with towed plankton samplers such as CPR and Utow. The comparisons between these and WP-2 nets show that the towed samplers undersample in comparison to a vertical net. This is caused by the shallow running depth, larger mesh size, and problems in estimating actual filtered volumes. In order to use data collected with towed samplers together with vertical net data, these problems must be solved.

10. Sea Fisheries Institute zooplankton activities (Piotr Margoński)

Piotr concluded the Baltic session by giving a short overview of zooplankton studies of the Sea Fisheries Institute of Gdynia, Poland. The institute is mostly focused on fish recruitment studies including trophic interactions between ichthyoplankton and zooplankton. Zooplankton samples are collected in the southern Baltic Sea (Polish, Danish, and Swedish EEZ) at 60 stations 2-3 times a year. The second study area is the Polish part of the Vistula Lagoon where samples are taken at 12 plankton stations several times a year mostly in spring and summer.

13   Next meeting (2008)

As noted in Section 5.2, the group feels it may be fruitful that the WGZE combine with the ICES Working Group on Modelling Physical Interactions (WGPBI) to explore how data and models may be used to elucidate mechanisms explaining the observed variation. During the meeting, the Chair (Astthor Gislason) called Charles Hannah, the other Co-Chair of WGPBI, and proposed to him that the groups would have their next annual meetings at the same time and place (University of Montpellier, France, where Dr Delphine Bonnet of the University of Montpellier has generously offered to host the meeting), with a one-day overlap for a joint meeting. The proposal was very well received by Charles Hannah and his group.

Some consultations followed as to when such a meeting should take place. Through post-meeting correspondence within both WGZE and WGPBI, the decision was made to hold the next (2008) meeting of the ICES Working Group on Zooplankton Ecology in the University of Montpellier, Montpellier, France, from 31 March to 3 April, kindly hosted by Dr Delphine Bonnet of the University of Montpellier. WGPI will run their meeting in parallel and it was decided that the two groups would have the one day overlapping meeting 2 April.

14   Actions, recommendations and draft resolutions

14.1   Actions

WGZE will continue working intersessionally for the achievement of the following actions and deliverables:

- Work towards finding a new editor for the Plankton identification Sheets to replace Alistair Lindley. The aim is to present a nomination resolution for a new editor at the ASC in Helsinki in September 2007 (Astthor Gislason).

- Collate taxonomic list from all time series sampling sites available in the ICES area for the next WG meeting (Damien Eloire).

- Make an inventory of zooplankton specialists and their expertise (Sigrid Schiel).

- Propose a ToR or a Theme Session on the role of microzooplankton for the upcoming WKZEM Workshop at the end of October 2008, in Heraklion, Crete (Astthor Gislason).

- Look for candidate members of a new Study or Working Group in their respective laboratories and send their suggestions to Luis Valdes, Chair of OCC (all)

- Actions in relation to future Plankton Reports (see also Section 5.1) (Luis Valdés, Todd O'Brien and Angel Lopez-Urrutia):

  1) Bring in more ICES countries to contribute to the Status Report. Russia (Vistula Lagoon, Barents Sea, Norwegian Sea).

  2) Enlarge the area covered by the Status Report to the Mediterranean Sea.

  3) Include data on the top ten species from more areas.

  4) Include at least one paragraph discussing previous topics.

  5) Include a discussion on the relationship between stratification and abundance pending on the temporal and spatial resolution of the data.

14.2 Recommendations

The ICES Working Group on Zooplankton Ecology recommends to the Oceanography Committee the following Theme Sessions for the 2008 ICES Annual Science Conference. Supporting information is given in Annex 4.

'Evidence of global warming effects on zooplankton populations and communities, including larvae of benthic invertebrates and fish.' Conveners: Wulf Greve, Steve Hay and Peter Wiebe.

14.3 Draft resolutions

WGZE Terms of Reference proposed for 2008

After discussion of future ToRs, the following suggestions were made, which cover review of plankton research and methods as well as maintaining and developing collaborative approaches and the useful products of the WGZE, particularly the ICES Plankton Status Report (Annex 5):

a) make a review of species lists from time series stations and/or areas;

b) review the response of OSPAR to the report of the WGZE particularly in regard to incorporating zooplankton monitoring into regulatory schemes and programmes;

c) combine field and laboratory data together with biological-physical models to examine processes controlling zooplankton populations;

d) compare different nets and mesh sizes and their efficiency;

e) compare/evaluate different measures for zooplankton biomass from regions within the ICES area;

f) review the planning of the WGZE/CIESM Workshop;

g) review the planning of a new working group related to phytoplankton and microbial ecology;

h) produce an evidence based rationale for incorporating zooplankton monitoring into regulatory assessment frameworks;

i) review evidence of the effects of climate change on plankton and review the outcomes of the 4th ICES/PICES/GLOBEC International Zooplankton Production Symposium;

Proposal for publication of Plankton Status Report

WGZE proposes that the Plankton Status Report be published in the ICES Cooperative Research Report series. Supporting information is given in Annex 6.

15   Closure of the meeting

Astthor Gislason (Chair) thanked all members for their contributions and the stimulating discussions. He also thanked the colleagues from the Baltic for their contributions and Dr Solvita Strake for her kind hospitality and the excellent organization. Astthor Gislason looked forward to seeing the participants at the meeting next year.

The meeting was closed at 12:30 on 29 March 2007.

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Annex 2: Agenda

Monday 26 March

11:00-12:30	**OPENING, AGENDA, ANNOUNCEMENTS**
12:30-14:00	Lunch
14:00-15:30	**DATA MANAGEMENT ISSUES** (Lead: Peter Wiebe, Rapporteur: Priscilla Licandro)

ToR i) discuss and report on quality assurance and control guidelines for sampling and analytical practices for zooplankton

ToR j) provide expert knowledge and guidance to ICES Data Centre (possibly via sub-group) on a continuous basis

15:30-16:00	Coffee break
16:00-18:00	**MICROZOOPLANKTON** (Lead: Roger Harris, Rapporteur: Delphine Bonnet)

ToR b) review the role of microzooplankton, including metazoans, in marine food web

Tuesday 27 March

9:00-10:30	**ICES PLANKTON STATUS REPORT**

ToR a) update the ICES Plankton Status Report
(Lead: Luis Valdes, Rapporteur: Mark Benfield)

ToR d) review the use of numerical methods in exploring and predicting long-term plankton variability in relation to climate
(Lead: Cabell Davis, Rapporteur: Mark Benfield)

ToR f) consider rate process studies and zooplankton phenology in association with time-series monitoring
(Lead: Wulf Greve and Astthor Gislason, Rapporteur: Mark Benfield)

10:30-11:00	Coffee break
11:00-12:30	**ICES PLANKTON STATUS REPORT (Cont.)**
12:30-14:00	Lunch
14:00-15:30	**CHANGES IN DISTRIBUTION OF SPECIES IN RELATION TO CLIMATE CHANGE (OSPAR CLIMATE REQUEST)** (Lead: Astthor Gislason and Priscilla Licandro, Rapporteur: Cabell Davis)

ToR m) assess and report on changes in the distribution, population abundance and condition of phytoplankton in the OSPAR maritime area in relation to changes in hydrodynamics and sea temperature

ToR l) assess and report on changes in the distribution, population abundance and condition of zooplankton in the OSPAR maritime area in relation to changes in hydrodynamics and sea temperature

ToR e) review and consider the impact on zooplankton communities of introduced or disappearing species

Presentation: Baebel Muellere-Karulis: Integrated assessment of the Baltic Sea

15:30-16:00	Coffee break
16:00-18:00	**CHANGES IN DISTRIBUTION OF SPECIES IN RELATION TO CLIMATE CHANGE (Cont.)**

Wednesday 28 March

8:30-9:00	**CHANGES IN DISTRIBUTION OF SPECIES IN RELATION TO CLIMATE CHANGE (Cont.)**
9:00-10:00	**JOINT MEETING WITH CIESM IN 2008** (Lead: Astthor Gislason and Ioanna Siokou-Frangou, Rapporteur: Steve Hay)

ToR c) compare the zooplankton ecology of the North Atlantic and the Mediterranean

10:00-10:15	Coffee break
10:15-11:30	**ZOOPLANKTON TAXONOMIC SKILLS** (Lead: Priscilla Licandro, Rapporteur: Webjörn Melle)

ToR g) consider the development of web-based taxonomic training and the promotion of the ICES WGZE to a wider community

11:30-12:30	**VISIT TO INSTITUTE OF AQUATIC ECOLOGY, UNIVERSITY OF LATVIA**
12:30-14:00	Lunch
14:00-15:30	**CENSUS OF MARINE LIFE** (Lead: Peter Wiebe, Rapporteur: Arno Pollumae)

ToR h) review and consider species biodiversity in zooplankton from coastal zones to oceanic deep sea: progress and prospects for the European Census of Marine Life Project (EuroCOML)

15:30-16:00	Coffee break
16:00-18:00	**NEW PHYTOPLANKTON WORKING GROUP** (Lead: Luis Valdes, Rapporteur: Steve Hay)

ToR k) take part in the intersessional work led by PGPYME in developing the mission and draft resolutions for a new working group related to phytoplankton and microbial ecology

REPORT ON THE BASIN PROGRAMME
(Lead: Peter Wiebe, Rapporteur: Roger Harris)

INFORMAL DISCUSSION OF FUNDING OPPORTUNITIES AND PLANS: EU-FP7 PROGRAMME

Thursday 29 March

9:00-10:30	**ZOOPLANKTON STUDIES IN THE BALTIC** (Lead: Piotr Margonski, Rapporteur: Juha Flinkman)
10:30-11:00	Coffee break
11:00-12:30	**SUMMARY DISCUSSION, FUTURE PLANS**

Consideration of Terms of Reference for 2008

Suggestions for future ASC Theme sessions, Workshops etc.

Editorship of the ICES Identification leaflets for Plankton

Next meeting

12:30	**FINISH**

Annex 3: WGZE report on the assessment of changes in the distribution and abundance of plankton in the OSPAR maritime area

APRIL 2007

Assessment of changes in the distribution and abundance of marine species in the OSPAR maritime area in relation to changes in hydrodynamics and sea temperature

REPORT ON THE ASSESSMENT OF CHANGES IN THE DISTRIBUTION AND ABUNDANCE OF <u>PLANKTON</u> IN THE OSPAR MARITIME AREA

PREPARED BY THE ICES WORKING GROUP ON ZOOPLANKTON ECOLOGY

EDITORS: PRISCILLA LICANDRO, DAVID JOHNS, MARTIN EDWARDS, PHILIP C. REID: Sir Alister Hardy Foundation for Ocean Science (SAHFOS) , The Laboratory Citadel Hill, Plymouth, PL1 2PB, United Kingdom

1. Assessment and report on changes in the distribution, population abundance and condition of <u>zooplankton</u> in the OSPAR maritime area in relation to changes in hydrodynamics and sea temperature

In the present document the ICES Working Group on Zooplankton Ecology (ICES WGZE) reports evidence of changes that have occurred in the marine zooplankton, in relation to changes in hydrodynamics and sea temperature occurring within the OSPAR maritime area.

This assessment has been done in response to a specific request of OSPAR and it is mainly derived by the analysis of the time series provided by the Continuous Plankton Recorder (CPR) survey, which covers the spatial and temporal scales requested by OSPAR, and is also supported by evidence provided by other time series around the North Atlantic.

1.1 Evidence of zooplankton changes in relation to temperature and hydrology

There is an accumulating body of evidence suggesting that in the last decades the zooplankton community has changed in response to changes in hydrodynamics and sea surface temperature (SST), related to fluctuations of the regional climate. In the OSPAR maritime area rising SST and ocean climate changes, has determined abundance changes as well as biogeographical, phenological and physiological changes in the zooplankton community.

A significant decrease of total **zooplankton** has been recorded in some OSPAR regions (e.g. North Sea, OSPAR Region II) in the last decade (Edwards *et al*., 2007). South of Iceland and west of the British Isles (OSPAR Region V), a general long term decline in total copepod abundance has been observed (ICES 2006a). In the North Sea, this is mainly due to the decrease of some key species representing the bulk of the zooplankton biomass, in particular *Calanus* species, that have declined 70% in total biomass between the 1960s and the post 1990s (Figure 1, Edwards *et al*., 2006a).

Biogeographical shifts of the **zooplankton** community have been recorded in the whole North Atlantic basin, along the routes sampled by the CPR. The increase in regional sea temperatures has determined a major re-organisation in calanoid copepod biodiversity, calanoid species with warmer-water affinities having moved northwards by 10° latitude in the north-east Atlantic over the last decade, and continuing this trend up to date (Figure 2, Beaugrand *et al*., 2002; Edwards *et al*., 2006a). **Changes in the distribution of dominant zooplankton** due to the northwards shift of taxa characteristic of warmer waters has been observed in CPR samples and in other long-term monitored coastal stations. Some examples are the increasing densities of *Calanus helgolandicus* in the North Sea and Bay of Biscay (Figure 3, Bonnet *et al*., 2005); the positive relationship between temperature and change in the abundance of *Centropages typicus* in the seas around the United Kingdom (Figure 4, Beaugrand *et al*., 2007); the northward shift of *Temora stylifera* (Figure 5, Valdés *et al*., in press) and *Penilia avirostris* (Figure 6, Johns *et al*., 2005).

Furthermore, **changes in the zooplankton community structure** associated with hydro-climatic changes have been recorded by the analysis of the plankton data from the CPR survey. In the North Sea, the 1960s were characterized by a colder-water community, while the warmer-water community has been established since the late 80s (Figure 7, Edwards *et al*., 2006a). The two most prominent ecological shifts have occurred in the late 1970s and in the late 1980s (Reid *et al*., 2001; Beaugrand, 2004). The late 1970s shift seems to have been an extreme event (cold-boreal anomaly) whereas the late 1980s shift has been classed as regime shift proper (Edwards *et al*., 2002).

In the North Sea, warmer conditions earlier in the year together with increased phytoplankton abundance occurring since the late 1980s, were related to **the increasing abundance of meroplankton** (i.e. temporary plankton species), in particular echinoderm larvae, that may

now control the trophodynamics of the North Sea pelagic ecosystem by competitive exclusion of the holozooplankton (i.e. permanent plankton species) (Kirby *et al.*, 2007). Such a change in the food-web structure may have a significant impact on the transfer of energy towards the benthic versus the pelagic component.

Climate warming has triggered **changes in the phenology of many zooplankton taxa** who's seasonal peak has moved forward (Figure 8, Greve *et al.*, 2001; Edwards and Richardson, 2004; Edwards *et al.*, 2006a; ICES, 2006a). The changes in phenology have varied between different species, functional groups and trophic levels, leading to a potential mismatch in the prey-predator relationship (Edwards and Richardson, 2004). In addition, recent investigations have shown the influence of winter temperature on the time of spawning of North Sea fish of commercial interest, warmer sea temperatures being associated with earlier fish recruitment (Figure 9, Greve *et al.*, 2005).

Hydroclimatic changes have been recently related to **jellyfish increases** recorded in several OSPAR regions (Lynam *et al*, 2004; Attrill *et al.*, 2007). Notwithstanding a still limited understanding, the increase in temperature appears to be one of the main triggering mechanisms for exceptional outbreaks of these gelatinous carnivores (CIESM 2001, Purcell, 2005). Jellyfish pullulations have a strong economic impact on the fisheries in the northern North Sea (e.g. mass occurrence of the siphonophores *Apolemia ulvaria* and *Muggiaea atlantica* in Norwegian waters, Greve, 1994; Båmstedt *et al.*, 1998). Furthermore, warm temperatures may be related to a prolonged period of occurrence and **increased abundance of the** ctenophore ***Mnemiopsis leidyi*** (Purcell, 2005, Figure 10). This gelatinous predator has been accidentally introduced into the Black Sea, and has contributed to the reduction in the fisheries there (see references in Purcell, 2005). The recent records of an increasing presence of *M. leidyi* in the southern part of the Norwegian Sea (Tone Falkenhaug, personal communication) suggests the importance of maintaining and possibly extending the monitoring of the zooplankton in the OSPAR area.

2. Assessment and report on changes in the distribution, population abundance and condition of phytoplankton in the OSPAR maritime area in relation to changes in hydrodynamics and sea temperature

OSPAR has requested to the ICES Working Group on Zooplankton Ecology (ICES WGZE) to report also evidences of changes occurred in the marine phytoplankton, in relation to changes in hydrodynamics and sea temperature within the OSPAR maritime area.

Notwithstanding the limited expertise, WGZE is able to provide some evidences of phytoplankton changes at meso- to macro- spatial scale.

This assessment is mainly based on the analysis of the time series provided by the Continuous Plankton Recorder (CPR) survey, which covers the spatial and temporal scales requested by OSPAR.

Because of the limitation of the sampling, the CPR time series represents only a small part of the phytoplankton community, i.e. the large diatoms and dinoflagellates. The Phytoplankton Colour Index (PCI), which is derived from the greenness of the silk mesh in the CPR samples, is used as a proxy for phytoplankton biomass. Nevertheless, comparison of this visual assessment with SeaWiFS data has shown that the PCI is a good indicator of phytoplankton standing stock (Raitsos *et al.*, 2005) and primary production (Reid et al. 1998).

2.1 Evidence of phytoplankton changes in relation to temperature and hydrology

In the OSPAR maritime area the phytoplankton changes at meso- and macro- spatial scales are mainly driven by hydroclimatic changes as opposed to nutrient driven changes which may occur at smaller spatial scales (Edwards *et al.*, 2006b)

A considerable **increase in phytoplankton biomass** (i.e. PCI) has been recorded since the mid-1980s particularly in the North Sea and in the area west of the British Isles (OSPAR areas II, III and V, Figure 11) in relation to increasing sea surface temperatures (Reid *et al.*, 1998; Edwards, 2000; Edwards *et al.*, 2001; Edwards *et al.*, 2007). In the same area an **extension of the seasonal PCI maximum** has also been recorded. These changes are likely related to the NAO index (Barton *et al.*, 2003).

Regional climate variability has been related to **changes in the phytoplankton community structure** observed since the 1960s in the North Sea, with an increase of dinoflagellates and a decrease of diatom abundance in response to warmer sea waters (Leterme *et al.*, 2005). The significant hydroclimatic changes that have occurred since the late 1980s and have continued to the present have resulted in an environment that favours the growth and **earlier succession** (Edwards and Richardson, 2004) of flagellates and dinoflagellates in the North Sea (Edwards *et al.*, 2006b). In the North Sea, dinoflagellates are positively correlated with the North Atlantic Oscillation (NAO) and SST, whereas diatoms are negatively correlated (Edwards *et al.*, 2001). Other long-term phytoplankton studies in the North Sea have also noted similar ecological changes occurring around the late 1980s (Fock, 2003) and, in particular, an increase in the ratio of dinoflagellates versus diatoms in the southern North Sea (Hickel, 1998).

Increasing records of Harmful Algal Blooms (HAB) taxa have been reported in the North Sea. **Anomalous high frequencies of HAB blooms** over the last four decades have been recorded in the late 1980s in the Norwegian coastal region and in the Skagerrak (Figure 12, Edwards *et al.*, 2006b). Such changes were related to regional climate change, in particular changes in temperature, salinity and the NAO.

Furthermore, **increasing abundance of warm-water phytoplankton** in the OSPAR area (e.g. records of warm-waters *Ceratium* spp. in the North Sea, Martin Edwards personal communication), the temperate to warm water diatom *Stephanopyxis turris* southwest of Iceland (Astthor Gislason personal communication) and **changes in the phenology of** dominant **phytoplankton** species (Edwards and Richardson, 2004) have been the consequence of hydroclimatic changes.

Key signs and evidence of changes in the plankton in relation to hydroclimatic changes

- The NAO, which is an important indicator of decadal climate changes in the North Atlantic, has been rising along with Northern Hemisphere Temperatures over the past 30 years and the surface waters of the European Continental shelf have been progressively warming (Stenseth *et al.*, 2002 and 2003). This has caused extensive changes in the planktonic compartment of the marine ecosystem affecting plankton production, biodiversity, species distribution which has had effects on fisheries production and other marine life (e.g. fish larvae, seabirds)

- In the OSPAR area, Region II (i.e. North Sea) the population of the previously dominant zooplankton species (the cold water *Calanus finmarchicus*) have decreased in biomass by 70%, between the 1960s and the post 1990s (Figure 1). Warm-water species have moved northwards to replace the species but their biomass is not as abundant.

- A shift in the distribution of many plankton and fish species by more than 10° latitude northward has been recorded in the OSPAR area over the past thirty years. This shift is particularly associated with the shelf edge current running north along the European continental margin (Figure 2. See also Figures 3–6 showing northwards shift of zooplankton species).

- The seasonal timing of phyto- and zooplankton production also altered in response to recent climate changes (Figures 8–9). This has consequences for plankton predator species, including fish, whose life cycles are timed in order to make use of seasonal production of particular prey species.

- In the North Sea and around the British Isles considerable increase in phytoplankton biomass (i.e. PCI) has been recorded since the mid-1980s (Figure 11).

- In the North Sea functional changes in the phytoplankton community have been recorded in recent decades, with an increase of dinoflagellates and a decrease of diatoms abundance in response to warmer sea waters (Figure 12).

- In the North Sea, warmer conditions earlier in the year together with increased phytoplankton abundance occurred since the late 1980s, has determined the significant increase of meroplankton (i.e. temporary plankton species), in particular echinoderm larvae of *Echinocardium cordatum* (Figure 8A) . This change in the food-web structure, due to the competitive exclusion of the holozooplankton (i.e. permanently plankton species) by the meroplankton, may significantly diminish the transfer of energy towards top pelagic predators (e.g. fish) while increasing the same transfer towards the benthic component.

- Future warming is likely to alter the geographical distribution of primary and secondary pelagic production, affecting oxygen production, carbon sequestration and biogeochemical cycling. These changes may place additional stress on already-depleted fish stocks as well as have consequences for mammal and seabird populations.

Conclusions

- The analysis of the time series has provided **evidences that in the OSPAR area significant changes have occurred in the** abundance, distribution, community structure and population dynamics of **zooplankton and phytoplankton**.

- **These events** in the plankton **are mainly responding to changes in regional climate**, caused predominately by the warming of air and sea surface temperatures, and associated changes in hydrodynamics;

- **The changes in** the **zooplankton and phytoplankton** communities that are at the bottom of the marine pelagic food-web, **affect higher trophic levels** [fish, seabirds, whales], as the synchrony between predator and prey (match-mismatch) plays an important role (bottom-up control of the marine pelagic environment) in the successful recruitment of top predators, such as fish and sea birds (Edwards and Richardson, 2004; Richardson and Schoeman, 2004; Frederiksen *et al.*, 2006).

- **The poor recruitment of several fish of commercial interest and the low seabird breeding productivity** recorded in recent years in some OSPAR regions **are associated with changes in plankton** biomass and in the seasonal timing of plankton production (Beaugrand and Reid, 2003; Beaugrand *et al.*, 2003; ICES, 2006, Frederiksen *et al.*, 2006).

Recommendations

- Long-term funding needs to be guaranteed to maintain the few time series that exist at single sites and along transects, and to expand the CPR Survey in order to cover un-sampled and poorly sampled areas in the OSPAR regions.

- As previously recommended by the WGZE community (ICES, 2002, 2004, 2005, 2006), zooplankton should be included as a mandatory biological variable in the management of the marine OSPAR area. In particular, zooplankton abundance, biodiversity, and population dynamics (e.g. phenology) as well as zooplanktonic species that act as indicators of ecological status, should be regularly monitored in the OSPAR regions.

- We wish to highlight the need to monitor for the appearance of non-indigenous species and draw attention to an important gap in information and sampling for gelatinous plankton.

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CPR Survey

<http://www.sahfos.org/>

Time series 'Helgoland roads'

<http://www.awi-bremerhaven.de/BAH/long_term_series_databases.html>

Time series 'Stonehaven'

<http://www.marlab.ac.uk/Delivery/standalone.aspx?contentid=1144>

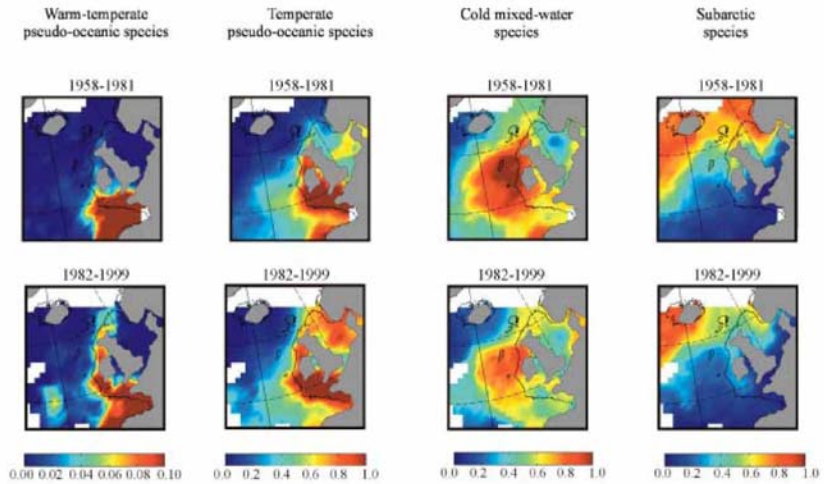Time series 'L4-Plymouth'

<http://www.npm.ac.uk/rsg/projects/observatory/l4/>

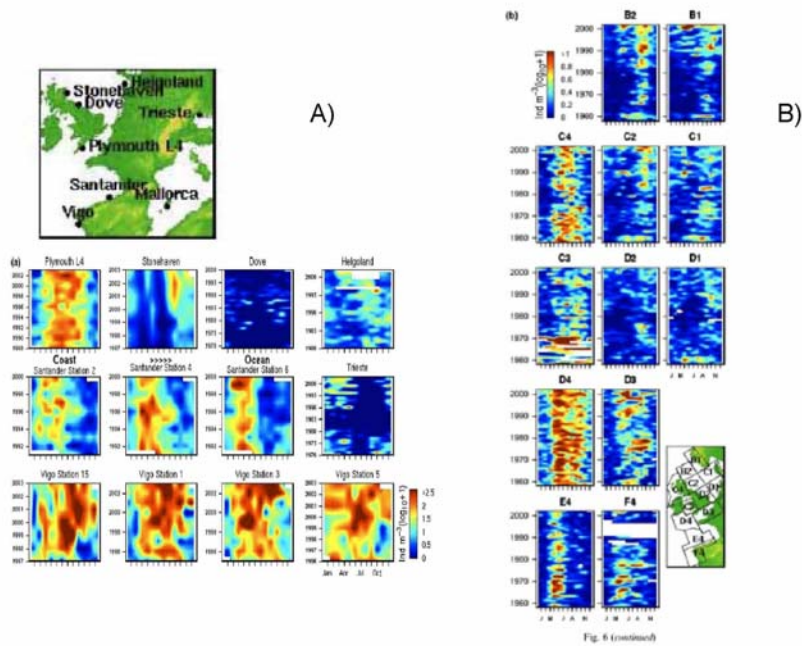Time series 'Santander/A Coruña'

<http://www.seriestemporales-ieo.net/>

Fig. 1.*Calanus*, a dominant zooplankton and important food source for larval fish, has declined in abundance and biomass in the North Sea over the past few decades. *C. finmarchicus* is a cold water species, whilst *C. helgolandicus* is indicative of more temperate waters A) Total *Calanus* biomass in the North Sea, showing decadal changes and northwards retraction (Edwards *et al.* 2006a) B) Long term bar chart of *Calanus finmarchicus* (blue) and *helgolandicus* (orange) in the North Sea, showing the decline of the colder water species, the increase in the warmer water species, but the overall decline in total numbers of *Calanus*.

Fig. 2. Maps showing biogeographical shifts of calanoid copepod communities in recent decades, with the warm water species shifting northwards and the cold water species likewise retracting north, by over 10° of latitude (Beaugrand *et al.* 2002).

Fig. 3. Long term changes in *C. helgolandicus* abundance A) from areas around Europe B) from CPR Standard Areas. This species has increased in many areas, particularly in the North Sea (Stonehaven, Helgoland and CPR areas C1,C2,B1 and B2) in recent years, due to rising SSTs (Bonnet *et al*. 2005)
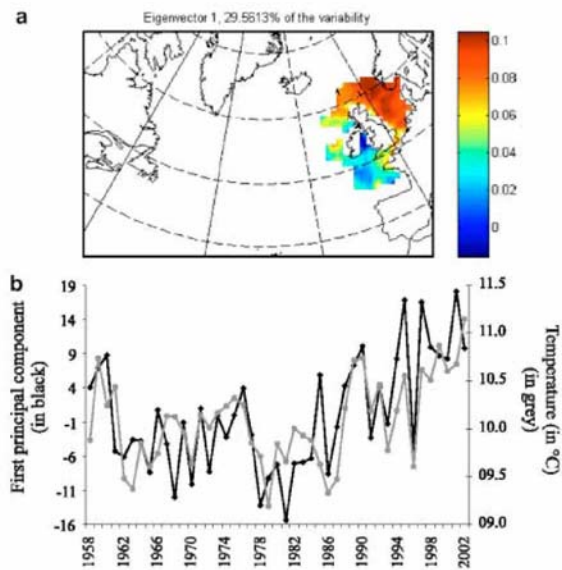

Fig. 4. Long-term changes in the spatial distribution of *Centropages typicus* investigated by Principal Component Analysis (PCA). The spatial variability of *C. typicus* is shown by the first eigenvector (a), while the long-term changes in the same species are represented the first principal component in black (b). In (b) also the first principal component of sea surface temperature has been plotted in grey. A significant relationship was found between long-term changes in the first principal component of *C. typicus* and SST (r2=0.51, p<0.01).
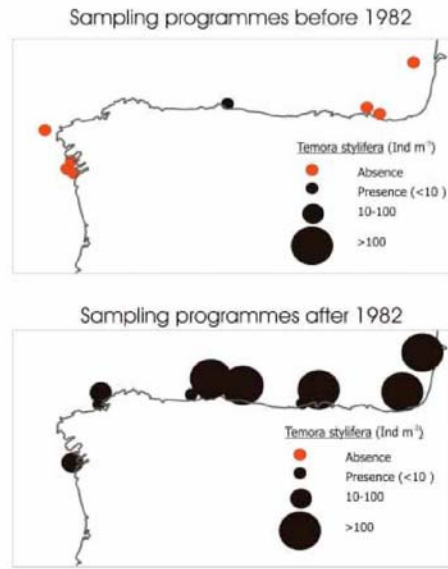From Beaugrand *et al*., 2007.

Fig. 5. Abundance of the warm-water copepod *Temora stylifera* in some transects off Vigo, Coruña and Santander (sampling from Radiales project). According to the monitoring in the N-NW Iberian peninsula, *T. stylifera* was absent before 1978. Since the first record in the Cantabrian Sea in 1980, this species has progressively become more abundant.
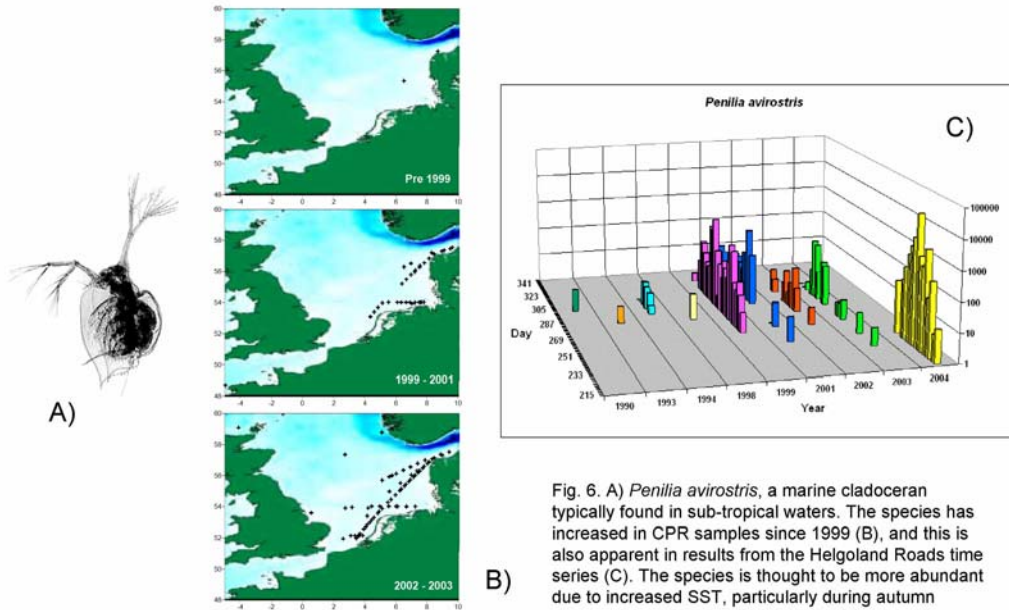In the Santander region, a marked increase has been observed since since the mid 1990s (Valdés *et al.*, in press).

Fig. 6. A) *Penilia avirostris*, a marine cladoceran typically found in sub-tropical waters. The species has increased in CPR samples since 1999 (B), and this is also apparent in results from the Helgoland Roads time series (C). The species is thought to be more abundant due to increased SST, particularly during autumn months. It may have arrived in the North Sea by a northwards advection due to increased SST, or as resting eggs in ships ballast waters (Johns *et al.* 2005).
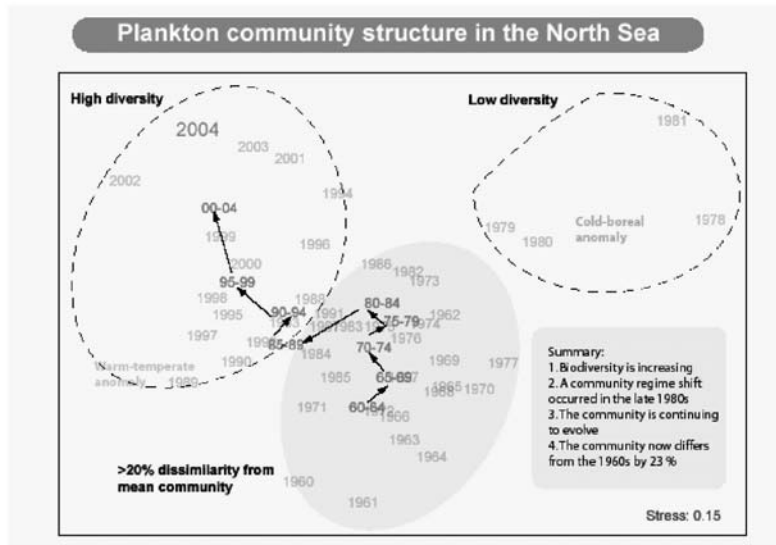
Fig. 7. Multi-dimensional scaling plot of the plankton community structure in the North Sea from 1960-2004 showing major structural shifts (late 1970s and 1980s) and five-year community averages. Years close in space have a similar community structure. There has been a clear shift in recent years to a more diverse plankton community, differing from the community of the 1960s by 23% (Edwards et al. 2006a).
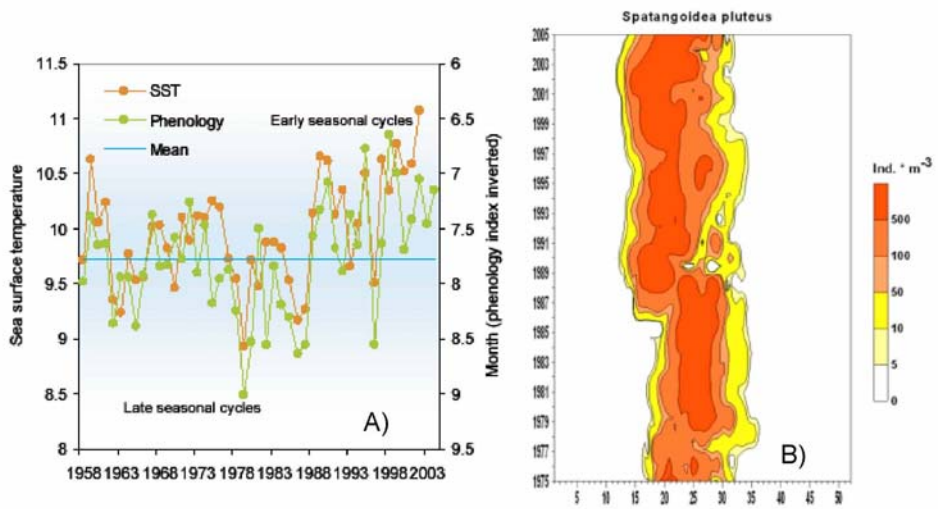

Fig. 8. A) Plot of long term phenology of Echinodermata larvae in the CPR survey, showing the earlier seasonal peak in the larvae, closely correlated with SST (Edwards et al. 2006a). B) Helgoland time series, SE North Sea. Contour plot showing abundance and seasonality of Spatangoid plutei (i.e. echinoderm larvae) from 1975 to 200, also showing the shift earlier in the year.
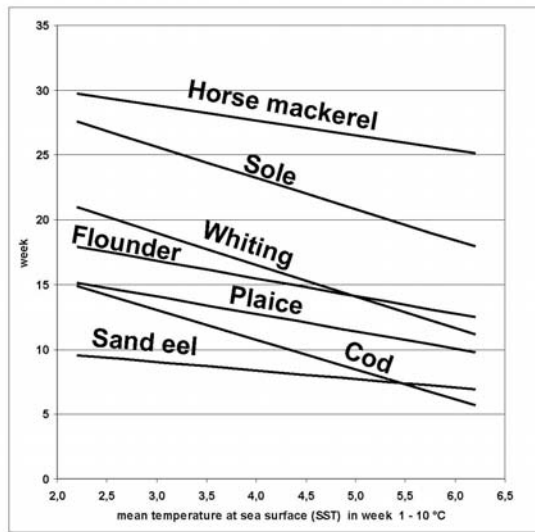
Fig. 9. Helgoland time series, SE North Sea. Influence of winter temperature on the time of spawning of North Sea fish of commercial interest, warmer sea temperatures being associated with an earlier fish recruitment (Grieve *et al.*, 2005).
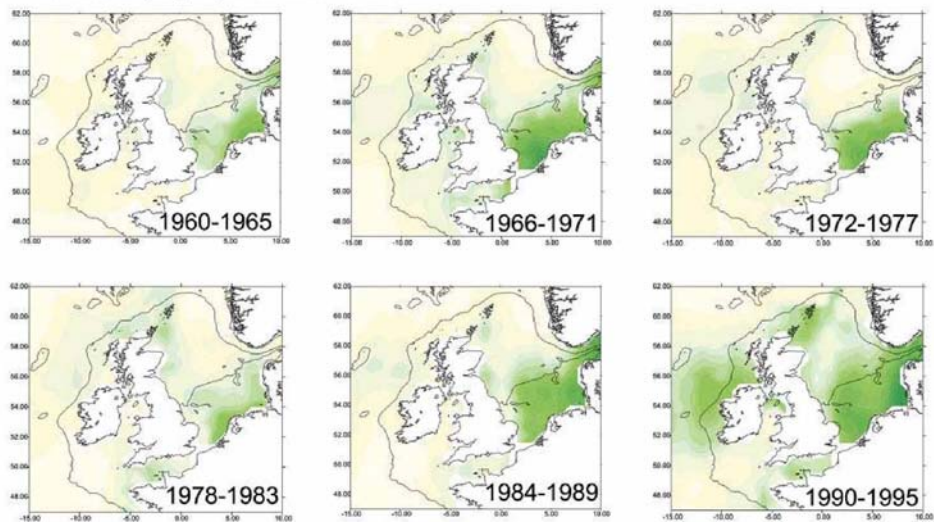
Means of phytoplankton colour

Fig. 10. Mean spatial distribution of phytoplankton standing stock (*i.e.* Phytoplankton colour, PCI) in five years periods from 1960 to 1995. A considerable increase in PCI has been recorded since the mid-1980s particularly in the North Sea and in the area west of the British Isles in relation to increasing sea surface temperatures (Edwards, 2000).
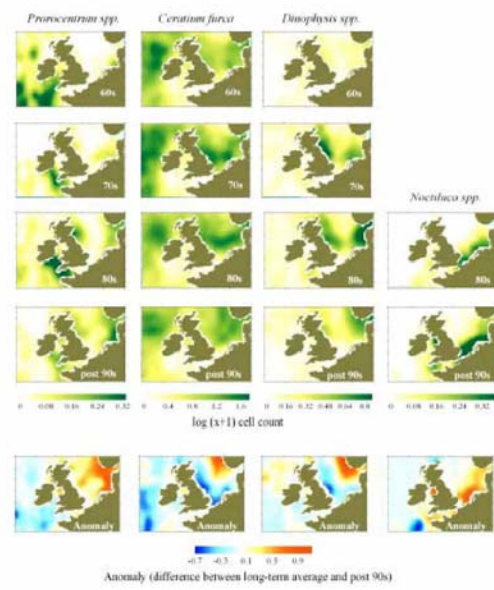
Fig. 11. Mean spatial distribution of four dinoflagellate taxa in the north-east Atlantic. Estimated cells counts were log (x+1) transformed. The anomaly maps show the difference between the long-term mean (1960-1989) and the post 1990s period (1990-2002). Values above the long-term mean are in red while values below the long-term mean are in blue. Zero mean values are in white (Edwards *et al.*, 2006).

Annex 4: Theme Session Proposal for 2008 ASC

The Working Group of Zooplankton Ecology (WGZE) proposes the following Theme Session for the ICES 2008 Annual Science Conference:

Evidence of global warming effects on zooplankton populations and communities, including larvae of benthic invertebrates and fish

Theme session conveners: Wulf Greve (Germany), Steve Hay (UK) and Peter Wiebe (USA).

Supporting information

To a large extent our current assessments of the ecosystem effects of climate change have been most effectively demonstrated by reference to the observed spatial and temporal changes in abundance, distribution, and phenology of plankton communities and key species. Some ecosystem regime shifts and links with fisheries harvests, recruitment etc. have been demonstrated over a range of scales, from basin scales in the Atlantic and Pacific oceans down to different responses noted for different regions of the North Sea. But more remain to be discovered and described.

Different organisms have evolved different life cycle strategies and adaptive capacities to exist and co-exist in the habitats and niches they occupy. Any population's success or failure depends essentially on the changing relationships between organisms and their habitats, and on the relative efficiencies of life cycle trajectories and functional abilities within communities. Study of phenology, the timing of life cycles and developmental processes in relation to environments over time and across latitudinal gradients, allows insight into the real expression of species adaptive capacities and ranges and into the factors determining resultant productivity across the food web.

The marine environment is changing, sometimes abruptly, due to habitat changes, climatic factors, anthropogenic pressures, or introduced species. All species adapt to their surroundings, which may involve underlying genetic traits and capacities as well as expression of phenotypic plasticity in relation to environmental trends and pressures, or are replaced by others. The study of functional relationships in relation to environmental gradients allows insight into the capacity and efficiency of organisms in their adaptations to change. Understanding the effects of such changes across the continuum of marine habitats demands a coming together of observations, ideas, and research efforts.

This theme session is designed to bring together zooplankton specialists studying 1) the variability in spatial distribution, productivity, and timing of life cycles, 2) the population dynamics in varied species and environments, 3) the rates and functional relationships of species, and 4) the modelling of these processes. The session should produce a better understanding of the strengths and gaps in current formulations, theories, and data. The session aims to span the marine food web, to find synergies, and to build towards better ecosystem understanding and management.

Annex 5: Proposed Terms of Reference for the 2008 WGZE meeting

The **Working Group on Zooplankton Ecology** [WGZE] (Chair: A. Gislason, Iceland) will meet in Montpellier, France from 31 March–3 April 2008 to:

a) make a review of species lists from time series stations and/or areas;

b) review the response of OSPAR to the report of the WGZE particularly in regard to incorporating zooplankton monitoring into regulatory schemes and programmes;

c) combine field and laboratory data together with biological-physical models to examine processes controlling zooplankton populations;

d) compare different nets and mesh sizes and their efficiency;

e) compare/evaluate different measures for zooplankton biomass from regions within the ICES area;

f) review the planning of the WGZE/CIESM Workshop;

g) review the planning of a new working group related to phytoplankton and microbial ecology;

h) produce an evidence based rationale for incorporating zooplankton monitoring into regulatory assessment frameworks;

i) review evidence of the effects of climate change on plankton and review the outcomes of the 4th ICES/PICES/GLOBEC International Zooplankton Production Symposium.

WGZE will report by 1 May 2008 for the attention of the Oceanography Committee, ACE and ACME.

Supporting Information

PRIORITY:	The activities of this group are a basic element of the Oceanography Committee, fundamental to understanding the relation between the physical, chemical environment and living marine resources in an ecosystem context. Reflecting the central role of zoo-plankton in marine ecology, the group members bring a wide range of experienced expertise and enthusiasm to bear on questions central to ICES concerns. Thus the work of this group must be considered of very high priority and central to ecosystem approaches.
SCIENTIFIC JUSTIFICATION AND RELATION TO ACTION PLAN:	Action Plan No: 1.2 - 1.13; 2.2, 2.9, 2.10; 3.2, 3.3, 3.15; 4.2, 4.10, 4.11, 4.14, 4.15; 5.2 – 5.5, 5.9, 5.10, 5.13 – 5.17; 6.1; 8.1, 8.2, 8.4, 10.1, 10.3 **a)** The WGZE will work intersessionally towards collating a unified taxonomic list of the zooplankton for the time series areas. This will aid data exchange and integration. The "APHIA-ERMS" (the European Register of Marine Species) taxonomic system will be adopted as MarBEF is currently using the ERMS system for its metadatabase. This work will identify common species between the time-series facilitating future comparative studies. The importance of rare or low abundance species together with new or introduced species should not be overlooked particularly in a context of climate change. Comparison of the relative importance of each species in the communities represented by the time-series will be aided by the common taxonomic approach. There are known to be indicator species of particular water masses, and there are now species appearing that were not present 30 years ago. The indicator species for each region will be determined. Material presented under this item will be utilized to prepare the Annual Plankton Status Report. **b)** Having contributed with a Report on changes in the distribution of plankton in the OSPAR region, the WGZE would like consider the response of OSPAR and provide feedback. The WGZE has produced substantial evidence that zooplankton distibutions are being strongly impacted by climate change. Therefore the WGZE strongly recommends that zooplankton monitoring be an essential component of OSPAR sampling protocols. **c)** Zooplankton represent a key component of marine ecosystems by effecting middle-

out control of food-web dynamics and mass/energy flow. By definition, zooplankton are 'drifters', and their abundance in time and space is determined by a combination of biological and physical processes. Building on the separate strengths of the WGZE and WGPBI, significant progress can be made in understanding zooplankton and ecosystem dynamics by combining knowledge, expertise, data, and models from these two WGs. The extensive data sets on zooplankton and environmental variables of the WGZE, together with the state-of-the-art biological-physical modeling techniques of the WGPBI, will be explored in a joint session to identify critical data and modeling needs, to gain insights into physical effects on zooplankton populations, and to formulate a plan for future collaborative research in these two important areas of biological oceanography.

d) Plankton nets have been used in quantitative zooplankton work for well over 100 years and the realisation that they have limited efficiency is probably as old as the technique itself. With the advent of acoustic and optical technologies, new sampling systems without nets have been developed. However, net sampling systems are still used extensively in most zooplankton monitoring programmes and will likely continue to be used in the future. The efficiency of net sampling systems is dependent on a number of factors, most notably probably being avoidance of the sampler by the organisms, clogging of the net meshes and extrusion of animals through the meshes (escapement). With this ToR we seek to elucidate the effects of different nets and mesh sizes on their efficiency.

e) The biomass of zooplankton may be measured or estimated in a number of ways (e.g. settled volume, dispalcement volume, wet weight, dry weight, ash-free dry weight, carbon weight). As with d), this ToR is an evaluation of methodology and new technology and will provide a basis for consistent monitoring.

f) The Joint WGZE/CIESM Workshop to compare Zooplankton Ecology and Methodologies between the Mediterranean and the North Atlantic (WKZEM) proposed by WGZE and adopted by the ICES Council in 2006 will be held in the end of October 2008 in Heraklion (Crete) (Co-Chairs: A. Gislason*, Iceland, and G. Gorsky*, France). The Workshop is very welcome and timely. Many of the issues the WGZE is dealing with will benefit from a wider, collaborative approach. The development of working links between both groups has been mentioned frequently in the past and this is an excellent opportunity to tackle a well defined agenda of common interest. With this ToR the WGZE will organize and review the plans for the Workshop and thus contribute to its successful outcome.

g) The WGZE recognizes the need for maintaining phytoplankton expertise within ICES, as processes within higher trophic levels cannot be understood isolated from those at the base of the food chain. It is not really possible for WGZE and many others in ICES and elsewhere to address adequately many of the important issues in marine ecology or marine system management and policy without reference to expertise in phytoplankton and microbial ecology. Therefore the WGZE strongly reccommends that a new working group of phytoplankton and Microbial Ecology be formed by ICES and would like to follow the progress.

h) The EU marine strategy document requires the inclusion of information on the typical phytoplankton and zooplankton communities in monitoring programmes, including key species, seasonal and geographical variability and estimates of primary and secondary productivity. However, several environmental agencies do not seem to recognise fully the importance of zooplankton as a key to the understanding the structure and functioning of ecosystems. Thus, zooplankton are only recently and briefly mentioned in the water or ecosystem monitoring documents and guidelines of OSPAR and HELCOM. This is unfortunate given the central ecosystem role of zooplankton and demonstrable links with climate change. With this ToR the WGZE seeks to produce an evidence based rationale for including zooplankton in present and future monitoring programmes. All environmental agencies should be encouraged to foster this request.

i) The 4th ICES/PICES/GLOBEC International Zooplankton Production Symposium will be a major international event. Zooplankton production is widely studied and highly relevant topic in marine research and for marine ecosystem and population management. This 4th symposium looks to be as well attended and productive as the previous ones. The outcomes will be important to the future aims and plans for plankton research. As the originators of the symposium, the WGZE should assist in producing a review of the outputs and issues highlighted.

RESOURCE REQUIREMENTS:	Resource required to undertake the activities of this group is negligible. However, ICES must be committed to provide some sponsorship and support for workshops, publication costs for the Plankton Status Report, and the 4th Zooplankton Symposium.
PARTICIPANTS:	The group has an enthusiastic core membership, and is successfully making efforts to attract broader participation both across ICES nations and across relevant skills The Group is normally attended by some 20-25 members and guests.
SECRETARIAT FACILITIES:	None beyond communication support.
FINANCIAL:	Beyond the 10,000DK support for the Symposium in 2007 and publication costs for the Plankton Status Report, no other current financial implications.
LINKAGES TO ADVISORY COMMITTEES:	The Group reports to the Oceanographic Committee, ACE and ACME (information also relevant to some ACFM aims) Mainly WGZE provides scientific information on plankton and ecosystems and welcomes input from other committees , working/ study groups etc.
LINKAGES TO OTHER COMMITTEES OR GROUPS:	Any and all working and study groups interested in marine ecosytem monitoring and assessments, modelling and/or plankton studies, including fish and shellfish life histories and recruitment studies.
LINKAGES TO OTHER ORGANIZATIONS:	Links with the WGMDM, WGRP, WGCCC, WGPE and WGHABD are intended and some contact is maintained. The WGZE input to REGNS is an ongoing effort. The Plankton Status Report is of interest and practical use to a range of interested groups within ICES, PICES, CIESM, GOOS and GLOBEC with other national and international research groups and agencies. Increasingly marine research, marine management and even marine institutes are re-aligning to take an ecosystem view. These linked and collaborative approaches between many working and study groups must be encouraged. IGBP, SCOR, ESF, COML/ CMarZ, and others have research activities meetings etc., of interest and relevant to the activities of the WGZE. Contacts are maintained through networking and collaborative activities.

Annex 6: Draft resolution for an ICES internal publication

The report **Zooplankton monitoring results in the ICES area: Summary Status Report 2006/2007**, edited by members of WGZE, as reviewed and approved by the Chair of the Oceanography Committee, will be published in the *ICES Cooperative Research Report* series. The estimated number of pages is 30.

The Working Group on Zooplankton Ecology agrees to submit the final draft of the proposed publication by 1 July 2008.

Supporting Information

PRIORITY:	This draft resolution enhances the development of the plankton status report, and makes it an official and citable ICES product.
SCIENTIFIC JUSTIFICATION:	The Cooperative Research Report series offers a good venue for the annual publication of the Plankton Status Report, making it available to the scientific community as a citable publication.
	This status report represents an annual assessment which can support the new advice format, providing regionally-based assessments of plankton in the ICES area.
RELATION TO STRATEGIC PLAN:	This resolution will contribute towards Scientific Objectives; 1a (Describe, understand and quantify the state and variability of the marine environment in terms of its physical chemical and biological processes.); 1b (Understand and quantify the role of climate variability and its implications for the dynamics of the marine ecosystems); 5c (Co-ordinate international, monitoring and data management programmes which underpin ongoing ICES core science.); 4c (To publicise the work of ICES and the contributions that ICES can make for its stakeholders, and for the wider public audience, regarding the understanding and the protection of the marine environment), and Institutional Objective 6 (Make ICES' scientific products more accessible to the public.)
RESOURCE REQUIREMENTS:	Cost of production and publication of a 15 page CRR
PARTICIPANTS:	
SECRETARIAT FACILITIES:	Help with document preparation/publication. Final editing.
FINANCIAL:	
LINKAGES TO ADVISORY COMMITTEES:	ACE, ACME, ACFM, Publications Committee
LINKAGES TO COMMITTEES GROUPS:	Oceanography Committee, REGNS
LINKAGES TO ORGANISATIONS	IOC, GLOBEC, OSPAR