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Report of the Working Group on Zooplankton Ecology (WGZE)

23–26 March 2010

Portland, Maine, USA

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Executive summary

The WGZE meets annually to review progress in zooplankton ecology, examine issues related to zooplankton in the ICES region, and address terms of reference developed within the working group and requested by ICES or other agencies. The WGZE produces the Zooplankton Status Report every two years, which is published as an ICES Cooperative Research Report.

The annual meeting of the WGZE followed a structured agenda (Annex 2) that included ToRs and research updates from members and guests. This group has always embraced major initiatives designed to advance the field of zooplankton ecology. Examples of products include the ICES Identification Sheets, the Zooplankton Methodology Manual, the seagoing gear intercomparison workshop, and the Zooplankton Status Report. The group has decided to move forward with new initiatives that include updating and revising the material in the Zooplankton Methodology Manual, and developing workshops to address physiological tolerances and species limits for zooplankton. Traditional taxonomic tools as well as new molecular and optical methodologies are essential to the field and the group is working with the new Study Group on Integrated Morphological and Molecular Taxonomy to ensure that it will have the support and advice necessary to succeed.

The Zooplankton Status Report is being prepared for publication. As is the case with each edition, the content is being updated and additional time-series data are included. Particular attention is being paid to standardized graphical representations of the time-series data along with climatic indices. This information will make the Zooplankton Status Report a uniquely valuable resource for understanding how planktonic communities within the ICES area are changing in relation to climatic forcing.

1 Opening of the meeting

The ICES Working Group on Zooplankton Ecology (WGZE) met at the Gulf of Maine Research Institute (GMRI) in Portland, Maine, USA on 23–26 March 2010. Our local host was Dr. Jeffrey Runge of the GMRI. The meeting was attended by 21 scientists representing eleven nations (Annex 1).

Mark Benfield (Chair) opened the meeting at 09:00 and welcomed the members and guests of the group to Portland. Following a round of introductions, the group was welcomed by Jeffrey Runge who summarized logistical details of the meeting.

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 2009 Annual Science Conference and Statutory Meeting. The agenda had been circulated amongst the working group membership prior to the meeting and incorporated most suggestions and comments. Last minute adjustments were discussed and the agenda was adopted by unanimous vote. The Terms of Reference for this meeting are to:

a) Review the outcomes of new initiative proposals and select one or more future initiatives based on a review of planning letters summarizing potential programs;

b) Review the work progress of the Study Group on Integrated Morphological and Molecular Taxonomy;

c) Review the progress of the ICES historical dataset digitization project, new enzymatic and size-classed methods for zooplankton, and the outcome of the 2009 ASC Session A;

d) Prepare and improve the ICES Plankton Status report including an examination of regional and cross-basin trends and recommend means of incorporating species information into the report;

e) Review plans for sessions and activities during the 5th Zooplankton Production Symposium;

f) Review the report on Zooplankton and Climate Change for the ICES Position Paper on Climate Change and revise as necessary based on comments from the SSICC; and

g) Discuss potential linkages and encourage joint activities with the Working Group on Phytoplankton and Microbial Ecology;

h) Monitoring methodologies for ocean acidification (OSPAR request 2010/2): To provide, on the basis of a review of existing methodologies and experience, recommendations for cost efficient methods for monitoring ocean acidification (OA) and its impacts, including possibilities for integrated chemical and biological monitoring. Specifically this should provide:

   i. advice on appropriate spatial and temporal coverage for monitoring, considering different oceanographic features and conditions and key habitats/ecosystems at risk from OA in the OSPAR maritime area;

ii. advice on the status and maturity of potential indicators of OA impacts, on species, habitats and ecosystems that could be considered for inclusion in OSPAR monitoring programmes.

i) Report by 15 March on potential contributions to the high priority topics of ICES Science Plan by completing the document named "SSGEF_workplan.doc" on the SharePoint site. Consider your current expertise and rank the contributions by High, Low or Medium importance;

j) Prepare contributions for the 2010 SSGEF session during the ASC on the topic areas of the Science Plan - which cover: individual, population and community level growth, feeding and reproduction; the quality of habitats and the threats to them; indicators of ecosystem health.

3 ToR A: Review the outcomes of new initiative proposals and select one or more future initiatives based on a review of planning letters summarizing potential programs

Roger Harris introduced the topic, noting that this was an important ToR for the future of the group. The issue had been discussed in Torshavn, but the planned planning letters had not been written intersessionally so the group would have to re-visit the discussions.

In the past the WGZE has been very productive, for example producing the Zooplankton Methodology Manuel, organizing the Zooplankton Production Symposia, seagoing-workshops, scanning the ICES Fiches etc. The discussion in Torshavn in 2009 focused on what could be the next practical project for the WG. It was recognize that it is important that the WGZE produces outputs of wide and long-lasting value.

Option 1: Updating the Zooplankton Methodology Manual

The discussion began with consideration of reviewing the ZMM with the view to producing either a revised 2nd edition or a journal review article updating topics covered by the original book. Peter Wiebe confirmed, from communications with the publishers, that that book is still in print and supported the idea of a review article/new edition. Aspects that might merit updating included, sampling gear and intercomparison of gear, and the genetics chapter. It was recognized that revising the book would be a major undertaking and in light of this Roger Harris suggested that maybe it would be better to concentrate on a review article covering subjects that would update the book topics. Lutz Postel pointed out that some practical tips and protocols on methods might not be suited to such a review article and that self-publishing or placing this information on a web-site might be more appropriate. Steve Hay observed that with self-publication it would be very easy and cheap to update the material. A number of WG members emphasized that a hard-copy book is necessary from a scientific point of view. However, to make the Zooplankton Methodology Manual more freely available either as an inexpensive paper-back version or as downloadable PDFs of the chapters would be very valuable, particularly for students.

Mark Benfield raised the possibility of producing science communication videos on particular practical techniques. Zooplankton techniques are fun and interesting and therefore suited for video and in some cases a technique would be much better understood in such a format than by reading a written document. A wide range of topics were reviewed and it was noted that many people were carrying out

methodologies that would be suitable to for such a format and that it would easy to capture a number of these on film.

Both the revision of the Methodology Manual and the development of video material would require a web-site that could be easily modified and updated by the WGZE members as both projects developed.

Option 2: Sea going workshop on high-tech zooplankton ecology

Cabell Davis and Mark Benfield introduced the topic in light of the discussions in Torshavn. While the previous proposal had been for a cruise in the Baltic, Cabell observed that such intercomparison of gear could be more interesting in more diverse area than the Baltic. The previous sea going workshop in Norway was organized by scientists bringing their own gear. Roger Harris raised the cost/logistics implications of a new effort. Peter Wiebe emphasized that there were lots of new techniques: ZooImage, Zooscan, FlowCAM, holographics, acoustics, and that there were lots of new things to discover. Regarding availability of ships it was thought that the provisional offer of a Finnish ship by Juha Flinkmann might still be explored. Webjoern Melle pointed out that the choice of ship was very crucial from a practical point of view in relation to deployment of gear cabling etc. Mark Benfield raised the issue of bad weather and how this might affect a sea-going workshop. Steve Hay felt that many of the techniques were not widely available and that it would be difficult to get some of them operating within the next 2 years. Cabell Davis and Peter Wiebe disagreed, feeling that the majority of these technologies are ready to be used. Janna Peters raised a concern as to whether it is realistic to do a cruise for two to three weeks and then have the necessary time to analyze all the data. You need to be able to pay people to analyze such complex samples and data, keeping in mind that funding is difficult. Roger Harris concluded the discussions by summarizing that such a workshop would be a major undertaking, which would need to be practical and achievable.

Option 3: Sustain, train and integrate new and traditional taxonomical tools

Steve Hay introduced this topic by saying that the new Study Group on Integrated Morphological and Molecular Taxonomy has this as a core aim. In this sense this topic is being addressed but it needs further evolving. A questionnaire has been sent out and the aim is to develop and promote a workshop approach. The SG will meet by correspondence due to limited funding. Ann Bucklin mentioned that she would raise a related issue when she reported on CMarZ later in the agenda.

Option 4: Determine physiological tolerances and factors that determine ranges of species

Jeff Runge and Erica Head reminded the group of the idea proposed in Torshavn; we need more basic information e.g. niches, adaptive ranges, temperature boundaries. Peter Wiebe pointed out that we do not know enough even about key species to say how their boundaries are controlled and that this was a conclusion at the RARGOM *Calanus* workshop on the previous Monday. Roger Harris asked what the practicalities of getting such an initiative started would be, perhaps through a short review/perspectives article. Peter Wiebe suggested that one way would be to start with ranges and boundaries e.g. the work on *Calanus helgolandicus* done by Delphine Bonnet, only afterwards do you conduct experimental work to see what the limits are. There are a lot of unknowns concerning basic life histories which make it impossible to "just heat up copepods and see when they boil". There are places at sea where high-resolution time series would make it possible to investigate and quantify the regulating role of abiotic variables. This could replace a lot of lab experiments.

In a concluding discussion a show of hands indicated that the majority of the WG were in favour of prioritizing the update of the Zooplankton Methodology Manual as a major project. It was agreed that discussions would continue during the course of the meeting among the groups interested and that the ToR be revisited to agree an intersessional action plan. Prior to close, Steve Hay suggested a biochemical workshop and this idea was taken forward in offline discussions between Lidia Yebra and Lutz Postel.

Action Plan

After further informal discussions during the meeting the ToR was returned to briefly and the following plan was agreed for work over the coming year. It was suggested that progress be reported on in an E-Newsletter circulated around the group after 6 months (around the time of the ASC).

Methodology Manual

Approach the publishers about the possibility of producing a paper-back edition of the existing Zooplankton Methodology Manual (Roger Harris and Peter Wiebe). Review the contents of the Zooplankton Methodology Manual chapter by chapter with the aim of making a framework for a review article update of selected topics (Peter Wiebe, Roger Harris and Jeff Runge). Prepare a list of potential videos that might be made, people who might be approached, and suggest a practical web-based way of organizing and developing this project (Mark Benfield, Cabell Davis and Peter Wiebe).

Seagoing Workshop

While both interesting and very desirable it was decided not to proceed at this time due to the cost/logistical implications.

Taxonomy Training

This initiative is going forward in the frame of the new Study Group and has the support of the WGZE (Steve Hay).

Physiological Tolerances and Species Limits

An outline structure for a potential perspectives/"Horizons" article reviewing some of the key issues will be prepared prior to writing such an article (Jeff Runge, Roger Harris and Peter Wiebe). Work on this topic is expected to take place over the summer.

4 ToR B: Review the work progress of the Study Group on Integrated Morphological and Molecular Taxonomy (SGIMT)

A questionnaire has been sent out to find parties who are interested in furthering the aims of the study group. It was sent to specialists in fields in addition to zooplankton ecology. A lot of interest has been expressed from all regions. There will be ongoing work via Email, and perhaps the occasional specialised workshop. Funding is very tight at the moment so people cannot travel easily.

Steve Hay will be reporting on his progress to the ASC in September. He will have a summary of all the questionnaire data and there may be one or more workshops organised based on the findings of the questionnaire.

The current ICES plankton identification sheets will not be updated in future; the level of interest in them seems very low.

Steve sees the Census of Marine Zooplankton (CMARZ) as the primary morphological/genetic taxonomic comparative study at the moment. While there are others who might like to use genetic techniques, they may not have access to the expertise.

Steve pointed out that it is important that policy makers get the message that morphological (traditional) taxonomy needs to be supported, i.e. with adequate funding, in future. There have been a number of initiatives related to genetic taxonomy, and they have garnered funding to set up labs etc.; morphological taxonomy, however, has been under-supported in comparison.

The WGZE, and SGIMT, need to provide recommendations on approaches to effective broad dissemination and resource requirements for traditional and genetic taxonomy. ZIMNES, (a website hosted by the Marine Biological Association in Plymouth, UK) is a web-based key that Steve started under NERC, which includes a species list, photos, descriptions etc. There are other initiatives to do this kind of thing, e.g. under OBIS and WORMS. These groups are getting information from a variety of sources/projects, but ICES does not have direct links to any of them.

Steve ended with a plea that group member fill out their questionnaires and that they pass them on to those colleagues (not just zooplankton specialists) who might have an interest.

5 ToR C: Review the progress of the ICES historical dataset digitization project, new enzymatic and size-classed methods for zooplankton, and the outcome of the 2009 ASC Session A

Review the progress of the ICES historical dataset digitization project

Mark Benfield gave a presentation on digitization, analysis and interpretation of plankton data for pre-1914 ICES sampling in the North Sea and adjacent waters. This project for digitization and making available historical data is led by Dr. Abigail McQuatters-Gollop (SAHFOS). The project data website can now be viewed at: http://cpr.cscan.org/ices/Default.asp. A progress update report is given twice a year. The results Mark showed were from October 2009, but the March 2010 report will soon be ready. Entry and quality checking of data from all seven historical ICES volumes is currently in progress. Of the 311 tables in these volumes, data from 121 tables have been entered, quality checked and are available in the database. Data from 103 tables are still being entered and data from 87 tables are currently being quality checked. Therefore approximately half of the data in the historical ICES volumes has yet to be made available for use. It is expected that all data will have been entered and quality checked and will be available by the next project update report (March 2010).

The geographic locations of the samples show a good coverage over a broad area. Where geographic coordinates for a sampling station were not listed in the historical ICES tables, a literature search has been conducted in order to locate station coordinates based on station name and sampling country. Another challenge is that as the data are a century old, many of the taxa have undergone taxonomic reclassification or changes in name. Resolving these names so that the historical data may be compared with contemporary data is time consuming. Concurrently, the WoRMS Aphia ID number is added to the ICES historical database. Many of the taxa recorded in the historical ICES volumes did not previously exist in WoRMS and have been added

(and new Aphia IDs created) during this project. Another challenge is that sampling methodologies vary between datasets. Some programs recorded plankton species as present or absent; others as very rare, rare, common, very common; and still others recorded species quantitatively. These terms were used differently by different investigators, which complicates their usage. Steve Hay commented that the data are still useful despite quasi-quantitative measurements. Until now, the ICES historical database will be analyzed at the presence/absence level, but the project will later go into more details for the datasets where it is possible.

Most samples are from upper 10 m and from February, May, June, August and November. Also phytoplankton data are available in the ICES historical database, and the progress report shows some preliminary results of phyto- and zooplankton. In 2010 the ICES historical database will be made available through OBIS. Mark concluded that the group working with digitalization have shown interesting results and that WGZE is satisfied with the progress of the work.

Review new enzymatic and size-classed methods for zooplankton

Steve Hay opened the discussion and he mentioned that his group have ongoing work with a Zooscan, which they are using to generate size spectra in order to investigate time-series. Webjørn Melle said that the plankton group at IMR also have ongoing work with a Zooscan. Both institutes have had some problems with Zooscans. Steve continued with the topic of biochemistry, and remarked that biochemistry has been discussed since the beginning of the group. Lately, more concrete work has been done and a number of WGZE members have agreed the need for a workshop on biochemical methods.

Lutz Postel gave a presentation about biochemical approaches related to growth, referring to several publications on methods based on RDA and enzymatic activities. Lutz presented some results from the method Santiago Hernandez Leon's group at the Universidad de Las Palmas de Gran Canaria has brought to his laboratory and a work of Biegala and Harris (1999). He mentioned potential problems using protein methods. For details see ICES WGZE Report 2004. Further, he discussed pros and cons of using biochemical methods. Lutz also gave a presentation of important aspects to be considered in any potential workshop. This presentation included a discussion with Ted Packard, and concluded that there is a need for: careful comparisons between classical and biochemical methods; comparison between measured and calculated metabolic rates using individual body mass and related properties (temperature, food concentration); and minor aspects, such as which protein method is the most suitable one? Lutz proposed that a workshop should be arranged and that a drafting group should outline the content of a workshop and when and where to meet. He proposed Lidia Yebra to lead the drafting group. Lidia accepted this responsibility and gathered interested WGZE members the next day. Steve suggested that an outcome of the workshop should be a manual or protocol describing what to do in different situations. A suggestion for funding was EUR-OCEANS with application deadline 25 April 2010.

Lidia Yebra presented results from three ongoing studies looking at metabolism of copepods (*Paracartia grani* and *Oithona davisae* nauplii) and fish (herring larvae). These found positive relationships between somatic growth and specific aminoacyl-tRNA synthetase (AARS) activity and RNA/DNA ratio under saturating food conditions in the laboratory. However, under starvation relationships between the three variables are weak or non significant. RNA/DNA is very sensitive to starvation and hence is a good index of nutritional condition, while specific AARS is better indicator

of weight-specific growth rates. Also, in *O. davisae* nauplii, it has been observed that the relationship between growth and RNA/DNA is different for nauplii and copepodites. Jeffrey Runge and Steve Hay noted that these methods are interesting for *Calanus* diapause research.

Report on the outcome of the 2009 ASC Session A

Janna Peters gave a presentation on the outcome of the 2009 ASC Session A – "Biochemical, biogeochemical, and molecular approaches to the study of plankton ecology and species diversity" for which, Steve Hay, Janna Peters and Ann Bucklin were conveners. The rationale for this session was, among others, that novel biochemical, biogeochemical, and molecular approaches and techniques will increase our knowledge of: plankton species diversity; material flow (e.g. nutrient uptake) and trophic relationships in pelagic food webs; correlation of dietary components and food quality with vital rates and recruitment success; physiological condition, growth, and impacts of biotoxins and pollutants; and reveal impacts of environmental variability on species.

Three main topics were addressed: 1) characterization of plankton species diversity, 2) effects of environmental variability on physiological processes, and 3) trophic relationships, rates and adaptive capacities in pelagic food webs. The session included 27 contributions (15 oral and 7 poster presentations, 5 withdrawn). The session discussion concluded that further integrated studies are needed on functional responses, adaptation and acclimation, and energy budgets of organisms, and that the potential for scientific integration - dissolving barriers between disciplines – is enormous and will lead to greatly enhanced understanding in coming years. Janna pointed out that some presentations at the ASC were conclusive and some non-conclusive, which led to an interesting discussion and new knowledge was forthcoming.

It was highly recommend that ICES continue to investigate, encourage and integrate molecular and biochemical techniques into broader scientific approaches, surveys and strategies. The session discussion resulted in a strong recommendation for the WGZE, in concert with other expert groups and individuals, to organize and hold a workshop to bring together scientific and technical experts to foster training, development and integration of molecular and biochemical approaches to advance marine ecology and ecosystem management. For theme synopsis, abstracts and a report, see: http://www.ices.dk/iceswork/asc/2009/themesessions.asp.

6 ToR D: Prepare and improve the ICES Plankton Status report including an examination of regional and cross-basin trends and recommend means of incorporating species information into the report

The "Plankton Status Report" should now be referred to as the "Zooplankton Status Report". This will distinguish it from similar works planned by the ICES Working Group on Phytoplankton and Microbial Ecology (WGPME), which formed this year and hopes to produce a corresponding (phyto)plankton status report in the future. Todd O'Brien, the data lead for the zooplankton report, will be working with WGPME to create their report.

This year's zooplankton status report will be based on data sampled through the end of 2008, adding three more years of data to the previous report's analysis (which included data through the end of 2005). At the time of the WGZE meeting, 75% of the zooplankton monitoring sites had submitted these additional data for the report.

Another change to this year's report is that it will be using the UK Met Office's "HadISST" temperature index set instead of the Reynolds ERSST temperature index. The main reason for this switch was because the HadISST has 1° spatial resolution, compared to the Reynolds 2° resolution, allowing for a tighter spatial match between the index and the zooplankton monitoring sites.

The standard figure sets used in the previous report were described and discussed. There was a question from Mark Benfield about adding a colour bar to the standard monthly mean and monthly anomaly matrix plots, but Todd suggested that because these are relative color categories (i.e., different for every variable and every time series), it might not be particularly meaningful or useful. Astthor Gislason asked about the utility of the standard figure sets for data sampling only one month or one season per year. Compared to a figure from a multi-month sampling program, for example, these figures may seem empty and have a lot of white space in the figures. Todd and others felt that keeping consistency in the plots across all 40 time series in the report was useful. There was also some discussion about the inclusion of long-term trends figures (i.e., plots of the zooplankton variable against relevant climate indices or the HadISST 100 year temperature trends). The long-term trends plots are interesting for longer time series, but they may be less suitable for shorter time-series.

There was a great deal of discussion about the inclusion of species tables or plots, particularly with respect to the top-ten species lists. It was generally decided that the plots were more useful than the tables, because the plots showed the relative contribution of different categories of taxa over time, whereas the tables showed only the relative contribution of different categories in the last year of the series (2008) compared to the average from the previous years of the series. Erica Head pointed out there also needed to be some caution about including general categories, such as "eggs" and "nauplii" in these species lists. This was not fully resolved, because while these may not be quantitatively sampled by some systems (depending on gear and net mesh) they may constitute an important component of fish diets. Some concern was also raised about how to deal with species that either drop out or appear in the time series over time. This was not fully resolved, although if species do appear, they would be added to the lists, increasing the total number of species in the list.

In the final discussion of the WGZE meeting, a ToR was proposed for the 2011 meeting to evaluate and define metrics of diversity, to address some of the issues raised during the discussion.

Todd prepared packets, both in hardcopy and electronic form, of the information included in the regional chapters, and asked groups from each region to update the introductory text for each chapter. Included in the packets were global and Atlantic basin maps of various parameters that will be included in the final status report. Variables mapped included: SST, average chlorophyll, scalar wind, mixed-layer depth (MLD). The data on these maps were plotted using various statistics of the data for each node, such as the average (mean), the mean climatological span (MCS), and interannual variability. Following the discussion the members broke up into regional groups to update the individual regional chapters.

7 ToR E: Review plans for sessions and activities during the 5th Zooplankton Production Symposium

Delphine Bonnet presented the plans for sessions and activities during the 5th Zooplankton Production Symposium "Population Connections, Community Dynamics, and Climate Variability", to be held in Pucón (Chile) on 14–18 March 2011.

The Topic sessions include Effects of climate variability on secondary production and community structure, Ecological interactions, Zooplankton life histories, Small scale processes and patterns, Zooplankton in upwelling and polar systems, Zooplankton physiology and the Role of zooplankton on biogeochemical cycles.

Also several Workshops are planned on topics like Advances in genomic and molecular studies of zooplankton, Updates and comparison of zooplankton time series, Individual Based Models, Impact of ocean acidification and Automated visual plankton identification.

Deadline for submission of abstracts would be June 2010. Further details can be found at www.pices.int/zooplankton2011.aspx.

8 ToR F: Review the report on Zooplankton and Climate Change for the ICES Position Paper on Climate Change and revise as necessary based on comments from the SSICC

The initial document was authored by Priscilla Licandro, Michel Harvey and Erica Head. Luis Valdes requested expansion in some areas and Mark Benfield, Astthor Gislason, and Joe Silke (WGHAB) and went to Copenhagen to work on editing the document.

This is the "official position paper" for ICES. It primarily uses published data and some data from the Plankton Status report. The final review will take place 15 May – 15 June 2010. Mark asked the group to look at, and comment on the document by 15 May. There will be another round after 15 June asking for more details. The final version should be ready for the ASC and the whole thing will go for publication in late autumn 2010. It will be a "glossy" or a CRR – most likely the latter. Our contribution is Chapter 7 mostly from the WGZE. Mark summarized an outline of chapter.

9 ToR G: Discuss potential linkages and encourage joint activities with the Working Group on Phytoplankton and Microbial Ecology

Mark informed the group that the new Working Group on Phytoplankton and Microbial Ecology (WGPME) was now established and had met for their first meeting in Aberdeen 3–5 March 2010. He told the group that he had received some information from William Li, the chair of the group, about their meeting. Jens Rasmussen and Steve Hay, both at the Marine Laboratory in Aberdeen and both members of our group, had been present for a short time at the WGPME meeting and informed about the activities of WGZE and SGMIT (Study group on Integrated Morphological and Molecular Taxonomy), respectively. Todd O'Brien of our group was invited to the WGPME meeting as they have visions of creating time series for microbes, which would include algae, bacteria, archaea, virus and protists (including microzooplankton). While some members of the WGPME group have data and undertake research on microzooplankton ecology, they did not incorporate explicitly microzooplankton issues into their ToRs. Microzooplankton will, however, always constitute a part of the discussion. WGPME are open for any suggestions from us on collaborations and linkages. They have strong linkages with WGHABD (Working Group on Harmful Algal Blooms Dynamics) and are positive to the idea of having a joint meeting of WGPME-WGZE in the future. The next meeting of the WGPME will be at the Marine Institute in Galway, Ireland, 21–24 March 2011.

Steve Hay told about his participation in the first meeting of the WGPME group in Aberdeen. He said that although he had only been present at the meeting for a short

time he sensed a lot of enthusiasm amongst the 25–30 people present. The group took a while to set up, but seems now to be firmly established. There are obvious linkages between our groups through microzooplankton, and in this context it might be an idea that we set up a subgroup of people to look at microzooplankton. Another link with the WGPME group is the fact that zooplankton are dependent on phytoplankton for food. Steve concluded that our group had several ecological linkages to the phytoplankton group. The fact that Todd was invited to their meeting says a lot.

There was some discussion on earlier attempts to establish a Phytoplankton expert group in ICES. Todd O'Brien suggested that one possible reason for the earlier phytoplankton group's failure was due to overlap with the successful ICES HAB group, and possibly an internal split focus within the group between working with ecology ("looking at numbers and interactions within the population") vs. taxonomy ("identifying the members in the population"). Todd O'Brien said that his mission with the WGPME group was to help them create a phytoplankton equivalent of WGZE's successful zooplankton status report series. Roger Harris felt that it would be interesting to see microzooplankton included, because at several of our last meetings the importance of incorporating microzooplankton in the work has been raised. He felt that this topic was an important area.

Erica Head said that a joint meeting was interesting and worthwhile. Mark Benfield said that we should reach out to the microzooplankton ecologists and ask them to take part in our meetings. He proposed that a list of microzooplankton specialists be made. In the discussion that followed the following tentative list of experts in microbial ecology was prepared, however this is by no means a comprehensive list: Albert Calbet (Barcelona); David Montages (Liverpool); Diane Gifford (Rhode Island); Diane Stoecker (stoecker@umces.edu, Univ. Maryland Center for Environmental Science, Horn Point Lab.); Elaine Edwards (PML); Joanna York (joanna.york@vt.edu, Biological Systems Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA, USA.); John Dolan (Villefranche); Judith O'Neil (joneil@hpl.umces.edu, Horn Point Lab, University of Maryland Center for Environmental Science, Cambridge, MD, USA.); Leo Procise (lprocise@odu.edu, Ocean, Earth and Atmospheric Sciences, Old Dominion University, Norfolk, VA, USA); Monica Modigh (Naples); Peter Lavrentyev (peter3@uakron.edu, Biology, University of Akron, Akron, OH, USA); Serena Fonda Umani (Trieste); Susanne Menden-Deuer (smenden@gso.uri.edu; URI, GSO); Suzanne Strom (Washington).

Mark suggested that a ToR be put together that would address microzooplankton ecology. Related to this we might invite some microzooplankton specialists to our next meeting. There was general consensus that this was a good idea. A discussion followed on linkages and collaborations with other groups, and Mark Benfield felt that in addition to microzooplankton, meroplankton was a potential linkage to other expert groups such as those working on benthic and/or fish ecology.

Steve Hay said that recruitment would remain one of the burning issues in marine ecology in the future. With reference to his project looking at the trophic ecology of sand eels, he felt that there was still a lot of interest in the field and scope of collaboration with other groups.

Mark Benfield said that it was important to try to understand how the fluctuations in zooplankton reflect on the predatory field for the fish stocks. This could serve as input to the Climate Change document that the SSICC (Strategic initiative on Climate Change) are currently working on.

10 ToR H: Monitoring methodologies for ocean acidification (OSPAR request 2010/2): To provide, on the basis of a review of existing methodologies and experience, recommendations for cost efficient methods for monitoring ocean acidification (OA) and its impacts, including possibilities for integrated chemical and biological monitoring.

Specifically this should provide: (i) advice on appropriate spatial and temporal coverage for monitoring, considering different oceanographic features and conditions and key habitats/ecosystems at risk from OA in the OSPAR maritime area; and (ii) advice on the status and maturity of potential indicators of OA impacts, on species, habitats and ecosystems that could be considered for inclusion in OSPAR monitoring programmes.

After reviewing the requests of OSPAR by the WGZE, the group tried to compile ideas from the zooplanktologist point of view. In general, the group felt that the ICES Marine Chemistry Working Group have the best expertise for recommendations for cost efficient methods for monitoring ocean acidification (OA) and its impacts. Current methodological developments are in discussion within the BONUS AMBER project in the Baltic Sea (http://www.bonusportal.org/files/625/Schneider.pdf).

Mark Benfield demonstrated the different OSPAR regions. The large spatial domain suggests that impacts of, or susceptibility to OA may vary among the different OSPAR areas. In this context, he mentioned a paper of Olafson *et al*. (2009). It shows an acidification of $-0.0024\ yr^{-1}$ in the Iceland Sea which is 50% faster than in subtropical areas.

For preparing advice on the status and maturity of potential indicators of OA impacts, on species, habitats and ecosystems that could be considered for inclusion in OSPAR monitoring programmes, a set of a few papers on species which are potentially affected were discussed. For example, *Gammarus locusta* could be used as a suitable indicator (Hauton *et al*., 2009). The same was discussed for *Hommarus gammarus* zoea (Arnold *et al*., 2009), and some other few species. The discussion covered a wider spectrum of potential direct and indirect indications and effects of acidification on zooplankton, like nauplii did not hatch at pH< 6.2 (Jeff Runge), influence on gastropods ´shells is likely and known for *Limacina* (Steve Hays, and others), indirect influence on oxygen minimum zones and daily vertical migration might play a role (Steve Hays, Peter Wiebe), and effects on survival of *Acartia* and tunicates were mentioned. Mark Benfield asked for a map on *Limacina* distribution.

It was concluded to send relevant papers and information to Mark Benfield by 15 April. Then, he is going to prepare a report of about five pages. Following the meeting, the draft report was circulated among the WGZE for comment and submitted to ICES on 19 April 2010. Mark attended an ADGMON meeting at ICES Headquarters on May 4–5 2010 where the report was edited and completed.

11 ToR I: Report by 15 March on potential contributions to the high priority topics of ICES Science Plan by completing the document named "SSGEF_workplan.doc" on the SharePoint site. Consider your current expertise and rank the contributions by High, Low or Medium importance

Prior to the WGZE meeting, the questionnaire from the SSGEF was circulated among the group. The responses from the WGZE were collated by Mark Benfield and as-

signed scores based on majority vote. In the case of ties, the scores were averaged and rounded to the nearest integer. Scoring: 1=Low, 2=medium, 3=high.

SSGEF Issue	111	112	113	114	115
WGZE	3	3	3	3	3
SSGEF Issue	121	122	123	124	131
WGZE	3	2	2	2	1
SSGEF Issue	132	133	134	141	142
WGZE	2	1	1	2	1
SSGEF Issue	143	144	145	146	147
WGZE	3	2	2	1	2
SSGEF Issue	151	152	153	154	155
WGZE	2	2	1	1	2
SSGEF Issue	161	162	171	172	173
WGZE	3	3	1	1	1
SSGEF Issue	211	212	213	214	215
WGZE	2	1	1	1	1
SSGEF Issue	221	222	223	231	232
WGZE	1	1	1	1	1
SSGEF Issue	233	241	242	243	244
WGZE	1	2	1	1	2
SSGEF Issue	245	251	252	253	254
WGZE	2	3	3	1	2
SSGEF Issue	311	312	313	314	321
WGZE	2	2	2	1	3
SSGEF Issue	322	323	324	325	326
WGZE	3	2	1	2	3
SSGEF Issue	327	331	332	333	334
WGZE	2	1	1	1	1
SSGEF Issue	335	341	342	343	344
WGZE	1	1	1	1	1
SSGEF Issue	345	346			
WGZE	2	2			

12 ToR J: Prepare contributions for the 2010 SSGEF session during the ASC on the topic areas of the Science Plan - which cover: Individual, population and community level growth, feeding and reproduction; The quality of habitats and the threats to them; Indicators of ecosystem health.

This ToR was not discussed during the meeting owing to its late inclusion in the list of ToRs for the WGZE and confusion about which version was current. It was circulated amongst the membership after the meeting and deliberated via correspondence.

The consensus of the group is that the WGZE Zooplankton Status Report provides an unrivalled resource with which to address where the resources are to address the issues and illustrate the diversity of the planktonic ecosystems in the ICES area. In terms of assessing indicators of ecosystem health, the Zooplankton Status Report con-

tains data from which temporal changes of species diversity, unusual occurrences of new species or absences of traditionally abundant species, as well as range extensions can all be assessed.

A major problem, with setting up and maintaining of surveys and monitoring of species diversity, lies in the lack of suitably trained and experienced taxonomic analysts in many marine institutes. Although new approaches through Imaging systems and genetics methods (barcoding, RT-PCR, etc) may go some way to help, these have limitations and still require very considerable support from trained taxonomists. Imaging and genetics do not distinguish developmental stages for example, which is critical when species population dynamics are studied.

However we should also emphasise the dearth of, and problems with obtaining, information on physiological rates and species responses to environmental pressures and variations. I think we should point out that WGZE has promoted such measurements (the Zooplankton Methods manual) and is championing molecular and biochemical methods development and applications (2009 ASC Theme session A and 2010 Workshop proposal).

Threats to habitats are real (e.g. climate change and alterations in temperature, storminess, stratification, upwelling; or ocean acidification or CO^2 sequestration, oil spills and other forms of pollution). In addition to directly affecting holoplanktonic communities, impacts on benthic habitat can affect benthic community structures and productivity and so the abundance and composition of the meroplankton.

How can WGZE Plankton Status report address Indicators of Ecosystem Health? The report contains a variety of indices that highlight system changes. These include: divergence/deviation in species diversity; occurrences or absences of new species in any year in significant numbers; unusual abundances of key species. At some sites, clear relationships exist with temperature and/or salinity (in the Baltic), as well as with chlorophyll biomass.

13 Progress Reports: Summary of the Proceedings of the "Joint ICES/CIESM Workshop to Compare Zooplankton Ecology and Methodologies between the Mediterranean and the North Atlantic (WKZEM)

Astthor Gislason announced that the formal workshop report has been published by ICES (http://www.ices.dk/pubs/crr/crr300/CRR-300-Final-web.pdf). Cooperative Research Report 300 includes 16 extended abstracts covering wide-ranging topics including distributions and variability, faecal pellet composition and structure, etc. There were relatively few comparative and North Atlantic studies, which had been an objective. Fostering collaborations between Mediterranean and North Atlantic scientists was an objective, which succeeded to a reasonable extent, however, the objective of comparing Mediterranean and North Atlantic ecosystems was not as well achieved.

Roger Harris asked whether the papers would be published on line. Astthor felt that this was likely. Steve Hay asked about the direction for further collaborations. Astthor indicated that at this point most collaborations were at the level of a few individuals however, there was not formal process for establishing ICES/CIESM linkages in place yet. Todd O'Brien indicated that time-series from the Mediterranean are now in the status report and that we're receiving a lot more data from this area.

14 Progress Reports: CMarZ and Barcoding Association

Ann Bucklin gave an update on the Census of Marine Zooplankton (CMarZ) and CMarZ Barcoding Association (CBA), referring to the interest in this project during the last Working Group meeting on the Faroe Islands and being encouraged by Steve Hay to give a brief updated overview.

CMarZ is a component of the Census of Marine Life (CoML) project and the goal is to produce accurate and complete information on zooplankton species diversity, biomass, biogeographical distribution, genetic diversity, and community structure.

CMarZ was initiated and funded since 2004 and the project leaders are Ann Bucklin (University of Connecticut, USA), Shuhei Nishida (University of Tokyo, Japan), Sigrid Schiel (Alfred Wegener Institute, Germany) and Peter Wiebe (Woods Hole Oceanographic Institution, USA). The period of field work and sample analysis of all CoML projects, including CMarZ, ended in 2009, being followed by synthesis activities that will continue through 2010. There will be an official closing finale in London during October 2010. Ann pointed out that although this successful project is ending that there is a lot of more work to accomplish.

The CMarZ goals have been integrated morphological and molecular systematic analysis of ~7000 described holozooplankton species and global surveys from ships of opportunity and dedicated cruises including the Biodiversity hotspots (deep sea, Southeast Asia). CMarZ completed so far more than 90 cruises, samples have been collected at more than 12 000 stations from every ocean basin and there are 6500 samples available for analysis.

Ann pointed out that her presentation is concentrating on the North Atlantic, since ICES has a focus on this area. She presented a table showing the Biogeography and Biodiversity of the North Atlantic that includes, according to Brinton and Longhurst, 3 different biogeographic and 11 multiple ecological zones that contain more than half of known metazoan holozooplankton species diversity. In total there are 3810 known Atlantic species ranging from the phylum Cnidaria up to Chordata.

The Barcoding of Zooplankton targeted on the coast of New England where the Ecosystem Monitoring Program (ECOMON) takes place and ECOMON survey samples have been collected for CMarZ since 2001. Barcoding is being done for ~300 species from 2008 samples, with 10–30 specimens per species from one or more samples.

In the following Ann showed how to access the information on the CBA Website (http://www.cmarz.org/barcode/index.htm) and guided through the homepage setup. The specimen tracking database is open access and everybody can see which species are already barcoded. Sampling from the Atlantic Ocean has yielded 2622 specimens of 679 species for DNA barcoding so far, and the barcoding analysis is still ongoing.

Ann encouraged everybody who is interested to become a member of the CMarZ Barcoding Association. She also called for assistance of the WGZE Study group on Integrated Morphological and Molecular Taxonomy (SGIMT) for barcoding North Atlantic holozooplankton species. This activity might be coordinated through the CBA Specimen Tracking Database to reduce duplication of effort and target species not previously collected, identified or analyzed. Requested are identified specimens from recent existing collections in alcohol (95% Ethanol), Barcoding will be done by the International Barcode of Life Project (iBOL) at the University of Guelph in Canada by high throughput sequencing, as part of a CMarZ – iBOL partnership.

The presentation was followed by an intense discussion within the group and many questions mainly referring to the problems of barcoding and taxonomic species identification. Steve proposed that often species compositions within a sample are totally different if classified by different taxonomists. Ann mentioned problems to identify especially appendicularians and euphausiids. COI, a protein-coding gene that is used for DNA barcoding because its mutation rate is often fast enough to distinguish closely related species, works for gelatinous plankton but not for corals and other Anthozoa.

Ann pointed out that sequencing everything would be very nice, and although it is very expensive it might be the way to go, because the data will be very useful once the library is completed.

15 Progress Reports: The GELAMED Project and *Paracartia grani* in the Mediterranean

Delphine Bonnet discussed two projects: the GELAMED Project and the occurrence of the copepod *Paracartia grani* in the Mediterranean.

The GELAMED Project is a study of the gelatinous plankton in the Mediterranean. The project runs from 2010–2012 and has collaborators from both scientific and non-scientific (fishermen) arenas. The goal of the GELAMED is to study the biodiversity and population dynamics of gelatinous organisms in the Mediterranean Sea. The field study sites are along the south coast of France from Banyuls (MOLA station) to Villefranche sur Mer. They have chosen two lagoons for study: Berre Lagoon near Marseille and Bages-Sigean Lagoon. These sites are being monitored every 2 weeks for 2 years. There are 3–4 stations per lagoon with a station in the connection between the lagoon and the sea.

They had a meeting in September 2009 to discuss sampling design and methods. Plankton nets were chosen for the lagoon stations with 80um and 200um mesh 50cm diameter. For the coastal stations, net tows are made from the bottom to surface using 200 and 700um mesh nets with mouth diameters of 57 cm and 1 m, respectively. The target gelatinous organisms being sampled are cnidarians ctenophores, siphonophores, tunicates, and chaetognaths. Two target species are being examined: *Aurelia aurita* in Thau lagoon and *Mnemiopsis leidyi* in Berre and Bages Sigean lagoons. They will do experiments on these two species. A workshop in gelatinous plankton taxonomy is to be held in Montpellier in July 2010. They are looking for taxonomic experts to join the group.

The second study Delphine presented examines the ecology of a newly appearing copepod species, *Paracartia grani*, in Thau lagoon in the south coast of France. The Thau lagoon is a semi confined system. There are many invasive species in the lagoon including sea horses and many microphytes. The lagoon is heavily impacted by anthropogenic activity including eutrophication and aquaculture. The lagoon accounts for 20% of the French national production of shellfish. They are monitoring with plankton net tows, every 2 weeks.

Paracartia grani was first observed in the lagoon in 2008. It is an opportunistic Atlantic coastal species. Delphine did a literature review of *P. grani*. She found that it was first recorded in Norway in early 1900s, making its way south, being found in the Bay of Biscay in the 1980s, south coast of France in 1990s, and in the eastern Mediterranean in 2000s. Both adults and juveniles of *P. grani* are present in Thau lagoon from June to December and absent before that in water column. These observations imply

that dormant resting eggs may be present in sediments during the time of the year when they are not found in the water column. This invasion brings up the question: Can introduction of this species affect the ecosystem? *Paracartia grani* can represent 90% of zooplankton abundance at certain times, so the answer appears to be yes. *Acartia clausi* and *A. discaudata* are disappearing later in the year over the past 50 years, from unpublished historical data found by Delphine's group. *Paracartia grani* has not been seen before in Thau lagoon. Another question is: What are the niches of the various *Acartia* species in this lagoon in terms of temperature, salinity, and food requirements? Delphine also presented an interesting map showing a correlation between aquaculture centers and *P. grani* presence. It has recently been found that *P. grani* may be an intermediate host for shellfish parasites in the Mediterranean and the Eastern Atlantic. There is a good correlation between *P. grani* and oyster culture sites. They are able to detect the parasite *Marteilia refringens* using PCR and in situ hybridization assays have been used to observe *Marteilia refringens* inside *P. grani*. This also may be a way to identify *P. grani*. Many questions remain to be answered including: How is *P. grani* infected and are other species of *Acartia* also hosts?

16 Progress Reports: The Enigmatic Role of Euphausiids in the Gulf of Maine

Lew Incze presented a proposed research thrust initiated by himself and Jeff Runge on euphauiids in the Northwest Atlantic to be initially held as a regional workshop in the NW Atlantic. The first plan is to go ahead with an informal workshop this spring (possibly May) as an initial organizing effort. Ultimately this initiative could be sponsored by ICES to synthesize across N Atlantic regions, similar to the effort underway in the Pacific.

Euphausiids represent an important but poorly understood link in marine food webs of the North Atlantic. It is a real problem to give a quantitative estimate of their abundance due to their size, fast swimming speeds, range of depths, and extreme patchiness all of which render them difficult to sample. Conventional plankton nets are too small and cannot be towed fast enough to sample them reliably beyond the larval stages. Nets with larger openings and mesh sizes catch them, but with unknown efficiency. Acoustic sampling with single frequencies that detect euphausiids (e.g., in the range 75–120 kHz) cannot distinguish them from other potentially abundant organisms, or from steep density gradients in the upper ocean. The present knowledge of euphausiids in this region is thus spotty, being confined mostly to a few focused studies. Emerging technologies are improving the prospect for broad-scale sampling and better estimates of distribution and abundance.

Lewis Incze took then as an example the importance *Meganyctiphanes norvegica* in the Gulf of Maine where it forms surface swarms, in association with internal waves, called red water by local fishermen. These swarms do not occur annually but are clearly important as whales, and fish, such as herring focus on, and search the banks where *M. norvegica* swarms.

The planned regional workshop will focus on: (1) distribution and abundance and sampling methods; (2) life history; (3) trophic role; (4) advection versus production; (5) interannual and longer-term drivers of change; (6) research questions such as local and regional scale studies, what is already underway and how to deal with sampling efficiency; (7) opportunities for data mining, analysis, and synthesis with existing data and information; (8) evaluation of broad estimates of trophic impacts based on existing information; and (9) ideas for funding and additional expertise.

The presentation triggered a lively discussion on problems of sampling, how different participants dealt with sampling with different tricks and methods; use of ADCP backscattering, camera systems, stunning with strobe or flash lights during sampling, and the use of fish stomachs. Working group members supported the initiative acknowledging the enormous importance of euphausiids, both as predators and prey and acknowledged the value of understanding and pooling information on their biology and abundance.

17 Progress Reports: Summary of the Calanus Life History Workshop

Jeff Runge reported on the outcome of the workshop on: Life histories of the planktonic copepods, *Calanus finmarchicus* and *Calanus helgolandicus*: Advances in understanding in the Gulf of Maine and across the North Atlantic, held at Portland Regency Hotel Portland, Maine, The workshop was part of the US GLOBEC Pan Regional Synthesis Project, and it was sponsored as a Regional Association for Research on the Gulf of Maine (RARGOM) Theme Session and held on 22 March 2010 at the Regency Hotel in Portland, Maine.

The objectives of the workshop were:

- Review present capabilities in terms of model development and data needs
- Exchange information on available demographic and vital rate data for two species of *Calanus* in the North Atlantic, *C. finmarchicus* and C. *helgolandicus*, throughout their range.
- Identify data analysis priorities and willing participants for large-scale comparative studies of *Calanus* across the whole Atlantic, encompassing the entire range of both species and using the compiled data sets.
- How to move forward: Make a tentative timetable for completion of analysis related to the compiled data sets and a timetable for data access

The workshop morning session provided a North American perspective on the development and capabilities of IBM and advective-diffusive models to describe *C. finmarchicus* life history and population dynamics in the North Atlantic. The afternoon session was devoted to assessment of available demographic and vital rate data for two species of *Calanus* in the North Atlantic, *C. finmarchicus* and C. *helgolandicus*, throughout their range. The workshop also identified willing participants in data analysis for large scale comparative studies of *Calanus* across the whole Atlantic, using the compiled data sets.

The workshop agreed on a number of priorities for the data analysis and an outline of the way forward.

Complete details of the workshop including abstracts are available online from: http://hpl.umces.edu/~jpierson/RARGOM.

18 Progress Reports: JPR Special Issue on L4 Time-Series

Roger Harris presented the JPR Special Issue on L4 Time-Series that is coming out in May 2010. The weekly monitoring at the L4 station started on 14 March 1988 and the Special Issue commemorates its 20th anniversary. The issue includes different papers, including an Introduction about the first 20 yrs of the L4 time-series as well as several articles compiling data of the multiple variables recorded at the station (from optical properties of the water column to dynamics of meroplankton). In relation to zooplankton, the special issue includes three articles, one being a compilation assessing

the variability of zooplankton on the western English Channel. Roger also highlighted that the L4 data are available online: www.westernchannelobservatory.org.uk/l4. This has been very important as has allowed for comparative studies that provided different views of the data from different groups. The L4 time-series has also benefited from being set within the frame of WGZE group.

19 Progress Reports: Use of PCR to study barriers between *Calanus* populations and biochemical indices applied to study growth of nauplii

Progress Reports: Barriers in the pelagic: Population structuring of *Calanus helgolandicus* and *Calanus euxinus* in European waters.

Lidia Yebra presented an overview of the study area including the sample collection sites, showing the regional co-occurrence of these species in the Atlantic. Following this, she presented PCR results, showing the relative distribution pattern of most common haplotypes. An analysis of molecular variance (AMOVA) as well as the 16S haplotype network showed significant differences between the study sites.

A morphological analysis showing prosome/urosome length differences indicated a similar relationship between the Atlantic and the Eastern Mediterranean data.

Finally she presented a map combining the structuring barriers of genetics, morphology and sea surface temperature data and concluded that there are important barriers between the Eastern and Western Mediterranean Sea, so Gibraltar is not the main population barrier. There were also important barriers between the East Mediterranean and the Black Sea. Hydrography (currents, fronts, etc.) was an important structuring factor both in the Mediterranean and the Atlantic; although within the Atlantic Ocean temperature might be the main factor controlling the latitudinal distribution. Further research is needed to ascertain relationships between the populations in the Western Mediterranean Sea and the Atlantic as well as the differences within the Eastern Mediterranean.

20 Progress Reports: FlowCAM Imaging System Demonstration

Harry Nelson from Fluid Imaging Technologies brought a FlowCAM imaging system down for a demonstration. The instrument was equipped with a low power objective and provided examples of zooplankton from a water sample collected near Portland.

Figure 1. Examples of zooplankton imaged with the FlowCAM.

21 Progress Reports: Comparison between automated analysis of zooplankton samples using ZooImage and traditional methodology

Astthor Gislason provided a report of a comparison of analysis of zooplankton samples using the ZooImage image analysis system and traditional enumeration of zooplankton under the microscope (Gislason, A. and T. Silva, 2009. Journal of Plankton Research. 31: 1505–1516). The objective of this study was to evaluate the accuracy of the ZooImage image analysis, which can be downloaded from the Internet, for taxonomic classification of samples. Zooplankton samples were collected in the Iceland Sea, split and placed in a shallow transparent tray. Individual specimens were separated from each other to ensure a clear image, and scanned with high resolution scanner (EPSON Perfection V700 Photo Scanner).

The classification of specimens was trained by sorting out taxa under a microscope and recording the known images to use as a guide for categorizing. There is a possibility of improving identification by scanning positively indentified taxa using a microscope. Six algorithms for use as recognition methods are included in ZooImage. The training set is divided into 10 parts, using one as the control test set. This exercise is repeated 10 times for calculation of % accuracy, displayed as a confusion matrix. The training needs to be done for each region and season.

ZooImage was able to classify zooplankton into main taxonomic entities (size classes and families or genera in some cases), while being less successful in identifying the zooplankton into species. Biomass and size distributions, which are difficult and time consuming to obtain by traditional microscopic methods were relatively easily measured with ZooImage. In total, the automated analysis takes much less time than the traditional methods. It is possible to analyze 6–12 samples a day by this method. While the study confirms that ZooImage is a promising tool for rapidly analysing zooplankton samples, it is also clear that the traditional microscopic approach is still needed, particularly in studies of zooplankton diversity and species population dynamics.

22 Progress Reports: Zooplankton ring net test in the Baltic

Piotr Margonski gave a presentation entitled "Species identification, counting and biomass determination of a zooplankton sample of the Baltic Sea" and summarized the zooplankton ring test carried out in the Baltic Sea between 2006 and 2009.

The objectives of this test were to assess identification skills of the participants, the accuracy of counting zooplankton taxa, and to check a new method for carbon mass determination aiming at updating the HELCOM COMBINE Manual Annex C-7 Mesozooplankton. Zooplankton experts of 15 institutions from all the Baltic Sea countries participated in this test.

The timetable of this project included ring test design and sampling in August 2006, preparation of the sampling material between October 2006 and March 2007 as well as the distribution of the samples in May 2007. The data was received and the samples returned between June and August 2007, during September the original data was reviewed and the statistical analysis of results and the compilation of the report took place from October 2007 to August 2009. Finally, the report was published in November 2009.

Three samples were collected at the BY-38 Station in the western Gotland Basin between 0 and 100m water depths during the second HELCOM MONAS Zooplankton Monitoring Expert Network Workshop in August 2006. These samples were combined with three other samples collected during the R/V Baltica cruise at stations located in the Bornholm Basin area in April 2006. All the samples were taken using a WP-2 net with 100μm mesh size. Samples were combined and then split into 1/1024 sub-samples using a large Motoda splitter. Finally, 50 randomly chosen sub-samples were used by the reference laboratory. All ring test participants received a list of the 196 zooplankton taxa known to be present in the Baltic Sea.

A table with the percentages of determination levels for the participants as well as for selected taxonomic groups were presented, thus giving an overview of those groups most taxonomy experts had problems with or disagreed about. The overall results were presented with some examples of statistical analyses.

In addition, the ring net test was also used to compare two methods for carbon biomass estimation. One method is based on existing conversion factors (CFs) and the other one on length measurements (LMs). All carbon biomass calculations were carried out by the Quality Assurance Panel and were based on abundance and length measurement results from the participants and the reference laboratory. The calculated carbon biomass results for two copepod species (*Acartia sp*. and *Temora sp*.) were presented showing that in most of the cases, by using the length measurements method, lower biomass estimations were obtained.

Two participants provided significantly more deviant abundance results comparing to the others, while results of seven participants were within the tolerance limits for all taxa considered. Taxa with characteristic shapes (e.g. *Bosmina sp*. and *Evadne sp*.) were identified correctly by all participants, *Pleopsis polyphemoides* was presumably subsumed to *Podon* sp. by some participants while *Fritillaria borealis* was sometimes not identified at all (probably due to problems with preservation of some samples). Efforts to solve the problems encountered in identification of taxa like the species of *Bosmina sp*., *Podon sp*. and *Pseudocalanus*/*Paracalanus sp*. should be made by organizing taxonomy workshops on a regular basis. The biomass estimations were usually higher when applying the HELCOM procedure of conversion factors.

More than half of the participants took part in any type of quality assurance or analytical quality control activity, however, laboratories involved in the zooplankton monitoring of the Baltic Sea should establish quality management systems and mandatory inter-laboratory comparisons and taxonomic workshops should be established on a regular basis.

Finally, Piotr Margonski presented some conclusions and recommendations pointing out, that if such ring tests are going to be organized in future, it is important to improve sample preparation procedure so that participants count smaller numbers of individuals in more than one sub-sample and when an identification to species level is too difficult it should be reported to genus and a general and more standardized procedure how to deal with development stages should be established and clearly presented in the HELCOM COMBINE Manual. The reporting of quantitative data on nauplii should be discussed. Furthermore, a uniform and regularly updated taxa list should be the basis for reporting and it was recommended to check the appropriateness of existing biomass conversion factors to avoid overestimations. To make it possible, the length to carbon relationships should be derived for the most common zooplankton taxa and at least 25 randomly selected individuals should be measured for biomass calculations based on length measurements.

Piotr summarized by stating that a regular scheme of ring tests and especially training workshops should be established and financed to maintain and improve the quality of zooplankton monitoring data.

Subsequently, a very lively discussion followed this presentation. Peter Wiebe pointed out the need and importance of length to biomass relations for modellers. Rubao Ji also mentioned this during the Calanus Workshop.

Roger Harris asked if there has been any feedback from the participants and Lutz Postel informed that an upcoming meeting presenting and discussing ring test results will be organised. Steve Hay pointed out the importance of sharing knowledge and exchanging experience among taxonomists who are identifying zooplankton samples.

23 Progress Reports: IQ Easy Measure INTEQ®: Counting, determining, measuring of Baltic Sea zooplankton- calculations and archiving data

Lutz Postel reported on a new analysis system for zooplankton (IQ-Easy Measure INTEQ) that is currently applied at the Institute for Baltic Sea Research (Warnemünde, Germany). The system uses a stereomicroscope, which is equipped with a camera system and connected to a computer. The software simplifies the procedure of measuring organisms and calculating abundances and biomasses on the basis on species, stage, or season specific carbon-length relationships, thus makes the analysis progress much faster.

24 Progress Reports: Greenland Climate Centre

Sigrun Jonasdottir introduced the Greenland Climate Centre (www.natur.gl), which is situated at the Greenland Institute for Natural Resources in Nuuk. The centre collaborates with several Danish and international universities and research institutions in a range of research projects as well as with Greenlandic monitory programmes like ASIAQ, DMI, Greenland Ecological Monitoring Network (GEM), Programme for Monitoring of the Greenland Ice Sheet (PROMICE) and monitory activities in

Greenland Institute of Natural Resources. The program started this year and will be funded for at least five years, potentially longer.

25 Progress Reports: Video Plankton Recorder and Optical Sampling Update

Cabell Davis presented an overview of his work with different optical sampling methods (Video Plankton Recorder (VPR) and the Holocamera). The title of his presentation was: "Real-time automatic identification and visualization of plankton taxa".

Cabell started with a quick overview of different Video Plankton Recorder Systems that have been developed during the past years, including the original, analog VPR, the VPRII system with a digital black and white camera, as well as the new digital colour VPR. These VPR systems have been used in various ways during different studies, e.g. as surface sampling VPR, autonomous mini-VPR, bottom moored profiling VPR as well as attached to other underwater vehicles (e.g. BIOMAPPER2, Remotely Operated Vehicles, and Autonomous Underwater Vehicles (AUV Remus)).

Cabell mainly discussed the VPRII Fast tow fish, a system that has been developed for rapid surveys of plankton and particles (Davis *et al*., 2005; Davis and McGillicuddy, 2006). The VPRII fast-tow system includes a towfish with flight control and data acquisition computers and shipboard computers for supervisory control and data logging, processing, and visualization. It can be towed in different ways (e.g. undulating through the whole water column, horizontal) controlled manually or with an autopilot at speeds up to 12knots behind research vessels, thus making it possible to sample small scale distribution of plankton and particles across large distances in real time. The high-speed capability allows the system to be used opportunistically during transit legs of research cruises. A cantilevered tow-bridle on the port side of the towfish provides an unobstructed flow of water and plankton on the starboard side of the towfish where the imaging takes place. This design reduces disturbance of the imaged volume to a level below the shear rate detectable by copepods (Davis *et al*., 2005). The VPRII is equipped with a high resolution digital camera and a strobe ("towed video microscope"), both laboratory adjusted and calibrated for quantitative sampling. In addition, it is equipped with various biological and hydrographical sensors. Each image is tagged with a timestamp and can thus be assigned with the corresponding sensor data (logfile entry) afterwards.

A software called "Visual Plankton" (Davis *et al*., 2005) is used for processing and classification of the images and Cabell gave a brief overview of it. Manually sorted training images are used to build a classifier, and the accuracy of the classification is given by a confusion matrix that shows machine versus human taxonomic identification results. Images are classified with a dual classifier (Neural Network and Support Vector Machine) based on special features (shape and texture based). Sample images taken with the Video Plankton Recorder were presented showing different plankton taxa and particles including black and white and colour images of delicate and robust plankton and marine snow.

Following this, Cabell provided an detailed overview of work in recent years using the Video Plankton Recorder, showing the advantages and possibilities of optical sampling, including: Comparison of VPR and MOCNESS data where the VPR was mounted on top of the frame of a MOCNESS for ground-truthing, showing similar results in the depth distribution of copepods but a higher depth resolution in the optical data; Stratification study on Georges Bank showing the small scale distribution and aggregation of *Calanus* and *Pseudocalanus* along a temperature gradient and their

different distribution patterns; Retention/Loss Study on Georges Bank, showing the change and flux of the distribution of *Chaetoceros* colonies during late spring; Cross frontal exchange of plankton and particles on Georges Bank; Trans Atlantic distribution of fragile colonies of nitrogen fixating *Trichodesmium* colonies along a transect from the Azores to Cape Cod; Aggregation of diatom chains within eddies in the Sargasso Sea; Small scale distribution of larval Krill over the Antarctic Shelf; and Vertical distribution of fragile plankton species in the deep Pacific.

Cabell pointed out the strength of this tool and that compared with typical net surveys in shelf areas, the VPRII counts more plankton per station, quantifies ubiquitous fragile forms, automatically identifies plankton to major taxa and measures their size, quantifies scales of patchiness down to a few cm, and displays high-resolution distributions of plankton taxa and hydrography while underway.

In the end Cabell briefly introduced a new digital plankton holographic camera (Loomis *et al*., 2007; Li *et al*., 2007). This underwater digital holocamera illuminates plankton and particles with a diode laser and captures a hologram of a 0.3–1.0 liter volume on an image sensor. Software was developed to reconstruct images from the hologram. Sample images from the digital holocamera were presented showing high quality images that allow even identification of copepods to species level. The holocamera is being modified to fit inside drifters and gliders.

Finally he concluded by saying that more work is required to enhance these optical sampling tools, e.g. incorporating colour information from images into the VPR classification system and developing automatic processing software for holographic images.

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26 Updates: Activities of the WGBIODIV

The Working Group on Biodiversity (WGBIODIV) held its annual meeting in February in Lisbon. Although our group was invited to send a representative and we had identified a volunteer, at the last minute a cruise delay prevented attendance. Among their ToRs of relevance was one to contribute to a strategic initiative on biodiversity led by the SSGUE. This has relevance to our Zooplankton Status Report, particularly the inclusion of the top 10 taxa. Other ToRs included a review of biodiversity indicators.

Steve Hay indicated that he expects to be contacted, but he thinks the group is rather benthic in its scope. Biodiversity is a very hot topic. Reports have to be more than just species lists. For example, we could contribute species lists from different sites

and these could be posted on the WGZE website. Todd O'Brien indicated that he'd been thinking along these lines. He pointed out that biodiversity depends on the expertise of the taxonomists to some extent and on the sample analysis (e.g. the Atlantic Zonal Monitoring Program does not analyse samples to look for rare species).

Ann Bucklin's data suggest that there are 3500 zooplankton species in the North Atlantic. Steve Hay pointed out that a continuation of CMARZ and bar-coding could be the WGZE response to biodiversity and could address the demise of CMARZ We could just commit to take alcohol samples to send to someone to pick out the "un-barcoded" species. Peter Wiebe said that Ann Bucklin already has a project that is going to do this for the New England Shelf. Expanding it to other regions could happen. We could have a workshop to look at morphological and genetic identifications. Mark asked Peter and Steve to write a one-page summary describing a way forward – a proposal. That document is summarized in Annex 5.

27 Update: 2010 ASC Meeting Summary of Sessions, Call for Abstracts

After a recap of the 2009 Theme Session, the discussion followed the summary related to suggested theme sessions for the 2011 ASC. One proposal was a session focused on the BASIN program, however on Friday further discussion identified a second session: Integrating microzooplankton and mesozooplankton research on food webs.

Another potential topic was to review physiological tolerances of organisms and how these tolerances define the distribution of organisms in the sea. This latter topic was discussed and the idea was proposed to write a review paper instead of the theme session, possibly as a Horizons article in JPR. Jeff Runge called this "a gap study to look at what we need to know to model the distribution of animals." *Calanus* was suggested as a type organism for this project. Peter Wiebe suggested a comparison of two organisms, and suggested euphausiids with a question about why they are not in the arctic. Jeff Runge will take the lead on this paper. Roger Harris suggested a mid-year progress report on this work, perhaps in September.

28 Update: Potential participation in the ICES Symposium: Hydrobiological and ecosystem variability in the ICES area during the first decade of the XXI century

Erica Head informed the group about two upcoming symposia that could be of interest to members of the group.

The symposium on "Hydrobiological and ecosystem variability in the ICES and NAFO area during the first decade of the XXI century" will be held in Spain in spring 2011. Conveners: Sarah Hughes (UK), Alicia Lavin (Spain), Stephen Dye (UK), and Glenn Nolan (Ireland). The scientific justification, exact time and place, and scientific program for the symposium will soon be available at the ICES web site http://www.ices.dk/iceswork/symposia.asp?topic=2011

The symposium on "Comparative studies of climate effects on polar and sub-polar ocean ecosystems: progress in observation and prediction" will be held in May/June 2011 in Seattle, Washington, USA. Conveners: George Hunt (USA), Ólafur Astthórsson (Iceland), and Michio Kishi (Japan). The scientific justification for the symposium is available on the ICES web site:

http://www.ices.dk/iceswork/symposia.asp?topic=2011

Roger Harris informed about the IMBER workshop: IMBER IMBIZO II Integrating biogeochemistry and ecosystems in a changing ocean - Regional comparisons to be held 10–14 October, 2010, Crete. Organizing Committee for the IMBIZO: Ken Drinkwater, Alexandra Gogou, Julie Hall, Raleigh Hood, Michio Kishi, Michael Landry, Lisa Maddison, Coleen Moloney, Wajih Naqvi, Dan Repeta, Rory Wilson, Jing Zhang. http://imbizo-2010.confmanager.com/main.cfm?cid=1683

29 Identification of Terms of Reference for 2011

- a) Identify current zooplankton sorting centres and laboratories and prepare a review of their services, costs, and taxonomic expertise.

Rationale: Taxonomic skills are vanishing quickly and organizing the next WGZE meeting in Gdynia is an excellent opportunity to invite representatives of the neighbouring sorting centres to present their competence, experience and discuss financial conditions. In the case of many laboratories there are numerous samples, which have not been analyzed so far and we should identify and review the centres capable of helping to solve this problem. This will enable a search for additional funds to be allocated for analyzing those samples. Moreover, identifying scientific laboratories or even single experts with taxonomic expertise on particular groups of zooplankton would be an additional and valuable information.

- b) Build on the work relating to microzooplankton completed in Riga (2007) and explore the extent to which microzooplankton could be included in the zooplankton time-series produced in the Plankton Status Report.

Rationale: Microzooplankton constitute 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 and can be a significant food source for larval fish. 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 (for details see Report of the Working Group on Zooplankton Ecology, ICES CM 2007/OCC:04).

- c) Prepare a report on updating the Zooplankton Methodology Manual including identifying areas of the manual that require updating and activities that lend themselves to multimedia tutorials (e.g. videos) to be served via the web.

Rationale: Two different approaches were identified regarding the update of Zooplankton Methodology Manual: (i) one group will consider revision of the existing edition specifying parts of the text which need to be updated and/or corrected, potentially leading to a paper-back edition and a review article updating new topics; and (ii) the other group will focus on multimedia methodological tutorials to be disseminated through the web page.

- d) Review the Zooplankton Status Report and consider further developments and improvements to its contents including new time-series and additional analyses.

Rationale: The Zooplankton Status Report continues to evolve as a major published output of the WGZE. New data analyses and techniques for comparative analysis of time-series within the ICES area are now a priority for discussion and development.

- e) Review the outcomes of SCOR 137 (Coastal Phytoplankton Time-Series) and SCOR 130 (Automatic Visual Plankton Identification) and summarize findings relevant to zooplankton ecology.

Rationale: Both these SCOR Working Groups are highly relevant to the ongoing work of the WGZE. The former WG is just beginning its work while the latter is more mature and moving towards a conclusion. Their work will be reviewed in relation to potential links with, and significance for, the WGZE.

- f) Define the meaning of the term 'biodiversity' with respect to zooplankton including its definition, measurement, and relevant indices based upon it.

Rationale: There are various definitions of diversity. Usually the approach depends on the question asked. Group needs to decide what is important from the WGZE perspective. A recent paper examines zooplankton biodiversity in the Gulf of Maine (Johnson *et al*. 2010). This manuscript has been prepared as a contribution of the Census of Marine Life global network. This issue might be of interest for the ICES community. Analysis of community structure as well as diversity and similarity indices has been described in Chapter 4 of the ICES Zooplankton Methodology Manual. This text could be a good starting point of further analyses.

- g) Review the progress towards the workshop: Cross calibration of biochemical indices of growth and validation against somatic growth rates.

Rationale: A review of the state of the art of enzymatic activity methods, and other biochemical approaches, is a longer lasting demand of the WGZE community (see Report of the Working Group ICES CM 2004/C:07). The wide variety of physiological rates (growth, respiration, excretion, reproduction, feeding, etc.) approached though biochemical indices makes it impossible to compile all of them in a single workshop. Therefore, the initiative group decided to tackle each metabolic rate in a separate workshop.

The assessment of growth in zooplankton is indispensable in zooplankton production and biogeochemical flux studies. Growth estimation is needed (i) to assess recruitment rates of zooplankton species and their predators, (ii) to observe the response of zooplankton to changes in the environment and (iii) to develop models coupling physical and biological parameters. Despite its importance, there is not a secondary production index as widely applied as the ^{14}C for the primary production. This has led to the publication of many papers on zooplankton production assessed using different methods, the results of which are difficult to compare.

Hence we propose the organization of a workshop entitled: "Cross calibration of biochemical indices of growth and validation against somatic growth rates". The proposed date for the workshop is the first half of 2011. The expected outcome of the workshop is a recommendation peer reviewed paper on which method is best for somatic growth rates assessment.

Any meeting lasting 20–30 days would be extremely expensive for participants and this should be taken into account. Costs might be diminished by dividing the meeting into several shorter parts. An official proposal needs to be prepared for SCICOM consideration.

- h) Review the progress of the SGIMT.

Rationale: This new study group is addressing issues of taxonomy that are directly relevant to zooplankton ecology as well as the broader ICES community. Close linkages between the WGZE and the SGIMT will ensure that the latter is successful and will keep members of the former informed about new developments in this area.

30 Theme session proposals for 2011 ASC

The WGZE came up with the following suggestions for potential theme sessions for the ASC 2011 meeting:

Integrating micro- and meso-zooplankton in marine food web research. Conveners: Jamie Pierson, Steve Hay and Sigrún Jónasdóttir

Climate and fisheries related influences on marine ecosystems at regional and basin scales. Conveners: Webjørn Melle and Erica Head

31 Assistance to the University of Concepcion Marine Laboratory

Mark Benfield reminded the group of the devastation suffered by our colleagues at the Dichato Marine Laboratory of the University of Concepcion, Chile. All members of the group were supportive of efforts to assist our colleagues there. A website has been established to channel donations to assist

(http://www.oceanleadership.org/2010/university-of-concepcion-oceanographic-relief-fund/).

Annex 1: List of participants

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Annex 2: Agenda

Tuesday March 23, 2010 Regency Hotel

08:30 Continental Breakfast (Meeting Room)

09:00 Welcome, introductions, approval of agenda.

09:30 ToR A: Future Initiatives. [Lead: Harris, Rapporteur: Van Ginderdeuren]

10:00 Summary of the WKZEM CRR [Lead Gislason, Rapporteur: Margonski]

10:30 Coffee Break

11:00 ToR D: Prepare and improve the ICES Plankton Status report including an examination of regional and cross-basin trends and recommend means of incorporating species information into the report [Lead: O'Brien, Rapporteurs: Pierson]

11:30 ToR D …

12:00 Lunch

13:00 Break out groups to discuss regional components of the Plankton Status Report

14:00 Summarize outcome of breakout groups

14:30 Coffee Break

15:00 ToR C

Review the progress of the ICES historical dataset digitization project [Lead: Benfield, Rapporteur: Broms-Arnes].

Review new enzymatic and size-classed methods for zooplankton [Lead: Hay, Rapporteur: Broms-Arnes]

Report on the outcome of the 2009 ASC Session A - Biochemical, biogeochemical, and molecular approaches to the study of plankton ecology and species diversity [Lead: Peters, Rapporteur: Broms]

16:00 CMarZ and Barcoding Association Update. [Lead: Bucklin, Rapporteur: Ove Möller]

16:30 The GELAMED Project and *Paracartia grani* in the Mediterranean. [Lead: Bonnet, Rapporteur: Davis]

17:00 The Enigmatic Role of Euphausiids in the Gulf of Maine. [Lead: Enze, Rapporteur: Jonasdottir].

17:30 Adjourn

Wednesday March 24, 2010: GMRI

09:00 Summary of the *Calanus* Life History Workshop. [Lead: Runge, Rapporteur: Melle].

09:30 Summarize and discuss Plankton Status Report [Lead O'Brien, Rapporteur: Wiebe]

10:30 Coffee Break

11:00 ToR G: Discuss potential linkages and encourage joint activities with the proposed Microbial Oceanography Working Group, should it be established by SCICOM [Lead: Benfield, Rapporteur: Gislason]

11:30 ToR H: Discussion OSPAR Ocean Acidification Report [Lead: Benfield, Rapporteur: Runge]

12:00 Lunch

13:00 ToR H: Ocean Acidification Report Discussion [Lead: Benfield, Rapporteur: Postel]

13:30 ToR B: Update on New Study Group on Integrated Morphologic and Molecular Taxonomy [Lead: Hay, Rapporteur: Head]

14:00 JPR Special Issue on L4 Time-Series [Lead: Harris, Rapporteur: Yebra]

Use of PCR to study barriers between *Calanus* populations and biochemical indices applied to study growth of nauplii. [Lead Yebra: Rapporteur: Harris]

14:30 Coffee Break

15:00 ToR F: Report on draft chapter for ICES Position Paper on Climate Change. [Lead: Benfield, Rapporteur: Head].

15:30 ToR E: Review plans for sessions and activities during the 5th Zooplankton Production Symposium [Lead: Bonnet, Rapporteur: Yebra]

16:00 FlowCAM Demonstration [Harry Nelson, Fluid Imaging Technology]

17:00 Adjorn followed by a selection of the Finest Wines of ICES.

Thursday March 25, 2010 Regency Hotel

08:30 Continental Breakfast (Meeting Room)

09:00 Summary: Activities of the WGBIODIV [Lead: Benfield, Rapporteur: Harris]

09:15 2010 ASC Meeting Summary of Sessions, Call for Abstracts [Lead: Benfield, Rapporteur: Pierson]

09:30 Potential participation in the ICES Symposium: Hydrobiological and ecosystem variability in the ICES area during the first decade of the XXI century. [Lead: Head, Rapporteur: Melle];

09:45 Comparison between automated analysis of zooplankton samples using ZooImage and traditional methodology. [Lead Gislason, Rapporteur: Runge]

10:15 Zooplankton ring net test in the Baltic. [Lead: Margonski, Rapporteur: Ove Möller]

10:30 Coffee Break

11:00 IQ Easy Measure INTEQ®: Counting, determining, measuring of Baltic Sea zooplankton- calculations and archiving data [Lead: Postel, Rapporteur: Peters]

11:15 Greenland Climate Center [Lead Jonasdottir, Rapporteur: Peters]

11:30 Discussion of top 10 species information for the Plankton Status Report [Lead: O'Brien, Rapporteur: Head]

12:00 Adjourn

13:00 Bus pickup for trip to Freeport

13:30 – 17:00 Freeport, Maine

17:00 Reception at Harraseeket Inn

18:00 Lobster Bake

20:30 Bus returns to Portland

Friday March 26, 2010 Regency Hotel

08:30 Continental Breakfast (Meeting Room)

09:00 Selection of location for the 2011 Meeting

09:15 Identification of ToRs for 2011

10:00 Video Plankton Recorder Update [Lead: Davis, Rapporteur: Molleur]

10:30 Coffee Break

11:00 Theme session proposals for 2011 ASC [Lead Benfield, Rapporteur: Jonasdottir]

11:30 Assistance to University of Concepcion, Dichato Laboratory

12:00 Adjourn

Annex 3: WGZE terms of reference for the next meeting

The **Working Group on Zooplankton Ecology** (WGZE), chaired by Mark Benfield, USA, will meet in Gdynia, Poland, 25–28 January 2011 to:

a) Identify current zooplankton sorting centres and laboratories and prepare a review of their services, costs, and taxonomic expertise;

b) Build on the work relating to microzooplankton completed in Riga (2007) and explore the extent to which microzooplankton could be included in the zooplankton time-series produced in the Plankton Status Report;

c) Prepare a report on updating the Zooplankton Methodology Manual including identifying areas of the manual that require updating and activities that lend themselves to multimedia tutorials (e.g. videos) to be served via the web;

d) Review the Zooplankton Status Report and consider further developments and improvements to its contents including new time-series and additional analyses;

e) Review the outcomes of SCOR 137 (Coastal Phytoplankton Time-Series) and SCOR 130 (Automatic Visual Plankton Identification) and summarize findings relevant to zooplankton ecology;

f) Define the meaning of the term 'biodiversity' with respect to zooplankton including its definition, measurement, and relevant indices based upon it;

g) Review the progress towards the workshop: Cross calibration of biochemical indices of growth and validation against somatic growth rates;

h) Review the progress of the SGIMT.

WGZE will report by 15 May 2011 (via SSGEF) for the attention of SCICOM and ACOM.

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 zooplankton 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. Term of Reference a) Taxonomic skills are vanishing quickly and organizing the next WGZE meeting in Gdynia is an excellent opportunity to invite representatives of the neighboring sorting centers to present their competence, experience and discuss financial conditions. In the case of many laboratories there are numerous samples, which have not been analyzed so far and we should identify and review the centers capable of helping to solve this problem. This will enable a search for additional funds to be allocated for analyzing those samples. Moreover, identifying scientific laboratories or even single experts with taxonomic expertise on particular groups of zooplankton would be an additional and valuable information. Term of Reference b) Microzooplankton constitute 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 and can be a significant food source for larval fish. 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 (for details see Report of the Working Group on Zooplankton Ecology, ICES CM 2007/OCC:04). Term of Reference c) This group has traditionally undertaken initiatives that have advanced our understanding of zooplankton ecology. The Zooplankton Methodology Manual was an initiative of the WGZE that has been widely adopted as the standard zooplankton methodology text. It is in need of updating. Two different approaches were identified regarding this update of Zooplankton Methodology Manual: (i) one group will consider revision of the existing edition specifying parts of the text which need to be updated and/or corrected, potentially leading to a paper-back edition and a review article updating new topics; and (ii) the other group will focus on multimedia methodological tutorials to be disseminated through the web page. Term of Reference d) The Zooplankton Status Report continues to evolve as a major published output of the WGZE. New data analyses and techniques for comparative analysis of time-series within the ICES area are now a priority for discussion and development. Term of Reference e) Both these SCOR Working Groups are highly relevant to the ongoing work of the WGZE. The former WG is just beginning it's work while the latter is more mature and moving towards a conclusion. Their work will be reviewed in relation to potential links with, and significance for, the WGZE. Term of Reference f) There are various definitions of diversity. Usually the approach depends on the question asked. This is an important question from the WGZE perspective and would be of interest to the broader ICES community. Term of Reference g) A review of the state of the art of enzymatic activity methods, and other biochemical approaches, is a longer lasting demand of the WGZE community (see Report of the Working Group ICES CM 2004/C:07). Term of Reference h) This new study group is addressing issues of taxonomy that are directly relevant to zooplankton ecology as well as the broader ICES community. Close linkages between the WGZE and the SGIMT will ensure that the latter is successful and will keep members of the former informed about new developments in this area.
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
Participants:	The Group is normally attended by some 20–25 members and guests.
Secretariat facilities:	None.
Financial:	No financial implications.
Linkages to advisory committees:	The Group reports to the SSGEF, SCICOM and ACOM. Mainly WGZE provides scientific information on plankton and ecosystems to the SSICC 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 ecosystem monitoring and assessments, modelling and/or plankton studies, including fish and shellfish life histories and recruitment studies. Strong working links have been developed between WGZE and Mediterranean colleagues (CIESM). The

	newly-formed WGPME will likely work closely with WGZE on issues of microzooplankton ecology.
Linkages to other organizations:	Links with the WGMDM, WGRP, WGCCC, WGPE, WGPME and WGHAB 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 4: Recommendations

RECOMMENDATION	FOR FOLLOW UP BY:
1. Theme session for 2010 ASC	SSGEF
2. ToRs for 2011 Annual Meeting, Gdynia, Poland	WGZE, SSGEF
3. Publication of the Zooplankton Status Report as a CRR	WGZE, Publications Committee
4. Review contents of Zooplankton Methodology Manual to identify areas in need of revision or updating	WGZE
5. Prepare an outline for a review article on Physiological Tolerances and Limits	WGZE
6. Prepare for SSGEF Session at 2010 ASC	WGZE, SSGEF
7. Prepare Theme Session proposal for 2011 ASC	WGZE, SSGEF

Annex 5: Biodiversity at WGZE monitoring sites in the ICES North Atlantic Region.

The WGZE has a strong interest in characterizing the biodiversity of zooplankton in the North Atlantic and any signals associated with climate change. The WGZE focus is on analysis at various levels of organization, including communities, populations, and individual species, including analysis of genetic diversity. The time-series monitoring stations that are compiled for the ICES WGZE Status Report (O'Brien *et al*., 2008) provide a unique opportunity to track changes in plankton biodiversity. To investigate further, the WGZE aims to assemble complete lists of the species composition at the time-series sites. Currently, there are more than 4300 species recorded in the North Atlantic Register of Marine Species (NARMS), so significant effort is required.

Identification of zooplankton species by traditional methods is time consuming and requires skilled individuals with considerable taxonomic expertise. Thus, complete analysis of time-series samples (i.e., to identify and count all of the species present in all samples) is not done at many time-series sites. Rare or newly-arrived species may be either ignored or unnoticed. The use of genetic markers (e.g., DNA barcodes) to identify zooplankton to species is becoming a routine and cost-effective method. Techniques are being developed to automate these analyses and to allow both rapid identification of known species and better discrimination of unknown species in a sample. The process requires a DNA barcode database as a "Rosetta Stone" that links the morphological species type to the genetic identifier (Bucklin *et al*., in review). Efforts to date have determined DNA barcodes for ~1500 zooplankton species, but the majority of zooplankton species have not yet been barcoded.

Currently the Census of Marine Zooplankton (CMarZ) is working to provide the basis for DNA-based assessment of zooplankton species diversity and distribution; for commercial fisheries management and ecosystem monitoring surveys on the Northwest Atlantic continental shelf (ECOMON; Bucklin, personal communication). The specific project goals are: (1) to determine DNA barcodes (i.e., portions of the mitochondrial cytochrome oxidase I gene) for identified specimens of zooplankton species collected during ECOMON surveys of the Northwest Atlantic continental shelf; and (2) to create a comprehensive barcode database to allow DNA-based identification of zooplankton species in ECOMON samples, with particular application for rapid analysis of species diversity by high though-put sequencing for fisheries management and ecosystem monitoring.

For this effort, 10 specimens of each species from selected ECOMON survey samples are being identified and prepared for barcoding. In addition, specimens or tissue fragments that cannot be identified to species due to difficulties of collection or preservation are being similarly prepared. These include the important but fragile Thaliacea (salps, doliolid, and pyrosomes), Hydrozoa (siphonophores, hydromedusae), Scyphozoa (jellyfish), Ctenophora (comb jellies), and others.

Many of the WGZE time-series stations are in regions of significance for commercial fisheries, thus DNA barcoding of the species in these samples will also contribute significantly toward the goal of DNA-based zooplankton assessment for fisheries and ecosystem monitoring. This will require genetic analyses of alcohol-preserved samples from each time-series site, identifying individuals of each species, and then determining a barcode for each species. Protocols for DNA barcoding of most taxonomic groups of zooplankton have already been developed, and the cost of the

barcoding is low. A web-based database exists to provide information on zooplankton species that are being or have already been barcoded, so avoiding duplication of efforts. (see http://www.cmarz.org/barcode/cba_database.html).

The WGZE strongly urges time-series managers and operators to support and collaborate in this DNA barcoding effort and to incorporate DNA barcoding into their protocols. DNA barcoding of time-series samples will be a significant contribution toward the goal of a North Atlantic zooplankton "Rosetta Stone" to be used to track biodiversity at key time-series sites using investigator-independent, standardized methodology.

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Report prepared by P.H. Wiebe, S. Hay, and A. Bucklin

Annex 6: OSPAR Ocean Acidification Report

Prepared by the ICES Working Group on Zooplankton Ecology (WGZE)

Edited by Mark C. Benfield, Chair, WGZE

1. Introduction

The concentration of carbon dioxide (CO_2) in the atmosphere has increased by approximately 107 ppm over a period spanning pre-industrial times to 2009 with more than half of this increase occurring since 1979 (Secretariat of the Convention on Biological Diversity 2009). Excess carbon dioxide in the atmosphere increases its partial pressure relative to that in surface waters driving a net flux of CO_2 into the upper ocean. The oceans are an enormous repository for atmospheric CO_2 with an average daily absorption of 22 million MT (Freely, Sabine *et al*. 2008).

When atmospheric CO_2mixes with water it becomes hydrated to form H_2CO_3(carbonic acid), which subsequently dissociates to form HCO_3^- (bicarbonate) and an H^+ (hydrogen) ion. In turn, bicarbonate dissociates to produce CO_3^{2-} (carbonate), and another hydrogen ion. Excess hydrogen ions can react with carbonate for more bicarbonate. Thus, CO_2 is present in the oceans either as undissociated CO_2, as carbonic acid, and as carbonate and bicarbonate ions. At pH 8.2, approximately 88% of the dissolved inorganic carbon (DIC) pool in the oceans consists of bicarbonate, while carbonate makes up about 11% and dissolved CO_2 and carbonic acid comprise 0.5%(The Royal Society 2005). The equilibrium reaction for DIC in seawater is:

$$CO_2 + CO_3^{2-} + H_2O \leftrightarrow 2\ HCO_3^{-} \qquad (1)$$

Adding more CO_2 to the ocean will cause the reaction to shift to the right resulting in less carbonate and more bicarbonate with a concomitant decline in pH owing to the increase in hydrogen ion concentration. The reduction in pH associated with these reactions is termed ocean acidification (OA). Increased atmospheric CO_2 loadings appear to be associated with OA. As Reid *et al*. (2009) point out, even under the most dire forecasts of atmospheric carbon dioxide loadings, the DIC buffering system will keep the pH of the oceans slightly alkaline and never drop below neutral (pH 7.0).

Calcium ions (Ca^{2+}) are very abundant in seawater and can react with carbonate to form different morphs of $CaCO_3$ (calcium carbonate): aragonite, calcite, and magnesium calcites. In surface waters the concentration of carbonate is normally supersaturated with respect to carbonate favouring the production of calcium carbonate:

$$Ca^{2+} + 2HCO_3^- \rightarrow CaCO_3 + CO_2 + H_2O \qquad (2)$$

Since equation (1) predicts that the addition of carbon dioxide to surface water at equilibrium will lead to a reduction in the carbonate concentration in favour of bicarbonate, then this has the potential to reduce carbonate concentrations below the saturation level necessary for precipitation of calcium carbonate. Moreover, the excess carbon dioxide results in a lower pH via an increased hydrogen ion concentration. When the pH is sufficiently low and temperature or pressure favour dissolution of calcium carbonate, then the latter will dissolve, producing calcium ions and carbonate ions.

Much of the calcium carbonate in the upper oceans is produced biogenically by planktonic or benthic organisms that utilize either aragonite or calcite as a structural material for shells, endoskeletal or exoskeletal components. Sequestration of various

forms of calcium carbonate requires the surrounding water to be supersaturated with respect to the necessary carbonate mineral (e.g. aragonite or calcite). The saturation state (Ω) describes the degree of saturation. When Ω >1, calcium carbonate structures can be laid down. When Ω <1, organisms will experience difficulty secreting calcium carbonate structures and the existing shells will be vulnerable to dissolution.

At this time, Ω exceeds 1 in the surface waters of all oceans, however, this is not the case for deeper waters. The solubility of calcium carbonate increases at lower temperatures and higher pressures. At certain depths, the solubility increases to the point that the Ω shifts below 1. This point is called the saturation horizon and its depth depends on the form of calcium carbonate (aragonite is more soluble than calcite) and the state of the carbonate buffering system in the region. The depth of the saturation horizon is relatively shallow (a few hundred meters in high latitudes, and approximately 3500 m in the Atlantic (IPCC 2007).

While much recent research has addressed the potential impact of OA on the abilities of coral species to secrete calcium carbonate (e.g. Gattuso, Frankignoulle *et al*. 1998; Langdon, Broecker *et al*. 2003), which forms the basis of coral reefs, there is an increasing body of literature that suggests that OA may produce potentially adverse consequences for a wide variety of planktonic organisms. In this review, we will: (1) summarize relevant studies on marine or estuarine zooplankton responses to OA; (2) compile a list of taxa, which are potentially vulnerable/sensitive to OA; and (3) compile available information regarding the degree to which the upper ocean in each of the OSPAR areas is sensitive to OA.

2. Relevant Studies on Marine or Estuarine Plankton Responses to Ocean Acidification

Most zooplankton biomass occupies the upper 200 m (epipelagic zone) where the proximity to the atmosphere means that ocean acidification changes are likely to be most pronounced (Sabine, Freely *et al*. 2004). Moreover, zooplankton exhibit rapid generation times, which make them potentially useful indicators of regional changes in pH. Many taxa incorporate calcium carbonate into their exoskeletons or shells rendering them potentially vulnerable to reduced pH. Finally, zooplankton are critical components in the biological carbon pump through their consumption of phytoplankton, and serve as essential prey for almost all larval and juvenile fishes. Thus, adverse responses by zooplankton to OA have the potential to cascade through both higher and lower trophic levels.

Although the majority of research has been directed towards taxa that incorporate various forms of $CaCO_3$, diminished pH has the potential to affect zooplankton in another way. Declines in pH have the potential to disrupt the internal acid-base balance within cells (Hauton, Tyrrell *et al*. 2009). Both calcifying and non-calcifying species would be subject to this impact. Such a disruption could affect the maintenance of normal protein conformation with consequent disruption of the normal functioning of enzymes and other proteins.

Most research on zooplankton responses to OA has focused on pelagic mollusks called pteropods; the meroplanktonic (temporary members of the plankton) larvae of benthic crustaceans (e.g. lobsters), and mollusks (oysters, clams, mussels), and echinoderms (sea urchins and starfish); and fish larvae due to the presence of calcified earbones called otoliths. While the number of studies examining the responses of these various taxa to decreased pH is steadily growing, it is important to reiterate that none of the scenarios of future ocean pH are predicting that the pH will decline be-

low neutral (pH 7.0) and the consensus is that the carbonate buffering system in the ocean will maintain slightly alkaline conditions (Reid, Fischer *et al*., 2009) with a likely decline of 0.3–0.4 units to approximately 7.7 – 7.8 (Caldeira and Wickett 2005). For this reason, studies that have subjected zooplankton to extreme pH fluctuations at or below neutral, are unrealistic and the results, while interesting, have little relevance when attempting to assess how zooplankton may respond to reasonable OA future scenarios. A second subset of studies has examined how OA would affect tropical taxa, principally scleractinian corals. Given the temperate and arctic conditions that prevail in the OSPAR area, research studies on the responses of tropical taxa, which do not occur within the OSPAR area and, which do not have analogous taxa present in cool or cold waters have been excluded.

Fabry *et al*. (2008) includes a summary of recent studies that examine the responses of various marine taxa to OA. In addition, results from other relevant organisms were obtained via a literature search and summarized in Table I. Many of the studies have examined the gametes or larvae of meroplantonic larvae of benthic or demersal taxa. The findings suggest that much work remains to be conducted on zooplanktonic taxa, particularly holoplankton.The ability of zooplankton to secrete calcium carbonate structures is clearly sensitive to the pCO2 and its consequent affect on the DIC pool and Ω. A striking illustration of how shell mass of a foraminiferan species (*Globigerina bulloides*) was provided by Moy *et al*. (2009) who related the shell mass of a particular size range of *G. bulloides* in a long-term sediment record to the pCO2 as estimated from the Vostok ice core data (Figure 1). Two studies (Orr, Fabry *et al*. 2005; Comeau, Gorsky *et al*. 2009) illustrate the sensitivity of thecosomate pteropods (planktonic mollusks) to reduced pH and suggest that pH shifts within the range predicted to occur by 2100 will lead to reduced calcification rates and measurable shell dissolution. Studies on fertilization and early larval development of various bivalve species generally indicated little measurable influence of pH shifts within the predicted OA range (Table I); however one study by Kurihara *et al*. (2007) did find substantial reductions in the proportion of oysters developing into normal veliger larvae as well as significant declines in calcification of the shells by trochophore larvae of the oyster *Crassostrea gigas*. It should be emphasized that the low-pH treatment in this study was 7.4, which is well below the pH decline projected for 2100. Sea urchin larvae cultured in reduced pH (7.8) water were smaller (Figure 2) than those in the control (pH 8.0) under both elevated pCO2 or HCl-induced reductions in pH Kurihara and Shirayama (2004), though no statistical test evaluating this difference were presented. A study by Dupont *et al*. (2008) found significantly greater instantaneous mortality rates in brittlestar larvae.

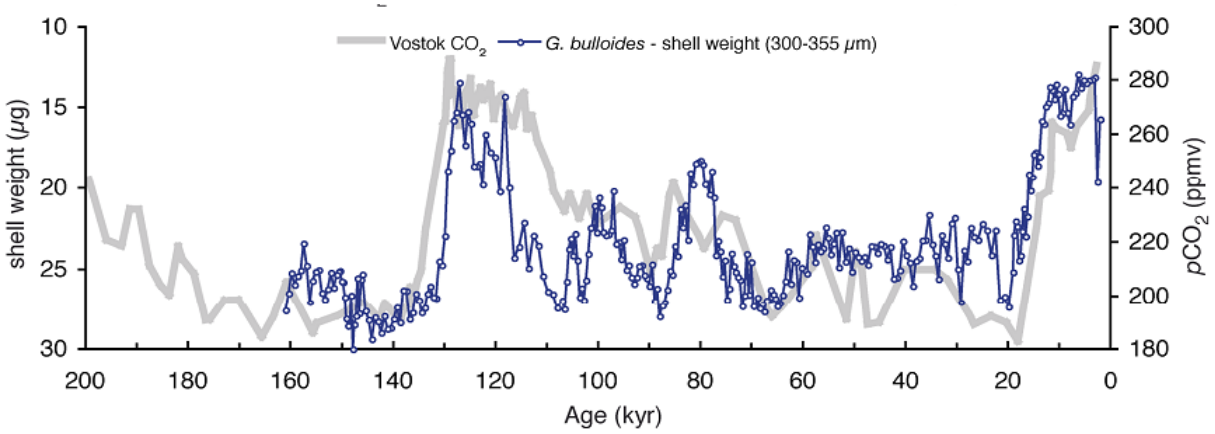

Figure 1.Vostok ice core pCO2 data and the shell weights of the foraminiferan *Globigerina bulloides* (300–355 μm diameter) collected from a Southern Ocean sediment core. Note the reversed axis direction for shell weight. [Figure credit: (Moy, Howard *et al*. 2009)]

The few data available on fish do not suggest short-term effects of low pH on the hatching success of larval fishes (Kikkawa, Ishimatsu *et al*. 2003), however a recent study by Checkley *et al*. (2009) found a surprising increase in the mass of otoliths in 7 d old white sea bass (*Atractoscion nobilis*) grown under elevated pCO2 treatments of 993 and 2558 μatm (corresponding to pH levels of 7.68 and 7.32, respectively). Otolith masses were 10–14% and 24–26% greater than the controls at pH's of 7.68 and 7.32, respectively. They attributed this finding to the ability of the fish to regulate their calcium and hydrogen ionsbut not the CO_2 in their endolymph leading to an elevated $\Omega_{aragonite}$ and enhanced aragonite deposition.

A recent review of the impact of OA on fishes (Ishimatsu, Hayashi *et al*. 2008) was critical of many studies because relatively few were conducted at pCO_2 (and therefore pH) levels relevant to predicted declines by the end of the century, most were conducted under very short-term periods, marine species were used in only 25% of studies, measured responses were largely limited to acid-base regulation and respiratory control, and none were field experiments. Some of these same objections may be made of studies conducted on zooplankton, particularly the lack of field studies, short-term nature of the studies, and unrealistically low pH conditions in treatments.

Table I. Summary of research examining the potential impacts of ocean acidification on $CaCO_3$-bearing zooplankton (meroplankton including ichthyoplankton and holoplankton).

Organism	Species	pH	Study Region	Observed Impact	Reference
Microzooplankton					
Foraminifera	Globigerina bulloides	Not reported	SW Pacific area of Southern Ocean (47°S 142°E)	Shells of forams collected from sediment traps were 30% lighter than shells from Holocene sediments. Shell masses from a 50,000 yearsediment record inversely correlated with atmospheric CO2 levels.	(Moy, Howard *et al*. 2009)

Ciliates Dinoflagellates	Strombidium Lohmaniella Gymnodinium Minuscula Gyrodinium	Not specified. pCO2 treatments of 350,700, 1050µatm	Mesocosm study in a Norwegian fjord (Bergen).	No difference in microzooplankton grazing rates at any of the pCO2 levels.	(Suffrian, Simonelli *et al*. 2009)
Cnidarians					
Jellyfish	Unspecified hydromedusae and scyphomedusa	8.1 – 8.3	North Sea (OSPAR Area II)	Increase in abundance of jellyfish correlated with a decline in pH over 1971 – 1995 (8.3 down to 8.1)	(Attrill, Wright *et al*. 2007)
Mollusks					
Thecosomatepteropod	Clio pyramidata	7.7 – 7.8	Southern Ocean and other high-latitude regions	Dissolution of shell along the growing edge of the shell aperture within 48h although animals survived	(Orr, Fabry *et al*. 2005)
Thecosomatepteropod	Limacinahelicina	7.78, 8.09	Laboratory study using a species that occurs in the Arctic and Southern Oceans	Calcification rates at 5°C were 28% lower at a pH of 7.78 relative to 8.09.	(Comeau, Gorsky *et al*. 2009)
Bivalve (oyster)	Crassostreagigas	7.80, 8.15	Laboratory study on swimming rates, motility, and fertilization kinetics of sperm.	No affect of a 0.35 reduction in pH on sperm swimming speed, motility or fertilization rates.	(Havenhand and Schlegel 2009)
Bivalve (oyster)	Crassostreagigas	7.4 – 7.5 versus 8.1 – 8.2	Laboratory study on development of larval stages	5% of low-pH group developed into normal veligers versus 68% of controls. Fully mineralized shells found in 30% of low-pH group versus 72% of controls.	(Kurihara, Kato *et al*. 2007)
Bivalve (scallop)	Placopectenmagellanicus	7.5, 8.0	Laboratory study on fertilization rates and early embryonic development	All tested stages tolerated full range of pH conditions (7.0–8.5). Completions of embryonic cleavage reduced at pH 7.5.	(Desrosiers, Désilets *et al*. 1996)
Bivalve (oyster)	Crassostreagigas	7.8	Laboratory study over 48 h	Shell malformation	(Kurihara 2008)

Arthropods					
Amphipod	Gammaruslocusta	7.6 – 8.1	Laboratory study using a cosmopolitan estuarine species	No impact on growth or survival at lowest pH. Significant increase in activity of a metabolic enzyme.	(Hauton, Tyrrell *et al*. 2009)
Calanoid copepod	Acartiasteueri	8.14 – 8.17 compared to 7.40 – 7.55	Laboratory study	No difference in survival rate over 8 days. No difference in egg production rate relative to controls	(Kurihara, Shinji *et al*. 2004)
Calanoid copepods	21 mesopelagic and bathypelagic species	7.74	Shipboard laboratory study	LT50 of 580h	(Watanabe, Yamaguchi *et al*. 2006)
Decapod Crustacean	Homarus gammarus	8.10, 8.39	Laboratory study rearing larvae in elevated pCO2	Carapace mass was reduced during the final larval stage in CO2-acidified seawater along with a reduction in Ca and Mg content of exoskeleton. Result attributed to disruption of metabolic function by acidosis rather than inhibition of carbonate supply.	(Arnold, Findlay *et al*. 2009)
Decapod crustacean	Palaemon pacificus	7.6, 7.9	Laboratory study of development from egg to settling larvae	Decreased settling size	(Kurihara 2008)
Euphausiids	Euphausia superba	7.7, 7.4	Lab study	Diminished hatching success	(Kurihara 2008)
Echinoderms					
Sea urchins	Hemicentrotus pulcherrimus Echinometra mathaei	7.97 – 8.01 versus 7.64 - 7.77 8.11 versus 7.82	Lab study on fertilization success and larval development using seawater acidified by adding CO2 or HCl	Although all measured parameters tended to decrease with declining pH, there were no significant differences in fertilization success or early cell cleavage. Pluteus larvae grown at pH 7.8 were smaller than controls.	(Kurihara and Shiarayama 2004)
Brittlestars	Ophiothrix fragilis	7.7, 7.9, 8.1	Lab study culturing larvae at three pH treatments	Mortality rates were 35±10.8% d-1(pH 7.9), 50.4±10.5% d-1 (pH 7.7) and 20% d-1 in controls. Low pH	

				delayed development and produced abnormalities.	
Chordates					
Fish	Pagrus major Sillago japonica Paralichthys olivaceus Euthynnus affinis	8.11 versus 7.76 at 24°C	Lab study examining influence of CO2 on hatching success and acute toxicity to larvae	No 24h short-term influence on hatching success. Unspecified study temperature in experiments made determination of pH difficult	(Kikkawa, Ishimatsu *et al*. 2003)
Fish	Atractoscion nobilis	Control mean: 8.01 treatment mean: 7.47	Lab study culturing larvae for 7 d under elevated pCO2 (993 – 2558 µatm)	Otoliths in low pH treatment were significantly larger.	(Checkley, Dickson *et al*. 2009)

3. Marine Zooplankton Taxa Potentially Sensitive/Vulnerable to Ocean Acidification

OA has the potential to impact organisms via a reduction in rates of calcification or dissolution of calcium carbonate structures. These may affect normal behaviour, buoyancy, vulnerability to predators or other responses. Both calcium carbonate-secreting and non-secreting taxa may be affected via disruption of enzyme activity through pH-altered protein conformation. Diminished reproductive success appears to be another potential impact of reduced pH.

Calcium carbonate-secretingtaxa include: meroplanktonic larvae of mollusks, echinoderms, crustaceans, and fish; and the holoplanktonicmicrozooplankton (foraminiferans), mollusks (pteropods and heteropods), and crustaceans (ostracods, amphipods, copepods).

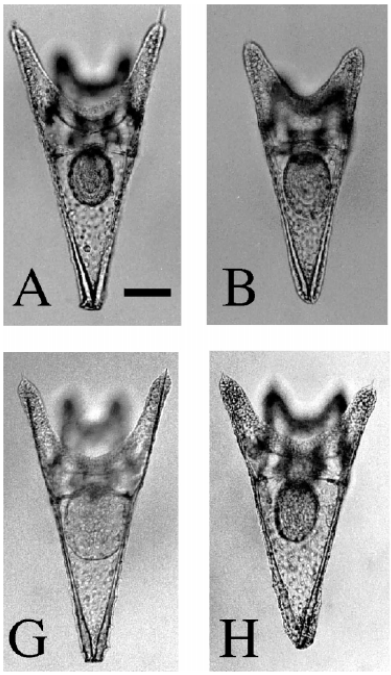

Figure 2. Four-arm pluteus larvae of the sea urchin *Hemicentrotus pulcherrimus* cultured at pH 8.0 (A,G) and 7.8 (B: CO2 treatment; H: HCl treatment). From Kurihara and Shirayama (2004).

4. Sensitivity of OSPAR Areas to Ocean Acidification

Arctic waters are a region where OA is likely exert a more pronounced impact than it other OSPAR areas. The solubility of CO_2 increases inversely with temperature. Consequently, cold waters can hold more CO2 and are more acidic than warmer waters (Guinotte and Fabry, 2008). Steinacher *et al*. (2009) and Bellerby *et al*. (2005) predict that the surface waters of the Arctic will experience the largest declines in pH through the end of this century with increases of hydrogen ions by 185% (0.45 pH units; Figure 3B). Studies off Iceland have demonstrated a decline in the pH of surface water of 0.0024 yr^{-1} over the period 1985–2008 (Olafsson, Olafsdottir *et al*., 2009). One consequence of this rapid change will be a reduction in the saturation state of aragonite ($\Omega_{aragonite}$) will reach an annual mean of 1.0 by 2032 (Steinacher, Joos *et al*., 2009). Given the abundance of pteropods and other calcifying planktonic organisms in Arctic waters, such predictions suggest monitoring programs should be considered.

It is difficult to predict how the waters of other OSPAR regions will be impacted by OA over the next century. Atmospheric CO_2 concentrations are heterogeneous at regional scales and proximity to the coast where elevated population densities occur, may result in locally enhanced pCO_2 with concommitently diminished pH. Upwelling regions typically contain water with substantially higher pCO_2 and this pattern is evident off the Iberian coast where upwelling along the western boundary of the continent introduces deep water rich in DIC to the surface (e.g. Figure 3B). Within the North Sea and Celtic Seas, the climatological mean pCO_2 levels are similar (Figure 3B) and the proximity of these marginal seas to population centres suggests that monitoring programs are warranted.

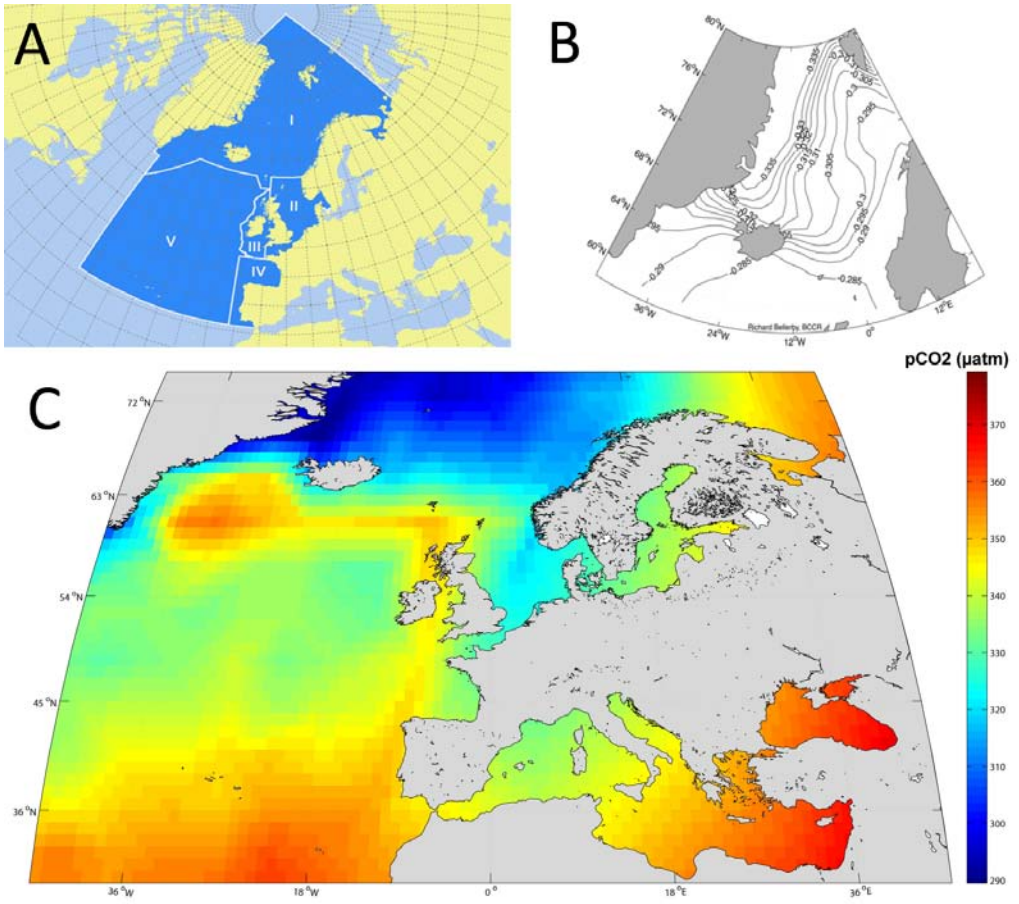

Figure 3. A. OSPAR Areas: I (Arctic Waters), II (Greater North Sea), III (Celtic Seas), IV (Bay of Biscay and Iberian Coast), V (Wider Atlantic) [Image: OSPAR]. B. Projected changes in surface pH (1997–2067) based on the assumption that atmospheric CO2 doubles during the same period [Image: Bellerby *et al*. 2005]. C. Climatological mean (1970–2007) pCO2 in surface seawater for a reference year (2007) based on data from Takahashi *et al*., (2009). Data from http://www.ldeo.columbia.edu/res/pi/CO2/carbondioxide/pages/air_sea_flux_2009.html gridded and rendered in Matlab using a Robinson projection.

5. Recommendations for Monitoring

Not clear if this is zooplankton or pH monitoring. Assuming it is pH monitoring, then this section is best covered by the Chemistry WG.

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Annex 7: Technical minutes of the Review Group MON1 2010

Review Group: Jarle Klungsøyr (Chair), Jacob de Boer, Michiel Kotterman, Colin O'Dowd*, Pia Andersson*

***Not present at the meeting**

Introduction

RGMON1 worked by correspondence and met at ICES HQ, Copenhagen on 3 May 2010 to review the work done by four ICES working groups answering requests by OSPAR on:

1) Monitoring methodologies for ocean acidification (2010/2)

2) Atmospheric monitoring of PFOS (2010/6)

3) Tools for coordinated monitoring of dioxins, planar CBs and PFOS (2008/6, 2010/6)

Expert Groups Reports

Marine Chemistry Working Group Report 2010 (MCWG2010)

Working Group on Marine Sediments in Relation to Pollution (WGMS2010)

Working Group on Deep Water Ecology Report 2010 (WGDEC2010)

Working Group on Zooplankton Ecology Report 2010 (WGZE2010), Annex 6

2010/2. Monitoring methodologies for ocean acidification

OSPAR Request

To provide, on the basis of a review of existing methodologies and experience, recommendations for cost efficient methods for monitoring ocean acidification (OA) and its impacts, including possibilities for integrated chemical and biological monitoring. Specifically this should provide:

a) advice on appropriate parameters, protocols and quality assurance for monitoring changes in pH and inorganic carbon chemistry in the OSPAR maritime area and other ancillary parameters that should be included in monitoring programmes

b) advice on the status of current knowledge on spatial and temporal variability of pH and inorganic carbon chemistry in the OSPAR maritime area

c) advice on appropriate spatial and temporal coverage for monitoring, considering different oceanographic features and conditions and key habitats/ecosystems at risk from OA in the OSPAR maritime area,

d) advice on the status and maturity of potential indicators of OA impacts on species, habitats and ecosystems that could be considered for inclusion in OSPAR monitoring programmes.

RG Comments

The MCWG 2010 Report with Annex 8 gives general advice on the inorganic carbon chemistry and other physical and biological factors that must be taken into account when studying ocean acidification.

The text is relevant and of generally good quality and gives an overview of existing methods for the chemical analysis of ocean acidification. The report gives general advice to most questions under bullet point a), b) and c) and can be used by the ADG to prepare advice. The language in Annex 8 is of variable quality/standard and some technical editing is needed, particularly so for section 9.

A general comment by the RG is that natural variation in the euphotic part of the water column is an obstacle/challenge to obtain a sufficient number of data from ship based on discrete sampling to resolve the present trend in ocean acidification. The winter season is less influenced by biological activity, and data from this period might therefore be well suited to determine the present development in long term trends in ocean acidification. Further development of modelling tools can be useful to better predict future development in ocean acidification.

The WGDEC 2010 Report gives a brief overview of a relatively limited amount of information available on biological effects of ocean acidification. It does not give any specific advice to the questions under bullet point d), but gives a general advice that more research is needed to be able to link ocean acidification to biological effects.

The WGZE2010 Report gives a more extensive overview of studies that has been performed during recent years on biological effects of ocean acidification, and also gives a general advice to carry out new and more realistic effect studies at proper pH ranges. Since the RG had no specific expertise on this topic it was not in a position to judge whether the information presented on biological effects of ocean acidification was complete or not. The main message in the mentioned working group reports was that both more controlled effect studies and monitoring studies are needed in the near future to be able to answer the questions raised under bullet point d). No specific recommendations were given in the two reports.

The RG have some few questions and comments to the text on ocean acidification in the WGZE2010 Report. There is some short text on saturation and omega (Ω). It would be useful to include an explanation on the links between Ω and pH, total alkalinity, total DIC and pCO_2. Some general remarks are made about ocean acidification in the different OSPAR regions. It might be useful to mention that also areas affected by large river runoff may deviate from the general remarks. A reference should be included to the sentence "In surface waters the concentrations of carbonate is normally supersaturated with respect to carbonate favouring the production of calcium carbonate". A reference should be included to the sentence "At this time Ω exceeds 1 in the surface waters of all oceans, however, this is not the case for deeper waters". Chapter 3 is brief and it might be useful at least to add some reference to the text (if available). In Chapter 4 it would be useful also to mention other factors that may impact the ecosystems in the future, like rises in sea temperature. There are some confusion/mistakes in the text and the links to Figure 3 (A, B, C) and this should be checked and corrected. Part of Figure 3 is difficult to read and the figure text could be improved. The RG question the correctness of the statement "Within the North Sea and the Celtic Sea, the climatological mean pCO_2 levels are similar" and this should be checked. In general the whole text on ocean acidification could benefit from technical editing to correct incomplete text and fill in missing references.