ICES WGZE REPORT 2017

SCICOM STEERING GROUP ON ECOSYSTEM PROCESSES AND DYNAMICS

ICES CM 2017/SSGEPD:07

REF. SCICOM
ACOM

Report of the Working Group on Zooplankton Ecology (WGZE)

27–30 March 2017

Boulogne-sur-Mer, France

ICES CIEM
International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

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Recommended format for purposes of citation:

ICES. 2017. Report of the Working Group on Zooplankton Ecology (WGZE), 27–30 March 2017, Boulogne-sur-Mer, France. ICES CM 2017/SSGEPD:07. 79 pp.

Contents

Executive summary

The ICES Working Group on Zooplankton Ecology (WGZE) met in Boulogne-sur-Mer, France, 27–30 March 2017. The meeting was hosted by Elvire Antajan (Ifremer) and chaired by Piotr Margonski. It was attended by 29 scientists in person, including 4 by correspondence, representing 12 nations.

All the multi-annual ToRs were completed. Moreover, the status of several manuscript preparations was presented and discussed.

Of all the recent achievements, the group would like to draw attention especially to the following three:

- The great success of the ICES/PICES 6th Zooplankton Production Symposium (9–13 May 2016, Bergen, Norway) would not be possible without an outstanding contribution by WGZE/WGIMT members (2 of 3 Symposium conveners, 4 of 7 members of the Scientific Steering Committee, several session and workshop conveners, several members of the Award Committee and significant participation and contribution to the Symposium presentations (http://www.ices.dk/news-and-events/symposia/zp6/Pages/default.aspx).
- WGZE was a significant contributor of North Atlantic time-series to the IOC/UNESCO International Group for Marine Ecological Time-series (IGMETS) global analysis and status report (http://igmets.net/report). IGMETS has compiled a global collection of over 300 time-series, covering the open-ocean, coastal areas, and estuaries. Of all the oceanographic regions, the best coverage within IGMETS is for the North Atlantic, with the WGZE and WGPME time-series being the largest contributor to this region.
- A book "Marine Plankton: A practical guide to ecology, methodology, and taxonomy" (Castellani & Edwards, Oxford University Press) was published in 2017. This book is a modern plankton identification and reference manual aimed at students, academics, and practitioners. It covers plankton identification, methodology, ecology, and distribution. It was led by WGZE member Claudia Castellani, and its chapters contain contributions from her and multiple other WGZE members.

Substantial part of the meeting discussions were devoted to summarising the group's achievements within the process of self-evaluation as well as drafting new 3-year Terms of References. As stated in the self-evaluation, the WGZE consists of scientists representing a wide range of expertise including zooplankton taxonomy, spatial and temporal distribution dynamics, knowledge of marine ecosystem structure and function, zooplankton community response to climate change and impact of microlitter on zooplankton. WGZE is addressing numerous priorities of the ICES Science Plan as well as having a long history of successful networking inside (e.g. ICES ASC Theme Sessions and face-to-face meetings with other EGs) and outside of the ICES community (e.g. with PICES, CIESM, IOC). Significant efforts were allocated for dissemination of knowledge through scientific publications (papers and books) and reports as Zooplankton Status Reports (published as ICES CRRs).

1 Administrative details

Working Group name

Working Group on Zooplankton Ecology (WGZE)

Year of Appointment within current cycle

2015

Reporting year within current cycle (1, 2 or 3)

3

Chair(s)

Piotr Margonski, Poland

Meeting venues and dates

Plymouth, UK; 16–19 March 2015; 32 (2 by correspondence), 13 nations

Lisbon, Portugal; 14–17 March 2016; 36 (1 by correspondence), 11 nations

Boulogne-sur-Mer, France; 27–30 March 2017; 29 (4 by correspondence), 12 nations

2 Terms of Reference a) – z)

a) Review progress and planning of the 6th Zooplankton Production Symposium;

b) Identify and develop information and data useful for modelling needs in collabo-ration with WGIPEM especially regarding to exploitation of resources at the lower trophic level;

c) Review the ICES response to the Norwegian request regarding the *Calanus finmarchicus* exploratory assessment;

d) Compile the information on micro-plastics pollution and its effects on zooplankton communities;

e) Review the new methods of automatic and semi-automatic plankton identification;

f) Expand and update the WGZE zooplankton monitoring and time-series compilation;

g) Revise lists of currently suggested (e.g. by OSPAR, HELCOM, and EU Member States) zooplankton indicators relevant for biodiversity and foodweb status assessment. Based on gap analysis, identify and test new candidate indicators considering their response to various pressures;

h) Design and carry out coordinated and collaborative activities with WGIMT and WGPME;

i) Refine and expand the compilation of information on zooplankton species, taxonomic categories, and life stages that are currently monitored in the ICES area;

j) Calculate zooplankton productivity and metabolic rates in the ICES area based on allometric approaches. Build a database of zooplankton individual species biomass, productivity, and metabolic rate equations;

k) Develop, revise and update of zooplankton species identification keys initially focusing on the most abundant taxa at the ICES time-series sites and ensuring their availability via the web, including especially ICES Zooplankton Identification Leaflets;

l) Produce four short paragraphs for the ICES Ecosystem Overviews on the zooplankton community (spatial variability, hot spots, and seasonality), one paragraph for each of the following ICES ecoregions: Greater North Sea, Celtic Seas, Bay of Biscay & the Iberian coast and Baltic Sea;

m) Contribute regional text (~ 150 words and 1-2 graphs in each case) on the state and trends of zooplankton to new ecosystem overviews for (i) Iceland, (ii) Norwegian Seas, (iii) Azorean ecoregion and (iv) the Oceanic north-east Atlantic ecoregion, if information is available.

3 Summary of Work plan

Year 1 We dealt with all of the ToRs in Year 1. Originally, there was a plan to finalize two of them: tasks regarding the Zooplankton Production Symposium (ToR a) and identifying and developing information and data useful for modelling needs (ToR b), however, we decided to continue with ToR a) in Year 2.

Year 2 We continued with remaining ToRs except for micro-plastics (ToR d) which has to be shifted to Year 3. Originally, we expected that three ToRs would be completed during the Year 2: *Calanus* assessment (ToR c), micro-plastics (ToR d), and automatic/semi-automatic identification (ToR e), however, we decided to continue with all of them in Year 3.

Year 3 During Year 3 we focused on completion of all of the remaining ToRs.

4 Summary of Achievements of the WG during 3-year term

- Contribution of the WGZE/WGIMT members to the organisation and success of the ICES/PICES 6th Zooplankton Production Symposium (9–13 May 2016, Bergen, Norway), where WGZE/WGIMT had 2 of 3 Symposium conveners, 4 of 7 members of the Scientific Steering Committee, several session and workshop conveners, several members of the Award Committee and significant participation and contribution to the Symposium presentations (http://www.ices.dk/news-and-events/symposia/zp6/Pages/default.aspx).

- WGZE is a significant contributor of North Atlantic time-series to the IOC/UNESCO International Group for Marine Ecological Time-series (IGMETS) global analysis and status report (http://igmets.net/report). IGMETS has compiled a global collection of over 300 time-series, covering the open-ocean, coastal areas, and estuaries. Of all the oceanographic regions, the best coverage within IGMETS is for the North Atlantic, with the WGZE and WGPME time-series being the largest contributor to this region.
- Joint WGZE-WGIPEM meeting to identify and develop information and data useful for modelling needs especially regarding to exploitation of resources at the lower trophic level provided an opportunity to discuss common interests and gaps in data and knowledge as well as conclude with the action plan.
- Future areas of coordinated and collaborative activities between WGZE, WGIMT, and WGPME were presented and discussed.
- The group provided six paragraphs for the ICES Ecosystem Overviews on the zooplankton community (spatial variability, hot spots, and seasonality), one paragraph for each of the following ICES ecoregions: Greater North Sea, Celtic Seas, Bay of Biscay & the Iberian coast, Baltic Sea, Icelandic waters, and Norwegian Seas. Two other ecoregion overview contributions will be delivered in 2017.
- WGZE contributed to the advisory process by discussing the Norwegian request regarding the *Calanus finmarchicus* exploratory assessment and reviewing Norwegian Assessment/Management Plan.
- In 2016, WGZE member Peter Wiebe (USA) received the ICES Outstanding Achievement Award a prestigious award that signifies the highest level of recognition for services to ICES science.
- In 2015, WGZE member Klas Ove Möller (Germany) received the Best Presentation Award for early career scientist ("Small-scale distribution of plankton and marine snow in the North Atlantic).
- Active role in submitting successful ICES ASC theme sessions' proposals:
    - the ICES ASC 2015 Theme Session S 'Basin-scale dynamics at lower trophic levels in the North Atlantic' was convened by two WGZE Members (Astthor Gislason and Peter Wiebe);
    - the ICES ASC 2016 Theme Session M 'The role of zooplankton in exploited ecosystems: top-down and bottom-up stresses on pelagic food webs' was convened by three WGZE Members (Angus Atkinson, Webjoern Melle, and Piotr Margonski).

Three theme sessions have been suggested and accepted for ICES ASC 2017:

- Theme Session E "Poleward shifts and ecological changes of Arctic and Subarctic zooplankton and fish in response to climate variability and global climate change" (Hein Rune Skjoldal (Norway), Carin Ashijan (USA), and Louis Forter (Canada));

- Theme Session L "Ecosystem monitoring in practice" (Sophie Pitois (UK), Mark Benfield (USA), and Christopher Zimmermann (Germany));
- Theme Session C (together with WGIMT) "Microbes to mammals: metabarcoding of the marine pelagic assemblage" (Ann Bucklin (USA), Rowena Stern (UK), Katja Metfies (Germany)).

The following papers have been published:

Wiebe P., Harris R., Gislason A., Margonski P., Skjoldal H.R., Benfield M., Hay S., O'Brien T., Valdes L. 2016. The ICES Working Group on Zooplankton Ecology: Accomplishments of the first 25 years. Progress in Oceanography 141: 179–201, DOI: 10.1016/j.pocean.2015.12.009

Yebra L., Kobari T., Sastri AR., Gusmão F. & Hernández-León S. 2017. Advances in Biochemical Indices of Zooplankton Production, Advances in Marine Biology, 76:157-240, DOI: 10.1016/bs.amb.2016.09.001

Castellani C. and Edwards M. (Eds). 2017. Marine Plankton. A practical guide to ecology, methodology, and taxonomy. Oxford University Press, 704 pp. ISBN: 9780199233267

Lindeque P. and Cole M. Plastics and plankton. Feature article. ICES newsletter 1 September 2016.

5 Final report on ToRs, workplan and Science Implementation Plan

ToR a) Review progress and planning of the 6th Zooplankton Production Symposium

WGZE Leads: Astthor Gislason, Padmini Dalpadado, and Lidia Yebra, Rapporteur in 2017: Webjörn Melle

Background

Recognizing the importance of zooplankton in the ecology of the seas, the success of the previous ICES/PICES Zooplankton Symposia, and that not more than 5-6 years should pass between successive symposia, the WGZE felt that it was timely to plan a new one, and proposed at its annual meeting in 2014 that the 6th Zooplankton Symposium should be held in 2016. Planning for the symposium was included as a multiannual ToR for the years 2015-2017. Astthor Gislason was nominated by the group to be co-convener on behalf of ICES. The proposal was approved by SCICOM in November 2014.

The symposium was the sixth in a series of international symposia sponsored by ICES, and in most cases also by PICES, dedicated to zooplankton research. The previous symposia were held in Copenhagen, Denmark (1961), Plymouth, UK (1994), Gijon, Spain (2003), Hiroshima, Japan (2007) and Pucón, Chile (2011).

Preparing for the symposium

After the decision was made to hold the symposium, an intensive planning process followed. In the very early stages of preparations, PICES was approached as a partner and they have been an integral part in the planning process at every stage. Early in the process of preparations a generous invitation from the Institute of Marine Reasearch (IMR) in Bergen to host the symposium was received and accepted.

To lead the work, a Scientific Steering Committee (SSC) was formed consisting of: Atsushi Tsuda (PICES), Astthor Gislason (ICES), Padmini Dalpadado (Norway/ICES), Se-Jong Ju (Republic of Korea/PICES), Desiree Tommasi (USA/PICES), Piotr Margonski (Poland/ICES), and Lidia Yebra (Spain/ICES). Coordinators assisting in the work were Adi Kellermann for ICES and Hal Batchelder for PICES.

A title was developed (6th International Zooplankton Production Symposium - New challenges in a changing Ocean) reflecting the focus on new challenges for the scientific community in our present era of climate change.

By mid-year 2015, sessions and workshops had been defined in co-operation with the scientific community, and conveners identified. During 2015, a symposium poster and symposium flyer were developed by the Communication Department at the Institute of Marine Research Bergen, and a symposium website created by the IT-team at ICES (http://www.ices.dk/news-and-events/symposia/zp6/Pages/default.aspx).

Relatively early in the planning process, it was decided that the 5-day symposium would consist of plenary sessions, parallel theme sessions, poster presentations and plenary summing-up session. In addition, half a day was dedicated to workshops, and half a day to sightseeing tours. The scientific sessions would include both invited and contributed papers. The plenary keynote speakers and the invited speakers for the session and workshops had all been identified by mid-2015.

After discussions with Editor Howard I. Browman of the ICES Journal of Marine Science it was decided that selected papers (both oral and poster) from the symposium would be included in a special issue scheduled for publication in 2017. The deadline for submitting papers was set at 31 July 2016.

The major sponsors of the symposium were the International Council for the Exploration of the Sea (ICES), the North Pacific Marine Science Organization (PICES), the Institute of Marine Research (IMR) and the Norwegian Research Council (NRC). In addition there were several commercial sponsors. All these organizations are thanked for their support.

Symposium content

The conference was attended by 383 persons from 38 countries and was thus the best attended ICES/PICES Zooplankton Production Symposium ever held.

The opening session took place on the morning of Monday 9 May 2016. The session started with a lovely and inspiring performance by the Bergen Cultural School saxophone quartet. This was followed by welcome and opening remarks by the ICES convener Astthor Gislason and short addresses by the Director of IMR Sissel Rogne, the Mayor of Bergen Marte Mjøs Persen, the Chair of PICES Science Board Thomas Therriault and ICES President Cornelius Hammer who declared the symposium as officially opened. The opening session ended with two excellent plenary talks by Norwegian scientists:

- *Calanus* species in the Arctic Mediterranean: from life history to ecosystem dynamics, by Hein Rune Skjoldal (Norway);
- Echosounders: Non-intrusive observations of the pelagic, by Stein Kaartvedt (Norway).

In the evening of the first day IMR hosted a reception welcomed by the local convener Padmini Dalpadado with refreshments at the conference hotel. The reception offered a perfect opportunity for people to make connections with new colleagues and renew existing relationships right in the beginning of the conference. The welcome reception included very nice musical performance by the Bjørgvin vokal choir.

In addition to the plenary talks given during the opening Session, the conference included four other excellent plenary talks given in the mornings of Days 2 and 4:

- Does climate change matter for zooplankton production in upwelling systems? by Ruben Escribano (Chile);
- Discovery of the new through scrutiny of the old: Odate Collection and future of zooplankton monitoring in the global observation initiatives, by Sanae Chiba (Japan);
- Modelling Southern Ocean Food Webs - Approaches and Challenges, by Eileen Hoffman (USA);
- On the adaptive potential of marine zooplankton to global change, by Erica Goetze (USA).

The theme sessions were run in parallel on Days 1, 2, 4 and 5 and included 117 oral presentations, there of 14 invited talks, and 170 posters. The theme sessions were:

- S1: Application of optical and acoustical methods in zooplankton studies. Conveners: Mark Benfield (USA) and Ian H. McQuinn (Canada);
- S2: Response of zooplankton communities to changing ocean climate. Conveners: Todd O'Brien (USA) and Tone Falkenhaug (Norway);
- S3: The diversity and role of macrozooplankton in marine ecosystems. Conveners: Priscilla Licandro (UK), Stig Falk-Petersen (Norway), and Se-Jong Ju (Republic of Korea);
- S4: Zooplankton diversity in the oceans by integrative morphological and molecular techniques. Conveners: Ann Bucklin (USA) and Ryuji Machida (Republic of China);
- S5: The role of microzooplankton in marine foodwebs. Conveners: Albert Calbet (Spain) and Karen E. Selph (USA);
- S6: Individual level responses of zooplankton to environmental variability and climate change. Conveners: Eva Friis Møller (Denmark) and Pamela Hidalgo (Chile);
- S7: Zooplankton in high-latitude ecosystems. Conveners: Kim Bernard (USA) and Rolf Gradinger (Norway);
- S8: New technologies and approaches in zooplankton trophic studies. Conveners: Monika Winder (Sweden) and Antonio Bode (Spain).

The workshops were run concurrently in the morning on Day 3, and as the theme sessions they included both oral and poster presentations, with 31 talks (5 invited) and 27 posters:

- W1: Use of zooplankton indicators to characterize state of pelagic ecosystems. Conveners: Alessandra Conversi (Italy), Hongsheng Bi (USA), and Sun Song (Chinese Academy of Sciences, China);
- W2: ICES/PICES cooperative research initiative: towards a global measurement of zooplankton production. Conveners: Lidia Yebra (Spain) and Toru Kobari (Japan);
- W3: Zooplankton as a potential harvestable resource. Conveners: Webjørn Melle (Norway) and So Kawaguchi (Australia);
- W4: Effects of microplastics on zooplankton. Conveners: Elaine Fileman (UK) and Maiju Lehtiniemi (Finland);
- W5: Zooplankton as the "to" in end-to-end models. Conveners: Geir Huse (Norway) and Rubao Ji (USA);
- W6: A hands-on Introduction to time-series analysis, visualization, and inter-comparison of plankton survey data. Instructor: Todd O'Brien (USA);
- W7: Toward a taxonomically-comprehensive global reference database for DNA barcodes of marine zooplankton. Conveners: Tone Falkenhaug (Norway) and Silke Laakmann (Germany).

The total number of oral presentations was 287 during the theme sessions and 59 during the workshops as shown in the tables below.

Table 1. Presentations given on the sessions during the 6th Zooplankton Production Symposium.

	Oral	Poster	Grand Total
S1	14	22	36
S2	22	27	49
S3	14	18	32
S4	13	18	31
S5	9	17	26
S6	13	26	39
S7	23	31	54
S8	9	11	20
Total	117	170	**287**

Table 2. Presentations given on the workshops during the 6th Zooplankton Production Symposium.

	Oral	Poster	Grand Total
W1	8	6	14
W2	3	3	6
W3	9		9
W4	4	2	6
W5	5	1	6
W6	1	9	10
W7	2	6	8
Total	32	27	**59**

There were almost 200 posters on display, and due to the high enrolment and the limited space, these were displayed in two sessions in the afternoons on Day 2 and Day 3, with ca. 100 on each day.

During the conference, Per Flood exhibited a selection of his excellent photographs of zooplankton. The images really convey the incredible diversity and beauty of this group of marine organisms.

In the Closing Ceremony, which began after the sessions on Friday 13, Hal Batchelder Deputy Executive Secretary of PICES offered a few summarizing remarks, pointing out the great success and the large attendance of the 6th Zooplankton Production Symposium signifying its importance. This was followed by Piotr Margonski Chair of the Awards Committee, who described the difficult task given to the Committee of having to select among the many excellent presentations of early career scientists. The best talks awards were given to Michael Blackett (National Oceanography Centre Southampton & Sir Alister Hardy Foundation for Ocean Science, UK), for his talk on 'Biology and ecology of the siphonophore *Muggiaea atlantica* in the northeast Atlantic', and Helena Hauss (GEOMAR, Germany) for her presentation titled 'Dead zone or oasis in the open ocean? Zooplankton distribution and migration in low-oxygen mode water eddies'. The best poster awards went to Ana Luisa Moran Ahern (Scripps Institution of Oceanography, USA), for her poster on 'Monitoring Spawning Activity in Cabo Pulmo National Park Using Molecular Identification of Fish Eggs and Larvae', and Carolyn L Faithfull (University of Hawaii, USA) for her poster titled 'Can nauplii use bacteria as a phosphorus or energy source?'.

After the awards presentations, Michelle Jungbluth (USA) and Svein Sundby (Norway), presented a few closing scientific remarks, Michelle from her perspectives as a young scientist and Svein as a senior one. The work of those who contributed most in the organizing and preparatory work was then acknowledged by Hal Batchelder, who then officially closed the symposium.

Most presentations given at the symposium are available at the symposium website. Some of the outcomes of the symposium have been reported to ICES SCICOM (September 2016) and to the Norwegian Research Council (2017), and in several articles appearing in PICES Press (July 2016, Vol 24(2)). In addition, as stated above, a special volume of ICES Journal of Marine Science will be published with selected papers from the symposium in fall 2017.

Figure 1 summarizes attendance and number of papers accepted for publication in the ICES Journal of Marine Science for the last five International Zooplankton Symposia. As stated above, the sixth symposium is the one with greatest attendance. However, it is noteworthy that it is at the same time with the lowest number of papers.

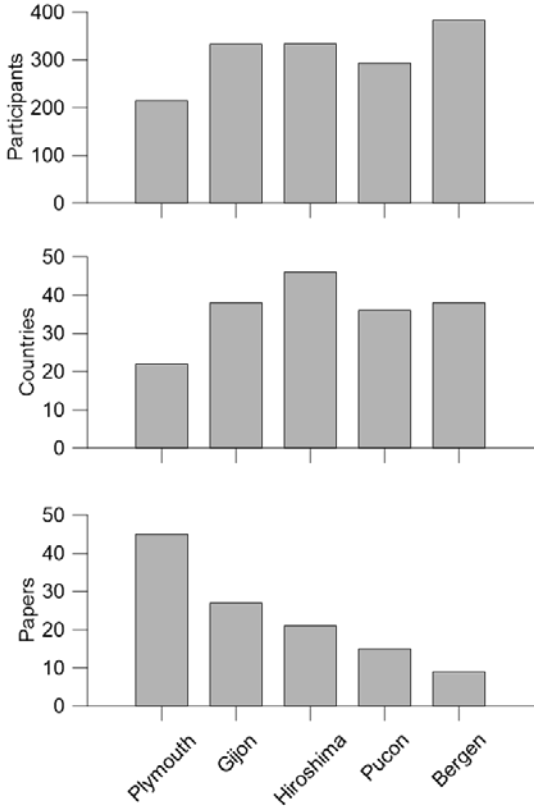


Figure 1. Attendance and number of papers submitted to ICES *Journal of Marine Science* symposium volumes of the last five International Zooplankton Production Symposia.

It is a disappointment that only ~20 articles were submitted to the special volume, and that after review process, only 9 will be published. At its annual meeting in 2017, the group expressed surprise for this outcome and discussed possible reasons for why so few papers were submitted to the special volume. Short deadline given (31 July 2016) were among the suggested explanations. But also lower interest among scientists to publish in symposium proceedings in general. Possibly we were not aggressive enough in urging people to submit. It was felt that other journals should be considered as a publication avenue for future symposia and possibly other ways of stimulating people to submit should be thought of.

In spite of this, the group feels that the symposium by most accounts was a great success, and the companionship, friendship and scientific interactions between participants was clearly evident. The groups is confident that communications and contacts established during the symposium will lead to new collaborations and endeavours among participants.

The group thanked and congratulated Astthor Gislason and Padmini Dalpadado for their huge effort as Symposium Conveners.

ToR b) Identify and develop information and data useful for modelling needs in collaboration with WGIPEM especially regarding to exploitation resources at the lower trophic level

WGZE Leads: Angus Atkinson, Erica Head, Todd O'Brien, Lutz Postel, Jeffrey Runge, Espen Strand, and Peter Wiebe

On 17 March 2015 a joint meeting between WGZE (Working Group on Zooplankton Ecology) and WGIPEM (Working Group on Integrative Physical-Biological and Ecosystem Modelling) was held. The day was organised around plenary state-of-the-art talks in order to provide an overview of the work currently achieved within each working group, and sub-group discussion on the following topics:

Topic 1 – Representing (climate-driven) spatiotemporal variability within models

1) What are the best examples of research combining observations and models to address temporal-spatial variability in zooplankton dynamics? Hopefully several studies will be listed.

2) What do these studies have in common? Is the same approach applicable across different regions?

3) How much model complexity and/or spatio-temporal resolution in field data is needed to adequately represent variability.

4) For linking models and observations, what are the implications for modelling approaches and data requirements (type, format, resolution,…)? What is the most urgent area of co-operation?

Topic 2 Observing and simulating zooplankton diversity: Frontiers in zooplankton ecology and modelling

1) What traits help define biogeographical changes in zooplankton composition among species and how have these been represented in trait-based models?

2) Within species (complexes), what natural barriers to populations have been inferred from genetic / taxonomical analyses of species/complexes and do models reproduce these barriers to gene flow?

3) If models do not capture observed population boundaries, are biological processes responsible which may not be adequately captured in models? The general question would be: Can we use models to understand processes establishing different populations of zooplankton species?

Topic 3 – Harvesting zooplankton (krill, *Calanus*): Observations and modelling carrying capacity

1) What are critical physical/biological processes affecting Calanus population biomass, distribution and productivity, how are they represented within models such as behavior (DVM, diapause) and mortality/loss terms, and are critical processes (sensitive parameters) similar across regions?

2) What are current gaps in knowledge and what new data exist that may provide answers?

3) Regarding ongoing Calanus modelling, how can various models help to increase our understanding of zooplanktons role in the ecosystem as well as the response of zooplankton community to the dynamics at lower trophic levels?

4) What are viable harvest rates of Calanus (among regions?) and how much are these expected to vary from year-to-year? Can models be used to forecast exceptionally poor or strong year classes?

Topic 1: Representing (climate-driven) spatiotemporal variability within models

Several examples of research combining observations and models to address temporal-spatial variability in zooplankton dynamics were listed:

- Pires *et al.* (2013) used a bio-physical model to track/predict dispersal and recruitment of two species, one coastal and the other estuarine. (Pires RFT, Pan M, Santos AMP, Peliz Á, Boutov D, dos Santos A. (2013) Modelling the variation in larval dispersal of estuarine and coastal ghost shrimp: *Upogebia congeners* in the Gulf of Cadiz. Marine Ecology Progress Series, 492:153-168. doi: 10.3354/meps10488)
- In Lewis *et al.* (2006), CPR data are used to validate the ERSEM model for the North Sea region. (Lewis, K., Allen, J. I., Richardson, A. J., and Holt, J. T. 2006. Error quantification of a high resolution coupled hydrodynamic-ecosystem coastal-ocean model: Part 3, validation with Continuous Plankton Recorder data. Journal of Marine Systems, 63: 209–224.)
- In Padmini *et al.* (2012) the Norwegian model "NORWECOM" is used to study seasonal and spatial variability of zooplankton biomass in Barents Sea. (Padmini, Ingvaldsen, Stige, Bogstad, Knutsen, Ottersen, Ellertsen, 2012. Climate effects on Barents Sea ecosystem dynamics. ICES Journal of Marine Science. doi:10.1093/icesjms/fss063)
- Chust *et al.* (2013) used statistical model (GAMS) and CPR data to study the northward shift of *Calanus*. (Chust, G., Castellani, C., Licandro, P., Ibaibarriaga, L., Sagarminaga, Y., and Irigoien, X. Are *Calanus spp*. shifting poleward in the North Atlantic? A habitat modelling approach. – ICES Journal of Marine Science, doi:10.1093/icesjms/fst147.)
- Chust *et al.* (2014). Using GAMS model in the North Atlantic (essentially habitat modelling), study on biomass changes/diversity in a warmer ocean. (Chust *et al.* 2014. Biomass changes and trophic amplification of plankton in a warmer ocean. Global Change Biology (2014) 20, 2124–2139, doi: 10.1111/gcb.12562)
- Li *et al.* (2005) studied the population dynamics of *Calanus finmarchicus* distribution and abundance on Georges Bank using a Finite element model (Li, X., McGillicuddy, D.J., Durbin, E.G., and P.H. Wiebe, 2006. Biological control of the vernal population increase of *Calanus finmarchicus* on Georges Bank. Deep-Sea Research II, 53 (23-24), 2632-2655, doi:10.1016/j.dsr2.2006.08.001).
- Carlotti and Wolf (1998). Population dynamics model on *Calanus finmarchicus* IBM model, with a field data component (Carlotti, F. and Wolf, K.-U. (1998), A Lagrangian ensemble model of *Calanus finmarchicus* coupled with a 1D ecosys-

tem model. Fisheries Oceanography, 7: 191–204. doi: 10.1046/j.1365-2419.1998.00085.x).

- Neuheimer, Gentleman *et al.* published a modelling study of *Calanus finmarchicus* mortality on Georges bank adjusting stage dependent mortality rates to give observed stage structures. (Neuheimer, A.B., W.C. Gentleman, P. Pepin & E.J.H. Head, 2010. Explaining regional variability in copepod recruitment: Implications for a changing climate. Progress in Oceanography 87: 94-105.)
- McGillicuddy *et al.* (1998) used a Lagrangian model with data assimilation on Georges Bank. (McGillicuddy, D. J., Jr., D. R. Lynch, A. M. Moore, W. C. Gentleman, C. S. Davis and C. J. Meise, 1998. An adjoint data assimilation approach to diagnosis of physical and biological controls of *Pseudocalanus spp*. in the Gulf of Maine Georges Bank region. Fish. Oceanogr., 7, 205–218.)
- Lutz Postel cited a study of Namibia in 2011 that used an Eulerian approach with measurements at differing distance from shore over a 4 week period. They are currently using the Cushing approach that uses different distance from upwelling to mimic seasonal difference. (Postel, L., V. Mohrholz and T. T. Packard (2014). Upwelling and successive ecosystem response in the northern Benguela region. J. mar. syst. 140, Part B, Special issue: Upwelling Ecosystem Succession: 73-81, doi:10.1016/j.jmarsys.2014.07.014). The *in situ* experiment covered changes in the pelagic and benthic domain over a wide set of stock and process parameters, which might be suitable for model adjustments.

Concerning what these approaches have in common and why people thought they were significant was that most if not all studies listed above involved broad spatial scale monitoring data with monthly or better sampling, i.e. dense data in space and time. In some cases, additional (spatially focused) sampling was used to supplement the otherwise regular sampling periods. The question of whether the predictive modelling community considered "statistical models" to really be models was raised and it was concluded that there should be a distinction between statistical models that try to match/explain already sampled data and predictive models that use mechanism or interactions to better understand ecosystem structure and functioning, and couple them to projections into the future. It was mentioned that none of the listed studies so far included sized-based models but were all focusing on biomass based or NPZD type models.

The use of model data and outputs is already a common practice and all scientists present regularly include model data in their analysis. Modelling of currents, circulation, and drift was the most common model element in combined observation + model approaches which in several cases further include behavior (most often diel vertical migration) in different degrees of complexity. Concerning future work the question of the possible use of satellite data in combined approaches was raised.

During the discussions it became obvious that clarifications between commonly used definitions were needed. The different groups (and also scientists within the groups) had different interpretations of the word "high frequency". It further became apparent that while some of the WGZE members regarded "data assimilation" as a process to derive parameters, WGIPEM members regarded it as a method to be used within an "operational" context to enhance the predictive capacity of models. Following that discussion questions were raised such as: whether data assimilation allows for interpolation or

prediction, whether it should rather be used to improve models and, how it should/can be applied for population models?

While the sub-groups tried to answer the question: "How much model complexity and/or spatiotemporal resolution in field data are needed to adequately represent variability?" the simple global answer would be "as much as possible", but also "it depends on the question that is being addressed". Concerning resolution and model complexity it is not possible to draw simple conclusions such as the larger or smaller the scale the simpler or more complex the model should be. Studies (and models) addressing life stage dynamics in small but dynamic regions require rather complex biological models, high resolution physical models and a detailed understanding of the underlying biological processes. Studies that address large scale questions require a high complexity as well as here a large variety of processes and organisms need to be included (and simplified) to resolve the interacting processes.

There seemed to be a tendency that models designed by modellers are generally "simpler" than those designed by biologists which are often rather complex. Re-worded: A modeller may focus on how to create the best (but still possible to program and manage) model for a question, while a taxonomist may get so tied up in the smallest details that the model is never formulated (or is overly complex). It was asked if anyone had read a study on primary production models that found that the more complex models were less accurate than simpler models or vice versa. It was noted that it is often necessary to start with a simplified "first step" before trying to capture every fine detail.

The main consensus of this discussion topic was that more taxon-specific size and biomass information is required to improve modelling capabilities. More species specific information especially from time-series sites and for taxa other than copepods. The biomass of these species can large (e.g. for gelatinous, macrozooplankton) in certain areas and during certain times of the year. In some systems, meroplankton can be a large/dominant component of the seasonal biomass, but often they are neglected or not included in models. One problem of linking observations and modelling efforts is the use of different units. While in models biomass is often used, biologists generally generate species counts. There is a need to generate seasonal and regional specific conversions between the two forms. The avoidance of sampling systems by some species, especially euphausiids, will cause bias in biological sampling data. Simplifying models or taxonomic analysis also depends on the region. While at northern latitude models can be species-specific lower latitude need to simplify and combine species groups. It was also pointed out that seasonal cycles and inter-annual variability in zooplankton abundance could not be modelled without an appropriate estimate of zooplankton mortality. Simply using a "closure term" for zooplankton in NPZD models will never adequately represent inter-annual or spatial zooplankton variation. Existing models and studies are not always transferable to other areas and have less explanatory power for the coastal ocean if they were designed for offshore areas. There are big differences in the questions asked about coastal/estuarine areas relative to the deep ocean. Modelling tools could be used to manage coastal areas as long as it is clear what the important variables are. Cooperation between modellers and observationalists is thus very important, but it remains a challenge to bring groups together for longer term studies or to at least study annual cycles. The holistic approach and the ecosystem based approach for management is moving more and more into focus, hence it is important to also have a holistic approach to observa-

tions, to obtain as much information as possible from expensive survey time and to include/provide these data in end-to-end models to obtain a better understanding of the ecosystem functioning.

The discussion focused on how useful data from the WGZE Zooplankton Status Report are and how they can be used. If "best" areas could be identified and analysed by representatives of both groups this could result in a presentations to be given at the Zooplankton Production Symposium. Such a presentation would constitute a major outcome of this joint meeting.

A remark was made on the degree to which patchiness is considered. Models tend to operate on rather coarse spatial scales while observations collected within these cells are usually limited. Since zooplankton distributions are inherently patchy, collecting only a few samples will result in a mean value (biomass, abundance) with very high variance. It is likely that model predictions will fall within this error range but if higher resolution data were collected, it is possible that model predictions will not fall anymore within the error bars. The question remains: How can we do a better job of collecting data to validate models and how can we mimic stochasticity and patchiness in models to fit observations? It might be useful to consult with the PGDATA - who provide guidance to those collecting standardized data - on how to provide the obtained information to the ICES data center in a unified format (e.g. standardized units, measurements).

Topic 2: Observing and simulating zooplankton diversity: Frontiers in zooplankton ecology and modelling

Depending on the question being asked, considering size as the only trait will not be sufficient. Diapause, ratio of volume versus biomass, growth rate (linked to temperature and tolerance for low oxygen) could be used. There is also a large variability in zooplankton stoichiometry (nutritional value for higher trophic level) and for example *Calanus finmarchicus* is quite lipid-rich. It has been shown that reproductive strategy is associated with the seasonality of the species. Egg-carrying species for example have an increased visibility to predators and lower fecundity, but egg mortality rates are very low. It is important to consider traits important for the question asked: considering *C. finmarchicus* being replaced by *C. helgolandicus* with temperature, will it have impact on fish only through size spectrum or does it also involve change in their caloric content of food? Furthermore behavior needs to be included as behaviors of species differ, and this will influence for example catchability or feeding interactions as different hunting strategies (visual or filtering) are used by different species. One possibility to address this diversity is by using trait-based models that include other factors in addition to size. These models already exist and use a number of traits that could also help to define bio-geographical changes in zooplankton composition among species. For these models knowing the diversity and taxonomy is critical. Information at the taxa (species) level may reveal important differences in traits. A summary by Thomas Kiørboe in a recent review lists specific differences in key attributes (the information is also available on Pangea). While full trait based models including all species and all important factors seem to be, due to the data basis, unrealistic at the moment, one first step could be to start with size-based models. When collecting data, it is recommended to record several traits but at least taxon and size. There is a need to have size distribution of species for trait-based (and size spectrum) studies.

At larger scales, a trait based approach might allow for differences in life history strategies to emerge. As several traits are linked, a suitable first step would be to identify "macro-traits". It was concluded that the trait-based approach may be a good avenue of cooperation between zooplankton ecologists and zooplankton modellers, e.g. by linking species lists and trait lists. A roadmap would be to identify which data for which trait already exist, which traits should be focused on and which information should be collected in the future and which traits matter most.

In terms of monitoring programs in Europe, it is hard to reconcile all the data needs. Modellers might be interested in one certain aspect while stakeholders and policy makers are interested in other aspects (e.g. biodiversity, indicators, productivity, etc.). It is time to start with an inventory of what the various stakeholders/users need in order to then decide what is tractable. It is worth pointing out that while there is a tendency to collect a lot of smaller datasets because they are tractable, it is often hard to reconcile/combine these datasets for examination of questions over larger domains. Open access, integration of information, and standardization of measurements and reporting is therefore required from both sides: observations and model results. Modellers and observationalists do not encounter the same constraints but need to communicate more on the possible areas of information exchanges. On one hand modellers could focus on models that utilize data that can be collected and that have practical applications, on the other they should also emphasize which data are required to improve predictions and ecosystem understanding. Given the limited budgets for monitoring, there is a need to know precisely which data are needed to inform the models, or if relatively inexpensive value-added measurements could be collected to enhance and inform models. For example, if modellers only need biomass in 3 or 4 size fractions in addition to total counts and total biomass - which are often/generally used for monitoring purposes - this could be obtained without an excessive extra effort. Since EU-MSFD budgets will not be expanded, there is a limit as to what can be done and provided by individual nations. Due to the number of countries involved, the observing systems are fragmented thus it might be useful to develop a proposal for unified collection of monitoring/observing data across national boundaries. For the modellers, it is important to know which data are available and where/for how long these data have been/are being collected in order to reconcile their ideal data requirements with the reality of what is actually being measured. The uncertainty of the observations would also be very useful information. From this, modellers could provide a priority list of data needed for the models. This list could be discussed in a second step to adjust measurements and data collections or to identify knowledge gaps. Furthermore models (and data) should be critically tested by, for example, Litmus tests following the general guidelines: 1) do the results make sense given the expert knowledge of zooplankton ecologists of the system and 2) do the model fit the observations? This might start an iterative process such that if the model does not fit the data and yet includes all known major processes, then the question becomes - what is missing? On the other hand, if the model fits the data well, and the major processes are represented and understood, we can move on to provide predictions and prognosis.

When moving towards the question of genetic (taxonomical) analyses of species (complexes) to infer natural barriers to populations, it appears that in most of the subgroups there was not enough expertise in the room to discuss the barriers. Some study results were briefly mentioned, that showed no genetic variation on a basin scale. However, that

could have been linked to the genes selected for analysis. Some are conserved over broad spatial scales. A question was whether genetics might be used to determine some sub-populations?

Time was also spent discussing within-species plasticity. Zooplankton ecologists want to understand how the distribution of species will change, and this requires information on the species physiology. Latitudinal gradients exist in specific traits – growth, reproduction, and survival (temperature-dependent vital rates) but these are intra-specific traits. Could it be that physiological plasticity is not the result of genetic differences? This could be an interesting future area of work: examining the genetic differences among populations and how these differences are linked to key life history traits. Incubation experiments have shown that metabolic rates and reproductive performance change among populations. Do we need to know what they experienced beforehand? Perhaps yes, and temperature versus length-at copepod C6 was one example. A comment was made regarding *Calanus finmarchicus,* that is difficult to maintain in the laboratory and that can interbreed with *Calanus* congeners. Phenotypic plasticity may or may not have a genetic basis, and it is also important to know how quickly traits can change within a species.

One very important question is: What limits the northern and southern distribution of species in the ocean? Stages and diapause traits can provide answers for Arctic systems, but can we use a similar approach in more temperate areas? Studying sub-population distributions may provide a successful method to understand the overall presence of a species. Thus modelling populations instead of species would help but this requires us to look at genetics in order to identify populations within a species. Another idea would be to use a trait-based approach where traits are linked to geographical presence.

When transported (e.g. through ballast water) some species can establish themselves in new areas, but for such processes that are not "natural": what and where are the barriers to range expansion? Also, what controls inter-annual or seasonal changes in species distributions and community composition? How can models deal with invasive species (e.g. size based models do not take account of taxonomic variability)? Some examples were mentioned: *Pseudodiaptomus marinus* has invaded the Dover Strait area, and its abundance is strongly increasing year after year.

As well, concerning the shift from *Calanus finmarchichus* to *Calanus helgolandicus* (e.g. in the North Sea), if we understand the shift, can we model it? In models we have control on the habitat, so habitat change could drive distributions. However, one has to be careful when using these kinds of results, since habitat may not be the only determining factor for the success of a particular species.

A recent paper (Melle *et al.* 2014 The North Atlantic Ocean as habitat for *Calanus finmarchicus*: Environmental factors and life history traits. Prog. Oceanogr., 129: 244-284) shows that there are differences in *C. finmarchicus* populations between the eastern and western North Atlantic. Mortality is an important process that may limit the northern distribution of *C. finmarchicus*. Where the species co-occur, *C. glacialis* and *C. hyperboreus* may prey on younger stages of *C. finmarchicus* and limit its northward expansion as the North Atlantic warms. On the other hand, it is more likely that the dependence of *C. finmarchicus* on phytoplankton to fuel its reproduction in spring limits its ability to reach a stage with the capacity to overwinter in areas where the growth season is short. One question is: why is *C. finmarchicus* not shifting northward from the Gulf of Maine? The Gulf of Maine is now

warmer than the statistical models suggest should be optimal for *C. finmarchicus*. Mean annual surface temperature appears to be an important limit defining the range of *C. finmarchicus*. An annual average of 10°C is thought to represent the statistical limit, but the Gulf of Maine has been warmer than this for quite a while. One interpretation is that the Gulf of Maine is seeded annually by *C. finmarchicus* from the Scotian Shelf via a cold coastal current, which provides conditions for high production by *C. finmarchicus.* These individuals then diapause in the deep basins of the Gulf of Maine. When they emerge from diapause, they enter warm waters which accelerate metabolism of their stored lipids. A large proportion of these animals and their offspring are likely advected south and ultimately lost from the Gulf of Maine, so that the Gulf is a one-way system. This shows the complex system understanding required if one wants to make future predictions.

Variables that could be considered include interspecies competition, temperature effects (noting that increasing temperature also increases the activity of (and potentially overlap with) predators), differences in inflow (e.g. in the Baltic), feeding environment (but note that most of the models only discuss "Chlorophyll a", which is probably a poor representative/predictor of food quality). It was noted that ecosystem complexity is easy to model when simple, but requires a lot of elements to be considered in more complex (e.g. tropical) areas.

Topic 3: Harvesting zooplankton (krill, Calanus): Observations and modelling carrying capacity

A presentation of the potential *Calanus* fishery and the current model was made in plenary, but based on this talk a full assessment of knowledge gaps was not possible.

Several questions arose, notably about:

- Which predators of *Calanus* have been identified (e.g. so far have only commercial fish predators been included?)
- What is the current knowledge about the extent and location of *Calanus* fishing? If the fishing is only on the shelf, what is the magnitude of the catch compared with the standing stock of *Calanus finmarchicus* on the shelf?
- If, as estimated by the model, only 10% of the *Calanus* production is consumed by the commercial species, where does the other 90% go?
- There is a general need for more information about how the model is being applied (e.g. the variables, parameters etc.)
- Does the model (mathematical or conceptual) consider effects on lower trophic levels as well as on species subject to commercial fisheries?
- It had been shown that herring condition varied with total zooplankton biomass (interannually), which was dominated by *C. finmarchicus*, but it was not clear how fishing might affect this relationship.

It was also suggested that the model being used (NORWECOm) should be further developed and tested at different catch levels and that its performance should be examined by other modellers. It was concluded that this issue should be a topic for exploration by the WGZE and WGIPEM working together, since the proposed "plan" involves models and knowledge of *Calanus finmarchicus* ecology. Both WGZE and WGIPEM are science work-

ing groups that do not report to (or discuss results with) an advisory counterpart group. If these two ICES WG groups do not explore this, who will/can/should do it?

It was suggested that the "*Calanus* question" should be a topic at the upcoming Zooplankton Production Symposium. Although there will be a workshop on zooplankton fishing (in general) it was suggested that the issue of *Calanus* fishing should be highlighted.

Summary and general conclusions of the joint meeting

- Observation activities across countries and programs are fragmented and are not coordinated: data are not always standardized and only partially represented in databases.
- It is not clear that the sampling frequency and sample analysis best suits modelling needs.
- There is a need for information exchange and guidance from modelling community as to their data requirements.
- There is a need for data collection that contributes to a dynamic, mechanistically driven understanding of change and impacts on ecosystems and processes
- There could/should be a synthesis presentation from WGZE and WGIPEM: "Reconciling zooplankton data collection with modelling needs in observing systems to understand ecosystem change"
    - What is being done vs what is needed?
    - What are the questions and types of models that need observing data? (biogeochemical, ecosystem, coupled physical biological population dynamics)
    - What variables needed by these models that are not presently or consistently measured by present observing activities?
    - Data distribution and management issues.
    - Making best use of WGZE data archiving efforts.
    - Making use of fisheries data management experience to help streamline data distribution and availability for modelling needs.
- Examples
    - Analysis of zooplankton samples to provide information on energy (lipid) concentration of zooplankton community, as determined from zooplankton species abundance and laboratory measurements of lipid content/species and developmental stages within species.
    - High frequency (monthly to semimonthly) sampling with stage resolution for coupled physical biological models of key species population dynamics.
- Are the zooplankton indicators recommended for MSTS by HELCOM and OSPAR needed by models?
    - Biomass calculations.

- Mean size of zooplankton community.
- Plankton life form analysis.

Future actions as discussed in 2015

1) Propose a joint presentation at the 6th Zooplankton Production Symposium to be held in 2016 in Bergen

Geir Huse and Rubao Ji will co-convene a workshop at the Zooplankton Production Symposium on the following topic: "Zooplankton as a "to" in end-to-end models". Since this workshop is 'hands-on' can we address the question "What do the modellers need in terms of data?" "How can we fit zooplankton into the end-to-end models?" Furthermore there might be one or two talks that would be relevant to the Symposium with at least two possible sessions where modelling/zooplankton ecology could fit in (see Session 2: Response of zooplankton communities to changing climate and Session 6: Individual variability and its response to environment and climate).

2) Initiate a precise list of data required by modellers and applied zooplanktologists (including traits to be informed by keeping the taxonomic information) to inform zooplankton ecologists in charge of data collection or data analysis.

ToR c) Review the ICES response to the Norwegian request regarding the *Calanus finmarchicus* exploratory assessment

Leads: Webjörn Melle and Erica J. Head, Rapporteur in 2017: Astthor Gislason

With a letter to ICES in 2012, the Norwegian Ministry of Fisheries and Coastal Affairs requested an "exploratory assessment of *Calanus finmarchicus* in the Norwegian Sea" (see the copy of the request below). After discussions between the Secretariat and the Advisory and Science Committee Chairs, the ICES Working Group on Zooplankton Ecology (WGZE) was asked to look at the request and consider how best to address it. During the meeting in 2012 there was a long discussion lead by Jeff Runge that included a description of a manuscript synthesizing what is known about *Calanus finmarchicus* from a basin perspective, which has been submitted to Progress in Oceanography (See discussion in ICES CM 2012/SSGEF:06). The final conclusion was summarized in the justification for ToR h for the meeting in 2013. The preferred approach was to host a workshop to consider not just the request, but its broader context. A summary of suggested topics was produced by WGZE for inclusion at the proposed workshop. Jeff Runge and Webjørn Melle (by the WGZE), Jason Link (through ACOM) and Mike Heath (through SCICOM) were approached to assess their willingness to chair such a workshop and they all accepted.

The four co-chairs were invited to correspond to:

- Finalize the ToRs – The original ToRs were developed by the WGZE, and have been edited by a number of individuals. These ToRs may need some editing before they are incorporated into the final resolution (WKCALANUS.doc) to be approved and publicized.
- Plan the residential meeting – venue and dates are open for discussion.

- Plan intersessional work – WGZE suggested 6 ToRs, focusing on ecological understanding, data and methodologies, preliminary assessment, ecosystem effects of harvesting, possible assessment schedules and data collection needs. They are clearly big questions and these cannot be responded through a residential meeting only. One of the reasons for a leadership of four Chairs is so that you could share the intersessional work according to your expertise, and engage participants as you see fit.
- Start publicising the workshop among those players that you think would be essential to secure a successful outcome.

DET KONGELIGE
FISKERI- OG KYSTDEPARTEMENT

Royal Ministry of Fisheries and Coastal Affairs

International Council for the Exploration of the Sea
H. C. Andersens Boulevard 44-46
DK-1553 Copenhagen V
Denmark

Your ref.	Our ref.	Date
	200600829- /BBE	

Request on exploratory assessment of *Calanus finmarchicus* in the Norwegian Sea

The copepod species *Calanus finmarchicus* is abundant in all parts of the Norwegian Sea, and is one of the most abundant zooplankton species of the North Atlantic. It is the major herbivore of the Norwegian Sea ecosystem, and the main food of important pelagic fish stocks. The role of *C. finmarchicus* for fish productivity in the large marine ecosystem of the Norwegian Sea and the Norwegian coast, calls for a better understanding of the stock dynamics. For this reason, the Ministry of Fisheries and Coastal Affairs hereby requests ICES to conduct an exploratory assessment of *C. finmarchicus* in the Norwegian Sea, in accordance with the attachment.

Yours sincerely,

Vidar Landmark
Director General

Elisabeth N. Gabrielsen
Acting Deputy Director General

Copy:
Institute of Marine Research
Directorate of Fisheries

Enclosure 1

Copy of the request on exploratory assessment of *Calanus finmarchicus* in the Norwegian Sea from the Norwegian Ministry of Fisheries and Coastal Affairs.

The following ToRs were prepared for the *Calanus* Workshop:

The Workshop on the "Exploratory Assessment of Calanus finmarchicus (WKCALANUS), convened by Webjørn Melle (Norway), Jeff Runge (USA), Michael Heath (UK) and Jason Link (USA), will meet on [Date – preferably autumn] at [Venue – preferably CPH], and will report to SCICOM and ACOM via SSGEF, with the following Terms of Reference:

a) Review the understanding of the ecology and dynamics of *Calanus finmarchicus*,

b) Evaluate the data sources and methodology that would be needed to conduct an exploratory assessment of *C. finmarchicus*, including survey and modelling needs.

c) Make an exploratory assessment of the abundance and production of *C. finmarchicus* based on available data, and evaluate appropriate candidates for Biological Reference Points.

d) Evaluate quantitatively the ecosystem effects of harvesting of *Calanus finmarchicus*, including effects on dependent species, and the potential by catch effects of the fishery.

e) Evaluate future assessment schedules and frequencies of both the stock and demands on it; in order to improve the understanding of the functioning of the ecosystem and to ensure resource sustainability.

f) Provide advice on improved data collection for the development of future assessments of *C. finmarchicus*.

Science workshops are normally funded via member countries (in many instances this means the experts own institutions). However, as this was an advisory request from a member country, the Secretariat decided to explore the willingness of Norway to contribute to the funding. In response Norway decided to raise the issue through the normal process in SCICOM without additional funding allocated for the workshop. All non-Norwegian chairs found it impossible to proceed further.

In Norway, work towards a management plan (including a harvest rule, quota, and assessment of *Calanus* in the Norwegian Sea) is being developed by the Norwegian Fisheries Directorate and the Institute of Marine Research. The first draft was initially planned to be finished by the end of April 2013 and the final draft by the end of the year. However, this was postponed to 2014 due to internal priorities at IMR. Calanus AS has requested and been approved a scientific catch quota of 1000 tonnes in Norwegian waters for 2013 by the Norwegian Ministry of Fisheries and Coastal Affairs. As a prerequisite for the allowance, sub-samples of all trawl catches have to be taken by Calanus AS and examined for by-catch of fish eggs and larvae by independent experts. The Norwegian Fisheries Directorate could decide to place inspectors onboard during the fishery.

As reported by Hildur Petursdottir, in a contributed talk, an exploratory survey on *Calanus* was made on the southwest shelf off Iceland in collaboration with Calanus AS, Tromso, Norway (http://www.calanus.no/About-us.aspx) to see if *Calanus* densities were high enough to make commercial harvesting profitable. Kurt Tande and Astthor Gislason were on the survey cruise in 2012. Eighty percent of plankton was in upper 50 m at stations where catches were high enough for harvesting. In January 2013, a request was

made to Iceland Ministry to harvest 300 tons in 2013 and this was approved. Areas selected for fishing are to be determined by the Marine Research Institute and the harvesting is to be done with an observer on board.

The WGZE discussed the way forward. One question was whether to immediately pursue plans for the workshop on this issue through SCICOM as a bottom up process. There was a consensus that such a workshop was essential and should take place, since the exploitation of a lower trophic level requires assessment along the lines defined by the workshop ToRs. But it was also obvious that Norway was not interested in pursuing this issue as a top down process in the ICES system. It was also considered important that the planners of the workshop have access to the management plans produced by Norway and Iceland. It was recommended that Piotr Margonski, as chair of WGZE, seek more information from SCICOM about the possible next steps in moving forward on this very important issue.

During summer 2013, Jeff Runge resigned, citing lack of financial support to continue. Erica Head agreed to take his place. During the fall of 2013, IMR agreed to provide up to 7000 Euros, to fund the three non-Norwegian Co-Chairs to attend the Workshop to discuss the *Calanus* fishery, in anticipation that it would be held in Bergen. Jason Link and Mike Heath both decided that this would be inadequate, since they considered that a panel of experts was required, which could not be assembled unless all participants were to receive external funding. At this point they both resigned as workshop Co-Chairs.

During the 2014 meeting there was consensus that the WGZE needs to include expertise from other ICES expert groups in order to address this ToR. WGZE suggested approaching the modelling group in order to make a joint effort on this task. In 2015, the WGZE met back to back with the ICES WGIPEM (Working Group on Integrative, Physical-biological, and Ecosystem Modelling). The conclusion of the WGZE was to suggest a joint WGZE/WGIPEM ToRs for the meeting in 2015, on the assessment of *Calanus*. This was viewed as a good opportunity to foster future co-operation between WGZE and WGIPEM.

Therefore, it was decided that:

- The Chair (Piotr Margonski) will approach the WGIPEM Chair (Myron Peck) regarding a joint ToR on the *Calanus* assessment. The preparation of this ToR should be made prior to the group meeting, and work should start as soon as possible by correspondence.
- Additional ecological modellers should be contacted and get involved in this work as soon as possible. Modellers at the Norwegian Institute of Marine Research, that have been working on *Calanus* populations modelling should also be contacted: (e.g. Solfrid Sætre Hjøllo).
- The WGZE decided to keep the *Calanus* assessment as a "Multi-annual ToR" 2015/2016 (1–2 years) led by Erica Head and Webjørn Melle.

This was later extended to 2017, partly due to lack of progress of the work on the Harvest Plan in Norway. The main purpose of the ToR was from now on to let the WGZE review the progress of the Harvest Plan.

The summary of the ToR c) progress in 2015:

A management plan for the *Calanus finmarchicus* fishery is being prepared in Norway. Given that ICES has not taken any action with regard to *Calanus*, it is recommended that WGZE will discuss the overview of the Norwegian plan (written in Norwegian). Webjørn also presented an overview of the stock assessment based on modelling data including the assessment of bycatch.

Total annual production of *Calanus* was estimated to be about 200 million MT. *Calanus* is primarily consumed by pelagic fishes: blue whiting, mackerel, and herring (based on model results). *Calanus* makes up about 50% of the total zooplankton consumption. This value is based on a model on how much fish need to consume combined with the proportion of *Calanus* in the zooplankton assemblage, however, within the consumption model, fish migration cannot be effectively modelled. Consumption by mesopelagic fishes is about same level (45 million MT) as the total pelagic fish consumption. Consumption by invertebrates (krill, amphipods, predatory copepods, chaetognaths, cnidarians, etc) is high (698 million MT). There is very little (if any) 'free' *Calanus* biomass available to be taken by a fishery. The seasonal production cycle of *Calanus* was illustrated based on cruise data from 1996–2012. These data were corrected for year-day and station effects since cruises cannot start on exactly the same day each year. These data provide what is considered the best estimate of variability in stock size of *Calanus*. During the period when the pelagic fishes had a very high abundance, the abundance of *Calanus* was relatively low. The range of *Calanus* abundance was about ½ - double the mean.

In 2006 the Ministry of Fisheries banned fishing for zooplankton in Norwegian waters without a permit/quota. From 2003–2007 there was an experimental quota of 1000 MT of *Calanus*. In 2014 the highest catch ever was at 280 MT level. Company goal is to fish 1000 MT. Institute of Marine Research (IMR) suspects that there will be attempts to catch more *Calanus* in-order to address the growing demand for aquaculture feed supplements.

The fishery uses 500 micrometer mesh nets targeting primarily C4 – C6. The trawls are large and fished within the upper 30 m of the water column. Fishing occurs during both day and night during the spring. Small test nets are deployed prior to fishing to assess both the *Calanus* abundance and the amount of by-catch (primarily fish and fish eggs). Relative by-catch (hr^{-1} tow^{-1}) was estimated. 48 samples were analysed and the bycatch were classified into fish eggs, herring larvae, cod larvae, and unidentified larvae. In total catch from sampling location (85 075 kg), which took 303 hours of fishing, there were: 79 513 600 fish eggs, 5 853 570 unidentified fish larvae, 1 960 000 cod larvae, and 9 433 700 herring larvae identified. To examine the consequences of this by-catch, the number of cod surviving to recruits was assessed. Known mortality data for eggs based on stages was used. Similar exercise was done for the larvae to juvenile period. When these data were scaled up to the total quota of *Calanus*, 41 724 cod would not recruit to 3 year old fishes.

The worst case scenario assuming the highest larval cod densities indicates the loss of 327 370 kg of cod. These results indicate that *Calanus* fishery needs to be regulated. It raises the question, what we would like to fish: *Calanus* or cod? The value of the *Calanus* oil is higher than then value of the cod. This is, however, an economic decision not a biological one.

During the joint WGIPEM-WGZE session there was evidence that herring condition was correlated with zooplankton biomass (with a 1 yr lag). This relationship is related to the NAO index of the prior year and it enables forecasting of the herring condition. This was used for many years but in 2004 the relationship broke down, possibly due to a change in the herring migration pathways and the fact that zooplankton biomass was not being measured at the herring feeding grounds.

The CPR data appear to show that *Calanus* are moving further north. Will this lead to a northward shift in the spawning grounds of cod? Could this lead to increased mortality of cod eggs and larvae due to by-catch? When the last 10 years' data are taken into account, the area is cooling thus the argument is probably not valid for now, but under warming conditions it has to be considered.

Jeff Runge asked if the recommendation of the management plan would be to sustain the 1000 MT quota? Webjørn Melle responded that the analyses are testing the potential effect of the 1000 MT and higher quotas on the by-catch. It is up to the Fisheries Directorate to decide whether to continue with the 1000 MT quota. Given that Calanus AS are not interested in fishing more than the current quota and in fact have not even reached that level, it is possible that the current quota will be sustained.

There is some interest by Calanus AS in a *Calanus* and krill fishery off Iceland. Company visited and carried out some mapping in 2012. This visit was purely an exercise in mapping. In 2013, an Icelandic fishing company requested to start an exploratory fishery for *Calanus*. Marine Research Institute recommended a catch quota of 300 MT but no further activities were recorded.

The group agreed to continue this ToR in the following year and include discussion of the *Calanus* fishery within the workshop on zooplankton fisheries at the 6th Zooplankton Production Symposium.

Progress in the Norwegian work on the Harvest Plan for *Calanus* was presented at the 2016 and 2017 meetings and reviewed by the WGZE. At the time of the 2017 WGZE meeting the Norwegian Harvest Plan for *Calanus* was finished and distributed for review in Norway by various authorities and stakeholders.

Summary of the 2017 meeting activities and discussions:

Webjørn Melle introduced this topic by reviewing the management plans for *Calanus finmarchicus* in Norwegian waters, which is now in place. At the last annual meeting of the group in Lisboa 2016, Webjørn gave a detailed account of how the biomass estimates and the bycatch estimates were done.

Based on field data and modelling, the total annual biomass of *C. finmarchicus* in the Norwegian Sea is estimated as ~33–40 million tonnes wet weight. Most of the biomass is located in the region of the Norwegian Sea influenced by Atlantic Water. During May, by far the main part of this biomass stays in the upper 200 m of the water column.

The biological advice of IMR and the management considerations of the Norwegian Fisheries Directorate considers the following components:

- The standing stock of *Calanus* in the open waters of the Norwegian Sea (~1.2 million km^2) is estimated as 33 million tonnes wet weight

- Biological advice suggests a potential catch of 10% of standing stock giving 3.3 million tonnes wet weight.

Based on this the actual quota was set by the Directorate of Fisheries:

- 50% area restriction makes 1.65 million tonnes wet weight.
- The effects of bycatch in coastal waters are considered minimal – still it is considered advisable to put stronger limits on the fishery in coastal areas of bottom depths less than 1000 m
- *Calanus* is considered to have a key role in the Norwegian Sea ecosystem. Temporal limitations in when the fishing takes place: 1 April – 1 September
- The fishery should be limited both geographically and temporally and a precautionary approach has been applied when issuing the quotas to 10% of 1.65 million tonnes giving 165 000 tonnes.
- In the coastal areas (<1000 m bottom depth) the quota was limited to 3000 tonnes.
- In the oceanic areas (>1000 m bottom depth) the quota will then be 165 000–3000 = 162 000 tonnes.

The Norwegian company Calanus AS is involved in experimental fishery of *C. finmarchicus* in Norwegian waters. From 2003 until present the annual catches of *C. finmarchicus* have ranged from ~10 to 600 tonnes. The main products are *Calanus* oil. The company is instructed by the Norwegian Fishery Department to take samples of the catches for bycatch of fish eggs and larvae. The analysis of the samples is done by IMR. Together Calanus AS and IMR work together towards improved sampling and conservation routines.

The quota is now out for hearing: The work that was finished more than a year ago is now under consideration by the Ministry of Fisheries.

The following discussion revealed that the fishery by Calanus AS is currently mainly in coastal areas but there has been some development of fishery off the Tromsöflaket (of the continental slope), which is defined as an offshore area. Currently, there is no fishery for other zooplankton species. However, a firm called Planktonic have expressed interest in catching 'summer plankton' and euphausiids in the Norwegian fjords. The question was raised if one has attempted to fish the overwintering stocks of *Calanus*. Webjørn answered that the fishery was currently directed at *Calanus* in surface waters where the concentrations were largest (the C5s), i.e. just before the stocks migrated down for overwintering. The importance of considering the productivity of *Calanus* and the importance of *Calanus* as food for herring in the advisory process was addressed. The NORWECON model is used in the advisory process, and it has physical, primary and zooplankton production modules incorporated. Model runs indicate that removing 3.3. million tonnes of *Calanus* has no effect on the annual productivity of *Calanus* and feeding of herring. The effects of cannibalism is not included in the model. It is realized that the model results are not the final answer but at least an indication that a part of the *Calanus* stocks may be taken from the system.

Work within this ToR reached its goals and may be considered as concluded.

ToR d) Compile the information on micro-plastics pollution and its effects on zooplankton communities

Leads: Elaine Fileman and Maiju Lehtiniemi, Rapporteur in 2017: Elvire Antajan

Microscopic plastic debris, termed 'microplastics' (plastic particles or fibres <5mm in size), have been accumulating in the oceans over the past few decades and are of increasing concern in the marine environment. Since microplastics occupy the same size range as many planktonic organisms they can easily be mistaken for food and affect a wide range of marine organisms including zooplankton. Microlitter is also used as one of the indicators of the status of the seas in EU Marine Strategy Framework Directive and therefore its abundance should be monitored from the water column and seabed.

During year 1, the Working Group compiled information on current and proposed microplastic monitoring and experimentation within the ICES area. 10 countries reported on testing of microplastic monitoring while only 4 had ongoing monitoring activities. The high variation in equipment and mesh sizes used for monitoring was clear. Six different mesh sizes (from 10 to 333 µm) were used. The most common methods used were the manta trawl or equivalent (mesh ~300 µm) and the WP2-net. Current methods and problems associated with these methods were highlighted during the meeting and discussed in particular with respect to net size, contamination and concentrations of microplastics used for experimental work. Presentations on current sampling techniques and experimental studies were followed by discussion on possible future activities.

In year 2: A workshop dedicated to assessing the risk that microplastics pose to zooplankton was convened by WG members at the 6th ICES/PICES Zooplankton Production Symposium in Bergen, May 2016 http://www.ices.dk/news-and-events/symposia/zp6/Pages/Effects-of-microplastics-on-zooplankton.aspx.

The workshop brought together >30 international researchers with a common interest in microplastics; discussion topics included issues with contamination, identification, standardisation of methods, net sizes leading to underestimation of smaller sized plastics and entanglement and best practice in monitoring microplastics were discussed; current research in this field was presented, gaps in our knowledge were highlighted as well as areas for future research. A participant email list was compiled to facilitate post-workshop discussion. The session concluded with a recommendation that this workshop be followed up with a submission by the workshop conveners of a session proposal to the 2018 ICES Annual Science Conference.

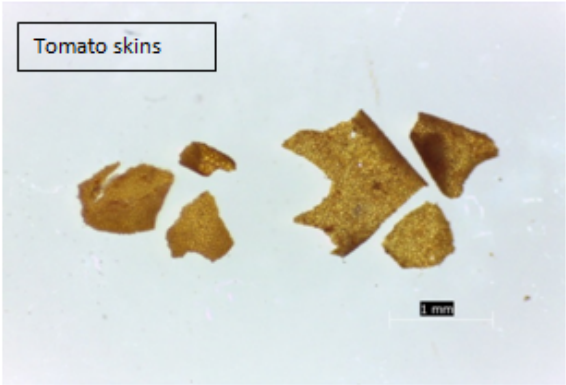
In year 3: Present abundance estimates of microplastics from different ICES sea areas were presented and the effects of different methods used in monitoring were discussed again. As a concluding activity for this ToR, the group agreed it would be useful to produce specific guidelines for monitoring of microplastics within zooplankton time-series samples. Guidelines were compiled, presented to the Working Group and discussed in the meeting. Guidelines provide information to zooplankton ecologists who may be considering enumerating microplastic particles in zooplankton monitoring samples, and raises awareness of contamination issues and the methods for correct identification of plastic particles. Guidelines will be uploaded to the ICES WGZE website.

Guidelines for microplastics enumeration from zooplankton samples (ICES Working Group on Zooplankton Ecology)

Elaine Fileman, Maiju Lehtiniemi

This summary table has been compiled to provide information to zooplankton ecologists who may be considering enumerating microplastic particles in zooplankton monitoring samples. The aim is to give some guidance on what researchers can hope to achieve (understanding the limitations) and what you should take into account to avoid the problems specific to microplastic research (e.g. contamination) which are not that familiar to zooplankton ecologists in general.

Activity	Notes
Sample collection- using standard zooplankton net hauls	When considering microplastic particles, it is important to reduce contamination wherever possible during all stages from sample collection, fixation, sub-sampling and analysis. Precautions: Contamination from airborne fibres, clothing or sampling vessels is a common problem therefore rigorous but relatively simple precautions should be taken. When net sampling from a boat take precautions to avoid picking up paint from the boat's hull, and avoid sampling near the boat's waste outlet, act quickly when rinsing the net and fixing to cut down contamination time and collect a procedural blank of filtered seawater. Rinsing the net from the outside will help avoid contamination from the hose pipe and taking a procedural blank of the hose pipe water is recommended. It is important to use sample storage bottles that do not release plastic particles into the sample e.g. through degradation of the lid or bottle. If possible use glass.  *Photo: S Railo* When processing and analysing samples keep samples covered wherever possible, wear a 100% cotton lab coat, rinse all equipment with filtered deionised water before use and if possible carry out all sample processing in a clean laminar flow cabinet. In addition, include a procedural blank (i.e. samples containing filtered seawater and no material) for every analysis, check these under a microscope to look for any possible contamination.

	It is worth noting that sub-sampling a very dense zooplankton sample could result in a very small fraction of the sample actually being counted. This could easily lead to overestimates of microplastics which are generally less abundant than zooplankton. Finding one or two fibres and multiplying up could lead to an overestimate of microplastic abundance compared to specifically targeted microplastic sampling methods which generally filter a larger volume of water. This can also result in the underestimation of microplastic abundance.
Sample treatment	Zooplankton net samples which are fixed in a plastic friendly fixative e.g. formalin, offer an ideal opportunity to enumerate microplastic particles alongside routine zooplankton counting. No specific treatment is required although during all stages of sample handling precautions (listed above) should be taken to avoid contamination. Sometimes the presence of biological material can mask the presence of microplastic particles in which case it is possible to extract microplastics from biological material using methods such as enzymatic digestion. See refs below.
Visual identification of microplastics	The literature reports error rates of visual identification of microplastics of between 20 and 70 % and this error increases with decreasing particle size. To minimise such error, microscopic inspection of particles in zooplankton net samples should be carried out according to standard criteria together with a strict conservative examination in order to reduce the possibility of misidentification. <u>What to look for:</u> The most common aspects that are used to describe visually sorted microplastics are type, shape, and colour and this information should be recorded as well as length and width. Observation criteria: (1) no structures of organic origin should be visible in the plastic particle or fibre,  *Photo: S Railo*

(2) fibres should be equally thick and have a three dimensional bending to exclude a biological origin,

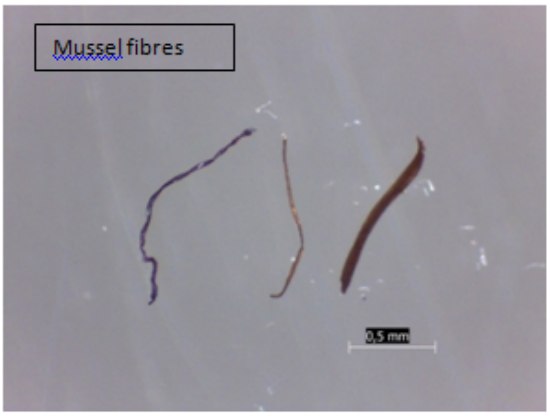


Photo: S Railo

(3) particles should be homogeneously coloured, e.g. pieces of bivalve shells are sometimes colourful and shiny, and may be misidentified as plastics, but these particles are not homogenously coloured.

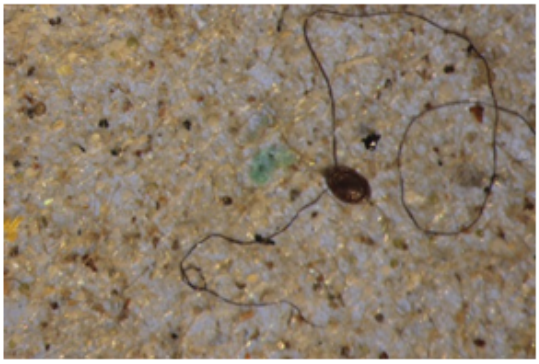


Photo: E Fileman

(4) transparent or whitish particles must be examined under high magnification and with the help of fluorescence microscopy to exclude a biological origin, sand and glass.

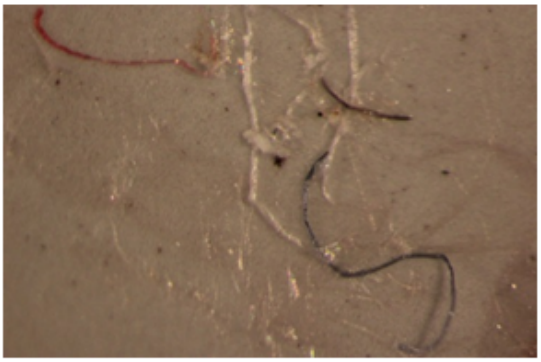
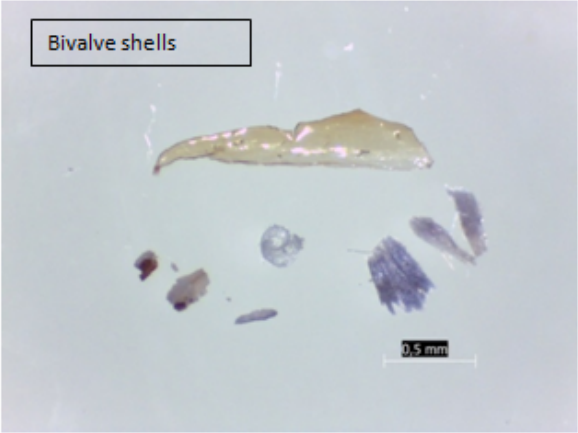


Photo: E Fileman

	Pieces of metal paint or aluminium foil may be present in the samples but these can be identified by their intense reflectivity and shininess and will not display the characteristic traits of most microplastics e.g. flexibility.  *Photo: S Railo* You may notice zooplankton and fibre entanglement, this is common in net samples. It may arise as a result of confinement in the cod end and does not necessarily mean entanglement in the sea. The hot needle test is a useful method to distinguish between plastic and organic material. When a hot needle touches the suspected plastic particle, plastic will curl. Once visual inspection has been carried out the recommendation is to verify this using more accurate methods which allow proper characterisation of plastics and their types (e.g. FTIR or Raman spectroscopy)- see below.
Chemical identification	If possible, further identification of particles using techniques that facilitate a proper identification of plastics should be performed. For example, FTIR or Raman spectroscopy could be carried out on a sub-set of the visually counted particles to confirm presence of plastic.

Suggestions for Further reading

MERI (2015) Marine and Environmental Research Institute: Plastics and microplastics research. Guide to Microplastic Identification

Löder, M. and Gerdts, G. (2015): Methodology Used for the Detection and Identification of Microplastics—A Critical Appraisal / M. Bergmann , L. Gutow and M. Klages (editors) , In: Marine Anthropogenic Litter, Marine Anthropogenic Litter, Berlin, Springer, 447 p., ISBN: 978-3-319-16510-3 . doi: 10.1007/978-3-319-16510-3_8

Eriksen, Marcus, et al. (2013) Microplastic pollution in the surface waters of the Laurentian Great Lakes. Marine pollution bulletin 77, 177-182.

Hidalgo-Ruz, V., Gutow, L., Thompson, R.C., and Thiel, M. (2012). Microplastics in the marine environment: a review of the methods used for identification and quantification. Environmental Science & Technology 46, 3060-3075.

Norén, F. (2007). Small plastic particles in coastal Swedish waters. KIMO Sweden Report, 1–11.

De Witte, B., Devriese, L., Bekaert, K., Hoffman, S., Vandermeersch, G., Cooreman, K., & Robbens, J. (2014). Quality assessment of the blue mussel (Mytilus edulis): Comparison between commercial and wild types. Marine pollution bulletin, 85(1), 146-155.

Avio, C. G., Gorbi, S., & Regoli, F. (2015). Experimental development of a new protocol for extraction and characterization of microplastics in fish tissues: first observations in commercial species from Adriatic Sea. Marine environmental research, 111, 18-26.

Imhof, H. K., Schmid, J., Niessner, R., Ivleva, N. P., & Laforsch, C. (2012). A novel, highly efficient method for the separation and quantification of plastic particles in sediments of aquatic environments. Limnology and Oceanography: Methods, 10(7), 524-537.

Cole, M., Webb, H., Lindeque, P. K., Fileman, E. S., Halsband, C., & Galloway, T. S. (2014). Isolation of microplastics in biota-rich seawater samples and marine organisms. Scientific reports, 4, 4528.

Setälä O, Magnusson K, Lehtiniemi M, Norén F 2016: Distribution and abundance of surface water microlitter in the Baltic Sea: A comparison of two sampling methods. Mar Pol Bull. DOI: 10.1016/j.marpolbul.2016.06.065

ToR e) Review the new methods of automatic and semi-automatic plankton identification

Leads: Klas Ove Möller, Elvire Antajan, Astthor Gislason, and Mark Benfield; Rapporteur in 2017: Piotr Margonski

A review article on image analysis is being prepared that will summarize a rapid development of those tools supporting the automatic and semi-automatic plankton identification.

The multiannual ToR on the review of new methods of automatic and semi-automatic plankton identification started during the working group meeting in Reykjavik 2015 due to the rapid development of image analysis systems, and progress since the publication of the Zooplankton Methodology Manual. The group discussed options for presenting this information: (i) submitting a new chapter for the Zooplankton Methodology Manual or (ii) a peer reviewed journal article that could be linked to the Manual via the WGZE website (preferred option). This article would deal with recent technical developments and include *in situ* systems, such as the VPR, UVP, ZooVIS, ISIIS, Holocam, and lab instruments like Flowcam, flowcytobot, Zooscan, and a benchtop VPR. It was agreed that it would be useful to have reviews of the capabilities of these systems that would factor in methods, calibrations, inter comparisons, classification software, and a summary of useful publications. Additionally, this term of reference facilitated exchange and discussions within the working group since the number of members using this new technique increased in combination with the development and availability of modern, automatic methods. Progress reports during the first year within this ToR included the presentation of preliminary results from the second ZooCAM prototype of a new imaging tool that was tested in January 2015 at IFREMER. By offering the possibility of analysing samples at sea, ZooCAM allows better integration of plankton sampling into fisheries surveys. Samples can be collected using traditional methods or CUFES systems (Continuous Underway Fish Egg Sampler). The image files can be rapidly processed and validated using the Plankton Identifier (PID) software as used by Zooscan. The system has been successfully utilised in the Bay of Biscay to count and identify anchovy and sardine eggs, with the target of automating the staging of these eggs. Trials on copepod species have also

been conducted in early 2015. Furthermore, the capabilities of the new ZOOVIS-DEEP, a high resolution zooplankton imaging system were presented. The system uses red LEDs to provide a long depth of field and rapid pulse width. It was initially tested in Chesapeake Bay, and despite the turbid conditions, it produced excellent results. It proved especially adept at imaging transparent and gelatinous specimens that would not normally be well sampled from a net. Every image is a hologram, so out of focus specimens can be brought into focus using a MATLAB toolbox. Results have been excellent so far for taxonomic identification and abundance calculations. As an outcome during the first year of ToR E a first outline of the manuscript will be prepared by expert members of the group and presented during next year meeting.

During the meeting in Lisbon 2016, the progress of the planned peer reviewed article on image analysis systems was presented. The articles outline included descriptions of commercially available in situ systems and lab instruments. Capabilities of the systems, calibrations, inter comparisons, classification software, and a summary of useful publications will be the main subchapters of the article. The group suggested to also include Flow Cytobot, Flowcam Macro, and non-commercial image analysing systems (such as the ZooImage) in the review article. Protocols should be included as supplementary material or as links to updated protocols. The group also agreed that the next step is to approach individual people outside WGZE and ask them to contribute to each section. The first draft of the manuscript will be distributed to the whole group for comments. All contributors to the different sections will be included as co-authors. Originally, there was a plan to finalize the ToR during the second year but it was agreed to extend for 2017 when the manuscript of the peer-review publication is ready for submission. Progress reports presented by group members included an image analysis system based on a flatbed scanner and a free R-software package. The analysis does not identify organisms to species level, but can distinguish between different copepod genera and at a higher taxonomic level of other taxa. A similar approach using non-commercial image analysis system based on a flatbed scanner with a free software was presented and showed good agreements between ZooImage and the results from microscopy. Conversion from numbers to biomass are made by using own developed algorithms. This method is used at IHM to analyse historical samples that would otherwise not be analysed. Additionally, a Zooscan Image analysis system used to distinguish anchovy and sardine eggs was introduced. It is also able to distinguish between 15 different copepod genera. The instrument is currently used at IFREMER to analyze old zooplankton samples taken during ichthyoplankton cruises. The group discussed advantages and disadvantages of image analysis methods such as ZooImage and if biomass estimates using ZooImage are more advantageous than direct biomass measurements of different size fractions and larger taxa. Most members of the group are convinced that ZooImage has a better resolution than the direct biomass measurements of size fractions, especially for the smallest size fraction. Image analysis could also be useful for analysing microplastics, but a good method for the characterization of different microplastics using image analysis is so far not well developed. A problem with image analysis is that the recognition by the software is not constant, but changes if specimens are attached, or if there are aggregates of phytoplankton and detritus in the sample. It is thus necessary to spend time to separate aggregates. Image analyses software procedures are available to separate specimens that are attached. Such problems and details are usually not well described in the method sections of papers and should be discussed in the review manuscript produced by the group.

The meeting in France 2017 in Boulogne-sur-Mer marked the third year of ToR but due to delays in the production of the manuscript the final outcome was not achieved by time of the WGZE meeting. There is still some input from co-authors missing but, the manuscript will be submitted within 2017. Progress report and discussion of the last year meeting included a recent deployed stationary underwater-camera system in the North-Sea close to the Helgoland Roads Time-series Station. The data from traditional plankton sampling will be compared to the optical system and will also be presented during the 2017 ICES Annual Science Conference.

Discussion in 2017

Considering rather extensive size of the discussed manuscript a selection of the journal that is accepting longer contributions is necessary. Roger Harris (Editor-in-Chief of the Journal of Plankton Research) declared that JPR is basically interested in the topic but the manuscript has to be closer to the final version (and size) to allow taking the final decision. Peter Wiebe commented that Progress in Oceanography is designed to accept longer texts. It was agreed that the missing parts should be finished as soon as possible and that the writing team should be contacted soon with information on the remaining work distribution.

ToR f) Expand and update the WGZE zooplankton monitoring and time-series compilation

Leads: Todd O'Brien, Peter Wiebe, and Tone Falkenhaug, Rapporteur in 2017: Antonina dos Santos

In 2001, the first WGZE "Zooplankton Status Report" was created as an Annex within the WGZE annual meeting report. This seventeen page text briefly summarized results from ten monitoring sites. WGZE has now produced nine zooplankton status reports, with the last report published in the fall of 2013. This 208-page, full-colour, ICES Cooperative Research Report featured data from 62 individual time-series sites plus an additional 40 time-series based on the Continuous Plankton Recorder standard areas running across the North Atlantic. The standardized graphical presentation and data analysis for this report were based on time-series data collected through the end of 2010.

The next zooplankton status report is scheduled to be completed in the autumn of 2017. This is a one year delay from the originally-planned 2016 release, intended to avoid time conflicts with WGZE's heavy participation within the ICES/PICES Zooplankton Production Symposium, which took place in May of 2016. This additional preparation time has been used to add new analyses, add additional data (new sites, more years, additional variables), and to co-develop an interactive web-component to be co-released with the next report. This next report will be a combined "Plankton Status Report" with the ICES WGPME phytoplankton group. Separately, the collection of time-series from the two groups have a roughly 60% overlap (e.g., sites that sample both zooplankton and phytoplankton), and combing the analyses together provides a broader ecosystem overview without duplication. The report will go through the full ICES editorial review and graphical layout steps, and then it will be distributed via high-resolution (electronic) PDF files instead of paper copies. In addition to reducing printing costs and saving trees, this switch to an electronic format better facilitates web visibility as well as within-PDF links to online components and supplemental materials.

Historically, WGZE (and WGPME) used the seasonally-corrected, annual anomalies method developed by Dave Mackas and SCOR Working Group 125 (Global Comparisons of Zooplankton Time-series). Based on suggestions from the joint WGZE/WGPME meeting in Malaga (2012), and the joint WGZE/WGPME "WKSERIES" time-series workshop (2013), the WGZE analysis will shift to more powerful, non-parametric methods (e.g., Mann-Kendall, Seasonal Mann-Kendall) and will include both annual and monthly based analyses in order to look for cases where the annual trend (e.g., increasing or decreasing over time) was created by a handful of months (e.g., a strong spring increase or warmer winters). In the next report the analyses will also look for synchrony across sites (e.g., "what sites are seeing strongly warming winters", "what sites are seeing decreases in fall biomass or abundance").

The addition of a month-based analysis is important as some regions are seeing strong changes in a single season (e.g., spring or winter) that are then dampened or less obvious in a twelve month (annual) view. Strong spring or winter changes, for example, can affect the strength of the spring bloom and/or productivity that may impact the rest of the season. Likewise, strong summer warming can lead to stratification and reduced production. Together, these possibly opposite effects can counter each other and show a "flat" annual pattern, even though large changes are happening at the seasonal level.

The next report will also include special "two page" topic discussions, covering topics that are relevant to zooplankton research and that also may have been discussed by WGZE in previous years. Current topic ideas would include:

- A general "Introduction to Zooplankton", briefly describing the major net-caught zooplankton groups and including a note about the importance of gelatinous members that can play a huge role in the ecosystem yet cannot always be quantitatively sampled by traditional net methods. On a related, gear-biased thread, the importance of (often under-represented) macrozooplankton, which can actively avoid the net, and microzooplankton, which usually require a bottle rather than a net to sample, will be briefly discussed in this section. Finally, a few sentences about the (seasonally) important of meroplankton at some sites will be noted.
- As this is a combined report with WGPME, a general "Introduction to Phytoplankton" section will also be created. This section will start out with discerning the terms "phytoplankton", "algae", and "microbial plankton" (almost similar to mesozooplankton vs. macrozooplankton vs. microzooplankton).
- A discussion on the merits and disadvantages of measuring total plankton biomass vs species-level abundances vs individual biomasses. For phytoplankton, this could also include a discussion on the merits and disadvantages of chlorophyll (representing "total phytoplankton biomass") from fluorometric, chemical, and HPLC methods.
- An introduction to new and upcoming technologies, such as image-based sampling techniques and molecular identification techniques (a tie-in to WGIMT).

The next version of the status report will also include species lists within each individual site summary, which will tie the report into ToR I and "COPEPEDIA" (see also

http://wgze.net/species-lists). This will be a first step in WGZE's path toward looking at species-level changes in the zooplankton.

Discussion on data access and abuse

There have been repeat discussions about providing actual (plankton) time-series data access through the WGZE web portal or a similar interface. An interactive website was created by ICES to support the ICES Report on Ocean Climate (IROC). That website featured interactive time-series plots as well as links to download the (pre-calculated) data elements used to generate those plots. The WGZE discussed the possibility of providing access to its own calculated data elements (e.g., annual anomalies, monthly anomalies), both of which are used in the zooplankton status report. During this discussion, some members from both WGPME and WGZE, who already had some of their data publicly accessible, reported cases of people misusing, misinterpreting, and/or publishing data from their projects without contacting them or properly acknowledging their time-series. Multiple sites also reported funding decreases and/or now live under the threat of their sampling program being discontinued. To justify continuation of their programs, these sites must know exactly who is using their data and about any papers in research in progress with them. This tracking usage information becomes more and more difficult as the data are served farther and farther away from the original source and creators (e.g., via third-party databases).

The current WGZE online time-series information elements (http://wgze.net/time-series) do not provide data directly, but provide either a web link or email contact info for requesting or getting those data directly from the collecting entity. The same system was set up for IOC/UNESCO International Group for Marine Ecological Time-series (IGMETS) global time-series study, whose many countries and participants have a broad range of data policies and concerns. This approach is currently the easiest solution to address the broad range of institutional data policies and access restrictions found within IGMETS and likewise the larger WGZE group.

Collaboration with IGMETS

WGZE was a significant contributor of North Atlantic time-series to the IOC/UNESCO International Group for Marine Ecological Time-series (IGMETS) global analysis and status report. IGMETS has compiled a global collection of over 300 time-series, covering the open-ocean, coastal areas, and estuaries. Of all the oceanographic regions, the best coverage within IGMETS is for the North Atlantic, with the WGZE and WGPME time-series being the largest contributor to this region. The forthcoming IGMETS status report was focused on giving a very general and broad overview of each ocean (e.g., the North Atlantic), and thus does not duplicate or compete with the ICES Plankton Status Report work.

Adding interactive content to the Plankton Status Report series

Todd O'Brien is a member and products-developer for both time-series working groups, and has been co-developing WGZE's next generation time-series analysis tools during his work with IGMETS. Through the cross-group work and collaboration, a WGZE-focused time-series explorer is being developed and will be linked-to from the WGZE.net web pages. As an example of what this may look like, the IGMETS (global) version of this

interactive tool is online at: http://igmets.net/explorer. Figure 1 is a North Atlantic example captured from the IGMETS Explorer interface. The WGZE version of this interface will be similar in design, but will focus on sub-areas of the North Atlantic (versus different oceans of the world). It will also include newer data than the IGMETS Explorer. While the IGMETS publication covered a time period up through the end of 2012, the next WGZE status report will go through the end of 2015. This three year, 2013-2015, period has seen dramatic changes in the North Atlantic and even globally.

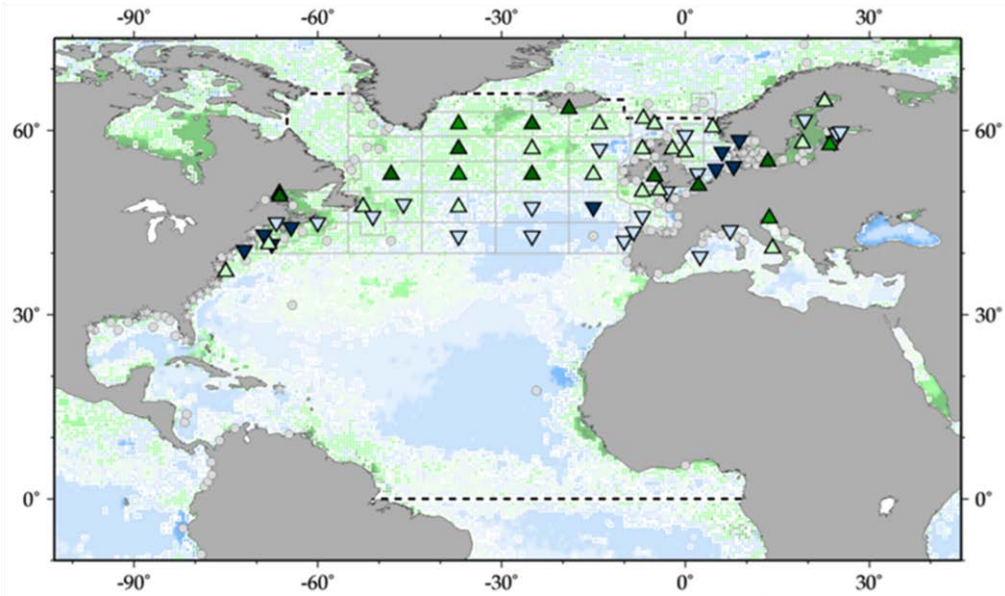


Figure 1. An IGMETS spatio-temporal trend map for the North Atlantic region, showing 15 year (1998–2012) trends in in situ "total copepod abundances" (triangles) on a background field of 15 (1998–2012) year satellite chlorophyll trends. Upward-pointing triangles and/or green colours indicate increasing concentrations of copepods and chlorophyll across the 15 year time period. Downward-pointing triangles and/or blue colours indicate decreasing concentration. Darker colour shades represent stronger increasing (or decreasing) trends.

The (in-development) WGZE/WGPME Plankton Explorer will allow a user to interactively select from over 15 time-series variables (e.g. copepods, temperature, nutrients, chlorophyll, diatoms), seven different time frames (e.g. from 5 to 35 years in length), a variety of backgrounds (e.g., SST, CHL, Wind), and zoom in to a variety of regions and sub-regions (e.g., the entire North Atlantic, the Baltic Sea, the Barents Sea).

ToR g) Revise lists of currently suggested (e.g. by OSPAR, HELCOM, and EU Member States) zooplankton indicators relevant for biodiversity and foodweb status assessment. Based on gap analysis, identify and test new, candidate indicators considering their response to various pressures

Leads: Alexandra Chicharo, Elena Gorokhova, Maria Grazia Mazzocchi, and Piotr Margonski, Rapporteur in 2017: Piotr Margonski

This ToR was planned as a three year activity.

In 2015, Elena Gorokhova gave a presentation on indicator work done in OSPAR and HELCOM areas within the MSFD implementation. Until recently, both regional conventions were mainly working independently. HELCOM is more advanced - indicators will be operationalized in June 2015 and they will be used in a Holistic Assessment (HOLAS). HOLAS work will be ready in mid-2017. The Zooplankton Expert Network (ZEN) started developing indicators in 2010 within the CORESET project using zooplankton monitoring data from the Baltic Sea. Mean size and total stock (MSTS) developed by HELCOM shows 4 different states of the zooplankton community. The best status (Good Environmental Status) is attained when large zooplankton species are abundant. This means that there is a high grazing pressure, moderate food limitation for fish feeding conditions, and high energy transfer efficiency. The worst community would be when the zooplankton abundance is low and composed of small sized species, which means that there is low grazing pressure, poor fish feeding conditions, and an unproductive pelagic food web. To calculate the indicator, the total zooplankton abundance (TZA) and the total zooplankton biomass (TZB) is needed. The indicator is then calculated as TZB:TZA. This is the only zooplankton indicator at present in HELCOM that belongs to the core category.

For defining the reference conditions, a period when herring and sprat (planktivorous fish) weight-at-age (WAA) have been at good levels together with the period when chlorophyll level has been acceptable. Future work in the Baltic Sea will include biomass calculation/measurement improvements and continuation of the validation process. It would also be good to establish better communication with OSPAR concerning indicator development.

Elena Gorokhova gave also a presentation prepared by Alexandra Chicharo for the OSPAR area. Biodiversity indicators suggested have been ratios between different groups: phytoplankton/zooplankton, large copepods/small copepods, and copepod grazers/non-copepod grazers. The food web indicators suggested were also ratios between different groups: gelatinous zooplankton/fish larvae, copepods/ phytoplankton, and holoplankton/meroplankton (benthic-pelagic coupling, how much benthic species are part in the pelagic communities).

There was a joint workshop for HELCOM and OSPAR indicator experts organised in October 2014. There were two indicators that could be potentially developed and tested together. The problem is that the areas are ecologically dissimilar meaning that separate calculations and assessments are required.

OSPAR work will include further development of indicators by developing standard methodologies for using zooplankton within MSFD maybe by linking to other descriptors e.g. D2 in the future.

Discussion in 2015

The group discussed whether regime shifts could be taken into account when defining the reference conditions. For short data sets and for some monitoring programs this would be even easier, by taking the whole period as a baseline.

The other issue was how the individual biomass was measured for the indicator data sets. Lutz Postel replied that, at the moment, it is wet weight, which is not measured but calculated based on species- and life stage-specific weights.

It was discussed why meroplankton are not considered in the Baltic Sea indicators. The reason being that the larvae of benthic animals which are released during a very short period in May/June, may easily be missed by a monitoring programme.

The next question was on how the small and large copepods were separated in the data. This concerns only the OSPAR area, and is probably based on species (small and large) distinction and not really on actual measurements of individuals. It was agreed that rate measurements e.g. zooplankton production have to be considered in the future ZEN work in the Baltic Sea. It was also discussed that although food web indicator discussions are often dominated by fish experts, there are aspects that could be useful in our zooplankton work as well, e.g. guild aspects.

Also modelling could be better linked with the ongoing work. E.g. in Sweden modelling has been discussed concerning D4 (food webs) and would help in the indicator work. It was mentioned that statistical models may show that there is a change in the community but we should be able to link it with pressures to reveal the cause-consequence-relationships. It was noted that it would have been beneficial from the beginning to foster discussions between experts working with different indicator groups (benthic, fish, pelagic, planktonic) but this could be improved now with increased communication. The conclusion of the HELCOM and OSPAR joint work was that it is still beneficial to continue the joint discussions as the work is continuing and the developments are ongoing. An unbalanced set of indicators affects the final assessment, thus we should get a set of indicators that represents all descriptors in a balanced manner.

In 2016, this part consisted of three presentations:

- Implementation of the EU Marine Strategy Framework Directive - A marine ecologist's perspective
- The Mediterranean approach to zooplankton indicators
- Testing of the zooplankton mean size and total stock (MSTS) indicator calculated based on the Polish monitoring data from the southern Baltic Sea

Implementation of the EU Marine Strategy Framework Directive – A marine ecologist's perspective (Piotr Margonski)

WGZE monitors various activities linked to zooplankton ecology in the North Atlantic region and various, recent scientific and management activities in Europe focus on subsequent steps of the EU Marine Strategy Framework Directive (MSFD) implementation. The main aim of the MSFD is to protect more effectively the marine environment across Europe. To introduce and summarize the MSFD concept to non-European group members, Piotr Margonski provided a general overview of its basic assumptions and goals, steps in the process, role of EU Member States and Regional Conventions, descriptors,

concept of good environmental status (GES), indicators and pressures, reference condition, (integrated) monitoring programmes, and programmes of measures. Special emphasis of the presentation was focused on the indicators and their role in evaluation of and achieving of GES.

The Mediterranean approach to zooplankton indicators (Maria Grazia Mazzocchi)

The Mediterranean Sea is the largest semi-enclosed sea in the world and is considered a biodiversity hotspot. Its high diversity concerns not only the marine fauna but also human beings. In fact, bordered by 26 between countries and territories of Europe, Africa, and the Middle East, the Mediterranean is not only one of the most densely populated regions of our planet, but the site of a large variety of populations and cultures. In 1975, under the umbrella of the UNEP (United Nations Environment Programme), the Mediterranean Action Plan (MAP) was adopted as a cooperative effort involving countries bordering the Mediterranean Sea, as well as the European Union. The initial focus of the MAP was on marine pollution and in 1976 in Barcelona, these Parties adopted the Convention for the Protection of the Mediterranean Sea against Pollution (Barcelona Convention, BC), which in 1995 was revised for the Protection of the Marine Environment and the Coastal Region of the Mediterranean. Today, the 22 Contracting Parties (including the EU) (of which 8 are also EU Member States) are also boosting regional and national plans to achieve sustainable development. The BC/UNEP-MAP framework provides the regional legal basis for the Mediterranean for setting common environmental standards and targets for all Contracting Parties (COP) to agree on, take coordinated measures and monitor their implementation.

In 2008, during the 15th conference of the contracting parties (COP15), the ecosystem approach (EcAP) was endorsed as an overarching principle of the UNEP/MAP system and 4 years later it was recognized as a guiding principle for the overall work under the BC. The EcAp has adopted 11 Ecological Objectives, which mirror the 11 descriptors of the EU Marine Strategy Framework Directive (MSFD). Among the work currently ongoing for the EcAp Roadmap there is the preparation of the Integrated Monitoring System based on the agreed indicators and Targets, in full synergy with MSFD. The initial phase (2016–2019) of the Integrated Monitoring and Assessment Programme (IMAP) implementation will focus only on a set of core common indicators where data and practice are more mature. After the initial phase, the IMAP will be implemented with possible adjustments and the inclusion of additional (candidate) common indicators. The initial core of common indicators includes Biodiversity, but not Food Webs, though. The Food Web is partially addressed by the biodiversity-related common indicators.

In relation to Biodiversity, the indicators agreed for the core of the IMAP that should be the basis of a common monitoring program in the Mediterranean are 5 and only one is applicable to plankton: Condition of the habitat's typical species and communities. For monitoring changes in zooplankton, simple life forms are considered: small and large copepods, holo- and meroplankton. The life-form pairs can provide an indication of changes in: the transfer of energy from primary to secondary producers, the pathway of energy flow and top predators, the benthic/pelagic coupling. It is proposed that this approach be adopted on an optional basis for the Mediterranean Contracting Parties, with a view to investigating the applicability of the methodology for Parties with existing time-series. As the knowledge base increases, new pairs can be developed as indicators. Data

on pairs can be expressed in abundance or biomass, whatever is most relevant to the group in question and available from monitoring programmes.

Next to the EcAp MED project, which is an EU funded project, specifically assisting the BC Secretariat in achieving this Roadmap, there were several other projects on Marine Research in the Mediterranean and Black Sea that were financed by the EC under the FP7 and are critical for the achievement of GES in the Mediterranean by 2020. The project PERSEUS (Policy-oriented marine Environmental Research for the Southern EUropean Seas), which ended in 2015 and was closely linked to MSFD, merged natural and socio-economic sciences to predict the long-term effects of natural and human pressures on marine ecosystems. Within PERSEUS, a comparative analysis of Initial Assessments for five SES countries (Spain, France, Greece, Cyprus, and Romania) was performed to identify the major pressures jeopardizing the environmental state of SES and link them directly to possible impacts in a coherent and integrated manner (Crise *et al.*, 2015). Despite the increasingly important effort made by Mediterranean countries, there are still critical gaps in the information and data for many key components of Mediterranean marine biodiversity. The main knowledge gaps consist in the lack of a proper understanding of marine biological diversity and food web functioning, which is far from operational and deserves a targeted study, being the backbone of any holistic approach to the management of the marine environment.

The latest recommendations of the UNEP-MAP for monitoring of biodiversity in the Mediterranean open and coastal waters highlight the need to build on existing:

- national databases such as checklists, lists of species at representative sites including ones for invasive species, information from existing national monitoring networks;
- existing time-series, e.g. minimum 20 years;
- network of marine protected areas (MPA);
- networks of observation systems, such as LTER, EMBOS, LIFEWATCH, CIESM Jelly Watch;
- network of laboratories.

In order to ensure feasibility and cost efficiency and at the same time scientific accuracy, the following realistic approach was recommended:

- agreement of *de minimis* common monitoring specifics, most cost-efficient methodologies that could be applicable for the whole Mediterranean;
- use of already existing and in place methods, tools or indices should be preferred or adopted;
- using the MPA's monitoring data also as a comparison, a point to calibrate level of difference or as a baseline in cases historical data do not exist;
- identification of key specific sites, so-called representative sites for biodiversity monitoring per country (and ideally also sub-regional stations with joint monitoring, possibly on a pilot basis).

Monitoring of plankton communities was recommended as an additional area where important changes in biodiversity could be identified.

References

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UNEP-MAP (2015) Draft Integrated Monitoring and Assessment Guidance. Agenda item 3: Draft Integrated Monitoring and Assessment Programme, 5th Meeting of the Ecosystem Approach Coordination Group, Rome (Italy), 14-15 September 2015. UNEP(DEPI)/MED WG.420/4.

UNEP-MAP (2015) Draft Decision: Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria. Agenda item 3: Thematic Decisions, 19th Ordinary Meeting of the Contracting Parties to the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean and its Protocols. UNEP(DEPI)/MED IG.22/10.

Testing of the zooplankton mean size and total stock (MSTS) indicator calculated based on the Polish monitoring data from the southern Baltic Sea (Piotr Margonski & Joanna Calkiewicz)

Results on mesozooplankton community structure dynamics provide valuable information on understanding of ecosystem functioning, changes in pelagic food webs, and contribute to the assessment of Good Environmental Status as defined in the EU Marine Strategy Framework Directive (MSFD).

The zooplankton Mean Size and Total Stock (MSTS) is a Baltic Marine Environment Protection Commission (HELCOM) core indicator primarily relevant for food webs (MSFD criterion 4.3: abundance/distribution of key trophic groups/species) with a secondary link to biodiversity (MSFD criterion 1.6: habitat condition). MSTS indicates that the investigated pelagic food web structure is or is not optimal for energy transfer from primary producers (phytoplankton) to fish.

The MSTS indicator was applied to test changes in the pelagic food web structure in the southern Baltic Sea. This core indicator appears to be very useful for this role: it considers the zooplankton mean size change as a consequence of an increase of small taxa biomass (along with an increasing eutrophication) and especially a decrease in abundance of larger copepods (due to the impact of hydrological conditions' change as well as predatory pressure of small pelagic fish). The MSTS indicator provides estimates of the feeding conditions for sprat, herring, and cod larvae, and the grazing pressure on phytoplankton.

MSTS is strongly linked to two anthropogenic pressures listed in the MSFD Annex III, Table 2: selective extraction of species and nutrient and organic matter enrichment.

Data that are the Polish contribution to the HELCOM COMBINE Programme were used for indicator testing. In most of the cases, samples were taken 5 times per year using a WP-2 net. The longest data series (since 1979) were collected at deepwater stations whereas those taken at more coastal ones started within the last twenty years. Considering the different length of presented data, two alternative strategies for setting reference conditions had to be applied: (i) for coastal stations the long term mean and the corresponding variance was calculated based on the entire dataset and (ii) for the open-water stations the reference periods were defined based on chlorophyll a concentrations and weight-at-age of clupeid fish.

In 2017, discussions started with a short summary of the work done within this ToR.

Subsequently, a Plankton Index was discussed based on Kathryn Cook *et al.* presentation provided at the ICES/PICES 6th Zooplankton Production Symposium. This OSPAR common indicator PH1/FW5 (Changes of plankton functional types based on the ideas of State Space and Life Form) has been adopted for the Greater North Sea, Celtic Seas and Bay of Biscay. The life-form indicator was originally developed in the UK and later adopted by OSPAR. Since a workshop in June 2016 both groups have agreed on a standard set of life-form pairs and analysis.

A manuscript 'Marine zooplankton indicators: present status and perspectives' being prepared as a follow up of the Indicator Workshop at the ICES/PICES 6th Zooplankton Production Symposium was shortly introduced. With Kathryn Cook and Piotr Margonski as a WGZE representatives it covers: (i) introduction, (ii) types of zooplankton indicators being used, including regional examples, (iii) applications of zooplankton indicators in continental management – regional comparisons, (iv) approaches for evaluating indicators' performance, and (v) recommendations and future developments drawn from the comparison.

Discussion in 2017

Peter Wiebe stressed that to use indicators regionally a standardized sampling and database structure is required. Piotr Margonski replied that in the Baltic Sea area a common database exists and data collected within the HELCOM Combined Monitoring Programme are delivered to the ICES Database. This is however a unique situation and in other areas (e.g. in France as mentioned by Elvire Antajan) a common database structure do not exist. Sophie Pitois informed that in OSPAR area there is another plankton indicator PH2 (Plankton biomass and/or abundance) and that in the UK analyses will be carried out using CPR data. Problems with necessity of collecting new data and implementation of new indicators were mentioned as regards various countries due to the financial constrains and e.g. in Spain, most probably plankton will be included as a foodweb indicator but a revised monitoring did not start yet. Similar situation appears to be in Portugal.

When summarizing the ToR, Piotr Margonski focused on the review of existing activities. He also admitted that the group did not suggest any new indicator as there is a lot of work already focusing on this issue. Testing common indicators in different regions appeared to be very difficult as experienced in OSPAR/HELCOM case with both areas ecologically dissimilar that required separate calculations and assessments.

ToR h) Design and carry out coordinated and collaborative activities with WGIMT and WGPME

Leads: Ann Bucklin, Alexandra Kraberg, and Piotr Margonski; Rapporteur in 2017: Jasmin Renz

The ICES Working Group on Integrated Morphological and Molecular Taxonomy (WGIMT) met annually during the 2015–2017 period: March 17/20, 2015 in Plymouth, UK; 18 March 2016 in Lisbon, Portugal; 31 March 2017 in Boulogne-sur-Mer, France. During each meeting, the members reviewed progress on multi-annual ToRs, reports, and recommendations; evaluated progress and sought opportunities for partnerships in the ICES science and advisory communities.

WGIMT was established in 2014 by conversion of the Study Group of Morphological Molecular Taxonomy (SGIMT), which had been established in 2009 within the Working Group on Zooplankton Ecology (WGZE). Throughout these years, SGIMT and then WGIMT has maintained close functional ties to the WGZE, including a numbers of members in common and a continuing, and much-appreciated, annual invitation from WGZE to hold our meetings in association. This synergistic relationship and extensive cooperation has served WGIMT very well, and is expected to continue into the future.

WGIMT membership in 2017 totals 46 members from 15 countries; reflecting addition of new members each year since 2013 (ToR a). A number of WGIMT members are concurrently members of other ICES SCICOM WGs, including WGZE, WGPME, WGBOSV, WGITMO, and WGAGFM. The continuing growth has expanded WGIMT membership and engaged new members who develop and use molecular and/or morphological approaches to taxonomic analysis of zooplankton.

Progress was reviewed in the continuing development and implementation of the WGIMT web platform for promotion and exchange of relevant scientific information for the morphological, molecular, and optical elements (ToR b). New contributions have been made in each area:

- Morphological methods: Information and URL links to keys for morphological identification of zooplankton.
- Optical methods: New images and explanations of instrumentation and methodologies.
- Molecular methods: Comprehensive summary of PCR and sequencing primers and protocols and associated references.
- Photo gallery: High-quality images of living zooplankton; migration of photo galleries from the Census of Marine Zooplankton site (www.cmarz.org).

WGIMT has continued work to initiate and support provision of standards, training materials, and taxonomy workshops through organized workshops (ToR c). One workshop, SAHFOS-MBA Zooplankton Taxonomy Workshop, exemplifying the WGIMT integrative taxonomic approach was held during 22–26 June 2015 in Plymouth, UK. ICES Zooplankton Identification Leaflets are being updated with oversight from ICES PubCom and new editors, Antonina Dos Santos (PT) and Claudia Castellani (UK), who are WGZE and WGIMT members (ToR c).

WGIMT promoted and encouraged the continuing integration of molecular and morphological taxonomy by organizing special sessions at national and international conferences, including ICES 2015 ASC, and ASLO/TOS Ocean Sciences Meeting (February 2014 and 2016); (ToR d). WGIMT made significant contributions to the ICES-PICES Zooplankton Production Symposium (2016), including co-convening four sessions and four workshops, with invited speakers for two sessions and two workshops.

WGIMT is seeking avenues via SSGEPD and other SCICOM EGs to advise on implications and applications of integrative taxonomy for marine science and management (ToR e) and engaged in discussion of joint activities on topics of common interest. WGPME shares focus on analysis of biodiversity using metabarcoding approaches, which will be the subject of a joint theme session (WGIMT, WGPME, WGZE) for ICES 2017 ASC. WGIMT will contribute to a WGPME-sponsored symposium on High-Throughput Methods Applied to Marine Biodiversity Time-Series (October, 2017; Hannover, Germany) (ToR e).

WGIMT members published papers in the peer-reviewed scientific literature on topics central to the WGIMT mission (ToR f) each year. Six papers were published in each of 2013, 2014, and 2015, with seven papers in 2016, and 11 papers to date in 2017. WGIMT members published a forward-looking HORIZONS review article assessing the progress and promise of integrative morphological and molecular taxonomy of zooplankton, specifically metabarcoding for assessment of zooplankton diversity by Bucklin, Lindeque, Rodriguez-Ezpeleta, Albaina, and Lehtiniemi (2016) J. Plankton Res. HORIZONS doi:10.1093/plankt/fbw023.

WGIMT's primary contributions have focused on the ICES Science Plan Priorities #1, 2, 9, 10, 27, 28, and 31. WGIMT seeks to contribute to the ICES mission to analyze, recognize, and understand changes in community structure, species diversity, and population connectivity. Our novel approaches to characterization of species-level diversity may be expected to become a foundation for the assessment and management of ecosystem goods and services. WGIMT future plans include targeted contribution toward quantifying the effects of climate change on regional ecosystems (ICES Science Plan Priority 3); understanding the influence of climate impacts from local to global and from seasonal to multidecadal space/time scales (ICES Science Plan Priority 4); quantifying the role of structural and functional diversity in marine ecosystems (ICES Science Plan Priority 5); and defining and quantifying North Atlantic Ecosystem Goods and Services (ICES Science Plan Priority 6). WGIMT plans to work toward development of standardized metagenetic protocols for assessment of pelagic biodiversity can help provide priorities and specifications for data collection frameworks supporting IEA's (Science Plan Priority 20).

WGIMT has been approved for continuation for another 3-year term (pending selection of a new WG chair for 2018), guided by new multi-annual 2017-2020 ToRs, including a recommendation for a new joint ToR with WGPME for review and evaluation of methodologies used for metagenetic analysis of plankton, with the specific goal of facilitating development of standardized protocols for applications in fisheries management and ecosystem assessment.

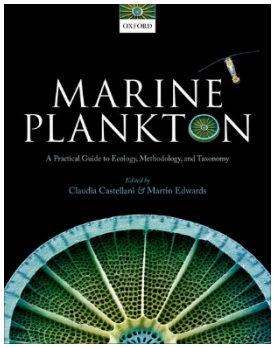
As discussed at the meeting common activities with WGPME are including a future joint Plankton Status Report (for detailed plans see the report on ToR f) and return to the idea of combined analyses of long-term data series. This, however, requires a detailed plan-

ning and the group discussed possibilities of the WGZE-WGPME face-to-face meeting in coming years. It was decided that this initiative is not possible in 2018 but it definitely might be beneficial for both groups in nearest future.

ToR i) Refine and expand the compilation of information on zooplankton species, taxonomic categories, and life stages that are currently monitored in the ICES area

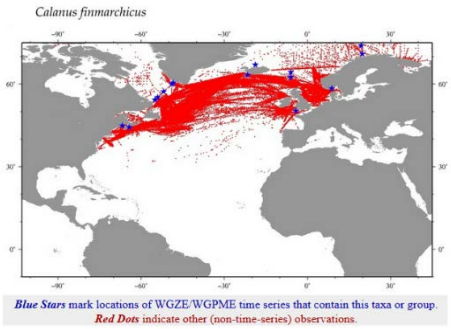
Leads: Todd O'Brien and Claudia Castellani; Rapporteur in 2017: Tone Falkenhaug

a) A WGZE-affiliated Publication: The book *Marine Plankton: A practical guide to ecology, methodology, and taxonomy* (Castellani & Edwards, Oxford University Press) was published in 2017. This book is a modern plankton identification and reference manual aimed at students, academicians, and practitioners. It covers plankton identification, methodology, and ecology and distribution.



Discussion: This book was led by WGZE member Claudia Castellani, and its chapters contain contributions from her and multiple other WGZE members. The working group exclaimed this to be an excellent resource and an incredible effort and accomplishment of Claudia and her contributing authors.

b) Status of the WGZE Monitored Species Lists: Todd O'Brien presented the status of the WGZE zooplankton species lists compilation ToR. A new "Species Lists" section has been added to the WGZE.net webpage (http://wgze.net/species-lists) to interactively present this collection of materials. This new web section provides lists, hierarchical tables, and location maps of the various zooplankton (and phytoplankton) taxa recorded at the WGZE time-series sites. This new data collection is part of the collaborative COPEPEDIA metabase (http://copepedia.org), which supports multiple ToRs within WGZE, WGIMT, and WGPME. The taxonomic information in COPEPEDIA is linked to from each entry in this new WGZE.net Species Lists section, and will also contain (when available) data on individual species biomass, productivity, metabolic rate equations, genetic markers, and photographs. This Species List section, and COPEPEDIA, will both continue to be developed and expanded over the next few years.



Todd pointed out some issues that may still need to be resolved:

- How should taxonomic groups which includes several species be presented (e.g., when an investigator reports "*Calanus finmarchicus* & *Calanus glacialis*" as a single, combined count and taxonomic entry). Taxa are not always identified to a single species or taxonomic entity. This is especially common within the phytoplankton or in groups where speciation is difficult or being repeatedly modified or disputed.
- How should name entries be validated, and how should invalid species names be treated?
- What forms of navigation should be added to the interface as development continues?

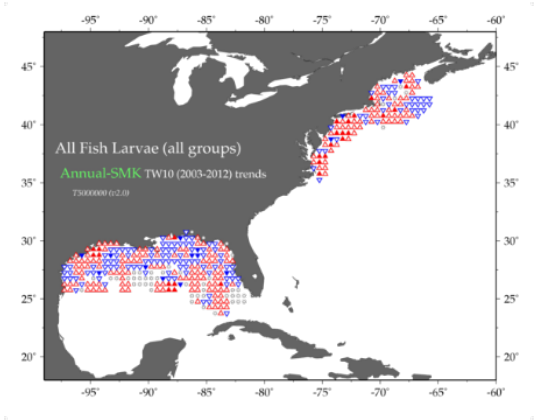
Discussion: The group agreed that the database should focus on species, and that species names should be included as the primary search option. It was suggested to include an option to enter directly into a "species page", e.g. by including a "search box". All species related information (molecular data, species range etc.) could be accessible from this species page.

Validation of taxonomic names and spelling will be made by crosschecking with WorMS database. In cases where taxonomic revisions have been made, it was decided to store the historical species names together with the new name.

Once accepted by SCICOM, over the new three year ToR cycle, biometric data will be added for many species, often with links to a reference database. The species pages will also contain links to species information in other databases. The following links were suggested by the group: WorMS, ITIS, Genebank and AkvaNis (alien species).

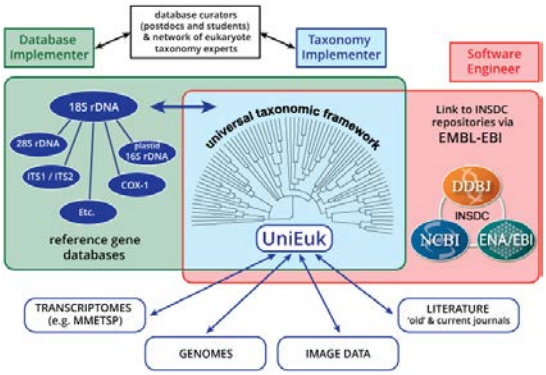
Conclusion: The deliverables of this Tor I has been made, and the ToR is now completed. However, the development of the database is still in progress and there is a plan to continue within the next three year cycle as a new ToR.

c) A possible new analysis/product of WGZE: Todd O'Brien demonstrated an in-development explorer tool for regional ichthyoplankton data (the Fish Larvae Explorer, Flex). This tool illustrates spatial variations in temporal trends (areas of increasing/decreasing trends). A similar analysis and tool could also be developed for the WGZE zooplankton data, but would require expanding the WGZE data compilation to include species data (this compilation currently only contains total counts (e.g., "total copepods", "total diatoms") or total biomass values).



Discussion: The group was generally open to pursuing a similar analysis with the zooplankton. The group suggested an option where the different years can be separated and plotted. By producing separate maps for each year, and then put together as a movie, this will show the changes in distribution over time.

d) UniEuk: Elvire Antajan presented a new taxonomic database: UniEuk (Universal taxonomic framework and integrated reference gene databases for Eukaryotic biology, ecology, and evolution): http://unieuk.org/. UniEuk is a community-based project to achieve a universal taxonomic framework for eukaryotes, focused primarily on protists. This project was launched in 2016, and the development of the database is still in progress. The database will contain species specific information on genetic markers, and classical morphology-based data.



Discussion: This is an excellent tool which may be useful for the WGZE group.

ToR j) Calculate zooplankton productivity and metabolic rates in the ICES area based on allometric approaches. Build a database of zooplankton individual species biomass, productivity and metabolic rate equations

Leads: Lutz Postel, Peter Wiebe, Todd O'Brien, and Patrik Strömberg; Rapporteur in 2017: Lidia Yebra

Allometric relationships, for example body length to individual mass are often used to calculate species and stage specific biomass concentration by known abundance. This is a common approach in taxa and stage specific biomass studies. Often, the mass currency is carbon, sometimes converted from other biomass sources such as wet mass, dry mass, or ash-free dry mass by applying conversion factors (Postel *et al.*, 2000).

Calculations of productivity P and metabolic rates M simply requires body mass, and at least ambient temperature for planktonic, i.e. ectotherm organisms because both influences are exponentially related to P and M, respectively.

However, the ecological theory behind mass and temperature scaling is hotly debated. The WGZE is following and evaluating different approaches to provide the most suitable relationships for application in the ICES area.

Additionally, The WGZE is providing the community with both a readily-available database of the most common factors, and a defined, consistent, estimation of key rate processes (e.g. secondary production, respiration, ammonium, and phosphate excretion) across the ICES area, based on the large number of available time-series.

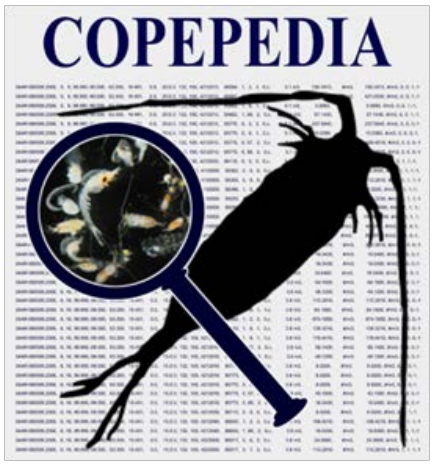
a) Use of empirical relationships to calculate zooplankton production and metabolic rates

A chapter contribution to the next Zooplankton Status Report (2017) and a publication are being written. The aim is to collate abundance and biomass data from as many as possible of the 62 ICES time-series sites and 40 CPR areas as possible. Nineteen data sets have been assessed. Different measuring length and sampling intervals had been considered in the analysis covering Labrador Sea (1), Scotian Shelf (1), Nordic and Barents Seas (1), Baltic Sea (4), North Sea and English Channel (3), Bay of Biscay and western Iberian Shelf (5), the Mediterranean Sea (1), the central North Atlantic (1), the US shelf (1), and the Malaga area (1).

The approach basically combines concurrent assessments of total mesozooplankton biomass and total abundance to derive a mean mass per individual. In combination with temperature, the mass scaling equations mentioned above are used to derive key rate processes per individual and sums over total abundance to derive a total mesozooplankton productivity, which can then be plotted as a time-series. The same principles have been applied to other metabolic rates such as respiration, ammonium, and phosphate excretion.

Methods evaluation, inter-regional comparisons e.g. of production in mg C m^{-2} d^{-1}, calculation of other metabolic rates, and mortality evaluation have been completed.

b) Build a database of zooplankton individual species biomass, production, and metabolic rates



The WGZE/WGIMT/COPEPOD collaborative taxonomic information database called "COPEPEDIA", accessible via the WGZE site (http://wgze.net/copepedia), has been used to store the information collected by this ToR (e.g., individual species biomass, productivity, metabolic rates, and inter-conversion equations) at their respective taxonomic levels (e.g., species or genus or higher). The layout of these data and equations have been reformatted and descriptively expanded so that they are useful to the wider, sometimes non-specialist community, while still being fully attributable to a citable source. The first step in creating the database was to locate and capture electronically and then collate the key references that either a) provide individual species and stage-specific mass, or b) link mass (in its various currencies) to length, volume, and various rate processes, or c) provide inter-conversions between various currencies of a single unit e.g. of mass. The actual data and equations, found in these published appendices and tables, have been digitized, and the resulting database is accessible through links provided on the WGZE website's "Traits and Rates" page (http://wgze.net/traits-n-rates). In building the database, the attribution (i.e. author) is glued to the conversion to provide a traceable path back to the original publication or data source. Large quantities of grey/unpublished literature as well as older data exist and have also been reviewed, collated, and will be added to the database.

The data sources collated thus far are extremely variable in terms of format and contents, i.e. some of those are bulk measurements and others are species-specific. They are also expressed in various units including e.g. wet mass, dry mass, ash free dry mass, protein, carbon. Use of allometric scaling equations to get a community mean has to be done carefully because of the different scaling of mass and length.

In terms of access and application, COPEPEDIA stores the information in a dual computer-usable and human-readable format such that same-taxa biomass and rate information is easy to co-combine into secondary ratios, products, and calculated data elements (supporting the productivity equations). The combined information in COPEPEDIA is a valuable asset for the zooplankton research and modelling community, its development and content will continue to be expanded over the coming years.

Reference

Postel, L., Fock, H., Hagen, W. (2000). Biomass and abundance. In: Harris, R., Wiebe, P., Lenz, J., Skjoldal, H.-R., and Huntley, M. (Eds), ICES Zooplankton Methodology Manual (pp. 83-192). San Diego, California, USA: Academic Press.

ToR k) Develop, revise and update of zooplankton species identification keys initially focusing on the most abundant taxa at the ICES time-series sites and ensuring their availability via the web, including especially ICES Zooplankton Identification Leaflets

Leads: Antonina Santos and Claudia Castellani; Rapporteur in 2017: Piotr Margonski

The Category 1 Resolution to PUBCOM to update and continue the publication of ICES Identification Leaflets for Zooplankton (formerly Fiches d'Identification du Zooplankton) series was submitted with the support of WGZE & WGIMT. It was approved at the SCICOM September 2015 meeting.

The historical ICES Identification Leaflets for Plankton will be revived and maintained on the following basis:

- Compile a list of experts covering the different taxa to act as authors for the update and creation process (There is already a first list of experts based on the SAHFOS Marine Crustacean Zooplankton Workshop 2015);
- All the leaflets need to be updated. The leaflets that require urgent updating will be identified and prioritized by the editors, with the help of the experts;
- Prepare a list of key plankton taxa (i.e., abundant and widespread in the ICES regions of the North Atlantic) that are not yet included in the series;
- The leaflets will be peer-reviewed under the editorship of Antonina dos Santos and Claudia Castellani;
- The series will be given a DOI number;
- The ICES secretariat will provide standard proofing and formatting services;
- The success and utility of the series will be reviewed in 2019.

The new template has been prepared by ICES secretariat, which will be published online only with a PDF version to free download. A new series cover has been prepared (Figure 1). The old Leaflets will be kept online with the previous series and numbers, and the new versions will be ascribed to new numbers and will replace it online when ready.

Figure 1. Template for the new cover of the ICES Leaflets for Plankton identification.

The new series structure and content is as follows:

Abstract (maximum 200 words)

[Provide the background of the taxonomy and the number of species/genus, etc. that are the subject of the Leaflet. The abstract should also indicate whether it is a new or a revised leaflet]

Introduction

[Information on systematics of the group.

Information on the morphology of the different stages of the life cycle.

How many taxa are the object of the Leaflet? How many species are in the ICES area? If available, provide information for worldwide distribution.]

Distribution

[Bathymetric / Spatial / Biogeographical within the ICES area which is all the North Atlantic from 36 °N to 85 °N latitude]

Keys

Figures and Photos

[…]

Link to molecular information and WoRMS

[…]

References

[selected references and important ones to help the identification]

ICES requested that the total length of the individual document should not exceed 10-12 pages, which is being followed.

The editors had spent the first year of work dealing with the several practical issues regarding the establishment of the new series. They have prepared the up-to-date ICES letter template to formally invite the authors, the final template for copyright request for the figures to be included in the Leaflets and have decided on the Progress tracking documents adopting the existing template for other ICES publications.

The list of authors to be contacted as contributors for the Leaflets and the experts to act as referees is still in progress and it was decided that the WGZE members will contribute with suggestions in order to have the most comprehensive list possible. The editors have assigned the first three Leaflets which are the ones for the copepods *Temora* and *Oithona* genus and to the Cnidaria Cubozoa.

ToR l) Produce four short para-graphs for the ICES Ecosystem Overviews on the zooplankton community (spatial variability, hot spots and seasonality), one para-graph for each of the following ICES ecoregions: Greater North Sea, Celtic Seas, Bay of Biscay & the Iberian coast and Baltic Sea

Leads: Piotr Margonski, Maiju Lehtiniemi, Jörg Dutz, Patrik Strömberg, Lidia Yebra, Antonina Santos, Arantza Iriarte, Martin Edwards

This work was completed in 2015. The group was asked to contribute to the ICES Ecosystem Overviews providing info on recent changes and the current state of the zooplankton community. At the moment ICES is preparing four reports on the Greater North Sea, the Bay of Biscay and the Iberian coast, the Celtic Seas, and the Baltic Sea. The WGZE role is to provide priority information on the "state of habitat and biological characteristics" (section 4 of reports). It is to describe the state of the ecosystem (in space and time) and to comment on pressures accounting for changes in state.

After a short discussion on data availability, group decided to prepare the relevant paragraphs on zooplankton community plus figures illustrating the changes. Chapters on the Bay of Biscay and the Iberian coast were prepared by Lidia Yebra, Antonina Santos, and Arantza Iriarte; the Baltic Sea text was drafted by Maiju Lehtiniemi, Jörg Dutz, Patrik Strömberg, and Piotr Margonski. It was agreed that figures would be generated by Todd O'Brien based on data used for preparations of the "Zooplankton Status Report". The overview of changes and the current status in the Greater North Sea and Celtic Seas was possible only using the CPR data series collected by SAHFOS. Martin Edwards kindly offered the SAHFOS contribution in that respect.

ToR m) Contribute regional text (~ 150 words and 1-2 graphs in each case) on the state and trends of zooplankton to new ecosystem overviews for (i) Iceland, (ii) Norwegian Seas, (iii) Azorean ecoregion and (iv) the Oceanic north-east Atlantic ecoregion, if information is available

Leads: Astthor Gislason, Cecilie Broms, and introduced by Piotr Margonski

This ToR is similar to the previous one but covers four other ecoregions. Overviews for Icelandic waters and Norwegian Seas were prepared as requested prior to the 2017 meeting by Astthor Gislason and Cecilie Broms, respectively. The remaining two are expected to be delivered later in 2017. Group discussed potential authors for Azorean and the Oceanic north-east Atlantic ecoregions. It was decided to explore existing opportunities after the meeting as those are not data rich areas except for SAHFOS CPR time-series.

During discussion Astthor Gislason raised the issue of necessity of changing name of the 'Iceland Sea' ecoregion to e.g. 'Icelandic waters' in the ICES system as the Iceland Sea is an existing geographical term and it is not located 'around' Iceland. It has already caused some confusion of Icelandic members. Based on the later correspondence with the ICES Secretariat, this request was treated seriously and the problem was solved.

5.1 Progress Reports of 2017

Recently established PICES-BIO WG37: Zooplankton Production Methodologies, Applications and Measurements in PICES regions (presented by Lidia Yebra)

PICES-BIO WG37 will focus on assessing the applicability of current methodologies (i.e., traditional and biochemical methodologies) for measuring rates of zooplankton production for natural mesozooplankton populations and communities (including non-crustaceans); and for applying the most practical methods to existing zooplankton time-series. Planned WG37 activities will be carried out over a period of three years (2017-2019), and include:

1) Summarize assumptions, recent advances and limitations of both traditional and biochemical methodologies for measuring zooplankton production of natural populations and communities.

2) Produce recommendations and protocols for both traditional and biochemical measurements of zooplankton production rates and make these available globally to users on a website.

3) Develop practical models for estimating zooplankton production rates for time-series.

4) Build a platform of information exchange on zooplankton production rate measurements through an interactive website for regional and/or global mapping.

5) Build a network of scientists and laboratories measuring zooplankton production among PICES and ICES nations as well as developing countries.

6) Promote international collaborations among zooplankton production researchers through international organizations such as ICES, PICES and IMBER.

7) Publish a final report summarizing results.

A novel underwater zooplankton observatory for integrative ecosystem monitoring within the framework of COSYNA (presented by Klas Ove Möller)

Increasing human activities and climate change have been shown as major stressors especially in coastal marine ecosystems worldwide. Although many methods have been developed to evaluate the status of single components of these ecosystems, there is still a crucial lack in assessing multiple ecosystem components in a holistic way. This is particularly true for the zooplankton community being a sensitive indicator to environmental changes. We here present first results from a novel zooplankton underwater observatory which has been recently deployed in the German Bight (Southern North Sea). The cabled underwater observatory combines a remote-controlled Video Plankton Recorder, Acoustic Doppler Current Profiler and CTD-probe allowing continuous and automatic small-scale observations in near real-time of zooplankton species abundance and behaviour (e.g. vertical migration and trophic interactions) and the associated hydrography covering temporal scales from hours to several months. This observatory is part of the Coastal Observing System for Northern and Arctic Seas (COSYNA) providing a unique dataset in combination with a suite of other sensor platforms including e.g. FerryBoxes, Research vessels, Gliders, HF-Radar, remote sensing as well as modelling. Furthermore, the zoo-

plankton observatory is located in close vicinity to the Helgoland Road time-series station allowing comparisons, ground truthing and combination of modern optical and traditional plankton sampling methods. Our integrative monitoring approach is bridging the gap between primary production and higher trophic levels, helps to identify and track rapidly occurring environmental changes and thereby provides a potential tool for integrated ecosystem assessment and management within the marine strategy framework directive.

The MedZoo initiative (presented by Maria Grazia Mazzocchi and Lidia Yebra)

MedZoo, the Working Group on Mediterranean Zooplankton Ecology, was recently established in December 2016. MedZoo stems from previous Gaby Gorsky's idea, on the tracks of the joint ICES/CIESM meeting organized by Gaby Gorsky and Astthor Gislason in Crete in 2008.

MedZoo revives now as a bottom-up initiative, coordinated by Maria Grazia Mazzocchi and Lidia Yebra. The group is a community working on all aspects of zooplankton in the Mediterranean and Black Seas; with the aim to develop an open forum for discussion of any topic of interest regarding zooplankton biology and ecology in the Mediterranean basins. Gathering Mediterranean and Black Sea experts, the group assembles more than 50 zooplankton ecologists from 15 countries and one representative from SPA/RAC (UNEP/MAP). The current work in progress includes the development of a web page (www.medzoo.bio) and the expansion to include further experts from both EU and non-EU countries.

Trophic ecology of zooplankton in the English Channel and the North Sea. Where are we? Where are we going to? (by Pierre Cresson, Morgane Travers-Trolet and Elvire Antajan)

As it is at the interface between primary production and fishes, the pivotal role of zooplankton in marine food webs is classically recognized. Changes in zooplankton assemblages, whether considering abundance or composition, classically result in trophic cascades affecting species at higher trophic levels in marine food webs. Despite this importance, few data are available in the English Channel and the North Sea regarding zooplankton trophic ecology. This lack makes necessary assuming the functioning of low trophic levels when trying to understand the trophic ecology of high trophic levels. Thus, suspended POM and zooplankton have been collected during several Ifremer ecosystems surveys in the English Channel and the North Sea, to measure C and N isotopic ratios and to provide some preliminary results about trophic relationships in zooplankton. Isotopic analyses are nowadays classically used to infer trophic ecology of marine organism, as they allow inferring trophic position of organisms, and the food source(s) they depend on. Consistently with the pivotal role of zooplankton in marine food webs, the data were then analyzed following two major axes, whether considering zooplankton as a consumer of primary production, or at the base of fish food webs. First, they were used to infer trophic relationship in zooplankton, and notably demonstrated that zooplanktonic organisms occur at several trophic levels, with a consistent high trophic position of chaetognaths, whatever the sampling period or location. Those results will be further exploited, notably to gain accuracy in ecosystem models based on trophic relationships, where zooplankton is commonly considered as one unique group regardless of trophic differences. Second, spatial similarities or discrepancies in zooplankton isotopic ratios will be useful

to precise how zooplankton could be accurately used as a trophic baseline, to root the fish's food web, whether considering larvae or adults. Preliminary analyses notably demonstrated that herring larvae share a similar position with chaetognaths. In addition, including zooplankton isotopic data in isotopic modelling allow excluding a major direct influence of pelagic production in fish food webs. Future analyses, based on fish stomach content analyses would allow understanding the feeding mechanisms driving OM fluxes in the area.

Microplastics in the Mediterranean Sea: recent investigations (presented by Maria Grazia Mazzocchi)

The Mediterranean Sea (MS) has been recently proposed as one of the most impacted regions of the world with regards to microplastics. This problem is due to many and different factors, such as a densely populated coastline and intensive maritime activities. According to the most recent simulations, the MS is retaining a very high percentage (21%–54%) of all plastic particles (i.e., between 3.2 and 28.2 10^{12} particles) and of the global plastic mass (5%–10%); (i.e. between 4.8 and 30.3 thousand tonnes); (van Sebille *et al.*, 2015). The first quantification of floating microplastics date back to 1997 and other studies were conducted in the last few years, focusing on specific basins or on the entire MS (Suaria *et al.*, 2016, their Table 1). The recent paper by Suaria *et al.* (2016) reports the results of a large-scale survey conducted in the spring of 2013 and provides information on microplastic abundance and geographical distribution in the Western MS and in the Adriatic Sea and the first extensive characterization of the microplastic chemical identity. The overall size-class distribution revealed a marked prevalence of smaller particles (26% < 300 μm and 51% <500 μ m (n*tot* = 14,106 particles). Only 1.4% of the total were larger than 5 mm. The mean abundance of these meso-particles was very low but strongly correlated to the abundance of micro-particles. The polymeric identity of all particles > 700 μm (96.2% of the total weight of collected material) showed 16 different polymer typologies with polyethylene as the predominant form with an overall frequency of 52%, followed by polypropylene (PP) (16%) and synthetic paints (7.7%). The amount of particles > 700 μm showed a very high spatial heterogeneity spanning two or three orders of magnitude across the study area.

One year after that spring survey, the schooner Tara sailed for an expedition in the MS to assess the impact of microplastics on Mediterranean ecosystem health and function. This expeditions, long 8000 nautical miles, lasted 7 months (May-Nov), visited 13 countries and involved 18 laboratories (350 net hauls, 2300 samples collected). This project is based on the contribution of 18 institutions linked in a Consortium that is coordinated by the French CNRS and UPMC, with ML Pedrotti from the Villlefranche Laboratory as PI. The neustonic plastics and plankton were collected by day and night Manta trawl net with 333μ. The samples were sorted and stored according to different analytical protocols. In the laboratory, plastics and plankton were digitally imaged, counted and sized with Zooscan. Plastics were weighed, classified according to types and chemically characterized by FT-IR analysis. Overall, the entire project is organized in 6 work packages: 1) Microplastic distribution and modelling; 2) Microplastic chemistry; 3) Plastic-bound fauna & flora; 4) Surface ecosystem structure; 5) Integrative approaches; 6) Outreach. WP4 is focused on zooplankton with the aim of characterizing the ecosystem structure of plankton in contact with plastic fragments, i.e. the taxonomic, spatial and daily variability of ipo- and neustonic communities, including the insects on the sea surface. This work on WP4 is conducted by ML Fernandez de Puelles (EIO), Stéphane Gasparini (LOV), Gaby Gorsky

(LOV), JL Jamet (University of Toulon), F. Lombard (LOV), ML Pedrotti (LOV), Valentina Tirelli (OGS) and is coordinated by MG Mazzocchi (SZN). The preliminary results of WP1 and WP4 will be presented at "MICROMED: International Conference on Microplastic pollution in the Mediterranean Sea" that will be held in Capri, September 26-29, 2017.

Long-term studies on floating microplastics show that there has not been a significant increase in surface waters microplastic from the 80s despite an increase in the production and development of plastic disposal in recent decades. In addition, the total amount of estimated global plastic in the ocean in the most recent survey seems much lower than expected. These studies suggest a process of removing microplastic from the surface, due to various possible mechanisms, such as the fragmentation into smaller particles (nanoplastics), the ingestion by the zooplankton, the sinking to the presence of biofouling, or the stranding. The few available observations in deep oceans indicate a significant presence of microplastic in deep sediments which proves their vertical transport mechanism (Woodall *et al.*, 2015). Early data seem to suggest that the plastic missing at the surface is concentrating in the ocean floor.

This is the overarching hypothesis of an Italian project launched in 2016 (in the frame of the Italian Flagship program RITMARE) that involves 6 national research institutions and is aimed at evaluating the impact of the anthropogenic debris that reach the marine environment from the surface the bottom habitats. The investigation is focused on (1) Abundance and distribution of marine litter (macro- and microplastics) and their transport mechanisms; (2) Target species as potential bioindicators of marine litter accumulation; (3) Mechanisms of distribution, dispersion and availability of contaminants; (4) Transfer and effects through the food web (zooplankton and zoobenthos). The investigated areas are part of submarine canyons in the Gulf of Naples (Tyrrhenian Sea), Gulf of Augusta (eastern Sicily), Gulf of Taranto and Gulf of Squillace (Ionian Sea), in coastal areas under severe environmental stress due to intense anthropic activities. The sample analyses are still in course but the ROV surveys showed in real time the occurrence, in the canyons, of marine litter and the fauna exposed to this pollution.

References

Suaria, G. *et al.* The Mediterranean Plastic Soup: synthetic polymers in Mediterranean surface waters, Scientific Reports. doi:10.1038/srep37551 (2016).

van Sebille, E. *et al.* A global inventory of small floating plastic debris. Environmental Research Letters 10, 124006 (2015).

Woodall, L. *et al.* The deep sea is a major sink for microplastic debris R. Soc. open sci. 1: 140317 (2015).

Report on the Plankton Image Analyser (PIA) – a high-volume plankton imaging and processing instrument (presented by Sophie Pitois)

The PIA is a high-speed colour line scan-based imaging instrument. The flow cell is 25 mm brass tube that has two quartz optical windows halfway along its length. The flow cell at the windows is square with the same cross sectional area as the 25 mm tube. A Basler 2048-70kc camera, sampling at 70K lines per second, images the water running through the flow cell. The flow rate is monitored by a Bell electro-magnetic flow meter and set to 34-40 L/min. colour images are captured using an EPIX E4 frame store. Essen-

tially, RGB composite images are constructed by joining consecutive lines together, thresholding and extracting a region of interest ROI, or vignette that is saved to hard drive as a TIF file. Each TIF image is time-stamped and named in the Zooscan convention of date+imageID.tif. Raw images are stored to maximise dynamic range of the captured particles. These are converted to 8-bit resolution through a process of scaling and conversion from 12bit to 8bit resolution, for viewing and for subsequent processing (Culverhouse *et al.*, 2015). Sophie Pitois presented trials performed using the PIA by Cefas in October 2016. During this trial, zooplankton was collected at 40 stations using 3 methods: the deployment of a vertical ring net (0.5m, 80μm mesh), the use of the Continuous Automated Litter and Plankton Sampler (CALPS, Pitois *et al.*, 2016) and the PIA. Strengths and weaknesses of each system was described in term of sampling methodology, image capture and analysis and data availability. Overall, zooplankton information resulting from the PIA clearly gives a different picture of both abundance and community composition, compared to that obtained from both the CALPS and ring net. This study suggests that the differences are mostly due to the analysis step rather than sampling methodology.

References

Culverhouse, P. F. (2015) An Instrument for Rapid Mesozooplankton Monitoring at Ocean Basin Scale. Journal of Marine Biology and Aquaculture, 1, 1-11.

Pitois, S. G., Bouch, P., Creach, V. and Van Der Kooij, J. (2016) Comparison of zooplankton data collected by a continuous semi-automatic sampler (CALPS) and a traditional vertical ring net. Journal of Plankton Research, 38, 931-943.

Report on a new project focused on understanding of the interaction of zooplankton, herring and environmental factors in the pelagic ecosystem east and northeast of Iceland (presented by Hildur Pétursdóttir)

The goal of this project is to gain a better understanding of the interaction of zooplankton, herring and environmental factors in the pelagic ecosystem east and northeast of Iceland. The research includes, for instance, study of spatial and temporal diversity in the species composition and development of zooplankton for the last 22 years (1995-2016). The relationship between zooplankton and environmental variables (e.g. temperature, salinity, nutrients and primary production) will be explored. In addition, the relationship of food availability (zooplankton) with information of diet composition of herring and mackerel as well as their survival will be studied. The outcome of this study will hopefully be an important link in an advancing understanding of the ecosystem variability that could explain changes in migration pattern and biology of pelagic fish stocks and could further be used for fisheries management.

Report from the ICES ASC 2016 Theme Session M "The role of zooplankton in exploited ecosystems: top–down and bottom–up stresses on pelagic food webs" (Angus Atkinson, Piotr Margonski, Webjørn Melle)

In a world of changing climate and increasing fishing pressure, the extent to which ecosystems are controlled by top-down, bottom-up, or middle-out controls is fundamental. Biogeochemists often view the system in terms of physics/nutrient availability whereas higher predator ecologists tend to take a more top-down perspective. Zooplankton at mid trophic levels channel these controls in both directions.

Top-down and bottom-up forcing functions act together and vary according to scale. However there is some controversy on their relative strengths and importance (e.g. whether overfishing really causes downwards trophic cascades affecting whole ecosystem).

Session M was one of 18 Theme Sessions at the ICES 2016 Annual Science Conference. Overall 30 presentations were submitted and 28 presented. Thirteen countries were represented by first author. The entire day was allocated for our session with 19 oral presentations plus 9 poster 2 min summaries.

Structure of session was to move broadly up through food web. Presented contributions were highly diverse, from microplankton to fish and most talks considered 2-3 trophic levels, often centred on zooplankton. There were however some areas under-represented as e.g. gelatinous predators, fishing pressure, and end-to-end models. Strong emphasis was on using time-series data. Studies combining time-series and modelling were presented in 4 talks. The overall message of the session is that:

- Simultaneous top-down/bottom-up control is now well established in our understanding and approach to zooplankton population dynamics.
- However, no presentation showed evidence for a downwards trophic cascade (i.e. predation controls affecting multiple successive trophic levels).
- Several studies emphasised planktivorous fish controls on copepod populations (but note under-representation of other key predators in this session).
- Likewise bottom up forcing of fish recruitment via zooplankton was clear.
- Top down control was increasingly emphasised as we travelled up through the food web.

6 Cooperation

Cooperation with other WG

- Joint WGZE-WGIPEM meeting to identify and develop information and data useful for modelling needs especially regarding to exploitation of resources at the lower trophic level provided an opportunity to discuss common interests and gaps in data and knowledge as well as concluded with the action plan.
- Areas of coordinated and collaborative activities between WGZE, WGIMT, and WGPME were regularly discussed and implemented.

Cooperation with Advisory structures

- The group contributed to the ICES Ecosystem Overviews on the zooplankton community (spatial variability, hot spots, and seasonality): four ICES ecoregions in 2015: Greater North Sea, Celtic Seas, Bay of Biscay & the Iberian coast, and Baltic Sea; two in 2016: Iceland and Norwegian Seas; two in 2017: Azorean and the Oceanic north-east Atlantic ecoregions.
- WGZE contributed to the advisory process by discussing the Norwegian request regarding the *Calanus finmarchicus* exploratory assessment and reviewing Norwegian Assessment/Management Plan.

Cooperation with other IGOs

- Contribution of the WGZE/WGIMT members to the organisation and success of the ICES/PICES 6th Zooplankton Production Symposium (9-13 May 2016, Bergen, Norway) where WGZE/WGIMT had 2 of 3 Symposium conveners, 4 of 7 members of the Scientific Steering Committee, several session and workshop conveners, several members of the Award Committee and significant participation and contribution to the Symposium presentations (http://www.ices.dk/news-and-events/symposia/zp6/Pages/default.aspx).
- WGZE is a significant contributor of North Atlantic time-series to the IOC/UNESCO International Group for Marine Ecological Time-series (IGMETS) global analysis and status report (http://igmets.net/report). IGMETS has compiled a global collection of over 300 time-series, covering the open-ocean, coastal areas, and estuaries. Of all the oceanographic regions, the best coverage within IGMETS is for the North Atlantic, with the WGZE and WGPME time-series being the largest contributor to this region.

7 Summary of Working Group self-evaluation and conclusions

WGZE consists of the members and chair-invited members representing a wide range of expertise including zooplankton taxonomy, spatial and temporal distribution dynamics, knowledge of marine ecosystem structure and function, zooplankton community response to climate change and impact of microlitter on zooplankton. Traditionally, WGZE is addressing numerous priorities of the ICES Science Plan as well as has a long history of successful networking inside (e.g. ICES ASC Theme Sessions and face-to-face meetings with other EGs) and outside of the ICES community (e.g. with PICES, CIESM, IOC). Significant efforts were allocated for dissemination of knowledge either through scientific publications (papers and books) and reports as Zooplankton Status Reports (published as ICES CRRs).

The group discussed and agreed to submit Theme Session proposals for 2018 Annual Science Conference on mesopelagic zone, multidisciplinary approach to pelagic biodiversity, and microplastics in biota.

WGZE Members are willing to continue and, as discussed at the meeting, the list of ambitious drat Terms of References is presented in Annex 3.

Provided the WGZE extension is granted by SCICOM, the group is planning to hold next meeting in Helsinki, Finland, 19–23 March 2018, hosted by Maiju Lehtiniemi (SYKE).

Annex 1: List of participants

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Annex 2: Recommendations

	RECOMMENDATION	ADRESSED TO
1.	Propose Theme Sessions for the 2018 ASC	SCICOM

Annex 3: WGZE draft Resolution 2018–2020

A **Working Group on Zooplankton Ecology** (WGZE), chaired by Sophie Pitois, UK & Lidia Yebra, Spain, will work on ToRs and generate deliverables as listed in the Table below.

	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2018	19–23 March	Helsinki, Finland	Interim report by 1 May	
Year 2019			Interim report by Date	
Year 2020			Final report by Date	

ToR descriptors

ToR	Description	Background	Science Plan topics addressed	Duration	Expected Deliverables
A	Design and carry out coordinated and collaborative activities with PICES-BIO WG37	a, c) Over the past two decades, quantitative evaluation of zooplankton production and its driving forces has been emphasized as a component of improving our understanding of how marine ecosystems respond to global change. While many methodologies to estimate zooplankton production have been proposed, we have limited knowledge identifying which methods are the most practical and relevant for measuring the production rates of natural zooplankton populations and/or communities across a wide range of phyla and trophic levels. The Working Group has identified and pursued the need for an evaluation of existing, new and emerging methodologies (see Reports of the Working Group ICES CM 2004/C:07, ICES CM 2011/SSGEF:01, ICES CM 2014/SSGEF:09 and ICES CM 2015/SSGEPD:05). At the workshop 'ICES/PICES cooperative research initiative: towards a global measurement of zooplankton production' (held during the 6th ICES/PICES Zooplankton Production Symposium in 2016), the community decided to propose to the PICES-BIO committee the Working Group entitled 'Zooplankton Production Methodologies, Applications and Measurements in PICES regions' (WG37) to promote necessary activities in order to improve the situation significantly and soon. WGZE and WG37 share common interests and their collaboration is of utmost importance for the success of the ICES/PICES cooperative initiative.	2.1.1, 4.1.1, 4.2.1 & 4.3.2	Year 1-3	Plan of collaborative activities (y1), List of scientists and laboratories measuring zooplankton production among PICES and ICES nations (y1-3), Coordinated compilation of zooplankton production data (online database, y1-3), Comparison between models in use to estimate zooplankton production (peer-reviewed publication, y2))
B	Compile data and provide expert knowledge and guidance in the	a) Zooplankton traits are increasingly needed to determine the relative fitness of plankton along environmental gradients and to predict and assess community shifts and their consequences. Although	1.3.1	Years 1-3	A compiled database of known species-level zooplankton traits for the North

	definition of key traits of zooplankton species in the ICES area	a wide range of traits has been classified in recent years, data are scattered in the literature and uncertainties remain from paucity of observations.			Atlantic and adjacent seas. A peer-reviewed publication on the methods and data of this compiled database. A "wish list" of key zooplankton species within the ICES area that are still missing some or all trait data.
C	Recovery of "Dark Data" (datasets that are not available publicly) collected on or before WGZE time-series were started around 1990.	a, b, c) Many scientific data sets over the past 50+ years were collected at a time when the technology for curation, storage, and dissemination were primitive or non-existent, and consequently many of these datasets are not available publicly. These so-called ''dark data'' sets are essential to the understanding of how the ocean has changed chemically and biologically in response to the documented shifts in temperature and salinity (aka climate change). This ToR will seek to identify and bring into the light, dark data about zooplankton collected in the North Atlantic over the past decades Needed are: 1) To prescribe a protocol for dark data recovery i.e. a best practice list of steps to document and submit data to a public repository. 2) To determine where dark data are located. 3) To identify and make contact with the holders of such data. 4) To persuade holders to provide the data and metadata to a public data repository in order to make them discoverable and re-useable for future research. 5) Provide adequate citation / publication of the data (DOI) so the originator is given full credit. One example is the collection of data sets associated with the TASC program in the early 1990's. The physical data were available (they were assembled on a CD), but many of the biological data sets remains hidden in file cabinets, on originator's floppy disks, or the like. A number of WGZE members have expressed interest in "rescuing" data sets they have participated in collecting over the years, but are not currently available.	4.3.2	Years 1-3	Metadata, database input, Possible peer-review publication (may include a "data paper" such as Earth System Science Data if our efforts appear to be successful)
D	Macrozooplankton in mesopelagic zone	a, b) The mesopelagic zone, stretching from 200 to 1000 m depth, comprises about 60% of planet's surface and 20% of the ocean´s volume, constituting a large part of the total biosphere. The bulk part of the fish of the world live there, by number as well as by biomass: a 2008 study put the world marine fish biomass at 0.899 billion tonnes, a number that is only	1.3.1, 2.3.3, 4.1.1, & 4.2.1	Years 1-3	This three-year ToR will review our knowledge about the mesopelagic macrozooplankton taxonomy, abundance and

		slightly lower than the 1980 estimate of mesopelagic fish biomass alone (~ 1 billion tonnes). It is, however, a zone of wide diversity; the dominating taxonomic groups are crustaceans, various jellyfishes and cephalopods in addition to the fishes. Recent studies indicate that the total amount of mesopelagic fish biomass globally has been grossly underestimated, possibly by a factor of 10. The new assessment suggests a biomass in the order of 10,000 million tonnes, roughly equivalent to 100 times the annual catch of traditional fisheries of about 100 million metric tons. Even though much is known about the mesopelagic community and its functioning in the marine ecosystems, still much remains unknown, especially the role of the many macroplanktonic taxa.			biomass, trophic ecology, reproductive biology, and their impact on the flux of carbon into the deep-sea, and the role of the mesopelagic zone as a site for carbon sequestration. The aim is to produce a summary publication.
E	Analyze changes in the geographic distributions, seasonal patterns, and interannual trends of Arctic and North Atlantic macro- and meso-zooplankton species	a) Climate-related changes in the physical and chemical oceanic environment have been considered as major drivers of significant fluctuations in zooplankton. Meso- and macro-zooplankton are key components in the marine food web, hence studies on their distribution, diversity, and population dynamics are significant for understanding ecosystem dynamics. This ToR will explore long-term data on the distribution (spatial and temporal), abundance, composition, and species diversity of zooplankton in the ICES regions. Within the rapidly changing subarctic and Arctic regions, a special focus will also be given to macroplankton data series (e.g., euphausiids and amphipods). To pursue this ToR, WGZE's existing time-series compilation and analysis tools (used for the ICES Plankton Status Report) will be expanded to include and handle full species data.	1.2.1, 1.2.2, & 1.3.2	Years 1-3	Zooplankton Status Report contribution, Link to 'dark data', Possible peer-review publication
F	Gelatinous plankton –time-series collection, and recommendations regarding monitoring	a) Gelatinous plankton plays an important role in the oceanic and coastal ecosystems, forming spectacular population blooms. Compelling evidence is showing that jellyfish bloom size, frequency, period, and magnitude is increasing, although a global increase in abundance has been widely debated. Gelatinous organisms are opportunistic species quickly adapting to environmental changes, enhancing their feeding, growth, and reproduction. Despite their increasing significance, gelatinous plankton is not conventionally monitored together with other zooplankton. Jellyfish sightings are common in the warm waters of the Mediterranean and monitoring has also become widespread in the ICES area including colder waters. However, often datasets are not available ("dark data") and a variety of methods are being used. This new ToR will provide the basis for future studies on distribution and temporal patterns of gelatinous zooplankton. Therefore, it will: i) provide an inventory of existing time-series on	1.3.1, 4.1.1, 4.2.1 & 4.3.2	Years 1-3	Zooplankton Status Report contribution, Link to 'dark data', Recommendations for the monitoring of gelatinous plankton

		gelatinous plankton in the ICES area together with a compilation of metadata on the available datasets. ii) establish a summary of quantitative methods used in studies of gelatinous plankton and provide recommendations for the best practice for the implementation of gelatinous plankton monitoring in current time-series in the ICES area			
G	Determine the status of microzooplankton time-series data collection within the ICES area.	a, c) In 2007, a WGZE ToR reviewed the role of microzooplankton in the marine food web and concluded i) that the group should include both micro-and mesozooplankton experts and ii) that microzoplankton time-series and monitoring within the ICES area should be encouraged. This new ToR will assess progress made in this area over the last ten years and will identify any collaboration, gaps or overlap with other WGs (e.g. WGIMT; WGPME).	1.3.1, 4.1.1 & 4.2.1	Years 1-3	List of scientists and laboratories measuring microzooplankton groups within time-series datasets. Data table to compare sampling & analysis methods and to indicate which groups are regularly counted and which groups are routinely being missed; Database input; Webpage content update.
H	Review the applicability of continuous and real-time zooplankton techniques in long-term monitoring	a) Sampling of zooplankton today is often conducted using a combination of acoustics and imaging systems in addition to sampling with nets. Both the acoustics and imaging data provide streams of information that can, with developing classification algorithms, be analyzed and distributed in realtime. In addition, acoustic scattering techniques have the potential to provide zooplankton data at a high temporal resolution over large spatial ranges. This ToR will endeavor to provide a synthesis of current realtime systems and make recommendations for how time-series sites can enhance and modernize their data and analysis data acquisition systems.	4.1.1, 4.2.1, 4.2.2 & 4.3.2	Years 1-3	Synthesis of current continuous and realtime systems. Recommendations for how time-series sites can enhance and modernize their data and analysis data acquisition systems.
I	Expand and update the WGZE zooplankton monitoring and time-series compilation	a, b, c) It gives a rare opportunity to examine regional and transatlantic distribution and temporal patterns within the zooplankton time-series, including new methods identified by WKSERIES, to discern significant changes over time and to identify potential environmental or climate drivers.	1.1.1, 1.2.1, 2.1.1, & 2.2.3	Years 1-3	Next edition of the Plankton Status Report (PSR) Webpage content update Additional peer-reviewed publication
J	Design and carry out coordinated and collaborative activities with WGIMT and WGPME (including the	c) Synergy is expected based on development of the common activities strategy	3.1.2 & 4.3.2	Years 1-3	Plan of activities

	molecular/taxonomic tasks)				
K	Develop, revise and update of zooplankton species identification keys initially focusing on the most abundant taxa at the ICES time-series sites and ensuring their availability via the web, including especially ICES Zooplankton Identification Leaflets.	a) Extremely important tool in terms of capacity building of the scientific community	4.3.2	Years 1-3	Updated Taxonomic Leaflets uploaded to the web page

Summary of the Work Plan

Year 1	At the moment, all the suggested ToRs are planned as three-years activities covering the entire extension period. Certainly, a various workload intensity in specific ToRs in each year is expected.
Year 2	At the moment, all the suggested ToRs are planned as three-years activities covering the entire extension period. Certainly, a various workload intensity in specific ToRs in each year is expected.
Year 3	At the moment, all the suggested ToRs are planned as three-years activities covering the entire extension period. Certainly, a various workload intensity in specific ToRs in each year is expected.

Supporting information

Priority	The activities of this group are a basic element of the SSGEPD, 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.
Resource requirements	Resource required to undertake the "normal" activities of this group is negligible.
Participants	The Group is normally attended by some 25–30 members and chair-invited members.
Secretariat facilities	None.
Financial	No financial implications.
Linkages to ACOM and groups under ACOM	The Group reports to the SCICOM SSGEPD. Mainly WGZE provides scientific information on plankton and ecosystems but irregularly contributing to the advisory part of ICES activities as well.
Linkages to other committees or groups	Any and all expert groups interested in marine ecosystem monitoring and assessments, modelling and/or plankton studies, including fish and shellfish life histories and recruitment studies. Close cooperation with the WGPME and WGIMT is planned and expected.
Linkages to other organizations	The Plankton Status Report is of interest and practical use to a range of interested groups within ICES, PICES, CIESM, and GOOS with other national and international research groups and agencies. Exchange of information and cooperation is expected with other organisations as IOC, SCOR, COML/CMarZ, and others which 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: Copy of Working Group self-evaluation

1) Working Group name

Working Group on Zooplankton Ecology (WGZE)

2) Year of appointment within the current 3-year cycle

2015

3) Current Chair:

Piotr Margonski (Poland)

4) Venues, dates and number of participants per meeting:

Plymouth, UK; 16–19 March 2015; 32 (2 by corresp.), 13 nations

Lisbon, Portugal; 14–17 March 2016; 36 (1 by corresp.), 11 nations

Boulogne-sur-Mer, France; 27–30 March 2017; 29 (4 by corresp.), 12 nations

WG Evaluation

5) If applicable, please indicate the research priorities (and sub priorities) of the Science Plan to which the WG make a significant contribution.

WGZE addressed numerous research priorities of the Science Plan:

- Contribution to the Integrated Ecosystem Assessments.
- Assess the physical, chemical, and biological state of regional seas and investigate the predominant climatic, hydrological, and biological features and processes that characterize regional ecosystems.
- Quantify the differential effects of climate change on regional ecosystems and develop species and habitat vulnerability assessments for key species
- Develop historical baselines of population and community structure and production to be used as the basis for population and system level reference points
- Develop methods to quantify multiple direct and indirect impacts from fisheries as well as from mineral extraction, energy generation, aquaculture practices, and other anthropogenic activities, and estimate the vulnerability of marine ecosystems to these impacts.
- Develop indicators of pressure on populations and ecosystems from human activities such as eutrophication, contaminant and litter release, introduction of alien species, and generation of underwater noise.
- Evaluate ecological, economic, and social tradeoffs between ecosystem protection and sustainable use to advise on the management of human activity in marine ecosystems.
- Identify issue-based ecosystem questions relevant to science and management needs that can be addressed by developing IEAs.
- Identify monitoring requirements for science and advisory needs in collaboration with data product users, including a description of variables and data products, spatial and temporal resolution needs, and the desired quality of data and estimates.

- Identify knowledge and methodological monitoring gaps, and develop strategies to fill these gaps.
- Promote new technologies and opportunities for observation and monitoring, and assess their capabilities in the ICES context.
- Allocate and coordinate observation and monitoring requests to appropriate expert groups on fishery-independent and fishery-dependent surveys and sampling, and monitor the quality and delivery of data products.
- Ensure the development of best practices through establishment of guidelines and quality standards.

6) In bullet form, list the main outcomes and achievements of the WG since their last evaluation. Outcomes including publications, advisory products, modelling outputs, methodological developments, etc. *

- Contribution of the WGZE/WGIMT members to the organisation and success of the ICES/PICES 6th Zooplankton Production Symposium (9-13 May 2016, Bergen, Norway) where WGZE/WGIMT had 2 of 3 Symposium conveners, 4 of 7 members of the Scientific Steering Committee, several session's and workshop's conveners, several members of the Award Committee and significant participation and contribution to the Symposium presentations (http://www.ices.dk/news-and-events/symposia/zp6/Pages/default.aspx).
- Joint WGZE-WGIPEM meeting to identify and develop information and data useful for modelling needs especially regarding to exploitation of resources at the lower trophic level provided an opportunity to discuss common interests and gaps in data and knowledge as well as concluded with the action plan.
- The group contributed to the ICES Ecosystem Overviews on the zooplankton community (spatial variability, hot spots, and seasonality): four ICES ecoregions in 2015: Greater North Sea, Celtic Seas, Bay of Biscay & the Iberian coast, and Baltic Sea; two in 2016: Iceland and Norwegian Seas; two in 2017: Azorean and the Oceanic north-east Atlantic ecoregions.
- WGZE contributed to the advisory process by discussing the Norwegian request regarding the *Calanus finmarchicus* exploratory assessment and reviewing Norwegian Assessment/Management Plan.
- In 2016, Peter Wiebe received the ICES Outstanding Achievement Award a prestigious award that signifies the highest level of recognition for services to ICES science.
- In 2015, Klas Ove Möller (Germany) received the Best presentation award for early career scientist ("Small-scale distribution of plankton and marine snow in the North Atlantic (S:16))

Active role in submitting successful ICES ASC theme sessions' proposals

The ICES ASC 2015 Theme Session S 'Basin-scale dynamics at lower trophic levels in the North Atlantic' was convened by two WGZE Members (Astthor Gislason and Peter Wiebe)

The ICES ASC 2016 Theme Session M 'The role of zooplankton in exploited ecosystems: top-down and bottom-up stresses on pelagic food webs' was convened by three WGZE Members (Angus Atkinson, Webjoern Melle, and Piotr Margonski)

Three theme sessions have been suggested and accepted for ICES ASC 2017:

Theme Session E "Poleward shifts and ecological changes of Arctic and Sub-arctic zooplankton and fish in response to climate variability and global climate change" (Hein Rune Skjoldal (Norway), Carin Ashijan (USA), and Louis Forter (Canada))

Theme Session L "Ecosystem monitoring in practice" (Sophie Pitois (UK), Mark Benfield (USA), and Christopher Zimmermann (Germany))

Theme Session C (together with WGIMT) "Microbes to mammals: metabarcoding of the marine pelagic assemblage" (Ann Bucklin (USA), Rowena Stern (UK), Katja Metfies (Germany))

Publications

Wiebe P., Harris R., Gislason A., Margonski P., Skjoldal H.R., Benfield M., Hay S., O'Brien T., Valdes L. 2016. The ICES Working Group on Zooplankton Ecology: Accomplishments of the first 25 years. Progress in Oceanography 141: 179–201, DOI: 10.1016/j.pocean.2015.12.009

Yebra L., Kobari T., Sastri AR., Gusmão F. & Hernández-León S. 2017. Advances in Biochemical Indices of Zooplankton Production, Advances in Marine Biology, 76:157-240, DOI: 10.1016/bs.amb.2016.09.001

Castellani C. and Edwards M. (Eds). 2017. Marine Plankton. A practical guide to ecology, methodology, and taxonomy. Oxford University Press, 704 pp. ISBN: 9780199233267

Lindeque P. and Cole M. Plastics and plankton. Feature article. ICES newsletter 1 September 2016 .

Manuscripts being prepared

1) Zooplankton Production and Metabolic Activity in the North Atlantic and Adjacent Seas - by Lutz Postel and many other WGZE members

2) Methods for calculation of zooplankton production and metabolism - by Lutz Postel *et al.*

3) Review paper on the new methods of automatic and semi-automatic plankton identification - Klas *et al.*

4) 4. Marine zooplankton indicators: present status and perspectives (manuscript being a follow up of the indicator workshop during ICES/PICES 6th Zooplankton Production Symposium (WGZE co-authors: Kathryn Cook and Piotr Margonski)

Zooplankton Status Report 2017

The next ICES Plankton Status Report will be a combined analysis and product of the WGZE (zooplankton) and WGPME (phytoplankton) working groups and their respective time-series. This report will feature a greatly improved statistical analysis as well as monthly and seasonal (vs. annual) examination of trends and patterns at the individual, regional, and trans-Atlantic scales. Coupled with the report will be an interactive "Explorer" web-based interface that will allow the reader to further explore the time-series and contents of the report (WGZE editors: Todd O'Brien, Peter Wiebe and Tone Falkenhaug)

The International Group for Marine Ecological Time-series (IGMETS) 2017

A current effort led by the Intergovernmental Oceanographic Commission of UNESCO (IOC), the International Ocean Carbon Coordination Project (IOCCP) and the Ocean Carbon and Biogeochemistry Program (OCB) has identified >300 ship-based, biogeochemical time-series throughout the globe. The International Group for Marine Ecological Time-series (IGMETS) seeks to integrate a suite of in situ biogeochemical variables from time-series stations, together with satellite-derived information, to look at holistic changes within different ocean regions, explore plausible reasons and connections at a global level, and highlight any locations of especially large changes that may be of special importance. This work will be in the form of a comprehensive, integrated report which will be published under the auspices of IOC-UNESCO and brings together the ship-based, biogeochemical time-series community in a way never before attempted.

This IOC Technical Series Report (led by Todd O'Brien, contributed to by multiple WGZE members) is an expanded, global-scale version of the ICES Plankton Status Report, which includes a full suite of physical (temperature, salinity), biogeochemical (nutrients, oxygen, pigments), and biological (phytoplankton, zooplankton) time-series variables (http://igmets.net/report). The North Atlantic chapter's data-contribution and authorship is heavily dominated ICES WGZE/WGPME members, and many of these members have also contributed to and co-authored the Arctic and Antarctic chapters.

7) Has the WG contributed to Advisory needs? If so, please list when, to whom, and what was the essence of the advice.

- Yes, as it was mentioned in question 6: WGZE contributed to ICES Ecosystem Overviews of 8 ecoregions as well as by discussing the Norwegian request regarding the *Calanus finmarchicus* exploratory assessment and reviewing Norwegian Assessment/Management Plan.

8) Please list any specific outreach activities of the WG outside the ICES network (unless listed in question 6). For example, EC projects directly emanating from the WG discussions, representation of the WG in meetings of outside organizations, contributions to other agencies' activities.

- As it was mentioned in question 6: WGZE/WGIMT members substantially contributed to the organization and success of the ICES/PICES 6th Zooplankton Production Symposium (9-13 May 2016, Bergen, Norway).

- International Group for Marine Ecological Time-series (IGMETS) (for more info see question 6)

9) Please indicate what difficulties, if any, have been encountered in achieving the workplan.

- The major problem appeared when WGZE suggested to organize a workshop focused on the Norwegian request regarding the *Calanus finmarchicus* exploratory assessment. We were unable to find sufficient funds within ICES system to gather not only experts from ICES community but especially experts from Academia with various and relevant expertise on possible consequences of ecosystem exploitation at the low levels of the foodwebs.

Future plans

10) Does the group think that a continuation of the WG beyond its current term is required? (If yes, please list the reasons)

- Yes, WGZE consists of the members and chair-invited members representing a wide range of expertise including zooplankton taxonomy, spatial and temporal distribution dynamics, knowledge of marine ecosystem structure and function, zooplankton community response to climate change and impact of microlitter on zooplankton. Traditionally, WGZE is addressing numerous priorities of the ICES Science Plan as well as has a long history of successful networking inside (e.g. ICES ASC Theme Sessions and face-to-face meetings with other EGs) and outside of the ICES community (e.g. with PICES, CIESM, IOC). Significant efforts were allocated for dissemination of knowledge either through scientific publications (papers and books) and reports as Zooplankton Status Reports (published as ICES CRRs). The list of suggested, future Terms of References is presented in the relevant Category 2 resolution draft.

11) If you are not requesting an extension, does the group consider that a new WG is required to further develop the science previously addressed by the existing WG.

- N/A as we are asking for extension

12) What additional expertise would improve the ability of the new (or in case of renewal, existing) WG to fulfil its ToR?

- More expertise on microplankton within WGZE to help the review of microplankton role in marine foodwebs

13) Which conclusions/or knowledge acquired of the WG do you think should be used in the Advisory process, if not already used? (please be specific)

- In future, a closer task-oriented cooperation with modellers (e.g. WGIPEM) may increase the WGZE potential to contribute more to the Advisory Process. This will however require some substantial changes in the current model ICES is operating.
- The group is also open to contribute to the projects as e.g. ICES Ecosystem Overviews.

Annex 5: Agenda of the WGZE 2017 meeting

Monday March 27, 2017

09:00 – 09:30 Opening, Introduction, Logistics, and Agenda Adoption (Elvire Antajan and Piotr Margonski)

09:30 – 10:30 Discussion on completion of MA ToRs in 2017, self-evaluation, and election of the new Chair(s) (Piotr Margonski)

10:30 – 11:00 Coffee Break

11:00 – 12:30 Final report on the 6th Zooplankton Production Symposium (**ToR A**, Astthor Gislason, Padmini Dalpadado, and Lidia Yebra)

12:30 – 14:00 Lunch Break

14:00 – 15:00 Revise lists of currently suggested (e.g. by OSPAR, HELCOM, and EU Member States) zooplankton indicators relevant for biodiversity and foodweb status assessment. Based on gap analysis, identify and test new, candidate indicators considering their response to various pressures (**ToR G,** summary by Piotr Margonski)

15:00 – 15:20 Advertisement of the theme session L "Ecosystem monitoring in practice" at the ICES ASC (Sophie Pitois)

15:20 – 15:40 Progress Report on 'on the plankton image analyser as part of the review of the new methods led by Elvire' (Sophie Pitois)

15:40 – 16:00 Coffee Break

16:00 – 16:20 Progress Report on a new project focused on understanding of the interaction of zooplankton, herring and environmental factors in the pelagic ecosystem east and northeast of Iceland (Hildur Pétursdóttir)

16:20 – 16:40 Recently established PICES-BIO WG37: Zooplankton Production Methodologies, Applications and Measurements in PICES regions (Lidia Yebra)

16:40 – 17:00 Opening discussion on the new MA ToRs (Piotr Margonski)

Tuesday March 28, 2017

09:00 – 10:30 Review the ICES response to the Norwegian request regarding the *Calanus finmarchicus* exploratory assessment (**ToR C,** Webjörn Melle +)

10:30 – 11:00 Coffee Break

11:00 – 12:30 Expand and update the WGZE zooplankton monitoring and time-series compilation (**ToR F,** Todd O'Brien, Tone Falkenhaug, and Peter Wiebe)

12:30 – 14:00 Lunch Break

14:00 – 15:30 Compile the information on micro-plastics pollution and its effects on zoo-plankton communities (**ToR D,** Maiju Lehtiniemi & Elaine Fileman) & Progress Report on zooplankton investigations in relation to microplastics distribution in the Mediterranean Sea (Maria Grazia Mazzocchi)

15:30 – 16:00 Coffee Break

16:00 – 16:30 Discussion on the new MA ToRs (Piotr Margonski)

16:30 – 17:00 Discussion on 2018 Theme Sessions (Piotr Margonski)

Wednesday March 29, 2017

09:00 – 10:30 Review the new methods of automatic and semi-automatic plankton identification (**ToR E,** Klas Ove Möller, Elvire Antajan, Astthor Gislason, Mark Benfield by correspondence????)

Progress Report on a successful deployment of an underwater plankton observatory in the North Sea – directly at the time-series station Helgoland Reede (Klas Ove Möller)

10:30 – 11:00 Coffee Break

11:00 – 12:30 Refine and expand the compilation of information on zooplankton species, taxonomic categories, and life stages that are currently monitored in the ICES area (**ToR I,** Todd O'Brien and Claudia Castellani by correspondence)

12:30 – 14:00 Lunch Break

14:00 – 15:30 Calculate zooplankton productivity and metabolic rates in the ICES area based on allometric approaches. Build a database of zooplankton individual species biomass, productivity and metabolic rate equations (**ToR J,** Lutz Postel, Peter Wiebe, Todd O'Brien, and Patrik Strömberg by correspondence????)

15:30 – 17:30 Walking tour of the old town of Boulogne-sur-Mer.

19:00 – 23:00 Welcome to the National Sea Center Nausicaà and dinner at the tropical lagoon

Thursday March 30, 2017

09:00 – 10:00 Design and carry out coordinated and collaborative activities with WGIMT and WGPME (**ToR H,** Ann Bucklin, Alexandra Kraberg, and Piotr Margonski)

10:00 – 10:30 Develop, revise and update of zooplankton species identification keys initially focusing on the most abundant taxa at the ICES time-series sites and ensuring their availability via the web, including especially ICES Zooplankton Identification Leaflets (**ToR K,** Antonina Santos and Claudia Castellani by correspondence)

10:30 – 11:00 Coffee Break

11:00 – 11:30 Contribute regional text (~ 150 words and 1-2 graphs in each case) on the state and trends of zooplankton to new ecosystem overviews for (i) Iceland, (ii) Norwegian Seas, (iii) Azorean ecoregion and (iv) the Oceanic

north-east Atlantic ecoregion, if infor-mation is available (**ToR M,** intro by Piotr Margonski)

11:30 – 11:50 Progress Report on the MedZoo initiative (Maria Grazia Mazzocchi and Lidia Yebra)

11:50 – 12:10 Progress Report on Trophic ecology of Zooplankton in English Channel and North Sea (Pierre Cresson)

12:10 – 12:30 Report on the 2016 Theme Session M 'The role of zooplankton in exploited ecosystems: top-down and bottom-up stresses on pelagic food webs' (Piotr Margonski, Angus Atkinson by correspondence, and Webjoern Melle)

12:30 – 14:00 Lunch Break

14:00 – 14:30 Discussion on the new MA ToRs (New Chair)

14:30 – 15:30 AOB, Next Year Venue & Timing, Work Plan, and Closure

15:30 – 16:00 Coffee Break