WORKING GROUP ON ZOOPLANKTON ECOLOGY (WGZE; outputs from 2020 meeting)

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Contents

i Executive summary

The Working Group on Zooplankton Ecology (WGZE) gathers zooplankton researchers from the North Atlantic and adjacent regions, performing comparative analyses of zooplankton time-series, and reviewing new zooplankton sampling and analysis technologies. This report is an overview of ongoing activities covering central aspects of zooplankton ecology.

Zooplankton production methodologies were reviewed, in collaboration with the PICES Working Group on Zooplankton Production Methodologies, Applications and Measurements in PICES Regions (WG37), resulting in the production of two review papers on methods to estimate zooplankton growth, several international workshops and theme sessions, the creation of a database of biomass/production data, and two manuscripts in preparations on evaluating methods for zooplankton productivity and metabolism. Information on key zooplankton traits was assembled to create a reference database, and data gaps were identified. A meta-analysis was conducted for an overview over the most important zooplankton species in terms of abundance, biomass or ecosystem function in the ICES seas. Fifteen traits were identified to be of greatest interest. The WGZE web site (wgze.net) now features the in-development WGZE Biometrics Atlas, summarizing available length and weight data for species common to the ICES regions. A couple of "dark" or legacy data sets have been brought forward by the WGZE members and, a mechanism was created to archive and serve them through the NOAA global plankton database COPEPOD, including automated QC. New data are now added each year.

Mesopelagic macrozooplankton knowledge, and their impact on the carbon flux into the deep-sea were reviewed, resulting in the ICES Annual Science Conference (ASC) theme session on mesopelagic ecosystems. Zooplankton time-series from the North Atlantic were compared to identify spatial coherence in patterns of community change. Species maps of average relative ranking as well as assessments of changes in relative rank over time and between regions, and correlations with environmental changes, were all produced. This work is ongoing, and an online interactive "atlas" of ICES region zooplankton species distributions and relative rank maps is being developed.

An inventory of time-series on gelatinous plankton in the ICES area was produced. Quantitative methods used to study gelatinous plankton were summarised and best practice recommendations provided for the implementation of their monitoring in the ICES area. Also, information on microzooplankton from over 60 time-series was compiled. Discussions regarding best practice for sample collection, fixation and enumeration resulted in a collaborative manuscript submitted to ICES JMS. Real-time zooplankton sampling systems were reviewed. These instruments could be incorporated into existing zooplankton monitoring programs throughout the ICES area.

The production of a Plankton Status Report, including 160+ phyto- and zooplankton time-series has been a challenging task, with an intended submission date of March 2021. A paper summarizing the history and major findings of the report will be submitted to ICES *Journal of Marine Science* (JMS) zooplankton time-series themed articles set promoted by WGZE.

Collaborative activities continued between WGZE, WGPME (Working Group on Phytoplankton and Microbial Ecology) and WGIMT (Working Group on Integrated Morphological and Molecular Taxonomy), with a number of joint theme sessions at the ICES ASC, a training workshop, three peer-reviewed papers and the production of updated and new ICES plankton identification leaflets, including five leaflets published and several in preparation.

ii Expert group information

Expert group name	Working Group on Zooplankton Ecology (WGZE)
Expert group cycle	Multiannual
Year cycle started	2018
Reporting year in cycle	3/3
Chair(s)	Lidia Yebra, Spain
	Sophie Pitois, UK
Meeting venue(s) and dates	20–23 March 2018 Helsinki, Finland (31 participants)
	11–14 March 2019 Las Palmas de Gran Canaria, Spain (30 participants)
	23–26 March 2020 by correspondence (26 participants)

1 Review the use of zooplankton production methodologies in collaboration with PICES BIO WG37 (ToR A)

Over the past two decades, quantitative evaluation of zooplankton production and its driving forces has been emphasized as a component of improving our methodologies in understanding of how marine ecosystems respond to global change. While many methodologies to estimate 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. WGZE has identified and pursued the need for an evaluation of existing, new and emerging methodologies since 2004. In 2016, at the workshop 'ICES/PICES cooperative research initiative: towards a global measurement of zooplankton production' (held during the 6th ICES/PICES Zooplankton Production Symposium), the community decided to propose to the PICES-BIO committee the creation of the Working Group on Zooplankton Production Methodologies, Applications and Measurements in PICES regions (WG37) to foster targeted activities for promoting scientific collaboration and better coordination in support of knowledge transfer on this important topic. WGZE and WG37 share common interests and their collaboration since 2017 has been key for the success of the ICES/PICES cooperative initiative.

Outcomes of the ongoing collaboration between both Working Groups:

- Worldwide list of scientists and laboratories measuring zooplankton production: A table of scientists, affiliated institutions, methods applied, and publications of zooplankton production studies has been compiled for the Atlantic, Mediterranean and Pacific. This table is available on the WGZE website (https://wgze.net/production) and will be periodically updated with additional researchers and new publications.
- Review of existing methods for the assessment of field zooplankton production: Two review papers on methods to estimate zooplankton growth have been produced:
- Yebra L, T Kobari, AR Sastri, F Gusmao, S Hernández-León (2017) Advances in biochemical indices of zooplankton production. Advances in Marine Biology 76(4): 157-240. 10.1016/bs.amb.2016.09.001
- Kobari T, AR Sastri, L Yebra, H Liu, RR Hopcroft (2019) Evaluation of trade-offs in traditional methodologies for measuring metazooplankton growth rates: Assumptions, advantages and disadvantages for field applications. Progress in Oceanography 178:102137. doi: 10.1016/j.pocean.2019.102137
- Organisation of scientific meetings and training courses on zooplankton production methodologies: WGZE and WG37 convened several international workshops and theme sessions:
    - Workshop Advantages and limitations of traditional and biochemical methods of measuring zooplankton production, PICES 2017 Annual Meeting, (2017, Vladivostok, Russia)
    - Workshop Regional evaluation of secondary production observations and application of methodology in the North Pacific, PICES 2018 Annual Meeting, (2018, Yokohama, Japan)
    - Workshop PICES/ICES collaborative research initiative: Toward regional to global measurements and comparisons of zooplankton production using existing data sets, PICES 2019 Annual Meeting, (2019, Victoria, Canada)

- Session Zooplankton Productivity as a Function of Trophodynamics in Marine Ecosystems, 2018 Ocean Sciences Meeting, (2018, Portland, USA)

Also, two training workshops on conceptual and practical aspects of various methodologies were organised to allow exchange of information, comparison and calibration among methods. Practical Workshop Phase I focused on traditional methodologies for *in situ* zooplankton production determination (2018, Yokohama, Japan) while Phase 2 dealt with biochemical production indices for *in situ* zooplankton production in (2019, Quadra Island, Canada).

Advances on the assessment of zooplankton production

- Compilation of zooplankton production data in an online database: A pilot database of biomass/production data has been created (http://wgze.net/traits-n-rates), including equations, rates and measures (e.g., allometric, biometric, and relationships with environmental variables). Addition of individual Nitrogen and Phosphorus content, and rates, is also being considered as a future expansion to this data collection.

- Comparison between models in use to estimate zooplankton production: Data from 20 time-series are being used to estimate zooplankton production using allometric approaches based on empirically derived formulas using both laboratory and theoretically-derived measurements. The primary goal is to calculate individual specific growth rates, multiplied with biomass concentration. 50 empirical models were tested. The results of these studies are being drafted as two manuscripts to be submitted to ICES JMS theme set on time-series by March 2021. The summaries are given below.

Calculation of potential zooplankton production and metabolism: I. Evaluation of methods. Lutz Postel (publication in prep.)

Practicable and standardized methods have been available for the global measurement of primary production since the middle of the last century (Uye *et al.* 1983, Yebra *et al.* 2017). Comparable smart routines are missing for the measurement of production of zooplankton which is the main food resource of pelagic fish. Successful management of fish stocks, however, requires reliable information about it and its fluctuations. Fortunately, quite a number of time-series exist in the ICES area (O'Brien *et al.* 2013) on which biomass concentration and often abundance and taxonomic composition of plankton are part of the data sets in addition to environmental parameters such as temperature and chlorophyll. Basing on these stock variables the zooplankton productivity could be calculated by using equations, which were empirically developed mostly on the basis of production measurements in laboratories. Calculations by allometric approaches seem to be the most convenient method because body mass is fundamental in ruling specific metabolic activity and growth (Peters 1983). For this purpose, the average individual-specific biomass is required, which is easy to obtain from the biomass concentration divided by the abundance. Approximately seventies equations had been assessed for their suitability for the calculations of growth rates here.

The data from the ICES Sea Going workshop from June 1993 in Storefjord, Norway (Skjoldal *et al.* 2013), were preferably used for this test. Attention was also drawn on the estimation of productivity from metabolic rates (physiological approach) because vertical profiles of potential rates of respiration, ammonia excretion, and relative growth had been measured during the same campaign in parallel to zooplankton biomass concentration and abundance.

Finally, a combination of criteria was used for the assessment: (1) the similarity with the values given in the literature, preferably from in-situ experiments, (2) the strength of the correlation between the calculated vertical profiles and the profile of the measured relative growth rate and (3) the similarity with the results of the change (slope) in the biomass concentration during the vegetation period (Rigler and Downing 1984). This approach requires high sampling frequency at least weekly sampling intervals.

Textbooks on zoology contain accepted knowledge on developmental times of different zooplankton taxa. In combination with recent results from *in situ* measurements (Renz *et al.* 2006) a median growth rate of 0.035 d^{-1} was found using N=136 reference values. There were smaller growth rates in "Subpolar – Temperate Waters" (median: 0.023 d^{-1}) in comparison to "Subtropical – Tropical Waters" (median: 0,080 d^{-1}) after splitting data into these two provinces.

The evaluation of the accuracy of calculated growth rates in terms of magnitudes and vertical distribution patterns required measurements that were made as close as possible to the acquisition of the initial data for the calculations. Fortunately, samples for determination of enzymatic activity as indicators for respiration (Electron Transport System, ETS), ammonium excretion (Glutamate De-Hydrogenase, GDH) and growth index (Aspartate Trans-Carbamylase, ATC) fulfilled this requirement in terms of expected vertical patterns.

Using Winberg 's balanced equations for fishes and adaptation for zooplankton (Winberg 1956), Ikeda and Motoda (1978a,b) estimated productivity from respiration. Applied in the present study, the median of the N = 51 measurements of potential activity (converted to *in situ* conditions) was 0.048 d^{-1}, which was twice as high as is to be expected in temperate latitudes (median: 0.023 d^{-1}), where the samples were taken. The vertical profile was neither clear decreasing, as with temperature, nor noticeably increasing, as with the body mass. In contrast, vertical profiles of growth index (ATC activity) and the O:N ratio determined by the ratio of ETS and GDH showed decreasing course with increasing depth. Both were strongly correlated between each other (c.f. Bidigare *et al.* 1982, Mayzaud and Conover 1988). This indicated that sampling in Storefjord / Norway took place in a phase of active growth in the upper layer.

The determination of *in situ* growth rates from the change (slope) in the biomass concentration during the vegetation period completed the opportunities to verify results of calculations. For this purpose, the seasonal course of the long-term mean of zooplankton time-series with weekly sampling interval off Plymouth /U.K. (Harris 2010) were investigated. It peaked in June and in October. Lows had been in December / January and in July. The monthly biomass concentration averaged over several years increased by 0.044 d^{-1} from January to June, and by 0.036 d^{-1} from July to October. Nevertheless, one need to consider the meridional difference of 12 degrees between the two locations (dataset was kindly provided by Plymouth Marine Laboratory).

Finally, those of the approximately seventies equations should be the most promising candidates for general use whose vertical profile fits to the growth indicator (ATC) in a statistically significant manner ($p<0.05$ and $p<0.1$). and who lie within the expected rates compiled from the literature (0.023 d^{-1} for the "Subpolar - Temperate Waters" and 0.080 d^{-1} for "Subtropical - Tropical Waters". The median for all references of 0.035 d^{-1} was set as the border between the two regions.

In result, there were seven equations which met the conditions. The equation for Post-Embryonic Development Time (PEDT) [d] of Gillooly (2000) fitted best with the expected magnitude in "Subpolar - Temperate Waters" ($p<0.1$). The equation (3) of Banse and Mosher (1980) were stronger correlated ($p<0.05$) with the growth index (ATC) profile. Practical aspects will lead to the final decision.

Calculation of potential zooplankton production and metabolism: II. Zooplankton productivity and metabolic rates in the ICES area. Lutz Postel *et al.* (publication in prep.)

This global goal should be achieved by applying both (1) the empirically developed equation for estimating zooplankton productivity and (2) the slope in the course of the plankton concentration during the vegetation period (Rigler and Downing 1984).

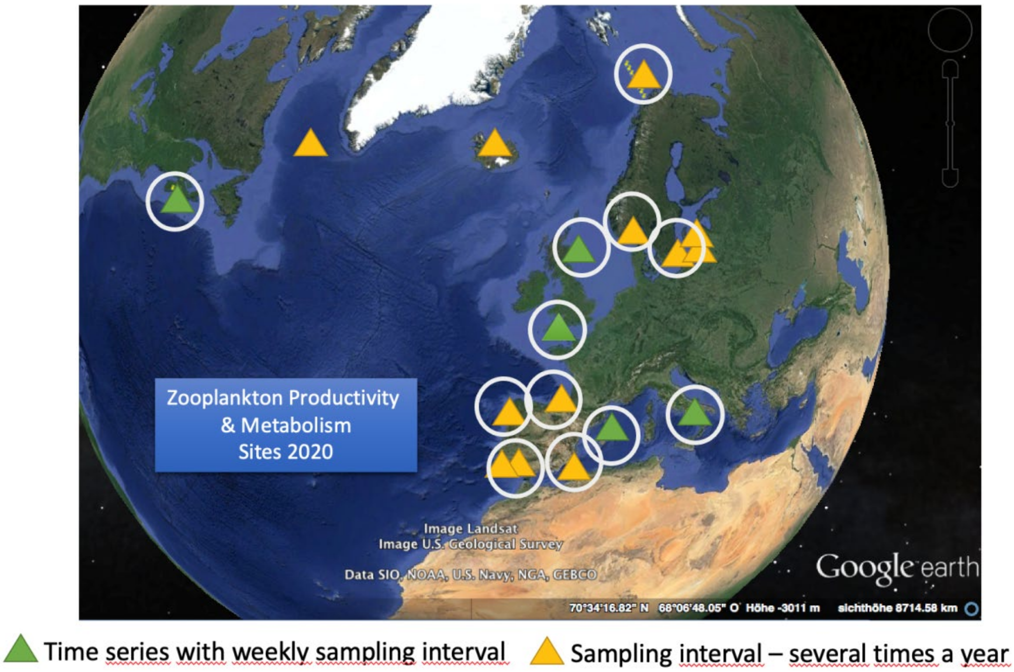

Figure 1. Current zooplankton times series in the ICES area used for this study

Starting with the determination of average individual specific biomass the average specific productivity will be available for the inter-comparison between the regions e.g., during the time when production peaks. According to it, largest organisms were detected on time-series “Halifax Line” (Labrador Sea) and the smallest in the Baltic Sea. Specific growth rates behaved opposite. Multiplying them with biomass concentration one obtains zooplankton productivity. The highest was found in the Baltic Sea while the lowest were located in the Mediterranean Sea as expected. This is a result of the differences between the humid and arid climate and its consequence for nutrient availability in the euphotic layer due to estuarine and anti-estuarine circulation in the Baltic and in the Mediterranean Sea respectively.

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2 Compile data and provide expert knowledge and guidance in the definition of key traits of zooplankton species in the ICES area (ToR B)

Traits are heritable properties of an individual that are interrelated through trade-offs and selected by the environment (per definition after Brun *et al.* 2017). Furthermore, a criterion of measurability is applied, and traits should be measurable on the individual without any assisting information (Violle *et al.* 2007). In general, trait-based approaches are used to reduce the complexity of zooplankton in ecosystem models. Litchman, Ohman and Kiørboe (2013) characterize traits according to their function and type with the function divided into feeding, growth and reproduction and survival and the type divided into life history traits, those belonging to behaviour, physiological and morphological traits.

The following goals of ToR B were discussed to be fulfilled within the 3-year term: 1) to compile a database of known species-level zooplankton traits for the North Atlantic and adjacent seas; 2) to compile a "wish list" of key zooplankton species within the ICES area that are still missing some or all trait data; 3) to write a peer-reviewed publication on the methods and data of this compiled database.

For the first ToR goal, already existing work (papers and databases) were assembled to find the missing taxa groups and other holes (e.g. geographic, entire taxa groups) and create a literature/ reference database to exchange papers and relevant documents. We identified this collection of zooplankton trait databases that are currently available:

- A database by Benedetti, Gasparini and Ayata, 2016, Journal of Plankton Research: Identifying copepod functional groups from species functional traits. This database includes functional traits of the most representative copepod species in the Mediterranean Sea for 191 species, described by 7 traits, which are minimal and maximal body length, trophic group, feeding type, spawning strategy, diel vertical migration and vertical habitat.
- A database by Brun, Payne and Kiørboe, 2017, Earth System Science Data: A trait database for Marine Copepods (includes Benedetti *et al.* 2016). This database includes planktonic copepods, mostly calanoids, some cyclopoids, harpacticoids, siphonostomatoids, with 9306 records for 14 functional traits, which are separated for different life stages when possible. Traits included are body size/mass (TL, mean, max, min), feeding mode, clearance rates, ingestion rate, spawning strategy, egg size, clutch size, fecundity, myelination, hibernation, resting eggs, respiration rates, growth rates, development duration and taxonomy.
- A database by Hebert, Beissner and Maranger, 2016, Ecology: A compilation of quantitative functional traits for marine and freshwater crustacean zooplankton. The database includes copepods (calanoids, cyclopoids), cladocerans from marine and freshwater habitats, with 8370 crustacean zooplankton trait observations, corresponding to 191 marine and 201 freshwater taxa. Traits included are zooplankton traits contributing to carbon, nitrogen, and phosphorus cycling. It includes traits on body stoichiometry and physiology based on the importance of zooplankton affecting individual energy fluxes and elemental processing (N, P and C content, N and P excretion rates and ratios, and respiration rates), species dry mass for mass-specific excretion and respiration rates. Dry mass estimates based on taxon-specific length-mass allometric equations are allowed and standardized temperature correction for zooplankton metabolic rates included.

WGZE member also introduced additional ongoing work:

- Padmini Delpadado introduced a (currently not public) database on zooplankton traits in the Barents Sea (BSECO), created by Marta Gluchowska and Padmini Delpadado, that includes different zooplankton groups from the Barents Sea and currently has information about body size and weight, longevity, fecundity, life cycle, feeding mode, diet, habitat and biogeography. The establishment of the database is an ongoing project.
- Angus Atkinson made the group aware of the 'Trait Explorer', which is developed within the UK "Marine Ecosystems" Programme (http://www.marine-ecosystems.org.uk/News/Trait_Explorer_traits_for_any_marine_species) and gives the option to explore traits obtained from existing databases (e.g., WORMS), published papers and new experiments. The Trait Explorer is a form of "automated expert judgement" that combines the taxonomic position of the species and any information on its traits, to provide the best possible estimate of all traits.

In support of the first and second goals of ToR B, data gaps were identified to be missing in available databases: The existing databases focus on calanoid copepods, other taxa, e.g. decapods, hydrozoans, mysids, euphausids, are mostly missing. Some traits, as e.g. growth rates, clearance rates, reproduction frequency, vertical migration, motility or size at maturation are currently missing, at least in the available databases (Figure 2). Furthermore, in the existing databases the areas of origin are not explicitly mentioned, although available via references given in the datasets, therefore the data/taxa coverage within the ICES area needs a detailed analysis.

For the second ToR goal, it was decided that a wish list of species and traits would be established, via WGZE group emails, to get an overview over the ecologically most abundant/important species for the ICES area and the traits needed to characterize these communities. Traits to be included into this wish list might be individual size or length or volume info, length-to-weight regressions, individual biomass info (wet, dry, carbon, N or P content), vertical depth distribution and migratory behaviour (DVM, ontogenetic vertical migration), reproductive strategy (free spawning, egg sac carrying, resting eggs), feeding modes (herbivore, carnivore, omnivore, filterer vs. ambush), life rates (respiration, excretion, growth, generation time), biogeographic realms (e.g., arctic vs tropical, cool vs warm, etc).

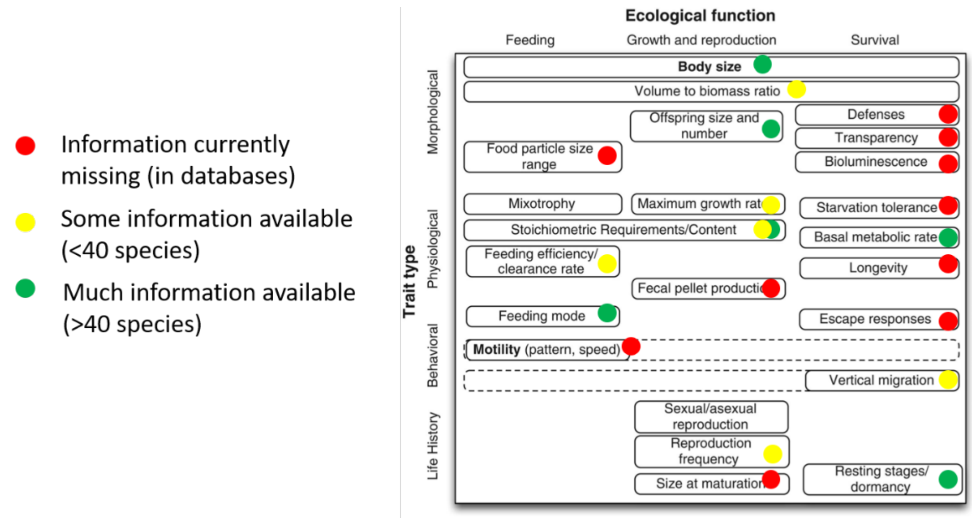

Figure 2. Meta analysis on traits available in online databases. Figure modified from Litchman, Ohman and Kiørboe, 2013, Journal of Plankton Research.

As part of the background work for this ToR, a meta-analysis was conducted, currently including data of 19 time-series in the North Atlantic and adjacent seas (Figure 3) to get an overview over the most important zooplankton species in terms of abundance, biomass or function in the ecosystem.

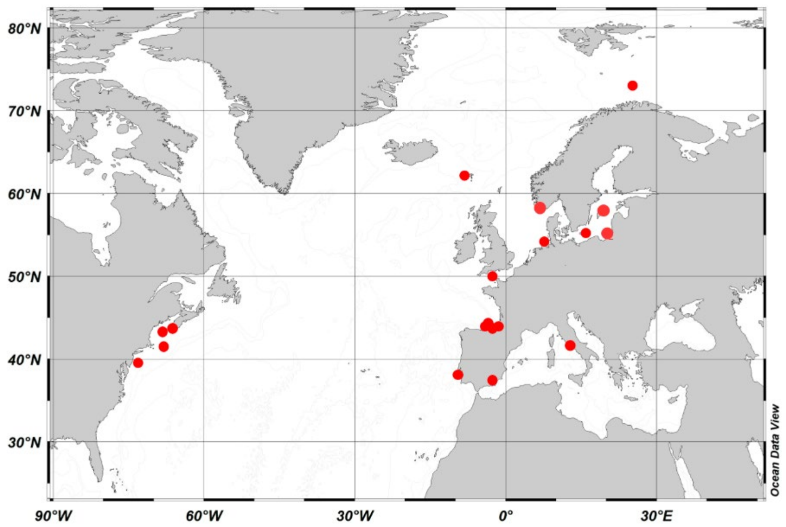

Figure 3. Time-series stations in the ICES area and the Mediterranean included into the meta-analysis on the most important species.

The analysis revealed 60 species, species groups and taxon groups (Table 1) to be of high importance in the ecosystems, with most of them calanoid copepods, the cyclopoid *Oithona* spp. or appendicularians. The group of cladocerans has high impact in several ecosystems, but species are varying between different areas. Fifteen traits were identified to be of greatest interest for the scientific community (body size, fecundity, growth rate, feeding mode, diet, ingestion rate, spawning strategy, resting egg production, hibernation, clutch size, egg size, body carbon mass, mortality rate, production rate, indigenous), with 5 of them accounting for categorical traits. Length data are considered to be of highest importance and are available for most species. They can be converted into carbon mass data, as directly measured carbon or nitrogen mass data are lacking for many species. Growth and ingestion rates are considered to be of high importance, but are rarely available as field or experimental data for different areas and species. Seasonal variation is rarely considered for most trait data and almost all species are lacking information on mortality rates. This meta-analysis will be continued in the following months. Based on the already existing work as well as a review of data that exist for the different time-series in the ICES area, a database connecting the ongoing efforts and work by WGZE and the reviewed work on traits is currently compiled. The format of the database is currently evaluated, e.g., a SQL database is already established and would be ready to use. The trait data collection as well as the build-up of the database will be an ongoing process over the next years.

Table 1. List of species, species groups and taxon groups with the number of stations in the ICES area where they are considered to play an important role in the ecosystem as assessed by experts associated with different time-series.

Paracalanus parvus	10	Appendicularia	2	*Clausocalanus pergens*	1
Temora longicornis	9	Decapod larvae	2	*Para-/Clausocalanus* spp.	1
Oithona similis	8	*Penilia avirostris*	2	*Synchaeta* spp.	1
Acartia clausi	7	*Bivalvia larvae*	2	*Microcalanus* spp.	1
Acartia spp.	6	*Pseudocalanus elongatus*	2	*Clausocalanus lividus*	1
Oithona spp.	6	*Bosmina coregoni maritima*	2	*Pleurobrachia pileus*	1
Centropages typicus	5	*Acartia tonsa*	2	*Oithona plumifera*	1
Calanus finmarchicus	5	*Evadne* spp.	2	*Podon* spp.	1
Centropages hamatus	5	*Centropages* spp.	2	*Calanus* spp.	1
Pseudocalanus spp.	5	*Fritillaria borealis*	2	*Muggiaea atlantica*	1
Oithona nana	4	*Limacina* spp.	2	*Clausocalanus* spp.	1
Acartia bifilosa	4	*Acartia longiremis*	2	*Pseudocalanus minutus*	1
Euterpina acutifrons	4	*Penilia* spp.	1	*Oikopleura* spp.	1
Evadne nordmanni	4	*Clausocalanus furcatus*	1	*Pseudodiaptomus marinus*	1
Metridia lucens	4	*Pseudo-/Paracalanus* spp.	1	*Cercopagis pengoi*	1
Oncaea spp.	3	*Evadne spinifera*	1	*Tachidius discipes*	1
Calanus helgolandicus	3	*Metridia* spp.	1	*Nannocalanus minor*	1
Clausocalanus arcuicornis	3	*Pseudocalanus acuspes*	1	Cirripedia larvae	1
Temora stylifera	3	*Podon intermedius*	1	*Oithona davisae*	1
Noctiluca scintillans	2	*Clausocalanus paululus*	1	Chaethognatha	1
Oncaea media	2	*Calanipeda aquaedulcis*	1	*Oithona longispina*	1

The third goal of this ToR, creating a peer reviewed publication, is waiting for final identification and collection of the important-yet-missing species and taxonomic group biometric data identified by this meta-analysis. Similar to the three biomass database papers earlier in this section, this new WGZE paper would also be a methods and data paper, focused on the methods of identifying and collecting these missing data, as well as making the data publicly available (and citable) in a data paper format.

As a side-product of this work, the WGZE web site (https://wgze.net/traits-n-rates) now features the in-development WGZE Biometrics Atlas, which summarizes the availability of length and weight data for zooplankton species commonly found in the ICES regions. It is hoped that this ToR will be continued and expanded over the next 3-years cycle, to include additional trait and rate data types, and will support the ongoing operational needs of the new WGZE ToRs.

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3 Recovery of "Dark Data" (datasets that are not available publicly) collected on or before WGZE time-series were started around 1990 (ToR 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). Zooplankton dark data sets collected in the past that are not available in public open data repositories are hidden in log books or on computer hard drives and discs in investigators labs, etc. Examples of application of successful "dark data" recovery were presented in the first year of the ToR (see for example Wiebe and Allison, 2015). The recommended metadata for zooplankton samples, created by the WGZE in 2003, was reviewed. A metadata spreadsheet provided by ICES, to provide zooplankton data to the ICES data repository, was also reviewed. A number of WGZE members were identified as having dark data sets, which was a starting point for this ToR's effort.

A couple of dark data sets have been brought forward by the WGZE members and by working with Todd O'Brien, a mechanism was created to archive and serve them through the NOAA database COPEPOD. Incoming data were processed into the COPEPOD master format, a documented, common format, suitable for archiving or submission to a data journal. Automated QC was applied, including WoRMS-based taxonomic verification, statistical outlier detection, and minimum metadata checks. The data provider worked with Todd to prepare documentation about the data and methods. COPEPOD can also help with archiving the data and getting a DOI. One of two data sets were recovered and now resides on COPEPOD and each year new data are added to this data set. The other data set was worked on by Todd, but unfortunately encountered permissions and release obstacles that have delayed its progress and completion. More recently, another data set of zooplankton species sequence data is being recovered as part of the SCOR working group MetaZoogene. Unpublished sequence data from a number of cruises together with essential metadata have been assembled and submitted to the GenBank, the NIH genetic sequence database. These along with other sequence data are being used to build a MetaZoogene reference database. Members of the WGZE have participated in this project.

WGZE will continue to encourage the determination of where dark data are located and will identify and contact the data holders to recommend that the data be deposited in a public repository.

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4 Macrozooplankton in the mesopelagic zone (ToR D)

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 tons, a number that is only slightly lower than the 1980 estimate of mesopelagic fish biomass alone (~ 1 billion tons). 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 tons, roughly equivalent to 100 times the annual catch of traditional fisheries of about 100 million metric tons. However, there is a lot of uncertainty coming with this biomass estimate.

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.

Figure 4. Example of mesopelagic species captured over NE Atlantic seamounts of the Madeira-Tore complex sampled with an Isaacs-Kidd Midwater Trawl during a survey of the BIOMETORE project from August- September 2016.

This three-year ToR reviewed the knowledge about the mesopelagic macrozooplankton taxonomy, abundance and 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.

Mesopelagic organisms are important conveyors of mass and energy into deeper waters. Diurnal migration and sound scattering layers are characteristic of the mesopelagic zone. Two new publications have characterized the biogeography of mesopelagic zones (200–1000m); (Sutton *et al.* 2017; Proud *et al.*, 2017). One based on acoustics and the other on environmental proxies such as primary production, salinity, temperature, and oxygen levels. It is important to highlight that much is unknown about the mesopelagic community and its functioning, especially the role of macroplankton taxa. Hence it is very important to address the role of macroplankton in the mesopelagic zone. The use of novel technology such as specially designed submersible transducers, optics, better trawls are considered, and several new projects are underway.

The international research project, MAR-ECO, studied the mid-Atlantic Ridge ecosystem from Iceland and to the Azores islands, with sampling from the whole water column using combined gears. Results are highly relevant to the present work and are published in a special volume of Deep Sea Research (2008). The main organisms observed were jellyfish, shrimps, euphausiids, and small mesopelagic fish. Diurnal migration of the mesopelagic organisms was evident during these cruises.

It is estimated that mesopelagic zooplankton should represent a higher biomass than fish, yet we know very little. To acquire the knowledge about sampling and adequate methods to do it are crucial. Several approaches are needed when studying the mesopelagic organisms (nets/trawls, optical and acoustic techniques) as none of the gears alone are optimal for catching quantitatively representative samples of the diverse mesopelagic fauna.

However there is the idea that using bigger gear e.g. larger trawls (800 m2 opening) with relatively small mesh sizes (3 or 10 mm mesh size) reduces avoidance, hence can catch representative samples and strobe lights could be used to get better catches of euphausiids.

Case studies

- **Distribution and diversity mesopelagic fauna in selected seamounts of Northeastern Atlantic** (García-Seoane *et al.* 2020): Mesopelagic fauna of three NE Atlantic seamounts (Gorringe Bank, Josephine and Seine) was sampled using an Isaacs-Kidd Midwater Trawl (IKMT) and acoustic records (EK-500 with 38 k), during a survey conducted from August-September 2016. A total of 98 taxa were identified: 52 crustaceans, 34 fish, 6 molluscs and 6 gelatinous organisms, belonging to 37 families. Multivariate analyses, based on presence-absence data, did not show significant differences among seamounts, day and night or position on the water column, neither detected seamount effect. However, some influence of the three NE Atlantic seamounts studied on the mesopelagic community was detected because higher biodiversity was found in oceanic waters compared to seamounts. In this work, the acoustic signal produced by mesopelagic organism was weakly detected by the echo sounder, probably due to a low level of aggregation of the mesopelagic resonant organisms. Echogram scrutiny suggests a diel vertical migration of the mesopelagic fauna.
- **Trophic Relationships in the mesopelagic layers south west of Iceland** (Hildur Pétursdóttir *et al.* 2008): Trophic relationships in the mesopelagic zone in the Mid Atlantic Reykjanes Ridge, South of Iceland, were presented. This region is characterized with high primary production, zooplankton biomass and fish diversity. This is also an important nursery and feeding ground for red fish. Stable isotope technique and fatty acids were used to structure trophic interactions of the mesopelagic organisms. The isotopic and fatty acid methods reflect dietary assimilation for longer periods than the traditional stomach content analysis. *Calanus finmarchicus* was used as a base. Two trophic pathways were observed, one via *C. finmarchicus* to mesopelagic organisms and the other with krill to red fish.
- **Species composition in the mesopelagic layer east of Iceland:** A macroplankton trawl was used to obtain samples. Species composition was resolved into several groups, including small mesopelagic fish. Species composition and abundance levels were compared in cold (west region) and warmer waters (east region). Amphipods and chaetognaths contributed more to the biomass in colder waters whereas euphausiids composed a major part of the biomass in warmer waters. Among amphipods, the Atlantic species

Themisto abyssorum dominated in numbers except at the coldest station where the arctic species *T. libellula* dominated. Among krill species *Meganyctiphanes norvegica* was in highest numbers in all study area.

WGZE also proposed a theme session for the ICES ASC in relation to mesopelagic ecosystems: **Mesopelagic ecosystems: fish and invertebrate population biomass and biodiversity, and role in carbon flux (ICES ASC in Hamburg, Germany -** Conveners: Webjørn Melle (Norway), Antonina dos Santos (Portugal), Peter Wieb**e** (USA)): The session was proposed by the WGZE recognizing that 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 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 in the sequestration of carbon in the deep sea. The purpose of the session was to provide a forum for presentations on:

- mesopelagic taxonomy;
- abundance and biomass;
- trophic ecology;
- reproductive biology;
- major gaps that remain to be addressed in order to sustain this system in the face of climate change and resource exploitation.

Concluding Remarks

From the theme session and all discussions within the WGZE, three questions were considered:

- What are the major problems in abundance estimation of the mesopelagic biomass? It was agreed that estimation is difficult, due to depth distribution of the taxa and there is a need for more sophisticated acoustic devices as well as models. Also, it was highlighted the importance of knowing the number of species that belong to mesopelagic and agreed that DNA techniques will be extremely helpful in this case.
- What are the major steps forward? It was considered the need to have more works on the relation of gelatinous organisms with the mesopelagic and to study the influence of water masses (e.g. gyres) with the mesopelagic distribution.
- What will be the future challenges for abundance estimation of mesopelagic species? It was considered that more technological developments with new instrumentation will help estimate abundance of mesopelagic species but, models are also very useful for that.

The aim of ToR D was to produce a summary publication on the mesopelagic community knowledge so far. Several international research projects are presently being carried out on the ecology of mesopelagics in the North Atlantic (e.g. SUMMER, MEESO, Mission Atlantic, WHOI'S Ocean Twilight Zone Project). Members of the WGZE are actively taking part in several of these projects (e.g. Klevjer *et al.* 2019, Klevjer *et al.* 2020). Awaiting the outcomes of these projects, the decision was made to postpone a summary review.

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5 Analyse changes in the geographic distributions, seasonal patterns, and interannual trends of Arctic and North Atlantic macro- and meso-zooplankton species (ToR E)

Zooplankton communities are strongly influenced by ocean circulation and environmental conditions, which have been changing in the N. Atlantic. Changes in zooplankton communities have been observed at sites across the North Atlantic and compared at a regional scale, but the common or contrasting patterns of community change have not yet been assessed across WGZE time-series stations at the basin scale.

The WGZE time-series stations are sampled in a diverse range of mainly coastal and shelf environments, and the frequency and sampling and analysis methodology used is not standardized among time-series. Therefore, comparison of communities and their variability requires a robust approach that is relatively insensitive to methodological differences. Development of this analysis was intended to be inclusive of all time-series, regardless of sampling frequency (e.g., once per week *AND* once per year), with a suite of analyses applied as appropriate to the time-series characteristics.

Most time-series are suitable for the "interannual study", but only those with near-monthly data are suitable for a seasonal analysis. Initial analysis has focused on a limited set of time-series. More time-series can be added as the analysis is developed, with consideration given to requirements to support comparability as additional time-series are included. Documentation of the sampling and analysis methodology at each site is an integral part of the project, as it will support identification of time-series at which more detailed comparisons of community change can be made.

Objectives of the ToR E analysis include the following:

- Compare zooplankton time-series (and co-sampled environmental data) from across the North Atlantic to identify spatial coherence in patterns of community change.
- Focus on copepods, in a complementary analysis to the macrozooplankton analysis. However, other mesozooplankton such as cladocerans and rotifers could be included in areas such as the Baltic Sea where they are dominant or subdominant.
- Interpret patterns and associated environmental changes to infer processes that may drive change.
- The analysis will address the following questions:
    - What are the changes in species composition and spatial distribution?
    - Are there changes in the seasonal timing of the dominant/subdominant species or functional types?
    - Are there common or contrasting patterns of change across the North Atlantic?

Data Sources

An initial set of participating time-series has been identified, and species-level (or lowest-taxonomic level ID'd) zooplankton abundance data were compiled (Table 2). Environmental metrics from a data assimilation model are available at most sites, and additional, standard environmental metrics can be added as the analysis is developed. To provide maximum flexibility in making updates and improvements to the analysis as more sites are added, most data sets include all zooplankton taxa, at the taxonomic resolution generated by the sample analysis, although initial analyses include only copepods, as well as rotifers and cladocerans at sites where they are dominant taxa. Data were reformatted and re-aggregated as needed for consistency.

Table 2. Initial set of participating time-series and associated metadata, organised clockwise from western to eastern Atlantic sites

Ocean Region	Country	Sampling / Monitoring Programme	Sampling Site Name	Sampling Location	Sampling Duration	Sampling Frequency	Sampling Gear (diameter)	Sampling Mesh (µm)	Samping Depth (m)
Northwest Atlantic Shelf	United States of America	NEFSC Ecosystem Monitoring Program	MAB	Mid-Atlantic Bight (MAB)	1977 - present	Cross-monthly surveys, six times per year	Bongo Net (60 cm)	333 µm	0 to 200 (or bottom)
			SNE	Southern New England (SNE)					
			GOM	Gulf of Maine (GOM)					
			GB	Georges Bank (GB)					
	Canada	Atlantic Zone Monitoring Program (AZMP)	Prince 5	Bay of Fundy	1999 - present	Monthly / Biweekly / Weekly	Ring Net (75 cm)	200 µm	0 to bottom
			Halifax Line 2	Scotian Shelf					
Nordic and Barents Seas	Norway	IMR-Bergen	Svinøy Transect	Norwegian Sea	1996 - present	4 - 6 times per year	WP-2 Net (56 cm)	180 µm	0 to 200
			Fugløya-Bjørnøya Transect	Western Barents Sea	1994 - present	3 - 6 times per year			0 to bottom
Baltic	Finland	Finnish Environment Institute SYKE / HELCOM Monitoring	Bothnian Bay	Northern Baltic Sea	1979 - present	August	WP-2 Net (56 cm)	100 µm	Surface-thermocline, thermocline-halocline, halocline-bottom (if no clines then 0 to bottom)
			Bothnian Sea	Northern Baltic Sea					
			Gulf of Finland	Gulf of FInland					
			The Baltic Proper	Central Baltic Sea					
	Poland	HELCOM Monitoring	Gdańsk Basin	Gdańsk Basin	1979-present	3-6 times per year	WP-2 Net (57 cm)	100µm	0 to bottom
			Southern Gotland Basin	Southern Gotland Basin					
			Bornholm Basin	Bornholm Basin					
North Sea and English Channel	United Kingdom	MSS Inshore Ecosystem Monitoring Program	Stonehaven	Northwest North Sea	1997 - present	Weekly (52 weeks per year)	Bongo Net (40 cm)	200 µm	0 to 50
			Loch Ewe	Northwest Scotland	2002 - present				0 to 35
		Plymouth Marine Laboratory (PML)	Plymouth L4	English Channel	1988 - present	Weekly (~40 weeks per year)	WP-2 Net	200 µm	0 to 50
Bay of Biscay and northwest Iberian Shelf	Spain	Instituto Español de Oceanografía (IEO) - Spain ; seRies temporAles De oceanografIA en eL norte de ESpaña (RADIALES)	A Coruña	Northwest Iberian Shelf	1990 - present	Monthly	Juday Net (50 cm)	1971–96: 250 µm; 1996-present 200 µm	0 to 50
North Atlantic Basin	United Kingdom	Continuous Plankton Recorder	CPR Surveys	Trans-Atlantic Basin	1946 - present	Monthly (with gaps)	CPR (1.24 cm)	270 µm	sub-surface (7-10 m)

Metadata at time-series stations (e.g., gear type, deployment method, mesh size, station and sampling depth, frequency of sampling, start year) have been compiled, and documentation of sample analysis protocols, and any changes over time, is in progress.

As most of the WGZE time-series measure their zooplankton samples in terms of abundance (# of individuals), we are working with WGZE ToR B (zooplankton biometric trait data) to assemble a list of average individual weights for each species in this study. Using total species biomass (versus total species abundance) is important since individual sizes can vary significantly. For example, 500 *Oithona* individuals have less total biomass than 50 *Calanus* individuals, so ranking by biomass versus ranking by abundance can give different results. This approach provides a biomass-based view of the impact of community change, which is complementary to the abundance-based perspective and reflects the impact of large biomass differences between small (e.g. *Oithona*) and large (e.g. *Calanus*) taxa.

Analysis Approach

Outputs of this ToR include species maps of average relative ranking (Figure 5) as well as assessments of changes in relative rank over time and between regions, and correlations with changes in environmental data. A pilot "Relative-Rank Analysis" was used to examine relative changes (e.g., "species X went from first place to third place") rather than exact numerical changes (e.g. "species X went from 10 g/m2 to 4 g/m2") in dominant and subdominant species, allowing for comparison between different gear types or methods, assuming the method remained consistent in each time-series itself. The maps in figure 5 are based on data from 1958–2017. By constraining the time period, ranking status over different time period can be examined. For example, looking at data from the last 10 years, a period of strong warming in the North Atlantic, maps of the cool water preferring *Calanus finmarchicus* shows visible changes. In some regions the Gulf of Maine and Scotian Shelf, this species went from being dominant to 3rd, 5th or even lower ranking.

Analysis of zooplankton community changes is ongoing, and outcomes from this ToR include development of an online interactive "atlas" of ICES region zooplankton species distributions and relative rank maps (see Figure 5).

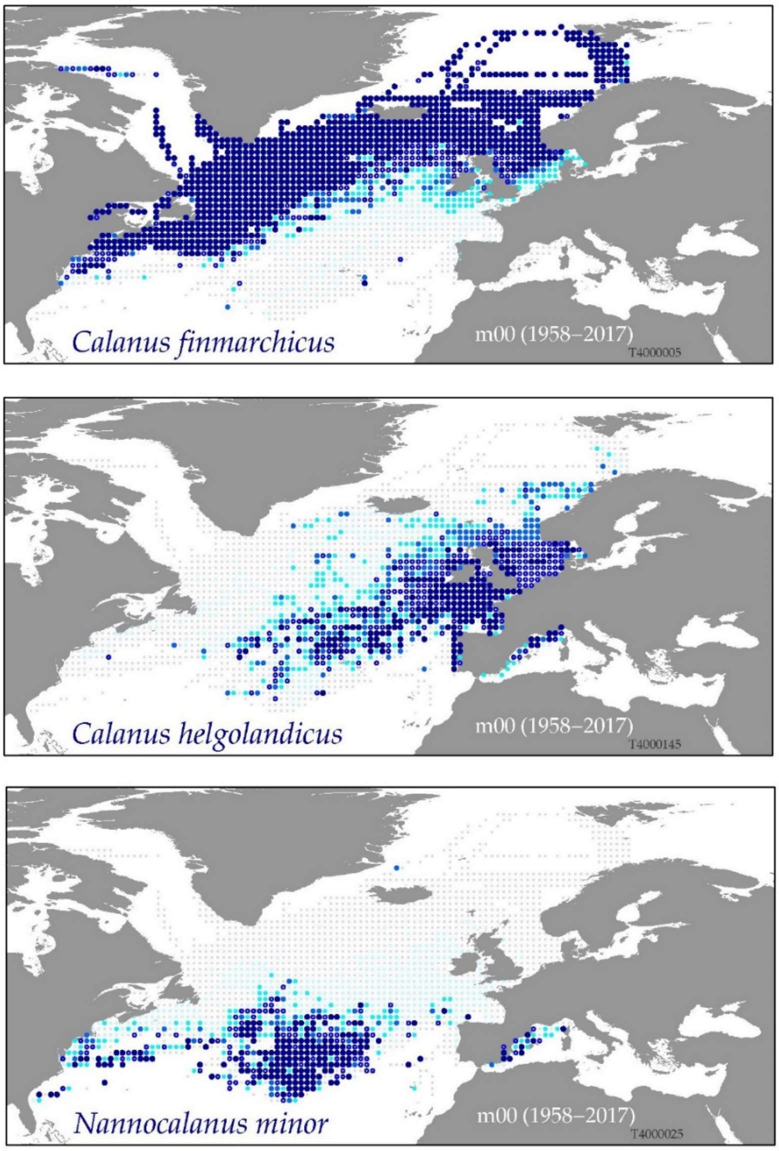

Figure 5. Spatial ranking maps of three common copepod species in the ICES North.

Atlantic Region

Based on average relative ranking during the 1958–2017 time period. Symbol colours, from darkest to lightest, represent the dominance of each species in the map area under that symbol. The darkest blue symbol indicates the species was the #1 ranked (most dominant, 1st) copepod species at that location. Symbol colors then lighten to indicate the species were not dominant but were 2nd, 3rd, or 4th-5th most abundant at that location. The faint gray symbols indicate sampling locations where the species was ranked 6th or lower. In this mapping method, only one species can have the very darkest symbol color (1st rank) at any location.

Case studies- Climate effects on temporal and spatial dynamics of mesozooplankton and macrozooplankton in the Barents Sea

This research above was partially conducted under ToR E activities of the ICES WGZE. The aim behind this work was to explore possibilities of expanding this research to broader areas, covering the north Atlantic. The Barents Sea is warming at an unprecedented rate, leading to a widespread Atlantification and changes in ecological boundaries. With the expanded Atlantic water areas, the biomass dominated by copepod *Calanus finmarchicus* has increased with Arctic *C. glacialis* showing decreasing tendencies. The study on Barents Sea showed that the conditions for mesozooplankton production are favourable, likely as a results of prolonged/increased net primary production (due to larger ice free areas), partly counteracting high predation levels occurring in this region. The above study indicated that the ice free conditions observed in high Arctic regions may promote further borealization of plankton in these regions. The species composition data of these surveys are incorporated in the study of contrasting patterns of community change across the North Atlantic.

Another aim of ToR E activities was to investigate spatial and temporal distributions of larger zooplankton such as euphausiids (krill) and amphipods. The sampling of the larger zooplankton using traditional gears is problematic due to their avoidance. A questionnaire was sent to ICES WGZE participants to map the ongoing activities, particularly focusing on the gears used to sample these larger zooplankton. The gathered information showed that the sampling spanned from large gears as trawls to simple ring nets. There is a strong need to standardize sampling methods across north Atlantic to obtain representative catches of these larger zooplankton. It is important to access the impact of warming on their biomass and species composition as these organisms are vital part of the food web in the north Atlantic. Recent studies indicate large changes in macrozooplankton communities, with decrease in cold waters associated species and an increase in more boreal Atlantic species. The largest of the krill species, *Meganyctiphanes norvegica,* which is regarded as a boreal species was in the past present only at the entrance of the Barents Sea. Using data from two time periods with opposing climatic conditions showed that *M. norvegica* has been expanding north- and eastwards into the Barents Sea in recent decades. Furthermore, this study showed that *M. norvegica* has increased in abundance, now constituting a significant part of the relative euphausiid species composition. With continuous warming of the Arctic Ocean, *M. norvegica* could become a resident species with potential to reproduce in the Barents Sea. As this species contribute largely to krill biomass in the north Atlantic, coordinated activities to monitor their distributional changes are of importance.

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6 Gelatinous plankton - time-series collection, and recommendations regarding monitoring (ToR F)

Gelatinous plankton play 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. Their fragile nature often excludes gelatinous zooplankton from regular monitoring programs, and recent time-series are still too short to document trends or conclude on the mechanisms behind blooms. 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 ToR will provide the basis for future studies on distribution and temporal patterns of gelatinous zooplankton.

The aims of this ToR were to:

- provide an inventory of existing time-series on gelatinous plankton in the ICES area together with a compilation of metadata on the available datasets;
- 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.

Metadata on existing time-series

In order to provide an inventory of existing time-series on gelatinous plankton in the ICES area, a metadata spreadsheet was distributed among WGZE members and others. In this ToR, the term "gelatinous zooplankton" includes planktonic cnidarians, ctenophores, and tunicates (appendicularians, pyrosomes, salps and doliolids). The compilation includes 52 time-series, with associated metadata on location, sampling techniques, responsible laboratories and contact persons (Table 3).

Thirty eight of the listed time-series are monitoring programs that are still running. The majority of the time-series have a time span of less than 20 years, while 11 of the listed monitoring programs have been running for > 30 years. The longest time-series is from the northern Adriatic Sea with data from 219 years of sampling (Kogovsek *et al.* 2010). The sampling frequency varies between locations. Coastal stations are typically sampled with higher frequencies (daily – weekly) compared to open ocean locations (annual cruises).

In more than half of the time-series (29) the gelatinous data is to be considered as "by catch" from fish surveys or from standard monitoring of crustacean zooplankton. The remaining 23 sampling programs have been designed for targeting gelatinous zooplankton.

A variety of sampling equipment and mesh sizes are being used, collecting different sizes and taxonomic groups of gelatinous zooplankton. In all sampling programs that are specifically targeting gelatinous plankton, vertical or oblique hauls with plankton ring nets (100–500 μm) are used. Seven time-series are based on by-catches from large-meshed fish trawls and fish traps. In addition, 6 citizen science programs have been established in Portugal, France, Finland, Latvia, Norway and in the Mediterranean Sea (CIESM).

Only 7 of the time-series listed in Table 3 are based on by-catches from fishery surveys. Considering the large amount of fishery surveys conducted in the ICES area, this is clearly an underutilized potential for obtaining data on gelatinous zooplankton. Most of the time-series are single stations located near the shore, which does not necessarily reflect the processes occurring offshore. By utilizing fish surveys, larger areas offshore will be covered.

Although fish trawls will only catch the larger species (macro- megaplankton), this will provide valuable information on spatio-temporal patterns of gelatinous plankton if standardized practices are followed. A protocol for collecting data on gelatinous by catches in fish trawls has been developed for fishery trawl surveys in the North Sea (Aubert *et al.* 2018). As a result, gelatinous zooplankton were included the French implementation of the EU's Marine Strategy Framework Directive (MSFD).

Data availability

Gelatinous zooplankton data collected in the past are often not available in public open data repositories (“dark data”). However, of the 51 time-series listed in Table 3, 32 have been published, or are available in open access databases. Several of the time-series are also available in the JeDI database (the Jellyfish Database Initiative, Condon *et al.* 2014), an accessible database on gelatinous zooplankton available at http://jedi.nceas.ucsb.edu, (last updated in 2011)

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

Knowledge on the ecology of gelatinous zooplankton for the ICES area are still limited when compared with the crustacean zooplankton mainly due to difficulties in sampling, quantifying and identifying gelatinous taxa from plankton samples. As showed above, most long-term monitoring programs through Europe do not consider jellyfish species, leading to a need to expand the current time-series programs as to include gelatinous zooplankton in the processing and analysis of plankton samples. This monitoring improvement will be crucial to clarify the hypothesis of the increase tendency of jellyfish populations as driven by climate changes which could lead to the deterioration of coastal marine ecosystems. Plankton nets are widely used to collect samples in the majority of the monitoring programs. However, net sampling and trawling often damage fragile plankton as gelatinous species, and therefore are not the best method to use, especially to quantify and assess biodiversity. A first approach to the challenges related to the sampling of gelatinous plankton is given by Magalhães *et al.* (2020), in a review of new technological developments that can be used to acquire information on gelatinous species. This chapter starts with a brief description of the life history and ecology of jellyfish, followed by an outline of their growing ecological relevance and impact on marine ecosystems. Then, it explores emerging technologies, such as the coupling of distributed autonomous systems with new real-time data processing methods, as well as the usefulness of autonomous *in situ* environmental DNA (eDNA) samplers. Citizen science programs are presented as an important tool to improve and complement the existing monitoring programs by increasing spatial and temporal resolution.

Considering that new equipment and techniques are starting to be used more broadly, it is still premature to indicate methods for quantify gelatinous plankton. The standard plankton nets that are used for sampling crustacean zooplankton are also used for the quantification of gelatinous plankton. However, samples should be analysed and processed as fast as possible to avoid the deterioration of gelatinous species.

Concluding Remarks

No single method offers a sole solution to comprehensively sample gelatinous zooplankton diversity. Plankton ring nets (200–500 µm) are an easy sampling method providing quantitative data on small and fragile species. However, rare and large species (e.g. scyphozoa) will be underestimated in small nets and may be better sampled with small pelagic trawls (Hosia *et al.* 2017) or using new technologies as DNA probes to automated vehicles and imaging systems (Magalhães *et al.* 2020). In addition to gear selectivity, ctenophores will be underestimated in preserved net samples, compared to *in situ* observations. Metabarcoding could in the future provide an alternative method to recover diversity information, but this requires further development of the methods as well as the reference databases (Almaru 2017). Considering the widely diverse group of gelatinous plankton, both in terms of densities and sizes, we recommend a combination of different sampling methods to provide the necessary spatio-temporal breadth in abundances and diversity.

Quantitative monitoring of gelatinous zooplankton often requires specialized sampling methods and taxonomic expertise. For this reason, gelatinous data collection activities are usually designed for short-term projects, rarely included in national monitoring programs, and long-term data sets covering larger areas is lacking. In order to secure gelatinous time-series, the methods should be simple, cheap and robust. To include gelatinous zooplankton in the standard plankton monitoring and fisheries surveys, is a realistic and cost effective alternative for providing long-term time-series on gelatinous plankton. We propose that gelatinous zooplankton are not exceedingly difficult to work with and suggest that they could be relatively easily included in on-going plankton monitoring.

Table 3. Metadata on time-series and monitoring of gelatinous zooplankton in the ICES area.

Region	Name of station/area	Latitude	Longitude	Ongoing? (YES or NO)	From	To	Frequency	Sampling design	Fixed samples	Sampling gear	Mesh size (mm)	Institute	Contact name	References
NW Atlantic	Halifax-2 (Scotian Shelf)	44.27 N	63.32 W	Y	1999	to date	2 /month	By catch	Y (F)	Plankton ring net	0.2	Atlantic Zone Monitoring Program (AZMP) - DFO Maritimes	Catherine Johnson	Johnson et al 2020
	Prince-5 (Bay of Fundy)	47.93 N	66.85 W	Y	1999	to date	1 /month	By catch	Y (F)	Plankton ring net	0.2	Atlantic Zone Monitoring Program (AZMP) - DFO Maritimes	Catherine Johnson	Johnson et al 2020
	Scotian Shelf	41.9 - 47.6 N	57.5 - 65.5 W	Y	1999	to date	2 / year	By catch	Y (F)	Plankton ring net	0.2	Atlantic Zone Monitoring Program (AZMP) - DFO Maritimes	Catherine Johnson	Johnson et al 2020
	Rimouski (Lower St. Lawrence Estuary)	48.67 N	68.58 W	Y	1994	to date	1 / week	By catch	Y (F)	Plankton ring net	0.2-0.333	Atlantic Zone Monitoring Program (AZMP) - DFO Quebec	Stephane Plourde	
	Shediac (southern Gulf of St. Lawrence)	47.78 N	64.03 W	Y	1999	to date	1 /month	By catch	Y (F)	Plankton ring net	0.2	Atlantic Zone Monitoring Program (AZMP) - DFO Quebec	Stephane Plourde	Galbraith et al 2013; Devine et al 2013
	S27 (Newfoundland Shelf)	47.5 N	52.59 W	Y	1999	to date	2 per month	By catch	Y (F)	Plankton ring net	0.2	Atlantic Zone Monitoring Program (AZMP) - DFO Newfoundland & Labrador	Pierre Pepin	
	Mid Atlantic Bight	35-44 N	65-75 W	NO	1977	2009	2-4 / year	By catch	NO	Plankton ring net, Fish trawl	0.333	Northeast Fisheries Science Center (NEFSC)	BRIAN E. SMITH;	Smith et al 2016
	Rhode River (Chesapeake Bay, MD, USA)	38.89 N	76.52 W	NO	2004	2018 (2004-2005, and	variable	Monitoring of gelatinous zoopl	NO	plankton ring net	0.2, 0.333, and 0.05	Smithsonian Environmental Research Center, NOAA	Michael Ford	Ford, et al. (2019); Graham et al (2009)
NE Atlantic	RADIALES A Coruña Station 2	43.75 N	8.75 W	Y	1989	to date	1 /month	By catch	NO	Plankton ring net	0.2	Instituto Espanol de Oceanografia	Antonio Bode;	Bode et al 2013
	RADIALES Vigo St. 3	42.14 N	8.95 W	Y	1994	to date	1 /month	By catch	NO	Plankton ring net	0.2	Instituto Espanol de Oceanografia	Antonio Bode;	Bode et al 2013
	Off Peniche (northeastern Atlantic)	39.44 N	9.67 W	Y	2014	to date	1 /month	By catch	NO	Plankton ring net	0.2	Instituto Português do Mar e da Atmosfera (IPMA)	Antonina dos Santos	
	Cascais Bay (Northeastern Atlantic)	38.67 N	9.44 W	Y	2005	to date	1 /month	By catch	NO	Plankton ring net	0.2	Instituto Português do Mar e da Atmosfera (IPMA)	Antonina dos Santos	
	All Portugal seas	42-29 N	6-20E	Y	2016	to date	Intermittent	Monitoring of gelatinous zoopl	NO	Citizen Science Program		Instituto Português do Mar e da Atmosfera (IPMA)	Antonina dos Santos	http://gelavista.ipma.pt/
	All Norwegian seas	58-71 N	4.5-31 E	Y	2018	to date	Intermittent	Monitoring of gelatinous zoopl	NO	Citizen Science Program		IMR (Institute of Marine Research, Norway)	Tone Falkenhaug	
Barents Sea	Barents Sea	68-80 N	15-57 E	Y	1980	to date	1 / year (August-September)	By catch	NO	Fish trawl	30-100	IMR (Institute of Marine Research, Norway)	Espen Bagøien	Eriksen et al 2012
North Sea	Plymouth L5	50.18N	4.30 W		1930	2011 (with major	1 /month	By catch	Y (F)	Plankton ring net	0.7-0.8	Marine Biological Association of the United Kingdom (MBA)	Angus Atkinson;	Blackett et al 2014
	Skagerrak, Swedish coast, Släggö	58.26 N	11.44 E	Y	2018	to date	2 /month	Monitoring of gelatinous zoopl	NO	Plankton ring net	0.45	BIOENV Kristineberg	Lene Friis Møller; Peter Tiselius	
	Skagerrak, Swedish coast, Släggö	58.25 N	11.44 E	NO	2007	2015	1 / week	Monitoring of gelatinous zoopl	NO	Plankton ring net	0.45	BIOENV Kristineberg	Peter Tiselius	Tiselius & Møller 2017
	Skagerrak, Swedish coast, Brofjordens angöring	58.17 N	11.18 E	Y	2018	to date	2 /month	Monitoring of gelatinous zoopl	NO	Plankton ring net	0.45	BIOENV Kristineberg	Peter Tiselius	
	North Sea			Y	2012	to date	1 / year (August)	By catch	NO	Fish trawl	20	Cefas	Sophie Pitois	Aubert et al 2018; Pitois et al (2019)
	North Sea	56-61 N	5-8 E		1971	1986	1-2 / year	By catch	NO	Fish trawl	100	ICES	Christopher Lynam	Hay et al 1990; Lynam et al 2004
	Eastearn English Channel, southern North Sea	57N - 50N	1W - 8E	Y	2009	to date	1 / year (Jan-Feb)	By catch	NO	MIK	1.6	IFREMER	Elvire Antajan	Aubert et al 2018; Pitois et al (2019)
	Gravelines Station (North Sea French coast)	51.03 N	2.15 E	Y	1999/2010	to date	1-2 /month	Monitoring of gelatinous zoopl	Y (F)	Plankton ring net	0.2-0.5	IFREMER	Elvire Antajan	
	Norwegian W coast (Raunefjorden)	60.27 N	5.23 E	NO	2009	2012	1/month (approx)	Monitoring of gelatinous zoopl	Y (F)	Plankton ring net	1	IMR (Institute of Marine Research, Norway)	Aino Hosia	
	Skagerrak (Norwegian coast)	58-59 N	8-11 E	Y	2005	to date	1/year (October)	By catch	NO	Fish trawl (beach seine)	15	IMR (Institute of Marine Research, Norway)	Tone Falkenhaug	
	Skagerrak (Norwegian coast), Flødevigen Research Station	58.42 N	8.75 E	Y	1992	to date	1/day (1992 - 2008); 3 /week (2009-present).	Monitoring of gelatinous zoopl	NO	Visual observations		IMR (Institute of Marine Research, Norway)	Tone Falkenhaug	Hosia et al 2014
	Marsdiep basin, western Dutch Wadden Sea	53 N	4.8 E		1960	2010	1/day (interrupted during winter)	By catch	NO	Fish trap (Kom-Fyke)	10	Royal Netherlands Institute for Sea Research	Lodewijk van Walraven	van Walraven et al 2015
	Limfjorden	56.5-56.9 N	8.5-9.1 E	NO	2007	2014	1/ year (summer)	Monitoring of gelatinous zoopl	NO	Plankton ring net	2	SDU (University of Southern Denmark, Marine Biological Research Centre, Kerteminde)	Hans Ulrik Riisgård	Riisgård (2017); Riisgård&Goldstein (2014)
	Kertinge Nor (Denmark)	55.43 N	10.55 E	Y	1991	to date	1/year	Monitoring of gelatinous zoopl	NO	Plankton ring net	0.5	SDU (University of Southern Denmark, Marine Biological Research Centre, Kerteminde)	Hans Ulrik Riisgård; FlorianLuskow	Riisgård et al (2010)
	Helgoland Roads	54.19 N	7.9 E	Y	1975	to date	3 / week	Monitoring of gelatinous zoopl	Y (F)	Plankton ring net	0.15-0.5	Shelf Seas Systems Ecology @ AWI (former Biologische Anstalt Helgoland)	Karen Wiltshire	Boersma et al (2017); Schlüter et al (2010); Greve et al (2004)
	Stonehaven	56.96 N	2.11 W	Y	1999	to date	1/week	By catch	Y (F)	Plankton ring net	0.068, 0.2	Marine Scotland Science (MSS), Aberdeen, UK	Margarita Machairopoulou	Bresnan et al (2016)
	Stonehaven	56.96 N	2.11 W	Y	2000	to date	1/week	By catch	Y (F)	Plankton ring net	0.35	Marine Scotland Science (MSS), Aberdeen, UK	Margarita Machairopoulou	
	Loch Ewe	57.85 N	5.65 W	Y	2002	to date	1/week	By catch	Y (F)	Plankton ring net	0.068, 0.2	Marine Scotland Science (MSS), Aberdeen, UK	Margarita Machairopoulou	Bresnan et al (2016)
Baltic	Kiel Fjord	54.47 N	10.25 E	Y	2006	to date	2/week	Monitoring of gelatinous zoopl	Y (F)	Plankton ring net	0.5	GEOMAR Helmholtz Centre for Ocean research Kiel	Catriona Clemmesen-Bockelmann	Paulsen et al (2014)
	Western Baltic Sea	54°N	11.3-13.3E	Y	1998	to date	5/year (Feb, March, May, Aug, Nov)	By catch	Y (F)	Plankton ring net	0.1	IOW	Joerg Dutz	
	Coastal Baltic Sea	57.3 -56.1 N	21.4 - 19.3 E	Y	2009	to date	1/ year (August)	By catch	Y (F)	Plankton ring net	0.1	Latvian Institute of Aquatic Ecology (LIAE)	Astra Labuce	
	Coastal Baltic Sea	57.7 - 56.1 N	20.9 - 24.4 E	Y	2009	to date	Intermittent	Monitoring of gelatinous zoopl	NO	Citizen Science Program		Latvian Institute of Aquatic Ecology (LIAE)	Astra Labuce	
	Baltic Proper	54N-56N	14E-20E	NO	2008	2014	1/ year in August	By catch	NO	Plankton ring net	0.5	National Marine Fisheries Research Institute, Gdynia, Poland	Piotr Margoński	
	Baltic Proper	54N-56N	14E-20E	NO	2009	2013	2 / year (May and August)	By catch	NO	Plankton ring net	0.5	National Marine Fisheries Research Institute, Gdynia, Poland	Piotr Margoński	
	Central Baltic Sea - Bornholm Basin	54N-56N	14E-20E	Y	1980	to date	2/ year	Monitoring of gelatinous zoopl	Y (F)	Plankton ring net	0.5	National Instutute of Aquatic Resources, DTU Aqua, Denmak	Fritz Köster, Bastian Huwer, Cornelia	Huwer et al (2008)
	Northern Baltic Sea	56-64 N	17-28 E	Y	2007	to date		Monitoring of gelatinous zoopl	NO	Plankton ring net	0.5	SYKE (Finnish Environment Institute, Finland)	Maiju Lehtiniemi	
	Northern Baltic Sea	56-64 N	17-28 E	Y	2010	to date	Intermittent	Monitoring of gelatinous zoopl	NO	Citizen Science Program		SYKE (Finnish Environment Institute, Finland)	Maiju Lehtiniemi	Lehtiniemi et al (2020)
Mediterranean	Guadiana lower estuary	37N-37.2N	7.4W-7.3W	Y	2012	to date	1 /month	By catch	Y (F)	Plankton ring net	0.2	CCMAR	Alexandra Teodósio	Criz et al (2020); Amorim et al (2018); Morais et al (2017); Muha et al (2017)
	Málaga Bay (MA-2)	36.16 N	5.38 W	NO	1992	2015	4/year (Quarterly)	By catch	Y (F)	Plankton ring net	0.2	IEO - Spanish Institute of Oceanography	Lidia Yebra	
	northern Adriatic Sea	45.4 -45.7 N	13.2-13.7 E		1790	2009	Intermittent	By catch	NO	Plankton ring net	0.5	Marine Biology Station, National Institute of Biology, Piran, Slovenia	Tjasa Kogovsek	Kogovsek et al (2006)
	Point B, Bay of Villefranche-surmer, Mediterranean	43.7 N	7.3 E	Y	1974	to date	2 / week	Monitoring of gelatinous zoopl	Y (F)	Plankton ring net	0.33-0.68	Observatoire Océanologique de Villefranche sur Mer		Licandro et al (2006)
	Gulf of Naples (western Mediterranean Sea), station LTER-MC	40.81 N	14.25 E	Y	1984	to date (interruptio	2/week (1984); 1/week since 1995	By catch	Y (F)	Plankton ring net	0.2	Stazione Zoologica Anton Dohrn (SZN)	Maria Grazia Mazzocchi	
	French Riviera from Monaco to Cannes			Y	1981	2008	Intermittent	Monitoring of gelatinous zoopl	NO	Citizen Science Program		University of Nice Sophia Antipolis	Patrice Brenard;	Bernard et al (2011)
	CIESM JellyWatch Program	32-45.5 N	5.5 W- 40.5 E	Y	2013	to date	Intermittent	Monitoring of gelatinous zoopl	NO	Citizen Science Program		The Mediterranean Science commission (CIESM)		http://www.ciesm.org/gis/JW/build/JellyBlooms.php
White Sea	White Sea,	64-67 N	34-40 E		1961	2003	1-4 times per year	Monitoring of gelatinous zoopl	NO	Plankton ring net	0.18	Moscow State University, Department of Biology, Russia	N. M. Pertsova	Petsova et al (2006)
Black Sea	Black Sea northeastern	44.6 N	38 E	Y	1992-1999	to date	2 / year (spring and summer)	Monitoring of gelatinous zoopl	NO	Plankton ring net	0.5	P.P. Shirshov Institute of Oceanology of Russian Academy of Sciences	Tamara Shiganova; Elena Alekseenko	Shiganova et al (2014)
	Blue Bay station	44.6 N	38 E		1991	1996	1/day - 1/month	Monitoring of gelatinous zoopl	NO	Plankton ring net	0.5	P.P. Shirshov Institute of Oceanology of Russian Academy of Sciences	Tamara Shiganova; Elena Alekseenko	Shiganova et al (2014)

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7 Determine the status of microzooplankton time-series data collection within the ICES area (ToR G)

Planktonic organisms can be categorised by their size range. The microzooplankton category (Figure 6) comprises heterotrophic protozoa and metazoa <200µm, and includes heterotrophic flagellates, dinoflagellates, ciliates, foraminifera, rotifers, copepod eggs and nauplii, some copepodites, and some meroplanktonic larvae. This size-based categorisation is not only useful for classification purposes, but also serves to understand the functional roles of these plankters in an ecosystem. Their fast growth rates enable them to respond rapidly to food increases. Grazing by microzooplankton significantly impacts bacterial and primary production and usually exceeds that of mesozooplankton. In addition, microzooplankton are important nutrient recyclers and contributors to the diet of higher trophic levels. The role of microzooplankton in the marine food web was previously reviewed by the WGZE, as a term of reference (ToR) in 2007, and their findings were discussed in the annual meeting in Riga, Latvia. The group at that time decided that WGZE should include both micro- and meso-zooplankton experts and that microzooplankton time-series and monitoring should be encouraged in the ICES area. In particular, the WGZE identified a data gap for plankton between 100 and 200 µm. This size range encompasses the part for the copepod life- cycle where the mortality is highest, so it is very important to have abundance data for this size fraction. The purpose of this current ToR, therefore, is to assess progress made in this area over the last ten years, and identify collaboration, gaps or overlap with other expert groups.

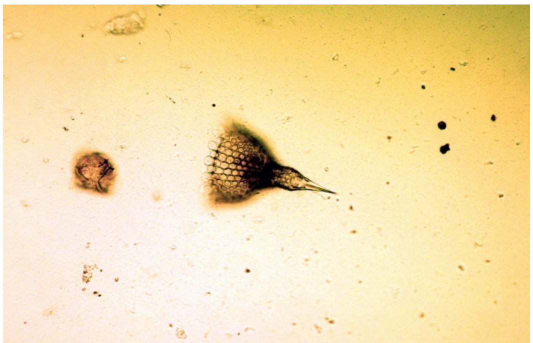

Figure 6. Radiolarian

Members of WGZE, WGPME and WGIMT were surveyed to request information on which of their time-series include a sampling regime for microzooplankton. A compilation of the survey results is shown in Table 4.

Table 4. Compilation of responses to microzooplankton sampling survey.

	Sampling method	*Sample Frequency*	*Start date*	*Fixative*	*Volume collected*	*Volume analysed*	*Analysis method*
Plymouth L4							
Phagotrophic protists							
Dinoflagellates	Niskin Water bottle	weekly	1992	Lugol's	200ml	50ml	Microscopy
Ciliates	Niskin Water bottle	weekly	1992	Lugol's	200ml	50ml	Microscopy
Acantharia	water bottle/63µm net	weekly	1992 & 2012	Lugol's /live	200ml/12 m3	50ml	Microscopy/FlowCam

Radiolaria	water bottle/63µm net	weekly	1993 & 2012	Lugol's / live	200ml/12 m3	50ml	Microscopy/FlowCam
Foraminifera	water bottle/63µm net	weekly	1994 & 2012	Formalin / live	200ml/12 m3	100ml	Microscopy/FlowCam
Metazoa							
Copepod nauplii	63µm net	weekly	2012	Live	200ml/12 m3	100ml	FlowCam
Rotifera	63µm net	weekly	2012	Live	200ml/12 m3	100ml	FlowCam
Meroplankton	63µm net	weekly	2012	Live	200ml/12 m3	100ml	FlowCam
Plymouth E1							
Phagotrophic protists							
Dinoflagellates	Water bottle	fortnightly	2014	Lugol's	200ml	50ml	Microscopy
Ciliates	Water bottle	fortnightly	2014	Lugol's	200ml	50ml	Microscopy
Acantharia	Water bottle	fortnightly	2014	Lugol's	200ml	50ml	Microscopy
Radiolaria	Water bottle	fortnightly	2014	Lugol's	200ml	50ml	Microscopy
Foraminifera	Water bottle	fortnightly	2014	Formalin	200ml	100ml	Microscopy
Metazoa							
Copepod nauplii	63µm net	fortnightly	2002-2005; 2012-	Formalin	12 m3	50ml	FlowCam
Rotifera	63µm net	fortnightly	2002-2005; 2012-	Formalin	12 m3	50ml	FlowCam
Meroplankton	63µm net	fortnightly	2002-2005; 2012-	Formalin	12 m3	50ml	FlowCam
Finland's phytoplankton and zooplankton monitoring program (HELCOM)							
F2, BO3, F16, SR5, US5B, F64, IU7, LL17, LL12, Längden, GF1, LL9, LL7, LL3a, XV1							
Phagotrophic protists							
Dinoflagellates	Rosette / Tube sampler	once a year	1979	Lugol's	300 ml	10-50 ml	Microscopy
Ciliates	Rosette / Tube sampler	once a year	1986	Lugol's	300 ml	10-50 ml	Microscopy
Metazoa							
Copepod nauplii	100 µm net	twice a year	1979	Formalin	1000ml/25 m3	3-120 ml	Microscopy
Rotifera	100 µm net	twice a year	1979	Formalin	1000ml/25 m3	3-120 ml	Microscopy
Meroplankton	100 µm net	twice a year	1979	Formalin	1000ml/25 m3	3-120 ml	Microscopy
Continuous Plankton Recorder survey							
Phagotrophic protists							
Dinoflagellates	CPR- 270µm silk	monthly	1958	Formalin	3m3	3m3	Microscopy/molecular
Ciliates	CPR- 270µm silk	monthly	1958	Formalin	3m3	3m3	Microscopy
Acantharia	CPR- 270µm silk	monthly	1958	Formalin	3m3	3m3	Microscopy
Radiolaria	CPR- 270µm silk	monthly	1958	Formalin	3m3	3m3	Microscopy
Foraminifera	CPR- 270µm silk	monthly	1958	Formalin	3m3	3m3	Microscopy
Metazoa							
Copepod nauplii	CPR- 270µm silk	monthly	1958	Formalin	3m3	3m3	Microscopy
Rotifera	CPR- 270µm silk	monthly	1958	Formalin	3m3	3m3	Microscopy

Meroplankton	CPR- 270µm silk	monthly	1958	Formalin	3m3	3m3	Microscopy
Helgoland Roads							
Phagotrophic protists							
Dinoflagellates	bucket	daily	1962	Lugol's	200ml	25ml/50 ml	Microscopy
Metazoa							
Copepod nauplii	150 µm net	thrice weekly	1975	Formalin	400l	100ml	Microscopy
Rotifera							
Meroplankton	150/500 µm net	thrice weekly	1975	Formalin	400l/4000l	100ml	Microscopy
Å17 (Skagerrak) Släggö (Skagerrak) N14 Falkenberg (Kattegatt)							
Phagotrophic protists							
Dinoflagellates	Hose	fortnightly	2000	Lugol's	125	25	Microscopy
Ciliates	Hose	fortnightly	2000	Lugol's	125	25	Microscopy
Acantharia							
Radiolaria	Net 90µm	fortnightly	2007	Formalin	200-400ml	varies	Microscopy
Metazoa							
Copepod nauplii	Net 90µm	fortnightly	2007	Formalin	200-400ml	varies	Microscopy
Rotifera	Net 90µm	fortnightly	2007	Formalin	200-400ml	varies	Microscopy
Meroplankton	Net 90µm	fortnightly	2007	Formalin	200-400ml	varies	Microscopy
Baltic proper: BY2, BY5, BY15, REFMIVI, BY31, B1							
Phagotrophic protists							
Dinoflagellates	Hose	fortnightly	1999	Lugol's	125	25	Microscopy
Ciliates	Hose	fortnightly	1999	Lugol's	125	25	Microscopy
Radiolaria	Net 90µm	fortnightly	2007	Formalin	200-400ml	varies	Microscopy
Metazoa							
Copepod nauplii	Net 90µm	fortnightly	2007	Formalin	200-400ml	varies	Microscopy
Rotifera	Net 90µm	fortnightly	2007	Formalin	200-400ml	varies	Microscopy
Meroplankton	Net 90µm	fortnightly	2007	Formalin	200-400ml	varies	Microscopy
LTER-MC							
Phagotrophic protists							
Dinoflagellates	Niskin bottle	1984-1991 fortnightly; 1995 to date weekly	1984	Formalin	500ml	3-100 ml	Microscopy
Ciliates	Niskin bottle	weekly	1997	1997-1999 formalin; 2000-to date Lugol	250ml	25-250 ml	Microscopy
Note: Ciliate samples regularly collected and stored up to date, but counts performed only until 2009. Metazoans counted in mesozooplankton samples collected with 200 µm mesh net							
Málaga Bay (MA2)							

Phagotrophic protists							
Dinoflagellates	Niskin bottle	quarterly	1992	Lugol’s	125 ml	50 ml	Microscopy
Ciliates	Niskin bottle	quarterly	1992	Lugol’s	125 ml	50 ml	Microscopy
Acantharia	200µm WP2 net	quarterly	1992	Formalin	120-200ml/ 6-10m3	2.5-10ml	Microscopy
Radiolaria	200µm WP2 net	quarterly	1992	Formalin	120-200ml/ 6-10m3	2.5-10ml	Microscopy
Metazoa							
Copepod nauplii	200µm WP2 net	quarterly	1992	Formalin	120-200ml/ 6-10m3	2.5-10ml	Microscopy
Meroplankton	200µm WP2 net	quarterly	1992	Formalin	120-200ml/ 6-10m3	2.5-10ml	Microscopy
Stations T-0030, -0012, -0030, -0113 (Baltic Sea)							
Metazoa							
Copepod nauplii	100 µm net	Feb/Mar/May/Aug/Nov	1980/1998	Formalin	~ 2- 12 m³	variable	Microscopy
Rotifera	100 µm net	Feb/Mar/May/Aug/Nov	1980/1998	Formalin	~ 2- 12 m³	variable	Microscopy
Meroplankton	100 µm net	Feb/Mar/May/Aug/Nov	1980/1998	Formalin	~ 2- 12 m³	variable	Microscopy
Cantabrian Sea RADCAN, RADIAL Gijón, Station 2							
Phagotrophic protists							
Dinoflagellates	Water bottle	monthly	2004	Lugol's	100	10 to 50 ml	Microscopy
Ciliates	Water bottle	monthly	2004	Lugol's	100	10 to 50 ml	Microscopy
Acantharia	Water bottle	monthly	2004	Lugol's	100	10 to 50 ml	Microscopy
Radiolaria	Water bottle	monthly	2004	Lugol's	100	10 to 50 ml	Microscopy
Foraminifera	Water bottle	monthly	2004	Lugol's	100	10 to 50 ml	Microscopy
West Gabbard / Dowsing / Liverpool Bay							
Phagotrophic protists							
Dinoflagellates	Automated Water Sampler	Monthly	2001	Lugol's	250ml	10/25/50 ml	Microscopy
Ciliates	Automated Water Sampler	Monthly	2001	Lugol's	250ml	10/25/50 ml	Microscopy
Baltic Station P40/P140 & P5 (National Monitoring Programme)							
Metazoa							
Copepod nauplii	WP-2 net 100µm	5 per y (recent)	1979	Formalin	various (according to the HELCOM COMBINE Manual)		Microscopy
Rotifera	WP-2 net 100µm	5 per y (recent)	1979	Formalin	various (according to the HELCOM COMBINE Manual)		Microscopy
Meroplankton	WP-2 net 100µm	5 per y (recent)	1979	Formalin	various (according to the HELCOM COMBINE Manual)		Microscopy
Baltic Station P1 (National Monitoring Programme)							

Metazoa							
Copepod nauplii	WP-2 net 100µm	5 per y (recent)	1986	Formalin	various (according to the HELCOM COMBINE Manual)		Microscopy
Rotifera	WP-2 net 100µm	5 per y (recent)	1986	Formalin	various (according to the HELCOM COMBINE Manual)		Microscopy
Meroplankton	WP-2 net 100µm	5 per y (recent))	1986	Formalin	various (according to the HELCOM COMBINE Manual)		Microscopy
Baltic National Monitoring Programme Station K6, KW, L7, P16, P110							
Metazoa							
Copepod nauplii	WP-2 net 100µm	5 times/y	2003	Formalin	various (according to the HELCOM COMBINE Manual)		Microscopy
Rotifera	WP-2 net 100µm	5 times/y	2003	Formalin	various (according to the HELCOM COMBINE Manual)		Microscopy
Meroplankton	WP-2 net 100µm	5 times/y	2003	Formalin	various (according to the HELCOM COMBINE Manual)		Microscopy
Baltic National Monitoring Programme Station ZP6							
Metazoa							
Copepod nauplii	plankton net 100µm	12 times/y	2003	Formalin	various (according to the HELCOM COMBINE Manual)		Microscopy
Rotifera	plankton net 100µm	12 times/y	2003	Formalin	various (according to the HELCOM COMBINE Manual)		Microscopy
Meroplankton	plankton net 100µm	12 times/y	2003	Formalin	various (according to the HELCOM COMBINE Manual)		Microscopy
Baltic National Monitoring Programme Station B13							
Metazoa							
Copepod nauplii	plankton net 100µm	5 times/y	2007	Formalin	various (according to the HELCOM COMBINE Manual)		Microscopy
Rotifera	plankton net 100µm	5 times/y	2007	Formalin	various (according to the HELCOM COMBINE Manual)		Microscopy
Meroplankton	plankton net 100µm	5 times/y	2007	Formalin	various (according to the HELCOM COMBINE Manual)		Microscopy
Dunkirk West							
Phagotrophic protists							
Dinoflagellates	Water bottle	weekly	1989	Lugol's	200ml	10ml	Microscopy
Ciliates	Water bottle	weekly	1998	Lugol's	200ml	10ml	Microscopy
Metazoa							
Copepod nauplii	200µm net	monthly/bimonthly	1994	Formalin	5-60 m^3	subsample	Stereomicroscope
Rotifera							

Meroplankton	200µm net	monthly/bi-monthly	1994	Formalin	5-60 m³	subsample	Stereomicroscope

Information was returned on 57 time-series stations and of these only 4 stations do not conduct sampling for any of the microzooplankton groups listed in the survey, but may include them in their sampling program in the future. The results of the survey indicated a range of different sampling and analysis techniques by different institutes for monitoring microzooplankton at their time-series stations. These findings led to discussions regarding best practice for sample collection, fixation and enumeration. Discussions were guided by existing recommendations in Chapter 5 of the ICES Zooplankton Methodology Manual (Gifford and Caron 2000). A summary of survey results focussing on showing frequency of sampling at each time-series station is shown in Table 5. Details of sample collections, preservation and identification from the survey results are described below.

Table 5. Summary information supplied by surveyed institutes showing frequency of sampling of different microzooplankton categories.

Time series station	Institute	Stations	Protozoa: *Dinoflagellates*	Protozoa: *Ciliates*	Protozoa: *Radiolarians*	Protozoa: *Foraminiferans*	Metazoa <200µm: *Copepod juveniles*	Metazoa <200µm: *Rotifers*	Metazoa <200µm: *Meroplankton*
Plymouth, UK	PML	2	Weekly or fortnightly	Weekly or fortnightly	Weekly or fortnightly	Weekly or fortnightly	Weekly or fortnightly	Weekly or fortnightly	Weekly or fortnightly
Finland- (15 stations)	SYKE	15	<monthly	<monthly	Not included in time series	Not included in time series	<monthly	<monthly	<monthly
CPR survey	MBA	1	Monthly	Monthly	Monthly	Monthly	Monthly	Monthly	Monthly
Helgoland Roads	AWI	1	Weekly or fortnightly	Not included in time series	Not included in time series	Not included in time series	Weekly or fortnightly	Weekly or fortnightly	Not included in time series
Kattagat /Skagerrak/Falkenberg	SMHI	4	Weekly or fortnightly	Weekly or fortnightly	Weekly or fortnightly	Not included in time series	Weekly or fortnightly	Weekly or fortnightly	Weekly or fortnightly
Baltic proper	SMHI	6	Weekly or fortnightly	Weekly or fortnightly	Weekly or fortnightly	Not included in time series	Weekly or fortnightly	Weekly or fortnightly	Weekly or fortnightly
LTER-MC	SZN	1	Monthly	Monthly	Not included in time series	Not included in time series	Not included in time series	Not included in time series	Not included in time series
Málaga Bay	IEO	1	Monthly	Monthly	Monthly	Monthly	Monthly	Monthly	Not included in time series
Baltic Sea	IOW	4	Not included in time series	Not included in time series	Not included in time series	Not included in time series	Monthly	Monthly	Monthly
Cantabrian Sea	IEO	3	Monthly	Monthly	Monthly	Monthly	Not included in time series	Not included in time series	Not included in time series
North Sea, Liverpool Bay	CEFAS	3	Monthly	Monthly	Not included in time series	Not included in time series	Not included in time series	Not included in time series	Not included in time series
Baltic Sea Stations	MIR	9	Not included in time series	Not included in time series	Not included in time series	Not included in time series	<monthly	<monthly	<monthly
Dinkirk West	Ifremer	1	Weekly or fortnightly	Weekly or fortnightly	Not included in time series	Not included in time series	Weekly or fortnightly	Weekly or fortnightly	Weekly or fortnightly
Stonehaven/ Loch Ewe	MSS	2	Not included in time series	Not included in time series	Weekly or fortnightly	Weekly or fortnightly	Weekly or fortnightly	Weekly or fortnightly	Weekly or fortnightly
Guidiarna Estuary, Portugal	UALG	1	Not included in time series	Not included in time series	Not included in time series	Not included in time series	Not included in time series	Not included in time series	Not included in time series
Portugal	IPMA	1	Not included in time series	Not included in time series	Not included in time series	Not included in time series	Not included in time series	Not included in time series	Not included in time series
SE Bay of Biscay	EHU	2	Not included in time series	Not included in time series	Not included in time series	Not included in time series	Not included in time series	Not included in time series	Not included in time series

Frequency

- Weekly or fortnightly
- Monthly
- <monthly
- Not included in time series

Sampling

Across time-series, the frequency of sampling ranged from daily through to yearly, but the majority of samples were collected on a weekly or fortnightly basis. Whilst a fine mesh size can be used for collecting net samples of more robust microzooplankton, the more delicate protozoan component, (ciliates and dinoflagellates) need to be collected and preserved directly. The survey results revealed that methods for sample collection of protozoa varied from water bottle, through to bucket, and hose pipe. Metazoans and more robust radiolarians on the other hand, were collected using fine mesh nets ranging in mesh size from 50–150µm. Some time-series stations used a mesh size of >200µm, but this would be considered too large for the capture of many metazoans that fall in to the microzooplankton size category. This is demonstrated by a study on the effect of mesh size using samples collected from Plymouth Station L4 whereby copepod nauplii abundance was significantly higher in samples collected with a 63µm net compared to 200µm (Figure

7). A number of time-series sampled micrometazoans using fine nets but did not collect water samples for ciliates and dinoflagellates.

For time-series where microzooplankton samples are analysed, the approaches used include light microscopy and FlowCam, and two stations (CPR survey and Plymouth L4) reported collection of samples for molecular identification (Fileman, Rodriguez *et al.* WGIMT final report 2019). Some time-series reported sample collection but due to lack of resources and/or expertise, not all of the samples had been analysed, some were still in storage.

Preservation

The preferred fixative for protists was Lugol's iodine solution, whereas formalin was most commonly used for preserving net samples. Some live analyses were also carried out using FlowCam, which was found to be particularly useful for the 50–200µm size fraction. Success rate of species recognition from these images was reported to be good, although a taxonomist is still required to cross-check and analyse the results.

Identification

A number of WG members involved in time-series data analysis indicated that they would benefit from a dedicated identification course in particular for ciliated microzooplankton. Attention was also drawn to the WGIMT.net portal which hosts information and links to identification guides and web pages such as the valuable 'User friendly guide to coastal planktonic ciliates' developed by David Montagnes at Liverpool University.

Copepod eggs are also considered to belong to the microzooplankton although they are not always included in monitoring programs and analyses. It was noted that some time-series studies, such as those in the US, L4, and CPR generally quantify copepod eggs whilst others such as those in the Baltic Sea states do not.

Data quality

The choice of sampling and analytical methods used need to produce reliable data and the importance of using /developing protocols with levels of traceability and reproducibility was recognised. Some time-series analysts who enumerate microzooplankton as part of standard phytoplankton counts reported counting only a small sub-sample sometimes as little as 25 ml, which could result in a low precision of counting. In order to obtain a statistically robust result from the quantitative analysis a representative number of cells should be counted.

Information on WGZE.net

Time-series containing microzooplankton categories can now be identified in the WGZE time-series variable search on WGZE.net. Microzooplankton-related variables were identified in the WGZE time-series network and "microzooplankton" is now a variable searching option in the time-series interfaces (i.e., in additional to "phytoplankton" and "zooplankton").

Further collaborative work

ToR discussions during annual WG meetings lead to two case studies being carried out. The first, a collaborative study between colleagues at the Finnish Environment Institute (SYKE, Finland) and Plymouth Marine Laboratory (PML, UK) using microzooplankton time-series data was carried out to explore how different sampling intervals impact the quality and usefulness of heterotrophic microplankton monitoring data. The outcome of this collaboration was preparation of a manuscript to provide recommendations on sampling frequency for optimising heterotrophic microplankton monitoring which would provide valuable information for scientists and regions where microzooplankton are not monitored (Lehtiniemi *et al.* ICES JMS, submitted).

The second study involved Stonehaven zooplankton time-series, in Scotland, which is sampled with two mesh sizes of plankton net (68 and 200 µm), but only samples from the 200 µm mesh are analysed. A small collaboration is underway, between Marine Science Scotland (MSS) and PML, to explore the best options for analysing the microzooplankton from the Stonehaven time-series. As part of this collaboration, in summer 2020, an MSc student examined microzooplankton samples from one spring season of both time-series, and this project provided a base for further discussion between MSS and PML. The collaboration is ongoing with an aim to have a collaborative output in the near future.

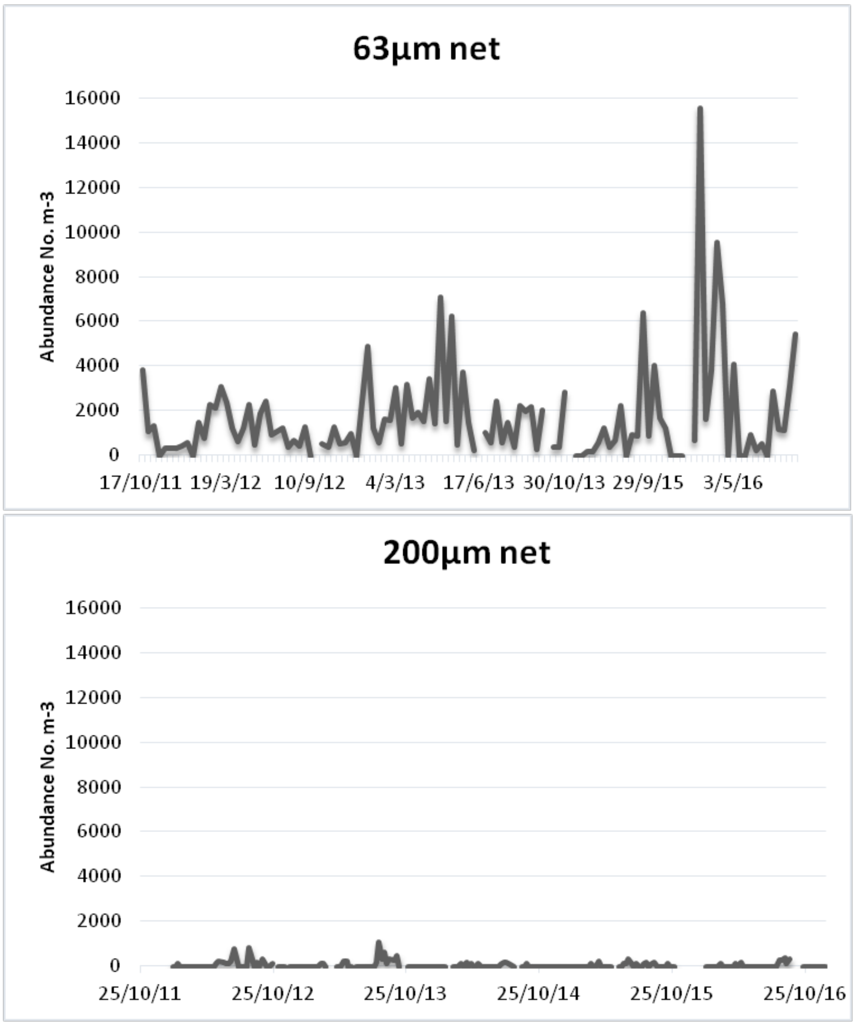

Figure 7. Comparison of the abundance of copepod nauplii at Plymouth L4 captured using a WP2 63µm net and a WP2 200µm net; data supplied by E Fileman & A McEvoy, Western Channel Observatory.

References

Fileman E S, Rodriguez N. *et al.* (2019) Working Group on Integrated Morphological and Molecular Taxonomy (WGIMT). ICES Scientific Reports. 1:44. 20 pp. http://doi.org/10.17895/ices.pub.5538

Gifford DJ, Caron DA (2000) Sampling, preservation, enumeration and biomass of marine protozooplankton. In: Harris RP *et al.* (eds) ICES Zooplankton methodology manual. Academic Press, London, p 193-221

Lehtiniemi M, Fileman E S, *et al.* Sampling strategy options for heterotrophic microplankton with notable biomass fluctuations. ICES JMS -Submitted.

8 Review the applicability of continuous and realtime zooplankton techniques in long-term monitoring (ToR H)

The WGZE continued to survey and evaluate the present real-time zooplankton sampling technology and sites with the focus to make recommendations for the possible implementation of these techniques into current WGZE long-term time-series sites. A number of time-series sites presently using real-time methods were identified and highlighted. Most sites use imaging systems, but the software for processing the images is currently a limiting factor. In the final year, it was intended that recommendations for how ICES time-series sites can enhance and modernize their data and analysis data acquisition systems would be presented. However, the covid-19 pandemic prevented the face to face meeting from taking place and a consensus of methods that could be introduced to on-going time-series sampling sites was not attained.

During the first two years, WGZE reviewed a number of systems to make real-time zooplankton sampling techniques and systems that could be implemented into current and future long-term time-series sampling sites. The systems reviewed included: bottom mounted (Kaartvedt *et al.* 2015), moored (Lemon *et al.* 2012), and glider based multi-frequency echosounders (Guihen *et al.* 2014), and bottom mounted (Sosik and Olson 2007), moored, and ship board high resolution imaging systems (Culverhouse *et al.* 2015; Pitois *et al.* 2018). It was noted that autonomous vehicles for observation at sea were quickly developing including Sail Drones (Chu *et al.* 2019) and Zooglider (Ohman *et al.* 2019). New genetic techniques (metabarcoding and eDNA) are also being introduced to determine taxa and species living in time-series site areas (Bucklin *et al.* 2019). Cabled observatories were briefly discussed, and significant advances have been achieved (Fischer *et al.* 2020). They are now used for time-series data collection globally.

These instrument packages or similar ones now being manufactured could be incorporated into existing zooplankton time-series programs throughout the ICES area.

References

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Chu, D., Parker-Stetter, S., Hufnagle, L.C., Thomas, R., Getsiv-Clemons, J., Gauthier, S., and Stanley, C., 2019. "2018 Unmanned Surface Vehicle (Saildrone) acoustic survey off the west coasts of the United States and Canada," OCEANS 2019 MTS/IEEE SEATTLE, Seattle, WA, USA, 2019, pp. 1-7, doi: 10.23919/OCEANS40490.2019.8962778.

Culverhouse, P.F., Gallienne, C., Williams, R., Tilbury, J. 2015. An Instrument for Rapid Mesozooplankton Monitoring at Ocean Basin Scale. J Marine Biol Aquacult 1(1): 1-11.

Fischer,P., Brix, H., Baschek, B., Kraberg, A., Brand, M., Cisewski, B., Riethmüller, R., Breitbach, G., Möller, K.O., Gattuso, J-P., Alliouane, S., van de Poll, W.H., and Witbaard, R. 2020. Operating Cabled Underwater Observatories in Rough Shelf-Sea Environments: A Technological Challenge. Front. Mar. Sci., https://doi.org/10.3389/fmars.2020.00551

9 Expand and update the WGZE zooplankton monitoring and time-series compilation (ToR I)

This ToR was written with three objectives/deliverables:

- Update and expand content and capabilities of the WGZE/WGPME online time-series content and interactive interface.
- Prepare (cooperatively with WGPME) the next edition of the ICES Plankton Status Report.
- Write a peer reviewed publication based on the findings of the Plankton Status Report, ideally released in conjunction with the report to help advertise it to the broader scientific community.

Online Content

Combined, the WGZE and WGPME members and associated institutions represent a collection of over 160 plankton time-series (Figure 8), distributed across the North Atlantic, Baltic and Mediterranean seas. A shared online interface provides graphical summaries and contact information for every time-series site and monitoring program, available through both the WGZE (https://wgze.net/time-series) and WGPME (https://wgpme.net/time-series) web pages. The content on these pages is updated every 1–2 years with additional years of data and new or updated analyses results. Significant amounts of new content and improvements were also made during the preparation phase of the latest Plankton Status Report.

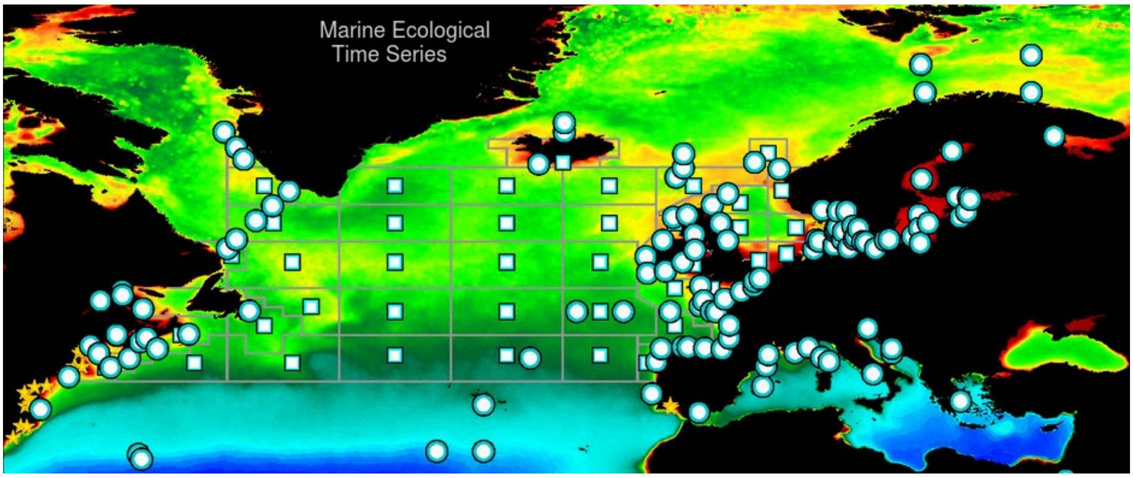

Figure 8. Marine ecological time-series locations across the North Atlantic region Baltic and Mediterranean seas.

The ICES Plankton Status Report: In the past, WGZE and WGPME each created their own reports (e.g., a zooplankton status report and a phytoplankton status report). As there was considerable overlap between these two report-series, and to focus on more of a general lower trophic level ecosystem overview, these two reports are being combined into a single plankton status report. This has proven to be a daunting and time-consuming task, as working with 160+ time-series (and trying to combine two 200-page reports into a single 200-page report) is not a trivial task. A heavy push on completing the report will begin after the December holidays, with an intended submission date of March 2021.

A paper summarizing the history and major findings of the Plankton Status Report will be submitted to the ICES Journal of Marine Science time-series themed articles set that is being prepared in memory of Steve Hay. In addition to being a long-running WGZE member, Steve Hay was a time-series site author/contributor to the report series (Stonehaven and Loch Ewe), and was a co-editor of the 2008 and 2011 zooplankton status reports.

10 Design and carry out coordinated and collaborative activities with WGIMT and WGPME (including the molecular/taxonomic tasks); (ToR J)

Since the start of WGIMT, WGZE and WGIMT have held coordinated meetings to ensure that members of WGZE have contributed to define the needs of zooplankton ecology with respect the integration of molecular and morphological taxonomy in their studies and that members of WGIMT are aware of the challenges zooplankton ecologists face when it comes to perform morphological and molecular taxonomy.

Collaborative activities continued in 2019 when the WGZE annual meeting in Las Palmas was held in parallel with WGPME (Figure 9). The meeting provided an opportunity for the three working groups to come together to discuss and contribute to shared multi-annual ToRs. For the past three years WGZE has been jointly involved with WGPME and WGIMT in ToR G which looked to determine the status of microzooplankton time-series data collection within the ICES area (see ToR G report above). Given that the size spectra of phytoplanktonic organisms overlaps with microzooplankton, and phytoplankton are an important food source for zooplankton, both groups share several ecological linkages.

Figure 9. Joint meeting between WGZE, WGIMT and WGPME, Las Palmas 2019.

A number of joint theme session proposals have been successfully submitted and organised between members of the three working groups. These include:

- ICES 2018 Annual Science conference (Sept 2018 Hamburg, Germany) Molecules and morphology: integrative taxonomic analysis of marine planktonic assemblages - Co-convenors: Ann Bucklin(WGIMT), Pennie Lindeque (WGIMT), Lidia Yebra (WGZE).
- ICES 2019 Annual Science conference (Sept 2019 Gothenburg, Sweden); Session K New approaches to the understanding of energy transfer through the food webs. Co-convenors: Hildur Pétursdóttir (WGZE), Janna Peters (WGZE/WGIMT), Marie Johannsen (WGPME).
- First Advanced Zooplankton Course – Morphological and Molecular Taxonomy of Marine Copepods organised by Maria Grazia Mazzocchi and Iole Di Capua was held on 22 October-2 November 2018 at the Stazione Zoologica Anton Dohrn of Naples (SZN), Italy.

Members of both WGZE and WGIMT have worked together to produced joint publications (3 peer-reviewed papers):

Bucklin, A., Yeh, H.D., Questel, J.M., Richardson, D.E., Reese, B., Copley, N.J., Wiebe, P.H. 2019. Time-series metabarcoding analysis of zooplankton diversity of the NW Atlantic continental shelf. ICES Journal of Marine Science 76: 1162-1176. doi: 10.1093/icesjms/fsz021

Walczynska, K.S., Soreide, J.E., Weydmann-Zwolicka, A., Ronowicz, M., Gabrielsen, T.M. 2019. DNA barcoding of cirripedia larvae reveals new knowledge on their biology in arctic coastal ecosystems. Hydrobiologia 837: 149-159. doi: 10.1007/s10750-019-3967-y.

Yebra, L., Hernández de Rojas, A., Valcárcel-Pérez, N., Castro, M.C., García-Gómez, C., Cortés, D., Mercado, J.M., *et al.* 2019. Molecular identification of the diet of *Sardina pilchardus* larvae in the SW Mediterranean Sea. Marine Ecology Progress Series 617-618: 41-52. doi: 10.3354/meps12833.

Collaboration between WGZE and WGIMT is ongoing with the update and revision of the ICES plankton identification leaflets (ToR K).

WGZE has recently commenced working closely with WGIMT to identify the most important zooplankton taxa in time-series to produce a review for publication on taxonomical challenges in these species and the relevance of identification issues for time-series studies.

11 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 Plankton Identification Leaflets (ToR K)

The ICES Plankton Identification Leaflets are extremely important tool in terms of capacity building of the scientific community. The first series consists of 186 leaflets published between 1939–2001. Since 2013, WGZE with WGIMT started working on taxonomic issues and integrated taxonomy that lead to the initiative of reviving the leaflets. The WGs agreed that there was a need to update the leaflets and to produce some new ones (Table 6), and a new series of leaflets was started. The leaflets of this new series are peer-reviewed under the editorship of Antonina dos Santos and Lidia Yebra. The series have a DOI number. ICES secretariat provides standard proofing and formatting services, advertising and publishing of the leaflets at the ICES webpage.

The first leaflet of the new series was published in 2019, and currently there are 6 Leaflets published.

Table 6. ICES Plankton Identification Leaflets published in the new series.

Plankton Leaflet No	Previous No	Previous Author	Author(s)	Title
188	NEW		Maria Grazia Mazzocchi	Copepoda: Cyclopoida: Oithona
189	38 (part)	J.P Farran	Maria Grazia Mazzocchi	Copepoda: Calanoida: Clausocalanus
190	NEW		José Antonio Cuesta, Juan-Ignacio González-Gordillo	Decapoda: Brachyura: Varunidade, Ocypodidae
191	NEW		Juan-Ignacio González-Gordillo, José Antonio Cuesta	Decapoda: Brachyura: Pinnotheridae
192	2	FS Russell	Priscilla Licandro	Cnidaria: Hydrozoa: Tubulariidae
193	1	JH Fraser	Annelies Pierrot-Bults	Chaetognatha

There are also 2 Leaflets under review and 6 in preparation. Of them, 3 are new ones: Copepoda: Calanoida: Temoridae: *Temora*; Crustacea: Decapoda: Plagusiidae and Grapsidae; Copepoda: Calanoida: Pseudodiaptomidae, and 5 are updates from old ones: Cladocera;; Copepoda: Calanoida: Acartiidae; and 3 on Foraminifera.

12 Planning of the 7th Zooplankton Production Symposium (ToR L)

The next Zooplankton Production Symposium was to be hosted by Antony Richardson (University or Queensland/ SCIRO) and Kerrie Swadling (University of Tasmania), in Hobart (Tasmania) during 13–18 March 2022.

Due to covid-19 and the associated incertitude in relation to people ability to travel and finding necessary funds to do so, the conveners (Antony Richardson (host), Kerrie Swadling (host) and Sophie Pitois (ICES, WGZE) decided to postpone the conference rather than taking the risk of having a poorly attended conference (assuming that travel would have resumed by then). The option of holding the conference online was discussed but regarded as unpractical considering that popularity of the event across zooplanktologists spans across the world and all time zones. The conference is now scheduled to take place in March 2024 at the same location. Conveners are currently working on identifying a convener representing PICES and the Scientific Steering Group.

Figure 10. Facilities proposed for the next Zooplankton Production Symposium to be held in Hobart.

Annex 1: List of participants

WGZE 2020 meeting

Name	Institute	Country (of institute)	Email
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WGZE 2019 meeting

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WGZE 2018 meeting

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Annex 2: WGZE Resolution

The **Working Group on Zooplankton Ecology** (WGZE), chaired by Sophie Pitois, UK, and 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	11–14 March	Las Palmas de Gran Canaria, Spain		Meeting in association with WGIMT and WGPME.
Year 2020	23–26 March	by corresp/ webex	Final report by 15 May	physical meeting cancelled - remote work

ToR descriptors

ToR	Description	Background	Science Plan codes	Duration	Expected Deliverables
A	Review the use of zooplankton production methodologies in collaboration 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 foster targeted activities for promoting scientific collaboration and better coordination in support of knowledge transfer.. WGZE and WG37do share common interests and their collaboration is of utmost importance for the success of the ICES/PICES cooperative initiative.	1.3; 1.9	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	a) Zooplankton traits are increasingly needed to determine the relative fitness of plankton along environmental gradients and to predict and assess	1.8 ; 1.9	Years 1-3	A compiled database of known species-level

	guidance in the definition of key traits of zooplankton species in the ICES area	community shifts and their consequences. Although a wide range of traits has been classified in recent years, data are scattered in the literature and uncertainties remain from paucity of observations.			zooplankton traits for the North 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, acquire, and help make public (i.e., “bring into the light”) dark zooplankton data sets collected in the North Atlantic over the past decades. Each data set rescued by this process will be submitted for archiving and a DOI, and then made publicly available through data centers such as the ICES Data Centre, BCO-DMO, and COPEPOD. 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 engage with data 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) To 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.	1.4; 1.9	Years 1-3	Metadata, database input, Possible peer-review publication (may produce a “data paper” such as Earth System Science Data if our efforts appear to be successful)
D	Macrozooplankton	a, b) The mesopelagic zone, stretching from 200 to	1.3; 1.9	Years 1-3	This three-year ToR

	in mesopelagic zone	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 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.			will review our knowledge about the mesopelagic macrozooplankton taxonomy, abundance and 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.	1.3; 1.4; 1.9	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	3.1; 3.2; 3.6	Years 1-3	Zooplankton Status Report contribution, Link to 'dark data' to provide a metadata compilation. Recommendations for the monitoring of gelatinous plankton

		including colder waters. However, often datasets are not available ("dark data") and a variety of methods are being used. This new ToR will providethe basis for future studies on distribution and temporal patterns of gelatinous zooplankton. Therefore, it will: i) provide an inventory of existing time-series on 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; 1.9; 3.2; 3.4	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; 4.4	Years 1-3	Synthesis of current continuous and realtime systems. A recommendation document on 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.	1.3; 1.4; 1.9	Years 1-3	To update the 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 molecular/taxonomic tasks)	c) Synergy is expected based on development of the common activities strategy	1.6; 1.8	Years 1-3	Plan of activities
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	1.6	Years 1-3	Updated Taxonomic Leaflets uploaded to the web page
L	Planning of the 7th Zooplankton Production Symposium.	This symposium is a common initiative of ICES and PICES and if both organizations would like to keep 5-years intervals the next one should be organized in 2021. Discussion on the planning of the 7th ZPS started between WGZE and PICES Deputy Executive Secretary (Hal Batchelder). WGZE members from USA and Canada will explore possibilities to organise the next ZPS in North America.		Year 2, 3	To engage in preparations and organisation of Theme sessions.

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 EPDSG, 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 EPDSG. 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.