D1.5a: Biomass, species composition and spatial distribution of zooplankton.

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Acknowledgments:

This report was produced as a result of the European Maritime and Fisheries Fund project NEA-PANACEA (Northeast Atlantic project on biodiversity and eutrophication assessment integration and creation of effective measures). The project was funded by the European Union (EU). Grant No. 110661/2020/839628/SUB/ENV.C.2

Note:

The Deliverable D1.5a is composed of two candidate indicators. The first indicator has been produced under an OSPAR pilot assessment of the candidate indicator FW2 'Primary Production'. The second indicator could not lead to the production of an OSPAR pilot assessment of the candidate indicator FW6 'Biomass, species composition and spatial distribution of zooplankton'. This report is intended to develop a methodology for this indicator and some recommendations for future assessments.

Abbreviations

CEMP: Coordinated Environmental Monitoring Programme

EcApRHA: Applying an Ecosystem Approach to (sub) Regional Habitat Assessment

FW: Food Web

GES: Good Environmental Status

HELCOM: Helsinki Commission

ICES: International Council tor the Exploration of the Sea

OSPAR: Oslo Paris Commission

QSR: Quality Status Report

WGZE: Working Group on Zooplankton Ecology

1. Background

Most of marine food webs rely on plankton. Zooplankton is a heterogeneous group of animal organisms that move freely in the water and play a crucial role in marine ecosystems. It represents the second (herbivorous zooplankton) and third (carnivorous zooplankton) levels of the marine food webs being a food source for fish, marine mammals and birds thus transferring the energy flow from small to large organisms. Traits such as abundance, size, body mass and biomass are metric shaped by abiotic pressures and prey-predator relationships. Thus, traits represent a numerical function of the population structure influenced by ecosystem functioning. In the ecosystem functioning approach, total zooplankton abundance and biomass are even more important as that they are considered as a proxy of zooplankton production (a measure of the carbon fluxes through zooplankton organisms).

Studies on zooplankton biomass in the Northeast Atlantic have shown that biomass varies considerably in space and time (e.g. Pitois & Fox, 2006). Indeed, zooplankton respond quickly to environmental and biological changes because of its short life cycle. Spatial and temporal variations are related to seasonal and interannual climate variability expressed as variation of temperature, salinity and/or primary productivity. Anthropogenic drivers and long-term processes such as climate change also impact zooplankton biomass in space and time (Wakelin et al. 2015). Consequently, the fluctuations in space and / or time of zooplankton production impact the upper levels in the food web.

Zooplankton biomass is also of economic importance, as it closely supports fish recruitment and production through bottom-up control (Lomartire et al. 2021). Fisheries in the Northeast Atlantic are indeed an important economic activity for many countries in the region and the health of marine ecosystems is crucial to maintain the sustainability of these fisheries. Zooplankton biomass and species composition in the Northeast Atlantic are therefore important indicators of the health of the marine ecosystems in this region.

Changes in the structure and functioning of food webs are particularly important and obvious for the development of food web indicators under Descriptor 4 (Gorokhova et al. 2016). Until now, zooplankton fluxes were not yet considered in OSPAR (Magliozzi et al., 2021) despite the relevance of zooplankton stocks and fluxes for marine management (Suthers et al. 2019). Since OSPAR QSR 2023, the FW6 “Biomass, species composition and spatial distribution of zooplankton” indicator intends to complement the assessment of food webs by looking at zooplankton fluxes linking the FW2 ‘primary production’ to higher level of the food web. The Intermediate Assessment in 2017 provided the context and the methodological basis for building the FW6. With the support of NEA-PANACEA project, this report represents a trial to establish a pilot assessment of OSPAR FW6 “Biomass, species composition and spatial distribution of zooplankton” indicator. Due to a lack of data and a methodology to be developed, the pilot assessment of the candidate indicator FW6 could not be carried out for the QSR 2023.

2. Methodology

Methodology and concept:

The main objective of this report is the analysis of zooplankton biomass time-series. Because datasets of zooplankton biomass are scarce, other possibilities to compute the indicator include the use of zooplankton abundance. The work uses EcApRHA deliverable 3.4.1. (known as the FW6/PH2 CEMP Guidelines) as a base and we followed the recommendations given by the authors. OSPAR Intermediate Assessment 2017 identified three main gaps limiting the production of a pilot assessment: (i) the estimation of zooplankton biomass from existing abundance data in OSPAR regions; (ii) the test the two-dimensional HELCOM indicator in OSPAR regions; and (iii) the definition of reference conditions to make an operational indicator assessment. In this document, we present some actions to answer the first out of the three main gaps. The second and third issues remained major gaps at this stage of development.

Biomass datasets:

For the OSPAR assessment of QSR 2023, we only had one zooplankton biomass dataset (**Table 1**). The data were collected by the Bundesamt für Seeschifffahrt und Hydrographie from 2008 to 2011 at monthly or lower frequency.

Table 1: Contracting Parties and institutes that provided the zooplankton biomass datasets used for this food web assessment.

Contracting Party	Institute	Dataset name	Data range	Sampling frequency	Parameters
Germany	Bundesamt für Seeschifffahrt und Hydrographie	BSH_Phyto_Zoo	2008-2011	Monthly or lower frequency	Taxa, biomass and size class

The BSH_Phyto_Zoo dataset is distributed along 12 stations located in the North Sea, more precisely in the German Bight (**Figure 1**). The sampling of the twelve stations is non-uniform in time. The DTEND station was sampled the four years while ES1 and NSB3 stations were sampled only in 2010.

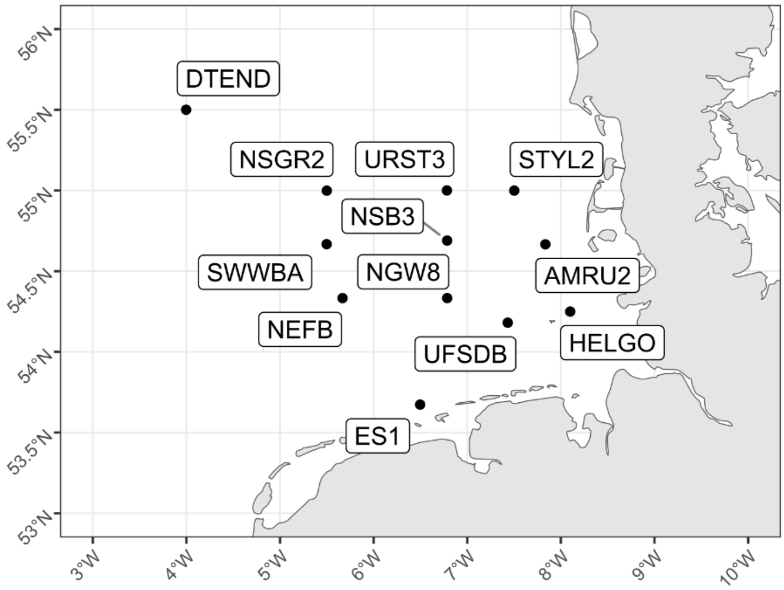

Figure 1: Location of the twelve sampling stations of the monitoring networks of the Bundesamt für Seeschifffahrt und Hydrographie Institute.

Masterlist of carbon content per taxon:

Since the dataset provided only covers 4 years, which is less than the 6 years needed for an OSPAR assessment, we also created a master list of carbon content per taxon to increase the spatial resolution of the assessment. This master list is based on the taxa found at other monitoring sites. The information of carbon content per taxon were find in Copepedia database compiled by ICES Working Group on Zooplankton Ecology (WGZE). Other sources included literature review and the TraitBank database of Encyclopedia of Life (https://eol.org/traitbank). In this table, we list carbon content as dry mass, wet mass or carbon after as Kiørboe (2013). Therefore, analyst should be careful to treat the different carbon content separately. The estimation of zooplankton biomass per taxon (matrix ***B;* Figure 2**) can be summarized as the multiplication of a carbon content per taxon matrix (matrix ***C***) by an abundance per taxon matrix (matrix ***A***).

Matrix ***C***

Taxon	AphiaID	Carbon content
Sp_1	ID_{Sp1}	C_{Sp1}
Sp_2	ID_{Sp2}	C_{Sp2}
…	…	…
Sp_n	ID_{Spn}	C_{Spn}

×

Matrix ***A***

Taxon	AphiaID	Abundance
Sp_1	ID_{Sp1}	A_{Sp1}
Sp_2	ID_{Sp2}	A_{Sp2}
…	…	…
Sp_n	ID_{Spn}	A_{Spn}

Matrix ***B***

Taxon	AphiaID	Biomass
Sp_1	ID_{Sp1}	B_{Sp1}
Sp_2	ID_{Sp2}	B_{Sp2}
…	…	…
Sp_n	ID_{Spn}	B_{Spn}

Figure 2: Workflow to estimate zooplankton biomass per taxon using the abundance and carbon content per taxon.

At the moment of writing this report (April 2023), the list includes a mainly the taxa observed in Western English Channel at L4 station (Plymouth Marine Laboratory) and in the Skagerrak at multiple stations (Swedish Meteorological and Hydrological Institute). However, this process is ongoing and it is necessary to continue the effort by regularly feeding this database to generate a more robust assessment of the "Biomass, species composition and spatial distribution of zooplankton" in the future. This master list is associated to this document as an excel file in NEA-PANACEA sharepoint (NEA-PANACEA Task 1.5.xlsx).

Statistical analysis:

The biomass of zooplankton is represented by the time-series of each sampling location. For each station, the data are displayed at the annual scale because of inconsistency in the months sampled within a year. We propose here an assessment of zooplankton biomass at the scale of OSPAR cycle and a broad temporal scale. The method is based on a trend analysis of zooplankton biomass time-series. The Mann-Kendall trend test is applied to data sets with a length of minimum 4 years. The Mann-Kendall trend test is used to determine whether or not there is a linear monotonic **trend** in a given time series. The procedure is currently applied for the assessment of OSPAR PH1/FW5 indicator. Refers to Holland et al. (2022) for detailed information on the Mann-Kendall trend test in OSPAR assessments. Prior the analysis, the data were log10 transformed.

Spatial scale of assessment:

There is no spatial scale of assessment defined yet for the FW6. However, since the FW6 has a strong link with the Pelagic Habitat (PH1/FW5, PH2 and PH3) and some Food Webs indicators (FW2 and FW9), all these indicators should share the same spatial assessment scale. Since OSPAR QSR 2023, PH1/FW5, PH2, PH3, FW2 and FW9 work at the COMP4 spatial scale (Enserink et al., 2019) which is also divided in four habitats (variable salinity, coastal, shelf and oceanic/beyond shelf). Using the same spatial assessment scale would facilitate future implementation of FW6 into the FW9 indicator. Therefore, we recommend the use of COMP4 assessment units and the division in four habitat types for the future assessments.

Assessment of the GES:

Because the datasets of zooplankton biomass are scarce and the time-series are not long enough, it is not possible yet to assess the GES for the FW6. To deliver a clear and comprehensive message to the scientific and non-scientific community, the results of the future pilot assessment of the FW6 indicator must be summarised by their quality status. The quality status is defined by the change in indicator value according to assessment threshold and / or the impact of anthropogenic pressures and climate change on the indicator change (McQuatters-Gollop et al., 2022). Thus, the quality status can be categorised in 4: Not good, Uncertain, Good and Unassessed. **Table 2** provides a detailed explanation of the different categories.

Table 2: Categorization of the quality status and their associated narratives.

Quality status categories	
Not good	Indicator value is below assessment threshold, or change in indicator represents a declining state, or indicator change is linked to increasing impact of anthropogenic pressures (including climate change), or indicator shows no change but state is considered unsatisfactory

Uncertain	No assessment threshold and/or unclear if change represents declining or improving state, or indicator shows no change but uncertain if state represented is satisfactory
Good	Indicator value is above assessment threshold, or indicator represents improving state, or indicator shows no change but state is satisfactory
Unassessed	Indicator was not assessed in a region due to lack of data, lack of expert resource, or lack of policy support.

3. Results

This report acts as a pilot assessment of the FW6 'Biomass, species composition and spatial distribution of zooplankton' in OSPAR area.

Dataset with available zooplankton biomass

Zooplankton biomass were represented as time-series within each station (**Figure 3**) as well as spatial distribution at each year (**Figure 4**). Both figures revealed that the twelve stations were inconsistently sampled. 2010 was the most sampled year with all stations sampled. At the opposite, 2009 was the less sampled year with only STYL2 and DTEND stations sampled. Overall, the maximum biomass was reached in 2010 at all stations while the minimum was always found in 2009 and 2011. The maximum biomass was measured from 26581 µg m^{-3} at UFSDB to 403056.11 µg m^{-3} at URST3. The minimum biomass was measure from 18.44 µg m^{-3} at SWWBA to 2105 µg m^{-3} at NGW8.

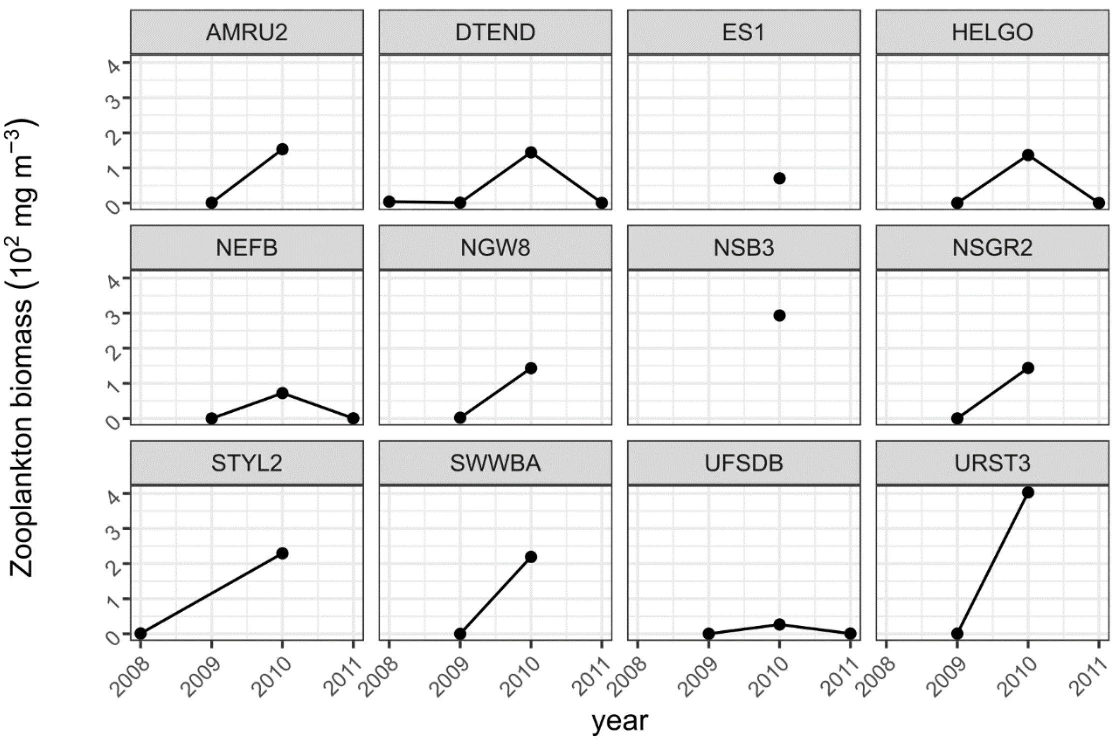

Figure 3: Time-series of zooplankton biomass at the twelve monitoring sites of the Bundesamt für Seeschifffahrt und Hydrographie Institute.

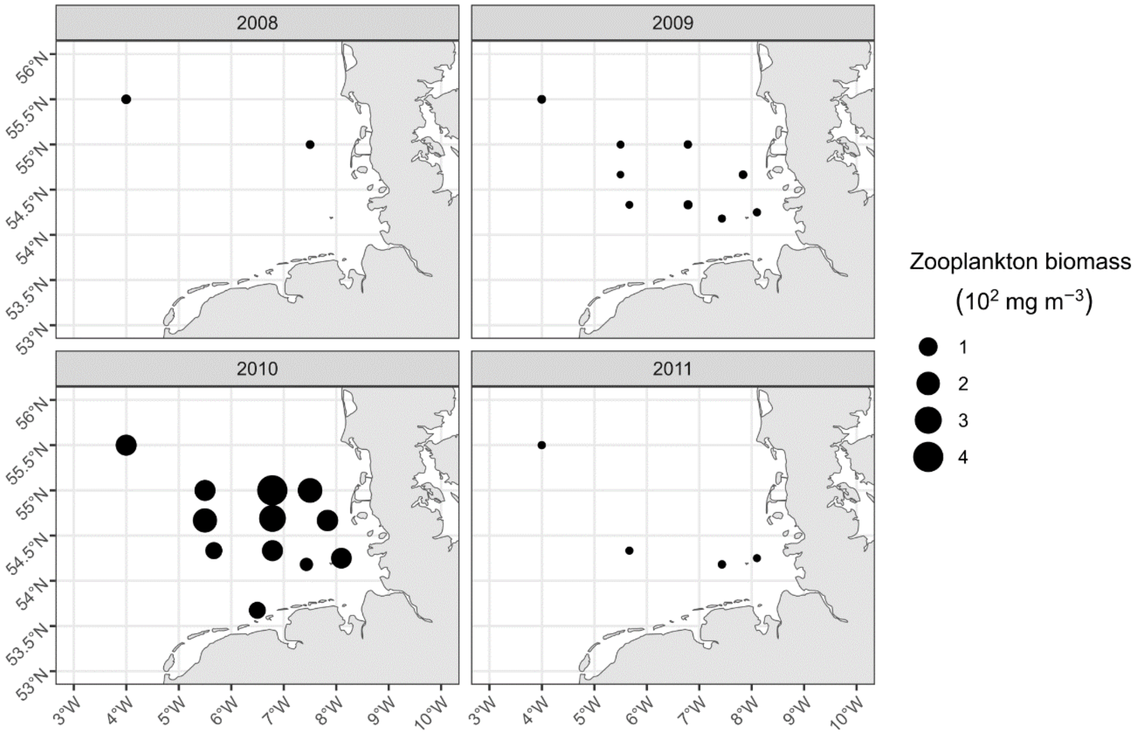

Figure 4: Annual Zooplankton biomass at the twelve monitoring sites of the Bundesamt für Seeschifffahrt und Hydrographie Institute.

In a second step, we compute the sampling frequency of each station to understand the origin of the large variation in zooplankton biomass at each site (**Figure 5**). Briefly, the sampling frequency is the number of samples per month across the whole the time-series. The figure 5 showed us that the high zooplankton biomass in 2010 was because of many samplings. For example, the DTEND station was sampled up to 24 times in May 2010. The stations NSGR2 and URST3 were visited 82 times in 2010 while they were both visited 2 times in 2009. The low zooplankton biomass found in 2008, 2009 and 2011 was because the stations were visited very few times compared 2010.

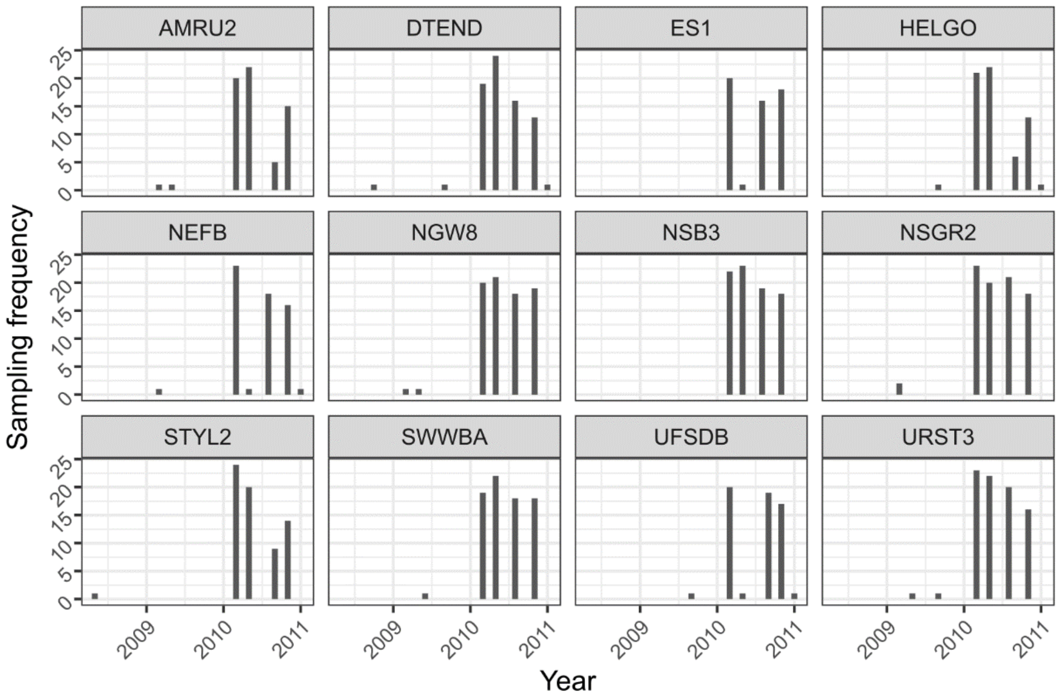

Figure 5: Sampling frequency at the twelve monitoring sites of the Bundesamt für Seeschifffahrt und Hydrographie Institute.

Rebuilt biomass datasets

The **figure 6** showed the estimated zooplankton biomass from 1988 to 2021 at L4 stations (western English Channel). The estimated biomass was reconstructed from the carbon content masterlist timing the abundance per taxon. A general relation was then plotted on the dataset to obtain the long-term trend of the zooplankton biomass. No further test was processed on the zooplankton biomass as several taxon are not comprised in the masterlist which bias the zooplankton biomass.

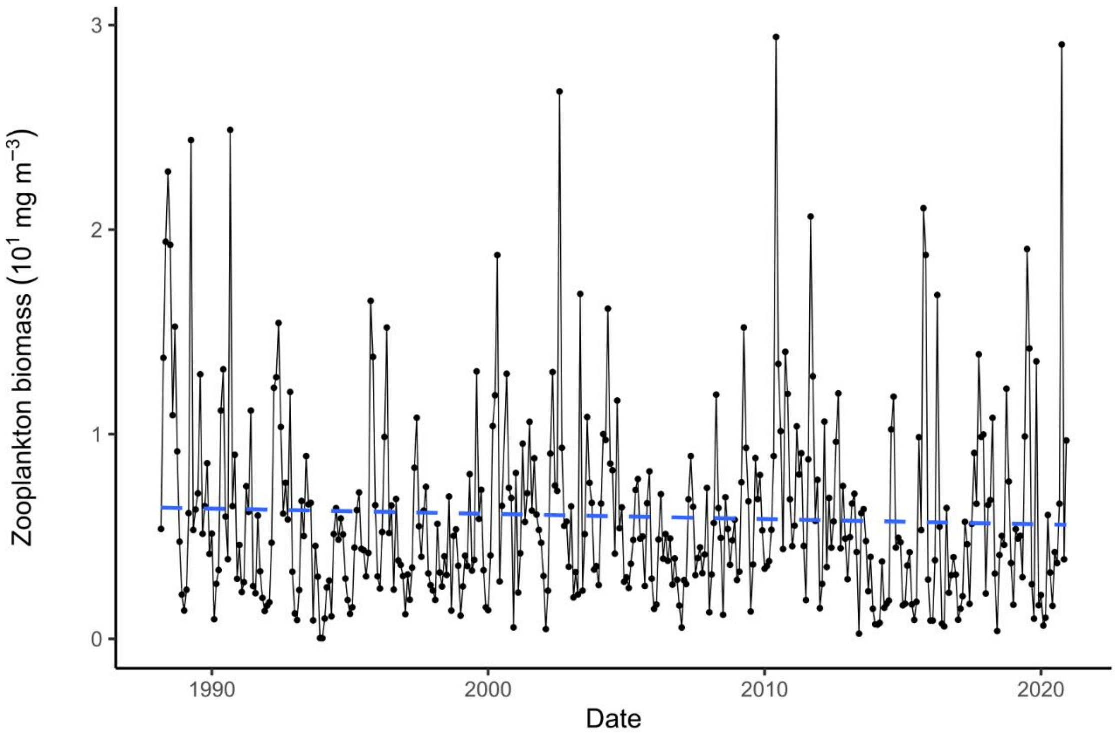

Figure 6: Zooplankton biomass at station L4 (UK-PML) rebuilt from abundance and carbon content.

To check if the rebuilt zooplankton biomass results were consistent with existing values of zooplankton biomass, we compared the magnitudes of the rebuilt data with the magnitudes of the direct measured data (BSH datasets). For this we pooled the monthly data to estimate the annual biomass budget at L4 station (**Figure 7**). We found out that the estimated biomass ranged from 0.4 to 1.2 10^5 µg C m^{-3} which was the same magnitude than the biomass found by the BSH from direct biomass estimation.

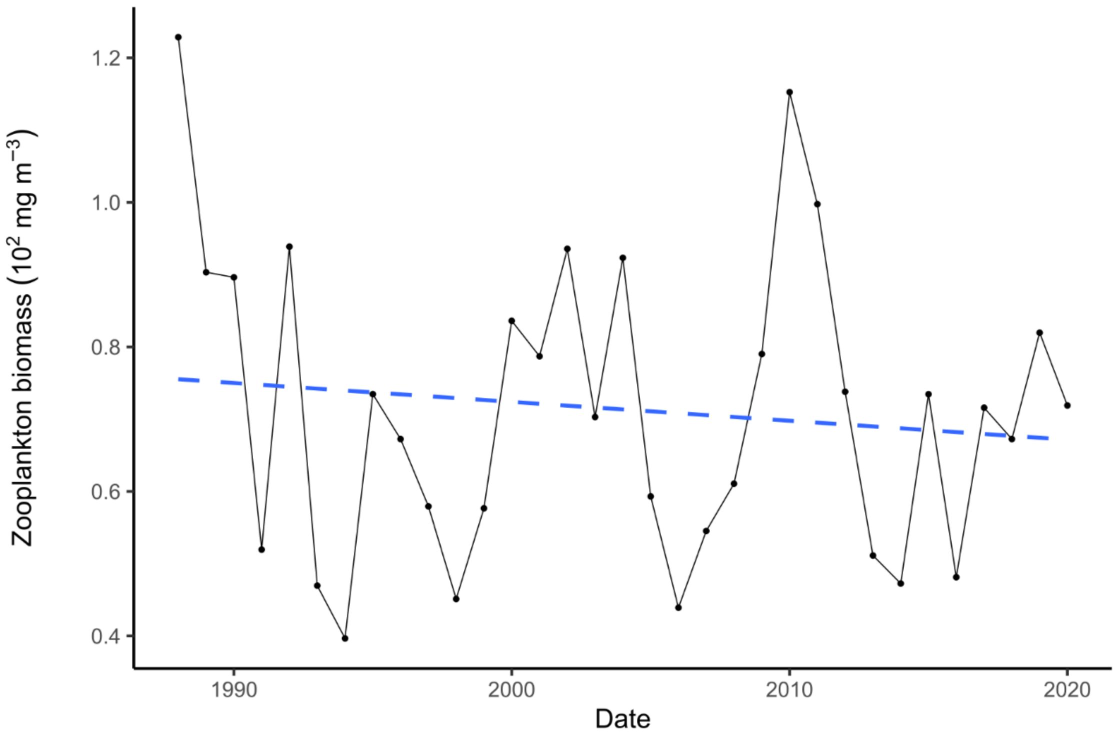

Figure 7: Annual zooplankton biomass budget at station L4 (UK-PML) rebuilt from abundance and carbon content.

The estimation of zooplankton biomass from the masterlist was also conducted for Å17, Alsbäck, Anholt, N14 Falkenberg and Släggö stations (SE-SMHI; **Figure 8**). The biomass estimated at these five stations is higher than the zooplankton biomass estimated at L4 station. The linear model (blue lines) showed that the zooplankton biomass tends to decrease over the time-series at each station except at Släggö. These linear models were directly computed on the estimated biomass. Further developments are needed to better identify the changes in zooplankton biomass over the long term.

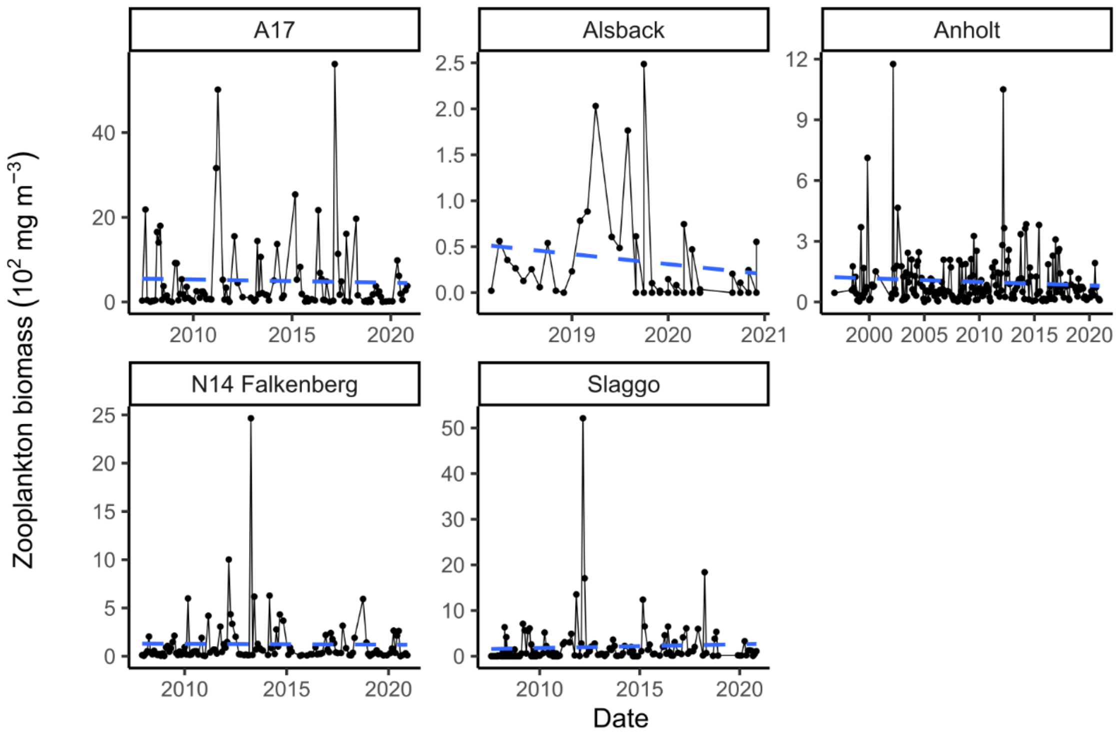

Figure 8: Zooplankton biomass at Å17, Alsbäck, Anholt, N14 Falkenberg and Släggö stations (SE-SMHI) rebuilt from abundance and carbon content.

4. Knowledge gaps

Further development of this indicator is needed, particularly on the following points:

- Adapt the sampling frequency to marine policy issues:

Existing zooplankton biomass consists of distributed monitoring (e.g. BSH dataset). The stations were usually inconsistently sampled in space and time, making inaccurate an assessment of the GES. Ongoing monitoring should adapt their sampling frequency to make consistent across time this effort to produce a reproductible and reliable assessment of zooplankton biomass. In addition, it is necessary to adapt the sampling frequency to other related indicators such as monthly frequency for integration with the FW2 primary production (Louchart et al. 2022) and annual budgets for integration with the FW9 Ecological Network Analysis indicator (Schückel et al 2022).

- Include additional datasets:

Biomass datasets that include numerical (non-categorical) size may be useful to construct a size-biomass model by zooplankton group like the model established by Pitois et al. (2021) for copepods. Obtaining the model equation for zooplankton groups can therefore allow a bulk estimation of zooplankton biomass for datasets where the average size and abundance of each taxon has been measured. Imaging sensors such as in benchtop (ZooScan; Gorsky et al. 2010) or *in situ* (Under Video Profiler, Picheral et al. 2010; Video Plankton Recorder, SeaScan, Inc.) are powerful tools to obtain functional traits at for each organism. Images are stored in local database or in EcoTaxa, a web application dedicated to the visual exploration and the taxonomic annotation of images (https://ecotaxa.obs-vlfr.fr/). The available images can be used to build a library and train a machine learning model to automate the classification of organisms and obtain the functional traits of each organism. The morphometric traits such as volume and size are then used to obtain the carbon content of each organism and thus the biomass by relating carbon content to abundance.

- Improve the master list (spatial expansion of measurements and space-time variation of carbon content):

As reported, zooplankton biomass datasets are scarce. This report presented a masterlist of zooplankton carbon content per taxon associated with WoRMS AphiaID. At this stage, the masterlist includes mainly zooplankton organisms found in the Western English Channel, the Kattegat and Skagerrak. The list should be now expanded to other locations to provide an estimation of zooplankton biomass of the five OSPAR regions. There is also a need to consider space and time of carbon content measurements in the masterlist because the carbon content depends on the size and volume of the individuals (Kiørboe, 2013) which vary in space (usually across latitudes) and time (seasonal and annual variations). Furthermore, an extensive review of ICES Identification Leaflets (www.ices.dk/Science/publications/Pages/ID_leaflets_plankton.aspx) for Plankton can be used to estimate carbon content from organisms morphometrics.

- Consider the sampling period and location:

In the case where the carbon content and size are derived from literature or database and not directly provided by the Institute, it should be mandatory to deliver the information of the sampling date as carbon content and size of organisms vary between years at the same location (Fransz et al., 1991). For the most accurate assessment, the environmental conditions of the sampling locations from the literature that are used to build the master list must match the environmental conditions of the assessment sampling location, as morphometric characters undergo plasticity due to environmental parameters.

- Refinement of the methodology:

The candidate indicator is at an early development stage. This work is based on the recommendations and methodologies of EcApRHA deliverable 3.4.1. (known as the FW6/PH2 CEMP Guidelines). In addition to the challenges mentioned above, further discussions should consider the incorporation of the spatial distribution and the specific composition of zooplankton within the indicator. In addition, to better capture the zooplankton biomass cycle beyond natural variations, there is a need to identify and remove the natural zooplankton biomass cycle for each location. This procedure is currently used in the PH1/FW5, PH2 and FW2 indicators and can be explored for the FW6 indicator.

- Definition of thresholds and or reference conditions:

To perform an assessment of the GES of zooplankton biomass, species composition and spatial distribution, it is necessary to compare the assessment data with reference values. These reference values can be, as in the case of the pelagic habitat and primary production indicators, established by averaging values from the period before the assessment, called the comparison period. A second option to establish the GES is to define a threshold value to compute an Ecological Quality Ratio as of OSPAR eutrophication indicators.

5. Conclusion

Zooplankton biomass datasets are scarce in OSPAR area. Only one contracting party provided zooplankton biomass data to conduct a pilot assessment of the FW6 indicator. Monitoring stations were sampled between 2008 to 2011 with inconsistent sampling frequency across years. The assessment could not be conducted because of scarcity of the data within a year in addition to too short time series. We give some recommendations to improve this indicator in the future.

6. References

Enserink, L., Blauw, A., van der Zande, D. and Markager S. (2019). Summary report of the EU project ‘Joint monitoring programme of the eutrophication of the North Sea with satellite data’ (Ref: DG ENV/MSFD Second Cycle/2016). 21 pp.

Fransz, H. G., Colebrook, J. M., Gamble, J. C., & Krause, M. (1991). The zooplankton of the North Sea. Netherlands Journal of Sea Research, 28, 1-52.

Gorokhova, E., Lehtiniemi, M., Postel, L., Rubene, G., Amid, C., Lesutiene, J., Uusitalo, L., Strake, S. and Demereckiene, N. (2016). PloS one, 11, e0158326.

Gorsky, G., Ohman, M.D., Picheral, M., Gasparini, S., Stemmann, L., Romagnan, J.B., Cawood, A., Pesant, S., Garcia-Comas, C. and Prejger, F. (2010). Digital zooplankton image analysis using the ZooScan integrated system. Journal of plankton research, 32, 285-303.

Holland, M., Louchart, A., Artigas, L.F. and Mcquatters-Gollop A. (2023). PH1/FW5 - Changes in phytoplankton and zooplankton communities. In: OSPAR, editor. The 2023 Quality Status Report for the Northeast Atlantic, OSPAR Commission, London.

Lomartire, S., Marques, J. C. and Gonçalves, A.M.M. (2021). The key role of zooplankton in ecosystem services: A perspective of interaction between zooplankton and fish recruitement. Ecological Indicators, 129, 107867.

Louchart, A., Lizon, F., Claquin, P., Artigas, L. F., 2022. *Pilot assessment on primary production*. In: OSPAR, 2023: The 2023 Quality Status Report for the Northeast Atlantic. OSPAR Commission, London.

Kiørboe, T. (2013). Zooplankton body composition. Limnology and Oceanography, 58, 1843 – 1850.

Magliozzi, C., Druon, J.N., Palialexis, A., Aguzzi, L., Alexande, B., Antoniadis, K., Artigas, L.F., Azzelino, A., Bisinicu, E., Boicenco, L., Bojanic, N., Borrello, P., Boschetti, S., Carmo, V., Cervantes, P., Coll, M., Curmi, M. Del Amo, Y., Dutz, J., Francé, J., Garcés, E., Gea, G., Giannakourou, A., Goberville, E., Goffart, A., Gomes Pereira, J.N., González-Guirós, R., Gorokhova, E., Helaouet, P. Henriques, F., Heyden, B., Jaanus, A., Jakobsen, H., Johansen, M., Jurgensone, I., Korpinen, S., Kremp, A., Kuosa, H., Labayle, I., Lazar, L., Guglielmo, L., McQuatters-Gollop, A., Nincevic, Z., Pagou, K., Penna, A., Pettersson, K., Ruiter, H., Skejić, S., Spada, E., Spinu, A., Tew-Kai, E., Totti, C., Tunesi, L., Vadrucci, M.R., Valavanis, V., Varkitzi, I., Vasiliades, L., Veldeki, G., Vidjak, O, Vincent, D. and Zervoudaki, S. (2021). Pelagic habitats under the MSFD D1: scientific advice of policy relevance. European Commission, Luxembourg.

McQuatters-Gollop, A., Guérin, L., Arroyo, N.L., Aubert, A., Artigas, L.F., Bedford, J., Corcoran, E., Dierschke, V., Elliott, S.A.M., Geelhoed, S.C.V., Gilles, A., Gonzalez-Irusta, J.M., Haelters, J., Johansen, M., Le Loc'h, F., Lynam, C.P., Niquil, N., Meakins, B., Mitchell, I., Padegimas, B., Pesch, R., Preciado, I., Rombouts, I., Safi, G., Schmitt, P., Schückel, U., Serrano, A., Stebbing, P., De la Torriente, A. and Vina-Herbon, C. (2022). Assessing the state of marine biodiversity in the Northeast Atlantic. Ecological Indicators, 141, 109148.

Picheral, M., Guidi, L., Stemmann, L., Karl, D. M., Iddaoud, G., & Gorsky, G. (2010). The Underwater Vision Profiler 5: An advanced instrument for high spatial resolution studies of particle size spectra and zooplankton. Limnology and Oceanography: Methods, 8, 462-473.

Pitois, S.G. and Fox, C.J. (2006). Long-term changes in zooplankton biomass concentration and mean size over the Northwest European shelf inferred from Continuous Plankton Recorder data. IECS Journal of Marine Sciences, 63, 785 – 798.

Pitois, S.G., Graves, C.A., Close, H., Lynam, C., Scott, J., Tilbury, J., van der Kooij, J. and Culverhouse, P. (2021). A first approach to build and test the Copepod Mean Size and Total Abundance (CMSTA) ecological indicator using in-situ size measurements from the Plankton Imager (PI). Ecological Indicators, 123, 107307.

Schückel, U., Nogues, Q., Brito, J., Niquil, N., Blomqvist, M., Sköld, M., Hansen, J., Jakobsen, H. and Morato, T. 2022. Pilot Assessment of Ecological Network Analysis Indices. In: OSPAR, 2023: The 2023 Quality Status Report for the North-East Atlantic. OSPAR Commission, London.

Suthers, I., Rissik, D., and Richardson, A. (2009). Plankton: A Guide to Their Ecology and Monitoring for Water Quality (Csiro Publishing). 248 pp.

Wakelin, S.L., Artioli, Y., Butenschön, M., Allen, J.I., and Holt, J.T. (2015). Modelling the combined impacts of climate change and direct anthropogenic drivers on the ecosystem of the northwest European continental shelf. Journal of Marine Systems, 152, 51 – 63