Document title	Discussion paper: Initial ideas on pelagic habitats and food webs-plus comments
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This document is the document that was shared by the Secretariat with identified HELCOM Expert and Working Groups members on 10 September to initiate discussion on the topics of pelagic habitats and food webs/ecosystems. Comments received to this document have been compiled in the text, shown in red text below. Comments so far received from Sweden, Denmark, Finland and Germany have been included.

Background (text here essentially identical to email)

At the 1st HELCOM Indicator Workshop the topics of pelagic habitats and food webs were raised as issues that should be addressed at the 2nd HELCOM Indicator Workshop (16-18 October 2019) – see information provided within the document below. Since there is currently no designated HELCOM Expert Group that covers these topics directly the Secretariat has drafted a discussion paper on the two topics, see below, that is now shared with existing HELCOM Expert and Working Groups that may address the topics (in part or in full). The document is provided now in preparation for the 2nd HELCOM Indicator Workshop, simply as a way of initiating discussion on the topics. This document could form a document that is submitted to the 2nd HELCOM Indicator Workshop, if needed, but comments directly to it or alternative and more appropriate approaches for shorter-term and longer-term development of suitable HELCOM indicators on these topics would also be most welcomed.

Is 'pelagic habitats' not covered by PEG?

To provide input on the document in the form of additional possibilities, comments or better alternatives please send comments to the Secretariat (owen.rowe@helcom.fi). Ideally comments would be submitted no later than 9 October (i.e. the INF document deadline for the Workshop). Ideally, substantial documents such as better alternatives/proposals requiring deeper consideration nationally would be submitted no later than 24 September so that they can be provided to Workshop participants 3 weeks in advance of the Workshop.

Action requested

As identified HELCOM Expert or Working Groups for which this discussion may have relevance you are invited to provide comments, solutions, or better alternative related to the content of this document.

Preparation for the HELCOM indicator workshop 2-2019

The following topics (pelagic habitats and ecosystems/food webs) were addressed in the first HELCOM indicator workshop in May 2019. These form important components contributing to HELCOM Baltic Sea Action Plan aims and objectives, e.g. Favourable status of Baltic Sea biodiversity, natural marine and coastal landscapes, thriving and balanced communities of plants and animals, viable populations of species. Below in this document are some initial ideas put on paper to initiate discussion. The ideas are loosely formed and the main aim is to address issues raised at the first workshop so that concepts can be developed and progress be made towards a better third holistic assessment (short term), and beyond. Some of the ideas here should be considered in a longer-term perspective (i.e. post-HOLAS III) as the plan here is devise an ideal conceptual approach and then identify what can be realistically achieved in the shorter-term perspective also (e.g. by HOLAS III).

Please adjust, correct, or proposal better alternatives to all aspects below as these are initial ideas only by way of starting the discussion.

Pelagic habitats

FROM 1st HELCOM INDICATOR WORKSHOP 2019: HIGH priority areas/indicators identified for adjustment/development – for HOLAS III: Pelagic habitats, particularly a rationalization of existing indicators, a plan forward to develop an appropriate assessment approach (MSFD D1C6) for post-HOLAS III, and clarification of what can be achieved and how the topic can be tackled for HOLAS III. Define indicator components that can contribute to an assessment, an integration approach, a clear rationale for the assessment system, and longer-term aims (i.e. post-HOLAS III).

Primarily, pelagic habitats, needs to see the development of one or two solid indicators, with justified causality and a solid scientific background. The rational and justification behind several of the current test indicators is weak at best. What is a change in the diatom/dinoflagellate index for instance supposed to signify? Can this be linked solidly to specific pressures?

- Pelagic habitats (taking an MSFD perspective) will explore aspects related to phytoplankton and zooplankton. Other aspects that can be considered as important include flagellates, ciliates, and bacteria (currently no HELCOM indicators for these components). The logic of this is that other components inhabiting the pelagic environment, such as fish or mammals, are assessed independently and subsequently considered under food webs.

'Flagellates' and 'Ciliates' also fall within the groups 'phytoplankton' and 'zooplankton'. This distinction does not make sense.

- Possible aspects to consider when assessing pelagic habitats (for each component): species composition, relative abundance, size structure, sensitive species, functional traits (especially when related to rare or sensitive species), and abiotic structure.
- Habitat types to be assessed: variable salinity, coastal, shelf, oceanic (beyond shelf), other types defined by regional or sub-regional cooperation (from MSFD). Can be made more specific for the Baltic Sea? Could simply applying scale 3 HELCOM assessment units work?

Are there any truly pelagic species in coastal areas? Potentially a simple division into 2 could be applied in the Baltic Sea – coastal and pelagic.

- Identified HELCOM indicators of potential relevance include: phytoplankton (seasonal succession, diatom-dinoflagellate index, cyanobacterial bloom index, chlorophyll-a) and zooplankton.
- Identified HELCOM expert areas: Phytoplankton Expert Group (PEG), Zooplankton (ZEN) and Intersessional Network on Eutrophication (IN EUTRO).
- Identified HELCOM working group of relevance: State and Conservation.

Brief (gu)estimation of available data and information (though does not mean it is relevant):

What is this table based on? Are there scientists who have this data? Future work in indicators for pelagic habitats is likely needed in order to assemble this kind of data.

BIOTIC	**Spp. composition**	**Relative abundance**	**Size structure**	**Sensitive species**	**Functional traits**
Bacteria	Possible*	Possible*	NA†	Possible*	Possible*
Phytoplankton	Available	Available	NA†	Possible?	Possible***
Ciliates/ Flagellates	Possible**	Possible**	NA Possible?	Possible?	Possible***
Zooplankton	Available	Available	Available/Possible	Possible	Possible***

*Next generation sequencing techniques (NGS) are becoming cheaper and more viable here, as are metagenomic and metatranscriptomic approaches and functional analyses.

**Available in some areas, though more from research than monitoring. Cost of implementing monitoring may be an issue. But could be very good indicators, especially with climate change and food web shifts (e.g. towards net heterotrophy).

***Is there not a list of functional traits that is or is to be published? This information probably exists from research basis, certainly for some taxa/habitats, and could be adapted to be considered in an indicator concept or used to identify critical species/groups that should be monitored.

†For bacteria and phytoplankton categories it could be possible to estimate changes in the population size structure or relative size structure (e.g. are the phytoplankton in a community getting smaller) which may have relevance for aspects such as grazing or longer-term community composition. Such information could be useful for comparisons between taxonomic groups (e.g. is a general population size change in phytoplankton influencing zooplankton communities). Could this aspect be covered more strongly in food webs?

Note that the table above is generally filled based using the thinking of comparisons within a taxonomic group, i.e. can you compare relative abundance, species composition or size structure within a taxonomic group and use that to indicate changes (rather than comparing changes between the taxonomic groups).

This is correct, but we are still quite far from coupling observed changes with causes (pressures). Lack of qualification makes it near impossible to set target values for such parameters.

ABIOTIC	Temperature	Oxygen	pH	Acidity (various components)	Water transparency	Dissolved Organic Matter (DOM)	Particulate organic matter (POM)	Carbon (could add DIC also)	Humic substances	Photosynthetically available radiation (PAR)	Salinity	Nitrogen (TN and DIN)	Phosphorus (TP and DIP)	Silica	Halocline (e.g. depth of, seasonal change)	Stratification	Ice cover
	Available	Available	Available	Under development	Available						Available	Available	Available				Available

Initial ideas to discuss/review/delete/develop

- Keep the system flexible so that new indicators or components can easily be added in the future as development/adjustment take place.
- A simple way could be to apply the One-out-all-out (OOAO) approach to do this between the selected (and justified) indicators compiled. It is also considered highly precautionary, comprehensive and robust (Borja et al., 2014. Frontiers in Marine Science 1, 72).
- A less stringent approach could be to apply a conditional rules approach where X% (e.g. 75%) of all considered indicators must achieve their threshold values.
- Would likely also be important to clearly state that number of indicators selected (n) must be of a viable number (e.g. n > 5), possibly also indicating specific parameters or groups that need to be covered by n. Otherwise a single indicator might skew the assessment results and misrepresent the overall reality.

Rather than developing a large number of indicators and relying on averaging for a sensible result, perhaps it would be better to develop one or two solid indicators instead?

- Alternatively, some form of scaling between the selected parameters could be applied – e.g. to reflect that the biotic factors respond to the abiotic and the abiotic may not be ones that can be controlled directly. A way to at least pinpoint the drivers of the biotic change would likely be critical so that it defines where measures etc could be addressed.
- Abiotic factors likely need to be considered as trends (this aspect is covered in draft proposals for new HELCOM indicator structure). Trends could be added into the evaluation based on trends for the same assessment period or the period plus a relevant preceding time frame.
- Another alternative could be to carry out the evaluation based on purely the biotic factors and apply the abiotic factors as additional explanatory or risk assessment factors that would inform the overall evaluation.

Some form of integration will likely be needed, but the 'correct' approach will depend on the number and nature of the final indicators. If many indicators are in play, a OOAO approach is perhaps too strict. This approach is likely more reasonable with relatively few indicators.

- If research is available on tipping points then a link could be made between abiotic and biotic factors, e.g. if temperature increase of 5 degrees is shown to alter species composition or cause a species to disappear, or cause functional changes, then that could be applied to this overall system too either by creating built in threshold values for abiotic factors as separate indicators or by ensuring that species composition aspects are not changed once a tipping point is met.

We will hopefully not see a 5 degree increase in temperature!

- Could threshold values be applied to abiotic factors (practical/justifiable)? Expert based? Could values for temperature in the marine environment for example be inferred from target values set for example by the Paris agreement?

Possible option # 1

Based on using existing HELCOM indicators.

As stated earlier, these lack qualification. What are changes believed to signify, and how is it coupled to specific pressures. More indicator development work is need at the moment in order to qualify indicators.

Phytoplankton: species composition (seasonal succession), relative abundance (diatom-dinoflagellate index, cyanobacterial bloom index), functional traits (cyanobacterial bloom index). Chlorophyll-a more abundance or biomass related.

Zooplankton: species composition (covered), relative abundance (covered, could possibly be expanded), size structure (covered in general terms as mean size), functional traits (could possibly be expanded, more relevant if flagellates and ciliates included).

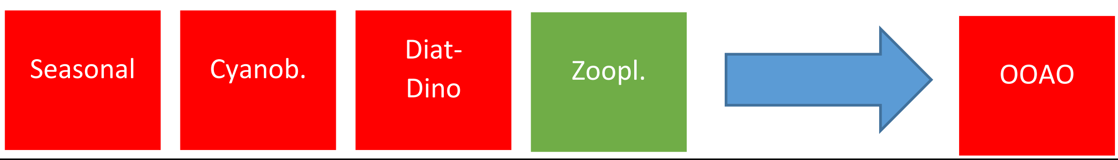
Abiotic structure: Data is available for some components, though not in indicator form – e.g. temperature, salinity, N, P, ice cover.

Components related to sensitive species and functional traits not strongly represented in current indicators.

Example: Apply the OOAO or conditional rules system, where n must be 4 or more (e.g. using individual components: diatom-dinoflagellate index, cyanobacterial bloom index, chlorophyll-a), and at least one must be representative of a non-primary producer (i.e. zooplankton). Abiotic factors could be then used as trend analyses to try and assign explanatory information to the outcome, for example fails due to high Chl-a due to elevated nutrients, or worsening due to increasing water temperature. Possibly if applying a scaling approach the values for the outcome could be further adjusted based on trends of abiotic factors (covering the same assessment period). For example if aggregating and categorizing or scaling the above indicators based on their outcome against independent threshold values (e.g. possibly using gap to good status as a scaling approach) the overall result could be downgraded by a category or a certain percentage if temperature was seen to increase over a set value (lets say 0.1 degree as an arbitrary example) over a given period (lets say 15 years). This would assess pelagic habitats as a whole rather than look at components on their own. Such an approach could be applied as an interim stage for short-term development using existing indicators. Not likely to achieve good status, but possibly a fair reflection of status and applies a highly precautionary approach.

As stated above, integration is of course a key point in the final assessment. It seems premature, however, to discuss specific integration rules before indicators are more well-established. Development of indicators should rest on a solid scientific foundation, and should thus be a task for relevant scientists rather than policy makers.

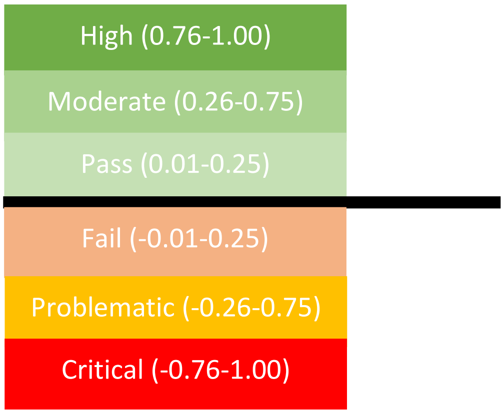
Option 1 a.



A box above can be considered as representing a single HELCOM assessment unit. Abiotic factors would have to be added on here via an alternative section, possibly as proposed above and in example below (or some alternative solution?).

Option 1 b.

Here the scaling is added as a form of normalized gap to threshold value and then as an average. Outcome average could be represented against a categorical scale (see initial idea below).



Idea on scaled average approach categorical assessment.

Option 1 b plus abiotic.

Identified important abiotic drivers (could for example identify those clearly linked to human activities or human induced climate change) could also be included. Such an approach could be applied to say that if one or more of the abiotic factors shows a then then a penalty is applied. It would require expert discussion to define what timeframes the trends should be set over or if a reference period should be applied etc. Chlorophyll-a could to some extent be considered here too as it is possibly more indicative of eutrophication aspects (i.e. N and P) than of the biotic aspects addressed under pelagic habitats (?).

Scaled assessment as above:

With penalty applied to above based on abiotic trends from same assessment period:

Possible option # 2

Based on alternative approaches (see Lehtinen et al., 2016. Frontiers in Marine Science 3, 220).

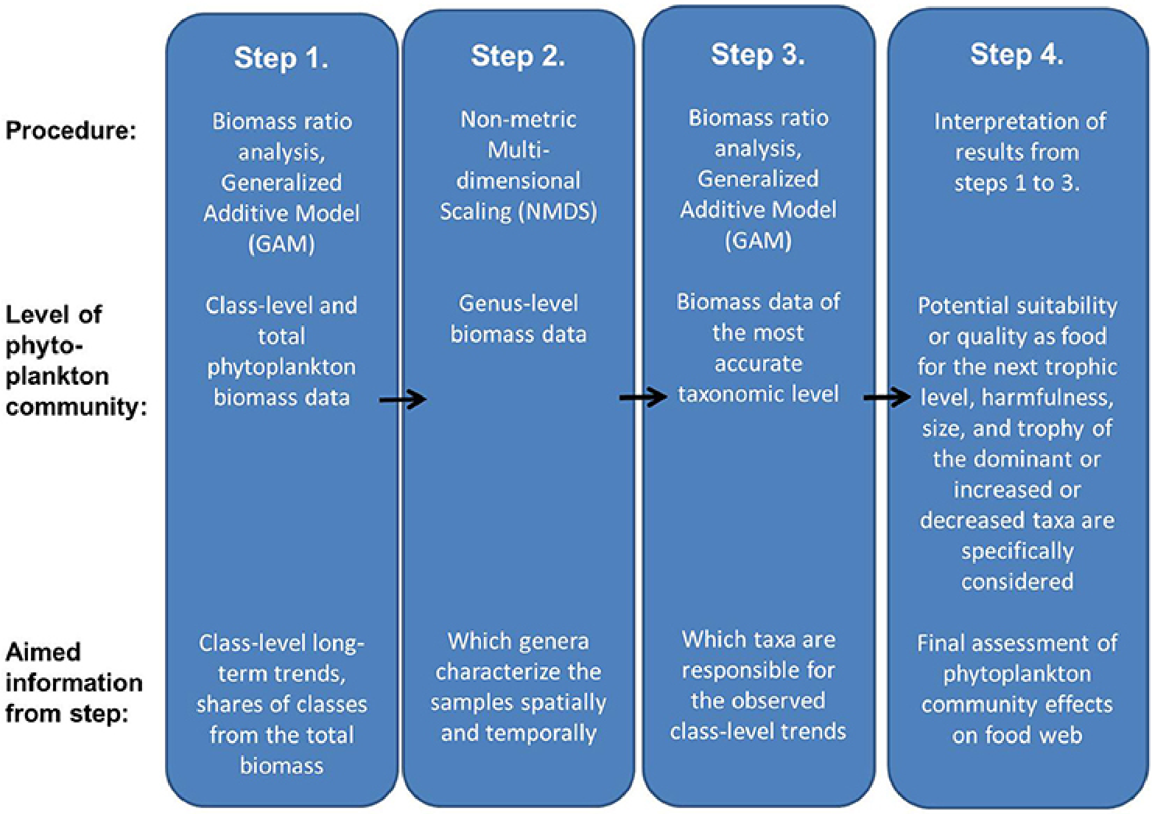


Figure taken from Lehtinen et al., 2016. Frontiers in Marine Science 3, 220.

Note that the information above taken from Lehtinen et al. (2016) is not correctly explained in the original document. The approach set out in the paper includes only the analysis of phytoplankton and infers potential effects on the food web from this.

It could conceivably be used in cooperation with a similarly analyzed zooplankton indicator but would require development.

Possible option # 3

Based on alternative approaches (see McQuatters-Gollop et al., 2019. Ecological Indicators 101, 913-925).

Plankton Index approach applied based on the accepted fact that plankton are the foundation of most pelagic food webs and have a critical role in carbon sequestration and energy flow to higher trophic levels. Plankton are also highly responsive to abiotic factors and climate change. To set the threshold value the approach sets out that good status is achieved if the plankton community is not significantly adversely influenced by direct anthropogenic pressures.

Considers heterogeneous nature of marine environment by dividing waters into six “eco-hydrodynamic” regimes (e.g. permanently mixed, permanently stratified, fresh water influence, seasonal thermal stratification, intermittent stratification, and indeterminate regions). Coastal areas also considered.

Defines plankton ‘lifeforms’ grouping taxa based on traits such as size, trophy, and motility (taxa can be in multiple lifeforms categories). Ecologically relevant lifeform pairs made so that changes in these components can indicate aspects such as altered energy flows or food web structuring. More lifeforms can be defined and added to the system as knowledge increases.

Table 2
Plankton taxa were assigned traits based on our simple definition based on key biological features.

Trait type	Trait categories
Plankton type	Phytoplankton: protista taxa that contribute to primary production
	Zooplankton: metazoan taxa of the kingdom Animalia
Zooplankton type	Fish/eggs: taxa of the subphylum Vertebrata
	Copepod: taxa of the subclass Copepoda
	Gelatinous: taxa of the phylum Cnidaria and Ctenophora
	Crustacean: taxa of the Subphylum Crustacea
Phytoplankton type	Diatom: taxa of the class Bacillariophyceae
	Dinoflagellate: taxa of the phylum Dinoflagellata
Zooplankton trophic mode	Carnivore: taxa which prey on zooplankton
	Herbivore: predominately suspension or filter feeders
	Omnivore: includes both carnivorous and herbivorous feeding
	Ambiguous: diet uncertain
Habitat	Holoplankton: taxa which spend their entire lifecycle in the plankton
	Meroplankton: taxa which spend part of their lifecycle in the plankton
	Tychopelagic: benthic diatoms which can become mixed into the water column
Size	Large: phytoplankton ($\geq 20\ \mu m$ diameter); zooplankton (≥ 2 mm adult body length)
	Small: phytoplankton ($< 19\ \mu m$ diameter); zooplankton (< 1.9 mm adult body length)

Table 3
Plankton lifeforms are comprised of taxa sharing the same traits.

Lifeform	Traits
Diatoms	Plankton type = 'Diatom'
Dinoflagellates	Plankton type = 'Dinoflagellate'
Gelatinous zooplankton	Plankton type = 'Gelatinous'
Fish larvae/eggs	Zooplankton type = 'Fish' AND 'Eggs'
Non-carnivorous zooplankton	Plankton type = 'Zooplankton' AND Trophic mode = either 'Herbivore', 'Omnivore', OR 'Ambiguous'
Crustaceans	Zooplankton type = 'Crustacean'
Large phytoplankton	Plankton type = 'Phytoplankton' AND Size = 'Large'
Small phytoplankton	Plankton type = = 'Phytoplankton' AND Size = 'Small'
Pelagic diatoms	Phytoplankton type = = 'Diatom' AND Habitat = 'Holoplankton'
Tychopelagic diatoms	Phytoplankton type = 'Diatom' AND Habitat = 'Tychopelagic'
Holoplankton	Plankton type = 'Zooplankton' and Habitat = 'Holoplankton'
Meroplankton	Plankton type = 'Zooplankton' and Habitat = 'Meroplankton'
Large copepods	Zooplankton type = 'Copepod' AND Size = 'Large'
Small copepods	Zooplankton type = 'Copepod' AND Size = 'Small'
Phytoplankton	Plankton type = 'Phytoplankton'

Table 4
Plankton lifeform pairs consist of two contrasting and ecologically-relevant plankton lifeforms. The rationale behind their selection is also described.

Lifeform pairs	Ecological rationale
Diatoms and dinoflagellates	Systems receiving high nutrient input are often dominated by dinoflagellates at the expense of diatoms (McQuatters-Gollop et al., 2009). In the North Atlantic, stratification plays a key role in structuring phytoplankton communities with dinoflagellate abundances connected to increased stratification while diatoms are better suited to mixed waters (Barton et al., 2015). Change in the relative abundance of the two plankton lifeforms can therefore indicate changes in nutrient and stratification regimes.
Pelagic diatoms and tychopelagic diatoms	Benthic disturbance, such as from development or storms, can resuspend tychopelagic (benthic) diatoms in the water column (Ubertini et al., 2012). A shift in the proportion of tychopelagic and pelagic diatoms can therefore indicate changes in the magnitude and frequency of benthic disturbance and resuspension events.
Large microphytoplankton (≥ 20 µm diameter) and small microphytoplankton (< 19 µm diameter)	Organism size is a key factor in energy transfer efficiency in pelagic habitats and may determine the system's potential to support higher trophic levels (Fox and Pitois, 2006; Thiebaux and Dickie, 1993). Changes in the relative abundance of large microphytoplankton (≥ 20 µm diameter) and small microphytoplankton (< 19 µm diameter) can therefore indicate alterations in energy flow to higher trophic levels.
Microphytoplankton and non-carnivorous zooplankton	Non-carnivorous zooplankton graze on microphytoplankton, thereby transferring energy from single-celled algae to metazoan animals. Changes in the relative abundance of the two plankton lifeforms can therefore indicate changes in energy flow through the pelagic food web.
Small copepods (< 1.9 mm) and large copepods (≥ 2 mm) adult body length	Copepods are a key food resource for higher trophic levels, including commercially important fish such as larval cod, whose survival is linked to the mean size of their prey (Beaugrand et al., 2003). A change in the proportion of large (≥ 2 mm in length) and small (< 1.9 mm in length) adult copepods can therefore indicate changes in food web structure (Capuzzo et al., 2018; Fox and Pitois, 2006).
Holoplankton and meroplankton	Meroplankton only spend a part of their lifecycle within the pelagic realm, and for their most part, are the larvae of benthic organisms. A change in the proportion of meroplankton and holoplankton (plankton spending their whole lifecycle within the pelagic realm) can indicate a change in the strength of benthic and/or pelagic production with consequences for pelagic-benthic coupling (Kirby et al., 2008; Lindley et al., 1995).
Crustaceans and gelatinous zooplankton	Gelatinous organisms within the plankton can have an important predatory effect on other crustacean plankton and fish larvae when abundant, thereby acting as a pressure on fish populations. A change in the relative abundance of crustaceans and gelatinous zooplankton can thus indicate a change from an ecosystem with numerous fish of commercial interest to an ecosystem dominated by gelatinous organisms of low commercial interest (Kirby et al., 2009; Purcell and Arai, 2001; Richardson et al., 2009).
Gelatinous zooplankton and fish larvae/eggs	Gelatinous organisms within the plankton can have an important predatory effect on other crustacean plankton and fish larvae when abundant, thereby acting as a pressure on fish populations. A change in the relative abundance of fish larvae/eggs and gelatinous zooplankton can thus indicate a change from an ecosystem with numerous fish of commercial interest to an ecosystem dominated by gelatinous organisms of low commercial interest (Kirby et al., 2009; Purcell and Arai, 2001; Richardson et al., 2009).

All tables above from McQuatters-Gollop et al., 2019. Ecological Indicators 101, 913-925.

A Plankton Index (PI) used to identify changes over time from a starting period (can be set as a reference period). This defines the starting/reference period around which an envelope (reference boundary) can be drawn. The subsequent data (i.e. the assessment period) can then be included and data outside of the reference period will be visualized. The output provides an indication of which of the lifeform pairs has changed and statistical significance, with a PI value of 1 indicating no change and a PI value of 0 indicating complete change. This can identify the components of the pelagic foodweb (even the interactions between pairs) that have changed during the assessment period and allow for suggestions on the reasons underlying the changes to be made.

Foodwebs

FROM 1st HELCOM INDICATOR WORKSHOP 2019: HIGH priority areas/indicators identified for adjustment/development– for HOLAS III: Food webs, particularly the diversity and balance of trophic guilds to initiate discussion related to the development of a viable assessment approach (MSFD D4C1 and D4C2). The immediate focus will consider how the topic can be tackled in HOLAS III and the longer-term aims for improved assessments post-HOLAS III. Clarify a framework for the assessment, a suitable constellation of indicators, and a clear rationale for the assessment system.

Thank you for this first draft overwiev of what could be done in regards to the food web indicators, some general comments to the document:

- As a HELCOM CP that are also member of EU, it is important that the indicators developed in HELCOM can also be used to support CP's in ther national obligations under MSFD.

- Since the the work with indepentend food web indicators are still in the initial phase, we are of the wiev that we should try to keep it as simple as possiple. Eg. By focusing on one of the proposed ecosystem (pelagic/coastal/benthic) and limit ouer focus to few areas as eg. diversity within trophic guilds and balance of abundance between guilds.

- Maybe it would be an idea to cooperate with OSPAR, since they are having the same discussions on how to assess food web.

- It would also be helpful to discuss the establishment of an official regional list of trophic guilds that will be assessed.

- Ecosystems, including food webs (taking an MSFD perspective) need to consider/develop a list of trophic guilds via regional/sub-regional cooperation (where species or lowest appropriate taxonomic level is considered).
- Must include minimum of 3 trophic guilds, 2 must not be fish, 1 must be a primary producer – ideally primary, secondary and top included.
- ICES list of tropic guilds as advice/guidance: primary (phytoplankton), secondary (zooplankton), benthos (filter-feeders, deposit-feeders, planktivores, benthic feeding fish, benthic-feeding birds, demersal predatory birds), pelagic fish (planktivores, sub-apex and apex), birds (planktovores, sub.-apex and apex), mammals (apex).

Apex could also include certain piscivorous fish.

- Other aspects raised in ICES Special Request Advice (published 20 March 2015): trophic and functional groups, potentially includes all living organisms and non-living organic components, network of feeding interactions between consumers and their food (Rogers et al., 2010), reproductive capacity maintains fertility and avoidance of reduction in population genetic diversity
- Possible aspects to consider when assessing ecosystems/foodwebs (for each taxonomic component): diversity, species composition, relative abundance, balance of total abundance between trophic guilds, size distribution of individuals, productivity (last two being secondary MSFD criteria).
- Identified HELCOM indicators of potential relevance include: phytoplankton (seasonal succession, diatom-dinoflagellate index, cyanobacterial bloom index, chlorophyll-a), zooplankton, fish (migratory, commercial (?), coastal and aspects such as length under development), birds (wintering birds, breeding birds and eagle), and mammals (three seal spp. and harbour porpoise).
- Identified HELCOM expert areas: Phytoplankton Expert Group (PEG) and Intersessional Network on Eutrophication (IN EUTRO), Benthic Habitats Expert Group (EN BENTHIC), Zooplankton (ZEN-ZIIM), FISH PROIII, EG MAMA, and JWG BIRD.
- Identified HELCOM working group of relevance: State and Conservation and FISH.

- Habitat types to be assessed? Should different assessments be made for different habitat types? If needed could this be done based on HELCOM HUB and existing HELCOM assessment units (e.g. scale 3 and coastal areas)? Same division as pelagic habitats in MSFD needed, i.e. variable salinity, coastal, shelf, oceanic (beyond shelf), other types defined by regional or sub-regional cooperation?

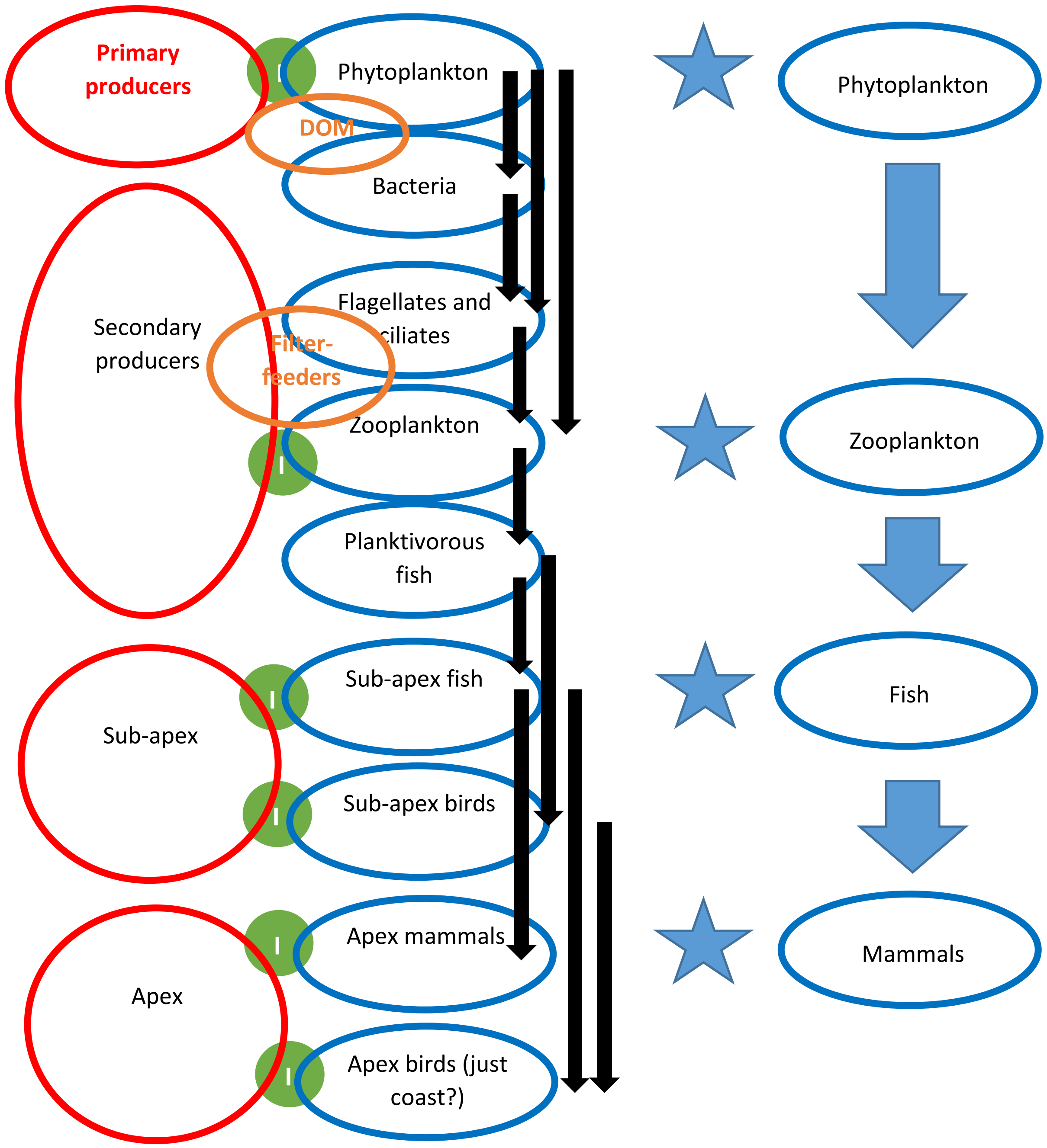
Is data for all suggested guilds represented at this scale? Perhaps scale 2 is better if mammals, birds and plankton should be included?

Very simplified food webs

Below are some simplified food web/ecosystem ideas for pelagic, coastal and benthic ecosystems. Outlined under that are some ideas on possible short- and longer-term indicator approaches.

Regarding the diagram below some changes and alteration should be considered, for example: are planktivorous fish seen as secondary consumers? No fish species in the BS are feeding on phytoplankton in the way that flagellates, ciliates and zooplankton do. Where are piscivorus fish? Is it the same as sub-apex fish? I think one should split fish that feed on benthos, planktivores and piscivores.

Pelagic ecosystems

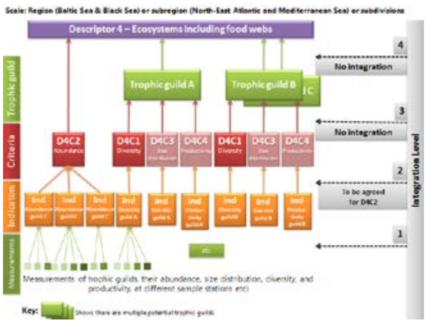


The above figure is a very crude food web for pelagic ecosystems (food webs). It tries to put together some of the taxa but also to divide them up into guilds, including based on functional aspects. The terms added try to take into consideration terms set out in the MSFD and in the ICES guidance from 2015. The black arrows are simplistic links between the compartments in the food web and the green circles suggest where there are HELCOM indicators (operational, or down to candidate) that may be relevant for the approach. Where the stars are indicates what could represent a simple but valid food web/ecosystem indicator (i.e. bringing the assessment of these four components together). Ideas on possible indicator/assessment approaches below.

The black arrows are more indicative of a food chain. Shouldnt there be links going the top-down path as well? This is very bottom-up focused in the current form.

Clarification – the stars indicate ’areas’ where there are existing or under development HELCOM indicators that could, in theory, be used for a simple assessment.

When it comes to the structure and what indicators to develop, I do not have a fixed solution, but we could be inspired by draft MSFD art 8 guidance, that shows some thoughts on how it could be done.



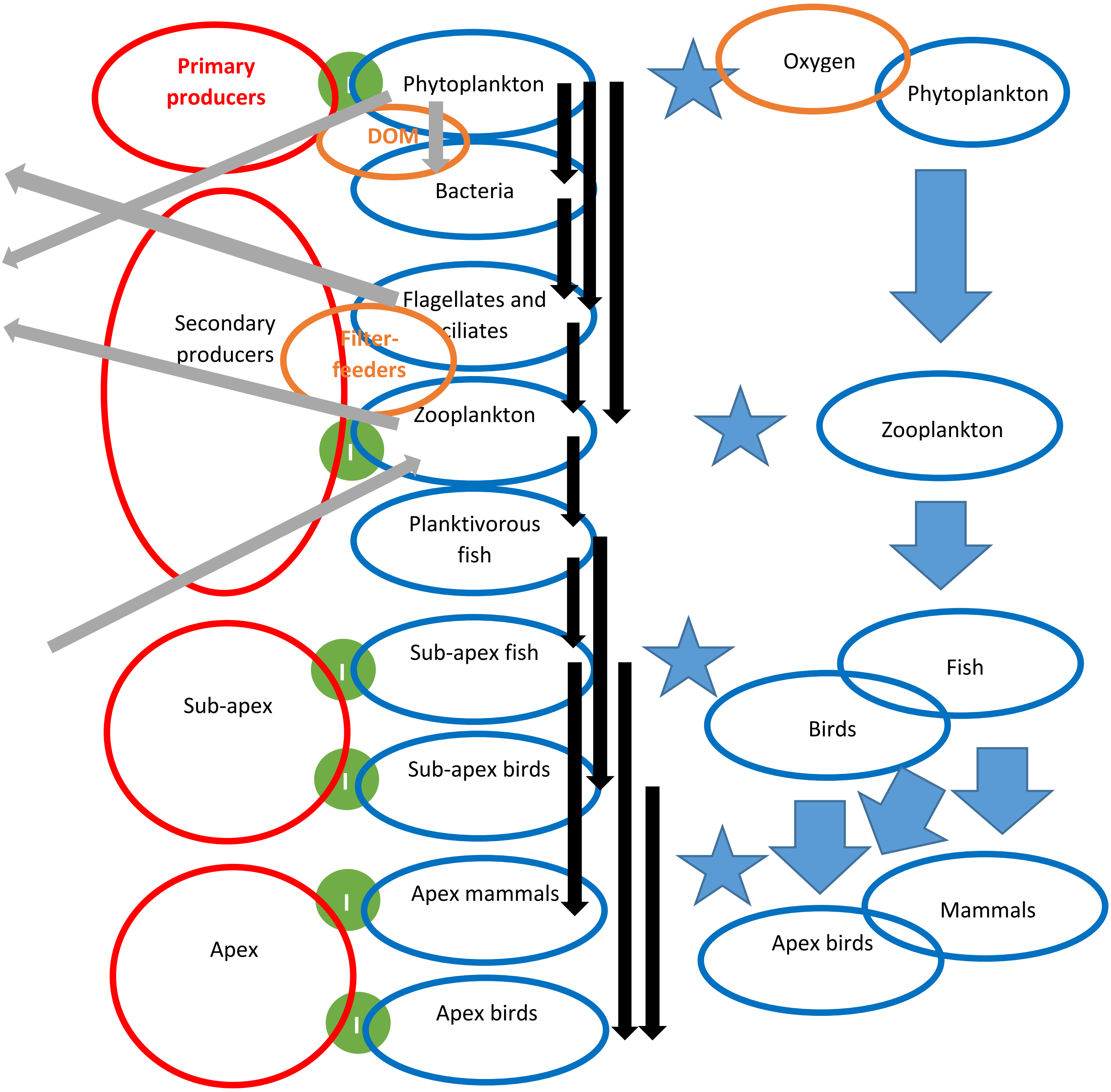
Here is a brief idea for developing indicators for food web.

<u>The top layer </u>(purple in the figure) could be an ”umbrella like” indicator giving an final description of the entire food web for the chosen ecosystem (pelagic/coastal/benthic). This owerarching indicator will include results from the assessment of abundance between throphic guilds in the current ecosystem and diversity within single trophic level in the same ecosystem. GES is not defined at this level.

One indicator is developed for <u>abundance</u> between throphic guilds in the the current ecosystem. GES is defined at this level. This assessment will go directely to the ”umbreala” indicator to be used in the joined description of the state of the current ecosystem.

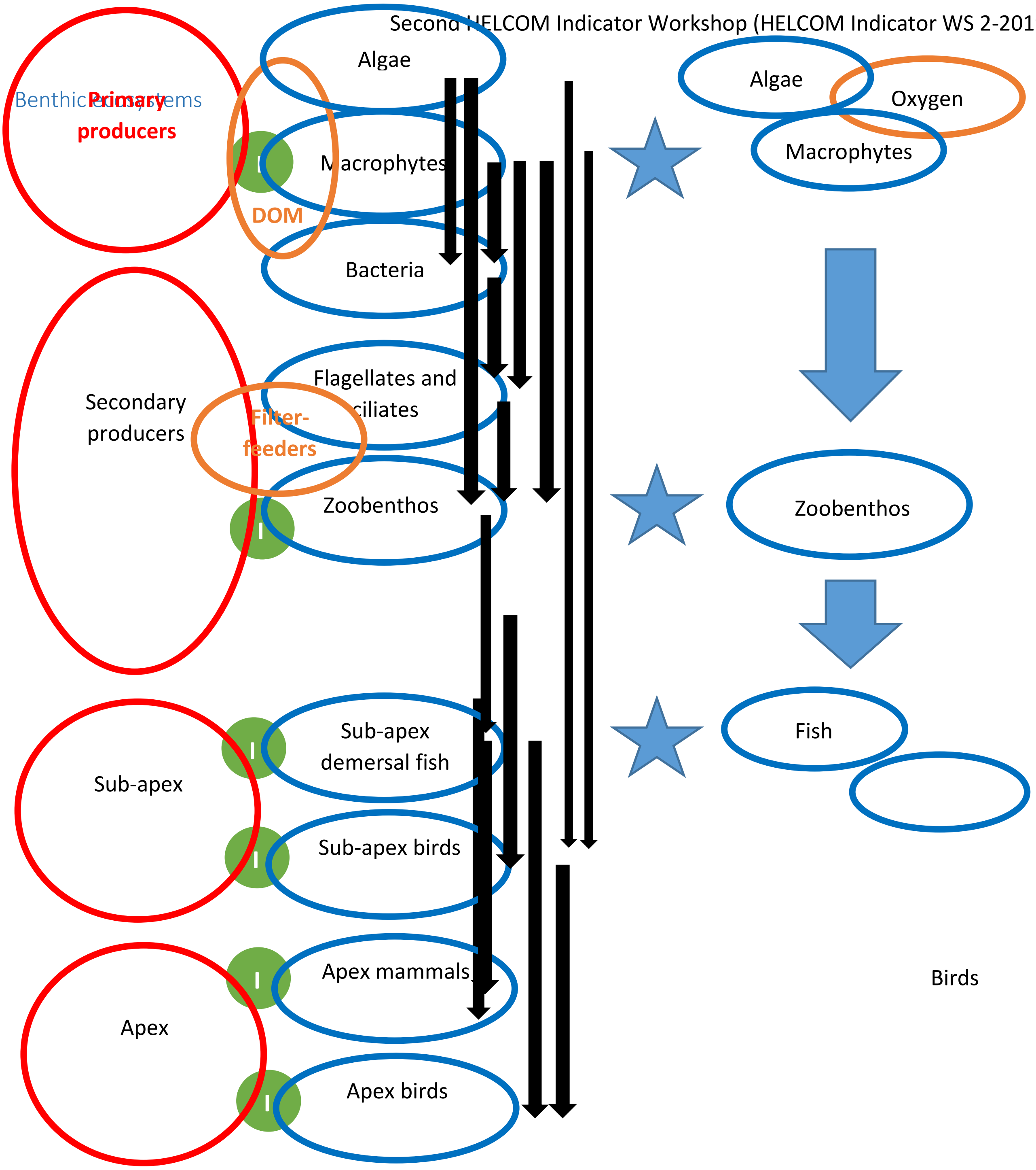
Several indicators (one per throphic guild - eg. Primary producers, sec. Producers, sub-apex and apex) are develop to assess <u>diversity </u>within single trophic level in the same ecosystem (pelagic/coastal/benthic). GES is defined at this level for each throphic gulid. All assessments of diversity will hereafter go to the ”umbrella” indicator to be used in the joined description of the state of the current ecosystem.

Coastal ecosystems (aquatic part)



As with pelagic habitats, above, but grey arrows indicate potential interaction with the benthic environment is coastal (especially shallow) areas. Could an assessment cover all or various routes in the above flow (right hand side) – i.e. using the productivity aspect for the eagle indicator, or using the haul out component in the seal indicators. Adding the abiotic oxygen factor could also be a strong factor as any poorly oxygenated coastal zone is unlikely to be of good status. It could also rely on selected aspects from the bird indicators, for example selecting the component related to waders.

Same comments as on above diagram.

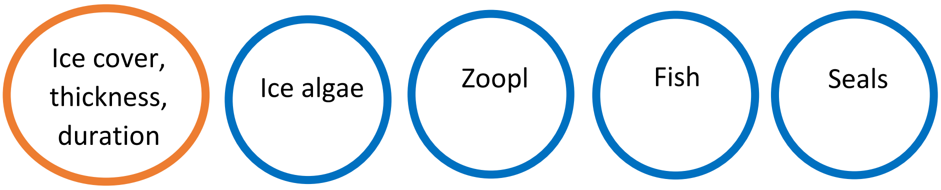


For benthic habitats could fish consider just demersal ones (e.g. could cod be used or could some flat fish be considered only), or could migratory fish also be relevant, possibly also juvenile stages of fish that use the coastal area for breeding? Birds could again be selected to only look at the benthic feeding group from the indicators. Mammals are excluded here, as is the eagle, since separating them specifically to only benthic appears difficult. Grey arrows from coastal above also relevant here. See more discussion below on benthic-pelagic coupling.

Same comments as on above diagram.

Ice ecosystems

Should ice-cover be considered here as part of the Baltic ecosystem assessment? It has critical importance for some things, e.g. ice algal and microbial communities, timing of spring blooms, and also for breeding of ringed seals.



While the middle three may be problematic or costly for monitoring then possibly number 1 and 5 (ice cover aspects and could act as an indicator of ice ecosystems for now.

From an MSFD perspective: a little bit strange to include the physical habitat here I think as there is no criteria for habitat within D4 in the MSFD. The algal and bacterial communities in the ice might very well be assessed, but not the ice cover itself.

Possible options could include:

1. Developing a specific food web indicator that summarises these aspects using a specifically designed method (e.g. some multi-dimensional scaling approach). Possibly a similar approach to those above for pelagic habitats but taking into account more trophic guilds. Could future developments in BEAT provide the integrated assessment for such ecosystems?

With this it is meant that a multivariate index based on several indicators of the food web are used to describe the ecosystem state?

2. Applying a one-out-all-out (OOAO) approach, or alternative to this aggregation approach to existing HELCOM indicators could provide an assessment in the short term (or longer). There are many assumptions involved here such as that all threshold vales are somehow in correspondence with one another.

It might be relevant to look at draft MSFD art 8 guidance that shows a possible way forward for the integratione of food-web indicators. And how to use the different componants for one assessment per throphic guild.

For example (as above some scaling/averaging approach could also be applied):

Should there be tresholds for status for food webs? Arent there just different states that we are observing?

3. As above with the OOAO approach, but set so that the approach only covers each issue/component separately (e.g. diversity, species composition, relative abundance, balance of total abundance between trophic guilds, size distribution of individuals, or productivity). This would mean that any integration/aggregation of indicators to assess a food web/ecosystem would only focus on a single parameter, i.e. comparison between trophic guild is only carried out with one of these components, for example abundance is used for all trophic guilds. This would require thresholds per tropic guild for each component to be in place so that a OOAO or some scaling approach could be applied.

Should there be thresholds at all? D4 might serve as a surveillance indicator wothout thresholds?

4. Using the above and subsequently combining multiple components so that ecosystem is assessed with greater overview/certainty, for example combining abundance, size and diversity components.

5. Baltic Sea ATLANTIS model (https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0199168). Could this model be used to evaluate an ecosystem or food web in the Baltic Sea? The model itself contains many of the tropic guilds and functional aspects covered above. Could the model be re-adapted by feeding in data from agreed reference periods (e.g. those used in established HELCOM indicators – for practical reasons currently the model uses data from 2005 as main input to structure the model)? Could the model be run using data inputted to the model for components where there are known data trends for an assessment period – and would forcing the model via the data inserted indicate if a functional food web/ecosystem was achieved (i.e. the model would be inhibited by data that was 'out of balance' – e.g. if oxygen was too low or if zooplankton biomass was too low then the model would fail to run beyond a certain stage and compute an error – result being a failure to achieve balance food web and red status)? Could applying the data for indicators on important sections of the food web (e.g. phytoplankton, zooplankton, fish and mammals) test if the model provided a balanced result – thus indicating of the ecosystem/food web is functional/in good status? Could this model be used to also evaluate if the good status threshold values for different assessment components are compatible (e.g. could it indicate if good status threshold for nutrients equates with good status in bird or zooplankton)? Could threshold values agreed in HELCOM be applied to the model output (e.g. all the trend figures per trophic group) also to determine which factors may be the 'break points' in the ecosystem (e.g. by adding in the status of zooplankton as a fixed value and running the model could it infer if fish or phytoplankton were the potential causative factor)? Could running the model driven by multiple different scenarios (including based on fixed values from known data or threshold values) inform on ecosystem/food web functionality and status?

Can we define a reference state for food webs? Arent they just in different states? Defining 'functionality' in this concept would need to be examined as all food webs can be considered as functional just in different ways.

Additional details provided by some of the the ATLANTIS model autors: It should be possible to cover most of the options you mention with Atlantis in point 5.

Concerning abundances and biomasses of different functional groups in the food web in the Baltic Sea ecosystem (see below) the Atlantis model can in context of HOLAS III be calibrated to other certain baseline year(s). Also, the Atlantis can be calibrated to a given year concerning physical and hydrographical forcing by the RCO-SCOBI climate and bio-geo-chemical models.

Atlantis estimates the biomass pool (and production) for each of the 29 functional groups in the Baltic Sea ecosystem and foodweb for the different areas (Atlantis polygons) on a seasonal and yearly basis (for any period). Accordingly, this can also used for evaluating species composition, relative abundance (or biomass), and to evaluate balance of/between total abundance/biomass in trophic guilds, and to define robust guilds on a regional basis according to ecosystem and forcing dynamics. Also, size distributions for the vertebrates can be evaluated for the vertebrates, which by the way are separated into age groups and the juvenile and mature part of the population. Furthermore, Atlantis estimate abundance, biomass, mean weight, mean length, size distributions and frequencies, weight distributions and frequencies, and age distributions and frequencies for the vertebrate functional groups. This among other covers bacteria (benthic and pelagic), phytoplankton, ciliates/flagellates, makro-algae, makrophytes, micro- and meso-zooplankton (two groups in the foodweb, but combined so far in biomass), mysids, gelatinous zooplankton, fish (cod, sprat, herring, whiting, flatfish, small demersals, small pelagics, carps and perch), Nephrops, marine mammals (seals, harbor porpoise), and pursuit diving seabirds. With respect to the benthic community the Atlantis also cover a long row of benthic invertebrate functional groups such as mussels, polychaetes, etc.

The model include carefully informed and data driven food web and biological interactions as well as food web interactions with the physical environment and habitats. Reproductive capacity is not evaluated in detail.

Furthermore, Chl.a is estimated as model output as well. Concerning biodiversity (species richness – see further below). Concerning non-living organic components Atlantis cover carrion, fractional and labile detritus, and groups of dissolved and particulate organic matter.

According to the above qualities, the Atlantis can contribute to evaluate the robustness, sensitivity, and possible reversibility of different food web indicators as described in the discussion paper.

We consider it in this context to be relevant and a good idea to make comparative evaluation of ensemble modelling outputs and approaches considering both estimates from and evaluations by the Baltic Atlantis model (Bossier et al. 2017) and the Baltic Ecopath w. Ecosim w. Ecospace model (Bauer et al. 2018). The Atlantis model may be more robust in evaluating gradual changes over time according to climate and eutrophication forcing also considering gradual changes in carrying capacity, while the latter model may be more robust in evaluating spatial changes in habitat distribution and quality for example in relation to oxygen depletion areas. Given assumptions in the EwE model on depletion of certain species in high resolution spatial areas this model may also be more robust in predicting changes in biodiversity. However, it demands very strong assumptions in biological models to estimate actual extinction of a species, so we would be careful with letting such models evaluate changes in biodiversity (species richness).

Please note that the above suggestion related to Baltic ATLANTIS is based purely on initial considerations, and a brief initial discussion with some of the authors. Thus, it is important to consider here that this may be impractical and the details need further discussion to determine if it could be applied. Any work on this would need to consider reviewing what can be done and would likely have resource implications for the experts.

6. Food web efficiency (FWE) approach. This approach would ideally utilize data related to production in terms of carbon and would show how efficiently carbon is transferred through the food web (e.g. Berglund et al., 2007 Limnology and Oceanography 52(1), 121-131).

7. There is also work in the North Sea looking at food web indicators and a national (Germany) project called StoPP that investigated food web interactions in the Wadden Sea by using the "ecological network analysis" (ENA) (see: https://deutsche-kuestenforschung.de/stopp-214.html). There are some publications from this project that can be found here: https://www.nationalpark-wattenmeer.de/sh/misc/publikationsliste/5434.

8. Food web assessment – using biomass and non-dimensional scaling approach to make everything comparable and then be able to estimate the relative balance between the selected partitions from the

food web. Can explore providing more details from former colleagues on this idea (based on contacts in Denmark, Sweden and Finland).

9. An approach which considers only selected species or taxa based on knowledge of pathways and interactions – e.g. cod/sprat/herring and zooplankton. See note below‡.

10. Other indicators where their evaluation can be defined as the result of the food web status associated to the measured variable(s) (e.g. seal health, longest fish, etc). For example reviewed in Tam et al., 2017 (https://doi.org/10.1093/icesjms/fsw230): guild level biomass and production, primary production to sustain a fishery, seabird productivity, zooplankton size biomass index. Other options such as integrated trophic indicators, ecological networks and dietary diversity indexes and condition indicators also discussed. See note below‡.

‡Do the above two meet the requirements of policy (don't directly cover multiple trophic guilds)? Can these approaches be considered to suitably address ecosystems in a holistic or ecosystem-based management approach? Are these valuable since they can miss defining the causal factors underlying the assessment?

11. Could coastal and benthic be combined in an assessment? For example, since benthic and pelagic habitats are logically inseparable, especially in shallow coastal areas (nutrient or biota exchange etc) could all coastal areas of a certain depth (e.g. <60 m or based on photic zone, say 20m) be assessed as a combination of benthic and coastal pelagic (i.e. to account for benthic-pelagic coupling)? It would then allow the combination of the coastal and benthic aspects and give a larger number of food web 'compartments' to construct an indicator from. Could a list of habitat types/ecosystem components be needed as a regional/sub-regional agreement?

12. Could balance of total abundance between trophic guilds be considered also? Is there sufficient information to know how much fish a seal needs to eat to grow well or sustain itself, how much zooplankton a fish needs to eat to grow well or sustain itself, etc. Could this be made as a model structure based on carbon transfer or energy requirements/transfer between trophic guilds? Could threshold values on required abundances for each trophic guild then be set that would relate to the balance between each gild to support a functional ecosystem in good status?

Concluding thoughts

Much of the information above is presented divided into sections for practical reasons (e.g. taxa, habitat type or benthic ecosystems). While this is practical for describing the topic into clear divisions it is likely important to consider how these assemble together. For example, when assessing ecosystems/food webs an ecosystem-based approach may not consider these as independent units that can be assessed alone, thus a broader evaluation may be important. This could be represented by assessing them independently (i.e. for practical and data collection purposes) followed by integrating this together at an end step such as an integrated assessment. Alternatively, an independent and ecosystem encompassing method may be the best development.

In addition, all of the above should be considered within the step-wise development process proposed for the indicators (i.e. short and longer-term developments). Are some of these options suitable for initial and interim developments to provide initial assessments in the shorter-term? Are others more suited to longer-term developments due to the required development involved? Do some provide an overview without delivering a really detailed and substantial assessment, enabling a status to be assigned but insufficiently addressing the Baltic Sea ecosystem? These aspects should be kept in mind so that any assessment system can be adapted and developed to ensure that the Baltic Sea is assessed using the highest level of scientific knowledge and considers the health and status of the ecosystem as its ultimate goal.