BENTHOS ECOLOGY WORKING GROUP (BEWG; OUTPUTS FROM 2023 MEETING) (BEWG)

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i Executive summary

The Benthos Ecology Working Group (BEWG) aims to study, describe and update on all aspects relevant to the ecology, functioning and interactions of marine benthic organisms across the Northeastern Atlantic, either living in or within the sediment, either animals or plants, either macro, meio or epibenthic, either littoral and sublittoral up to the deep sea.

Over the third period (2021–2023), the group continued to provide insights on the field of applied benthic ecology. This report contains the overview of ongoing initiatives covering central aspects of benthic ecology. The work is focused on benthic long-term series and climate change, benthic indicators, species distribution modelling, the link between biodiversity and ecosystem functioning and the role of benthos within Marine Protected Areas (MPAs). Several ongoing initiatives (case studies) have been further developed. They deal with the value of benthic long-term time-series to support management decisions, changes in functional composition along sediment gradients, the variability of expert assessment of benthic species tolerances or sensitivities, and functional indicators meeting the needs of the Marine Strategy Framework Directive (MSFD).

Over the last years several colleagues were invited to give an introductory presentation, members and non-members of the BEWG: E. Thiebaut (long-term benthic series of Pierre Noire), A. Sturbois (statistical methods to analyse benthic series: functional trajectories), L. Bacouillard (methodology: monitoring an area at different temporal and spatial scales), F, Cozzoli (combining data from monitoring programs and experimental work), M. Zettler (long-term data: variation and interpretation), A. De Backer (development of new molecular genetic techniques), O. Beauchard (traits), M. Uttieri (invasion of *Pseudodiaptomus marinus*). The latter two were invited to foster collaboration with other ICES Working Groups (WGEUROBUS, WGBIODIV).

ii Expert group information

Expert group name	Benthos Ecology Working Group (BEWG)
Expert group cycle	Multiannual
Year cycle started	2021
Reporting year in cycle	3/3
Chairs	Johan Craeymeersch (the Netherlands)
	Paolo Magni (Italy)
Meeting venues and dates	10-15 May 2021, online (28 participants)
	9-13 May 2022, Oristano, Italy (29 participants)
	8-12 May 2023, Bergen, Norway (22 participants)

1 Long-term benthic series and climate change

In 2009, BEWG established BELTSnet (Benthic Long-Term Series network) to foster collaborative work on long-term dataseries. The BELTSnet aimed at facilitating joint analysis of long-term data to further the understanding of temporal changes in marine ecosystems over larger spatial scales. In 2015 the group concluded due to a) the development of EMODnet that covers many of the aspects of BELTSnet and 2) the costs to maintain a website that the BELTSnet website may not be the best way forward. During these years, a time-series table was made. During the last years the table was updated, intersessionally. The table should be basis for further actions by members of the BEWG.

The BEWG recognizes the importance to discuss and assess the uses of new methodologies and its advances for the study of benthic systems. Benthic organisms are characterized by comparably low mobility, therefore there is a tendency to accumulate over time the presence of stressors. Their ability to show signs of stress and/or change is an important characteristic, as can be used for long-term studies with assistance to support management decisions. Thus, the operation of long-term series is one of the fundamental activities in marine monitoring.

The importance of maintaining benthic time-series has been even more pressing than before. Nowadays, marine management has moved from rather limited 'one-problem' objectives into more holistic approaches addressing interacting components of the ecosystems. Moreover, integrating the complementary approaches of scientific and management-driven effects monitoring into a single coherent monitoring strategy involving multiple stakeholders is challenging. Thus, to support marine management sufficiently, benthic long-term time-series remain to be essential, providing indications for patterns of change and responses across these valuable seabed systems, which are often sentinel to some of these observed changes.

In recent years, however, there has been a worldwide decline in long-term monitoring series (Hughes, 2017). Several time-series have been terminated, usually because of dwindling funds, change of personnel, or poor scientific or policy support. The future of long-term series may depend on both the ability to: 1) adapt established long-term series to address emerging ecological issues; and 2) implement and maintain new time-series to provide purpose-built information for management.

BEWG nearly finished a "food-for-thought" document, titled "**The value of benthic long-term series: compilation of science to support management decisions".** The document will cover some of the current challenges associated with long-term benthic time-series for soft sediments. The paper also considers the need to revise long-term monitoring in view of new, and currently unforeseen, technological, scientific and management issues. Ensuring that these new methods are complementary rather than providing datasets, which will be of limited use, causing further challenges to datasets collected over time and space.

2 Species distribution modelling and mapping

The biological reworking of sediments, known as bioturbation, results in modifying geochemical gradients, redistributing food resources and all other transport processes carried by animals, a process now described as ecosystem engineering (Meysman *et al*., 2006, Kristensen *et al*., 2012, Gogina *et al*., 2020). Moreover, bioturbation also affect the benthic-pelagic coupling and all the interactions at sediment-water-interface (Marcus and Boero 1998, Meysman *et al.*, 2006). Bioturbation also effects bio-irrigation, the mixing of water and solutes in sediments (Wilkinson *et al*., 2009) and is thus important for biogeochemical cycling, oxygenation of deeper layers, nitrogen cycling (Wrede *et al*., 2018 and references therein). Consequently, the loss of bioirrigation activity may have broad implications for overall ecosystem performance (Lohrer *et al*., 2004).

The trait-based semi-quantitative concept of community bioturbation potential (BPc) was originally introduced as an approach to estimate the effects of species extinctions on sediment reworking and ecosystem properties (Solan *et al*., 2004). Wrede et al (2018) propose a novel trait-based index in the style of BPc, the irrigation potential IPc, which incorporates specific bio-irrigation effect traits (i.e. burrow shape, injection pocket depth and feeding type). Nearly at the same time, Renz et al (2018) proposed an alternative bio-irrigation BIPc index, also based on effect traits, but distinguishing their weighting for diffusion dominated and advection dominated benthic systems. Using species distribution modelling based on machine learning methods the current distribution of latter index was mapped for the southwestern Baltic Sea (Gogina *et al*., 2022).

This approach can be utilized further. After the latest publication (Gogina *et al*., 2020), at the 2021 meeting, the group came up with a new case study. BEWG will analyse shifts in taxonomic and functional (i.e. composition in bioturbation and bioirrigation traits) composition in different European regions. Data on benthos and abiotic components have been compiled, trait information will come from the trait database under development (see further).

3 Developments in effective monitoring programmes (including design, harmonization, quality assessments and legislative drivers)

The group continued to discuss how to assess benthic habitats with respective to D6 MSFD and the potential role of ICES BEWG. At every meeting Dr L. Guérin presented an update on OSPAR benthic habitat works and the BAltlantic project.

The work of the BEWG has been aligned with the OSPAR and HELCOM assessments and the national MSFD D6 reportings, to maximize the input of the group. During the last meeting ICES BEWG focused on the practical implementation of the MSFD D6 criteria for determining the benthic seabed status across spatial scales, based on existing indicator approaches through case studies. This should further underpin the scientific development of the concept of 'adversely affected' habitats in relation to the MSFD assessment framework, to be published in a viewpoint paper.

In 2015 the BEWG started investigating the variability of expert judgement of sensitivity of indicator species, and its importance of indicator development and application. A questionaire has been set up and sent out, and at least a few responses have been received. Unfortunately, the main responsible member for this action has been inactive due to corona. At the 2023 meeting no updated information was available. The action is further considered in the next term to consider if this is enough for further analyses.

The BEWG reviewed the development of effective monitoring programmes for the Greater North Sea region, serving the assessment of the national and common benthic indicators within the OSPAR region. At the 2022 meeting, Gert Van Hoey reported on a two-day workshop held in December 2021 where the roadmap was developed. This roadmap used the very detailed online survey results (Van Hoey and Wittoeck, 2019) as a basis, and discussed monitoring practices (from sampling to data storage and sampling designs) in the Greater North Sea area. This survey listed the similarities and dissimilarities in monitoring practices between 15 institutes. At the meeting, the BEWG discussed this document, to agree on aspects that can be harmonized and to set up a road map to achieve some harmonization in the sampling, laboratory practices and sampling design (Van Hoey *et al*., 2022).

Given the rapid development and implementation of DNA techniques, the group decided to put on hold further discussion on involvement of the BEWG on advice, etc. for using DNA techniques in (long-term) monitoring programs (biodiversity, environmental assessments). At the 2022 meeting Dr A. De Backer (ILVO, Belgium) gave an introductory presentation on usability and complementary value of eDNA for monitoring of benthic macrofauna diversity. Items discussed included meta-barcoding vs. classical grab, possibilities to derive quantitative data, number of false-positive errors, and including eDNA in normal sampling routine. At the 2023 meeting, S. Birchenough provided an upate on the GEANS project, and the coming publication under the ICES TIMES manuals and protocols, approved by SCICOM.

4 Benthic biodiversity and ecosystem functioning

ICES BEWG has been working on a trait database for some years now. The group is aware that many trait databases have been compiled over recent years, but often these resources were compiled without thoroughly checking primary literature and, consequently, such databases contained mistakes. This turned out to be a time consuming task and, therefore, at the 2022 and 2023 meetings, the group discussed issues concerning prioritizing information and include missing information on the traits. In total the database will store trait information (Table 1) of about 600 species, and now already has more than 52 000 records. It was expected to have a final database by the end of 2022, but this activity has become a time-consuming task. At the 2023 meeting, the group discussed ways to really finalize the database in a timely manner and started analyses at the beginning of 2024 using the data compiled: analysis on relationship with sediment composition, and its consistency between regions, will be done.

Some years ago, the BEWG discussed how to develop a framework to bring together new knowledge and current gaps associated with functional indicators under MSFD. The approach has been developed and two case studies are almost finished. Unfortunately, the leading person has moved to another job. At the 2023 meeting, the team recapped and worked on the discussion and conclusions. A manuscript should be finalized in Autumn and submitted later this year.

Table 1 Overview of traits and modalities in the BEWG trait database.

trait_shortname	trait	mod_shortname	modality
A	Longevity (years, lifespan)	A1	<1
A	Longevity (years, lifespan)	A2	>1-2
A	Longevity (years, lifespan)	A3	>2-5
A	Longevity (years, lifespan)	A4	>5-10
A	Longevity (years, lifespan)	A5	>10
BT	burrow type	BT1	epifauna, internal irrigation (e.g. siphons)
BT	burrow type	BT2	open irrigation (e.g. U- or Y-shaped burrows)
BT	burrow type	BT3	blind ended irrigation (e.g. blind ending burrows, no burrow system
FH	feeding habit	FH1	surface deposit-feeder (incl. Grazer)
FH	feeding habit	FH2	subsurface deposit-feeder
FH	feeding habit	FH3	filter/suspension-feeder
FH	feeding habit	FH5	predator (opportunist/scavenger)
FH	feeding habit	FH6	parasite (commensal, symbiotic)
FT	irrigation feeding	FT1	surface filter-feeder
FT	irrigation feeding	FT2	predator (opportunist/scavenger)

FT	irrigation feeding	FT3	deposit-feeder
FT	irrigation feeding	FT4	sub surface filter-feeder
ID	injection pocket depth [irrigation depth]	ID1	0-2
ID	injection pocket depth [irrigation depth]	ID2	>2-5
ID	injection pocket depth [irrigation depth]	ID3	>5-10
ID	injection pocket depth [irrigation depth]	ID4	>10
LD	Larval development	LD1	pelagic/planktotrophic
LD	Larval development	LD2	lecitotrophic
LD	Larval development	LD3	benthic/direct
Mi	bioturbation mobility	Mi1	in a fixed tube
Mi	bioturbation mobility	Mi2	limited movement, sessile, but not in tube
Mi	bioturbation mobility	Mi3	slow movement through sediment
Mi	bioturbation mobility	Mi4	free movement via burrow system
MV	Adult movement	MV1	sessile
MV	Adult movement	MV2	burrower
MV	Adult movement	MV3	crawler
MV	Adult movement	MV4	swimmer (facultative)
Ri	sediment reworking mode	Ri1	epifauna
Ri	sediment reworking mode	Ri2	surficial modifiers
Ri	sediment reworking mode	Ri3	head-down/head-up feeder
Ri	sediment reworking mode	Ri4	biodiffusers
Ri	sediment reworking mode	Ri5	regenerators
S	size (mm)	S0	very small
S	size (mm)	S1	small
S	size (mm)	S2	small-medium
S	size (mm)	S3	medium
S	size (mm)	S4	medium-large
S	size (mm)	S5	large

SP	sediment position	SP0	hyperbenthic/demersal
SP	sediment position	SP1	emergent
SP	sediment position	SP2	surface
SP	sediment position	SP3	surface burrower
SP	sediment position	SP4	deep burrower

5 Benthic biodiversity and conservation: To review the role of benthic ecology in MPAs

Marine Protected Areas (MPAs) hold species and habitats protected under law. There is concern across the ICES region that the vulnerable components and wider support mechanizms underpinning benthic marine ecosystems may not be accurately incorporated in the process of MPA designation, management, and monitoring.

After the publication of an overview on the role of benthos in the design and monitoring of MPA's (Greathead *et al.*, 2020), the group discussed possible following up initiatives. A general idea was to review the contribution (direct and indirect) of benthos to achieving MPA objectives (including the delivery of ecosystem services), gathering experience from European case studies.

The overarching rationale for the initiative can be summarized as follows; 'MPAs' (even those that don't explicitly protect the benthos) are often reliant on the contribution of the benthos to be effective. If the role of the benthos in maintaining ecosystem services within 'MPAs' is not sufficiently understood, the benthos may not be included in the 'MPA' conservation objectives, management measures and monitoring programme. This increases the risk that benthos could be affected by human activities, which could undermine the effectiveness of the 'MPA' in conserving ecosystem services and reduce the likelihood of an 'MPA' achieving its conservation objectives.

Based on this vision the following structure of the paper was agreed upon and several meetings were held to develop this initiative.

Introduction

General overview of the ecosystem functions of benthos and how they contribute to the ecosystem services provided by a broad set of marine ecosystems covering from deep-sea habitats to estuaries.

Brief description of the role of 'MPA' conservation objectives, management measures and monitoring programmes in the context of conserving ecosystem services underpinned by the benthos.

What are the ecosystem service providers and the units? What could be lost with disturbance? Include how ecosystem services can be altered when the benthos is disturbed, highlighting the importance of protecting the benthos as part of a strategy to conserve ecosystem services.

Consider what stressors can affect the benthos and how will this affect ecosystem services. Potential pressures/stressors to consider include climate change, eutrophication, fishing, etc.

Provide background information to the specific ecosystems that are used as case studies in the paper. The purpose of case studies is to illustrate the importance of the benthos in achieving 'MPA' conservation objectives, including maintaining ecosystem services, through detailed examples in specific locations. Case studies are illustrative rather than exhaustive (final number of case studies has not been decided but at present 5 have been presented).

Main part

- Brief introduction to the case studies including their purpose, and how cases were selected (i.e. to illustrate the importance of the benthos for achieving 'MPA' conservation objectives, and not as an exhaustive list of examples, see Table 2). Consideration is needed

for whether any schematic figures or tables including biomass, energy, etc., are needed to illustrate case studies.

- For each case study 'MPA' there should be a short ecosystem description (ca. 300 words; half a page) to include relevant conservation objectives and the main ecosystem functions and links for the key organisms and show how they relate to expected ecosystem services. Within this text, consider the risk of not achieving the conservation objectives if benthos is not specifically included in the management of the MPA case study.
- The case study accompanying text should describe (qualitatively) to what extent the benthos contributes to achieving the conservation objectives for the MPA and / or ecosystem functions. This description could be an indicative percentage, e.g. birds are 90% dependent on benthos; or a descriptor, e.g. birds are 'highly dependent' on the benthos. This links to the concept of 'risk' – if the birds are directly included in the conservation objectives but the benthos is not, and the birds are 'highly dependent' on the benthos, not including the benthos in the conservation objectives could lead to a 'high risk' of not achieving conservation objectives.
- Case studies should focus on the biological contribution of the benthos to conservation objectives and / or ecosystem function. This could be presented at the species level, the contribution of habitats, or other biological features, considering the ecosystem level of the conservation objectives.
- Although wider ecosystem services should be included in the case studies, the focus of the paper is on ecology. There are no current plans to involve social scientists or economists, although additional contributions from other disciplines could be sought if needed.

Discussion

- The discussion will further explore the main messages from the case studies, the specific content of the discussion will depend on what we learn from the case studies. It will include future needs / perspectives, for effectively considering the benthos in 'MPA' conservation objectives, management measures and monitoring programmes. This could take the shape of a brief list of recommendations for how the contribution of the benthos towards achieving 'MPA' conservation objectives / maintaining ecosystem function can be more strongly considered.
- The text should make clear what risks to management goals are involved from not considering the interactions between the different parts of the ecosystem that are part of the 'MPA'. This should link to the role of benthos as ecosystem service providers and the broader concepts of marine ecosystem health and resilience.
- The discussion could explore the move away from a 'single species focus' (earlier approach to conservation) towards an 'ecosystem approach' (newer approach to conservation), with linkages to ecosystem function. Some consideration could be given to full 'no take' and 'full site' protection modes vs. partial protection through excluding some activities or only protecting a few features within a broader site. This could be linked back to the concept of ecosystem services and the ecosystem approach, as laid out in introduction.
- Example 1: in an 'MPA' designated for the conservation of birds, there may need to be an explicit management measure to restrict damaging activities to the benthos to protect the food source of the birds that the 'MPA' is set up to conserve.
- Example 2: implementing a full site 'no-take' / 'no damaging activities' approach to 'MPA' management should provide protection to all elements within the 'MPA' boundary, thus con-serving the broader ecosystem, including the known (and unknown) ecosystem services and connections within the site. This is broadly analogous to the

proposed UK Highly Protected Marine Area approach being developed (Benyon Review: 2022).

- Consideration should be given to monitoring of protection measures success, with case studies providing support that the benthos should be monitored as part of MPA management, considering the contribution of the benthos to achieving conservation objectives.
- There may need to be brief consideration of restoration, although this is probably beyond the scope of the review. It could be noted that the benthos may not recover to the original state where it is disturbed, which may have implications for ecosystem services.

Table 2 Example of case studies to illustrate the importance of the benthos in achieving 'MPA' conservation objectives, including maintaining ecosystem services, through detailed examples in specific locations.

"Penisola del Sinis - Isola di Mal di Ventre" MPA, Sardinia, Italy (BEWG hero: Paolo (with Stefania and Andrea))

Key ecosystem/ habitat type/ species/ benthic features present as appropriate	Ecosystem services provided	Selected current conservation objectives	Current management measures	Monitoring requirements for benthos	Ongoing stressors despite any existing management measures	Ongoing risk for not achieving conservation objectives if benthos not considered	Benthos contribution to current conservation objectives	Potential additional objectives benthos could contribute to
Seagrass meadows (*Posidonia oceanica*); *Patella ferruginea*; *Pinna nobilis*; *Paracentrotus lividus*	*P. oceanica*: carbon storage, habitat provisioning, coastal protection. climate regulation, primary production, sediment formation. *Patella ferruginea*: habitat provisioning; formal and traditional knowledge system; recreational values; ornamental resources, genetic resources. *Pinna nobilis*: habitat provisioning; formal and traditional knowledge system; cultural heritage values; recreational values, water purification, nutrient cycling, ornamental resources. *Paracentrotus lividus*: habitat provisioning; food; recreational values.	Protection of endangered species (seagrass meadows; *Patella ferruginea*; *Pinna nobilis*) and sustainable management of local target species (*P. lividus*)	Fishing and anchoring not allowed (*P. oceanica*); collection and detection of alive and dead individuals not allowed (*P. ferruginea*, *P. nobilis*), fishery regulations are defined annually based on the monitoring results (*P. lividus*)	Conservation status of protected species (e.g. *P. nobilis* - critically endangered) and fishery resources (*P. lividus*) need to be monitored to pursue adaptive management and assure biodiversity/habitat protection	*P. oceanica*: damage to seagrass from anchoring, fishing activities and climate change; algal overgrowth from sea urchins overfishing (cascade effect); climate change. *Patella ferruginea*: illegal collection; climate change. *Pinna nobilis*: mass mortality disease, illegal collection, trawling/anchoring, climate change. *Paracentrotus lividus*: IUU fishery, climate change.	Decreasing biodiversity, extinction of endemic species, decreasing of a key habitat forming (seagrass meadows), economic damage to fishery and loss of food resources/local tradition (e.g. *P. lividus*)	Assure high level of biodiversity/habitat heterogeneity, supporting local economy (fishery and tourism) and maintaining cultural diversity and social relations	Use of the 4 selected species to demonstrate the importance of the benthos to societal benefits, including local population, tourists, administration at various levels. NOTE: this MPA can be referred to as a case study where the benthos is "considered" (see M&M of the skeleton) due to a good availability of data

De Falco *et al*., 2006; Coppa *et al*., 2010; 2016; 2019; 2021; Pieraccini *et al*., 2017.

The Ria Formosa, Algarve, southern Portugal (BEWG hero: Lene)

Key ecosystem/ habitat type/ species/ benthic features present as appropriate	Ecosystem services provided	Selected current conservation objectives	Current management measures	Monitoring requirements for benthos	Ongoing stressors despite any existing management measures	Ongoing risk for not achieving conservation objectives if benthos not considered	Benthos contribution to current conservation objectives	Potential additional objectives benthos could contribute to
Marine habitats: Beaches, dunes, saltmarshes, canals, tidal mud flats, saltpans, fish cultures, lagoons	Aquaculture Fish and shellfish farming. Fishing in the lagoon Fish, crustacean and molluscs. Fish stocks in the adjacent waters Juveniles are recruited from the lagoon. Bird sanctuary Shelter, resting and feeding for numerous bird species	Portuguese Natural Park. Special Protection Area under the EU Birds Directive. Natura 2000 network site (site code PTZPE0017); Ramsar protection site 212, since 1980)			Fishing and Aquaculture		Fish and bird food. Crustacea and gastrops are heavily predated on by fish.	

Benthic ecology: S. Gamito 2006. Management measures: Newton *et al.*, 2022.

“Fehmarnbelt”/ The Fehmarn Belt MPA, Baltic Sea, Germany (BEWG hero: Mayya)

Key ecosystem/ habitat type/ species/ benthic features present as appropriate	Ecosystem services provided	Selected current conservation objectives	Current management measures	Monitoring requirements for benthos	Ongoing stressors despite any existing management measures	Ongoing risk for not achieving conservation objectives if benthos not considered	Benthos contribution to current conservation objectives	Potential additional objectives benthos could contribute to
Reefs, sandbanks, Species-rich gravel, coarse-sand and shell-gravel, harbour porpoises, harbour heals. Soft bottom biotope Muddy sediments in the aphotic zone dominated by Arctica islandica (Critically Endangered according to HELCOM Red List)	Habitat provisioning; spawning and rearing area, migration path for marine fauna and flora, formal and traditional knowledge system (geo-scientific and ecological value); recreational values (leisure fishing); water purification, nutrient cycling, genetic resources. Fishing (not yet ceased in mud habitat of the MPA by Sept 2023).	Federal Nature Conservation Act (BNatSchG), German Protected Area Ordinance (NSGFmbV). Habitats Directive. Natura 2000 network site (site code DE 1332-301). HELCOM (WDPA ID 555543242)	Not permitted are changes /disturbances that could lead to significant impairment of the area or its components relevant to the conservation objectives Any activities that may have significant affect require compatibility assessment Not allowed: construction of artificial islands, facilities and structures, introduction of dredged material, marine aquaculture, release of alien species, in parts of the MPA - recreational fishing. Special regulations for: energy production, exploration and extraction of mineral resources, laying and operation of pipelines and cables, construction, maintenance and operation of Fehmarn belt fixed link. Allowed: air traffic, shipping, military uses permitted under international law and professional fishery (so far, regulations are defined annually).	Monitoring is needed to pursue adaptive management and assure biodiversity/habitat protection. Monitoring of protected habitats is established, including assessment of conservation status for sandbanks and reefs every 6 years, evaluation of benthic "habitat structures" and “communities and characteristic species” with “specific structures and functions”, regional inventory lists of characteristic species, population status of (OSPAR) protected species ocean quahog *Arctica islandica*. Targeted monitoring of effects of closure for bottom-trawling fisheries in muddy habitats is currently the pilot stage.	Intensive ship traffic, fisheries (bottom trawling, pelagic, gillnet, longline), climate change, military use (ammunition areas)	Decrease of biodiversity, extinction of endangered species, decrease of key habitats or habitats forming species (macrophytes), reduction of bioturbation and change of habitat for microbial communities, economic damage to fishery and loss of food resources.	Benthos is predated on by fish, that find shelter and spawn between the stones densely covered with macrophytes. In turn marine mammals use the Fehmarn Belt as migration corridor and feeding ground, were they prey on fish.	Importance of benthos to societal benefits. MPA can be referred to a case study where the benthos is “considered”

Darr *et al*., 2022 Krause *et al*., 2022a, BfN, 2023.

The Pomeranian Bay – Rønne Bank MPA, Area III HD site Pomeranian Bay with Odra Bank EU Code: DE 1652-3017, Baltic Sea, Germany (BEWG hero: Mayya)

Key ecosystem/ habitat type/ species/ benthic features present as appropriate	Ecosystem services provided	Selected current conservation objectives	Current management measures	Monitoring requirements for benthos	Ongoing stressors despite any existing management measures	Ongoing risk for not achieving conservation objectives if benthos not considered	Benthos contribution to current conservation objectives	Potential additional objectives benthos could contribute to
Sandbanks, Sturgeon (*Acipenser oxyrhinchus*) shad (*Alosa fallax*) and harbour porpoise (*Phocoena phocoena*). Seabirds.	Habitat provisioning; spawning and rearing area, migration path for marine fauna and flora, formal and traditional knowledge system (geo-scientific and ecological value). Fishing (not yet fully ceased in the entire MPA by Sept 2023). Regeneration area for benthic fauna, dispersal source and corridor for recolonization of surrounding areas by benthic species & communities, feeding habitat for birds, marine mammals and fish. Fishing (not yet fully ceased in the entire MPA by Sept 2023). Regeneration area for benthic fauna, dispersal source and corridor for recolonization of surrounding areas by benthic species & communities, feeding habitat for birds, marine mammals and fish.	Special conservation area Federal Nature Conservation Act (BNatSchG), German Protected Area Ordinance (NSGFmbV) EU Habitats Directive EU Bird Directive Natura 2000 network site (site code DE 1652-301) HELCOM (WDPA ID 555543234)	Prohibited: exploration /exploitation of natural resources which may lead to damage or alteration of the reserve or its component; construction /modification of artificial structures; introduction of dredged material; marine aquaculture; recreational fishing; introduction of alien species. The above do not apply to air traffic, shipping, military use permitted under international law, scientific marine research and professional sea fishing, measures to manage MPA or fulfil public tasks (security, law enforcement, customs, radiation protection, monitoring of facilities, data collection necessary to secure fish stocks, disaster control, explosive ordnance disposal and accident prevention, including sea rescue). Two different levels of management: a Fully protected area and a partially protected area. In the Fully protected area, all activities are forbidden except circulation (with speed restriction) and snorkelling (just in surface). In the partially protected Area, spearfishing is forbidden, and fishing is strictly reglemented (both professional and recreational) Scuba diving needs to be reported.	Conservation status of protected species and fishery resources (*P. lividus*) need to be monitored to pursue adaptive management and assure biodiversity/habitat protection	Fisheries, wind energy, shipping, exploration and mining (hydrocarbons), sand and gravel extraction in the vicinity, military use, specific scientific research activities are subject to an affect assessment	Protection of shallow sandbank habitat type and its characteristic benthic species and communities is essential due to its function as a feeding habitat for birds, marine mammals and fish. Abundance of food in these structures and absence of ice, even in cold winters, attracts sea ducks and other seabirds that rest or moult here.	Assure functional structure of the habitat, contribute top biodiversity, provide food for fish, seabirds and marine mammals	Importance of benthos to societal benefits. MPA can be referred to a case study where the benthos is "considered"

Krause *et al*., 2022b, BfN, 2023.

Cerbère-Banyuls-marine reserve, Mediterranea Sea, France (BEWG hero: Celine)

Key ecosystem/ habitat type/ species/ benthic features present as appropriate	Ecosystem services provided	Selected current conservation objectives	Current management measures	Monitoring requirements for benthos	Ongoing stressors despite any existing management measures	Ongoing risk for not achieving conservation objectives if benthos not considered	Benthos contribution to current conservation objectives	Potential additional objectives benthos could contribute to
Coastal soft bottoms (71%), hard bottoms (15%) and other kinds such as Posidonia beds and Coralligeneous reefs (14%)	*P. oceanica*: carbon storage, habitat provisioning, coastal protection. climate regulation, primary production, sediment formation. Fish stocks: positive effect on fish biomass and exportation in the adjacent waters (Kayal *et al*., 2020) Recreational values (leisure fishing (Kayal *et al*., 2020), scuba diving); Pilote site for scientific research Public education	The priority challenges are the conservation of coralligeneous reefs, Posidonia beds and infralittoral hard substrates which are classified as Habitats of interest in the frame of the EU Habitat Directive The conservation of fish population is also a priority (key species and fishing resources) Conservation of soft-bottoms and mediolittoral hard substrates are also stated but not considered as priority.	Two different levels of management: a Fully protected area and a partially protected area. In the Fully protected area, all activities are forbidden except circulation (with speed restriction) and snorkelling (just in surface). In the partially protected Area, spearfishing is forbidden, and fishing is strictly reglemented (both professional and recreational) Scuba diving needs to be reported.	-EBQI (Ecosystem based Quality index) Posidonia beds (Personnic *et al*., 2014); IndexCore and EBQI Coralligeneous reefs (Ruitton *et al.*, 2014) Counting of *Paracentratus lividus*, densities and population structure of Corallium rubrum (every 5 yrs) Fish counting of *Epinephelus marginatus* and *Sciaena umbra* (Every 3 yrs) Macrofauna Soft substrates Frequency is not annual for all elements Continuous recording of temperature (from surface to bottom Hydrophonic recording	Increasing visitor numbers increasing number of lost fish nets wastewater and sewage temperature increase invasive species (i.e.. *Caulerpa racemosa*, *Nematochrysopsis marina*, *Callinectes sapidus*) input from catchments	Decrease of biodiversity, decrease of key habitats or habitat forming species (coralligeneous reefs and *Posidonia* beds),	Engineering species enhancing habitat heterogeneity and high level of biodiversity which increase resilience of the ecosystem Protection of species and habitat under protection status Fish food	?

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Annex 1: List of participants

Name	Institute	Country of institute	2021	2022	2023
Johan Craeymeersch	Wageningen University and Research	Netherlands	x	x	x
Paolo Magni	National Research Council	Italy	x	x	x
Alexa Wrede	Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research	Germany	x	x	x
Andrea De Lucia	National Research Council	Italy		x	
Annick Donnay	STARESO	France		x	x
Céline Labrune	Banyuls-sur-Mer Oceanological Observatory	France	x	x	x
Eilish Farrell	Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research	Germany		x	
Eivind Oug	Norwegian Institute For Water Research	Norway	x	x	x
Gert Van Hoey	Flanders Research Institute for Agriculture, Fisheries and Food	Belgium	x	x	x
Hans Hillewaert	Flanders Research Institute for Agriculture, Fisheries and Food	Belgium	x		
Henning Reiss	Nord University	Norway	x	x	x
Henrik Nygård	Finnish Environment Institute	Finland		x	
Hilde Cecilie Trannum	Norwegian Institute for Water Research	Norway	x	x	x
Jacopo Giampaoletti	National Research Council	Italy		x	
Jan Beermann	Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research	Germany	x	x	x
Jan Vanaverbeke	Royal Belgian Institute of Natural Sciences	Belgium	x	x	
Jan Warzocha	Sea Fisheries Institute	Poland	x		
Jennifer Dannheim	Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research	Germany	x	x	
Laurent Guérin	Office Français de la Biodiversité	France	x	x	x
Lene Buhl Mortensen	Institute of Marine Research	Norway	x	x	x
Louise Healy	Marine Institute	Ireland	x	x	x
Mats Blomqvist	Hafok AB	Sweden	x	x	x
Mayya Gogina	Leibniz Institute for Baltic Sea Research Warnemünde	Germany		x	x

Nicolas Desroy	National Institute for Ocean Science - Ifremer	France	x	x	x
Rachel Boschen-Rose	Marine Scotland Science	UK		x	x
Sanders Glorius	Wageningen Marine Research	The Netherlands		x	
Santiago Parra	Spanish Institute of Oceanography	Spain	x	x	x
Silvana Birchenough	ERM Ltd.	UK	x	x	x
Stefania Coppa	National Research Council	Italy		x	
Steven Degraer	Royal Belgian Institute of Natural Sciences	Belgium	x	x	x
Urszula Janas	University of Gdańsk	Poland	x	x	x
William Hunter	AFBI Fisheries and Aquatic Ecosystems Branch	UK		x	
Yessica Griffiths	Joint Nature Conservation Committee	UK		x	

Annex 2: Resolution

2023/MT/EPDSG07 The **Benthos Ecology Working Group** (BEWG), chaired by Johan Craeymeersch, the Netherlands; and Paolo Magni, Italy, will work on ToRs and generate deliverables as listed in the Table below:

	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2024	13–17 May	Bremen, Germany	E-evaluation	
Year 2025	12-16 May 2025	Oostende, Belgium	E-evaluation	
Year 2026	TBD	TBD	E-evaluation and scientific report to SCICOM	

ToR descriptors

ToR	Description	Background	Science Plan	Duration	Expected Deliverables
A	**Long-term benthic series**		1.1; 1.3; 1.4	Years 1-3	
	1.To review knowledge of drivers for changes	The need for the BEWG to work on current tools and techniques associated to the understanding of natural variability changes and climate changes onto the benthos is of importance			Review paper drafted on current knowledge of affects of Climate Change
	2.To identify methodological issues in long-term series comparability	There is a need to review and compile methodological issues (e.g. methods, tools) associated to long-term series comparability in marine assessments. Actions linked with ToR C (effective monitoring programs)			Report on comparsions of running programs (selection will be based on the updated table onlong-term benthic series on hard and soft sediments) and consequences of new methodologies (including new preservatives , new identification techniques, etc.)
B	**Species distribution, modelling and mapping**		1.6; 1.7; 1.9	Year 1-3	
	1.BEWG will analyse shifts in taxonomic and functional (i.e. composition in bioturbation and bioirrigation traits) composition in different European regions	BEWG will report on distribution and connectivity of species on different scales, e.g. using new data and population genetics, and of the performance of different qualitative and quantitative approaches and will consider new methods and applications , e.g. processes and functions as tools to support modelling and mapping approaches,			Research paper
	2.Micro-scale habitat use	Micro-scale habitat use might be related to differences at very fine scale in e.g. sediment characteristics, other species (e.g. commensalism)			Research paper
C	**Benthos and legislative drivers**		7.1; 3.1; 3.2	Year 1-3	
	1.To report on the use of benthic indicators and targets for management:	ICES BEWG will focus on the practical implementation of the MSFD D6 criteria for determining the benthic			NEW-Position paper

	Compatibility and complementarity	seabed status across spatial scales, based on existing indicator approaches through case studies. This should further underpin the scientific development of the concept of 'adversely affected' in relation to the MSFD assessment framework, to be published in a vewpoint paper.		
	2.To evaluate the development of effective monitoring techniques and programmes, e.g. design, techniques for species identification (e.g. molecular, imagery), improvements, harmonization and quality assessments	Management of larger water bodies need harmonizized monitoring to allow proper assessments.		Year 1-3: reports on the status of new techniques; year 2-3; report on how do different techniques fit together in monitoring programs
	3.To explore relationships between pressures and status of the benthos	Management of the marine environment depends on the understanding of the relationships between pressures and status. BEWG will deepen the knowledge of a selected set of pressure state relationships evaluating appropriate methodological approaches. Also extending to new areas under pressure, such as the deep sea.		-Scientific paper on methodological approaches to investigate pressure state relationships.
D	**Benthic biodiversity and ecosystem functioning**	Disentangling the link between biodiversity and ecosystem functioning is currently considered to be key to fully understand the health of marine ecosystems. This topic hence became a cross-cutting theme since the BEWG 2012 meeting. The BEWG will therefore review and identify benthic indicators to reflect the link between biodiversity and ecosystem functioning and review how ecological function and diversity relates to different parts of the benthic communities at different spatial scales, taking account of e.g. ecological processes and biological traits. BEWG will also scope for research on the functional diversity of macrobenthos in relation to ecosystem functioning.	2.2; 2.3; 2.4 Years 1-2	
	1.To report on the ongoing case studies to assess ecological responses across sediment gradients.			Research paper to report on a selected case study.
	2.To consider new functional indicator needs to support MSFD requirements.			Viewpoint paper
E	**Benthic biodiversity and conservation: to review the role of benthic ecology in MPAs**		6.1; 6.2; 6.4 Years 1-3	
	To review the role of benthic ecology, conservation in relation to ongoing issues (e.g. fisheries, NNIS, etc.) in relation to Marine Protected Areas (MPAs)	Understanding ecological issues associated to the development/proposal of MPAs and how effective MPAs are going to be for the conservation of priority benthic species is key to support conservation and management strategies. This TOR is relevant with regards to ongoing issues (i.e. management measures) being applied within MPAs. This work brings understanding to safeguard the species		NEW- Review paper

	in need of protection, creating further repercussions to the ecosystem function and processes in specific habitats and species. This ToR will consider issues associated with conservation/restoration, Autecological/environmental as well as human issues.

Summary of the Work Plan

Year 1	ToRs A1-2, B.1-2, c.1-3, D.1-2, E.1.
Year 2	ToRs A1.-2, B.1-2, C.1-3, D.1-2, E.1.
Year 3	ToRs A.1-2, B.1-2, C.1-3, D.1-2, E.1.

Supporting information

Priority	The current activities of BEWG will continue along the main priority within BEWG ToRs, based on: long-term series and climate change, benthic indicators and EU directives, and species distribution modelling, and one cross-cutting (horizontal) axis on benthic biodiversity and ecosystem functioning (including issues directly in connection to MPAs). The BEWG work and TORS are aligned with the ICES Science Programme and are of high priority. The BEWG are active contributors and aim to report their outcomes directly to ICES in their annual report, Biodiversity highlights and in parallel as peer reviewed literature. Some of the outputs will be submitted to ICES JMS, Ecological Indicators, Marine Pollution Bulleting, etc.)
Resource requirements	The research programmes which provide the main input to this group are already underway, and resources are already committed. The additional resource required to undertake additional activities in the framework of this group is negligible.
Participants	The Group is normally attended by some 20-30 members and guests.
Secretariat facilities	None.
Financial	No financial implications.
Linkages to ACOM and groups under ACOM	There are no obvious direct linkages.
Linkages to other committees or groups	There is a possibility for interaction of several ICES expert groups, among which WGBIOD, WGCEA, WGDEC, WGVMS, WGECO, WGMHM and WGEXT.
Linkages to other organizations	The group has had also interaction with OSPAR IGC-COBAM.