WORKING GROUP ON FISHERIES BENTHIC IMPACT AND TRADE-OFFS (WGFBIT; outputs from 2022 meeting)

VOLUME 5 | ISSUE 16

ICES SCIENTIFIC REPORTS

RAPPORTS
SCIENTIFIQUES DU CIEM

ICES INTERNATIONAL COUNCIL FOR THE EXPLORATION OF THE SEA
CIEM CONSEIL INTERNATIONAL POUR L'EXPLORATION DE LA MER

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

H.C. Andersens Boulevard 44-46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

ISSN number: 2618-1371

ICES Scientific Reports

Volume 5 | Issue 16

WORKING GROUP ON FISHERIES BENTHIC IMPACT AND TRADE-OFFS (WGFBIT; outputs from 2022 meeting)

Recommended format for purpose of citation:

ICES. 2023. Working Group on Fisheries Benthic Impact and Trade-offs (WGFBIT; outputs from 2022 meeting). ICES Scientific Reports. 5:16. 106 pp. https://doi.org/10.17895/ices.pub.22123193

Editors

Jan Geert Hiddink • Gert van Hoey • Marija Sciberras

Authors

Andrea Pierucci • Alessandra Nguyen Xuan • Bianca Di Lorenzo • Clare Bradshaw • Clement Garcia • Cristina Mangano • Cristina Vina-Herbon • Chris Smith • Daan Cuyvers • Daniel van Denderen • David Clare • Elisa Punzo • Gabriele Di Bona • Gert Van Hoey • Giada Rava • Irini Tsikopoulou • Jan Geert Hiddink • Jochen Depestele • Joanna Desmidt • Jolien Claes • Justin Tiano • Karline Soetaert • Kate Morris • Lene Buhl-Mortensen • Luisa Nicoletti • Lucas Porz • Luke Batts • Mairi Fenton • Mattias Sköld • Marina Penna • Marina Pulcini • Marta Mega Rufino • Marija Sciberras • Mats Blomqvist • Nadia Papadopoulou • Neve McCann • Olivier Beauchard • Pascal Laffargue • Paul Coleman • Ruth Parker • Sandrine Vaz • Sebastian Valanko • Sebastiaan Vandevelde • Stefan Bolam • Tobias Van Kooten • Wenyan Zhang

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

Contents

i Executive summary

The Working Group on Fisheries Benthic Impact and Trade-offs (WGFBIT) develops methods and performs assessments to evaluate benthic impact from fisheries at regional scale, while considering fisheries and seabed impact trade-offs.

In this report, new fishery benthic impact assessments (ToR A) are shown out for several subregions in (French Mediterranean, Celtic Seas). For other regions, updates of the whole assessment or specific steps only were presented.

To further standardise the different components of the WGFBIT approach across all (sub-)regional assessments, a more detail overview of those components was compiled. These components were slightly different among those regions, related to variation in data availability, environmental characteristics and implementation possibilities among the (sub-)regions.

In WGFBIT, assessments are sometimes based on trawl or grab data, which are sampling different components of the seafloor ecosystem and can have consequences on the created sensitivity layer. Therefore, there is looked in more detail how the sensitivity outcome (and layers) can differ due to the use of benthic data gathered with different gears (grab/core, trawl or video). The preliminary comparability analyses are performed on different levels: (1) based on co-located sampling; (2) comparing sensitivity maps of the (sub-) area, based on different gears. There were differences observed in longevity distribution at locations sampled with different gears and differences in data and models lead also to differences in the sensitivity layers.

The WGFBIT seafloor assessment framework is not the only way to assess benthic impacts from physical disturbance. A discussion session was held on how the future workflow on advice that ICES WGFBIT assessment contribute to, will be organized.

Marine sediments harbour significant levels of biodiversity that play a key role in ecosystem functions and services such as biogeochemical cycling, carbon storage and the regulation of climate. Through the removal of fauna, changes in physico-chemical nature and resuspension of sediment, bottom trawling may result in significant changes in the ecosystem functioning of shelf seas. An assumption of the current PD model is that high community biomass implies higher ecosystem functioning. However, total community biomass does not necessarily reflect changes in species and functional trait composition which play a key role in regulating ecosystem functions. ToR D is working on an improved understanding of the link between species functional effect traits and proxies and processes for specific ecosystem functions to improve our ability to predict the impact of fishing disturbance on benthic ecosystem functioning more accurately. Links between species traits and biogeochemical parameters and the impact of trawling on these links are being explored using multivariate ordination analyses using different fauna and biogeochemical datasets collected in the North Sea, Celtic Sea, Kattegat, Baltic Sea and the eastern Mediterranean. Changes due to trawling in the trajectories of species densities over time and the concurrent changes in the bioturbation and bioirrigation potential of communities are being modelled using a combination of data-driven mechanistic model and a biogeochemical model. We report on the different data analysis methods that ToR D members have developed over the last year.

ii Expert group information

Expert group name	Working Group on Fishery Benthic Impact and Trade-off (WGFBIT)
Expert group cycle	Multiannual
Year cycle started	2021
Reporting year in cycle	2/3
Chairs	Gert Van Hoey, Belgium
	Marija Sciberras, UK
	Jan-Geert Hiddink, UK
Meeting venue and dates	21-25 November 2022, Sete, France, 46 participants

1 Highlights from WGFBIT 2022 meeting

The major conclusions of the WGFBIT 2022 meeting are summarized as followed:

ToR A
Great progress has been made with the regional assessments of bottom trawling impacts on seabed ecosystems in many regions, and we now have a preliminary map of sensitivity to trawling impacts that covers about 2/3 of European continental shelf seas. In some regions several people have been working in parallel on overlapping regions, allowing us to assess the consistency between different assessments, and highlighting the need for standardisation in the future.

ToR B
For ToR B, two major exercises were undertaken during WGFBIT 2022. First, an overview is made of the methodologies used in the different steps of the FBIT approach, as certain steps (e.g. data treatment, traits, undisturbed state of samples, model) are differently tackled among those regions, related to variation in data availability, environmental characteristics and implementation possibilities among the (sub-)regions. This is a first step to further standardise step by step the elements in the FBIT approach (where possible). Second, there is looked in more detail how the sensitivity outcome (and layers) can differ due to the type of benthic data gathered with different gears (grab/core, trawl or video). As you are sampling different components of the seafloor ecosystem by the different gears, it will have consequences on the sensitivity layers. To have more insights in this methodological aspect on the FBIT outcomes, we have performed a comparability analyses on longevity distributions obtained by different gears. The preliminary comparability analyses are performed on different levels: (1) based on co-located sampling; (2) comparing sensitivity maps of the (sub-) area, based on different gears. There were differences observed in longevity distribution at locations sampled with different gears and differences in data and models lead also to differences in the sensitivity layers. So, such comparability needs to be done in order to improve the future sub-regional assessments.

ToR C

The WGFBIT seafloor assessment framework is not the only way to assess benthic impacts from physical disturbance. Therefore, based on a DG ENV request to ICES, two workshops (WKBENTH2 and WKBENTH3) were organized in 2022, to review the indicators, create and test a framework to evaluate and compare the indicator methods. This work covered the goals formulated in the workplan of ToR C, so no further work was done during the WGFBIT 2022 meeting on this aspect. Except, some brainstorm/discussion session was hold on how the future workflow on advice that ICES WGFBIT assessment contribute to, will be organized.

ToR D
Marine sediments harbour significant levels of biodiversity that play a key role in ecosystem functions and services such as biogeochemical cycling, carbon storage and the regulation of climate. Through the removal of fauna, changes in physico-chemical nature and resuspension of sediment, bottom trawling may result in significant changes in the ecosystem functioning of shelf seas. The current PD method utilized in the WGFBIT assessment method combines information on total benthic biomass with the relative abundance of different longevity classes to estimate the relative impact of different types of fishing on the seabed. A caveat of this, however, is that total community biomass does not necessarily reflect changes in species and functional trait

composition which play a key role in regulating ecosystem functions. ToR D of the ICES WGFBIT is working on an improved understanding of the link between species functional effect traits and proxies and processes for specific ecosystem functions to improve our ability to predict the impact of fishing disturbance on benthic ecosystem functioning more accurately. Links between species traits and biogeochemical parameters and the impact of trawling on these links are being explored using multivariate ordination analyses using different fauna and biogeochemical datasets collected in the North Sea, Celtic Sea, Kattegat, Baltic Sea and the eastern Mediterranean. Changes due to trawling in the trajectories of species densities over time and the concurrent changes in the bioturbation and bioirrigation potential of communities are being modelled using a combination of data-driven mechanistic model and a biogeochemical model. The WG members have been busy developing these analytical methods and aim to run analyses for different case-studies in shelf seas over the next year.

2 General introduction

The objectives for the fifth meeting of the Fisheries Benthic Impact and Trade-offs working group (WGFBIT) were to continue the benthic impact assessment for as many (sub-) regions as possible, to execute validation analyses, to discuss methodological issues and to explore the implementation of ecosystem functioning aspects into the assessments. This is grouped into four Tor's:

- ToR A: Regional assessments: Apply and improve the MSFD D6/D1 assessment framework developed by WGFBIT (2018–2020) to produce (sub-)regional assessments for the North, Celtic, Baltic, Arctic (Icelandic, Norwegian Barents Sea), Mediterranean Seas and the Bay of Biscay and the Iberian Coast
- ToR B: Updates for assessment framework: Explore and potentially implement options to improve the parameterisation of framework components, in shallow waters and deep-sea areas.
- ToR C: WGFBIT and the wider world: Alignment of the FBIT framework with other assessment methods for benthic habitats under relevant EU directives.
- ToR D: ecosystem functioning: Explore if ecosystem functioning can be incorporated more explicitly into the assessment methodology.

Aims and Deliverable for 2022

- Hybrid meeting with lots of time for informal chats and catch up to strengthen link within the group and progress towards WGFBIT aims (ToR A, B, C, D)
- Progress integration into WGFBIT framework state of the art methods to quantify ecosystem goods and services using traits and ecosystem function (ToR D)
- Present and discuss recent update of progress FBIT (pressure, impact, trade-offs) and next 2 years forward (ToR A, B, C)
- Improving the methods (ToR B): 1) Overview of the methodologies used in the FBIT assessment framework; 2) Comparability of sensitivity distribution based on different sampling methods (grab, core, trawl, video)
- Progress regional specific calibration, ground truthing, and assessment sheets (ToR A, C)
- The WGFBIT meeting was in a hybrid format, where half of the people were present in Sete, and the other half participated remotely via online platform (for the entire period or for certain agenda points). The agenda was structured around a seminar session (a theme related to the ToRs) in early afternoon and sub-group work in the morning and late afternoon.

3 Regional assessments (ToR A)

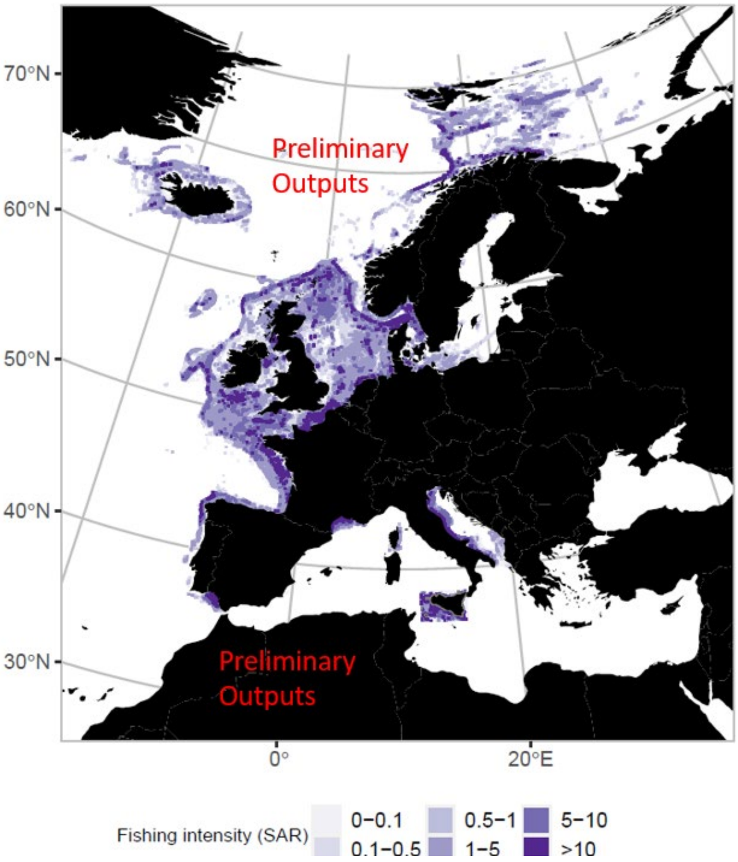
The aim of ToR A is to produce (sub-) regional fishery benthic impact assessments for the North, Celtic, Baltic, Arctic (Icelandic, Norwegian, Barents Sea), Mediterranean Seas and Bay of Biscay and the Iberian Coast.

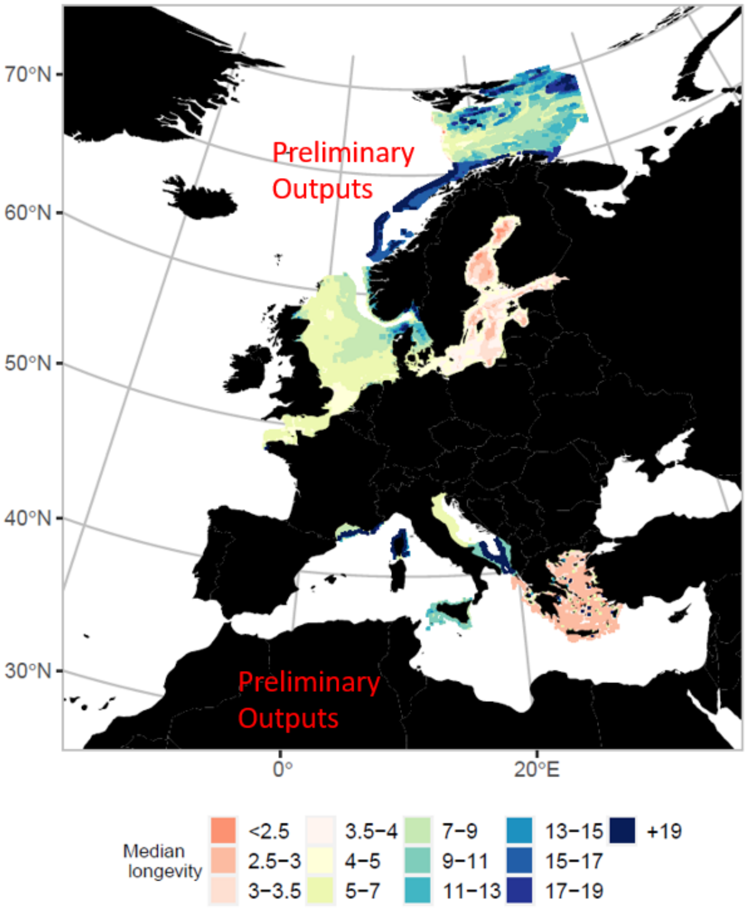
In Table 1, an overview is provided for how far the FBIT framework is implemented in each region and on which information the assessment is based. For each region, we have executed the FBIT framework to a certain level, which proves the applicability of it. Most of the assessments are preliminary and many steps need further developmental work, as indicated in the regional specific reports.

Preliminary maps with fishing intensity, estimated longevity and impact are provided in Figure 1 for the entire FBIT working group region.

Table 1. (Sub)regions for which assessment parametrization has been completed and/or available on GitHub, and for which VMS and logbook data has been used to run the assessment.

	Sensitivity layer covers most of the area < 800m	Sensitivity on FBIT GitHub	Assessment can be run from github (regional group is satisfied and VMS data available)
Norwegian Sea	Partly	Yes	No
Baltic Sea	Yes	Yes	Yes
Faroes	No	No	No
Arctic Sea	No	No	No
Barents Sea	Partly	Yes	No
Icelandic Sea	Partly	No	No
Azores	No	No	No
Oceanic North-east Atlantic	No	No	No
Celtic Sea	Yes	No	No
Bay of Biscay and Iberian Coast	Yes	No	No
Greater North Sea	Yes	Yes	Yes
Adriatic Sea	Yes / Partly	No	No
Greek waters	Yes / Partly	No	No


70°N
60°N
50°N
40°N
30°N
0°
20°E
Preliminary Outputs
Preliminary Outputs
Fishing intensity (SAR)
0−0.1
0.1−0.5
0.5−1
1−5
5−10
>10


70°N
60°N
50°N
40°N
30°N
0°
20°E
Preliminary Outputs
Preliminary Outputs
Median longevity
<2.5
2.5−3
3−3.5
3.5−4
4−5
5−7
7−9
9−11
11−13
13−15
15−17
17−19
+19

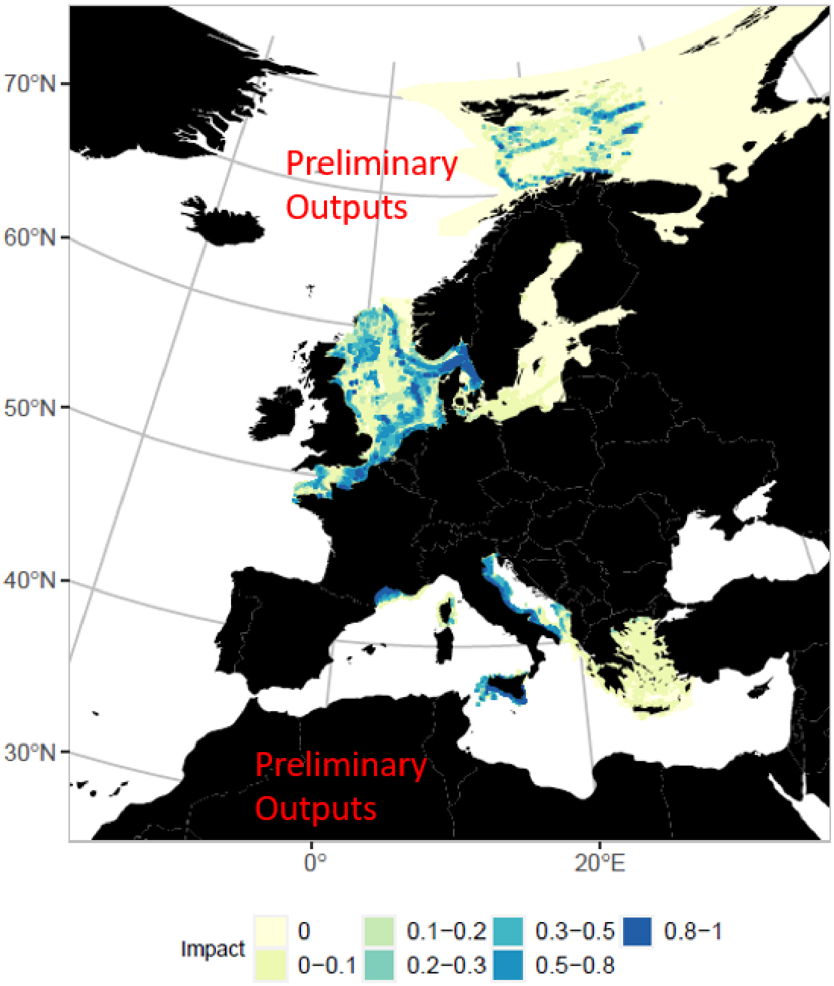


Figure 1. Maps of fishing intensity (upper panel), median longevity (middle panel) and impact (lower panel) following the estimated outputs from the different regions (only for regions where outputs were available and could be shared). Outputs are preliminary and many regions need further developmental work, as indicated in the regional specific reports. Not all regions have the same grid cell size which affects the SAR intensity distribution.

Table 2. Overview of the progress in the implementation of the FBIT framework in each region.

	(sub)-REGION	**Arctic Region**	**Arctic Region**	**Arctic Region**	**Baltic**	**Greater North Sea Region**	**Celtic, Bay of Biscay and Iberian Coast**	**Celtic, Bay of Biscay and Iberian Coast**	**Celtic, Bay of Biscay and Iberian Coast**	**Celtic, Bay of Biscay and Iberian Coast**	**Celtic Seas and North Sea**	**Mediterranean**	**Mediterranean**	**Mediterranean**	**Mediterranean**	**Mediterranean**	**Mediterranean**	**Mediterranean**	**Black Sea**
		Barents Sea	Norwegian Sea	Iceland	All	All	Irish EEZ excluding the Irish Sea	Bay of Biscay and Celtic Sea	Iberian Coast	ICES area 7agf	UK EEZ	Spain	France	Southern Adriatic	Italian Adriatic	Italy + international waters	Central and Ionian Seas	Aegean-Levantine Seas	
	Contacts	Julian Burgos	Julian Burgos	Julian Burgos	Josefine Egekvist	Daniel van Denderen	Paul Coleman, Neve McCann	Jose Gonzalez Irusta	Pascal Lafargue	Jochen Depestele	Kate Morris	Jose Gonzalez Irusta No progress for now	Sandrine Vaz, Daan Kuipers	Andrea Pierucci, Walter Zupa	Alessandra Nguyen Xuan and others	Giada Riva, Sasa Raicevich	Gabriele di Bona, Cristina Mangano, ISPRA	Chris Smith, Nadia Papadopoulou, Irini Tskikopoulou, Irida Maina, Sofia Reizopoulou, Stefanos Kavadas	Valentina Todorova for Bulgaria
STEP 1	**Pressure layer information**	ICES data (Otter trawls only). Excludes Russia.	ICES data	ICES data	ICES data 2009-2021	ICES data 2009-2021	ICES data	ICES data	ICES data	ICES data. Subsurface SAR	OSPAR data to 2017	OSPAR data to 2017	VMS from 2012 to 2020, full international split by gear types. Includes incertainty.	AIS data	SAR from VMS	SAR from ISPRA dataset (VMS +AIS), Italy only	SAR derived ISPRA VMS dataset 2007-2019. Not complete?	Complete 2015 to 2018. Greek Fleet	Effort map exist for Bulgaria and Romania

STEP 2	**Habitat information**	MSFD Broad habitat types	MSFD Broad habitat types	MSFD Broad habitat types	MSFD Broad habitat types, udated with latest EU SEAMAP.	MSFD Broad habitat types	MSFD Broad habitat types	MSFD Broad habitat types	MSFD Broad habitat types	MSFD Broad habitat types	MSFD Broad habitat types	MSFD Broad habitat types	MSFD Broad habitat types	MSFD Broad habitat types	MSFD Broad habitat types?	MSFD Broad habitat types	MSFD Broad habitat types	MSFD Broad habitat types
	Longevity curves based on:																	
STEP 3	**Biological traits**	Benthic data updated, more longevity classes. Compiling all available data	Benthic data updated, more longevity classes. Compiling all available data	Benthic data updated, more longevity classes. Compiling all available data	Benthis/ Tornroos & Bonsdorff 2012	Benthis	Data combined by Pascal for trawl samples including new CEFAS trait database	Benthis plus some extra from a Spanish database when missing	Benthis plus some extra from a Spanish database when missing	Benthis	Clare *et al.* 2022	None	Collated all trait data in a common database	Same list as for Sicilia	?	Biological traits for SOLEMON and GAP2 ADRIATIC SEA. Med group will collate all trait data in a common database	ISPRA Med mega epifauna + Bolam 2014	Complete, 898 macroinfaunal species. Full BENTHIS 11 traits.

Benthic samples	Norwegian-Russian Ecosystem Survey (only data from 2011 and 2015)	MAREANO project beam trawl data (2006-2017)	Icelandic Autumm Trawl Survey (4 years), but only for stations at depths >400m.	Only from low fishery, high oxygen data	Incl. fishery gradient data, but missing the deepest and most coastal parts and being updated with these areas	Irish Ground fish survey. Excluding beam trawl surveys	Data from IBTS	Data from IBTS	Collated grab samples	Collated grab samples and trawl samples	MEDITS exists but no access at the moment	MEDITS epifuan	MEDITS epifauna	Coastal samples only	SOLEMON Trawl survey (rapido). OTB and rapido trawl discard data from observers on fishery dependent data (GAP2);	MEDITS OTB survey. Aiming to convert abundance to biomass for some hauls.	Macrofaunal surveys and experiments. EU projects, PhDs, WFD and MSFD. 204 stations, 1364 samples. Aiming for additional analysis using MEDITS trawl data
Modelling basis (environmental variables)	Depth, temperature, sediment composition	Depth, temperature, sediment composition	Depth, temperature. Other variables are being explored.	Salinity, depth, wave exposure at the seabed (low oxygen areas omitted) van Denderen *et al.* 2020	Percentage mud and gravel, bottom-shear stress (fishing effect is fitted using subsurface abrasion)	EMODNET: Energy, depth, substrate type, SBT, surface chla	EMODNET: Energy, depth, substrate type, SBT, surface chla	EMODNET: Energy, depth, substrate type, SBT, surface chla	Depth Mud percentage Gravel percentage Median SAR (2009-2017) MSFD habitats	?		depth food availability max & mean chlorophyl-a mean bottom temperature stratification sediment grain size shear seabed stress oxygen	Depth only, EU-Seamap habitats	?	MFSD Depth	EU-Seamap habitats and depth. Depth only selected as explanatory variable.	Depth, Habitat

													saturation						
	Sensitivity layer generated?	Yes, but Norwegian section only.	Yes	Excluding shallow waters	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No
STEP 4	**Impact assessment**	2022	2018, preliminary	2021, preliminary	2009-2018	2009 - 2018	Not yet	Not yet	Not yet	2022	2022		2022	2021	2022	2022	2021	2022	
					Exclude hypoxic areas														Exclude hypoxic areas.

STEP 5	**Validation (alternative assessment availability)**	To do	To do	To do	Kattegat validation compare between the North Sea and Baltic assessment	Kattegat validation compare between the North Sea and Baltic assessment	Plan is to use earlier years for fitting, use 2020 for validation	Plan is to use earlier years for fitting, use 2020 for validation	To do	To do	To do	To do	To do	To do	To do	Solomon project Eliza Puzzo	To do
STEP 6	**Confidence / uncertainty**	To do	To do	To do	To do	Preliminary	To do	To do	To do	To do	To do	To do	To do	To do	To do	To do	Done
STEP 7	**Trade-off**	To do	To do	To do	ICES, 2021	ICES, 2021	To do	To do	To do	To do	To do	To do	To do	To do	To do	To do	Tried in TRADE3

3.1 Regional advice sheet documents

An assessment sheet template for use in communicating the results of WGFBIT seafloor assessments was finalized. We aim to use this template to produce a concise summary of the region-specific advice which WGFBIT provides. A template ensures that advice is consistently formulated across regions and years. The filled in templates will also form the basis of the update of WGFBIT output into the ICES Ecosystem Overviews. An annotated version of the advice sheet template is added to this report as Annex 3.

For Baltic Sea, Greek Sea area, North Sea, and North/Central Adriatic Sea an advice sheet document is compiled.

3.1.1 Greater North Sea Ecoregion

ICES seafloor assessment of mobile bottom fishing: Greater North Sea Ecoregion

Assessment summary

This is an assessment of mobile bottom fishing for the Greater North Sea Ecoregion. It is based on Vessel Monitoring by Satellite (VMS) fishing data up to 2021 and follows the methods described in ICES (2022a). Bottom fishing is the single most important impact on the seafloor in this area. Impact from other sources which are important in this area are aggregate dredging and wind farm construction, but their impact is only a fraction of that of bottom fisheries (ICES 2019). The impact threshold used in this assessment is arbitrarily set at 0.2. References to the full assessment can be found below under 'Format of the assessment'.

Assessment results

Status in year 2021

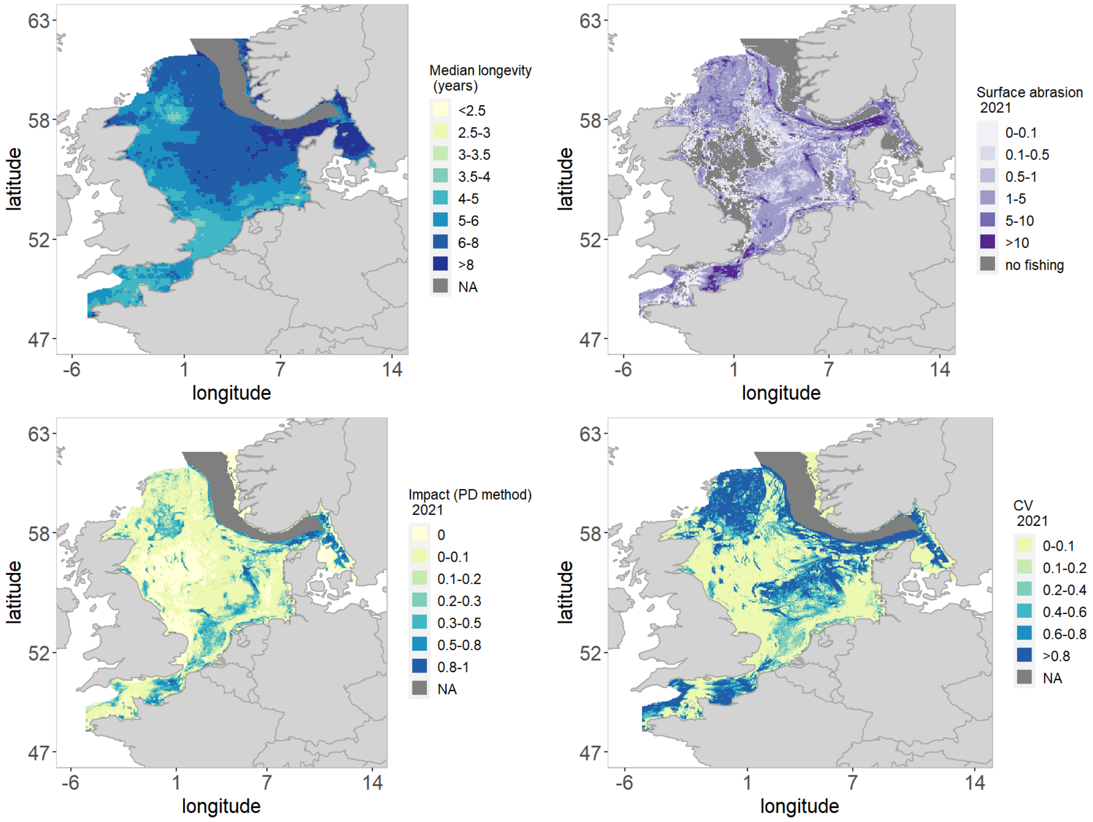


Figure 2.1 Assessment results for the Greater North Sea Ecoregion. Sensitivity (a), pressure (b) and impact (c) with uncertainty of estimate presented as the coefficient of variation CV (d). The indicators are explained in the technical guidelines for WGFBIT seafloor assessment (ICES 2021). n/a = not analysed/assessed. Areas deeper than 200m are masked out due to lack of longevity parameterisation.

Table 3 Summary of the pressure and impact indicators by (sub-)region for 0–200 and 200–800 m depths. The indicators are explained in the technical guidelines for WGFBIT seafloor assessment (ICES 2022a). n/a = not analysed.

MSFD broad habitat types	Area km2 (fraction of total)	Fraction untrawled (+-CI)	Mean SAR (+-CI)	Fraction SAR > 0.5	Mean Impact (+-CI)	Fraction with impact below 0.2
0-200m						
Offshore circalittoral sand	239 (0.34)	0.26	1.7 (0.05)	0.45	0.1 (0.002)	0.87
Offshore circalittoral mud	105 (0.15)	0.05	2.7 (0.07)	0.81	0.21 (0.005)	0.54
Offshore circalittoral coarse sediment	76 (0.11)	0.14	2.7 (0.14)	0.57	0.13 (0.004)	0.75
Circalittoral sand	72 (0.1)	0.14	1.9 (0.09)	0.6	0.12 (0.004)	0.8
Circalittoral coarse sediment	30 (0.04)	0.35	1.8 (0.14)	0.34	0.09 (0.005)	0.88
Infralittoral sand	14 (0.02)	0.43	1.5 (0.13)	0.37	0.08 (0.006)	0.9
Other	32 (0.05)	0.45	0.9 (0.04)	0.31	0.07 (0.003)	0.86
Total 0-200m	**640 (0.9)**	**0.27**	**1.8 (0.04)**	**0.49**	**0.11 (0.002)**	**0.8**
200-800m						
Upper bathyal sediment	61 (0.09)	0.59	1.3 (0.08)	0.3	n/a	n/a
Other	4 (0.01)	0.82	0.5 (0.08)	0.15	n/a	n/a
Total 200-800m	**69 (0.1)**	**0.62**	**1.2 (0.08)**	**0.29**	**n/a**	**n/a**

Time trends

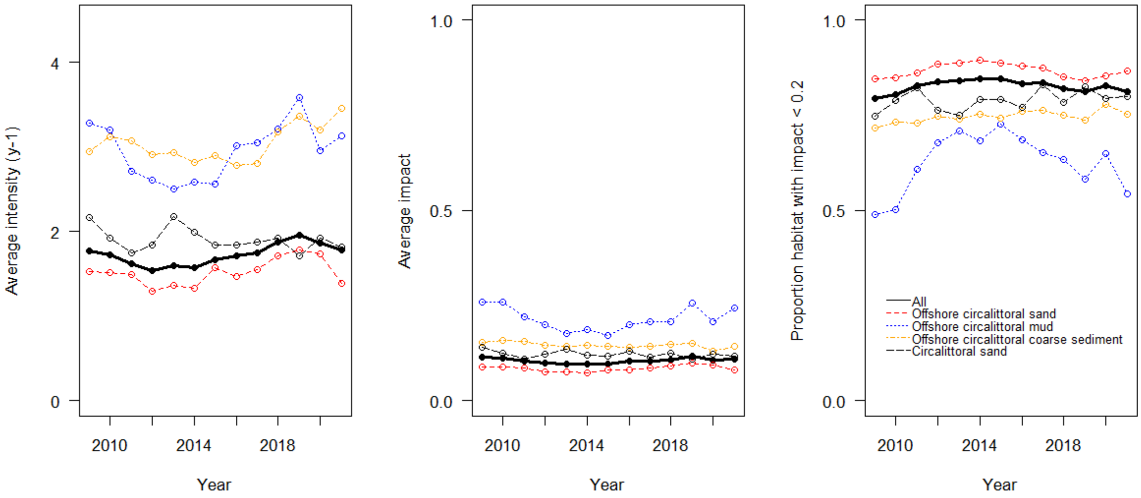


Figure 2.2 Temporal trends for the Greater North Sea Ecoregion. (a) Pressure presented as abrasion for four common habitat types and total area over time, (b) mean impact for four common habitat types and total by time, and (c) fraction below 0.2 threshold impact, for each habitat type and total, by time. The indicators are explained in the technical guidelines for WGFBIT seafloor assessment (ICES 2022a). n/a = not analysed.

Interpretation of results

The Greater North Sea ecoregion includes the North Sea, English Channel, Skagerrak, and Kattegat. It is a temperate coastal shelf sea with a deep channel in the north following the Norwegian coast. The Skagerrak and Kattegat in the east form the link to the Baltic Sea and are less saline and tidal than the rest of the ecoregion. The water column in the east is usually stratified.

The bottom fishing pressures vary spatially in the ecoregion (Figure 2a) with 27% of the grid cells untrawled in the depth zone 0–200m and 62% in 200–800m. The depth zone 0–200m is fished on average 1.8 SAR per year. Almost 50% of the region is fished > 0.5 SAR per year (Table 3).

The sensitivity of the Greater North Sea is highest in the north-eastern North Sea and Kattegat and lowest in the southern North Sea. The southern North Sea is less sensitive mainly due to the high natural disturbance from tidal waves and storms, and the associated tolerant benthic fauna in these shallow areas.

The MSFD habitat type that experiences highest fishing pressure and impact is offshore circalittoral mud in 2021. This habitat type represents 15% of the Greater North Sea and is mainly exploited by mixed fish and crustaceans fisheries. Only 5% of the grid cells are untrawled and 81% of the area is fished with >0.5 SAR per year. Offshore circalittoral coarse sediment is the second most impacted habitat type (Table 3).

The fishing intensity in offshore circalittoral coarse sediment has increased since 2016. Fishing intensity in offshore circalittoral mud has been lower in 2020 and 2021 compared with 2019.

Validity and limitations

Sensitivity and impact have not been calculated for grid cells > 200m depth because of data unavailability.

Temporal patterns in fishing activity are available from 2009 for vessels over 15m and from 2012 for vessels over 12m. Temporal variation in fishing activity hence represents vessels over 15m (2009–2011) and vessels over 12m (2012–2018).

Model validation is in an early stage but has been performed for Kattegat, the coastal area in the southern North Sea and Brown Bank. Further information can be found in ICES (2022b).

Format of the assessment

This seafloor assessment of the Greater North Sea Ecoregion consists of this PDF assessment text, the technical guideline report (ICES 2022a) and a series of interactive maps, figures, tables, and text (ICES 2021).

The scripts used to produce the assessment are available: https://github.com/ices-eg/FBIT

Sources and references

ICES. 2019. EU request to advise on a seafloor assessment process for physical loss (D6C1, D6C4) and physical disturbance (D6C2) on benthic habitats. In Report of the ICES Advisory Committee, 2019. ICES Advice 2019, sr.2019.25, https://doi.org/10.17895/ices.advice.5742.

ICES. 2021. ICES advice to the EU on how management scenarios to reduce mobile bottom fishing disturbance on seafloor habitats affect fisheries landing and value. *In* Report of the ICES Advisory Committee, 2021. ICES Advice 2021. sr.2021.08. https://doi.org/10.17895/ices.advice.8191.

ICES. 2022a. Technical guideline document for assessing fishing impact from mobile bottom-contacting fishing gears (version 2, 27 February 2022). *within*: Report from the working group on Fisheries Benthic Impact and Trade-Offs

ICES 2022b. Working Group on Fisheries Benthic Impact and Trade-offs (WGFBIT; outputs from 2021 meeting). ICES Scientific Reports. 4:9. 133 pp. http://doi.org/10.17895/ices.pub.10042

ICES. 2022c. Working Group on Fisheries Benthic Impact and Trade-offs - Sete

3.1.2 Baltic Sea Ecoregion

ICES seafloor assessment of mobile bottom fishing: Baltic Sea Ecoregion

Assessment summary

This is an assessment of mobile bottom fishing for the Baltic Sea Ecoregion. It is based on Vessel Monitoring by Satellite (VMS) fishing data up to 2021 and follows the methods described in ICES (2022a). The Baltic Sea Ecoregion is most impacted by eutrophication and eutrophication-induced hypoxia (ICES 2019). Bottom fishing occurs in the southern and southwestern Baltic Sea. The impact threshold used in this assessment is arbitrarily set at 0.2. References to the full assessment can be found below under 'Format of the assessment'.

Assessment results

Status in year 2021

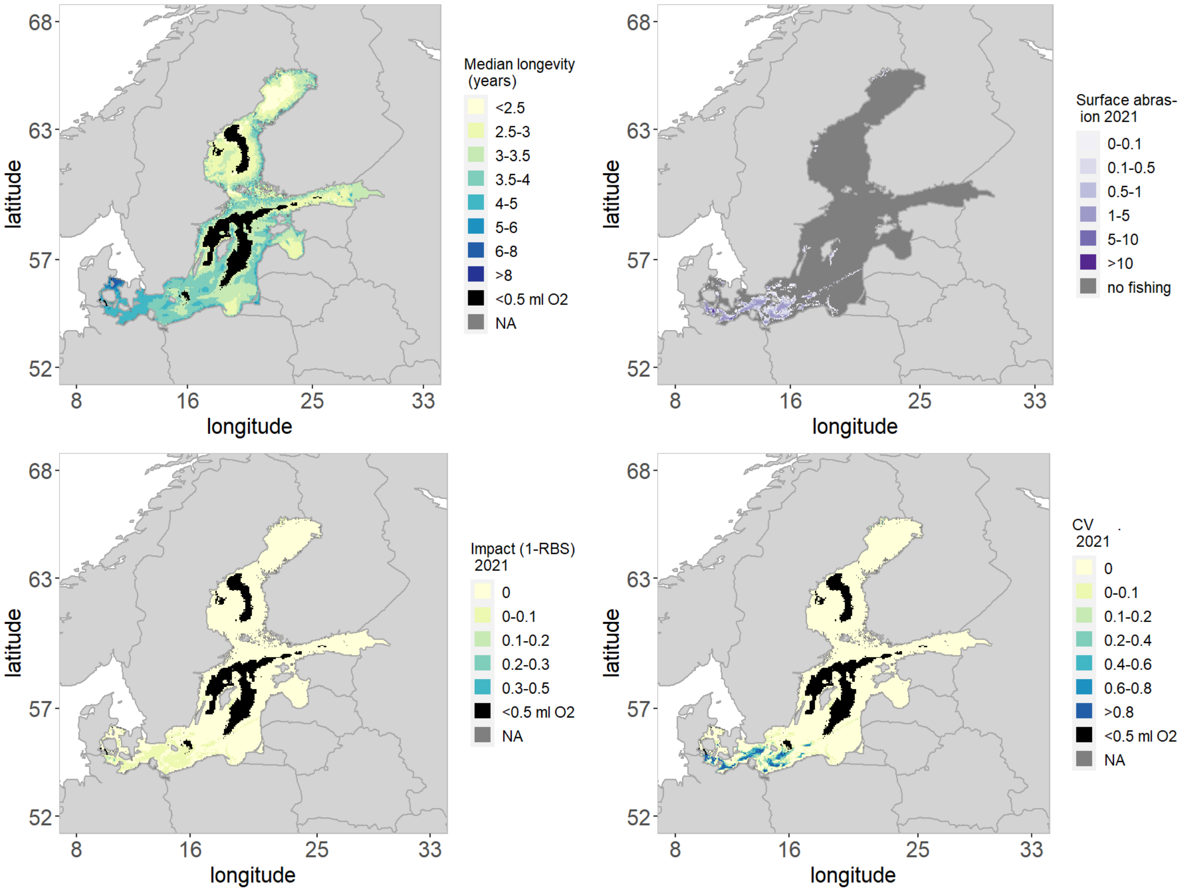


Figure 3 Assessment results for the Baltic Sea Ecoregion. Sensitivity (a), pressure (b) and impact (c) with uncertainty of estimate presented as the coefficient of variation CV (d). The indicators are explained in the technical guidelines for WGFBIT seafloor assessment (ICES 2021). n/a = not analysed. Black cells have seasonal oxygen concentrations <0.5 ml O_2 per litre, a concentration below which oxygen deprivation generates mass mortality in benthos.

Table 4 Summary of the pressure and impact indicators by (sub-)region for 0–200 and 200–800 m depths. The indicators are explained in the technical guidelines for WGFBIT seafloor assessment (ICES 2022a). n/a = not analysed. Areas with seasonal oxygen concentrations <0.5 ml O_2 per liter are classified as anoxic/hypoxic.

MSFD broad habitat types	Area km2 (fraction of total)	Fraction untrawled	Mean SAR (+-CI)	Fraction SAR > 0.5	Mean Impact (+-CI)	Fraction with impact below 0.2
0-200m						
Circalittoral mixed sediment	95 (0.26)	0.96	0 (0)	0.01	0 (1e-04)	1
Anoxic/hypoxic*	52 (0.14)	0.99	0 (0.01)	0.01	n/a	n/a
Circalittoral mud or Circalittoral sand	43 (0.12)	0.98	0 (0)	0	0 (0)	1
Circalittoral sand	31 (0.08)	0.78	0.1 (0.02)	0.08	0 (4e-04)	1
Circalittoral mud	27 (0.07)	0.88	0.1 (0.01)	0.06	0 (3e-04)	1
Infralittoral sand	21 (0.06)	0.62	0.2 (0.03)	0.16	0.01 (8e-04)	1
Other	56 (0.15)	0.91	0.1 (0.01)	0.03	0 (1e-04)	1
Total 0-200m	**365 (0.99)**	**0.9**	**0.1 (0.01)**	**0.04**	**0 (1e-04)**	**1**
200-800m						
Total 200-800m	**2 (0.01)**	**1**	**0 (0)**	**0**	**n/a**	**n/a**

* Anoxic/hypoxic is included as a separate habitat to avoid averaging trawl impact over unfished but depauperate areas

Time trends

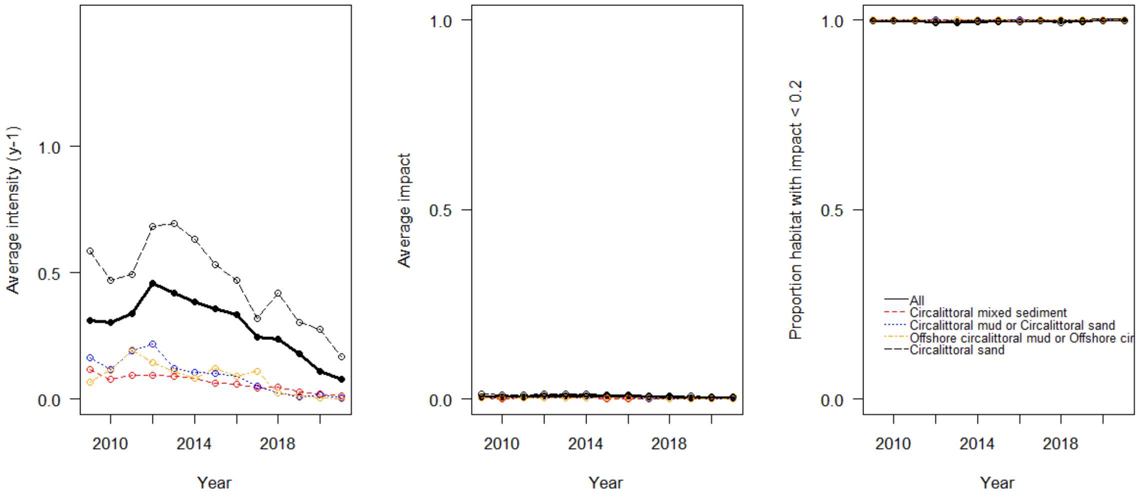


Figure 4 Temporal trends for the Baltic Sea Ecoregion. (a) Pressure presented as abrasion for four common habitat types and total area over time, (b) mean impact for four common habitat types and total by time, and (c) fraction below 0.2 threshold impact, for each habitat type and total, by time. The indicators are explained in the technical guidelines for WGFBIT seafloor assessment (ICES 2022a). Average trends exclude areas with seasonal oxygen concentrations <0.5 ml O_2 per liter.

Interpretation of results

The Baltic Sea is one of the largest brackish water bodies in the world. It is a semi-enclosed shallow sea with an average depth of 60 m. This ecoregion is characterized by strong salinity gradients and large areas with low bottom oxygen concentrations.

Bottom fishing solely occurs in the southern and southwestern part of the ecoregion (Figure 3). More than 90% of the grid cells are untrawled and average fishing intensity is 0.1 SAR per year (Table 4).

The sensitivity of the Baltic Sea to bottom fishing disturbance is highest in the southwestern waters where species longevity is relatively high (Figure 4). Sensitivity is lower in the deeper and northern parts of the Baltic Sea.

The MSFD habitat types that experience highest fishing pressure and impact are infralittoral and circalittoral sand. These habitat types represent 6 and 8% of the Baltic Sea (Table 4). 14% of the area experiences seasonal oxygen concentrations <0.5 ml O_2 per liter and benthic fauna in these areas is either absent or in a depauperate state.

Average fishing intensity has decreased significantly since 2013 due to the poor status of the Baltic cod stocks, and at present only a limited trawl fishery targeting flatfish is allowed. Average impact has been low since 2009 (Figure 4).

Validity and limitations

Temporal patterns in fishing activity are available from 2009 for vessels over 15m and from 2012 for vessels over 12m. Temporal variation in fishing activity hence represents vessels over 15m (2009–2011) and vessels over 12m (2012–2018).

Model validation is in an early stage but has been performed for the Gotland basin and in the Southern Baltic Sea in Polish waters. Further information can be found in ICES (2022b).

Format of the assessment

This seafloor assessment of the Baltic Sea Ecoregion consists of this PDF assessment text, the technical guideline report (ICES 2022a) and a series of interactive maps, figures, tables, and text (ICES 2021).

The scripts used to produce the assessment are available: https://github.com/ices-eg/FBIT

Sources and references

ICES. 2019. EU request to advise on a seafloor assessment process for physical loss (D6C1, D6C4) and physical disturbance (D6C2) on benthic habitats. In Report of the ICES Advisory Committee, 2019. ICES Advice 2019, sr.2019.25, https://doi.org/10.17895/ices.advice.5742.

ICES. 2021. ICES advice to the EU on how management scenarios to reduce mobile bottom fishing disturbance on seafloor habitats affect fisheries landing and value. *In* Report of the ICES Advisory Committee, 2021. ICES Advice 2021. sr.2021.08. https://doi.org/10.17895/ices.advice.8191.

ICES. 2022a. Technical guideline document for assessing fishing impact from mobile bottom-contacting fishing gears (version 2, 27 February 2022). *within*: Report from the working group on Fisheries Benthic Impact and Trade-Offs

ICES 2022b. WKBENTH3 workshop report xxx.

ICES. 2022c. Working Group on Fisheries Benthic Impact and Trade-offs - Sete

3.1.3 Eastern Mediterranean Sea

ICES seafloor assessment of mobile bottom fishing: Eastern Mediterranean (Eastern Ionian, Aegean and Cretan Seas) ecoregion

Assessment summary

This is a seafloor assessment of the Greek sea areas in the Eastern Mediterranean (Eastern Ionian, Aegean and Cretan Seas). It is based on estimates of sensitivity of grab sampled benthic macroinfauna, otter trawl swept area ratios based on Vessel Monitoring by Satellite (VMS) fishing data and habitat maps and follows the methods described in ICES (2022a). The bottom contact fishery is the most widespread activity impacting the seafloor of this area. Other impacts restructuring seabed morphology occur from dredging and depositing of materials, coastal defences or shipping and tourism/leisure related seabed interactions, but are of much lesser importance (ICES WKBEDPRES1, 2018). The impact threshold used in this assessment is arbitrarily set at 0.2. References to the full assessment can be found below under 'Format of the assessment'.

Assessment results

Status in years 2015–2018

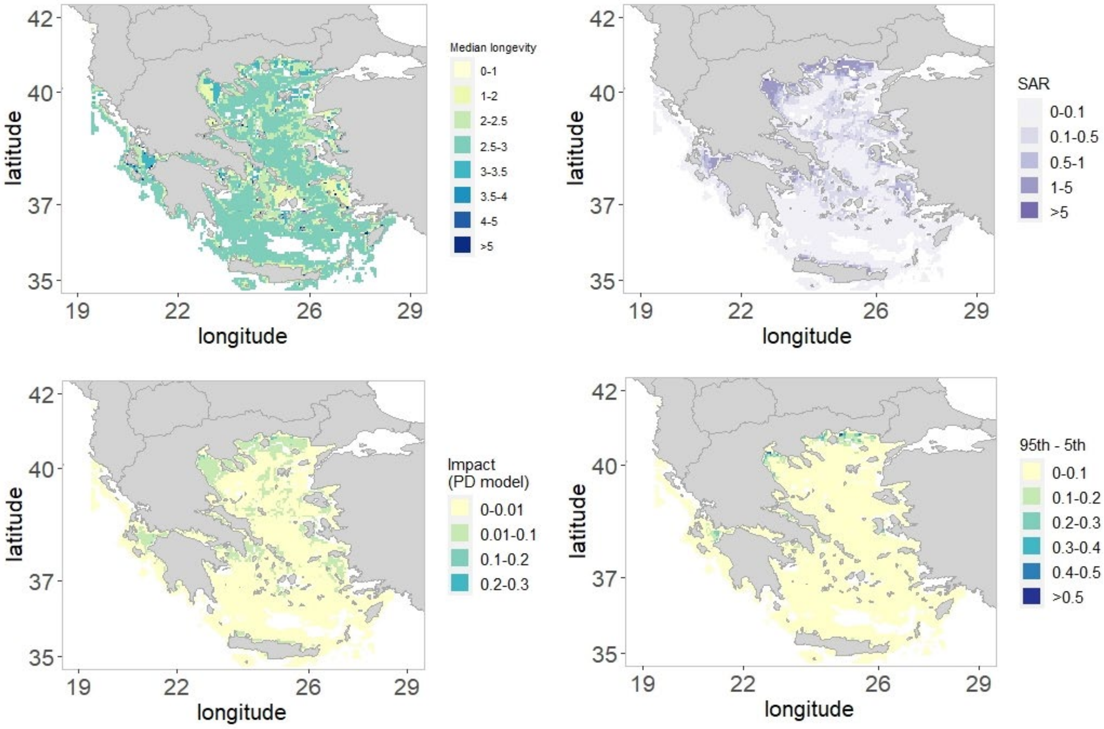


Figure 5 Assessment results for the Greek sea areas in the Eastern Mediterranean. Sensitivity (a), pressure (b) and impact (c) with uncertainty measured as the difference in state between 5th and 95th percentile (d). The indicators are explained in the technical guidelines for WGFBIT seafloor assessment (ICES 2021).

Table 5 Summary of the pressure and impact indicators by (sub-)region for 0–200 and 200–1200 m depths. The indicators are explained in the technical guidelines for WGFBIT seafloor assessment (ICES 2022a). n/a = not analysed.

MSFD broad habitat types	Area 10^3km2 (fraction of total)	Fraction untrawled (+-CI)	Mean SAR (+-CI)	Fraction SAR > 0.5	Mean Impact (+-CI)	Fraction with impact below 0.2
0-200m						
Infralittoral mud	7.30 (0.03)	0.99	0.01	0.01	0.001	1
Infralittoral sand	5.87 (0.03	0.97	0.05	0.03	0.003	1
Infralittoral mixed sediment	0.53 (0.00)	0.98	0.02	0.00	n/a	n/a
Circalittoral mud	20.66 (0.09)	0.67	0.48	0.36	0.013	1
Circalittoral mixed sediment	0.63 (0.00)	0.82	0.26	0.19	0.007	1
Circalittoral sand	11.36 (0.05)	0.63	0.63	0.36	0.024	0.004
Circalittoral coarse sediment	0.75 (0.00)	0.91	0.09	0.03	0.003	1
Offshore circalittoral mud	14.24 (0.06)	0.69	0.39	0.25	0.013	1
Offshore circalittoral mixed sediment	0.17 (0.00)	0.99	0.01	n/a	n/a	n/a
Offshore circalittoral sand	4.55 (0.02)	0.69	0.4	n/a	n/a	n/a
Offshore circalittoral coarse sediment	0.29 (0.00)	0.94	0.06	n/a	n/a	n/a
Total 0-200m	**82.26(0.37)**	**0.77**	**0.33**	**0.21**	**0.012**	**0.001**
200-1200m						
Upper bathyal sediment	133.66 (0.61)	0.92	0.08	0.04	0.003	1
Total 200-1200m	**136.05(0.63))**	**0.92**	**0.08**	**0.04**	**0.003**	**1**

Time trends

n/a

Interpretation of results

In this subregion, the impact of trawling on the benthic status is low with values mainly ranging from 0.01 to 0.1. The highest fishing intensity is mainly concentrated in the northern part of Greece and coastal large area gulfs. The main explanatory variables for mapped longevity distribution (sensitivity) were benthic habitat type and depth. Overall low median longevity characterizes muddy circalittoral habitats, whilst deeper and more coarse sediments are characterized by higher values of median longevity. The most extensive habitat, upper/lower bathyal sediment is indicative of the characteristic deep waters of the area with an overall low proportion of area fished. Results of the uncertainty analysis show that the predicted impacts are mostly with low uncertainty and with areas of higher uncertainty in areas with higher bottom fishing intensity.

Validity and limitations

Validation is in an early stage but there is a plan to estimate several ecological indicators that are used in the Water Framework Directive (WFD) and in the Marine Strategy Framework Directive (MSFD) such as AZTIs Marine Biotic Index (AMBI), multivariate AMBI (M-AMBI) and Biotic Index (BENTIX), and compare the outcome with the Relative Benthic State indicator.
Although the Greek fleet is the primary fleet in the Greek sea area, there are vessels from other national fleets fishing in some of the assessment area with no data on those vessels in the current assessment. In undertaking a Mediterranean regional assessment, it will be important to have standard methodologies and data selection.

Format of the assessment

This seafloor assessment of the Eastern Mediterranean consists of this PDF assessment text. The scripts used to produce the assessment are available: https://github.com/ices-eg/FBIT

Sources and references

ICES. 2018. Workshop on scoping for benthic pressure layers D6C2 - from methods to operational data product (WKBEDPRES1), 24–26 October 2018, ICES HQ, Copenhagen, Denmark. ICES CM 2018/ACOM:59. 62 pp.

ICES. 2021. ICES advice to the EU on how management scenarios to reduce mobile bottom fishing disturbance on seafloor habitats affect fisheries landing and value. *In* Report of the ICES Advisory Committee, 2021. ICES Advice 2021. sr.2021.08. https://doi.org/10.17895/ices.advice.8191.

ICES. 2022a. Technical guideline document for assessing fishing impact from mobile bottom-contacting fishing gears (version 2, 27 February 2022). *within*: Report from the working group on Fisheries Benthic Impact and Trade-Offs

ICES. 2022b. Working Group on Fisheries Benthic Impact and Trade-offs - Sete

3.1.4 North/Central Adriatic Sea

Assessment summary

The Adriatic Sea is one of the most exploited area in the Mediterranean, given the high intensity of trawling. For the Northern-Central Adriatic Sea (GSA17, Italian waters and international waters), two different seafloor assessments were implemented based on the PD model. The models (hereinafter referred to as “Model 1” and “Model 2”) differed in the data sources used for the assessment and the EUSeaMap version used for the broad benthic habitat types (BBHT) extent, reflecting a slightly different spatial domain of the analyses, as well as some further specific elements used for the application of the models themselves. Whilst the epibenthic data sources mainly belong to GSA17, estimates were extended to assess GSA18 for the same BBHT and within the same depth range based on SAR. The main features of the two evaluations are presented in the following comparative table, and then the results of the two different assessments are shown.

A single assessment will be performed in the future, integrating the different available benthic datasets and applying a common methodology.

Table 6. Comparative table of the input data and modelling basis applied for the two regional assessments.

	RBS assessment: model 1	RBS assessment: model 2
Study area	North-Central Adriatic Sea (GSA17) Depth range: 10-100m	North-Central Adriatic Sea (GSA17) Depth range: 10-100m
Pressure layer information	VMS as SAR data on a grid with 1 km*1 km cell resolution Otter-trawl (OTB) and beam trawl (TBB). Mean of yearly assessed value from 2017 to 2019 (3 years period)	Integration of VMS and AIS data on a grid with 1 km*1 km cell resolution Otter-trawl (OTB) and beam trawl (TBB). Mean of yearly assessed value from 2014 to 2016 (3 years period)
Adriatic Sea Habitats	Broad Benthic Habitat Types from EU-SeaMap 2019	Broad Benthic Habitat Types from EU-SeaMap 2021
Benthic samples	MSFD monitoring plan performed by ARPAs (2017-2020) including always abundance data and biomass data only for selected samples ISPRA survey (2019) both abundance and biomass data	GAP2 survey (otter trawl; 2012-2014) SoleMON rapido trawl survey (TBB; 2014-2016) Biomass data (kg/km^2)
Longevity classification	3 longevity classes assigned by the Italian Society of Marine Biology (SIBM): (<1; 1-10; >10)	4 longevity classes: (0-1; 1-3; 3-10; >10)
Modelling basis (environmental variables)	The cumulative biomass-longevity relationship was estimated based on Generalized Linear Mixed-Effect Models (GLMMs) including MSFD habitat type as fixed effects and assuming stations as a random effect.	The cumulative biomass-longevity relationship was estimated based on Generalized Linear Mixed-Effect Models (GLMMs) including MSFD habitat type and Depth as fixed effects and assuming stations as a random effect.
Median longevity estimation	mod2 <- glmer(Cumb ~ ll + MSFD + (1 | ID), data=fulldat, family=binomial) According to the selected model, two longevity classes were estimated: 5 – 6	Cumb ~ ll + MSFD + Depth + (1 | ID) According to the selected model, three longevity classes were estimated: 4 – 5 – 6

Assessment 1 results

Status in year [2017-2019]

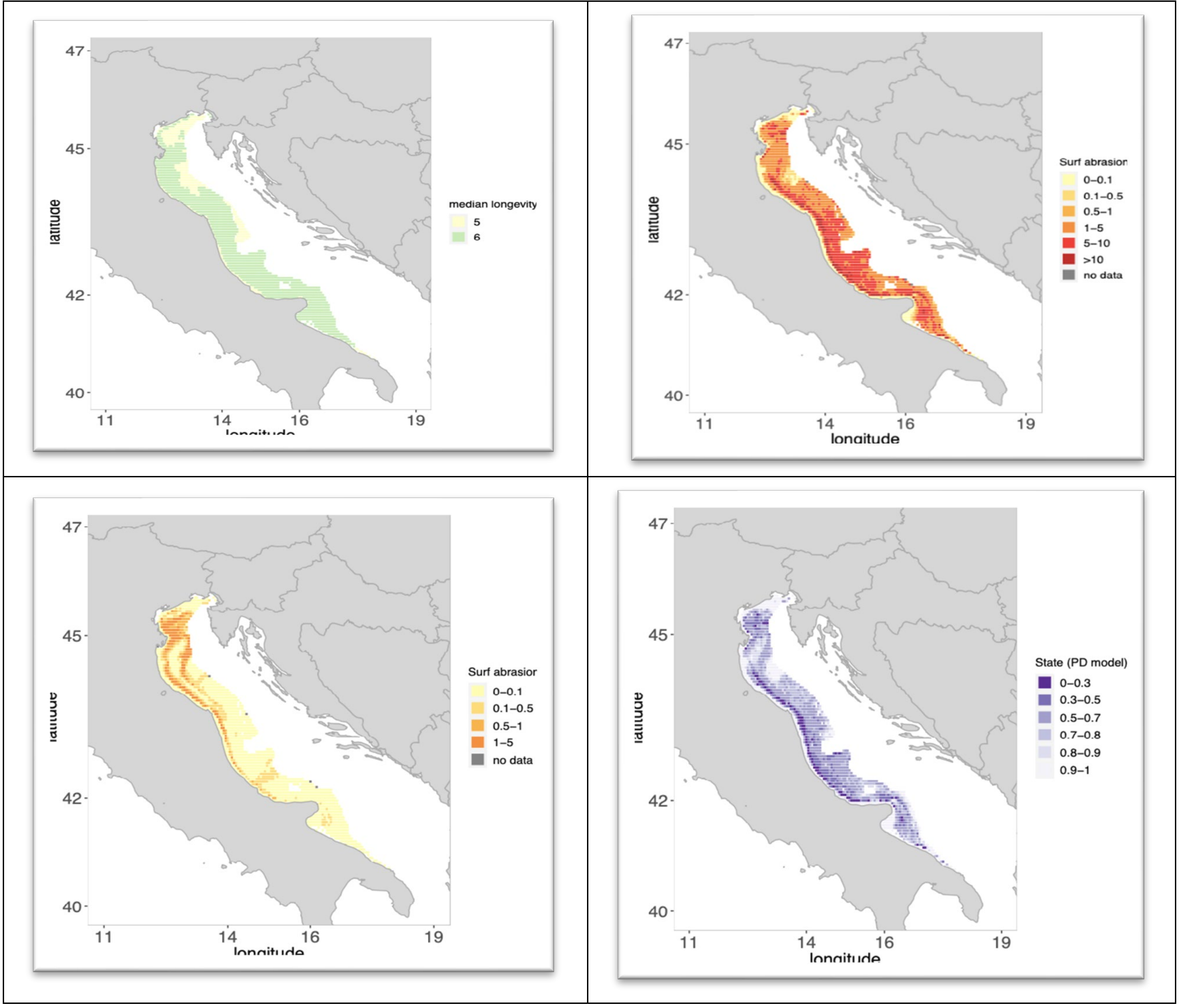


Figure 6 Adriatic Sea (GSA 17) areas maps of i) predicted median longevity (top left); ii) SAR (average of the year 2017-2019) OTB (top right) and TBB (bottom left); iii) SAR (average of the year 2017-2019) based on VMS and AIS data for beam trawls (TBB) (bottom left); iv) relative benthic impact (bottom right). The indicators are described in the technical guidelines for WGFBIT seafloor assessment (ICES 2021).

Table 7 Summary of the pressure and impact indicators in the Northern and Central Adriatic Sea areas. The indicators are described in the technical guidelines for WGFBIT seafloor assessment (ICES 2021).

Habitat type (BBHT)	Area km^2 (fraction of total)	Fraction untrawled (+-CI)	Mean SAR OTB (+-SD)	Mean SAR TBB (+-SD)	Mean Impact (+-SD)	Relative benthic state (+-SD)
Circalittoral mud or Offshore circalittoral mud	30581 (49%)		0.87 ±2.32	0.27 ±0.52	0.34 ±0.22	0.66 ±0.22
Circalittoral sand	6845 (11%)		2.46 ±2.42	0.38 ±0.56	0.21 ±0.19	0.79 ±0.19
Infralittoral sand	1748 (3%)		0.29 ±1.86	0.17 ±0.46	0.03 ±0.12	0.97 ±0.12

Assessment 2 results

Status in year [2012-2016]

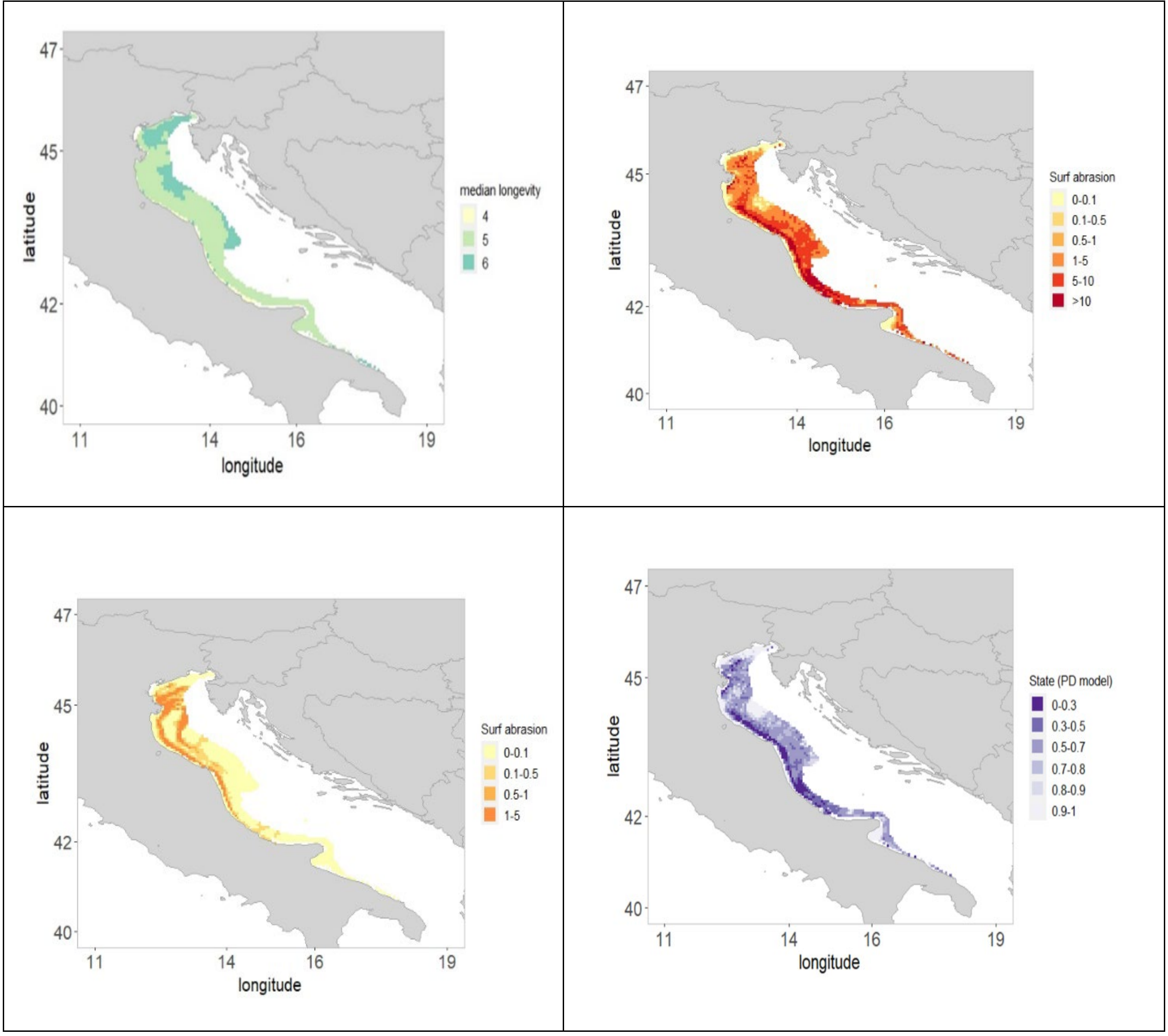


Figure 7 Adriatic Sea (GSA 17) areas maps of i) predicted median longevity (top left); ii) swept area ratio SAR (average of the year 2014-2016) based on VMS and AIS data for otter trawls (OTB) (top right); iii) SAR (average of the year 2014-2016) based on VMS and AIS data for beam trawls (TBB) (bottom left); iv) relative benthic impact (bottom left). The indicators are described in the technical guidelines for WGFBIT seafloor assessment (ICES 2021).

Table 8. Summary of the pressure and impact indicators in the Northern and Central Adriatic sea areas. The indicators are described n the technical guidelines for WGFBIT seafloor assessment (ICES 2021).

Habitat type	Area km2 (fraction of total)	Fraction un-trawled (+-CI)	Mean SAR OTB (+-SD)	Mean SAR TBB (+-SD)	Mean Impact (+-SD)	Relative benthic state (+-SD)
Circalittoral mud	21044.79 (34%)		5.78 ±4.56	0.33 ±0.67	0.41 ±0.23	0.59 ±0.23
Circalittoral sand	6771.07 (11%)		2.63 ±2.8	0.34 ±0.56	0.24 ±0.20	0.76 ±0.20
Infralittoral sand	1724.14 (3%)		2.52 ±4.79	0.17 ±0.46	0.15 ±0.24	0.85 ±0.24

Time trends
Not yet available

Interpretation of results

Both the assessments refer to periods where high intensity of fishing effort is reported for the Adriatic Sea.

Assessment 1: the majority of the available sampling stations are localized on the same BBHT (namely 3 the following three BBHTs: Infralittoral sand, Circalittoral sand, Circalittoral mud or Offshore circalittoral mud; and within the same depth, i.e. from 10 to 100 m). Longevity distribution presented two longevity fuzzy classes (the central ones), thus showing a very low variability in the estimated median longevity. The relation between Cumulated Biomass and Longevity was modelled by Generalized Linear Mixed-Effects Models where the best-fitting model is that one where the fixed effect is described by Habitat, while random effect is defined by ID Station. As expected, there is a clear state worsening with the increase of depletion, as swept area ratio; RBS (PD State) almost overlays with the fishing effort given that the longevity (and therefore sensitivity) has a very low variability that smooths the relevance of this variable. Consequently, the fishing impact is mainly driven by the fishing effort.

Assessment 2: The best-fitting model considers Depth and Habitat as the main explained variables. Longevity distribution reflects the depth gradient with lower depth along the coast associated to lower longevity class. The overall low variability of the median longevity (ranging from 4 to 6 ys) may reflect the lower environmental gradients of the study area. Relative Benthic State (RBS) distribution appears to correlate strongly with SAR distribution. Muddy habitats are the most impacted, possibly because of the higher trawling intensity and the large proportion of habitat affected, despite the relatively lower sensitivity of the benthos, while the infralittoral sandy habitat is the least impacted due to the combination of a relatively low trawling intensity and the relatively low sensitivity of the benthos.

Validity and limitations

Despite the differences in the model 1 and 2 settings and reference years, both the assessments highlight the presence of high impact of trawling on benthic communities of the Northern and Central Adriatic Sea and agree in identifying the circalittoral mud habitat as the most impacted habitat. The integration of the two datasets to build a common assessment could allow broadening the spatial scope of the assessment although some "noise", due to differences in sampling procedures and sample analyses, could be introduced. The integration could also allow exploring temporal trends in RBS. Currently, there are some important differences between the two assessments: in assessment 1, lower SAR emerges for Circalittoral mud and Infralittoral sand (0.89 and 0.29 respectively) as compared to assessment 2, where SAR presented higher intensities (5.78 and 2.89). This difference reflects both the different reference years and the use, in the two models, of two Broad Habitat extent, adopting EUSeaMAp 2019 and 2021, respectively. Also, the lower variability of median longevity values estimated by the assessment 1 compared to the assessment 2 is related to the different longevity classifications and spatial scale coverage adopted. Despite such differences both the assessments agreed in ranking circalittoral mud as the most impacted habitat followed by ciralittoral sand and infralittoral sand, with assessment 2 pointing to higher impact values. In both the assessments, data relates to sampling sites within the 100m depth; therefore, the results of RBS could not be extended to habitats below this depth; in addition, there is a general issue concerning the limited number of representative unfished sites across BBHT for assessing longevity in undisturbed conditions. Another critical point for both the assessments is that related to the longevity classification adopted and to be translated into the FBIT r code fuzzy classes, i.e., in assessment 1 SIBM 3 class classification, in assessment 2, the 4 classes, as derived from a literature review. A common approach should be reached. Finally, a future goal for the overall assessment will be to adopt, as far as possible, the latest updated Habitat map.

Future analyses will need to be tested based on the latest version of EUSeaMap, and include SAR into the model or collecting more data from the less impacted areas, covering also higher benthic habitat distribution. Caution should be adopted when interpreting habitat sensitivity distribution maps estimated in the Southern Adriatic Sea (GSA18) along the coastline since the sampling area is limited to GSA17, and no data were available for direct assessment and ground truthing.

Format of the assessment

This seafloor assessment of the North/Central Adriatic Sea consists of this PDF assessment text, the technical guideline report (ICES 2022a) and a series of interactive maps, figures, tables, and text (ICES 2021). The scripts used to produce the assessment are available: https://github.com/ices-eg/FBIT

Sources and references

ICES. 2021. Technical Guidelines - ICES ecosystem overviews (2021). ICES Technical Guidelines. Report. DOI: https://doi.org/10.17895/ices.advice.7916

ICES. 2022a. Technical guideline document for assessing fishing impact from mobile bottom-contacting fishing gears (version 2, 27 February 2022). within: Report from the working group on Fisheries Benthic Impact and Trade-Offs

ICES. 2022b. Working Group on Fisheries Benthic Impact and Trade-offs (WGFBIT; outputs from 2021 meeting). ICES Scientific Reports. 4:9. 133 pp. http://doi.org/10.17895/ices.pub.10042

3.2 Regional assessment updates

3.2.1 Icelandic Waters

No updates have been made for this ecoregion.

3.2.2 Norwegian Sea

Intersessional work resulted in an estimate of longevity for some areas in the Norwegian Sea based on data from the MAREANO program.

No updates have been made for this ecoregion during the working group meeting.

3.2.3 Barents Sea

Intersessional work resulted in an estimate of longevity for some areas in the Barents Sea. These areas cover most of the area where fishing occurs (based on available VMS data). A preliminary assessment of the area is shown in Figure 8.

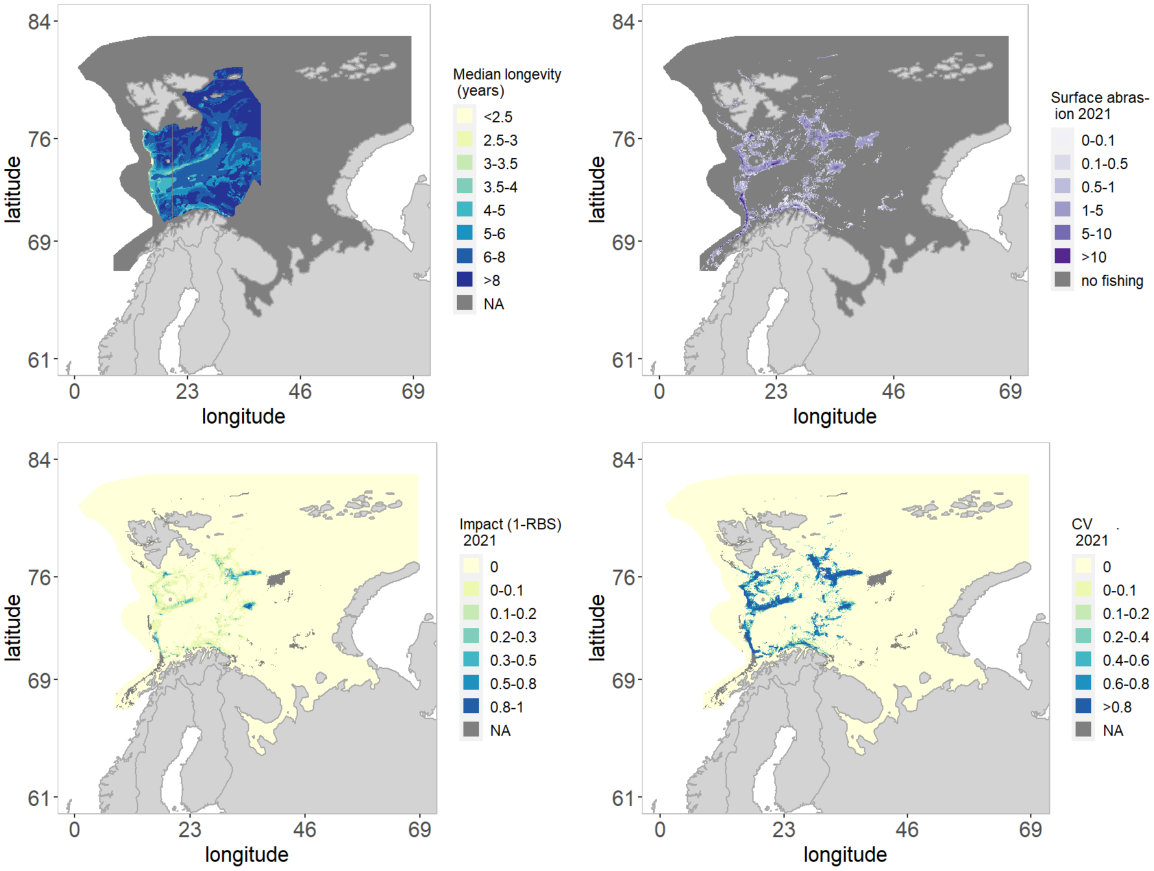


Figure 8. Preliminary assessment results for the Barents Sea Ecoregion. Sensitivity (a), pressure (b) and impact (c) with uncertainty of estimate presented as the coefficient of variation CV (d). The indicators are explained in the technical guidelines for WGFBIT seafloor assessment (ICES 2021). n/a = not analysed/ no information available.

3.2.4 Celtic Sea, Bay of Biscay, Iberian Coast

3.2.4.1 Celtic Sea (Irish area) (ICES Divisions 6a, 7, 7b, g,& j)

Sampling data from the Irish Groundfish Survey (IGFS), and Irish Anglerfish and Megrim Survey (IAMS) from 2003–2021 and 2016–2021 respectively, was incorporated into the WGFBIT methodology (Figure 9). The surveys operate under agreed protocols; IGFS operates in daylight hours with 30min hauls, whereas IAMS operates on a 24hr rotation with 60min haul durations.

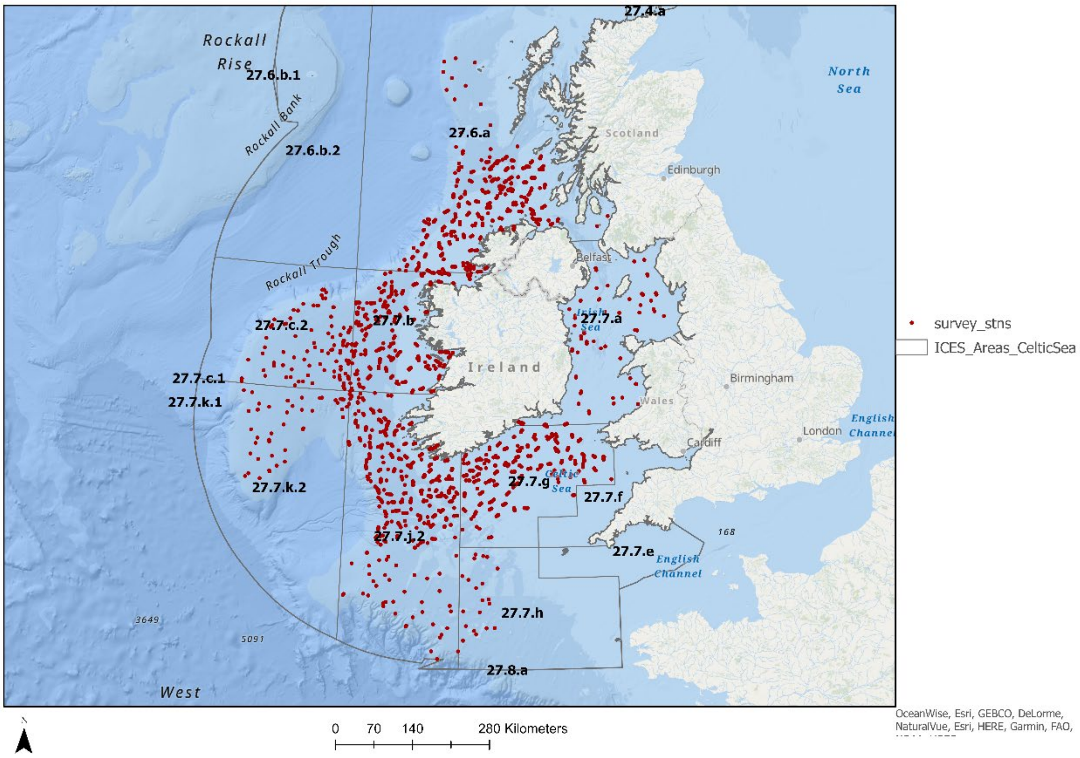


Figure 9. Coverage of the IGFS and IAMS surveys present in ICES divisions 6a, 7, 7b,g&j.

Benthic samples were extracted from the ICES DATRAS database, using valid hauls. Records with invalid information or no species name were removed.

The species list was taken from Worms and catch numbers were standardized by the swept area. Swept area was calculated using the width of the sampling gear, ground speed and haul duration with AphiaIDs matched with the longevity traits database. The proportion of benthic data matched to the longevity database was lower than expected; prompting the need for further investigation. Due to varying time and resource constraints; further analysis into this anomaly could not be conducted in time to be reported in 2022.

Further analysis and modelling of the data based on the environment variables (step 3 WGFBIT workflow) would not be appropriate at present. Further investigative analysis of the benthic and longevity trait data will be conducted in the coming year in order to progress the Irish survey data through the WGFBIT workflow steps.

3.2.4.2 Sensitivity layer based on benthic megafauna from trawling survey in the Bay of Biscay, Celtic Sea North and the northern Iberian continental shelves

The WGFBIT workflow was applied to the western waters region (Celtic Seas, Bay of Biscay, Iberian Coast, Irish Sea). The results presented complement those obtained in the previous year but are still preliminary and should not be considered as a relevant assessment for the area under consideration. Moreover, analyses were performed for a set of subareas consistent with the available biological datasets.

As last year, we used standardized scripts for pre-processing the biological data, the longevity trait base and the environmental data. We also set up a certain number of standardized "tests" to evaluate the data used, in particular biological data. We will thus be able to propose a combined analysis of all or part of the data available on the "western waters" area.

For this interim report, in addition to a new analysis for certain sub-regions (Bay of Biscay), we also conducted analyses combining data from several regions (Bay of Biscay/Celtic Sea+north Iberian shelves). These preliminary combined analyses will be continued and refined in 2023 at the next working session of the group.

3.2.4.2.1 Workflow

Fishing pressure variables

Fishing pressure layers were available for the whole area. We used data from the ICES 2022 data call covering the period 2009 to 2021. The annual SAR (Surface Area Ratio) variable was aggregated on different time scales to obtain an integrated average value over 1 to 5 years prior to the year of the biological sampling station. These SAR variables were used to test the effects when modelling median longevity. The stations providing the reference state for the biological variables were also selected according to different levels of « low » SAR: : $\leq 1\ y^{-1}$ and $\leq 2\ y^{-1}$.

Environmental variables

The sources of the environmental dataset are those described in the 2021 WGFBIT report. Some derivatives of the initial environmental variables were also used for modelling (e.g. minimum, maximum value or standard deviation). On this basis, a selection of 5 major environmental variables was finally used to perform the analyses: depth, minimum of Chlorophyll, mean annual temperature, Substrate code (from EUNIS) and mean annual bottom current.

The sediment layer is based on the EUNIS substrate categories. This choice was driven by the lack of data at the scale of the study area, but these categories do not reflect quantitative values such as grain size and should therefore be considered with caution.

Longevity modelling

The work focused on the estimation of longevity curves from biological samples from marine surveys in the regions evaluated. Biological traits were based on the matrix of benthic taxa and longevity traits as constructed within various projects (e.g. BENTHIS) and expert groups. More than 1000 taxa were covered into the whole data matrix; the trait matrix was completed for some of these taxa using the longevity values assigned to the same genus or families. The species were not fully described in terms of longevity, but the biomasses covered were well over 80% of the total biomass for the case studies treated.

3.2.4.2.2 Bay of Biscay and Celtic Sea (ICES Divisions 8ab,7fghj)

The work conducted this year and presented in this report used similar data and followed the same analysis protocol as described in the 2021 WGFBIT report. Particular effort was put this year into understanding the variation in longevity estimates as a function of choice criteria including the variable describing fishing effort and the selection of biological data to define the reference longevity distribution (zero or low SAR).

The benthic invertebrates epifauna datasets used to model the longevity distribution are derived from bottom trawl catches made during the IBTS-Q4 EVHOE survey series (https://doi.org/10.18142/8). For the 2022 FBIT exercise, we used data from 2008 to 2018 and providing a total of 1457 sampled stations. The longevity trait database includes 344 taxa covering close to 90% of the species richness (total of 390 taxa) and 85% or more of the total biomass of the megabenthic epifauna of the Bay of Biscay and Celtic Sea.

Based on all the environmental data available in the study area, we selected 5 environmental variables (Depth, minimum chlorophyll, mean annual temperature, substrate code, bottom current) considered as major and presenting a relatively weak correlation between them (Figure 10).

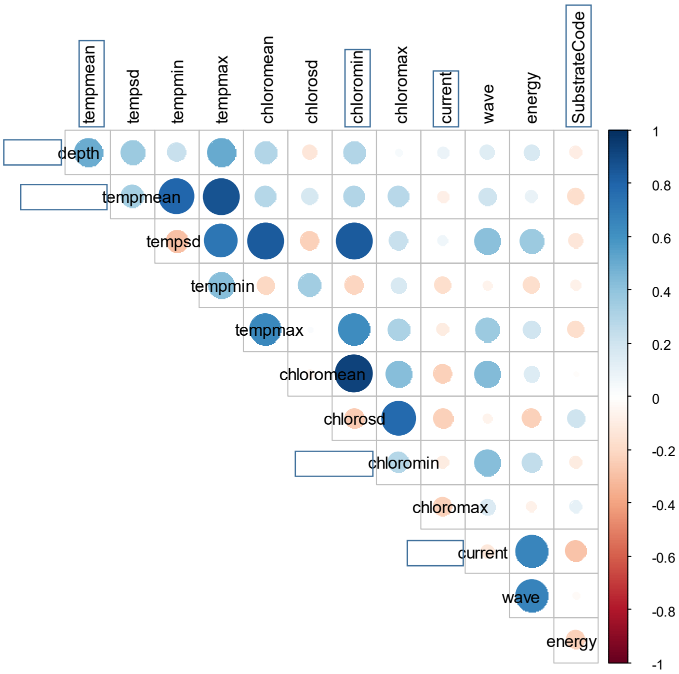


Figure 10. Correlation between the environmental variables available for the Bay of Biscay and Celtic Sea area (EVHOE survey). The 5 variables selected for the modelling exercise are highlighted: minimum of chlorophyll (chloromin), bottom current (current), mean annual temperature (tempmean), bathymetry (Depth) and substrate from EUNIS map (SubstrateCode).

Longevity models have been computed with the cumulative epifauna biomass (« Cumb ») as a function of longevity category (« ll », log+1 of longevity 1, 3 or 10 years) and summed with selected and rescaled environmental variables.

The modelling of the longevity was carried out on the basis of biological data filtered to retain only the stations with low fishing pressure. It was impossible for the analysed region to recover enough data corresponding to stations with zero trawling pressure. We therefore tested 2 filters for the selection of the SAR variable : $\leq 1\ y^{-1}$ and $\leq 2\ y^{-1}$. In addition, we tested different calculations of SAR as a 1 to 4 year average from the stations sampling year. Finally, some of the low or zero SAR values correspond to areas poorly covered by VMS data, especially by small vessels (<12m) that are relatively numerous in the coastal zone. To limit this effect, we also tested an additional filter on the fishing data by using depth as a proxy of the inshore area and only taking data deeper than 50m (“DepthFilter” in Table 9). The GLMM models of longevity distribution were carried out by testing all the combinations of selected environmental variables. The best retained model (9) was the one meeting the criterion of no "singularity" (i.e. no variance of one or more linear combinations of effects equal or close to zero) and having the lowest Akaike Information Criterion (AIC).

The number and nature of the models obtained out of the 31 possible combinations vary greatly according to the data selection criteria. The differences between AICs are sometimes small and the choice of this single criterion for selecting the "best longevity model" should certainly be reconsidered. 10 provides an example of the analysis process but the model retained should not be considered as the best possible choice.

Table 9 "Best" selected GLMM models* corresponding to minimal AIC for all the possible combinations of selected environmental variables (Depth, Chlorophyll, Temperature, Current and Substrate) and depending on selection of option for mean SAR computation (1 to 4 years), value considered as low/null fishing pressure limit (1 or 2y^{-1}) and spatial restriction or not for SAR data (DepthFilter: station deeper than -50m).

Fishing pressure (SAR)			Nb retained stations (tot =1457)	Models* retained		Environnemental variables (X: "Best model")				
SAR mean year(s)	Low SAR limit (y^{-1})	DepthFilter		Nb (tot.=31)	AIC ranges	Depth	Chloro	Temp	Current	Substrate
1	1	None	146	17	31.8-64.7	X	X	X	X	X
	2	None	384	4	53.2-65		X	X	X	X
	1	<-50m	126	-	-			NONE		
	2	<-50m	353	1	26.7	X		X		X
2	1	None	109	19	36.4-59.1		X	X		
	2	None	330	13	48-67.6		X	X	X	
	1	<-50m	91	2	20.6-23.6		X	X	X	
	2	<-50m	305	1	29.7	X			X	X
3	1	None	89	5	33.8-37.9	X	X	X		X
	2	None	270	4	36.1-42;2		X			
	1	<-50m	74	1	18.6			X	X	
	2	<-50m	247	3	21.9-24	X		X	X	
4	1	None	67	3	29.4-35.5		X			X
	2	None	220	1	35.3	X	X	X	X	X
	1	<-50m	55	2	19.5-19.8	X			X	X
	2	<-50m	203	3	22-23.5	X	X	X		

* **Complete model formula**: Cumb ~ ll + **Depth + Chloro + Temp + Current + Substrate** + (1 | Station)
with **Cumb**: cumulative biomass, **ll**: log+1 of longevity category (1,3 or 10 years) **Depth**: bathymetry, **Chl**: minimal annual chlorophyll concentration, **Temp**: mean annual temperature, **Current**: mean annual current velocity, **Substrate**: sediment type, **Station**: sampling station

Applied data filters lead in some cases to a very limited amount of data (*e.g.* not more than 55 stations retained with SAR average over 3 years, low SAR threshold ≤ 1 year^{-1} and area <-50m. Table 9). Moreover, it induced a biased spatial distribution and low coverage of benthic habitats that raises questions about the validity of the models of longevity distribution. The method could be adapted along the lines of what has been proposed in the Mediterranean (Gulf of Lion) by proposing modelling only for sufficiently sampled habitats or by introducing the SAR variable as an explanatory variable in the modelling and thus artificially recovering the longevity distributions for low or zero SAR values. Furthermore, the differences in AIC between the models selected are generally small. The sole criterion of prioritising the models by the minimum AIC can lead to results that are not robust, varying significantly according to the options and data chosen.

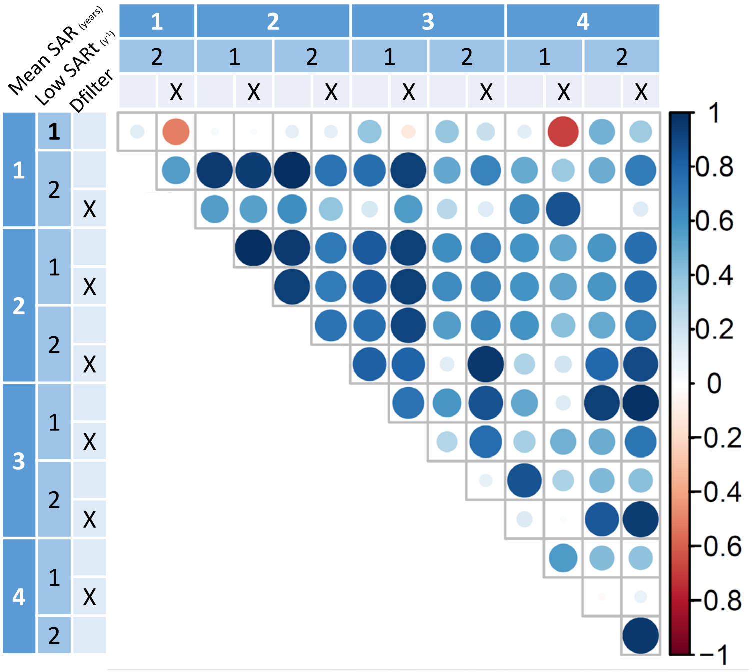


Figure 11. Correlations between median longevity values according to data selection criteria for modelling. Mean SAR (year): number of considered years for SAR average; Low SAR (y^{-1}): SAR value selected as low fishing pressure; DFilter: spatial restriction from depth limit <-50m (X).

The comparison of the resulting longevity distributions shows varying correlations depending on the different modelling options and data selections (Figure 11). Further analysis of these results is required, but the nature of the environmental variables selected for the "best model" or the stations retained logically play a role in the similarity between the longevity distributions. The median longevity maps thus show varying spatial distributions (Figure 12).

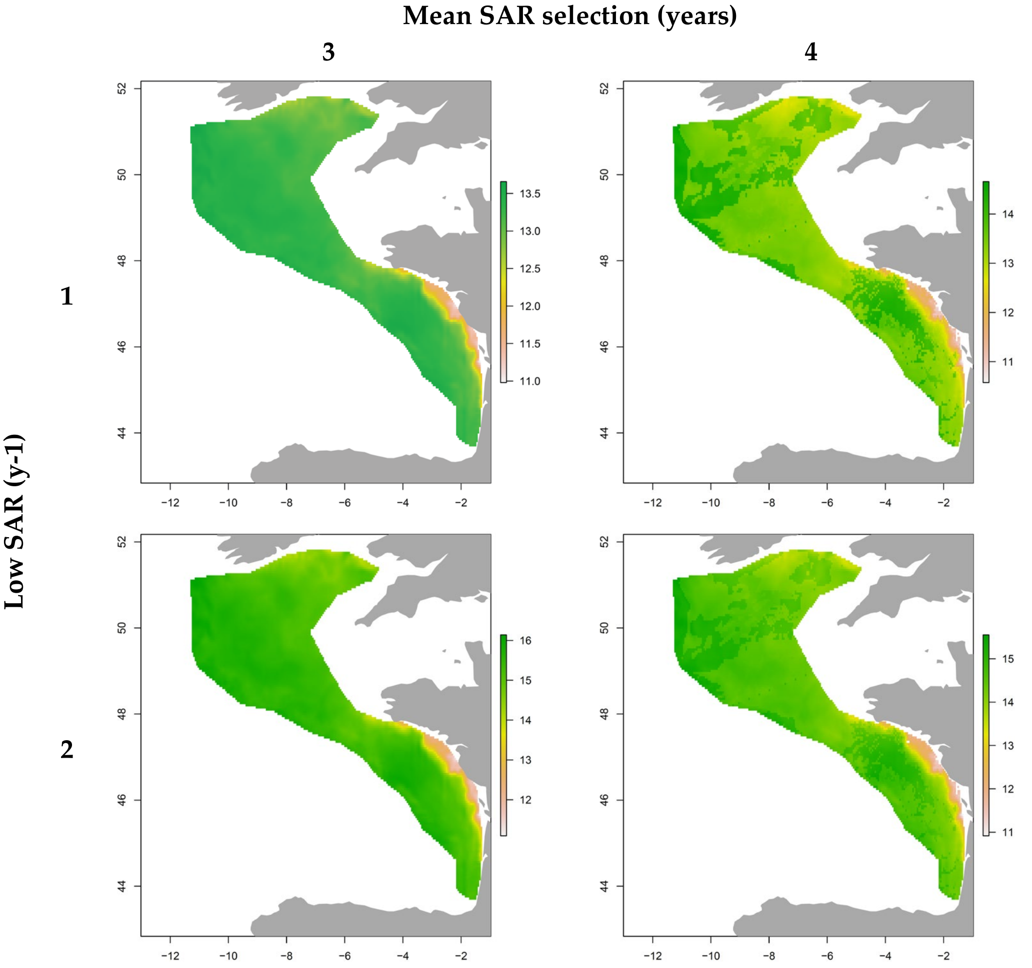


Figure 12. Examples of median longevity distribution (in years) according to data selection criteria for modelling: mean SAR average 3 or 4 years and Low SAR threshold 1 or 2y^{-1}.

The results presented here do not constitute a final and relevant assessment of the status of the benthic communities in the studied area. These results are preliminary and should only be understood as a demonstration of the applicability of the FBIT workflow to epifauna data for the Bay of Biscay/Celtic Sea areas.

3.2.4.2.3 Aggregated North Iberian, Biscay and Celtic areas

The datasets from the EVHOE and DEMERSALES surveys were combined to generate a joint estimate of median longevity at the scale of the North Iberian, Bay of Biscay and Celtic Sea region. The methodology is the same as that described in the Biscay/Celtic section. These data can be combined as long as the gears and the nature of the observations are relatively comparable. The interest of this combination of data is twofold: to increase the number of stations corresponding to a reference situation (low or zero SAR), and to cover a greater number of habitats or larger environ-mental gradients.

For this test, we only kept the stations corresponding to years common to both surveys. The selected data thus covered the period 2013 until 2018.

Here again, the results show a relatively low robustness of the evaluated models with relatively strong variations depending on the modelling options chosen (Table 10). While the main longevity gradients are maintained, some local inversions of longevity values can be observed depending on the modelling options chosen (e.g. North Iberian zone, Figure 12). Finally, the modelled longevity values should be treated with caution (highest median values below 5 years, Figure

12) and do not appear to be consistent with the initial longevity distributions of the megafauna. A review of the application of the method is to be considered for the next working session of the group.

Table 10. “Best” selected GLMM models* corresponding to minimal AIC for all the possible combinations of selected environmental variables (Depth, Chlorophyll, Temperature, Current and Substrate) and depending on selection of option for mean SAR computation (1 to 4 years), value considered as low/null fishing pressure limit (1 or 2y^{-1}) and spatial restriction or not for SAR data (DepthFilter: station deeper than -50m).

Fishing pressure (SAR)			Nb retained stations (tot =1560)	Models retained		Environnemental variables (X: “Best model”)				
SAR mean year(s)	Low sar limit (y^{-1})	DepthFilter		Nb (tot.=31)	AIC ranges	Depth	Chloro	Temp	Current	Substrate
1	1	None	199	6	256.4 – 295.7	X	X	X	X	
	2	None	466	12	570.3 – 683.9	X	X	X	X	X
	1	<-50m	181	2	210.6 – 233.3	X	X	X		X
	2	<-50m	438	9	489.6 – 613.9	X	X	X	X	X
2	1	None	175	11	236.6-274.7	X	X		X	X
	2	None	455	12	563.1 – 666.6	X	X	X	X	
	1	<-50m	157	3	192.9 – 207.7		X	X	X	X
	2	<-50m	430	11	506.1 – 611.7	X	X	X	X	X
3	1	None	170	10	239.7 – 265.7		X	X	X	X
	2	None	446	7	554.9 – 667.4	X	X	X	X	
	1	<-50m	151	2	199.7 – 203.5		X	X		X
	2	<-50m	419	3	470.9 – 529.9	X	X	X	X	X
4	1	None	166	13	228.6 – 259.4	X	X		X	X
	2	None	454	12	533.5 – 649.0	X	X	X	X	
	1	<-50m	147	2	185.6 – 195.7		X	X	X	X
	2	<-50m	428	9	466.9 – 558.1	X	X	X	X	

The different longevity estimation models generally provide highly correlated median longevity distribution maps (Figure 13, 14).

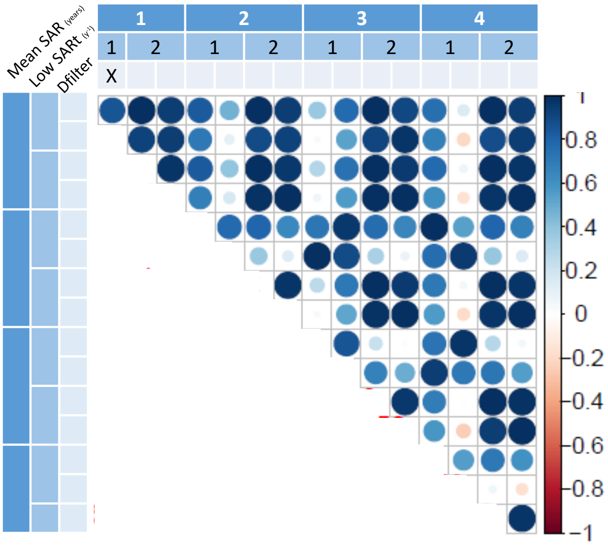


Figure 13. Correlations between median longevity values according to data selection criteria for modelling. Mean SAR (year): number of considered years for SAR average; Low SAR (y^{-1}): SAR value selected as low fishing pressure; DFilter : spatial restriction from depth limit <-50m (X).

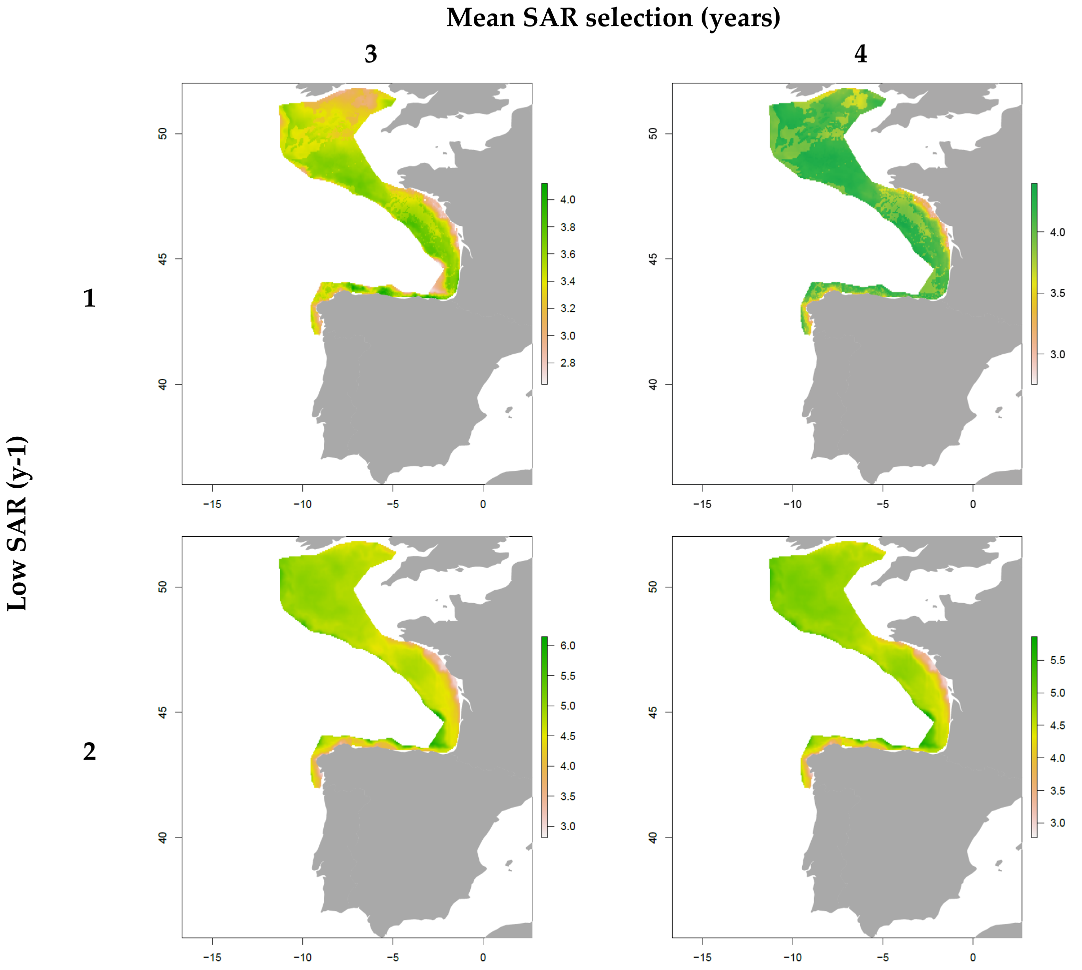


Figure 14. Examples of median longevity distribution (in years) according to data selection criteria for modelling: mean SAR average 3 or 4 years and Low SAR threshold 1 or 2y^{-1}.

These preliminary analyses have made it possible to significantly increase the number of stations corresponding to a reference situation for longevity modelling. The environmental gradient covered is also much wider and offers better possibilities in terms of modelling. The results of this combined analysis should be compared with the independent results for each of the sub-regions and the gains or risks inherent in this combination should be better explored.

3.2.4.3 Sensitivity layer based on benthic infauna in the Irish Sea, the Celtic Sea North and the Bristol Channel (ICES divisions 7afg)

3.2.4.3.1 Study area and data collation

The study area for this analysis was restricted to the ICES division 7.a (Irish Sea), 7.f (Celtic Sea North) and 7.g (Bristol Channel). Benthic infaunal samples were compiled from the database used for the UK EEZ assessment (see Section on UK EEZ). The samples were restricted to the data that can be shared publicly, implying that the survey Swallow Sands “CEND0218” was excluded from further analysis. Samples were also restricted to infauna biomass by retaining samples collected with grabs (Day grab, Hamon grab or Van Veen grab) with 0.1m^2 sampling area. Fuzzy-coded longevity classes were obtained from Clare *et al.* (2022). Environmental predictors were selected from publicly available datasets and included bathymetry (depth in m), mud and gravel percentage, EUNIS habitat and the median subsurface SAR over the sampling period (2009–2017).

The cumulative biomass—longevity relationship estimated by the null model of Rijnsdorp *et al.* (2018) for sample station *j* and longevity classes *L* with normally distributed random effects for sampling stations *j* (Eq. XYZ-1)

$$\ln\left(\frac{B_{ij}}{1-B_{ij}}\right) = \beta_0 + \beta_1 \ln(L_i) + \varepsilon_j \qquad \text{(Eq. XYZ-1)}$$

We followed Rijnsdorp et al (2018) and added a selection of environmental predictors to the null model using the glmer command from the lme4 package. The environmental predictors included

- scaled bathymetry (*'depth_m_scaled'*)
- sediment parameters taken from Wilson *et al.* (2018): scaled tidal energy, median grains size (d50) and the percentage of sediment taken from Wilson et al (2018). We used a maximum of two percentages (e.g. sand and mud) for any model equation.
- the log-transformed subsurface SAR or the log-transformed surface SAR
- MSFD habitat as categorical predictors

Correlation between environmental predictors is high between sand and mud percentages, as well as between mud percentages and fishing (log_subsar or log_sar). We excluded any interaction terms with *LL* and with MSFD habitats and tested a total of 1211 equations using the GLMMTMB formulation, because it outperforms glmer in terms of speed (Brooks *et al.* 2017). Model improvement using environmental predictors was comparing using the Akaike Information Criterion (AIC) (Table 9, Figure 15).

The null model explained the observed variation of the cumulative biomass distribution substantially (R^2=44.7%). The environmental predictors contributed only marginally to explaining the variation in the response (around 4%) following (Nakagawa & Schielzeth 2013). Environmental predictors are required to enable spatial predictions of sensitivity outside the sampled locations. Model selection was assisted by visual inspection of the proportional longevity distribution by sampled station (Figure 16). All but one of the top 10 models included fishing as a predictor. Visual exploration of the proportional longevity distribution by sampled station (from the pie charts) with the predicted median longevity provided a first, preliminary assessment of our confidence in the spatial assessment of median longevity (Figure 17).

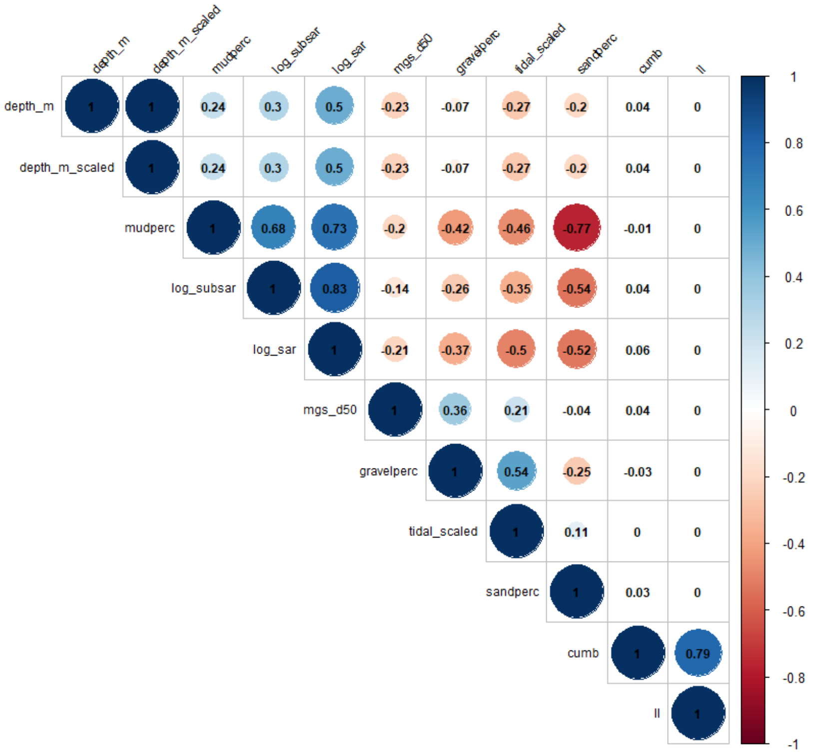


Figure 15. Correlation plot between environmental predictors (including the response variable).

Table 11. Top 10 GLMMTMB models have a difference of AIC <5

	Model formulations	AIC	Δ(AIC)	R²
	NULL MODEL (ll)	789.3	100.8	0.447
1	ll + log_sar * tidal_scaled + mgs_d50 * sandperc	688.5		0.492
2	gravelperc * mgs_d50 + ll + log_sar * tidal_scaled	689.5	1.0	0.490
3	ll + log_sar * mudperc + mgs_d50 * sandperc	690.2	1.8	0.489
4	gravelperc * sandperc + ll + log_sar * tidal_scaled	690.6	2.2	0.489
5	gravelperc * log_sar + ll + mgs_d50 * tidal_scaled	691.9	3.4	0.487
6	depth_m_scaled * gravelperc + ll + mgs_d50 * sandperc	692.2	3.8	0.487
7	ll + log_sar + mgs_d50 * sandperc + tidal_scaled	692.4	3.9	0.483
8	gravelperc * mgs_d50 + ll + log_sar * mudperc	692.8	4.3	0.486
9	ll + log_sar + mgs_d50 * sandperc	693.2	4.8	0.479
10	ll + log_subsar * mudperc + mgs_d50 * sandperc	693.3	4.8	0.485

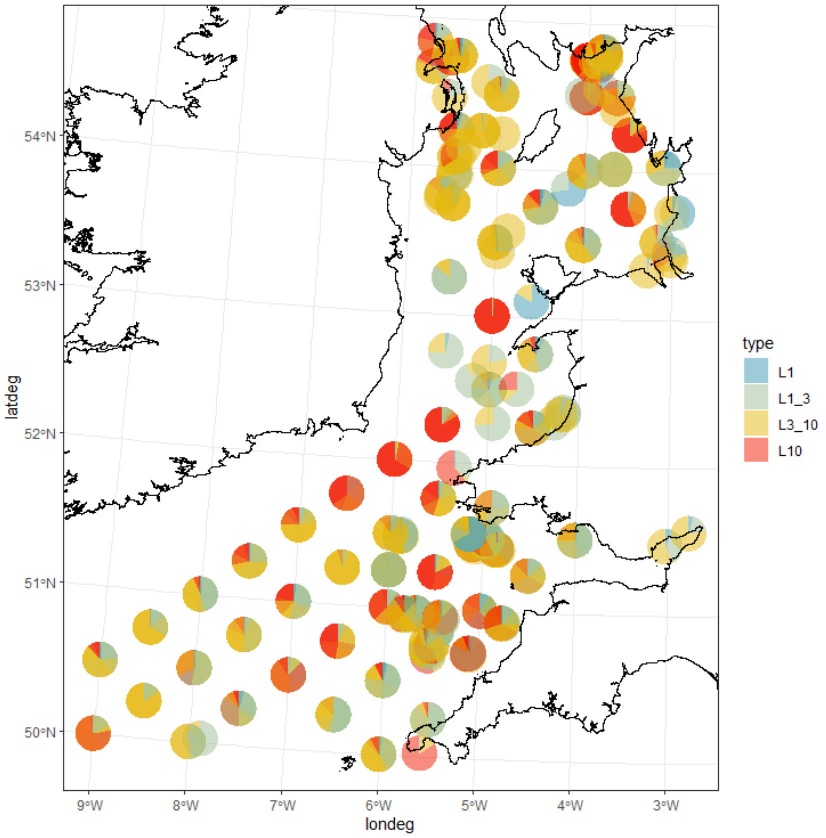


Figure 16. Proportional distribution of the longevity classes of infaunal biomasses across the Irish Sea, the Celtic Sea North and the Bristol Channel.

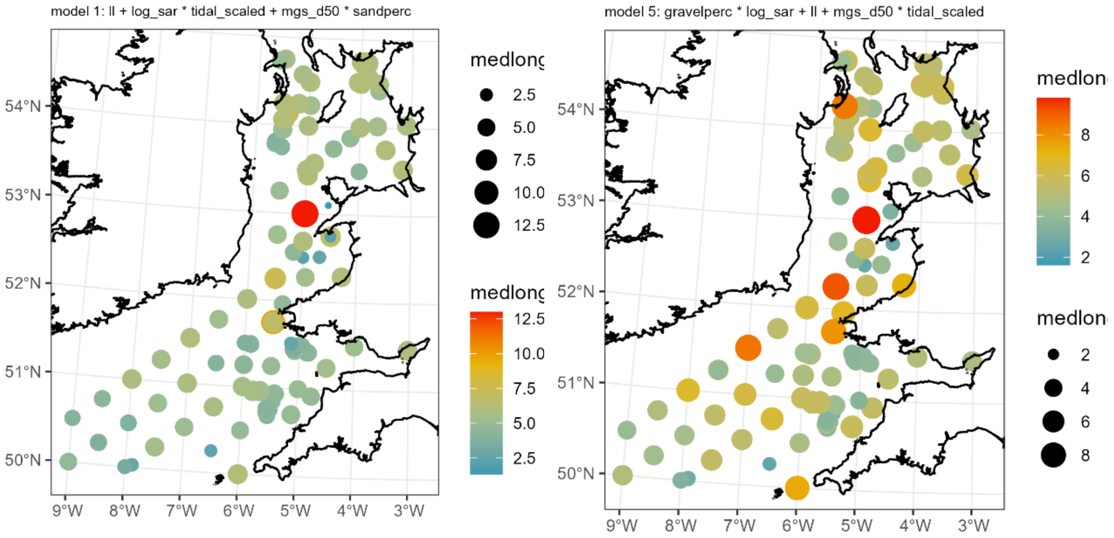


Figure 17. Maps of median longevity by sample for model 1 (left panel) and model 5 (right panel).

3.2.4.3.2 References

Brooks, M.E., Kristensen, K., van Benthem, K.J., Magnusson, A., Berg, C.W., Nielsen, A., Skaug, H.J., Machler, M. & Bolker, B.M. (2017) GLMMTMB Balances Speed and Flexibility Among Packages for Zero-inflated Generalized Linear Mixed Modeling. *R JOURNAL,* **9,** 378-400.

Clare, D.S., Bolam, S.G., McIlwaine, P.S.O., Garcia, C., Murray, J.M. & Eggleton, J.D. (2022) Biological traits of marine benthic invertebrates in Northwest Europe. *Scientific Data,* **9,** 339.

Nakagawa, S. & Schielzeth, H. (2013) A general and simple method for obtaining R2 from generalized linear mixed-effects models. *Methods in Ecology and Evolution,* **4,** 133-142.

Rijnsdorp, A.D., Bolam, S.G., Garcia, C., Hiddink, J.G., Hintzen, N.T., van Denderen, P.D. & van Kooten, T. (2018) Estimating sensitivity of seabed habitats to disturbance by bottom trawling based on the longevity of benthic fauna. *Ecological Applications,* **28,** 1302-1312.

Wilson, R.J., Speirs, D.C., Sabatino, A. & Heath, M.R. (2018) A synthetic map of the north-west European Shelf sedimentary environment for applications in marine science. *Earth Syst. Sci. Data,* **10,** 109-130.

3.2.5 Mediterranean Sea

3.2.5.1 Southern Adriatic Mediterranean

No updates have been made for this ecoregion.

3.2.5.2 Spanish Mediterranean

No updates have been made for this ecoregion.

3.2.5.3 French Mediterranean

Benthic data acquired during MEDITS (Jadaud, 2018), EPIBENGOL (Vaz, 2018) and NOURMED (Vaz, 2018) trawl surveys were used comprising of mega-epifaunal benthic invertebrate biomass (expressed in g km^{-2}). Only benthic invertebrates were considered and cephalopods were excluded. The benthic biomass data was assigned to the fuzzy coding longevity classification, on the lowest taxonomic level possible. After associating the benthic biomass data with longevity data, 91.5% of the taxa could be directly associated to longevity, the others needed to be associated at higher aggregated taxonomic levels.

France has updated SAR data in its Mediterranean EEZ from 2012 to 2020 including all fishery vessels operating in the area (George *et al.*, 2021). A first assessment carried out in 2021 (ICES, 2022) revealed that abrasion was dominated by bottom trawl and other gears such as dredge or beam trawl were negligible, therefore the total abrasion was used and considered resulting from only bottom trawling (Figure 18).

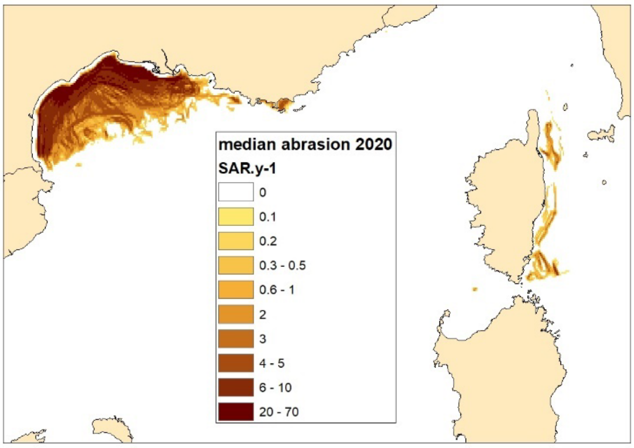


Figure 18. Median abrasion for all gears in GSA7 and 8 in 2020 (SAR, y^{-1}).

Biological observations were related to four SAR metrics based on 1) the previous year SAR value, 2) the 5 previous year average SAR value, 3) the 5 previous year maximum (or 90th percentile) value or 4) a weighted average of the 5 previous years, giving decreasing weight to years that are most distant in time. The 5 years period was chosen based on literature reporting that recovery was often observed over such duration following trawling impacts (Hiddink *et al.*, 2017). The approach (2) was used for the main assessment but the other metrics were also used to investigate the impact of this choice on the results. Depletion rate value was set to the usual 0.06 value in the following assessment steps.

In order to identify reference stations, a cut-off criterium of 0.5 is recommended as a rule of thumb, instead of 0.1 (ICES, 2022). However, in our data, using SAR<0.5 does not affect whether the habitats can be modelled by using the reference stations or by including abrasion as a predictor. Therefore, in order to best represent the pristine state stations, we decided to use the stricter criterium (SAR<0.1).

'Upper bathyal sediment or Lower bathyal sediment' and 'circalittoral sand' had enough reference stations while 'Circalittoral mud' and 'Offshore circalittoral mud' did not (Table 1). Figure 19 shows all the stations used in the biomass-longevity model, after both habitat and abrasion filtering.

Table 12. Number of stations per MSFD Broad Habitat type and year. Only habitats covered by a minimum of 5 stations per year were investigated. The number of reference stations (previous 5 year's average SAR value < 0.1) are shown between brackets. Habitats in grey indicate the habitats that were not included in the assessment. Habitat in pink did not have enough reference stations.

MSFD Broad Habitat type	2017	2018	2019
Circalittoral coarse sediment	3	5	5
Circalittoral mixed sediment	1	0	0
Circalittoral mud	12 (0)	75 (5)	76 (4)
Circalittoral sand	7 (3)	35 (17)	43 (22)
Infralittoral coarse sediment	0	0	1
Infralittoral sand	0	10	9
Offshore circalittoral mud	37 (1)	47 (0)	46 (0)
Offshore circalittoral sand	4	4	5
Upper bathyal sediment or Lower bathyal sediment	26 (18)	25 (15)	23 (14)

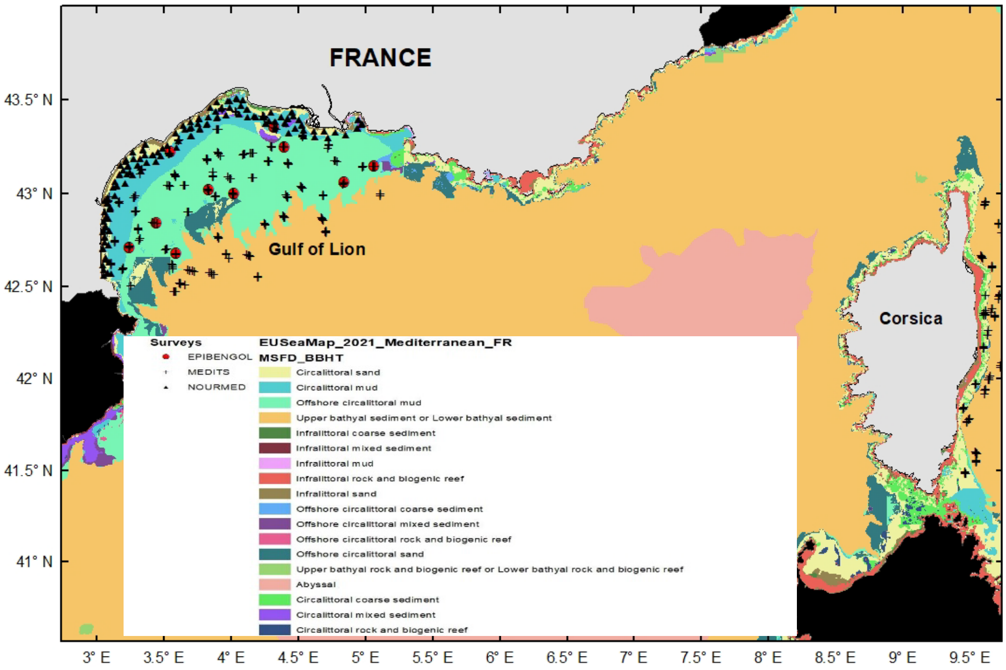


Figure 19. Map of the MFSD broad habitat types and observations used in the assessment after habitat and abrasion filtering.

Other environmental predictors were also available to account for habitat variability. Following an exploration of these predictors correlations at the biological observation locations, a subset was chosen that was sufficiently different to avoid model overfitting. These were depth, mean bottom temperature, sediment average grain size, seabed stress, mean chlorophyll-a, mean bottom oxygen concentration and stratification (Figure 20).

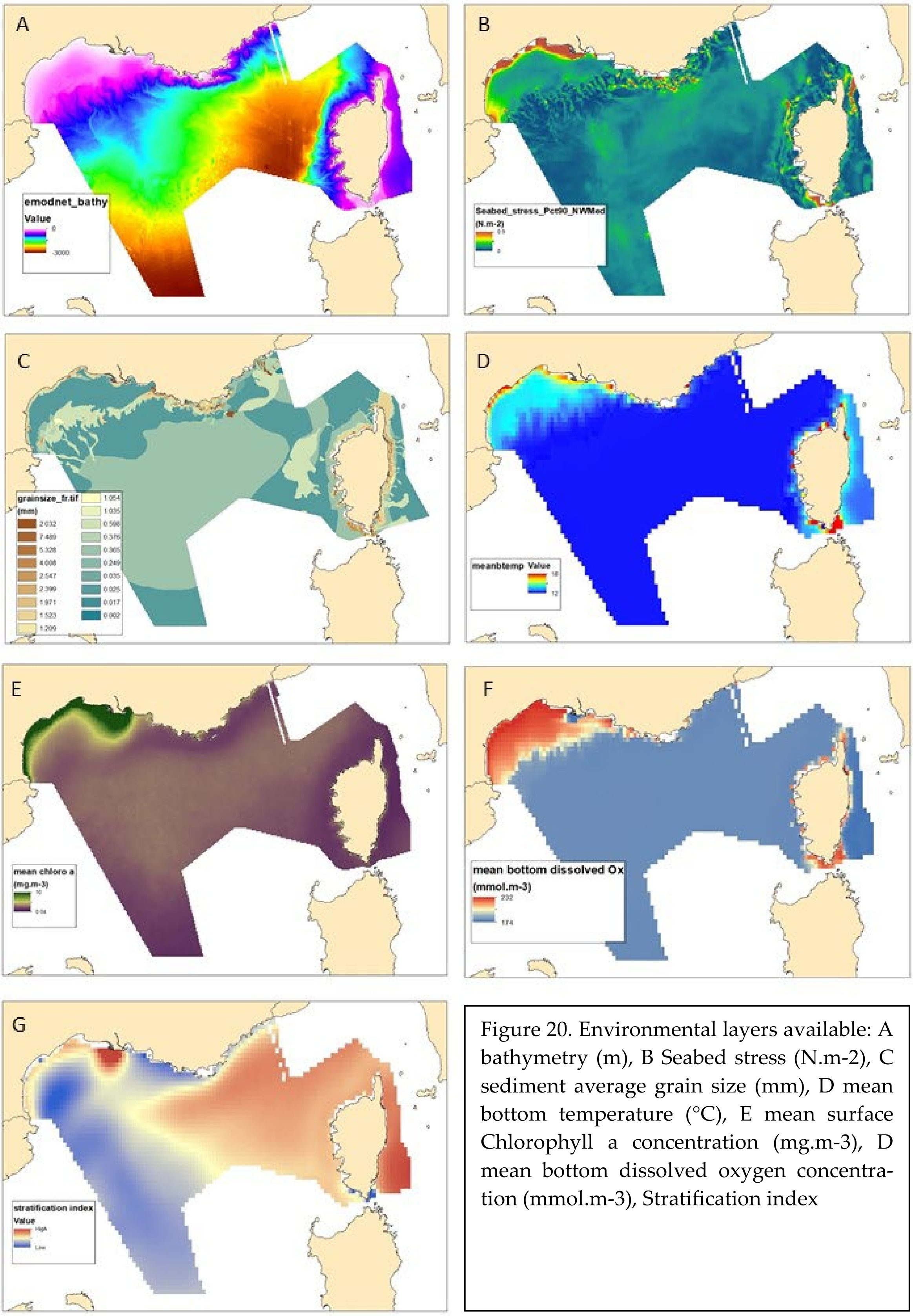


Figure 20. Environmental layers available: A bathymetry (m), B Seabed stress (N.m-2), C sediment average grain size (mm), D mean bottom temperature (°C), E mean surface Chlorophyll a concentration (mg.m-3), D mean bottom dissolved oxygen concentration (mmol.m-3), Stratification index

Generalized linear mixed model (GLMM) were fitted by habitat type to link the cumulated biomass to longevity, environmental predictors and abrasion where necessary. The dredge-function of the R-package MuMIn was used to evaluate all possible model formulations based on the Bayesian information criterium (BIC). This criterium was preferred over AIC (Aikake Information Criterion) as it is known to be more parsimonious and may better prevent model overfitting (Brewer *et al.*, 2016). For each habitat a distinct model was selected, relating the cumulative biomass to log-transformed longevity and environmental predictors (Table 13). It must be noted that the selected GLMM models did not differ largely in BIC with the next best models.

Table 13. Best model selection results per MSFD Broad Habitat type. Cumulative biomass is fitted as response variable with sample stations (ID) as random factor and log of longevity (ll) as fixed effect. meanBtemp = mean bottom temperature; ABR = abrasion estimate (SAR); stratif = stratification.

MSFD Broad Habitat type	Model selection	Number of observations*	BIC	Conditional R2
Circalittoral sand	~ ll + (1 ǀ ID) + meanBtemp	213	138.9	0.74
Upper bathyal sediment or Lower bathyal sediment	~ stratif + ll + (1 ǀ ID)	132	120.0	0.76
Circalittoral mud	~ ABR + ll + (1 ǀ ID)	258	498	0.80
Offshore circalittoral mud	~ ABR + ll + (1 ǀ ID)	480	360.8	0.63

*after omitting all rows containing NA’s

Bottom temperature in the warmest and shallowest waters (circalittoral sand) and stratification index in the deepest habitat (upper bathyal sediments) were selected instead of disturbance related variables such as seabed stress. This result is in line with those found by Jac *et al.* (2022) that revealed that in the French Mediterranean waters, environmental parameters linked to growth potential and resilience were more structuring and probably more limiting than in the Atlantic.

The intercept and coefficients obtained from the GLMM were used to predict median longevity at 50 % cumulated biomass per habitat type which were afterward combined into one map for the French Mediterranean (Figure 20). The prediction was limited to the French EEZ above 800m (deepest observation available).

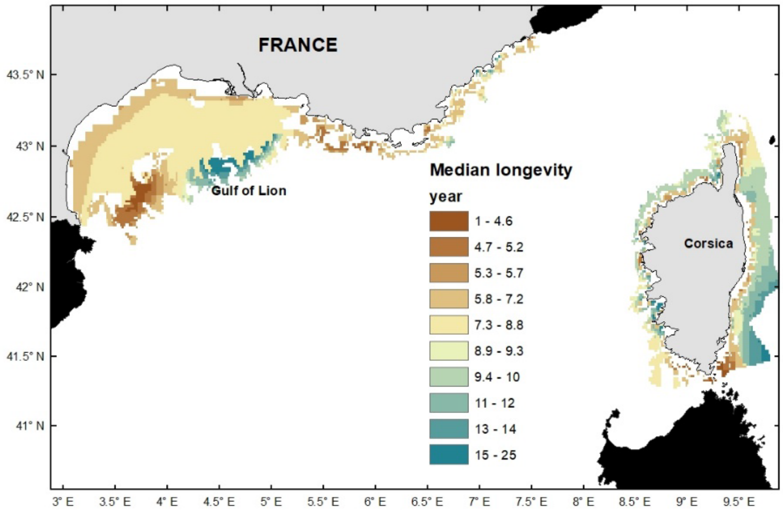


Figure 21. Predicted median longevity for French Mediterranean (Four habitats combined).

As a result, the predicted median longevity differs between the four habitats (Figure 22) Upper/lower bathyal sediment appeared to be the most sensitive to trawling disturbance with a median of 12.2 year in contrast to Circalittoral sand with a median of 5.6 years. Circalittoral mud and offshore circalittoral mud are predicted to be constant (as only abrasion entered the model) and to have respectively 6.2 and 8.8 years of median longevity.

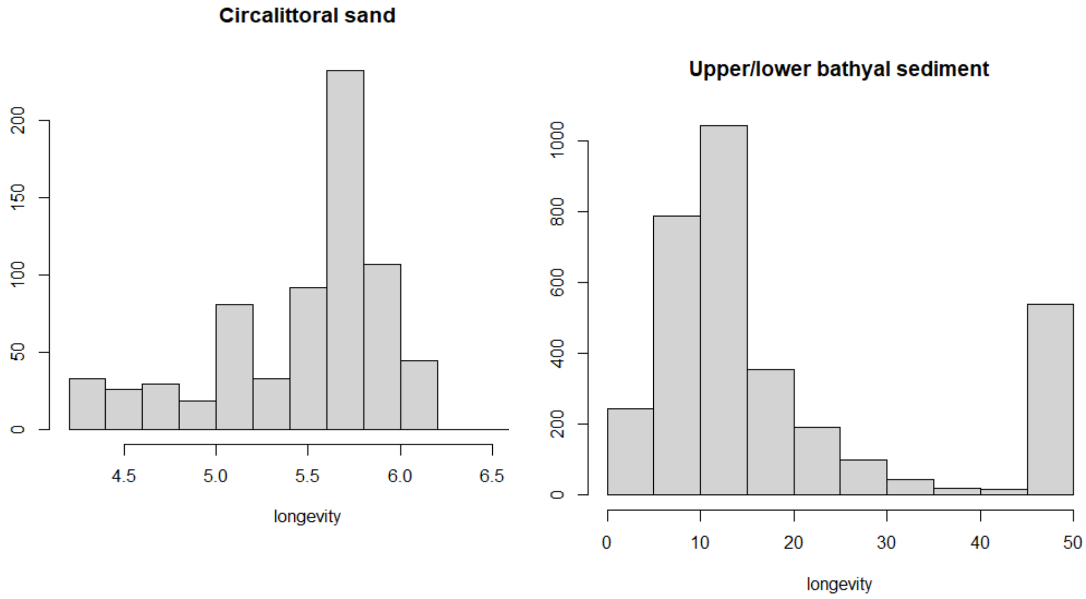


Figure 22. Distribution of median longevity in the investigated MSFD broad habitat types.

The distribution of the Relative Benthic State (RBS) indicator across the gulf of lion and Corsica was estimated per habitat base on the 2020 abrasion map and then combined into one map (Figure 23). The prediction was limited to the French EEZ above 800m (deepest observation available).

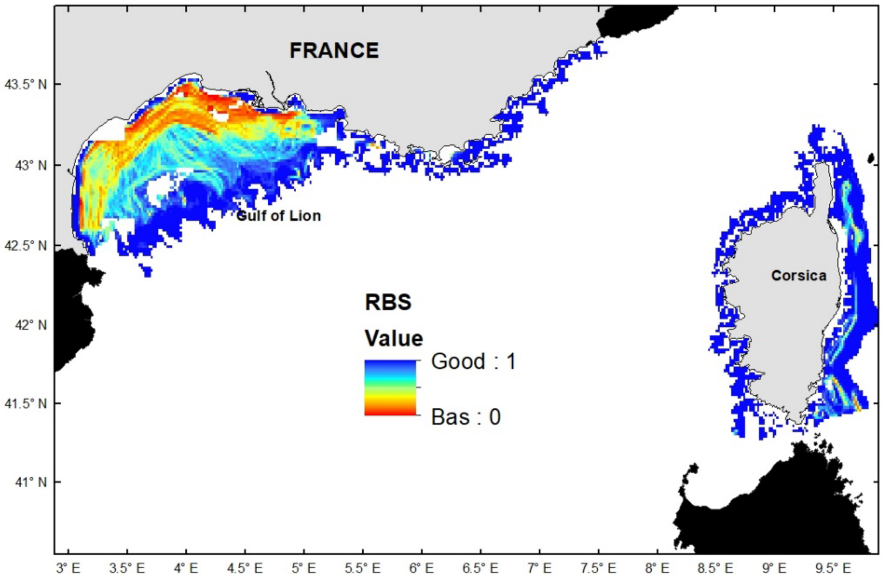


Figure 23. Relative Benthic State for the French Mediterranean (four habitats combined). The scale goes from 0 = bad state, to 1 = good state.

Based on our prediction, the gulf of Lion's seabed is in a worse state than that of Corsica. In the gulf of Lion, the state gets progressively worse when following a gradient towards the coastline. Upper/lower bathyal sediment is predicted to be in the best state. Jac *et al.*, (2022b) estimated the ecological state of the French Mediterranean seabed in respect to bottom fishery pressure. According to their study, all investigated habitats around Corsica were either in Good Environmental State (GES), or had suffered adverse effects. This is in line with our results that show an RBS close to one around Corsica. The gulf of lion on the other hand barely had any areas in GES and was mostly either in the categories 'adverse effects' or 'probably habitat loss' (Jac *et al.*, 2022b). The latter category was predicted for areas closer to the coast which coherent with our predicted RBS lowest values.

The negative correlation between our RBS prediction and the abrasion in 2020 (the year used for the RBS prediction) was very high, significant and almost constant over the four habitat types investigated (Table 14), highlighting how influent this variable is in this particular instance.

Table 14. Pearson correlation between RBS and 2020 abrasion. All values are significant ($p < 0.001$).

Broad Habitat type	Pearson correlation coefficient
Circalittoral sand	- 0.86
Upper/lower habythal sediment	- 0.99
Circalittoral mud	- 0.96
Offshore circalittoral mud	- 0.97

To determine the effects of the abrasion metric used on the assessment framework results, we reran the whole analysis, including model selection, with the other three abrasion metrics. The standard deviation between the four resulting sensitivity and RBS prediction maps were then computed and are presented in figures 24 and 25 respectively. The results show that large uncertainty levels, of up to 21 years, in estimated longevity are present in upper bathyal sediment and offshore circalittoral mud. It was however very low in circalittoral habitats. This did not result in high uncertainty in RBS which was generally low or moderate but could reach up to 31% in some areas.

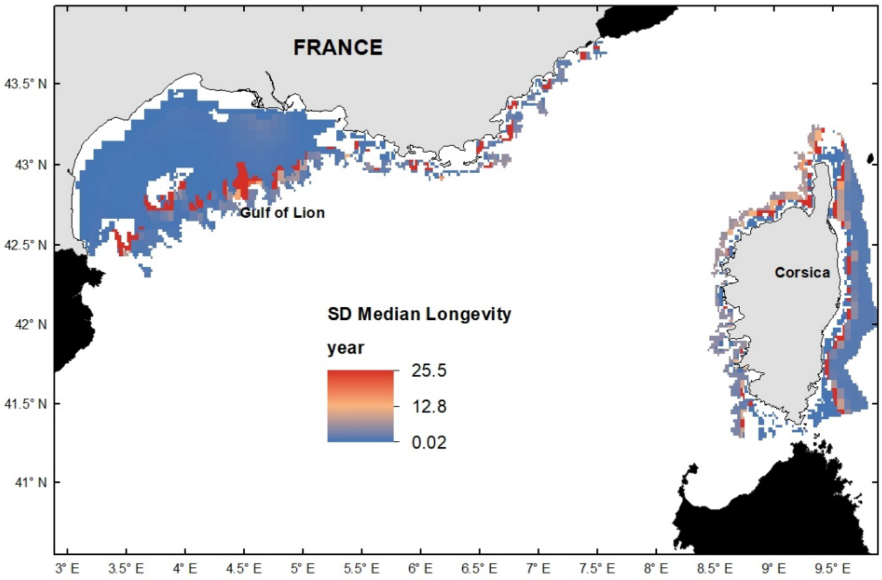


Figure 24. Standard deviation of the predicted median longevities based on four alternative abrasion metrics.

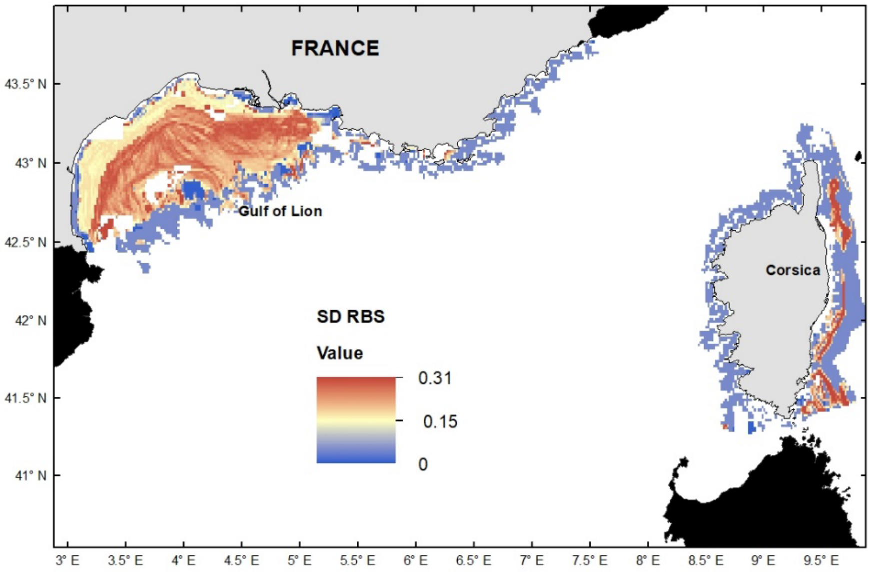


Figure 25. Standard deviation on the predicted RBS based on four alternative abrasion metrics.

Other biological traits than longevity may be used to compute sensitivity indices such as Trawl Disturbance related indices proposed by Jac *et al.*, (2022a). These were compared to the predicted median longevity and revealed moderate at regional scale and not always coherent relationships at the scale of each broad habitat types (Table 15). Since the median longevity of Circalittoral and offshore circalittoral mud habitats were constant, these could not be compared to the values obtained in this previous study.

Table 15. Pearson correlation values between median longevity and four indices used by Jac *et al.* (2020b) per habitat and for all habitats. All values are significant ($p < 0.001$).

Broad habitat type	TDI	mTDI	pTDI	mT
All habitats	0.29	0.33	0.31	-0.33
Circalittoral sand	0.84	0.85	0.89	-0.80
Upper/lower habythal sediment	-0.16	-0.46	-0.29	0.50

Based on these indices, Jac *et al.* (2020b) identified abrasion thresholds by habitat and defined benthic status as a result of this reclassification (Figure 26).

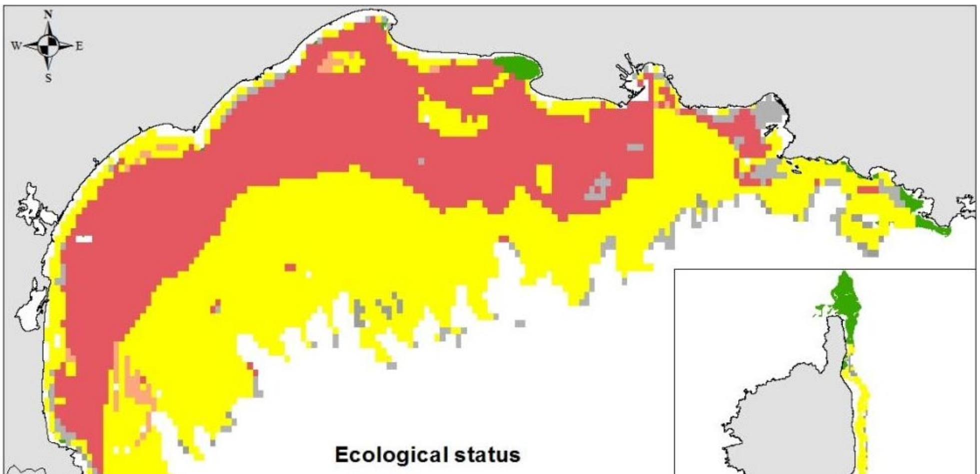


Figure 26. Ecological status of benthic habitats in the French Mediterranean Sea (Jac *et al.*, 2020b).

The range of the RBS status obtained in the present study were studied within each status class obtained in the Gulf of Lion and in Corsica in this former study (Tables 16 and 17). The average RBS value seems to generally decrease with deteriorating status in the Gulf of Lion with the exception of circalittoral mud where a reversed trend could be observed. The pattern was similar for most habitat in Corsica but for Upper/lower bathyal sediment where it was reverse again.

Table 16. Mean RBS value (and minimum- maximum range) per Jac *et al.* (2020b) predicted status per habitat type in the Gulf of Lion.

Broad habitat type	**adverse effects**	**adverse effects or possible habitat loss**	**probably habitat loss**
Circalittoral sand	0.071 (0 - 0.999)	0.043 (0 - 0.632)	0.003 (0 - 0.999)
Upper/lower bathyal sediment	0.029 (0 - 0.999)	0 (0 - 0)	0.002 (0 - 0.854)
Circalittoral mud	0.024 (0 - 0.999)	0.072 (0 - 0.773	0.1465 (0 - 0.999)
Offshore circalittoral mud	0.613 (0 - 0.999)	0.289 (0 - 0.849)	0.234 (0 - 0.999)

Table 17. Mean RBS value (and minimum- maximum range) per Jac *et al.* (2020b) predicted status per habitat type in Corsica.

Broad habitat type	GES	adverse effects
Circalittoral sand	0.688 (0 - 0.999)	0.675 (0 - 0.999)
Upper/lower bathyal sediment	0.149 (0 - 0.999)	0.204 (0 - 0.999)
Circalittoral mud	0.057 (0 - 0.999)	0.029 (0 - 0.999)
Offshore circalittoral mud	0.105 (0 - 0.999)	0.0172 (0 - 0.999)

GES: Good Environmental Status relative to abrasion

Based on these preliminary results, it may not possible to distinguish a possible RBS threshold that would separate GES from adverse effects as defined in Jac *et al.* 2020b. A next step in the development of this assessment would be to identify thresholds based on the RBS prediction in reference areas and contrast them with those in impacted areas. However, the very high correlation between RBS and abrasion indicate that it might be equivalent to setting pressure threshold directly.

References

Brewer, M.J., Butler, A. and Cooksley, S.L. (2016). The relative performance of AIC, AICC and BIC in the presence of unobserved heterogeneity. Methods Ecol Evol, 7, 679-692. https://doi.org/10.1111/2041-210X.12541

Cuyvers Daan, Vaz Sandrine (2023). Seabed sensitivity to bottom trawling in the French Mediterranean. Application of ICES WGFBIT assessment framework. RBE/MARBEC/LHM. https://doi.org/10.13155/92506

Georges, V., Begot, E., Duchene, J., Fabri, M.-C., Laffargue, P., Leblond, E., Rodriguez, J., Vaz, S., Woillez, M., & Menot, L. (2021). Développement d'un indicateur d'abrasion des fonds marins par les arts de pêche trainants pour l'évaluation du bon état écologique des habitats benthiques. Ifremer. https://doi.org/10.13155/85532

Hiddink, J. G., Jennings, S., Sciberras, M., Szostek, C. L., Hughes, K. M., Ellis, N., Rijnsdorp, A. D., McConnaughey, R. A., Mazor, T., Hilborn, R., Collie, J. S., Pitcher, C. R., Amoroso, R. O., Parma, A. M., Suuronen, P., & Kaiser, M. J. (2017). Global analysis of depletion and recovery of seabed biota after bottom trawling disturbance. Proceedings of the National Academy of Sciences, 114(31), 8301–8306. https://doi.org/10.1073/pnas.1618858114

ICES. (2022). Working Group on Fisheries Benthic Impact and Trade-offs (WGFBIT). https://doi.org/10.17895/ICES.PUB.10042

Jac C., Desroy N., Certain G., Foveau A., Labrune C., Vaz S. (2020a). Detecting adverse effect on seabed integrity. Part 1: Generic sensitivity indices to measure the effect of trawling on benthic mega-epifauna . Ecological Indicators , 117, 106631 (14p.) https://doi.org/10.1016/j.ecolind.2020.10663

Jac C., Desroy N., Certain G., Foveau A., Labrune C., Vaz S. (2020b). Detecting adverse effect on seabed integrity. Part 2: How much of seabed habitats are left in good environmental status by fisheries? Ecological Indicators , 117, 106617 (13p.) https://doi.org/10.1016/j.ecolind.2020.106617

Jac C., Desroy N., Foveau A., Vaz S (2022). Disentangling trawling impact from natural variability on benthic communities . Continental Shelf Research , 247, 104828 (17p.) . https://doi.org/10.1016/j.csr.2022.104828

Jadaud, A., Certain, G. (1994). MEDITS, https://doi.org/10.18142/7

Vaz, S. (2018) EPIBENGOL 2018 cruise. RV L'Europe. https://doi.org/10.17600/18000589

Vaz, S. (2018) NOURMED, https://doi.org/10.18142/296

3.2.6 Black Sea

No updates have been made for this ecoregion.

3.2.7 North Sea

No updates have been made for this ecoregion.

3.2.8 Baltic Sea

The Baltic Sea seafloor assessment now excludes areas with low oxygen levels following the WGFBIT recommendation from 2021: "*The group recommends to map areas with seasonal oxygen concentrations <0.5 ml* O_2 *per liter as a separate habitat, as any concentration below that threshold generates mass mortality in benthos.*".

Seasonal minimum bottom oxygen concentrations per grid cell were obtained from Schernewski *et al.* (2015) – for further information see van Denderen *et al.* (2019).

3.3 Validation

3.3.1 Complementarity of benthic indicators methods to assess benthic status: comparative assessment in the Adriatic Sea (GSA17)

The biological data and environmental layers reported in Table 7 for Assessment 2 were also used to test different indicators approaches and assess the impact of trawling on seafloor integrity.

A comparative analysis between nine diverse ecological indicators was carried out in the context of the Central and Northern Adriatic Sea (GSA17) considering biomass and abundance indexes, Shannon index, Margalef index, Evenness, TDI, mTDI, pTDI, and mT. Epibenthic data from SoleMON trawl survey and GAP2 were used for this purpose (see Table 7, assessment 2 model). A species-traits matrix was defined based on a set of five biological traits (size, benthic position, mobility, fragility, and feeding mode). Five different statistical tests were conducted to evaluate each indicator’s performance to assess the trawling impacts on the benthic community (Spearman correlation test; Redundancy Analysis (RDA); Spatial correlation test; Skewness and Kurtosis); the pressure layer, expressed as Swept Area Ratio (SAR), was evaluated over a period of 5 years (from 2012 to 2016). Following the methodological procedure proposed by Cyrielle *et al.* (2020), a score was assigned for each index for each statistical analysis. According to the total score, the results highlight that the sensitivity indexes (TDI- based), followed by biomass and abundance indices, achieved a higher score than the diversity indices. The TDIs indices perform well in response to trawling as they negatively correlate with trawling effort (Figure 27). This result is inconsistent with the outcomes of WKBENTH3, which reported the TDIs indices to be not sensitive to fishing effort in the given assessments, and will be further investigated also considering possible links/correlation with environmental gradients.

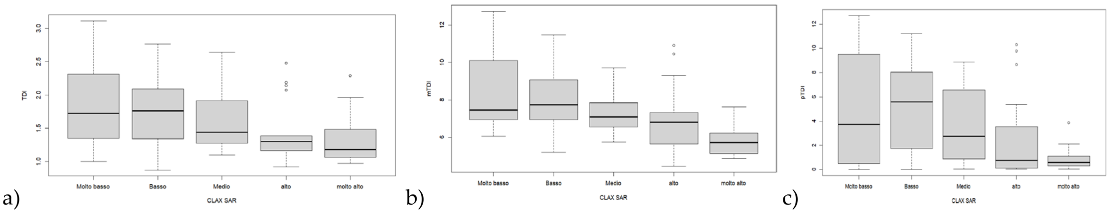


Figure 27. Index distribution across 5 abrasion classes. a) TDI; b) pTDI; c) mTDI.

A second assessment approach was applied based using the BESITO index, implemented according to Gonzàlez-Irusta *et al.* (2018). Eight biological traits were considered (size, mobility, benthic position, attachment, flexibility, fragility, longevity, and feeding mode); species were divided into five sensitivity groups according to the BESITO scores. A statistical model was also implemented to estimate each sensitivity group's relative biomass at different fishing effort levels (SAR), considering other environmental variables like primary production, depth, sample position, broad habitat type, and year. The results show a good performance, particularly for the less and the most sensitive groups, with a high percentage of total deviance explained by each GAM. The trawling intensity, like depth and latitude, was a significant variable in estimating the relative biomass of each group. The outputs’ models confirm the biomass distribution trend discovered by experimental data: the less sensitive species tend to increase in response to trawling. At the same time, the most sensitive species decreased strongly also at low levels of pressure. The more tolerant species tend to increase at the beginning, and then they are negatively affected at a higher level of trawling effort. The analyses highlight an alteration of the epibenthic community's structure and composition in the Adriatic Sea, with higher consequences for more long-lived and sensitive species. However, in the study area, given the high levels of trawling effort established in the area since several decades, the effects of trawling might be underestimated because they are affected by “shifting baselines”, given the lack of pristine sites/data. Further analyses and tests need to be done to better assess the effects of trawling on benthic communities in this area using more updated data.

References

Jac, C., Desroy, N., Certain, G., Foveau, A., Labrune, C., and Vaz, S. (2020a) Detecting adverse effect on seabed integrity. Part 1: Generic sensitivity indices to measure the effect of trawling on benthic mega-epifauna. *Ecological Indicators*, 117: 106631. https://doi.org/10.1016/j.ecolind.2020.106631

Gonzalez-Irusta, J.M., De la Torriente, A., Punzón A., Blanco, M, Serrano, A. (2018). Determining and mapping species sensitivity to trawling impacts: the BEnthos Sensitivity Index to Trawling Operations (BESITO). *ICES Journal of Marine Science*, 75(5): 1710-1721, https://doi.org/10.1093/icesjms/fsy030

Riva G. (2022). Applicazione e confronto di indici per la valutazione degli impatti della pesca a strascico demersale sulle comunità epi-bentoniche dell'Adriatico. Tesi di laurea magistrale, Università degli Studi di Padova

Russo, T., Morello, E.B., Parisi, A., Scarcella, G., Angelini, S., Labanchi, L., Martinelli, M., D'Andrea, L., Santojanni, A., Arneri, E., and Cataudella, S. (2018) A model combining landings and VMS data to estimate landings by fishing ground and harbor. Fisheries Research, 199: 218-230. https://doi.org/10.1016/j.fishres.2017.11.002

4 Updates of assessment framework (ToR B)

4.1 Overview of the methodologies used within the assessment framework: some standardisation

The WGFBIT approach is applied in all (sub-)regions, so we have an European wide assessment of fishery benthic impact. To accomplish this, the methodologies used in the different steps of the FBIT approach are slightly different among those regions (Table 1 & 2), related to variation in data availability, environmental characteristics and implementation possibilities among the (sub-)regions. Nevertheless, there will be strived to standardize some of the elements in the FBIT approach (where possible), step by step. This to have a more harmonized assessment of fishery benthic impact across the EU regions in the coming years. In this section, an overview is given on the current methodologies used and evaluated what standardisation is needed or can be done. This can be taken forward when updating the FBIT assessments.

4.1.1 Biological data

The inclusion/exclusion of certain fauna groups in the trawl or grab samples used for the longevity predictions shall play a role in the assessment outcomes, so some guidance is needed. Each equipment has a certain catch efficiency for certain fauna groups or in certain datasets not all taxa are taken into account (e.g. Hydrozoa or Bryozoa in grab sampling; Polychaeta in trawl samples) or determined to the lowest taxonomical level possible. Therefore, a common set of fauna groups should be used within the region (among subregional assessments) or even across regions (if possible) when using trawl or grab samples. This aspect is currently not clearly tackled in the FBIT assessments, except the advice to remove commercial species and cephalopods from trawl sample data (ICES FBIT report, 2021). An overview of excluded fauna groups in the (sub-)regional assessment is given in Table 18.

Table 18. Overview of the fauna groups included or excluded for the assessment.

	Type of data	Fauna included/Excluded
Greece	Grab	Bigger fauna (X>biomass) out.
South Adriatic	Trawl	Not yet defined/reported
North/Central Adriatic	Trawl	Exclusion of commercial species, pelagic, high mobility species (fish) and cephalopods
Sicily	Trawl	Not yet defined/reported
French Med.	Trawl	Exclusion of vertebrates, cephalopods and pelagic invertebrates
Iberian Coast	Trawl	Benthic taxa were restricted to Arthropoda, Mollusca, Echinodermata, Annelida, Cnidaria, Porifera, Platyhelminthes, Sipuncula, Priapulida, Nemertea, Acanthocephala
Bay of Biscay/Celtic Sea	Trawl	Exclusion of vertebrates, highly mobile cephalopods and gelatinous species
Celtic Sea/Irish Sea	Grab	Not yet defined/reported

North Sea	Grab/core	All fauna included from grab/core. Part of the data was converted from ash free dry weight to wet weight to make a more similar comparison of longevity between locations with wet weight and ash free dry weight observations.
Baltic Sea	Grab/core	All fauna included that were collated in Gogina *et al.* (https://doi.org/10.1093/icesjms/fsv265)
Islandic waters	Trawl	Not yet defined/reported
Norwegian Shelf	Video	Not yet defined/reported
Barentz Sea	Trawl	Not yet defined/reported

4.1.2 Trait dataset used

The longevity information per species is coming from different sources, also partially adapted over time. Therefore, we tried to summarize the data sources used for the trait data in the 19.

Table 19. Overview of the sources used for the trait data (longevity).

	Type of data	Source of trait data
Greece	Grab	HCMR trait database
South Adriatic	Trawl	Biological traits for SOLEMON and GAP2
North/Central Adriatic	Trawl	HCMR trait database
Sicily	Trawl	Benthis database (Bolam)
French Med.	Trawl	Merged longevity database (see below for details)
Iberian Coast	Trawl	Benthis plus some extra from a Spanish database when missing
Bay of Biscay/Celtic Sea	Trawl	Merge longevity trait data from Bolam, Beauchard and additional local additions
Celtic Sea/Irish Sea	Grab	Clare *et al.* (2022)
North Sea	Grab/core	Longevity trait data as compiled by Bolam *et al.* (2014).
Baltic Sea	Grab/core	Longevity trait data as compiled by Bolam *et al.* (2014) and Tornroos & Bonsdorff (2012). The trait data is available here: https://github.com/Dvandenderen/Baltic-benthic-status/tree/master/Benthic%20trait%20data
Islandic waters	Trawl	Existing longevity databases (Degen and Faulwetter 2019, the trait list from the BENTHIS project) and on expert judgment (ICES 2020).
Norwegian Shelf	Video	Existing longevity databases (Degen and Faulwetter 2019, the trait list from the BENTHIS project) and on expert judgment (ICES 2020).
Barents Sea	Trawl	Existing longevity databases (Degen and Faulwetter 2019, the trait list from the BENTHIS project) and on expert judgment (ICES 2020).

Merged longevity database

Collating available Mediterranean and Atlantic longevity databases, a common database based on fuzzy coding of longevity classes was developed to be associated to the benthic biomass data. Seven longevity databases were available (Table 20) that were first standardised then merged by averaging.

Table 20. Available databases for collating longevity.

Name	Number of taxa	Data source	Methods used for longevity estimates	Reference area
BTA_EMODNET_LifeSpan-OBeauchard	616	Unknown	Unknown	Atlantic
full_list	323	Italian National monitoring programme - Medits	Expert judgment; SIBM ISPRA Experts Literature	Italian coasts
Lista delle specie con score_	323	Medits survey 2015-19	Expert judgment; SIBM ISPRA ICES experts literature	GSA 18
longevity data	219	Solemon Rapido Trawl survey 2014-16 and GAP 2 epibentic data	Expert judgment; SIBM ISPRA experts literature	GSA 17 Italian Northern Central Adriatic Sea
LongevityDatabaseMega&Macrofauna241121	164 (mega) + 889 (macro)	HCMR	Allocations by fraction fuzzy logic , Other databases Literature Expert Judgement	GSA 20, 22, 23 Greek waters: Aegean Sea, Cretan Sea, Eastern Ionian Sea
Cefas traits data from Clare et al 2022	1025	CEFAS database	Clare et al 2022	Atlantic
Glandiceps talaboti	1	WGFBIT22	expert judgment Chris Smith	Mediterranean

The general procedure consisted of uploading the taxon lists in WORMS to match them to their accepted scientific names and AphiaID (WoRMS Editorial Board, 2022). Second, the longevity classes were transformed into four classes: <1, 1–3, 3–10 and >10 years and fuzzy coded so that the longevity classes always summed at one. The result of the final dataset merging is one dataset containing the fuzzy coded average longevity (and standard deviation) for 2264 taxa and for each, the number of databases used. A sample of this database is given below (Table 21).

Table 21. Subset of collated longevity database. Per taxon, the longevity is fuzzy coded and standard deviations are given. Freq. gives the number of databases available for each taxon.

taxon	mean L1	mean L1.L3	mean L3.L10	mean L10	sd L1	sd L1.L3	sd L3.L10	sd L10	freq
Abyssoninoe	0.00	0.50	0.50	0.00	0.00	0.00	0.00	0.00	3.00
Acanthocardia	0.00	0.16	0.18	0.66	0.00	0.35	0.34	0.48	8.00
Adamsia palliata	0.00	0.08	0.68	0.25	0.00	0.15	0.47	0.50	4.00
Aeolidia	0.00	0.50	0.50	0.00	0.00	0.71	0.71	0.00	2.00
Aequipecten	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	4.00

This database as well as the original datasets and the R script used were made available on the group sharepoint (WGFBIT/2022 Meeting Docs/06. Data/TorA_data files/FR_MED_merged_longevity_v2.zip). Specifically, the database may be found in the "output" folder in the "longevityfull.csv" file.

4.1.3 Fishery data

The determination of the longevity curve should be based on data from reference stations, meaning locations which are not or little subjected to fishery disturbance in the last 3–5 years (more guidance in ICES FBIT REPORT 2020; Bolam *et al.*, 2017). It is possible to use both samples from untrawled (i.e. a zero fishing pressure estimate) locations and locations with low trawling intensity. In Bolam *et al.*, (2017), they found that for the more sensitive shelf habitats locations with trawling intensities up to 0.1 per year could be used for estimating the reference state, whereas locations with even higher fishing intensities could be included in areas less sensitive. If you have not enough reference stations, another solution is to include SAR (fishery pressure) into the longevity model. The advantage of using the latter is that you can use all your data. The availability of appropriate reference locations for the regional assessments seems not that straightforward, so several options were tested and/or applied, by using SAR threshold values of 0,1; 0,5 or 1. An overview is given in Table 22.

Table 22. Used SAR definition for selecting reference stations (overview of current practices). X = used method; x = tested approach.

	Type of data	SAR 0,1	SAR 0,5	SAR 1	SAR in model	Concluding remark
Greece	Grab	X	x	x		SAR levels tested to see the effect on availability for data for different MSFD habitats. However 0.1 chosen as it the least impacting (1 coverage every 10 years)
South Adriatic	Trawl	To be tested	x			
North/Central Adriatic	Trawl			To be tested	x	
Sicily	Trawl				X	
French Med.	Trawl	X	x		X	
Iberian Coast	Trawl		X			
Bay of Biscay/Celtic Sea	Trawl			x		
Celtic Sea/Irish Sea	Grab				X	Log-SAR (surface or subsurface SAR)
North Sea	Grab				X	Both surface and subsurface abrasion were tested in the model. Subsurface abrasion was selected based on AIC. Longevity responded as predicted to increasing levels of subsurface abrasion.
Baltic Sea	Grab	x				Bottom fishing intensity is low in the Baltic Sea. Up to 1558 locations could be identified with intensity levels <0.1 (average SAR based on ICES data 2012–2016). Stations with bottom oxygen concentrations <3.2 ml per liter were also excluded in the estimation of longevity.
Islandic waters	Trawl					No selection yet of “untrawled” locations, or SAR included in the model.
Norwegian Shelf	Video					Model detail not reported yet
Barentz Sea	Trawl					Model detail not reported yet

4.1.4 Environmental drivers / models

The biomass-longevity distribution of untrawled communities need to be estimated in relation to environmental variables (i.e. the reference state). This will require samples of benthic communities over the main environmental gradients. A statistical model is used to estimate a biomass-longevity distribution. The model used is a logistic mixed effect model with the cumulative biomass proportions (*Cb*) as the response variable and longevity (*l*) and environmental conditions (*H*) as the predictor variables.

$$Cb \sim \beta_0 + \beta_1 \ln(l) + \beta_2 H + \beta_3 \ln(l) * H + \varepsilon_1 + \varepsilon_2$$

If environmental data layers (e.g. sediment composition, bottom shear stress, salinity, …) are not available but EUNIS classified habitat maps are available, it may be possible to derive a longevity distribution by EUNIS habitat instead. If some sampling locations are trawled, trawling intensity has to be included in the statistical model after which an untrawled "reference" biomass-longevity distribution can be obtained (see above), see for example Rijnsdorp *et al.* (2018). Only where a large number of stations with no or very low trawling intensity are present, trawling intensity does not need to be included in the models.

In this section, an overview is given on the environmental predicators that are finally used in the model, see Table 23. With this overview, we see which are the main environmental drivers, where updates on environmental predicator layers are desirable and where model updates are needed.

Table 23. Environmental predictors finally used in model and final model selection equitation.

	Type of data	Predictor 1	Predictor 2	Predictor 3	Predictor 4	Selected model equitation
Greece	Grab	MSFD habitat	Depth			Longevity + Habitat*Depth
South Adriatic	Trawl	Depth				mod4 <- glmer(Cumb ~ ll + Depth + (1 ǀ station), data=fulldat, family=binomial) Depth and MSFD habitat type was tested
North/Central Adriatic	Trawl	MSFD habitat	Depth			Longevity + MSFD habitat + Depth
Sicily	Trawl	Depth	SAR			Cumb ~ ll + Depth + SAR + (1 ǀ ID)
French Med.	Trawl					Depending on habitat Log(Longevity) + meanBtemp (circalittoral sand) Or Log(Longevity) + stratification (upper bathyal sediment) Environmental layers available: A bathymetry (m), B Seabed stress (N.m-2), C sediment average grain size (mm), D mean bottom temperature (°C), E mean surface Chlorophyll a concentration (mg.m-3), D mean bottom dissolved oxygen concentration (mmol.m-3), Stratification index The dredge-function of the R-package MuMIn was used to evaluate all possible model formulations based on the Bayesian information criterium (BIC).
Iberian Coast	Trawl	Depth	Substrate			LL + Depth + Subst + D Available environmental layers: Depth: bathymetry, Chl: mean annual Chlorophyll concentration, Temp: mean annual temperature, Energy: mean annual hydrodynamic energy, Substrate: sediment type
Bay of Biscay/Celtic Sea	Trawl	MSFD habitat	Depth	Bottom mean temperature	Bottom current	Cumb ~ ll + Depth + Chloro + Temp + Current + Substrate + (1 ǀ Station)

Celtic Sea/Irish Sea	Grab					Top 10 models reported, but no selection made
North Sea	Grab	Mud%	Gravel%	Bed shear stress	Subsurface abrasion	Log(Longevity) + log(subsurf. Abras) + mud, + gravel + log(shear stress) + log(subsurf. Abras) x log(shear stress) + log(longevity) x gravel
Baltic Sea	Grab	Salinity	Depth	Wave exposure at bottom		Log(longevity) + salinity + log(depth) + log(wave expos) + log(longevity) x salinity + salinity x log(depth) + log(longevity x log(depth)
Islandic waters	Trawl	Depth	Temperature			ll + temp*ll + depth + (1/ID)
Norwegian Shelf	Video					Model details not reported yet, but those used are: Depth, temperature, sediment composition
Barentz Sea	Trawl					Model details not reported yet, but those used are: Depth, temperature, sediment composition

4.1.5 Grid scale

The grid scale to be used for the FBIT assessment is minimum 0.05°. This is the case for the North-East Atlantic regions, the North and Central Adriatic and Greek waters. For the South Adriatic a grid scale of 0.01° is used, whereas for the French Med a grid scale of 0.016° is used.

4.1.6 Habitat data layer

As habitat data layer for the FBIT assessment the EUSEAMAP 2021 should be used to delineated the MSFD broad habitat types. The habitat layer limit is 1200m (upper bathyal) and rock habitats should be excluded. Regarding the depth layer, there is still a discrepancy with the legislative depth boundary limit for fishery, which is 800m (Atlantic) and 1000m (Med). It does not imply that fishery fish that deep as the practical limit seems to be 500/800m.

4.2 Benthic data samples with different gears: assessment consequences

The sensitivity layers in WGFBIT are constructed based on benthic data gathered with different gears (grab/core, trawl or video). As you are sampling different components of the seafloor ecosystem by the different gears, it will have consequences on the sensitivity layers. Trawl data is generally better available because it originates from the national fish trawl surveys, whereas similar surveys targeted at benthos only do not exist. However, trawls generally target a different component of the benthic communities, with higher catch rates for the larger epibenthic species. Grabs, on the other hand, dominantly catch the smaller infaunal species. It can be expected that this causes for differences in the longevity estimates, with the epifauna-dominated trawl samples having a higher longevity than the infauna dominated grab samples. This may also be region dependent. This could result in deviating predictions of the sensitivity layer, which could subsequently result in differences between RBS-estimates.

To get more insights in this methodological aspect on the FBIT outcomes, we are performing comparability analyses on longevity distributions obtained by different gears. The comparability analyses have to be performed on different levels: (1) based on co-located sampling; (2) comparing sensitivity maps of the (sub-) area, based on different gears; (3) combined gear datasets. This need to be tackled stepwise, as those three levels require more complex data handling and analyses. Work is made on level 1 and 2 and outlined in this section. Level 3 is for the moment too ambitious and can/shall be tackled in later FBIT work, depending on the outcomes of the level 1 & 2 analyses.

There is not yet defined on how to go forward with the FBIT assessments based on data from trawl or grab or both. In first instance, it is good to keep the assessments separately and investigated on how to integrate the data or combine the sensitivity layers.

4.2.1 Comparability longevity distributions trawl-grab: previous examples

An analyses comparing the longevity distribution generated from day grab and 2 and 4m beam trawl samples collected in a particular study area of the Celtic Sea was presented in ICES FBIT report (2019); (Figure 28). This analysis show that the fraction of long-lived fauna was highest in grabs rather than in trawls, and that using grabs to parameterise the model is therefore will not lead to an underestimate of sensitivity to trawling.

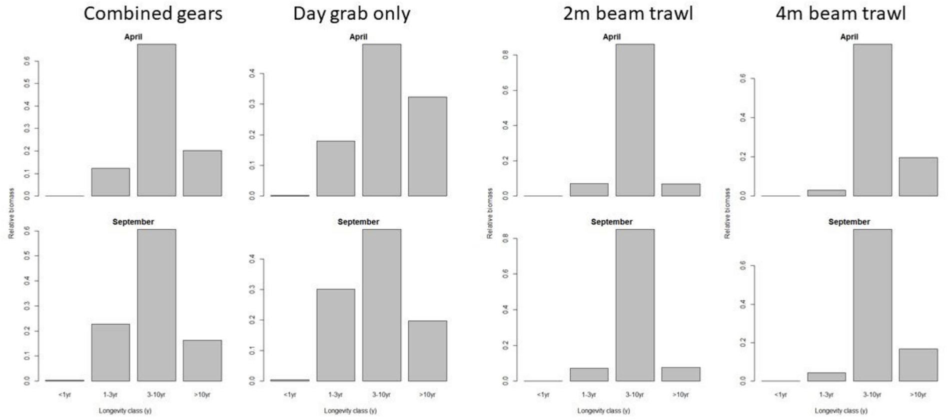


Figure 28. Biomass-longevity distribution of benthic invertebrates in the Celtic Sea in April 2016 and September 2015. Mean over 20 stations that were sampled using grabs and trawls, data corrected for differences in gear efficiencies. Data from (Howarth *et al.*, 2018a; Howarth *et al.*, 2018b).

Another example is extracted from a first attempt to run a FBIT assessment for the Celtic Sea (ICES, 2019), where there is grab and trawl data used and compared. Several grab sample datasets were supplied from the UK Marine Protected Area survey programme (North Celtic Deep, South Celtic Deep, North St Georges Channel, North West of Jones Bank, Greater Haig Fras and East of Haig Fras). Samples were mostly collected with a mini Hamon grab with some collected with a Day grab. Trawl samples from IBTS fisheries survey were also available (French EVHOE or potentially from the Irish IGFS). The Megafauna dataset had a dominant proportion of biomass in the longevity class 3–10 years, regardless of the habitat considered (Figure 29). In addition, the lower longevity class (>1year) was missing from the megafauna dataset.

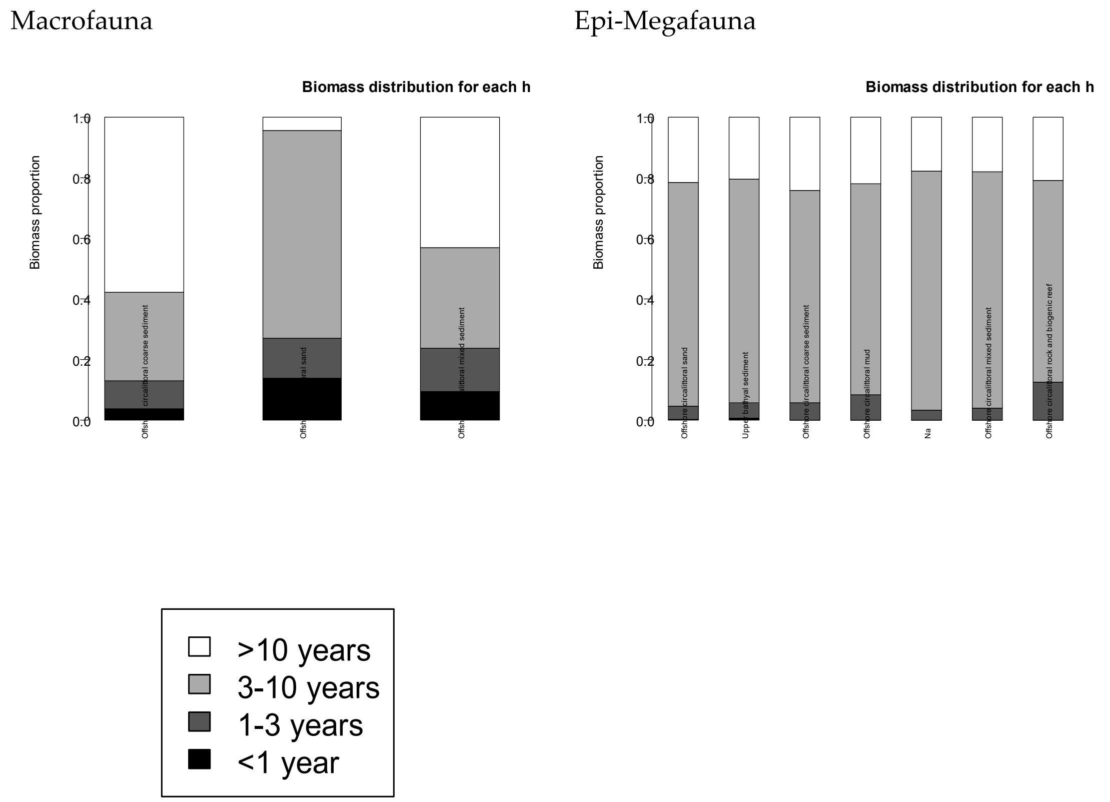


Figure 29. Distribution of biomass (log+1 transformed) within longevity classes for macrofauna (grabs samples) or epi-megafauna (trawl samples) datasets per habitat types

4.2.2 Comparability longevity distributions trawl-grab: co-located sampling

A straightforward way to test if the longevity distribution in an area differs between trawl or grab sampling is make used of co-located samples. Two examples are worked out, one on grab/beam trawl data in the Southern North Sea and one on day grab/Agassi trawl in the Greek waters.

4.2.2.1 Comparability longevity distributions trawl-grab: co-located sampling-Eastern Mediterranean case-study

Differences in the longevity distribution in two MSFD broad habitat types based (1) on grab data and (2) on Agassiz trawl data were estimated in Heraklion Bay (S. Aegean, Mediterranean) where co-located samples were available. Replicate sampling was conducted periodically through a year to cover seasonal variability (although the years were different for the gears). Samples for macrofauna infauna were collected with a 0.1 m2 Smith-McIntyre grab and sieved through a 0.5 mm mesh. Fauna characterized by megafaunal and epifaunal species were collected with an Agassiz trawl (2 m beam; 10 mm mesh liner). Sampling area includes stations within the MSFD broad habitat type circalittoral mixed sediment (79–90 m depth) and also the upper bathyal zone (200–220 m depth, muddy sediment).

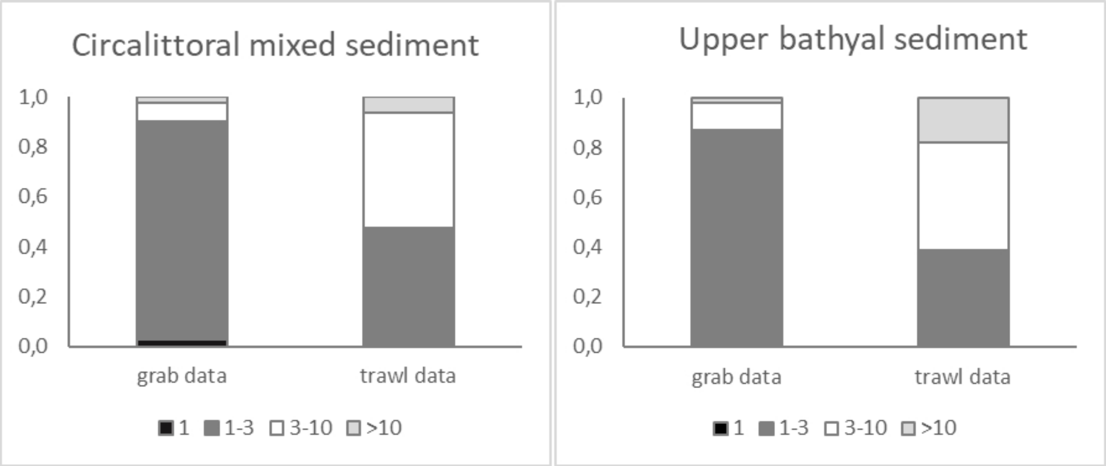


Figure 30. The proportion of abundance of longevity classes (<1, 1–3, 3– 10, and >10 years) of the benthic community in two Mediterranean MSFD Broad habitat types based on co-located grab data and Agassiz trawl data.

Figure 30 shows the differences in longevity distribution between macrofaunal/grab data and megafauna/trawl data. In macrofaunal data, the highest proportion of abundance was in the longevity class 1–3 years, in both habitat types. In contrast, for megafaunal data, the higher proportion of abundance was shared between the two longevity classes, i.e., 1–3 years and 3–10 years, and there was also a high proportion of abundance in the longest longevity class (>10 years), especially in the upper bathyal sediment. In addition, the short-lived species (1-year longevity class) were absent in the megafaunal data. This difference mainly reflects the different species composition collected from the two sampling devices, since fish species and large decapods with high longevity are dominant in the trawl samples but absent from the grab samples.

In the next step, we aim to generate and compare the sensitivity layers based on grab and Agassiz trawl data respectively, using a logistic mixed effect model (GLMM) and a stepwise forward selection approach, including depth and habitat type as fixed effects and assuming sites as random effect.

4.2.2.2 Comparability biomass longevity distributions trawl-grab: Belgian part of the North Sea a case-study

This case study aims to understand how the data obtained by different sampling methods affect the longevity distribution of benthic species caught in the Belgian part of the North Sea (BPNS). Estimation of the relative biomass per longevity class was done for two MSFD broad habitat types using data collected over 2010–2020 in the BPNS by (a) Van Veen grab and (b) beam trawl. Only stations included in our yearly sampling and for which co-located samples are available were included in the dataset. Macrobenthos fauna was sampled using a 0.1m2 van Veen grab and the collected specimens were sieved through a 1mm mesh. The collection of epifauna and megafauna was done by an 8m beam trawl (mesh size of 22mm). For this study, all Chordata specimens collected by beam trawl were excluded. The sampling area covered the entire BPNZ and includes all stations from muddy sand (Abra alba community) and sand (Nephtys community) habitats. The relative biomass for each longevity class was calculated per habitat type and sampling method. Furthermore, the effects of both the sampling method and MSFD habitat type were assessed using a non-parametric Kruskal-Wallis test.

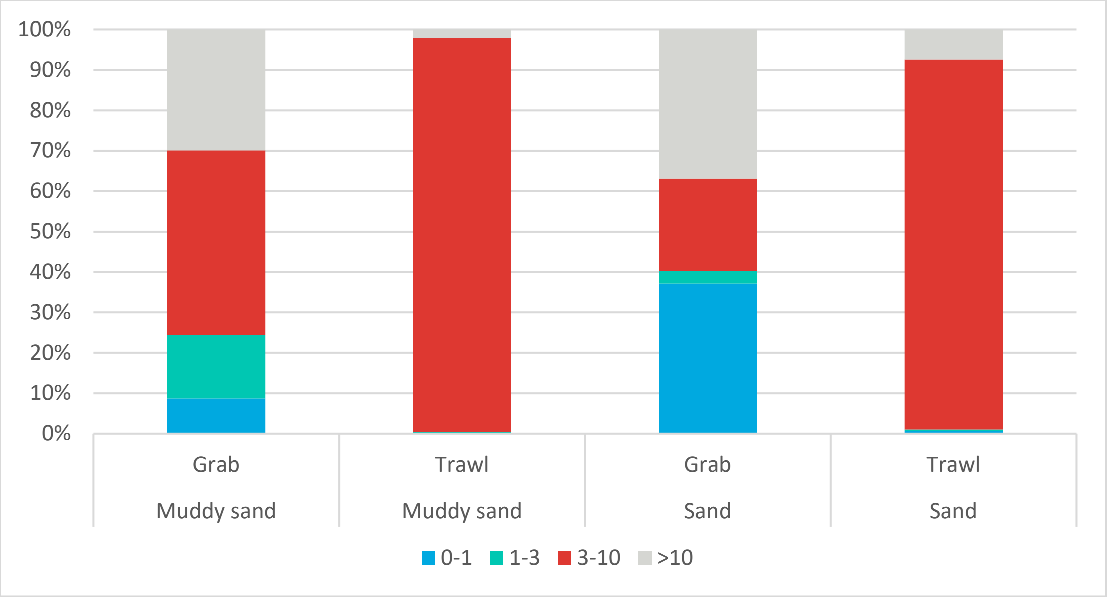


Figure 31. The relative biomass proportion of the benthic communities found in the BPNZ, divided over four longevity classes (0–1, 1–3, 3– 10, and >10 years) and based on samples collected by Van Veen grab and beam trawl in two habitat types (Muddy sand and sand).

As shown in Figure 31, the sampling method selected will influence the outcomes in the relative biomass distribution in each longevity class. In grab data, the highest proportion of biomass found for each longevity class differs between habitat types, where the muddy sand sediment is mainly dominated by 3–10 years and the sandy sediment's relative biomass is shared over 0–1 years and >10 years. The 3–10 year longevity category dominates strongly in regard to relative biomass in the trawl data for both habitat types. On the other hand, short-living species are almost completely absent from the trawl data with 0–1 years and 1–3 years being absent in the muddy sand and sand samples respectively.

It should be noted that for the grab samples the relative biomass proportion for each longevity class was found regardless of habitat type. In contrast, biomass proportions were not found for each longevity class for the trawling data, with the biomass proportion of either of the lower longevity classes, depending on which habitat type, being absent from the dataset. The use of this method could thus have affected the produced longevity sensitivity layers for BPNZ which are partially based on the same dataset. The contrast between the biomass longevity distribution outcomes between grab and trawl could be the result of differences in species selectivity between both sampling methods. Trawl samples are dominated by long-living larger decapods (grouped in the 3–10 years longevity class) which are absent from the grab samples. Our outcomes are further highlighted in table 1, where the sampling method significantly affected (non-parametric Kruskal-Wallis test with $p < 0.05$) the biomass distribution for each longevity class. Habitat type played no significant role in biomass distribution except for longevity class 1–3 years.

Table 24. The effect of both the sampling method and habitat type on the relative biomass proportion, of the benthic communities found in the BPNZ, divided over four longevity classes (0–1, 1–3, 3–10 and > 10 years). P-values obtained by non-parametric Kruskal-Wallis test.

Longevity Class	0-1	1-3	3-10	>10
Sampling method	$<2.2^{-16}$*	$<2.2^{-16}$*	$<2.2^{-12}$*	0.01474*
Habitat	0.6541	0.028*	0.8399	0.3425

4.2.3 Comparability trawl-grab: sensitivity layers

In previous FBIT report (ICES, 2022), we already listed multiple datasets for North Sea, Adriatic and Celtic Sea, where grab and trawl data on a large scale are available. This allows to generate sensitivity layers based on respectively grab or trawl data. For the Greater North Sea, not yet an FBIT assessment on trawl data is available, for the other areas, some examples are given, based on previous and recent analyses. Those comparisons of sensitivity layers need to be developed in the next reporting.

1) Celtic Sea area

Different sensitivity maps are produced, based on preliminary analyses and different data and models. The most recent tests are published in section 3.2.4. Only a comparison for the Celtic Sea part is possible based on the available maps. The predicted median longevity scales are quite different, but the areas with higher median longevity seems to be similar in both exercises.

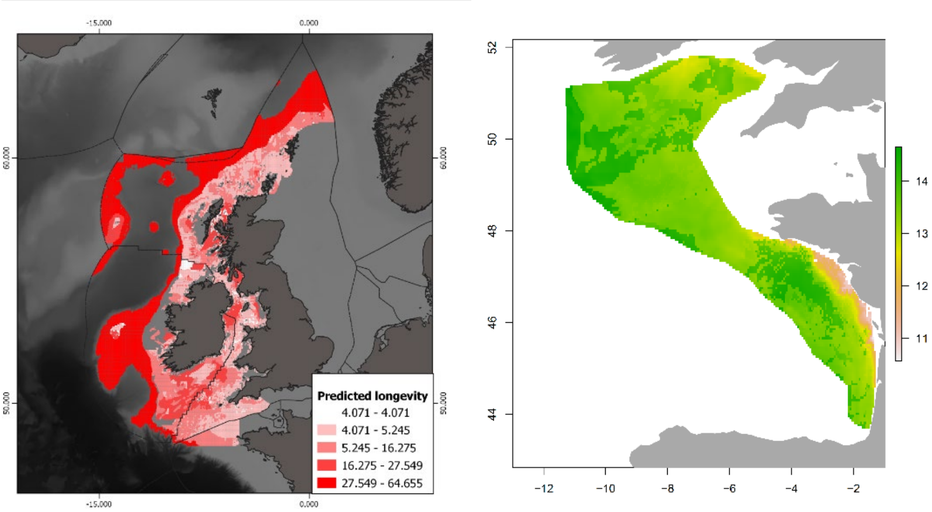


Figure 30. Left: Sensitivity layers made for the Celtic Sea region: left, Preliminary analyses, longevity modelled based on MSFD habitat type as predictive layer (ICES, 2019); Right: Preliminary analyses for Celtic Sea/Bay of Biscay, made in this report (see section 3.2.4.2.2).

2) Barents Sea – Norwegian Shelf

For the Barents Sea sensitivity layer developments (Figure 31), the global patterns seem visually the same, despite a different scaling. More fine scale discrimination of the patterns visible in the later version. The prediction of the longevity at the western edge of the Barents Sea seems to differ in relation to the different modelled versions (Figure 31 and 32).

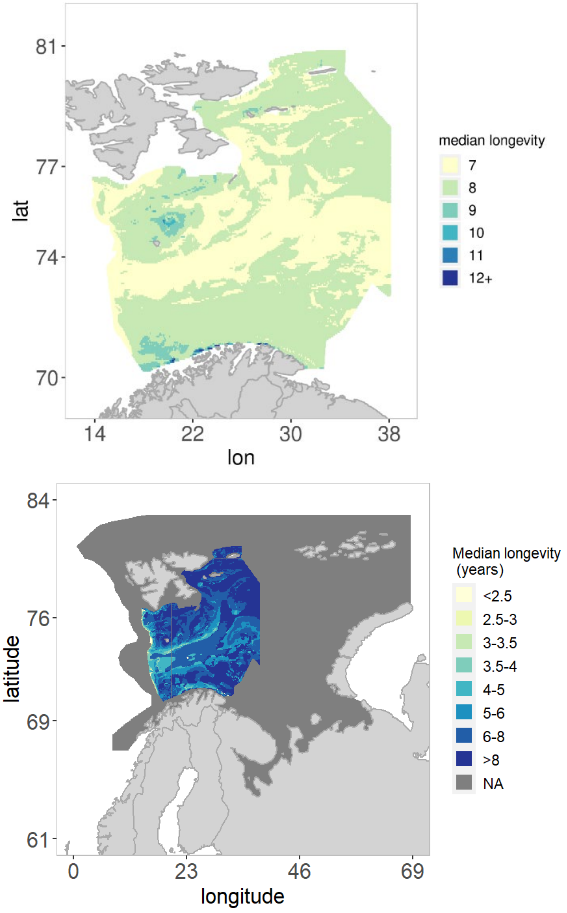


Figure 31. Left: Mean longevity of the benthic community in the Barents Sea, estimated from by-catch data from the Joint Annual Norwegian-Russian Ecosystem Survey (ICES, 2019); Right: Median longevity update (this report) for Barents Sea (same data).

3) Norwegian Shelf

For the Norwegian Shelf, the median longevity is quite high and only a bit similar with some Barents Sea locations (see figure 1, figure 32). Also, the scaling has a large influence on discriminating differences within the area in the median longevity. And there is also a very sharp (and deep decline) in median longevity between the Norwegian Shelf and Barents Sea. The difference in type of data and fauna looked at can have had an influence on those differences.

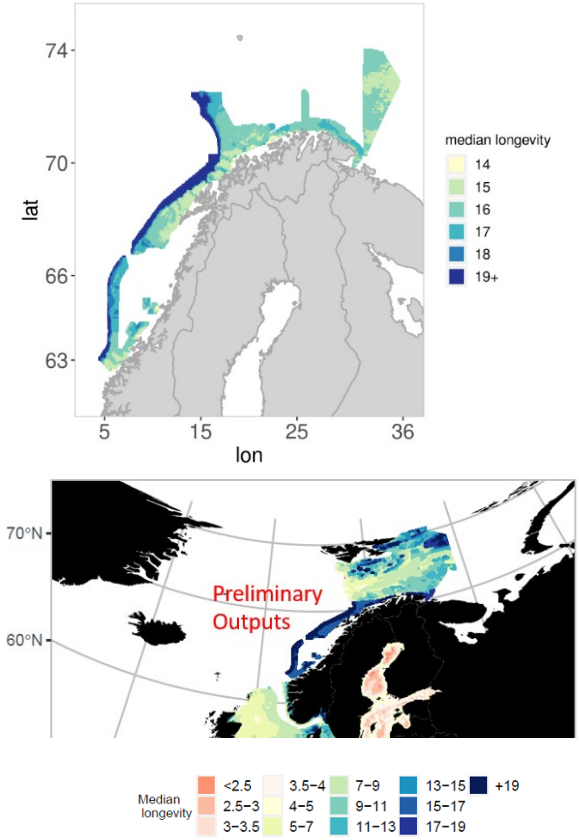


Figure 32. Left: Mean longevity of the benthic community in the Norwegian Shelf and southern Barents Sea, estimated from beam-trawl data from the MAREANO programme. Right: Taken from figure 1, with another updated run for Norwegian Shelf and Barents Sea.

4) Italian waters

For Italian waters, sensitivity layers are already generated based on several datasets, summarized in this section. The first attempt, based on Rapido trawl and grab data (ICES, 2019) gives very low median longevity values, which even decrease with depth. In the other examples (South Adriatic and Sicilian coast), it is the reverse. The difference is that the later are based on local trawl data, with larger spatial coverage, especially along the depth gradient in the area. This is not the case in the first attempt, where most of the data is from the shallow North Adriatic of coast of Sicily. So, in this case, the difference is probably not related to the collection method, but rather to the origin and coverage of the dataset used. Nevertheless, it shows that care has to be taken to the type of dataset used.

The data in the first attempt is based on data from the Adriatic Sea (GSA1 17) (Figure 10, left), which were derived from the SoleMon project. Megazoobenthos samples were collected at 69 stations (for geographical coordinates see Santelli *et al.*, 2017) using a Rapido trawl, a modified beam trawl commonly used by Italian fishermen to catch flatfish and other benthic species. Data from the Northern Sicily (Western Mediterranean) were derived from Romano *et al.* (2016), this study takes eighteen replicate sediment samples with a 0.4 m^2 Van Veen grab in each gulf (total n. 72) in 2005.

For the North Adriatic, in 2022 an assessment was executed based on two datasets (see higher), the one based on otter trawl (2012–2014) and SoleMON rapido trawl survey (TBB; 2014–2016) is given as well in Figure 33 (right).

Another example but of the South Adriatic Sea (Figure 34, left), the benthic longevity estimates (GSA 18) were based on epifauna data from MEDITS scientific survey. The hauls were carried out in the 10–800m depth-range using the standard MEDITS trawl net GOC73 (AAVV, 2017; Spedicato *et al.* 2019). A total of 264 hauls were surveyed from 2017 to 2019.

The example of the Sicilian Coast (Figure 33), right) is based on data derived from three datasets (Fishing trawl surveys from Interreg HARMONY Project year 2019 and 2020, (11 hauls); Fishing trawl survey from ISPRA campaign year from 2016 to 2020 derived from Italian National Monitoring Programme (57 hauls); Fishing trawl survey from M.C. Mangano (MEDITS protocol) campaign from 2010 to 2013 (85 hauls).

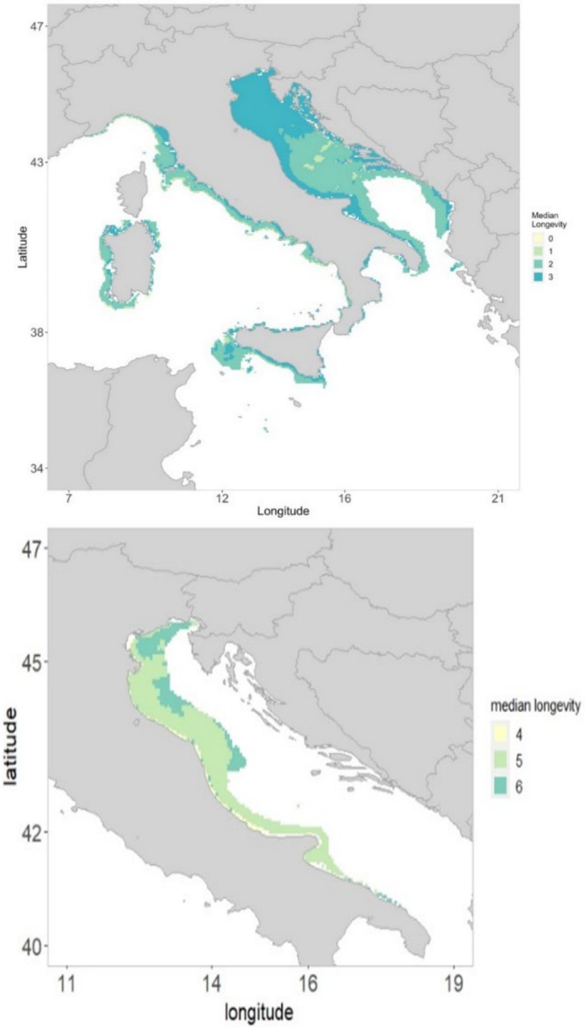


Figure 33. Left: Mean longevity for the Italian waters (ICES, 2019), sensitivity modelled based on depth as environmental predictor; right: predicted median longevity, based on MSFD habitat and depth as environmental predictors and data from GAP2 survey (otter trawl; 2012–2014; SoleMON rapido trawl survey (TBB; 2014–2016)); (see this report).

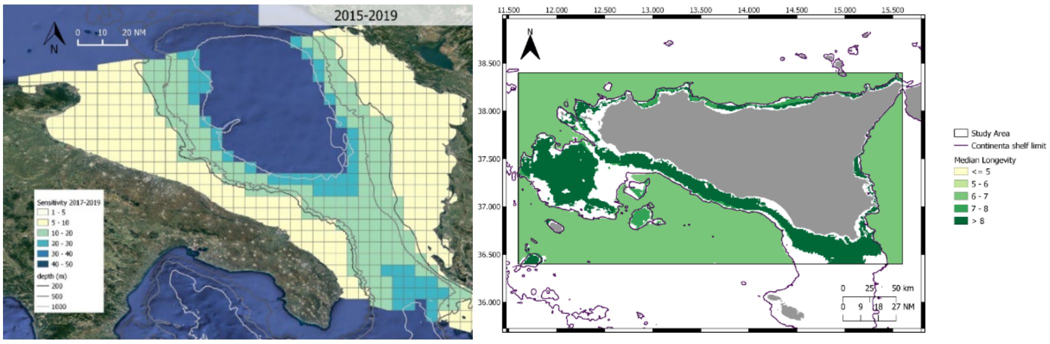


Figure 34. Left: The predicted longevity curves by MSFD habitat and maps for median longevity (sensitivity) of the Southern Adriatic Sea (screening samples SAR < 0.5). Right: Median longevity estimates obtained from GLMM applied to each selected habitat. The bold black line underlines the limit of the continental shelf.

5 WGFBIT and the wider world (ToR C)

The WGFBIT seafloor assessment framework (based on assessing the relative benthic state) is not the only way to assess benthic impacts from physical disturbance. Therefore, comparison with other methods (alternative assessment methods) needs to be explored, as we advised in previous FBIT reports and was part of a DG ENV request to ICES. Therefore, two workshops (WKBENTH2 and WKBENTH3) were organized in 2022, with as goal to give:

1. A detailed review of indicators used, or under development, by Regional Sea Conventions, Member States and ICES, for assessing the state/condition of seabed habitats suitable for MSFD assessments. The indicators considered can also include peer-reviewed indicators which have large-scale application.
2. Advise, using a set of agreed criteria, on a common framework to evaluate methods to assess benthic risk (model) and state (data) indicators, with respective threshold values [could be clearer].
3. A targeted benthic data call (via TG Seabed), in order for ICES to evaluate the performance of selected (reviewed) benthic risk and state indicators, in relation to their ability to assess the state/condition of seabed habitats and adverse effects from specified pressures.
4. Advice on threshold values to assess the quality of seabed habitats.
5. Advice on the suitability and shortcomings of both risk and state indicators for MSFD assessment purposes at national and regional scales.

Many members of the FBIT working group participated in the above workshops and results are published in the respective reports (ICES, 2002a; 2002b) and as an ICES special request advice (sr.2022.18). This work covered the goals formulated in the workplan of TorC, so no further work was done during the FBIT 2022 meeting on this aspect. Except, some brainstorm/discussion session was hold on how the future workflow on advice that ICES WGFBIT assessment contribute to, will be organized.

5.1 How the WGFBIT assessment will be used in ICES advice?

There are two main bits of advice that the ICES WGFBIT assessment will contribute with towards: the 1) ecosystem overviews; and 2) EU DGENV request on trade-offs.

Ecosystem Overviews

Aim: For the ecosystem overviews (as per the TORs of WGFBIT) the (sub)regional assessment will feed into a so called "ICES ecosystem overviews pipeline proposal" that has been accepted by the ICES advisory committee (ACOM).

Required from WGFBIT: as input to the pipeline workshop a shorter EOs summary assessment sheet showing the main results per (sub)region. This will include Baltic Sea, Greater North Sea, Norwegian Sea, Barents Sea, Icelandic Waters, Celtic Seas, Bay of Biscay and the Iberian Coast ecoregions.

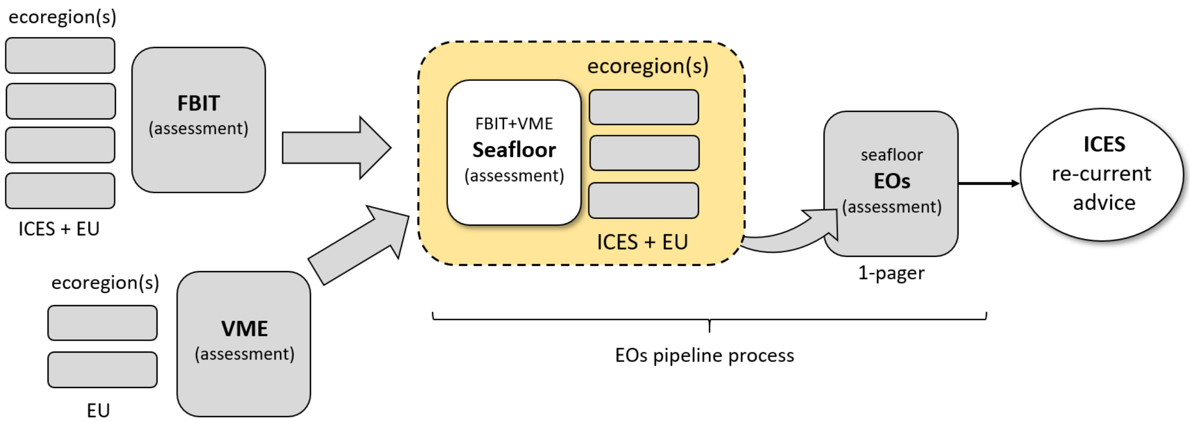


Figure 35. Flow of information from FBIT to other ICES products.

Rationale: As part of the ICES ecosystem overviews pipeline proposal process WGFBIT products for the ***regional seafloor assessments*** for widespread habitats and communities will be brought together with the assessment products developed for particularly valued and sensitive habitats and communities in deep and shallow waters, i.e. ***Vulnerable Marine Ecosystems (VMEs)***. These approaches already also form the basis of the recurrent and special request ICES advice. This pipeline proposal reconciles these two approaches to assessing the seafloor, by developing an integrated regional seafloor assessment template applicable for all ecoregions. The proposal is to produce ecoregion-specific spatial ***management options*** balancing VME protection and the condition of benthic habitat with sustainable fishing.

An ICES workshop will be convened in Q2 of 2023 to build the required foundation product, an "ICES seafloor assessment". The aims of this workshop are two-fold:

- Develop and document an operational evidence-based procedure for the production of recurrent (every 2–3 years) regionals seafloor assessments with the focus on disturbance caused by bottom fishing.
- Produce for all ICES ecoregions seafloor assessments using established ICES methods for widespread habitats and communities, and particularly valued and sensitive habitats and communities in deep and shallow waters, i.e. Vulnerable Marine Ecosystems (VMEs). Include in the assessment ecoregion-specific spatial management options enabling to balance VMEs protection and the condition of benthic habitats with sustainable fishing.

Based on these (sub)regional seafloor assessment products, a shorter version will be extracted for EOs advice-purposes. This scaled down product will present indicators of pressure and impact and regional-specific management options that maximize the benefits to the seafloor and minimize the loss of fishing area and weight / value of landings per ICES ecoregion. The product will contain one multi-panel figure, very likely one small table and a few paragraphs text summarising the key messages, in total max. 1-page long contribution. The assessments are reproducible (using TAF) and can easily be updated using a workflow hosted by existing working groups. The data sources (VMEs, VMS and logbook data, etc.) are referenced, catalogued and metadata made available (e.g. data profiling tool, following the ICES data management best practices principles).

EU DGENV request on trade-offs

Aim: Upon request building from ICES advice on trade-off (2021, eu.2021.08) to run the trade scripts with newest available VMS data.

Required from WGFBIT: regional assessment updated as input to the running of the TRADE script (2021, eu.2021.08).

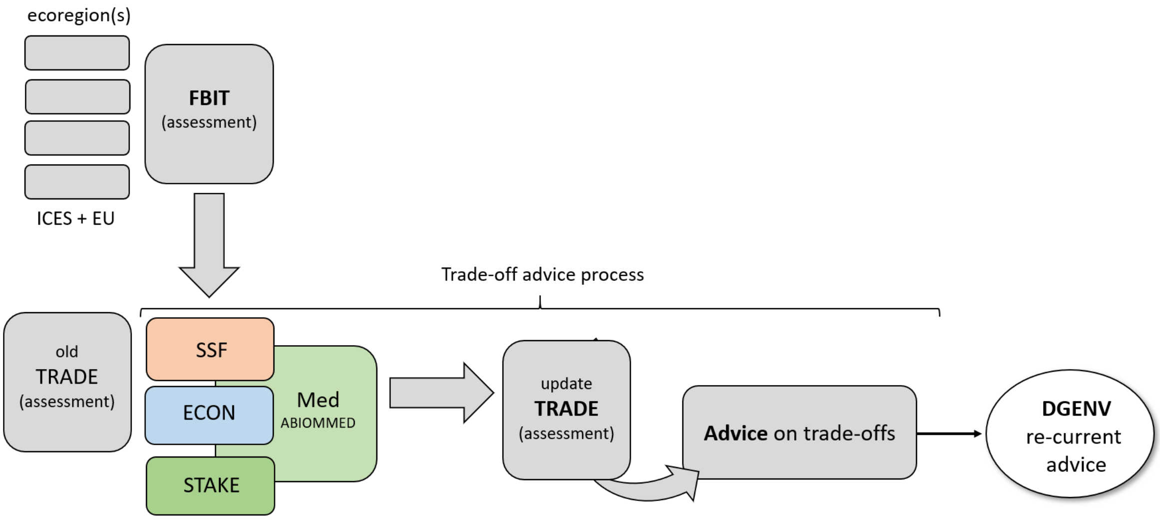


Figure 36. Flow of information from FBIT to DGEVN advice.

***SSF** = small scale fisheries workshop, ***ECON** = WKTRADE4, linking VMS, STECF FDI and AER data, ***STAKE** = stakeholder workshop, ***Med abiommed** = synergy + focus on Mediterranean

Rationale: WGFBIT (as well as WGECON) were established following the 2017 ICES advice process and series of workshops (WKBENTH, WKSTAKE, WKTRADE). In 2021 ICES produced as advice an update of the 2017 advice on trade-off (2021, eu.2021.08). Similarly, in 2023 and upon request from the EU DGENV, ICES will require WGFBIT regional assessment updated as input to the running of the TRADE script using the latest VMS and logbook data. The advice process in 2023 will have modular input from a series of workshops on small scale fisheries workshop, linking VMS data with STECF FDI and AER data, a stakeholder workshop, and in particular ensure synergy with the project ABIOMMED that has a focus on Mediterranean. The specifics of these workshops are being drafted to be ready to be announced in early 2023.

6 Ecosystem functioning (ToR d)

Marine sediments harbour significant levels of biodiversity that play a key role in ecosystem functions and services such as biogeochemical cycling, carbon storage and the regulation of climate (Covich *et al.* 2004; Solan *et al.* 2004). Bioturbation and bioirrigation, the faunal behaviour that results in particle displacement and increased exchange of solutes (e.g. O_2, CO_2, dissolved organic matter, inorganic nutrients) across the sediment-water interface and within the sediment matrix (Kristensen *et al.* 2012; Wrede *et al.* 2018), constitute significant drivers of ecosystem functioning (primary production, benthic-pelagic coupling, biogeochemical cycling) (Lohrer *et al.* 2004; Middleburg 2018).

Ecosystem functioning is defined here, as the movement and transformation of substances within the ecosystem (Boero & Bonsdorff 2007; Hooper *et al.* 2005). This encompasses the movement of carbon in a food web, the incorporation of nutrients into organic matter through primary production, and the degradation of organic matter into inorganic bioavailable forms (CO_2 into the atmosphere etc.). All processes and organisms are essential for the functioning of ecosystems, and they are deeply interconnected.

By depleting fauna and changing the species composition, bottom fishing may result in alterations in the functional effect traits (bioturbation, bioirrigation) of a community, which in turn may have broad implications for the overall ecosystem performance (Figure 37).

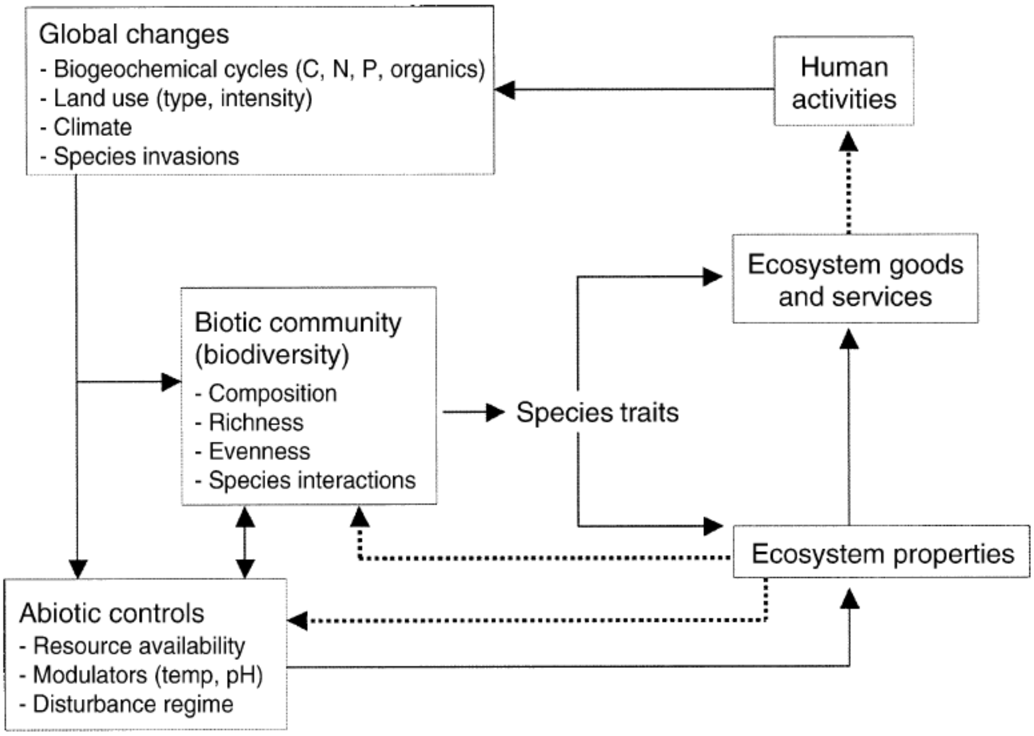


Figure 37. Feedbacks between human activities, global changes, and biotic and abiotic controls on ecosystem properties. Bottom fishing may alter both the biotic community and abiotic conditions (e.g. porosity and pH) that influence process rates and control ecosystem properties. Changes in ecosystem properties can feed back to further alter the biotic community either directly or via further alterations in abiotic controls (dotted lines). Feedbacks from altered goods and services can lead to modification of human activities. This figure is taken from Hooper *et al.* 2005.

Species biological traits

Biological traits are useful descriptors of the functional features of benthic organisms. For example, species longevity is used to assess species recoverability following trawling disturbance in the FBIT approach. Traits such as burrowing, sediment mixing and bioirrigation influence benthic organism-mediated processes such as bioturbation and bioirrigation occurring in soft sediment shelves. In soft sediments, especially those with rich organic content, organism activities can have profound effects on the physico-chemical nature of the substratum, altering redox potential and nutrient concentrations. Species traits that are known to alter ecosystem states are defined as ‘effect traits'. Figure 38 illustrates the functional duality of response and effect traits.

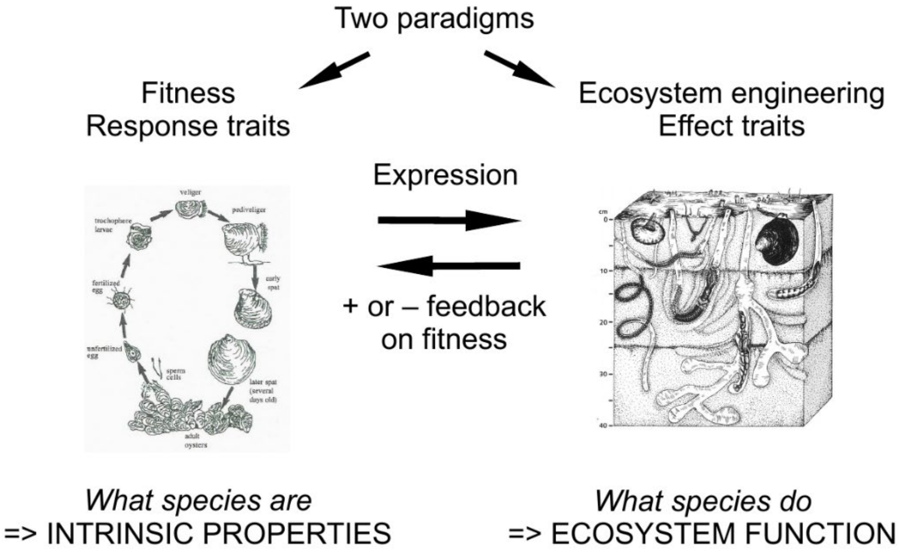


Figure 38. The duality of response and effect traits influencing the response to trawling disturbance and influencing changes in ecosystem functioning.

Whereas the use of response traits has been the object of numerous investigations on the effects of environmental disturbance and stress on species community dynamics (Beauchard *et al.* 2022), the specific use of effect traits in the marine benthos remains relatively marginal in the growing literature of trait studies (Beauchard *et al.* 2017). Nevertheless, an abundant literature provides evidence of the importance of bioturbation (sediment mixing) and bioirrigation in terms of ecosystem functions (Kristensen *et al.* 2012, Meysman *et al.* 2006). Thus, focusing on effect trait composition in benthic communities may help understand better the effect of trawling on ecosystem functioning.

Research focus for ToR D

The current PD method utilized in the WGFBIT assessment method combines information on total benthic biomass with the relative abundance of different longevity classes to estimate the relative impact of different types of fishing on the seabed. The working assumption of this method is that high community biomass will coincide with communities where the body size distribution, age structure as well as numbers of the benthic fauna are close to natural, and thus a community where its ecosystem functioning is less likely to be impaired by trawling. A caveat of this, however, is that total community biomass does not necessarily reflect changes in species and functional trait composition which play a key role in regulating ecosystem functions.

An improved understanding of the relationships between total community biomass and ecosystem functioning may assist in setting acceptable thresholds for ecosystem impacts. Furthermore, an improved understanding of the link between species functional effect traits and proxies and processes for specific ecosystem functions could help increase our ability to predict the impact of fishing disturbance on benthic ecosystem functioning more accurately. ToR D sets out to explore how ecosystem functioning can be incorporated more explicitly into the assessment methodology. The ecosystem function we focus on is the biogeochemical cycling of organic matter. Two approaches are being explored:

1. Multivariate ordination between species traits and biogeochemical parameters to link the two and ultimately explore the effects of bottom trawling on ecosystem functioning through the depletion of species with certain biological traits
2. Modelling approach - Whilst the biological traits approach focuses more on the effect of trawling on ecosystem functioning through the loss of biota, the biogeochemical modelling approach also considers changes in functioning due to changes in the biogeochemical nature of the sediment due to sediment erosion, mixing or deposition.

6.1 Fauna functional traits and ecosystem functioning – Multivariate ordination

Led by Clement Garcia, Olivier Beauchard
Participating in case-studies: Clare Bradshaw, Irini Tsikipoulou, Marija Sciberras, Jolien Claes, Stefan Bolam, David Clare, Matthias Skold, Mats Blomqvist

This work explores the potential of using multivariate analysis to study the effects of bottom trawling on ecosystem functioning. We use species biological traits of soft sediment (in)fauna to link effect traits which define "what species do on and, in the seabed," to seabed biogeochemistry. Two research questions are addressed:

- Can we identify the link(s) between the faunal traits and proxies (metrics) of seabed biogeochemical processes?
- Can we detect the impacts of trawling on those links?

Data requirements

An ideal case-study would involve different areas with similar environmental conditions with one reference (pristine) and several impacted by trawling with increasing frequencies. Whereas the reference (no trawling) area allows examination of the influence of the physico-chemical setting on the link between traits and biogeochemical processes, trawled areas allow examination of changes in trait-biogeochemical relationships due to trawling. We expect that various levels of trawling will restructure the existing trait-biogeochemistry links by either decomposing or changing the strength of existing links and/or create new ones. However, most seabed habitats are frequently impacted by trawling or otherwise, the context specific links between traits and biogeochemistry will already be interacting with the existing and historic level of pressures. To account for different environmental contexts, the multivariate correlative exploration requires data describing the environmental context, trawling effort, species communities (presence-absence, density, biomass data), traits and biogeochemical metrics at each study area.

In the first instance, we will start with a broad set of possible effect trait modalities which relate to bioturbation (movement of particles within the sediment), bioirrigation (movement of solutes within the sediment) and biodeposition (movement of particles from the water column to the sediment); (i.e. a combination of those shown in Table 25).

Table 25. Suggested traits and trait attributes to use in multivariate correlation of traits and biogeochemical processes. Left side of table is from the CEFAS trait database (*). Right side of table is from Wrede et al (2018) (¥).

*Trait	Attribute	¥Trait	Attribute
Feeding mode	Suspension feeder	Burrow type	Epifauna, internal irrigation (e.g. siphon)
	Surface deposit feeder		Open irrigation (e.g. U- or Y-shaped burrows)
	Sub-surface deposit feeder		Blind ended irrigation (e.g. blind ended burrows, no burrow systems)
	Scavenger or opportunist	Injection pocket depth	0–2 cm
	Predator		2–5 cm
Sediment reworking	Surface deposition		5–10 cm
	Upward conveyor		>10 cm
	Downward conveyor		
	Surface modifier		
	Sediment regenerator		
Mobility	Sessile or slow moving		
	Burrower		
	Crawler		
	Swimmer		
Sediment position	Surface		
	Shallow depth (0–5 cm)		
	Intermediate depth (5–10cm)		
	Deep (>10cm)		
Maximum size	<10 mm		
	10 – 20 mm		
	21 – 100 mm		
	101 – 200 mm		
	>200 mm		

Table 26. Datasets identified among FBIT members.

Data provider		**CEFAS - SSB**	**Sweden - Clare**	**Sweden - Clare**	**Sweden - Clare**	**NIOZ - MWTL**	**NIOZ - de Borger study**	**HCMR - Irini**	**HCMR - Irini**	**HCMR - Irini**	**HCMR - Irini**
Location		Celtic Sea	W and NW of Bornholm, Southern Baltic		Kattegat	Dutch EEZ	North Sea transect	Dia Island, Eastern Mediterranean	Dia Island, Eastern Mediterranean	Heraklion, Eastern Mediterranean	Pagasitikos Bay, Eastern Mediterranean
Sampling time		March 2015	May 2019	May 2020	October 2021	1995 - 2018 Spring	May - June 2018	1994-1995 Jul, Nov	1995-1996 Sept, Oct, Nov, Jan, Mar, May, Aug	1995 Apr, May, Jun, Jul, Aug	1994 Aug,Sept, Oct, Nov
Number of stations		gradient (50)	6 per year		gradient and MPA (27)	gradient (30 stations)	11	4	4	4	7 4
Depth		90 - 100 m	40 m	40 m	50 +/- 10 m	10 - 55 m	45 - 135 m	200 m	200 m	70 m	90 m
Trawling pressure		Gradient	high vs. low	high vs. low	Gradient	Gradient	No fishing	Control vs trawl	Control vs trawl	BACI	BACI
Fauna parameters	**abundance & biomass**	>1mm	0.5-1mm >1mm	0.5-1mm >1mm	>1mm	x	x	x	0.5mm	0.5mm	0.5mm
	sampling gear	NIOZ box core	Grabs	Grabs	Grabs	Box core	Box core	Box core	McIntyre grabs	McIntyre grabs	McIntyre grabs
Biogeochemical / Physico-chemical parameters	**TOC (LOI)**		x	x	x	x	x				
	Organic carbon	%m/m				x	x	0-2, 2-4 cm	0-2, 2-4 cm	0-2, 2-4 cm	0-2, 2-4 cm
	Nitrogen	%m/m									

	C/N	x									
	Chlorophyll	(ug/g)	x	x	x		x	0-2, 2-4 cm	0-2, 2-4 cm	0-2, 2-4 cm	0-2, 2-4 cm
	Pheopigments	(ug/g)					x	0-2, 2-4 cm	0-2, 2-4 cm	0-2, 2-4 cm	0-2, 2-4 cm
	DIC fluxes		x	x	x						
	porewater N conc	x					x				
	porewater P conc	x					x				
	porewater Si conc	x					x				
	NH_4 fluxes		x	x	x		x				
	NO_x fluxes		x	x	x		x				
	PO_4 fluxes		x	x	x		x				
	O_2 fluxes		x	x	x		x	x			
	Oxygen Penetration Depth	microelectrodes			x						
	Oxygen microprofiles	microelectrodes			x		x				
	total carbohydrate		x	x	x						
	protein		x	x	x						
	lipid		x	x	x						

	extracellular enzyme activities		x	x	x						
	derived C turnover rates		x	x	x						
	degradation rates		x	x	x						
	aRPD	x									
	Surface Boundary Roughness	x									
Sedimentological parameters	**% Gravel**	x	x	x	x	x	x	x	x	x	x
	% Sand	x	x	x	x	x	x	x	x	x	x
	% Silt/clay	x	x	x	x	x	x	x	x	x	x
	Porosity	x	x	x	x		x				
Other environmental parameters	**depth**	x	x	x	x	x	x	x	x	x	x

Ordination method adopted

Several 'multi-table' ordination methods have been considered. Co-Inertia-type methods such as simple co-inertia and RLQ analysis are better adapted to low number of stations, are less complacent with random variables and cope better with collinear descriptors. RLQ allows for 3 tables (species, environment/biogeochemical metrics and traits) which means that it reduces the prerequisite data preparation and does not necessitate the creation of a "trait-at-site" table thereby avoiding all together some statistical quirks emerging from the Community Weighted Means (CWM). The RLQ will allow for the creation of a reduced-space where functional traits and biogeochemical metrics can be related and can provide correlative groups of traits and biogeochemical metrics.

The influence of trawling on these traits-biogeochemistry relationships will be examined differently depending on the data available. Generally, RLQ will return axes with stations coordinates which can then be related to trawling and graphically represented along the main axes. The significance of these relationships can be tested by the Fourth-Corner method. Two separate RLQ with and without trawling may be necessary to understand the difference between the pristine and the impacted structure. Another possibility is to "detrend" trawling on the environmental variables and the biogeochemical metrics.

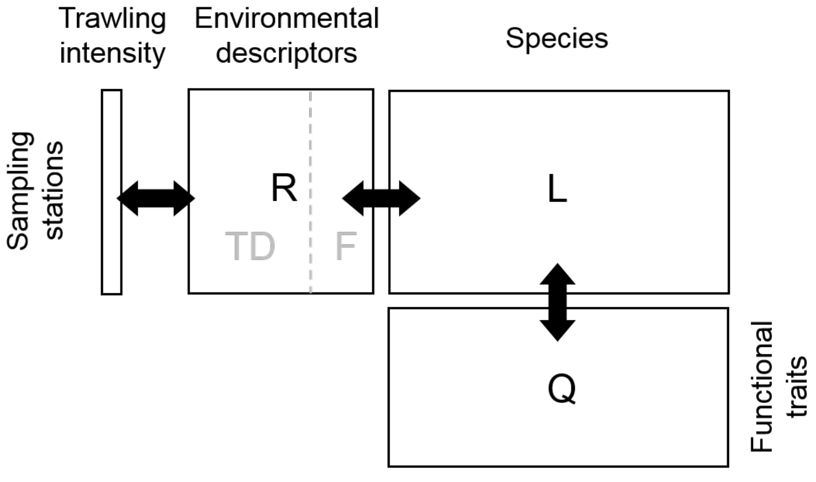


Figure 39. Data matrices and relationships. Table R can include traditional descriptors ("TD"; e.g. depth, hydrodynamics, sediment granulometry) and nutrient fluxes ("F"). The relationship between tables R and L represents a first level of data exploration through co-inertia analysis; this R-L covariation can be related to trawling intensity after being detrended on R variable in order to circumvent a confounding effect on table L. A significant R-L relationship may suggest variable functional requirements along R-L gradients, with a possibly significant R-Q covariation, investigated through RLQ analysis and the Fourth-corner method. As for R-L covariation, RLQ axes, that provide sampling station scores, can be related to trawling intensity.

Hypothesis-based interpretation

(1) No significant relationship between tables R and L. This can be due to natural conditions such as a homogeneous area with no environmental gradient. An extreme scenario can also be a large-scale trawling devastation that affects both environment and fauna in spite of slight natural R-L covariation, leaving impoverished assemblages of opportunistic and resilient species. No trawling effect is expected. Of course, no R-Q link is neither expected.

(2) Significant relationship between tables R and L. This represents a very typical scenario in which trawling effect on taxonomic composition can be expected. A very particular case is the absence of R-L link in a homogeneous area that becomes significant after including trawling intensity in table R; various trawling intensities might become an environmental determinant by selecting some resistant taxonomic assemblages. Absence of trawling effect can be expected in case of a too strong confounding effect where too much variation is removed from trawling intensity when detrending.

(3) Significant relationship R-L and insignificant relationship R-Q. This scenario can be envisaged in pristine areas were environmental variations, although affecting significantly the fauna (R-L), are too weak to induce changing species trait niches (i.e. allopatric species spatial distributions but sympatric functional distributions). This can also be induced by trawling when the specific community functionalities are found in the most vulnerable species. This last point advocates for a confrontation of the effect traits used in the analysis and response traits indicative of poor recoverability (e.g. life span, offspring characteristics; Beauchard *et al.*, under review).

(4) Significant relationships R-L and R-Q. This scenario is expected in untrawled areas with strong R-L variation that induced strong functional variations; it is unlikely on European shelves, although gradients partially affected by trawling can show true R-Q links (Beauchard *et al.* 2022). If R-L covariation is strong enough, the inability of trawling to modify environmental characteristics in table R (e.g. depth, hydrodynamics, sediment granulometry, stratification), may not prevent a significant R-Q relationship. A major question lies in the case of no significant R-L or R-Q link, becoming significant after including trawling in table R. Such a problematic situation could happen in areas chronically trawled and would mean that trawling acts as a functional driver of the sea floor ecosystem.

Example of a case study: the Dutch sector of the North Sea (DSNS)

The area (57 000 km^2) includes the Southern Bight in its southern part and Oyster ground in the North, with a part of the Dogger Bank in the northernmost part. The southern part and the Dogger bank are shallow, highly dynamic with high bottom current speeds (wave shear stress for the Dogger Bank) and coarser sediments whereas the northern part is deep, sheltered and muddy. The faunal data comprises macro-invertebrates (sieve mesh size, 1 mm) sampled yearly at 81 stations from 1995 to 2010, and then every three years from 2010 to 2018. The environmental descriptors include depth, bottom current speed, wave energy, sediment type, stratification, POC, POM and primary productivity. Detailed descriptions are provided in Beauchard *et al.* (2021) and Beauchard *et al.* (2022). Fourteen effect traits from Beauchard *et al.* (in revision) are considered as sea floor functions.

The bottom trawling intensity data (ICES 2012) cover the period 2009–2015. They consist in total swept area ratio (SAR) for gears penetrating less than 2 cm deep and gears penetrating deeper than 2 cm; data were averaged per sampling station. Accordingly, the period 2010–2018 was considered for the fauna. The analyses reveal highly significant R-L and R-Q covariations. A single and dominant first RLQ axis (84 % of total inertia) was significantly correlated to all environmental descriptors and many trait modalities (Figure 40a).

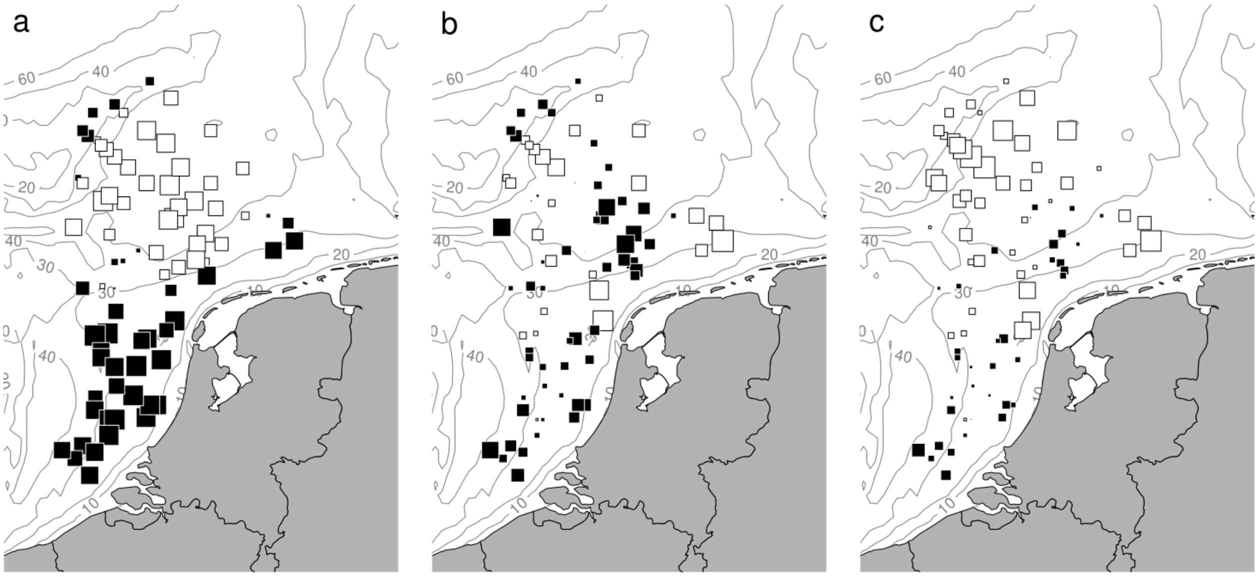


Figure 40. Dutch sector of the North Sea case study. a) Spatial distribution of the first RLQ sampling station axis score; white and black squares for respectively low and high axis scores; square size proportional to the deviation from the mean score (0, small square). High scores (black) indicate a more surficial mobile and biodiffusive fauna, whereas the low scores (white) correspond to deeper burrowing species assemblages, building more complex burrows and moving vertically the sediment. SAR < 2 cm (range: 0.10–5.60). c) SAR > 2 cm (range: 0.02–4.62). SAR data were *ln*(x)-transformed for a better visualization.

There are strong confounding effects between the two SAR variables and table R (environmental descriptors, $R^2 = 0.52$ and 0.57 for SAR < 2 cm and > 2 cm respectively), which constrains to detrend SAR variables on table R. The large amount of variance removed (0.52 and 0.57) probably explain the absence of significance of the relationship between the detrended variables and the RLQ axis through the Fourth corner test.

For the multiple case studies, important analytical information will be listed as in the following table:

Case study	Faunal density	R-L relationship	R-Q relationship	Confounding effect	RLQ-trawling relationship
DSNS	Presence-Absence	0.63	Significant	0.52-0.57	Not significant
…	…	…	…	…	…

Faunal density indicates which type of faunal abundance (among presence-absence, biomass and individual density) brings the best R-Q relationships. R-L relationship (*RV* coefficient) indicates the strength of the environmental variation that could lead or not to a significant R-Q relationship. Confounding effect indicates the R^2 between trawling intensity and table R that could or could not prevent a significant relationship between RLQ axes and trawling intensity (possibly detrended); here, if trawling intensity is not detrended, RLQ-trawling relationship is highly significant. All this information indicates that the DSNS case study follows a certain context within scenario 4 as previously formulated. It can be concluded that the strong latitudinal habitat gradient, not evenly trawled, induced very strong functional variations, but the strong confounding effect of trawling prevent to conclude on a possible trawling effect in the southern part where trawling intensity is higher. Additionally, the highest densities of vulnerable species (i.e. long-lived) occur in the northern part (Figure 41). Future analyses could envisage two separate case studies based on the two separate habitats (shallow dynamic and deep sheltered).

Other perspectives

This work should not be limited to statistical procedures as simple descriptive graphs bring already ecological information. Spatial distribution of key traits, compared with distributions of fishing efforts will be done to discuss significant as well as insignificant results. As part of WGFBIT, mapping sample-aggregated life span and burrowing depth intervals may be particularly relevant (Figure 41). In a more comprehensive way, mapping functional group distributions can also be envisaged. Lastly, co-inertia and RLQ methods provide rich analytical outputs that enable to identify synthetic patterns in massively multivariate contexts.

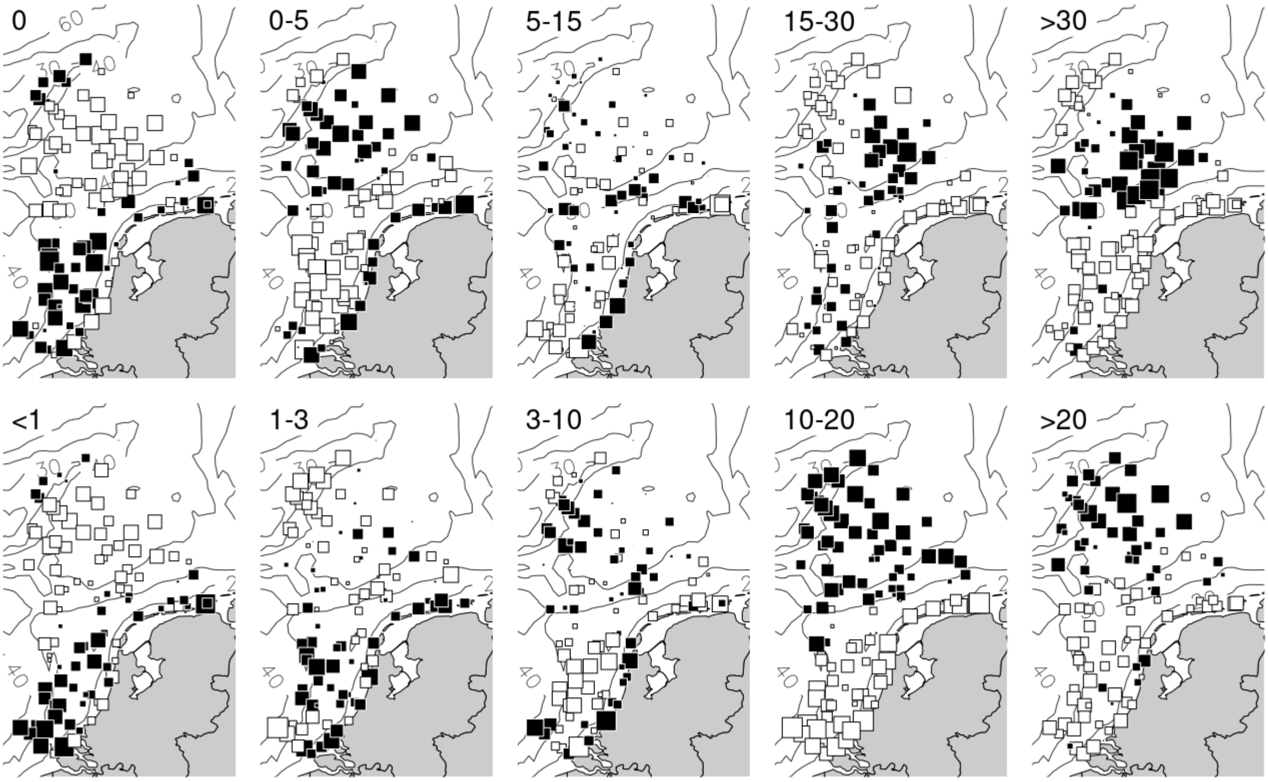


Figure 41. Illustrative example of trait data mapping from the Dutch EEZ case study. First series of maps: burrowing depth; top-left, depth stratum in cm. Second series: life span (in years). Symbol size is proportional to individual organism density (relative frequency as proportion of sample total). White and black squares for respectively low and high densities; square size proportional to the deviation from the mean (small square). The most vulnerable communities (long-lived, > 10 years) are quite shallow buried (0–5 cm).

Challenges

As the (unimpacted) links between functional traits and biogeochemistry are dependent on the physico-chemical contexts but as similar links are assumed to emerge from broadly similar contexts irrespective of the biological community bearing the traits, the available case-studies are expected to complement each other. A first RLQ approach will allow to understand which environmental context to control for, sand/coarse processes are more likely to be hydrodynamically driven when mud/sild more likely to be biologically driven. A mix of both types of stations may lead to spurious trait-biogeochemical links that are only representing the environmental gradient as opposed to describing the specific links to the biology which is our main interest here. A challenge here may be that controlling for the environmental context may decrease the statistical power (number of stations) and the underlying variation which is critical for the RLQ to detect differences. A lack of detection between trait-biogeochemistry link does not mean that the relationships does not exist but that the variation in the data do not allow to detect it. Incorporating the effects of trawling will need to either be a case of trawling versus no trawling if the data allows it or for the (most likely) cases where trawling was not controlled for (i.e., gradient) detrending environmental variables and biogeochemical metrics.

Future work

Depending on the case-studies, we will explore how they can complement each-other to potentially answer different facets of the main questions presented above. Some may be better at investigating the (pristine) relationships between trait and biogeochemistry and how they vary with physico-chemical contexts while others will be more appropriate to explore the impacts on either traits, biogeochemistry or both. Finally, collating results and complementing conclusions will allow to put us in a better position to comment on the effect of trawling and the relationships between traits and biogeochemistry.

6.2 Modelling trawling effects on ecosystem functioning – a modelling approach

Led by Karline Soetaert,
Participating: Sebastiaan van de Velde

The impact assessment couples a biological and biogeochemical model:

(i) in the *biological part*, a data-driven mechanistic model is used to model species depletion and recovery between trawling events. The model describes the increases of benthic species density using the logistic growth equation; its parameters are derived from density and/or biomass data from a particular site combined with species trait information, such as the longevity of the species, and the depth of occurrence in the sediment.

The outcome of this biological model describes trajectories of species densities over time. As the species densities change, so do the *ecosystem functions* that are delivered by the community. The bioturbation and bio-irrigation activity are important ecosystem functions that affect sediment biogeochemistry and that are required to run the biogeochemical model. To couple the biological and biogeochemical model, the so-called bioturbation potential (BPc) and bio-irrigation potential (IPc) of the community, is estimated at each timepoint and used to scale the bioturbation and bio-irrigation in the biogeochemical model.

(ii) the *biogeochemical model* is the mechanistic early diagenetic model that was used to assess fisheries impact in de Borger *et al.*, 2021, and that is based on the OMEXDIA sediment biogeochemical model (Soetaert *et al.* 1996). OMEXDIA is a 1-dimensional numerical early diagenetic model that describes the oxygen, carbon, nitrogen and phosphorus cycle in a number of layers in the sediment. Upon trawling, the sediment is mixed and partly resuspended, while porewater with nutrients is lost to the overlying water column. This model was described in the previous ICES report, and this is not repeated here.

Software

The models are run in the open source framework R (R core team, 2022) and have been implemented in the *Bfiat* R-package (Soetaert *et al.*, 2022). Biological data and traits are compiled in the R-package *Btrait* (Soetaert and Beauchard, 2022) that also contains functions to work on these datasets. The diagenetic model is in the R-package CNPDIA (Soetaert, 2022). The packages Btrait and Bfiat are still under construction and will be made publicly available beginning of 2023.

Data requirements

Central in this impact analysis is the use of a combination of data:

<u>Benthic community composition</u>

Benthic biological data used in this assessment should comprise density and preferentially also biomass of individual species.

The densities are used to estimate the "carrying capacity" of the species at a particular site; this is the maximal abundance the species can attain. Biomass, or mean weight of a species is necessary to estimate the ecosystem functions considered here: bioturbation and bioirrigation.

The MWTL monitoring data from the monitoring of the Dutch part of the North sea is used as a case-study for the analysis. Data comprises both species densities and biomass and these were estimated for 103 stations sampled for 19 years, extending from 1995 till 2018 (yearly at first, then less frequently).

For use in the model, the averages over the sampling period are used. See Figure 42 for the location of the MWTL stations.

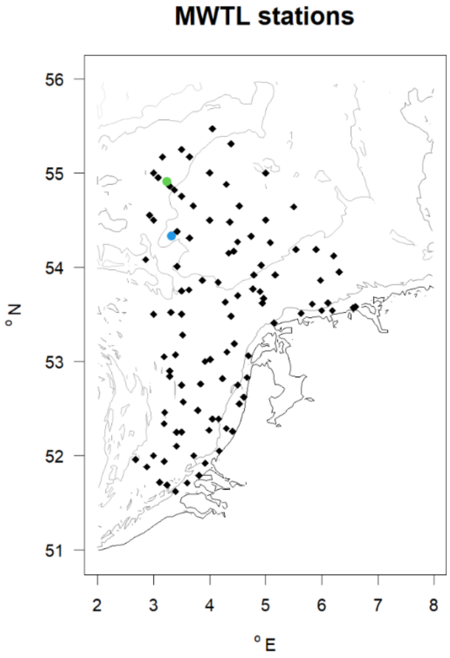


Figure 42. The MWTL sampling stations, with indication of stations DOGGBK04 (green) and OESTGDN13 (blue).

Trait characteristics of the benthic species

The following species traits are used:

- The life span (longevity) of species is used to estimate their "rate of increase" (r)
- The depth at which species live is used to derive their vulnerability to bottom trawling: it is used to derive the model's "depletion parameter" (d)
- The reworking and mobility mode of species, as well as their weight and density, is used to estimate their "bioturbation potential", a parameter that affects sediment biogeochemistry
- The feeding type, burrowing mode, injection depth, combined with their weight and density, is used to estimate the species' "bioirrigation potential", also important for sediment biogeochemistry

We will use the species-specific trait data from *nioz* that were compiled by Beauchard *et al.* (2021) and Beauchard *et al.* (in revision). This database records 32 different traits for 281 taxa, mainly on species level.

The traits required for the bioturbation potential were compiled in Queiros *et al.* (2013). Traits to estimate bioirrigation potential were described in Wrede *et al.* (2018); they were derived from the *nioz trait* dataset.

Fishing intensity

The model also needs the *fishing intensity* for a certain area, for instance expressed as the swept area ratio (SAR); this is the cumulative area contacted by a fishing gear over one year and per surface area. From the swept area ratio (hereafter denoted as S), we calculate the time inbetween fishing events.

The fisheries impact model

The dynamic model is based on the logistic growth equation that describes how species density changes in between fishing events. The logistic growth model is a mechanistic model, where density-limiting factors such as food limitation, predation, … are subsumed in a "maximal" abundance the species can attain, i.e. the carrying capacity K. The model for species i reads:

$$\frac{dD_i^t}{dt} = r_i \cdot D_i^t \cdot \left(1 - \frac{D_i^t}{K_i}\right),$$

where t is time, D_i^t is the density of species i at a particular time, K_i is the carrying capacity of species i, r_i is the logistic growth parameter (units [/time]). The term on the left-hand side, $\frac{dD_i^t}{dt}$ expresses how density D_i changes over time t (it is a derivative). The first part on the right-hand side ($r_i \cdot D_i^t$) expresses how density increases in the absence of limitation, i.e. when the density is far below the carrying capacity. The term between brackets $\left(1 - \frac{D_i^t}{K_i}\right)$ becomes more important as the density approaches carrying capacity and causes the change in species density over time to decrease and eventually disappear (when $D = K$). The parameters r_i and K_i are specific for species i; the carrying capacity K_i also depends on the site where the species is found.

Fishing events

When the sediment is trawled, at times t_j, the density of each species i, is instantaneously reduced, so that only a fraction p_i remains:

$$D_i^{t_j^+} = D_i^{t_j^-} \cdot p_i,$$

Where $D_i^{t_j^+}$ and $D_i^{t_j^-}$ are the density immediately after and before trawling occurs at time t_j respectively, and p_i is the species-specific and trawl-specific reduction fraction; it is estimated as ($p_i = 1 - d_i$), with d_i the depletion fraction. The higher the depletion factor, the more the density of a species after trawling will have been reduced.

Model parameter values

Rate of increase

In line with Hiddink *et al.*, 2019, we estimate the rate of increase (r_i) for each species from its longevity l_i (in years) as:

$$r_i = \frac{5.31}{l_i}$$

Depletion due to fishing

The *depletion fraction* (d_i) for a certain species i depends on traits such as their depth distribution in the sediment, and likely also their mobility.

It is to be expected that species living near the sediment surface will be more vulnerable to fishing-induced mortality than deep-living species. The ones that are most vulnerable will be species living *on* the sediment surface, and that do not have the ability to escape by swimming.

The depth distribution of a species is a trait that is recorded in the nioz trait database, where the distinction is made between species living on top of the sediment, species living in the upper 5 cm (0–5 cm), from 5–15 cm, from 15–30 cm and deeper than 30 cm. Also, the motility mode of species is recorded (as the fraction that swims).

To parameterise the depletion rate of organisms due to fishing, we use the relationship in Hiddink *et al.*, 2017, that expresses, for the *entire* community, the depletion rate as a function of the penetration depth of the fishing gear (p_G). This relationship was derived based on a meta-analysis.

We recreate this relationship, assuming that:

- any species, living *in* a depth zone that is penetrated by the gear experiences a mortality that increases linearly with the gear penetration depth in its living zone, and below its living zone. Thus, a species living in the 0–5 cm will experience mortality for any gear penetration depth p_G; species living in the 5–15 cm zone will experience depletion only for gear penetration deeper than 5 cm, etc…

We estimate the depletion rate of a species i as a function of the occurrence in a layer $[z_u, z_l]$, with z_u and z_l the upper and lower boundary of this layer as follows:

$$d_i = \sum_{z=[z_u,z_l]} m \cdot max(0, p_G - z_u) \cdot fi_{[z_u,z_l]},$$

where m is a coefficient that scales the depletion to the depth that the gear has penetrated in the species's living space (the sediment depth inbetween z_u, z_l), and where $fi_{[z_u,z_l]}$ is the fractional occurrence of species i in that zone.

As this formula leads to an exponential increase with gear penetration, which is not observed in Hiddink *et al.*, (2017), the total depletion fraction of any species is limited to 0.45.

$$d_i = min(d_i, 0.45)$$

This value is the maximum depletion observed in Hiddink *et al.*, 2017.

- Species living *ON* the sediment, and that do not swim are added to the species living in the upper 5 cm, so their mortality is estimated as:

$$d_i(z = 0) = m \cdot p_G \cdot fi_{z=0} \cdot (1 - fi_{swim}),$$

where $fi_{z=0}$ and fi_{swim} is the fractional occurrence of species i on the sediment, and the fraction that is swimming respectively.

Based on these simple formulations, only the value of the mortality parameter m (units of fraction/cm) should be estimated to parameterize d. We do this by calculating the community-averaged depletion rate as a function of gear penetration depth for all 103 stations in the MWTL dataset, and comparing the results with the data points as in Hiddink *et al.*, 2017. A value for the mortality coefficient $m = 0.075cm^{-1}$ gives a good fit to the data (Figure 43).

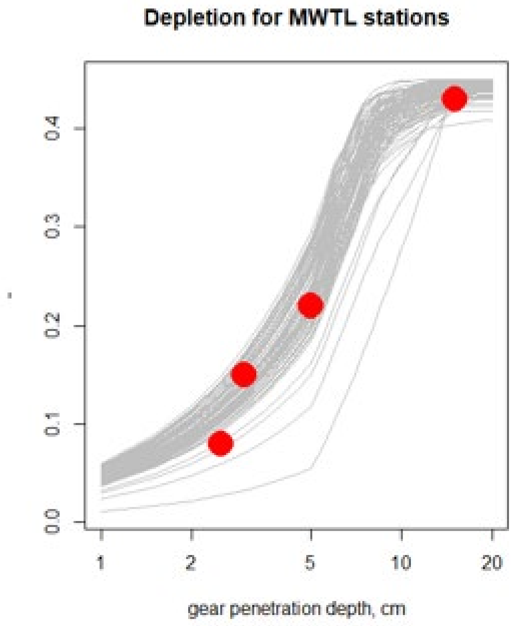


Figure 43. Estimated community-average depletion rates as a function of gear penetration depth, for the 103 MWTL stations (grey lines), compared to the data from Hiddink *et al.*, 2017 (red dots).

Fishing intensity

- The annual *swept area ratio*, SAR is used to estimate the mean *time in between fishing events* : $\Delta T = \frac{1}{SAR}$, in years. SAR values can be obtained from ICES.

From the SAR, the times of fishing events can be estimated, e.g. as $T_j = j \cdot \Delta T$, where we assume equally spaced fishing events.

Carrying capacity

The species- and site- specific *carrying capacity*, K_i, is estimated from the density data recorded at any particular site. To estimate K, we assume that the estimated density during monitoring is the density obtained at dynamic equilibrium under the current fishing pressure (and the observed density is thus lower than the actual carrying capacity). K can be estimated from the model itself, and therefore depends on the fishing intensity SAR, the species-specific parameters r_i, d_i, as well as on the species density D_i.

In summary:

The following parameter sources are used

parameter	estimated from	Source
ΔT	Swept Area Ratio	ICES / OSPAR
r_i	longevity	Nioz trait database
K_i	density	MWTL species distribution data
d_i	living depth/mobility	Nioz trait database

Case-study: the effect of trawling on ecosystem functions

We demonstrate how this model can be used to estimate the impact of fishing on the species densities for two North sea stations (based on MWTL data); (Figure 44), and how these species densities affect the bioturbation potential, BPc, and the bio-irrigation potential, IPc (Figure 45).

Station OESTGDN13 is located in the Oystergrounds, a muddy, relatively eutrophic area, while DOGGBK04 is located on the Doggerbank, a sandy, relatively oligotrophic area. We assumed trawling took place with a beam trawler, penetrating 3.2 cm into muddy sediment, 1.9 cm into sandy sediment. The SAR for both areas, based on averages from 2009 till 2017 were 1.2 and 0.4/year respectively. Trawling occurred for 20 years, after which both areas were unfished for 20 years.

Results indicate that trawling has a minor effect on the bioturbation and bioirrigation potential in the Dogger bank compared to the Oyster grounds which are typically populated by species that take longer to recover (Figure 44, 45).

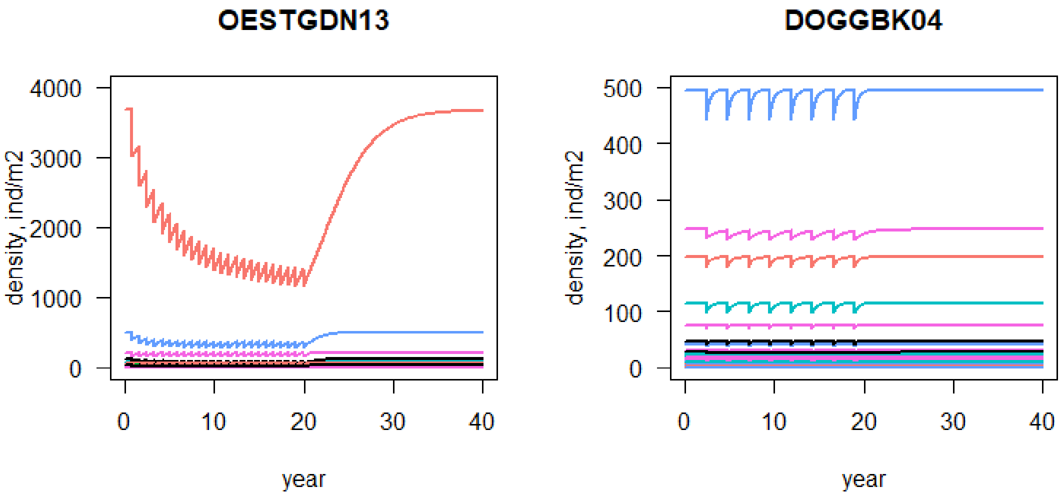


Figure 44 Density versus time for the main species in the station (depicted by individual coloured lines) located on the Oystergrounds OESTGDN13 (left) and on the doggerbank DOGGBK04 (right). See Figure 40 for the location of these stations. Density at year 0 is the community prior to trawling occurs, this defines also the carrying capacity, K, of the community. Trawling starts in year 0 and stops in year 20.

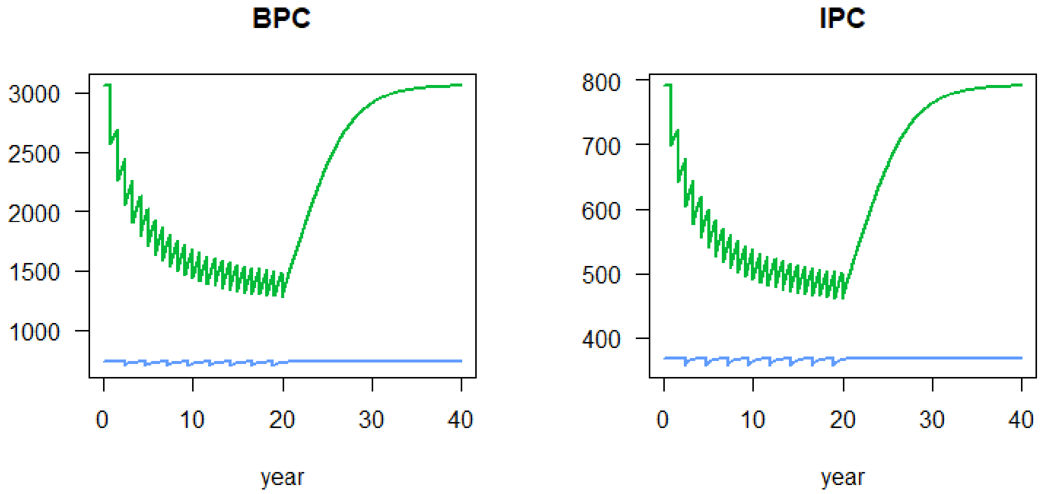


Figure 45. Bioturbation potential (BPc) and bio-irrigation potential (IPc) for the station OESTGDN13 (green) and DOGGBK05 (blue).

Future work

In the future, the current parameterizations need to be ground-truthed. The coupling with the early diagenetic model needs to be done. This will allow to estimate the (indirect) impact of fishing -via impairment of ecosystem functions- on biogeochemistry.

Acknowledgements

The trait database, the preparation of the MWTL data, and the software in R-package Btrait were created in the frame of the EMODnet biology project (https://www.emodnet-biology.eu/); the fishing models were created in the frame of the BFIAT project (bottom fishing impact assessment tool, NWO 18523).

6.3 Ongoing relevant work on integrating bottom trawling into 3D numerical coastal ocean modelling - Case study in the North Sea

Led by Lucas Porz, Wenyan Zhang - Institute of Coastal Systems, Helmholtz-Zentrum Hereon

A coupled numerical ocean-carbon-macrobenthos model is utilized to quantify the effects of bottom trawling on the distributions of macrobenthos and sedimentary organic carbon in the North Sea. The model resolves the mechanistic feedbacks between macrobenthos growth and decline, bioturbation, organic carbon fluxes across the sediment-water interface, sediment transport and bottom trawling. Daily bottom trawling activity is modelled through sediment resuspension, macrobenthos depletion and mechanical mixing of the upper sediment layers, taking into account gear types, penetration depth, vessel size, trawling speed and sediment properties. Short-term simulations show a 20% reduction in re-mineralizable organic carbon from the sediment compared to a no-trawling scenario after one year, roughly equivalent to emission of 0.6 Mt CO_2. Long-term simulations using reconstructed fishing effort data from 1950–2020 show an accumulative trawling-induced reduction of total macrobenthos biomass by 10–17% and an associated loss of carbon sequestration capacity in North Sea sediments by 21–67% when compared to the no-trawling scenario. The highest trawling-induced carbon and biomass losses occur in muddy, depositional areas with high trawling intensities: the slope of the Norwegian Trench, Skagerrak, Fladen Ground, Oyster Ground and parts of UK's east coast.

This method can complement the FBIT strategy by quantifying both short-term and long-term effects of trawling on seafloor habitats and ecosystem services (e.g. carbon sequestration and nutrient fluxes). The method can further be used to assess the effects of different management scenarios in the past and future.

References

Beauchard O, Brind'Amour A, Schratzberger M, Laffargue P, Hintzen NT, Somerfield PJ, Piet G. 2021. A generic approach to develop a trait-based indicator of trawling-induced disturbance. Mar Ecol Prog Ser 675:35-52. https://doi.org/10.3354/meps13840

Beauchard O., Mestdagh S., Koop L., Ysebaert T., Herman P.M.J., 2022. Benthic synecology in a soft sediment shelf: habitat contrasts and assembly rules of life strategies. Marine Ecology Progress Series 682:31–50.

Beauchard O., Veríssimo H., Queirós A.M., Herman P.M.J., 2017. The use of multiple biological traits in marine community ecology and its potential in ecological indicator development. Ecological Indicators 76:81–96.

Beauchard O, K.E. Ellingsen, M.S.A. Thompson, G. Piet, P. Laffargue, K. Soetaert, subm. Assessing sea floor functional diversity and vulnerability. Marine Ecology Progress Series.

Boero, F., and Bonsdorff, E. 2007. A conceptual framework for marine biodiversity and ecosystem functioning. *Mar. Ecol*. 28, 134–145. doi: 10.1111/j.1439-0485.2007.00171.x

Covich, A. P. *et al.* 2004.The role of biodiversity in the functioning of freshwater and marine benthic ecosystems. Bioscience 54, 767–775

De Borger, E., Tiano, J., Braeckman, U., Rijnsdorp, A., & Soetaert, K. 2021. Impact of bottom trawling on sediment biogeochemistry: a modelling approach. *Biogeosciences*, *April*, 1–32. https://doi.org/10.5194/bg-2020-328

Hiddink, JG, Jennings, S, Sciberras, M, *et al.* 2019. Assessing bottom trawling impacts based on the longevity of benthic invertebrates. J Appl Ecol. 2019; 56: 1075– 1084. https://doi.org/10.1111/1365-2664.13278

Hiddink, JG., Jennings, S., Sciberras, M. *et al.* 2017. Global analysis of depletion and recovery of seabed biota after bottom trawling disturbance. Proc. Nat. Aca. Sci, 114 (31) 8301-8306 https://doi.org/10.1073/pnas.161885811.

Hooper, D. U., Chapin, F. S., Ewel, J. J., Hector, A., Inchausti, P., Lavorel, S., *et al.* 2005. Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. *Ecol. Monogr*. 75, 3–35. doi: 10.1890/04-0922

Kristensen E., Penha-Lopes G., Delefosse M., Valdemarsen T., Quintana C.O., Banta G.T., 2012. What is bioturbation? The need for a precise definition for fauna in aquatic sciences. Marine Ecology Progress Series 446:285–302.

Lohrer, A.M., Thrush, S.F., Gibbs, M.M. 2004. Bioturbators enhance ecosystem function through complex biogeochemical interactions. Nature 431: 1092 - 1095

Meysman F.J.R., Middelburg J.J., Heip C.H.R., 2006. Bioturbation: a fresh look at Darwin's last idea. Trends in Ecology and Evolution 21:688–695.

Middleburg, J.J. 2018. Reviews and syntheses: to the bottom of carbon processing at the seafloor. Biogeosciences 15: 413-427

Queiros, A. M., S. N. R. Birchenough, J Bremner, J.A. Godbold, R.E. Parker, A. Romero-Ramirez, H. Reiss, M. Solan, P. J. Somerfield, C. Van Colen, G. Van Hoey, S. Widdicombe, 2013. A bioturbation classification of European marine infaunal invertebrates. Ecology and Evolution 3 (11), 3958-3985

Soetaert, K., Herman, P. M. J., & Middelburg, J. J. (1996). A model of early diagenetic processes from the shelf to abyssal depths. *Geochimica et Cosmochimica Acta*, *60*(6), 1019–1040.

Soetaert, K (2022). CNPDIA: Diagenetic Model with Simple Nitrogen, Carbon, Phosphorus Dynamics. R package version 1.0. https://rdrr.io/rforge/CNPDIA/

Soetaert, K. and Beauchard, O. (2022). Btrait: Working with Biological density, taxonomy, and trait composition data. R package version 0.0.

Soetaert, K., Beauchard, O., van der Kaaden, A., Tiano, J. (2022). Bfiat: Bottom Fishing Impact Assessment Tool. R package version 0.0.

Solan, M. *et al.* 2004. Extinction and ecosystem function in the marine benthos. Science 306, 1177–1180

Wrede, A., Beermann, J., Dannheim, J., Gutow, L., Brey, T. 2018. Organism functional traits and ecosystem supporting services – A novel approach to predict bioirrigation. Ecological Indicators, 91: 737 – 743 https://doi.org/10.1016/J.ECOLIND.2018.04.026

Annex 1: List of participants

Name	Institute	Country	Email
Andrea Pierucci	COISPA	Italy	andrea.pierucci@hotmail.it
Alessandra Nguyen Xuan	ISPRA	Italy	alessandra.nguyenxuan@isprambiente.it
Bianca Di Lorenzo	ISPRA	Italy	bianca.dilorenzo@isprambiente.it
Clare Bradshaw	Stockholm University	Sweden	clare.bradshaw@su.se
Clement Garcia	CEFAS	UK	clement.garcia@cefas.co.uk
Cristina Mangano	SZN	Italy	mariacristina.mangano@gmail.com
Cristina Vina-Herbon	JNCC	UK	cristina.herbon@jncc.gov.uk
Chris Smith	HCMR	Greece	csmith@hcmr.gr
Daan Cuyvers	IFREMER	France	daancuyvers@hotmail.com
Daniel van Denderen	DTU Aqua	Denmark	pdvd@aqua.dtu.dk
David Clare	CEFAS	UK	david.clare@cefas.gov.uk
Elisa Punzo	CNR	Italy	elisa.punzo@cnr.it
Gabriele Di Bona	UNIPA	Italy	gabriele.di.bona16@gmail.com
Gert Van Hoey (chair)	ILVO	Belgium	Gert.vanhoey@ilvo.vlaanderen.be
Giada Rava	University of Padua	Italy	giada.riva@studenti.unipd.it
Irini Tsikopoulou	HCMR	Greece	itsikopoulou@hcmr.gr
Jan Geert Hiddink (chair)	Bangor University	UK	j.hiddink@bangor.ac.uk
Jochen Depestele	ILVO	Belgium	Jochen.depestele@ilvo.vlaanderen.be
Joanna Desmidt	ILVO	Belgium	Joanna.desmidt@ilvo.vlaanderen.be
Jolien Claes	Heriot-Watt University	UK	jc2066@hw.ac.uk
Justin Tiano	WUR	Netherlands	Justin.Tiano@wur.nl
Karline Soetaert	NIOZ	Netherlands	Karline.Soetaert@nioz.nl
Kate Morris	Heriot-Watt University	UK	kjm2001@hw.ac.uk
Lene Buhl-Mortensen	Institute of Marine Research	Norway	lenebu@hi.no
Luisa Nicoletti	ISPRA	Italy	luisa.nicoletti@isprambiente.it
Lucas Porz	Helmholtz-Zentrum Hereon	Germany	lucas.porz@hereon.de
Luke Batts	Marine Institute	Ireland	luke.batts@marine.ie
Mairi Fenton	Heriot-Watt University	UK	mmf13@hw.ac.uk
Mattias Sköld	University of Gotheburg	Sweden	mattias.skold@slu.se
Marina Penna	ISPRA	Italy	marina.penna@isprambiente.it
Marina Pulcini	ISPRA	Italy	marina.pulcini@isprambiente.it
Marta Rufino	IPMA	Portugal	marta.m.rufino@gmail.com
Marija Sciberras (chair)	Heriot-Watt University	UK	M.Sciberras@hw.ac.uk
Mats Blomqvist	HAFOK	Sweden	mb@hafok.se

Nadia Papadopoulou	HCMR	Greece	nadiapap@hcmr.gr
Neve McCann	Marine Institute	Ireland	Neve.McCann@marine.ie
Olivier Beauchard	NIOZ	Netherlands	olivier.beauchard@nioz.nl
Pascal Laffargue	Ifremer	France	Pascal.Laffargue@ifremer.fr
Paul Coleman	Marine Institute	Ireland	paul.coleman@marine.ie
Ruth Parker	CEFAS	UK	ruth.parker@cefas.gov.uk
Sandrine Vaz	Ifremer	France	Sandrine.Vaz@ifremer.fr
Sebastian Valanko	ICES		sebastian.valanko@ices.dk
Sebastiaan Vandevelde	Royal Belgian Institute of Natural Sciences	Belgium	svandevelde@naturalsciences.be
Stefan Bolam	CEFAS	UK	stefan.bolam@cefas.co.uk
Tobias Van Kooten	WUR	Netherlands	tobias.vankooten@wur.nl
Wenyan Zhang	Helmholtz-Zentrum Hereon	Germany	wenyan.zhang@hereon.de

Annex 2: WGFBIT Resolution

The **Working Group on Fisheries Benthic Impact and Trade-offs (WGFBIT)**, chaired by Gert van Hoey, Belgium; Jan-Geert Hiddink, UK; and Marija Sciberras, UK, will work on ToRs and generate deliverables as listed in the Table below.

	MEETING DATES	VENUE	REPORTING DETAILS	COMMENTS (CHANGE IN CHAIR, ETC.)
Year 2021	22–26 November	Palermo, Italy		
Year 2022	21–25 November	Sete, France		
Year 2023	20–24 November	Tvarminne, Finland	Final report by 15 January 2024 to SCICOM	

ToR descriptors

TOR	DESCRIPTION	BACKGROUND	SCIENCE PLAN TOPICS ADDRESSED	DURATION	EXPECTED DELIVERABLES
a	**REGIONAL ASSESSMENTS** Apply and improve theseafloor assessment framework developed by WGFBIT (2018–2020) to produce (sub-) regional assessments for the North, Celtic, Baltic, Arctic (Icelandic, Norwegian Barents sea), Mediterranean Seas and the Bay of Biscay and the Iberian Coast.	Produce a worked example of how science can operationalize EBM (ecosystem based management) and contribute towards IEAs (intergrated ecosystem assessment) as ICES advice products. I.e. develop an EU MSFD D6/D1 assessment with management options that can be applied also by non-EU ICES countries. Links (avoiding overlaps) will be established with key experts also attending WGECO, WGDEC, WGSFD, BEWG, MHWG, WGIMM, WGMBRED, and WGMPCZM.	1.9; 2.1; 2.4; 6.3	3 years	Year 1: a worked example for all regional seas, based on the preliminary achievements in the period 2018–2020. Initiating the 'pipeline process' for inclusion of relevant outputs to ecosystem overviews, starting with North and Baltic Sea. Year 2: Updating of the regional and sub-regional assessments for the different regions. Year 3: Final regional assessments of the impact of bottom abrasing fisheries for all regions in the ToR, which can feed into the ICES fishery and ecosystem overviews.
b	**UPDATES FOR ASSESSMENT FRAMEWORK** Explore and potentially implement options to improve the parameterisation of the WGFBIT seafloor	These updates can focus on following aspects: E.g. through; i) standardisation of benthos data sampled with different gears, ii) development of methods to predict	2.3; 2.4	3 years	Year 1- 3: Stepwise progress for the different aspects that can be tackled. Updates or adaptations need to feed in ToR A, to improve the regional assessments. If appropriate progress or

	assessment framework components, in shallow waters and deep-sea areas.	benthos longevity biomass in data poor areas, iii) integration of environmental drivers in the predictions, iv) improve the resolution of gear-specific depletion rates, v) estimation of parameter uncertainty			results, research paper(s) will be conducted.
c	**WGFBIT AND THE WIDER WORLD** Alignment of the WGFBIT seafloor assessment framework with other assessment methods for benthic habitats under relevant EU directives.	The WGFBIT seafloor assessment framework (based on assessing the relative benthic state) is not the only way to assess benthic impacts from physical disturbance. Therefore, alignment with other methods needs to be explored.	2.3; 2.4	3 years	Year 1-3: Research paper(s)
d	**ECOSYSTEM FUNCTIONING** Explore if ecosystem functioning can be incorporated more explicitly into the WGFBIT seafloor assessment methodology.	This can be done through examining the direct influence of bottom fishing on sediment parameters related to ecosystem functioning (e.g. apparent redox discontinuity potential layer). The link between total benthic community biomass and/or particular traits (e.g. longevity or sediment position) with biogeochemical parameters that are related to particular benthic ecosystem functions will also be explored – for this part links to work by BEWG and WGECO will be sought.	1.3; 1.9; 2.3	3 years	Year 1-3: Research paper(s)

Summary of the Work Plan

ToR a) **REGIONAL ASSESSMENTS**. Apply and improve the EU MSFD D6/D1 assessment framework related to bottom abrasion of fishing activity at the regional / subregional scale, which was developed by ICES WGFBIT (2018–2020). Priority will be given to improve the parameterisation of framework components at regional and sub-regional scale and with that also improve the overall assessment of benthic status and of alternative management options to achieve good environmental status (GES). The framework should remain generic enough that it allows cross regional comparison and specific enough that it addresses regional-specific trade-offs (i.e. incorporating other pressures than fisheries).

ToR b) **UPDATES FOR THE ASSESSMENT FRAMEWORK.** Explore and potentially implement options to improve the parameterisation of framework components. This can be done through the below action points.

i) The default WGFBIT seafloor assessment framework uses data collected by grab or box corer and therefore targeting the infauna. For some regions, such infauna data is not always available, and assessments are therefore based on epi-benthic data from trawl samples. The use of different sampling methodologies, with subsequent assessment focus on different parts of the ecosystem, has influence on the outcome. Therefore, these differences or commonalities in a regional context, need to be investigated,

ii) The determination of grid cell recovery values are based on longevity compositions sampled from unfished areas. In some regions this type of data is sparse, so alternative approaches/data are needed. A thorough investigation of this aspect will enlarge the WGFBIT assessment framework applicability and increase the confidence of the assessments,

iii) Application of the WGFBIT assessment framework for regional areas requires the development of statistically robust relationships between the benthic biomass longevity distribution and environmental drivers, such as depth, sediment, bottom shear stress, salinity, temperature, primary production, etc. For some regions it has been difficult to obtain meaningful relationships that distinguish sensitive and less sensitive areas spatially, and improved modelling (inclusion of more and better enviromental data across larger cross-regional scales) could potentially solve this,

iv) The gear-specific depletion rate of the assessment method is currently based on only 3 different metiers; beam trawl, otter trawl and dredges. Recent approaches have provided the basis for having a finer gear resolution of the depletion rates (cf Rijnsdorp *et al.*, 2020) and this should be pursued. Methodology to estimate the seabed disturbance area of passive fishing gears is on its way and inclusion of these gears in the assessment framework can be explored in alignment with ICES WGSFD, where these aspects are already being investigated,

v) It is necessary to quantify the uncertainty in the risk assessment methodology developed by WGFBIT. This is required to a) identify which input parameters and modelling steps account for the majority of the uncertainty, and therefore will benefit from efforts to reduce it (e.g. by carrying out further studies), and b) to map the distribution of the overall uncertainty in the assessment area in order to consider it when evaluating management scenarios. The utility of a bootstrapping approach will be explored.

ToR c) WG**FBIT AND THE WIDER WORLD**

i) Alternative EU MSFD D6/D1 assessment frameworks are under development. Comparing different methods has several advantages; 1) Multiple assessments with similar outcomes will increase the confidence of the assessment within a region, as locations with a low or high state/impact should be clearly distinguishable across assessment methods. Areas that differ between assessments, need more investigation, 2) Multiple assessments will help to improve approaches and the guiding of decision making. A more profound decision can be made, when it is based on several outputs.

ii) Threshold Values for determining adverse effects (and loss) and GES is highly requested for policy purpose in relation to: 1) impacts of physical pressures (and bio-geo-chemical pressures); 2) specific indicators (and response value levels) and 3) areal protection – what, where, how much and how strict? (securing ecosystem functioning). The lack of empirically based threshold values is an upcoming and increasingly urgent concern internationally (TG Seabed, HELCOM, OSPAR) and at the national level concerning the implementation of the EU MSFD D6C3 and D6C5, as well as for the D1 and D5. The options to integrate GES threshold values in WGFBIT will be explored by looking to current practices under the WFD and NATURA 2000 management at the national level.

ToR d) **ECOSYSTEM FUNCTIONING**

The WGFBIT seafloor assessment framework uses total benthic community biomass as key metric to assess seabed impacts under the assumption of a strong correlation with ecosystem functions such as carbon mineralization and nutrient cycling. We propose to test this assumption and investigate how ecosystem functioning can be incorporated into the PD methodology. This will not only ascertain that RBS is a good way forward, but also help us in setting thresholds for acceptable ecosystem impacts. This can be done through examining the direct influence of bottom fishing on sediment parameters related to ecosystem functioning (e.g. apparent redox discontinuity potential layer). The link between total benthic community biomass and/or particular traits (e.g. longevity or sediment position) with biogeochemical parameters that are related to particular benthic ecosystem functions will also be explored – for this part links to work by BEWG and WGECO will be sought.

Year 1	ToR a, b, c, d
Year 2	ToR a, b, c, d
Year 3	ToR a, b, c, d

Supporting information

Priority	The activities of this Group will lead ICES into issues related to the ecosystem effects of fisheries, especially with regard to the application of the Precautionary Approach. Consequently, these activities are considered to have a very high priority.
Resource requirements	Experts that provide the main input to this group have been involved in successful EU funded projects (BENTHIS). It is envisoned that future funding will be availble and that this ICES working group experts can also provide an international platform to establish a consortium. This would allow to commit future resources to the group’s work.
Participants	The Group is normally attended by around 30 members and guests.
Secretariat facilities	Standard support
Financial	No financial implications
Linkages to ACOM and groups under ACOM	Advice products and working groups (e.g. WGECO and WGDEC)

Linkages to other committees or groups	There is a very close working relationship with all the groups under the Ecosystem Pressures and Impacts Steering Group. It is also very relevant to the Workings Groups WGECO, WGDEC, WGSFD, BEWG, WGMHM, WGIMM, WGMBRED, WGMPCZM.
Linkages to other organizations	EU (DG-ENV, DG-MARE), RSCs (Baltic's HELCOM, North Atlantic's OSPAR, Mediterranean's Barcelona Convention and Black Sea's Bucharest Convention), JRC, STCEF.

Annex 3: Advice sheet template

ICES seafloor assessment of mobile bottom fishing: XXYY ecoregion

Assesment summary

This is an assessment of [UU] for region [VV] it is based on [XX] data and follows the methods described in [ZZ]. Bottom fishing is the single most important impact on the seafloor in this area. Impact from other sources which are important in this area are [XX], [YY] and [ZZ], but their impact is only a fraction of that of bottom fisheries (ICES 2019). [Which threshold is used (arbitrary or GES)? What is this advice to be used for?] References to the full assessment and advice documentation can be found below under 'Format of the assessment'.

Assessment results

Status in year [XX]

Map of sensitivity	*Map of abrasion (fishing and/or other)*
Map of Impact	*Map of uncertainty, preferably analogous to coefficient of variation (blank if not available)*

Figure 1 Variation across assessment of [UU] for region [VV]. Sensitivity (a) , pressure (b) and impact (c) with uncertainty of estimate presented (d). The indicators are explained in the technical guidelines for WGFBIT seafloor assessment (ICES 2021). n/a = not analysed.

Table 1. Summary of the pressure and impact indicators by (sub-)region for 0–200 and 200–800 m depths. The indicators are explained in the technical guidelines for WGFBIT seafloor assessment (ICES 2021). n/a = not analysed.

Habitat type (Eunis lvl X)	Area km2 (fraction of total)	Fraction untrawled (+-CI)	Mean SAR (+-CI)	Fraction SAR>[X] (+-CI)	Mean Impact (+-CI)	Fraction with impact below [X] (+-CI)
A	x (y)	..(..)	..(..)	..(..)	..(..)	..(..)
B	..(..)	..(..)	..(..)	..(..)	..(..)	..(..)
C	..(..)	..(..)	..(..)	..(..)	..(..)	..(..)
..	..(..)	..(..)	..(..)	..(..)	..(..)	..(..)
Total	..(..)	..(..)	..(..)	..(..)	..(..)	..(..)

Time trends

Plot of mean abrasion for each habitat type and total area over time	*Plot of mean impact for each habitat type and total by time (with conf limits)*	*Plot of fraction below specific threshold impact [X], for each habitat type and total, by time (with conf limits)*

Figure 1 Temporal trends for the assessment of [UU] for region [VV]. (a) Pressure presented as abrasion for each habitat type and total area over time, (b) mean impact for each habitat type and total by time (with conf limits), and (c) fraction below specific threshold impact [X], for each habitat type and total, by time (with conf limits). The indicators are explained in the technical guidelines for WGFBIT seafloor assessment (ICES 2021). n/a = not analysed.

Interpretation of results

[Brief interpretation of results (max ½ page). A verbal reference to factors in ecology, management and/or fishing practices which are important in understanding the indicated results. Whether the trends are related to changes in specific locations or not. Special emphasis on uncertainty map and significance of trends.]

Validity and limitations

[Summary of limitations and caveats, listed in the more detailed online assessment sheet, should be taken into account when considering the advice. These relate for example to issues concerning the provision of vessel data and their interpretation, the scale at which the data are informative, other important developments in the area (e.g. unfishable areas due to anoxia) and the information used to assess impact.]

Format of the assessment

This seafloor assessment of [UU] for region [VV] it consists of this PDF assessment text and a data product, consisting of a series of interactive maps and regional assessments and the VMS aggregated fishing data [REFS]. The seafloor assessment text should be read in conjunction with the interactive maps and can also be informed by the regional assessments. Within the text, references to the interactive maps and regional assessments and their specific "sections" are made. The limitations and caveats described in [VV] should be considered before using the data products.

The data product is [UU website].

[Diagram showing the various components of this seafloor assessment [UU] for region [VV]: the seafloor assessment text in PDF format and a ZIP file containing interactive maps, regional assessments, and the VMS aggregated fishing data in CSV and shapefile format. The aggregated CSV data products are provided by ICES to allow elements of this seafloor assessment to be incorporated into spatial analysis software, e.g. GIS software.]

Download the ZIP file.

Sources and references

ICES. 2019. EU request to advise on a seafloor assessment process for physical loss (D6C1, D6C4) and physical disturbance (D6C2) on benthic habitats. In Report of the ICES Advisory Committee, 2019. ICES Advice 2019, sr.2019.25, https://doi.org/10.17895/ices.advice.5742.