WORKING GROUP ON FISHERIES BENTHIC IMPACT AND TRADE-OFFS (WGFBIT; outputs from 2019 meeting)

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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. WGFBIT has attempted to per-form these assessments for as many regions as possible, and for each region indicate, prioritize and execute (if feasible) potential improvements. In order to broadly anchor the assessment methodology, demonstrate its utility and flexibility and identify relevant data gaps and appropriate improvement potentials it was key that each assessment was per-formed and discussed by the regional experts at the meeting.

The FBIT assessment framework was successfully applied in 5 ecoregions; the Arctic Sea, the Baltic Sea, the North Sea, the Celtic Sea and the Mediterranean Sea, with variable level of completeness and robustness. Standard structured regional outputs from the WGFBIT assessment workflow, in terms of pressure, sensitivity and impact estimates, were produced and presented for each region. This is a significant step towards the WGFBIT term of reference 'to produce a framework for MSFD D6/D1 assessment related to bottom abrasion of fishing activity at the regional scale'.

An additional outcome from the assessments was an increased consensus and appreciation of the utility of the FBIT assessment framework. Each regional group identified where and how the assessment and methodology could be further improved; e.g. the need for updated and region-wide fishing pressure data and the inclusion of additional region-specific environmental variables in the estimation of habitat sensitivity. Moreover, a strategy was agreed on to further operationalize the current ecoregion assessments as well as bring in additional ecoregions.

Four intersessional subgroups (trade-off, deep sea, data-script management, communication and advice) were established to facilitate future advances in the work of WGFBIT. These groups will be seeking to update and increase coverage of fishing pressure data (mainly for the Mediterranean), develop longevity estimation methods for deep-sea species and habitats, refine assessment approaches, integrate additional physical disturbance pressures, in addition to fishing, in the assessment and further develop communication material addressing dissemination of the methodological details, the actual assessment procedures and standardized workflow.

ii Expert group information

Expert group name	Working group on Fishery Benthic impact and trade-off (WGFBIT)
Expert group cycle	Multiannual
Year cycle started	2018
Reporting year in cycle	2/3
Chair(s)	Gert Van Hoey, Belgium
	Tobias Van Kooten, the Netherlands
	Ole Ritzau Eigaard, Denmark
Meeting venue and dates	7–11 October 2019, Ancona, Italy (33 participants)

1 Background and introduction

The main purpose of the Fisheries Benthic Impact and Trade-offs working group (WGFBIT) 2019 meeting was to execute the benthic impact assessment framework for mobile bottom-contacting fishing gears (MBCGs) for as many regions as possible. The assessment framework follows earlier ICES advice in 2016 and 2017 in response to requests of DG ENV. To make such assessment possible, an assessment tutorial was given to guide the experts through the assessment procedure, which is now on GitHub (see: ices-eg/ FBIT) to ensure TAF. The MSY-type of approach in fish stock assessment was not adopted overnight and similarly the benthic assessment procedure will need to be established stepwise with experts that adopt the new methods and take them forward. Thus, the emphasis of this second year of WGFBIT was to allow experts to run the assessments and calibrate them to their ecoregions, with available data collated by the attendees. For each region, outputs were produced in the form of standardized "fact sheets" (see next chapter) that can be used to produce demonstration advice. The development of how this standard advice sheet looks (scope, target audience) will need to be further refined within an inter-sessional sub-group on communication. The products developed can be considered as input towards the next generation of the ICES Ecosystem Overviews (link). The assessments are produced with the latest VMS data collated by WGSFD and using the ICESvms package developed by the ICES secretariat. For the Mediterranean sub-regions that were assessed, a fishing pressure data set from the BENTHIS project was used (Eigaard *et al.* 2017). The regional assessment fact sheets are provided in Chapter 3.

Beside the work with implementation of as many regional assessments as possible, some general methodological issues were tackled during the meeting, concerning availability of longevity data, use of biomass versus abundance data and the applicability of the FBIT framework to incorporate other pressures. The outcomes of these methodological investigations are presented in Chapter 4.

A number of WGFBIT participants presented related scientific work during a daily after-lunch-break science session. Short summaries of the presentations are provided in Chapter 5.

Finally, four intersessional subgroups (**trade-off, deep sea, data and script management, communication and advice**) were established to facilitate advances in the agreed work plan towards meeting the objectives for next meeting. A short summary of group rationales as well as the work plans are reported in Chapter 6.

2 Summary of outcomes and conclusions

Main conclusions from WGFBIT 2019:

- Successful application of the FBIT framework in 5 regions with variable level of completeness and robustness.
- Increased consensus and utility of executing the FBIT framework.
- A strategy was agreed on whom and what would be required to further operationalize the ecoregions and bring in other ecoregions to the assessment procedure.
- Identified where the assessment could be further improved with better data for full application.
- FBIT agreed that a number of intersessional subgroups are formed (trade-off, deep sea, data-script management, communication) to advance in the work plan.
- More recent and complete fishery pressure data Mediterranean is needed.
- Deep-sea longevity methods proposed, based on WGDEC input.
- It was agreed to advance the trade-off calculations further based on the WKTRADE2 outputs.
- The FBIT framework has been a key component of the recent ICES advice process to the EU on a seafloor aassessment process for physical loss (D6C1, D6C4) and physical disturbance (D6C2) on benthic habitats. FBIT ddefinitions were updated accordingly, allowing future iterations to better accommodate other pressures than abrasion (namely: removal, depositions and sealing).
- Further development of communication material to target managers (i.e. EU's TG Sea-Bed), as well as further refinement of standard "advisory products" based on the assessment was agreed and initiated.

3 Regional specific reports

Table 1 provides an overview of 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. Of course, the assessments are preliminary and many steps need further developmental work, as indicated in the regional specific reports. Nevertheless, we are currently at the stage where the proof of concept is made and we can start to refine the different steps and also focus more on validation and confidence.

Table 1. Overview of the progress in the implementation of the FBIT framework in each region.

	ECOREGION		**Arctic Region**		**Baltic Region**	**North Sea region**	**Celtic Region**	**Mediterranean region**
	SUB-REGION		Barents Sea	Norwegian Sea	ALL	ALL	ALL	Adriatic + Italian coastal waters
STEP 1	**Pressure layer information**							
	ICES VMS call (WGSFD)		Otter trawls only, 2018	Otter trawls only, 2018	2018	2018	2015	
	BENTHIS Eigaard *et al.*, 2017							V
STEP 2	**Habitat information**							
	EUSeamap (July 2019)		MSFD broad habitat types	MSFD broad habitat types	MSFD broad habitat types	MSFD broad habitat types	MSFD broad habitat types	MSFD broad habitat types
	Eunis (2016)							
STEP 3	**Construction longevity curves**							
	Longevity traits info		updated and more longevity classes		Benthis	Benthis	Benthis	HCMR & Benthis
	Continuous Environmental variables	Benthic samples low fishery			and low anoxia	Rijnsdorp *et al.*, 2018		
		Benthic samples entire fishery gradient	V	V				V
	EUSeamap	Benthic samples low fishery						

		Benthic samples entire fishery gradient					V	
		Longevity relation from other region						
STEP 4	**Impact assessment**		2018, preliminary	2018, preliminary	2018	2009 - 2018	2015	Test of framework
STEP 5	**Validation**		To do	To do	To do	To do	To do	To do
STEP 6	**Confidence / uncertainty**		To do	To do	To do	Preliminary analyse executed	To do	To do
STEP 7	**Trade-off**		To do	To do	To do	ICES, 2017	To do	To do

3.1 Arctic Sea

General info

Original Code

https://github.com/ices-eg/FBIT/tree/dev

Adapted code for Arctic Sea

https://github/Arctic

Contributors ***(in alphabetic order)***

Julian Borgos, Lis Lindal Jorgesen, Lene-Buhl Mortensen

Datasets

Seabed Sampling: Joint Annual Norwegian-Russian Ecosystem Survey and MAREANO program

Seabed Habitat: EMODnet seabed habitat data portal (EUSeamap 2017)

Fishing Effort: Extraction from ICES VMS/Logbook data call made for WGFBIT 2019

Step 1: Assign region of interest

During the 2019 meeting of the WGFBIT, two independent assessments were carried out in areas of the Barents Sea and Norwegian Sea Ecoregions using two distinct sources of data:

a) By-catch data from bottom trawls conducted as part of the Joint Annual Norwegian-Russian Ecosystem Survey in the Norwegian sector of the Barents Sea (Jørgensen *et al.* 2015, 2016, 2019). The data included in this assessment was collected in two periods, 2011–2013 and 2015–2017, and consisted of a total of 425 taxa captured in 779 bottom trawls.

b) Beam-trawl data from the national MAREANO programme mapping: bathymetry, geology, pollutants, benthos diversity and vulnerable ecosystems (Buhl-Mortensen *et al.* 2015 a, b). The data consisted of benthos recorded from 268 samples collected by beam-trawl (each covering ~460 m^2 of seafloor) collected between 2006 and 2014. The data included biomass and count of a total of 1796 taxa. Stations were from areas covered by the MAREANO programme and covered parts of the Norwegian Sea and the Barents Sea (Figure 1).

Each of the two assessments was carried out within a polygon defined by the proximity of the sampling locations, in order to avoid extrapolations to areas were no information is available about the distribution of benthic organisms (Figure 1).

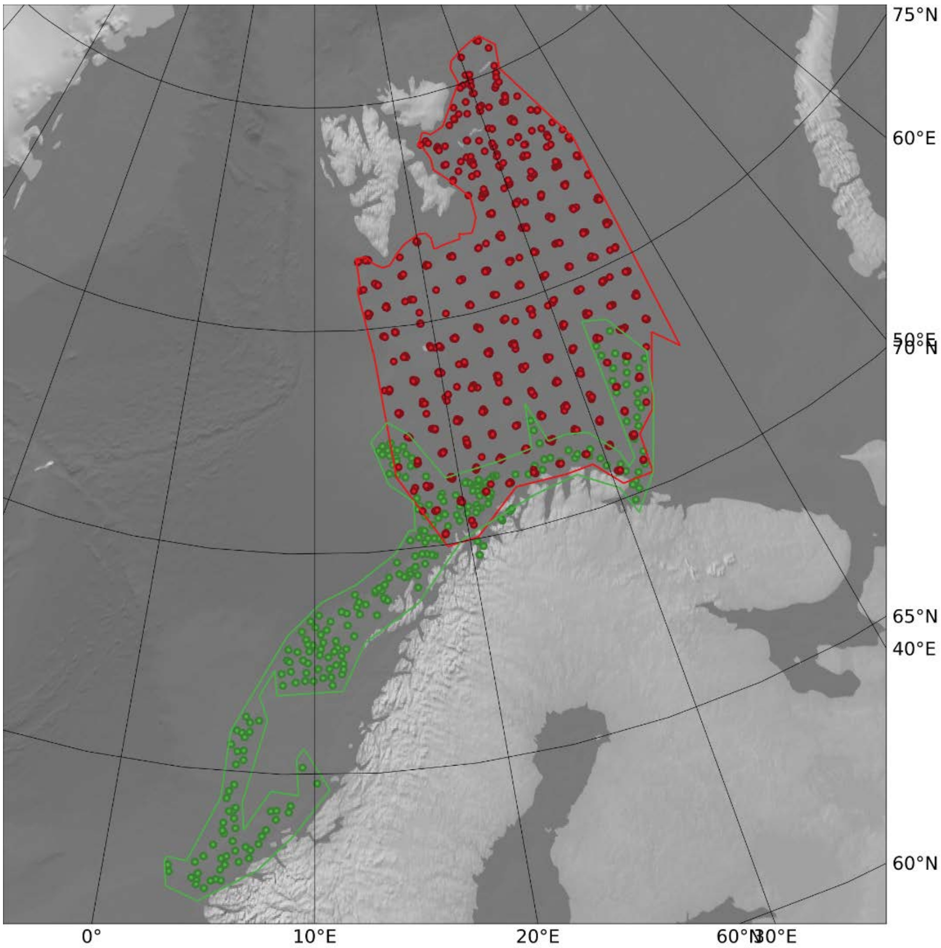

Figure 1. Sampling locations of bottom trawls from the Joint Annual Norwegian-Russian Ecosystem Survey (in red) and the MAREANO programme beam-trawls (in green). The polygons show the assessment areas based on each source.

Step 2: Pressure layer information

Annual estimates of abrasion for the period 2009–2018 were estimated from VMS data reported to ICES. In this period, fishing activity from otter trawlers and purse seiners was reported for the Barents Sea and the Norwegian Shelf, except for 2009 and 2018 when only otter trawlers were reported. Abrasion estimates for 2018 are shown in Figure 2 and Figure 3. Similar to other years, fishing intensity in 2018 was relatively low and unevenly distribution.

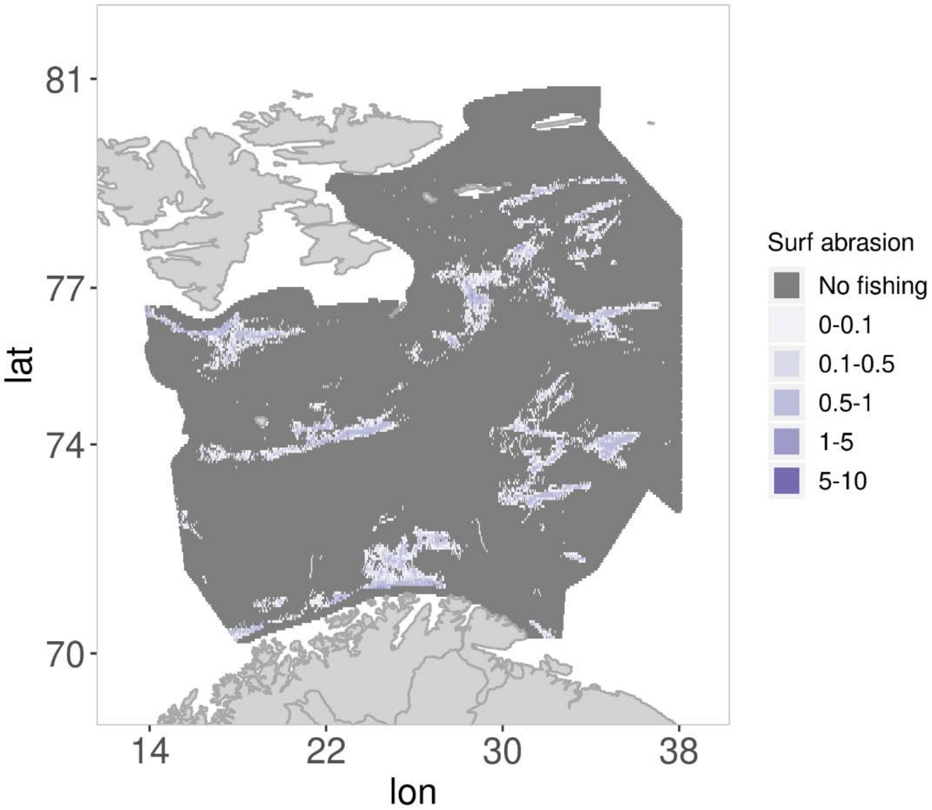

Figure 2. Swept area ratio (SAR) from otter trawlers (OT) during 2018 in the Barents Sea.

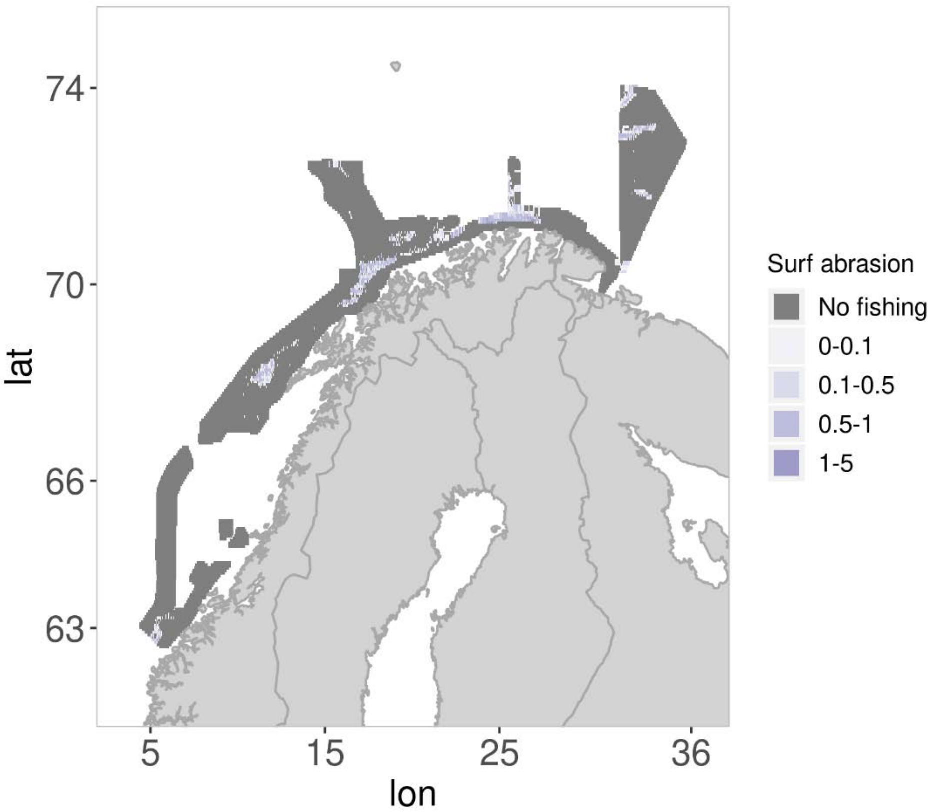

Figure 3. Swept area ratio (SAR) from otter trawlers (OT) during 2018 in the Norwegian Shelf and southern Barents Sea.

Table 2. Mean swept area ratio (SAR) from otter trawlers in 2018 by MSDF habitat type in the assessment areas.

MSDF habitat	Barents Sea	Norwegian shelf and southern Barents Sea
Abyssal	NA	0
Circalittoral coarse sediment	0.00034	0.128
Circalittoral mixed sediment	0.00274	NA
Circalittoral mud	0.001	0
Circalittoral rock and biogenic reef	0	0.0418
Circalittoral sand	0	0
Infralittoral coarse sediment	0.047	0.917
Infralittoral mixed sediment	0	NA
Infralittoral mud	0	NA
Infralittoral rock and biogenic reef	0	0
Lower bathyal rock and biogenic reef	NA	0
Lower bathyal sediment	0	0
Offshore circalittoral coarse sediment	0.0612	0.229
Offshore circalittoral mixed sediment	0.0688	NA
Offshore circalittoral mud	0.0501	0.0809
Offshore circalittoral rock and biogenic reef	0.00746	0.0399
Offshore circalittoral sand	0.122	0.203
Upper bathyal rock and biogenic reef	0.0625	0.0186
Upper bathyal sediment	0.0957	0.0914

Step 3: Habitat information

Broad scale MSFD habitats (Euseamap 2019).

Step 4: Estimation of longevity relationship

The methodology adopted by WGFBIT to evaluate the sensitivity of benthic environments to bottom trawling is based on the estimation of the mean longevity of the benthic community. The original methodology was based on four longevity classes: Less than 1 year, 1–3 years, 3–10 years and more than 10 years. In the case of the trawl by-catch data, and to some degree for the beam-trawl data, small organisms that often have low longevity were rarely caught while larger and often more long-lived species are more common. This produced a longevity distribution that was skewed towards the two higher classes, which did not allow the assessment model to converge. To make the longevity classes more relevant, 552 taxa of benthic organisms were reclassified into six longevity classes: < 2 years, 2–5 years, 5–10 years, 10–20 years, 20–50 years and > 50 years. These taxa accounted for most of the sampled biomass and did not included taxa from the hyperbenthos. Longevity estimates were based on literature, existing longevity databases (Degen and Faulwetter 2019, the trait list from BENTHIS), and on expert judgement.

To estimate the mean longevity in both assessment areas we utilized three predictors:

- Bottom depth, derived from the General Bathymetric Chart of the Oceans (GEBCO).
- Bottom temperature, estimated from data collected in the NISE (Norwegian Iceland Seas Experiment) project (Buhl-Mortensen *et al.* 2019).
- Sediment grain size, data provided by the Geological Survey of Norway.

In each assessment area a total of eight longevity models were fitted, with different combinations of the three predictors and interactions with longevity. Models were fitted used only data from stations where no fishing was reported in the period 2009–2018. The best model was selected based on the Akaike Information Criterion (AIC) value. For the assessment in the Barents Sea, the best model included the three predictors, plus an interaction term between longevity and grain size. For the Norwegian shelf and southern Barents Sea assessment, the model with the lowest AIC value only included depth as a predictor (result not shown), but because this model tended to significantly overpredict the mean longevity in the deeper areas we used the same model as in the Barents Sea. Model results are shown in Table 3.

Table 3. Akaike Information Criterion values for the eight longevity models tested in the two assessment areas: the Barents Sea, and the Norwegian Shelf and southern Barents Sea. The terms of the models included different combinations of longevity (ll), temperature (temp), depth, and sediment grain size (grain). The c-square was included in the models as a random term (1 | ID). Models 6, 7 and 8 included an interaction term between longevity and one of the environmental predictors. Only stations where no fishing was reported were used in this analysis.

Model	Terms	Barents Sea	Norwegian Shelf and southern Barents Sea
1	ll + (1 | ID)	398.99	421.92
2	ll + temp + (1 | ID)	400.63	422.75
3	ll + depth + (1 | ID)	399.32	420.56
4	ll + grain + (1 | ID)	400.88	423.90
5	ll + temp + depth + grain + (1 | ID)	400.33	424.52
6	ll + temp * ll + depth + grain + (1 | ID)	402.29	425.20
7	ll + temp + depth * ll+ grain + (1 | ID)	372.92	424.69
8	ll + temp + depth + grain * ll+ (1 | ID)	386.28	426.41

The model selected was used to predict the mean longevity in both assessment areas as function of bottom temperature, depth, and grain size (Figure 4 and Figure 5). The mean longevity is considered a measurement of the seabed sensitivity to bottom trawling.

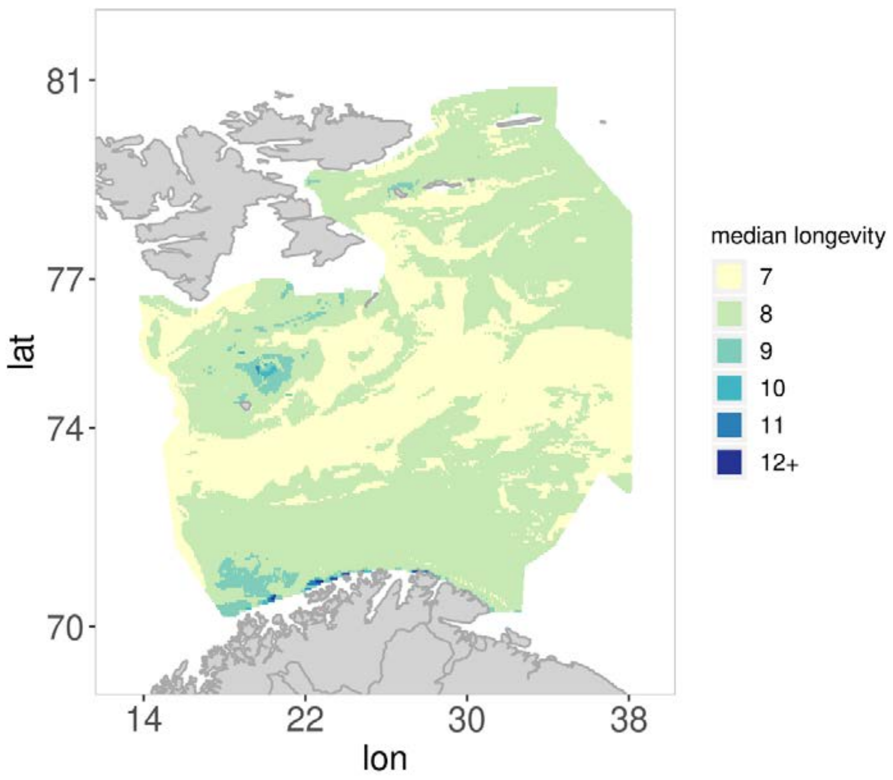

Figure 4. Mean longevity of the benthic community in the Barents Sea, estimated from by-catch data from the Joint Annual Norwegian-Russian Ecosystem Survey.

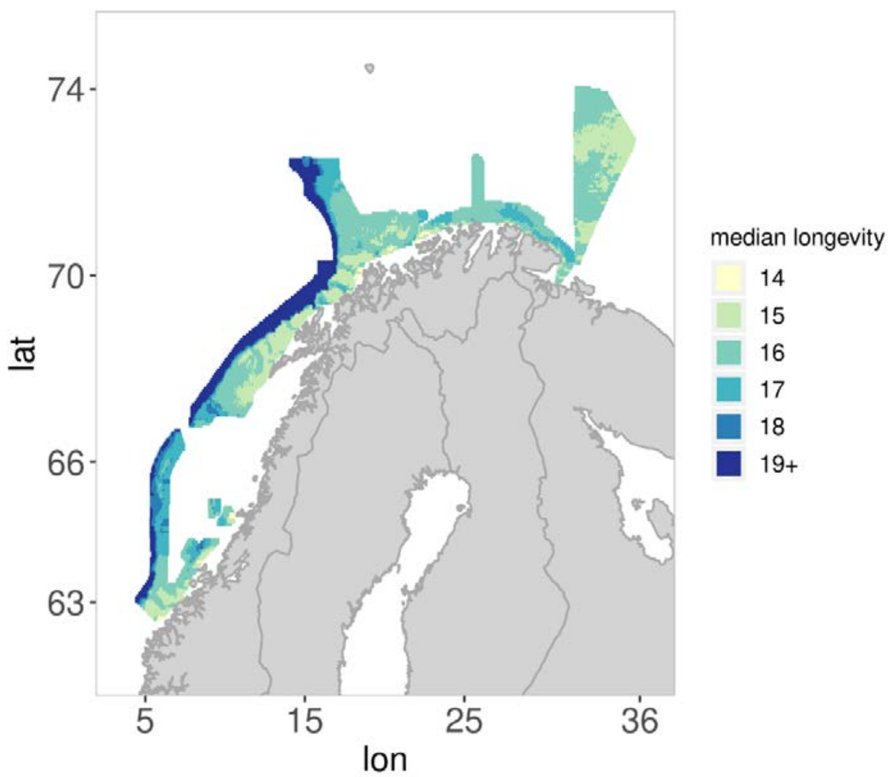

Figure 5. Mean longevity of the benthic community in the Norwegian Shelf and southern Barents Sea, estimated from beam-trawl data from the MAREANO programme.

Step 5: Impact assessment

The relative benthic status (RBS) was obtained for the years 2009–2018. Figure 6 and Figure 7 show the relative benthic status (RBS) in 2018 in both assessment areas. In general, the abrasion impact values obtained from the beam-trawl data are higher than those obtained from the by-catch of the fishery survey in the Barents Sea (Table 4).

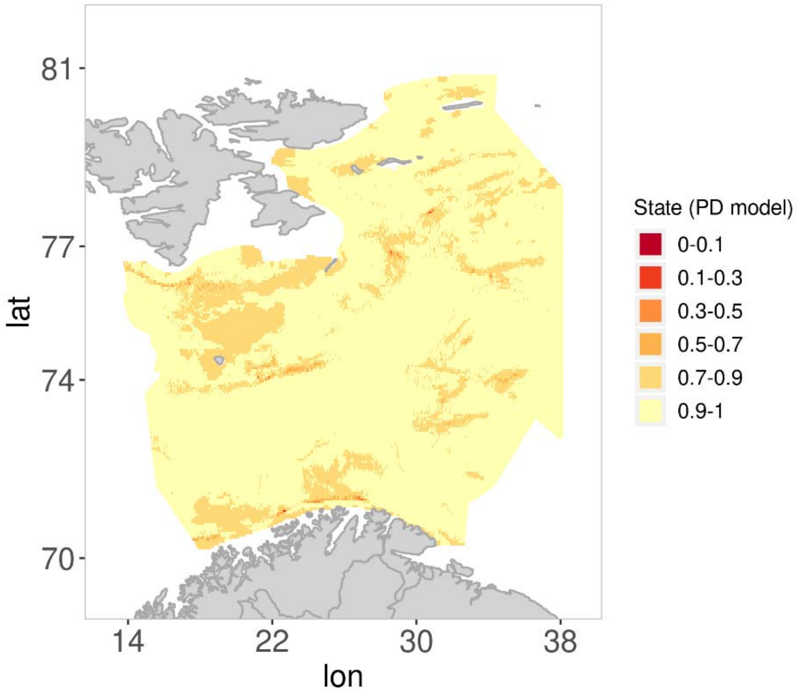

Figure 6. Relative benthic status (RBS) in the Barents Sea in 2018.

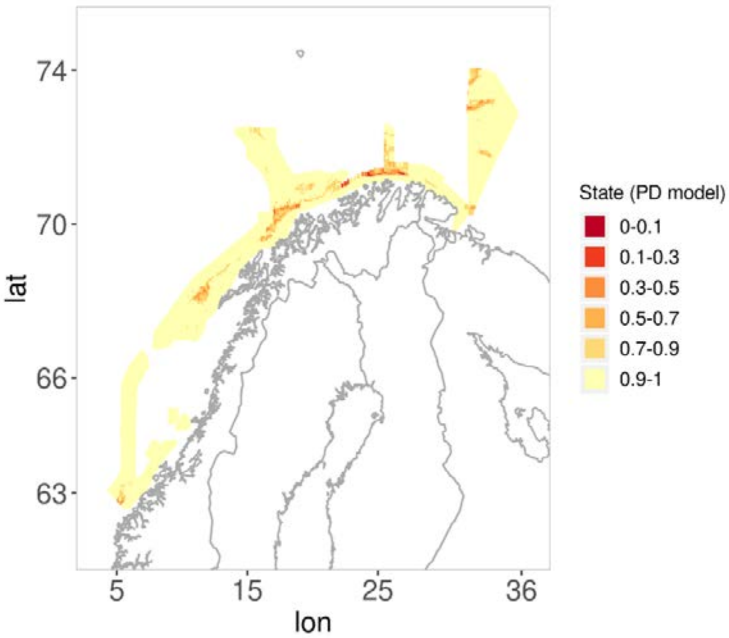

Figure 7. Relative benthic status (RBS) in the Norwegian Shelf and southern Barents Sea in 2018.

Table 4. Mean relative benthic status (RBS) in the assessment areas in 2018 by MSFD habitat.

MSDF habitat	Barents Sea	Norwegian shelf and southern Barents Sea
Abyssal	NA	1.000
Circalittoral coarse sediment	1.000	0.971
Circalittoral mixed sediment	1.000	NA
Circalittoral mud	1.000	1.000
Circalittoral rock and biogenic reef	1.000	0.991
Circalittoral sand	1.000	1.000
Infralittoral coarse sediment	0.995	0.799
Infralittoral mixed sediment	1.000	NA
Infralittoral mud	1.000	NA
Infralittoral rock and biogenic reef	1.000	1.000
Lower bathyal rock and biogenic reef	NA	1.000
Lower bathyal sediment	1.000	1.000
Na	1.000	NA
Offshore circalittoral coarse sediment	0.994	0.946
Offshore circalittoral mixed sediment	0.994	NA
Offshore circalittoral mud	0.995	0.977
Offshore circalittoral rock and biogenic reef	0.999	0.990
Offshore circalittoral sand	0.987	0.953
Upper bathyal rock and biogenic reef	0.995	0.995
Upper bathyal sediment	0.991	0.979

Steps 6, 7 and 8: Validation, Confidence and trade-off

These aspects are not yet taken forward.

Conclusions

The analysis presented were carried out in order to test the applicability of the assessment methodology on the Barents Sea and Norwegian Shelf. The results should be considered as preliminary.

Further analyses are needed to confirm the validity of the longevity models. For the purposes of testing the assessment methodology we utilized three environmental variables to predict the longevity of the benthic community: depth, bottom temperature, and sediment grain size. It is apparent that these variables alone cannot predict with enough accuracy the distribution of longevity values in an area with high environmental variability and diversity of benthic habitats such as the Norwegian Shelf and Barents Sea. For example, recent biotope maps obtained by MAREANO for the southern Barents Sea revealed a diversity of benthic communities and spatial patterns that are not reflected in the maps of estimated mean longevity. We consider that is necessary to further develop the longevity models, by incorporating additional environmental predictors and by comparing the resulting patterns of predicted longevity with the longevity of the species in areas where detailed biotope maps are available.

The differences in mean longevity estimates and relative benthic status values obtained in the southern Barents Sea from both data sources, the Joint Annual Norwegian-Russian Ecosystem Survey (fish-trawl) and the MAREANO programme (2m beam trawl) suggest that the assessment methodology is susceptible to the degree to which the benthic community is represented in the samples. This introduces difficulties when comparing RBS values obtained in different areas with different sampling gear. Further work is necessary to understand the effect of different sampling gears in characterizing the distribution of biomass in the different longevity classes and its effect in the assessment results. In this regard, the analysis of predicted longevities in areas sampled with multiple gear types may provide some insights.

3.2 Baltic Sea

General info

Original Code

https://github.com/ices-eg/FBIT/tree/dev

Adapted code for Baltic Sea

The code is stored on the WGFBIT sharepoint at

https://community.ices.dk/ExpertGroups/WGFBIT/

under '0.7 Software/Baltic'

Contributors *(in alphabetic order)*

Grete E. Dinesen, Josefine Egekvist, P. Daniel van Denderen, Francois Bastardie, Mattias Sköld, Sebastian Valanko and Ole R. Eigaard.

Datasets

Seabed Sampling: Gogina *et al.* (2019)

Seabed Habitat: EMODnet seabed habitat data portal (EUSeamap 2017)

Fishing Effort: Extraction from ICES VMS/Logbook data call made for WGFBIT 2019

Step 1: Assign region of interest

The entire Baltic region was taken into account for the assessment.

Step 2: Pressure layer information

Fisheries using mobile bottom-contacting gears (MBCGs) mostly take place in the south-western part of the Baltic Sea ecoregion (Figure 8).

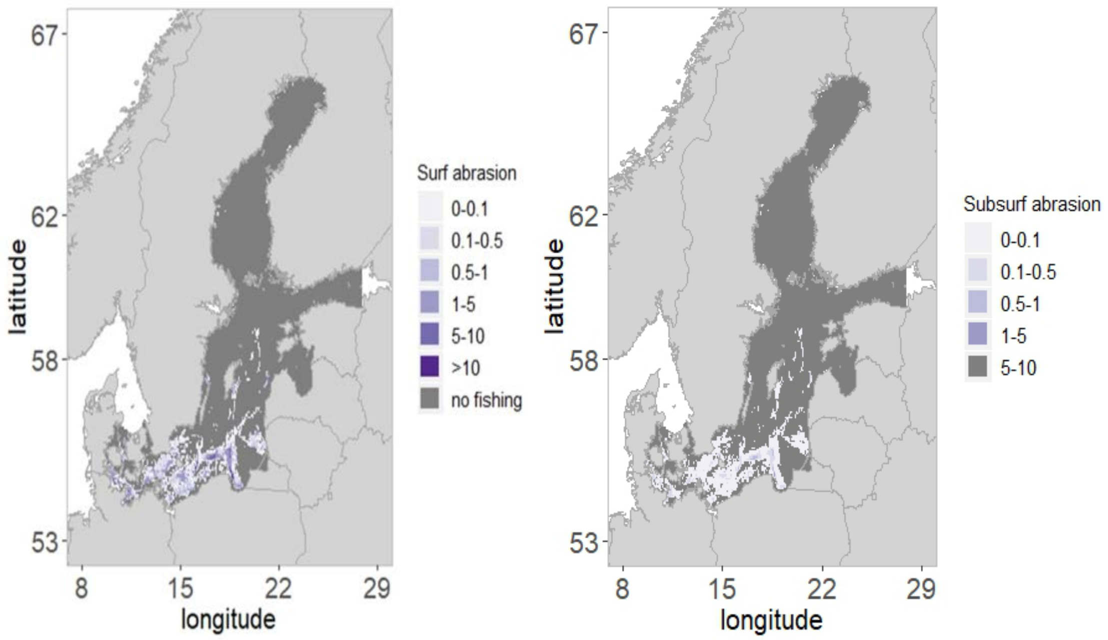

Figure 8. Map of surface (0–2 cm sediment depth) and subsurface abrasion (>2 cm) based on VMS and logbook data for all mobile bottom-contacting gears in 2018. Coverage incomplete, only c-squares with records from ≥3 vessels were included due to data confidentially issues.

Five ICES standard indicators for fishing pressure and two for fishing impact (ICES, 2017) were estimated based on 2018 effort data (Table 5). The total MBCG footprint covered 5.2% of the ecoregion area (indicator 3) and average intensity was 0.095 annual swept area ratio (SAR year^{-1}) (indicator 1) across the full ecoregion. The fishery had 90% of the effort within 5% of the grid cells (c-squares) of the ecoregion (indicator 4), and with a total proportion of grid cells fished of 14% (indicator 2) the fishery is very concentrated and has a substantial number of grid cells that are marginally fished. Average impact is estimated to 0.01 (indicator 7) and the proportion of area with impact < 0.2 is 0.99 (Table 5).

Table 5. ICES standard indicators for fishing pressure for the Baltic Sea based on 2018 effort data.

Fishing pressure indicators	Value
Indicator 1 intensity	0.095
Indicator 2 proportion of grid cells fished (fished irrespective of swept area > 0.001)	0.144
Indicator 3 proportion of area fished	0.052
Indicator 4 aggregation of fishing pressure	0.051
Indicator 6 average impact	0.010
Indicator 7 proportion of area with impact < 0.2	0.988

An additional table was produced outside the current workflow, providing landing weight and total landing value of the individual fishery métiers based on 2018 effort data (Table 6).

Table 6. Catch values (in total weight, kg and total value, €) of 2018 by fisheries métiers.

DCF metier level 6	total_weight (kg)	total_value (€)
OTB_DEF_<16_0_0	74146	25895
OTB_DEF_>=105_1_120	24231790	22941021
OTB_DEF_>=120_0_0	788133	783668
OTB_DEF_100-119_0_0	530	841
OTB_DEF_90-104_0_0	781445	1207447
OTB_FWS_>0_0_0	213413	263913
OTB_SPF_16-104_0_0	3298530	488322
OTB_SPF_16-31_0_0	2868021	519560
OTB_SPF_32-104_0_0	116524	52576
OTB_SPF_32-89_0_0	9132	13297
OTT_DEF_>=105_1_120	159800	187931
OTT_DEF_>=120_0_0	934	1129
PTB_DEF_>=105_1_120	108883	202950
PTB_FWS_>0_0_0	805507	3561926
PTB_SPF_>=105_1_120	6000	1158
PTB_SPF_16-104_0_0	65700	73664
PTB_SPF_16-31_0_0	268500	59323
PTB_SPF_32-104_0_0	79174	31711
PTB_SPF_32-89_0_0	436656	118770
SDN_DEF_>=105_1_120	137428	193662

The depletion rates per gear type in this Baltic Ecoregion fishery impact assessment test run (Table 7) were based on the values provided in Hiddink *et al.* (2017).

Table 7. Depletion rates per gear type (values from Hiddink *et al.* 2017, Table S4).

Gear type	Depletion rate
Otter trawls (OT)	0.06
Demersal seines (DS)	0.06

Only otter trawls and demersal seine gears were included in the fishing pressure layer due to data confidentiality (see Figure 1, caption), which means that a small Danish fishery for blue mussels in the inner Danish waters is not accounted for in the summary of effort.

Step 3: Habitat information

The EUSeaMAP 2019 (version July 2019) layer="EUSM_BalticSea" was used as basis for delineation of MSFD Broad Scale Habitats in the Baltic Sea region (Table 8). It should be noted that the EUSeaMAP 2019 is based on geological information of highly varying spatial resolution.

Table 8. Spatial coverage (km²) and proportion of total seabed area (%) of the individual MSFD Broad Scale Habitats in the Baltic Sea region, delineated from the EUSeaMap 2019 (version July 2019).

MSFD broad habitat type	Area (km^2)	Pct
Circalittoral coarse sediment	11098	2.9
Circalittoral mixed sediment	108284	28.7
Circalittoral mud	22803	6.0
Circalittoral mud or Circalittoral sand	52514	13.9
Circalittoral rock and biogenic reef	6406	1.7
Circalittoral sand	32933	8.7
Infralittoral coarse sediment	7501	2.0
Infralittoral mixed sediment	21369	5.7
Infralittoral mud	2354	0.6
Infralittoral mud or Infralittoral sand	3941	1.0
Infralittoral rock and biogenic reef	4110	1.1
Infralittoral sand	25854	6.8
Offshore circalittoral coarse sediment	807	0.2
Offshore circalittoral mixed sediment	19757	5.2
Offshore circalittoral mud	21092	5.6
Offshore circalittoral mud or Offshore circalittoral sand	33869	9.0
Offshore circalittoral rock and biogenic reef	287	0.1
Offshore circalittoral sand	2672	0.7
Na	76	0.0
Total	**377652**	**100.0**

Step 4: Estimate of longevity relationship

Benthic longevity estimates for the Baltic Sea ecoregion were based on macrofauna data from Gogina *et al.* (2016). This dataset has information on macrofauna biomass for 2268 locations. Each location contains one or multiple sampling events, taken in different years or different periods in the year, that are aggregated to a 5 x 5 km cell. At all locations, benthic samples were collected with box-cores or grab-samplers. For each location, species were linked to a species-by-trait matrix of longevity (see link for dataset). Benthic longevity information was derived from available literature (Törnroos and Bonsdorff, 2012; Bolam *et al.*, 2014, 2017).

In order to estimate benthic longevity, sampling locations were selected that are largely undisturbed by fishing or hypoxia in order to derive, as far as possible, an undisturbed reference state. For this reason, locations with average fishing intensities > 0.1 in years 2012 - 2016 and/or oxygen concentrations < 3.2 ml O_2 per L in one season were removed. Oxygen concentrations were estimated using model output from the coupled hydrographical and biogeochemical model ERGOM-MOM (Schernewski *et al.*, 2015). After the removal, 1558 locations were retained in the dataset and used in the analysis of benthic longevity.

The cumulative biomass-longevity relationship was estimated based on Generalized Linear Mixed Models (GLMMs) using a stepwise forward selection approach and including fixed variables of bottom water salinity, depth and seabed shear stress and assuming stations as random variables. The statistical model analysis is based on a similar approach as in Rijnsdorp *et al.* (2018). Alternative model versions were compared using the Akaike information criterion (AIC) and Model #4 was identified as fitting the data best (Table 5).

Table 9. Results from fitting linear mixed effects models with station (ID) as random variable and salinity, depth and bottom sheer stress as fixed independent variables to the longevity response variable.#

Models	AIC
1 glmer(Cumb ~ ll + Salinity + Depth + Stress + (1 | ID)	2600
2 update(mod1, ~ . + ll*Salinity + ll*Depth)	2561
4 update(mod1, ~ . + ll*Salinity + Depth*Salinity + ll*Depth)	2525
5 update(mod1, ~ . + ll*Salinity + Depth*Salinity + ll*Depth - Stress)	2557

#Model 3 (update(mod1, ~ . + ll*Salinity + Depth*Salinity) could not be run without violation.

The parameter estimates of the best fitting model (model #4 in Table 9) were used to predict the median longevity in each c-square in the Baltic Sea (Figure 9).

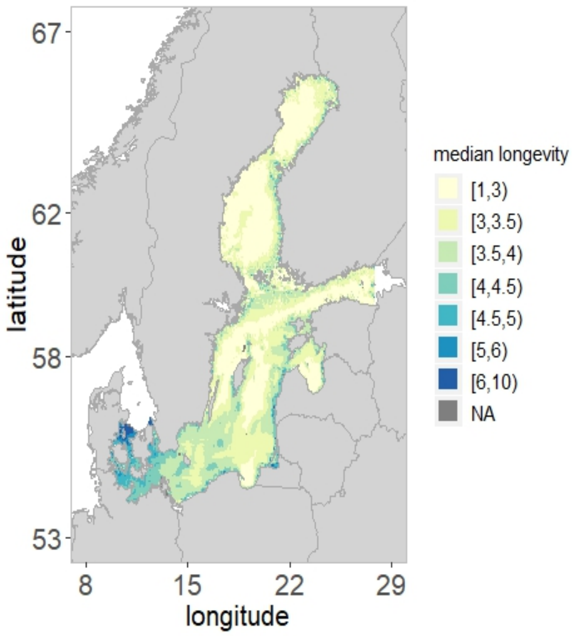

Figure 9. The predicted median longevity of the Baltic Sea ecoregion. It should be noted that c-squares with low bottom oxygen levels (<3.2 mg L^{-1}) were not excluded in the sensitivity assessment.

Sediment was not included in this demonstration run of the assessment due to lack of data. This variable is highly important in structuring the benthic fauna composition and thus essential to include in estimation of biomass-longevity relationships. Preferably, this variable should be included in the statistical models as a continuous variable, alternatively as a categorical variable.

Habitats in the Baltic Sea are subjected to low oxygen concentrations in many areas, notably in the deeper basins, of the Baltic Sea. In shallower coastal hypoxia may occur during the summer months in connection with high water temperatures. Infrequent influx of high saline oxygenated water combined with nutrient enrichment is a major cause of hypoxia and anoxia, which strongly influence community composition of benthic habitats throughout the Baltic Sea.

Permanent anoxic areas can be considered an azoic habitat and should be omitted from the dataset prior to the prediction of median longevity by c-square. Bottom oxygen data are available via the Baltic Sea-Ice Ocean Model (BSIOM for the period 1979–2018); (Lehman *et al.* 2014).

Step 5: Impact assessment

The estimated state of the benthic habitats is good across very large areas of the Baltic Sea, when based on an assessment where all other pressures than fishing are ignored (Figure 10, left). This is also reflected in an Indicator 7 value of 0.99 (proportion of area with impact < 0.2) (Table 10).

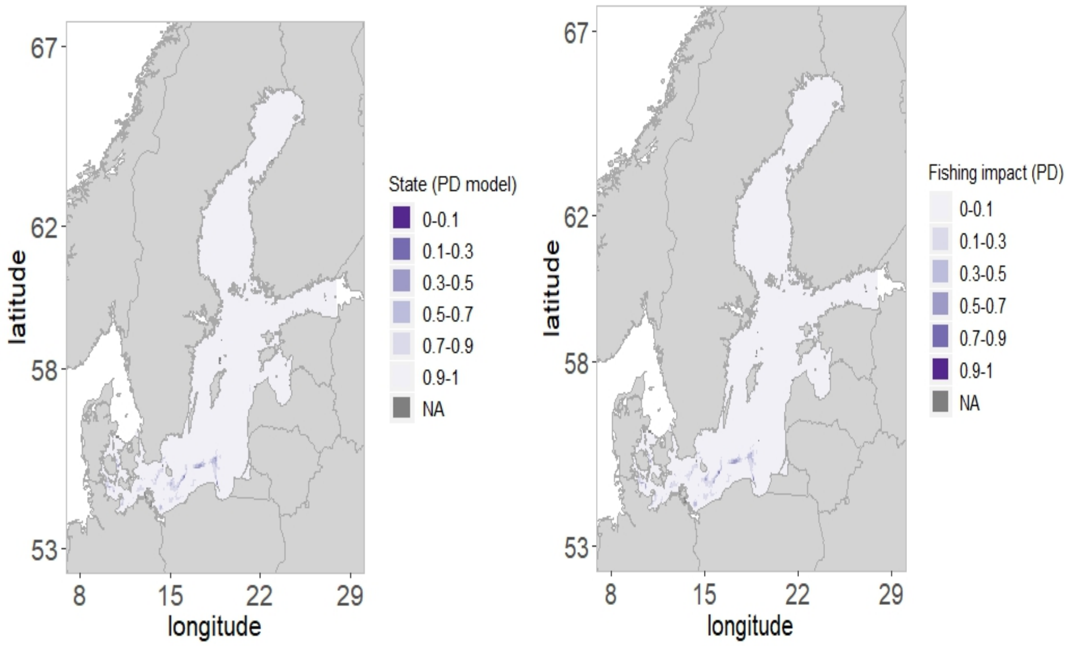

Figure 10. Map of relative benthic status (left) and impact (right). It should be noted that c-squares with low bottom oxygen levels (<3.2 mg L^{-1}) were not excluded in the impact assessment.

The impact of fishing in an area is given as the deviation of that area from a zero impact situation (A state value of one). This (one minus the state of that area) is shown in Figure 10, right panel. Furthermore, a table was produced indicating state and impact per MSFD broad scale habitat for the Baltic (Table 6).

Table 10. Assessment estimates of state and fishing impact per habitat type in the Baltic Sea. The estimates are average values across all c-squares of a habitat (corresponding to impact indicator 6).

MSFD broad habitat type	state 2018	fishing impact 2018
Circalittoral coarse sediment	0.997	0.003
Circalittoral mixed sediment	0.996	0.004
Circalittoral mud	0.982	0.018
Circalittoral mud or Circalittoral sand	0.997	0.003
Circalittoral rock and biogenic reef	0.998	0.002
Circalittoral sand	0.980	0.020
Infralittoral coarse sediment	0.996	0.004
Infralittoral mixed sediment	0.997	0.003
Infralittoral mud	0.976	0.024
Infralittoral mud or Infralittoral sand	0.997	0.003
Infralittoral rock and biogenic reef	0.997	0.003
Infralittoral sand	0.980	0.020
Offshore circalittoral coarse sediment	0.996	0.004
Offshore circalittoral mixed sediment	0.965	0.035
Offshore circalittoral mud	0.966	0.034
Offshore circalittoral mud or Offshore circalittoral sand	0.997	0.003
Offshore circalittoral rock and biogenic reef	0.997	0.003
Offshore circalittoral sand	0.939	0.061
Na	0.997	0.003

Step 6: Validation

The fishing impact assessment appears appropriate for bottom trawls and demersal seines. However, due to low vessel numbers the mussel dredgers operating in the western Baltic Sea were not included in this assessment, which locally and habitat specifically may result in an underestimation of impact.

Ground truthing based on independent data was not conducted in the impact assessment trial. Data from national monitoring programmes, individual research projects and environmental assessments could be used for ground truthing of the longevity estimates.

Step 7: Confidence

This aspect is not yet taken forward.

Step 8: Trade-off

The trade-off analysis was not conducted for the Baltic Sea, but two maps were produced to provide spatial information of yields (catch weight in kilos and landings value in Euro); (Figure 11).

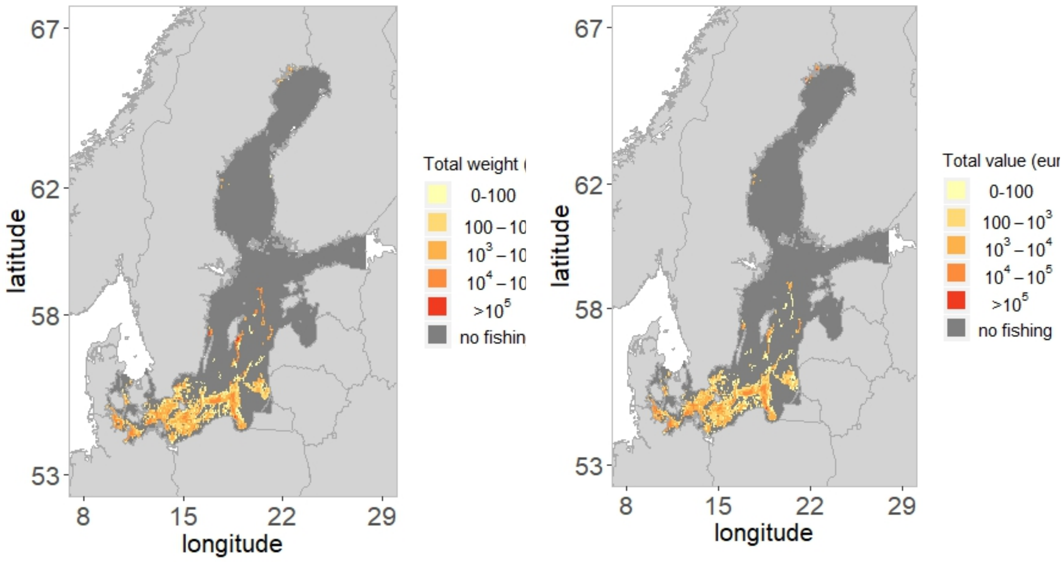

Figure 11. Map of fishery yield by weight (kg) and monetary value (€) in the Baltic Sea region based on 2018 effort data.

Gaps identified

Baltic Sea assessment

- Inclusion of sediment in modelling of the median longevity
- Permanently anoxic areas should be identified and treated as a separate habitat, and excluded from the fishery impact assessment of the broad scale habitats in the Baltic Sea
- Check if AICc should be used instead of AIC in the longevity modelling selection
- Data from national monitoring programs, individual research projects and environmental assessments could be used for ground truthing of the Gogina *et al.* (2016) based longevity estimates.

Generic

- Exploration of differences in assessment results caused by habitat-type allocation to c-squares by dominant habitat, or proportional habitat, rather than the current center point habitat
- Estimation of uncertainty should be explored. This can be done by running the analysis using the upper and lower confidence limits of the depletion and recovery estimates from Hiddink *et al.* (2017) and of the longevity distribution per habitat type (Rijnsdorp *et al.* 2018).

The Baltic Sea specific gaps listed above will be addressed intersessionally by the Baltic subgroup.

Other pressures

All other anthropogenic activities and pressures leading to physical disturbance or loss of benthic habitat, such as dredging and depositing of materials and extraction of minerals, are assessed to have a smaller effect than fishing in the Baltic Sea ecoregion (ICES 2018).

In the Baltic Sea infrequent influx of high saline oxygenated water combined with nutrient enrichment is a major cause of hypoxia and anoxia, which strongly influences community composition of benthic habitats throughout the ecoregion.

Conclusions

In 2018, the total trawling footprint made up 5.2% of the ecoregion area. Within this footprint the fishery was very concentrated and had a substantial number of grid cells that were marginally fished.

Average impact was low and estimated to be 0.010 when taken as an average across all c-squares of the ecoregion. By habitat type average impact was also low, ranging from 0.002 (circalittoral rock and biogenic reef) to 0.061 (offshore circalittoral sand).

The assessment methodology was successfully applied, but methods to integrate the significant effects of hypoxia need to be developed and integrated in the assessment workflow.

3.3 Celtic Sea

General info

Original Code

https://github.com/ices-eg/FBIT/tree/dev

Adapted code for Celtic Sea

The code is stored on the WGFBIT SharePoint

Contributors ***(in alphabetic order)***

Bolam, Stephan; Boulcott, Philip; Coleman, Paul; Herbon, Christin; Martinez, Roi; Laffargue, Pascal; Parry, Megan

Datasets

Seabed Sampling: UK MPA survey programme & IBTS EVHOE

Seabed Habitat: EMODnet seabed habitat data portal (EUSeamap 2017)

Fishing Effort: Extraction from ICES VMS/Logbook data call made for WGFBIT 2019

Step 1: Assign region of interest

For the Greater North Sea, no further method development was needed to run the assessment, as this was already completed in the 2018 report (ICES, 2018). However, an update to the MSFD broad habitat map (EUSeaMap (2019) Broad-Scale Predictive Habitat Map - MSFD Benthic Broad Habitat Types) has recently become available, as well as recent data on the distribution of the fishing fleet. In light of this, the assessment for the Greater North Sea was run using the most recent data. Below follows a brief summary of the output of the 2018 assessment. The main concern of WGFBIT in this update was that the existing North Sea assessment code and procedures were robust to the addition of novel VMS data and a new habitat map. This was found generally to be the case. With minor streamlining it has been possible to re-run the assessment for the

Greater North Sea. Finally, a first exploration of the uncertainty underlying the assessment was conducted. This was aimed primarily at developing a working procedure to estimate sensitivity.

To define the region of interest have been selected the Celtic Seas ICES ecoregion covering an area of 923 608.5 km2 (Figure 12). The Celtis Seas ICES ecoregion latitudes ranges from 47 to 67 degrees north and longitudes ranges from 2 degrees east to 15 degrees west. The area of interest cover the whole Irish Economic Exclusive Zone (EEZ) and partially the UK and French EEZs. The fact the area of interest goes across multiple national waters the biological data availability is not consistent across the ecoregion.

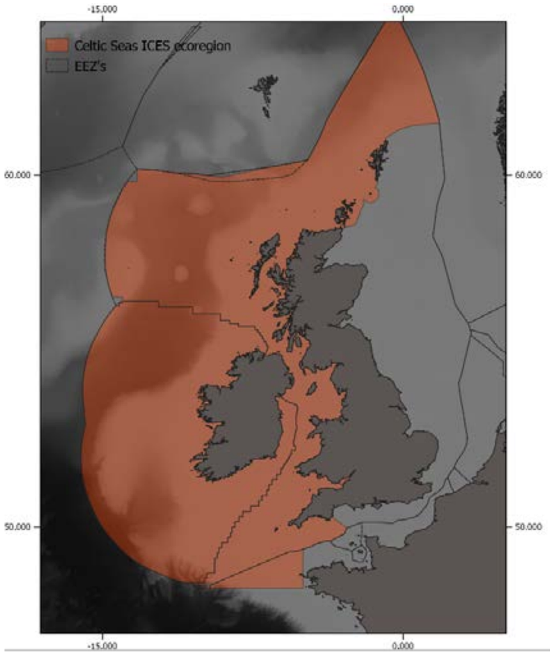

Figure 12. Area of interest defined for the Celtic sea ecoregion.

Step 2: Pressure layer information

The seafloor abrasion layer have been obtained from the outputs of ICES WGSFD, providing the abrasion indicator as the swept area ratio (area swept by a bottom contact fishing gear in a given c-square / c-square area). The fishing pressure layers is available between the 2009–2018 period at a high spatial and temporal resolution (0.05 degrees c-squares and monthly temporal resolution). However, for this case of study we have select uniquely the data form 2015 since is the year with more biological survey data available, therefore we analysed the biomass abundance with it related depletion from fishing activity coincidence in space and in time.

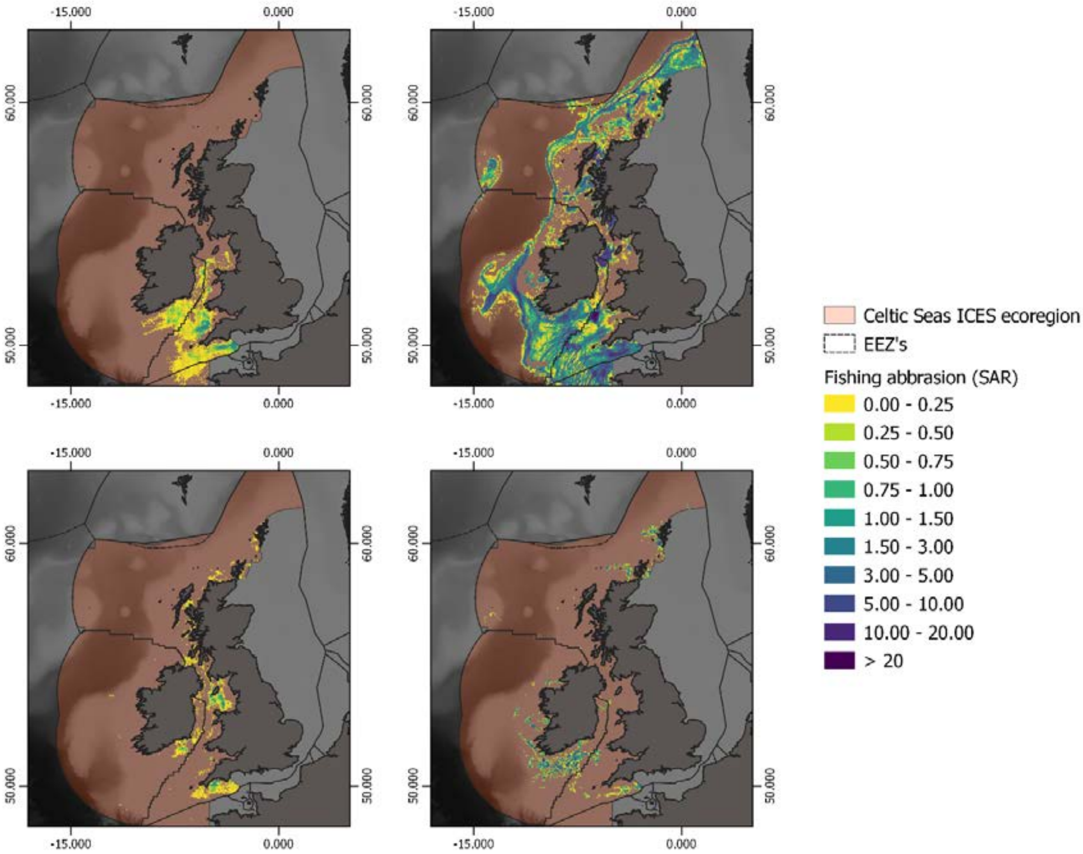

Figure 13. Abrasion indicator in the Celtic sea eco-region as the swept area ratio (area swept by a bottom contact fishing gear in a given c-square / c-square area) derived from the outputs of ICES WGSFD.

Table 11. Fishing pressure indicator and main fishing metier in the Celtic sea ecoregion.

Fishing pressure indicators	Value
Indicator 1 intensity	2.41
Indicator 2 proportion of grid cells fished (fished irrespective of swept area > 0.001)	0.43
Indicator 3 proportion of area fished	0.28
Indicator 4 aggregation of fishing pressure	0.18
Indicator 6 average impact	0.63
Indicator 7 proportion of area with impact < 0.2	0.72

Metier Level 4	Total catch (Kg)	Total values (€)
OTB_DEF	1.20E+10	2.39E+08
OTB_CRU	1.75E+07	7.83E+07
OTT_DEF	1.60E+07	5.09E+07
SSC_DEF	6.57E+06	1.34E+07
PTB_DEF	1.67E+07	2.41E+07
OTT_CRU	3.28E+06	1.12E+07
TBB_DEF	1.32E+07	5.24E+07
OTB_DWS	4.29E+06	1.08E+07
DRB_MOL	1.08E+07	3.50E+07
OTB_CEP	2.22E+06	6.60E+06
OTB_MCD	139681	580986
SDN_DEF	785685	1.54E+06
OTB_MOL	1.31E+06	3.30E+06
OTT_CEP	178831	692760
SDN_CEP	14610.3	67803.4
OTT_DWS	83571.4	291622
OTB_SPF	1.42E+07	1.08E+07
OTT_MOL	45153.2	188013
PTB_CRU	28430.4	131388
TBB_CRU	6395.6	28743.3

Step 3: Habitat information

The EU Sea Map 2019 broad habitat types (MSFD BBHT) have been used to define the habitat distribution within the Celtic Seas Ices ecoregions (Figure 14). In order to link the habitat information to the fishing intensity, habitat types have been transferred into the c-square grid. The MSFD broad habitat type with more presence within a give c-square have been assigned to the whole c-square.

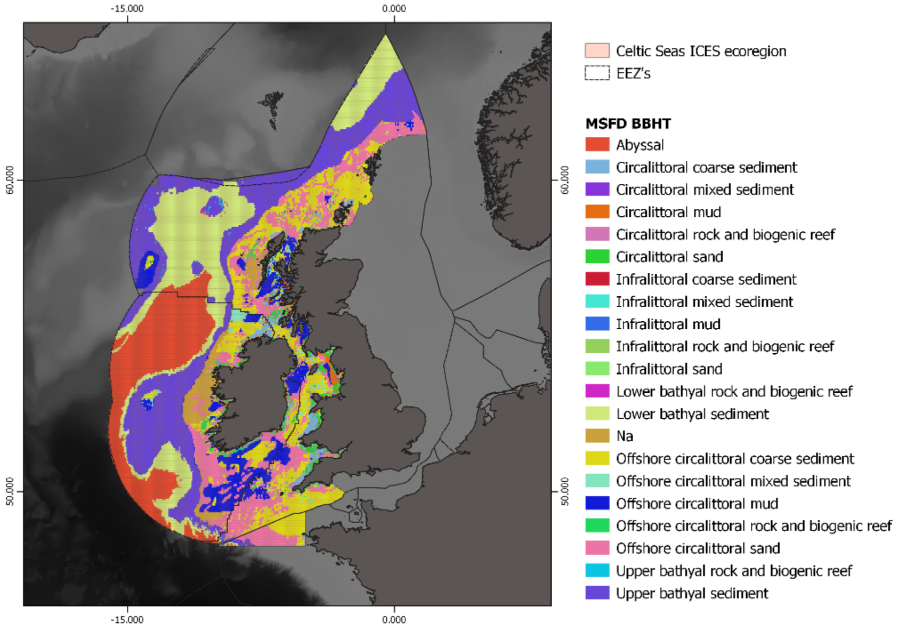

Figure 14. EU Sea Map 2019 broad habitat types for the Celtic sea ecoregion.

Table 12 includes the existing MSFD broad habitat types within the ICES ecoregion and its area extension. The larger habitat presented in the Celtic Sea ecoregion is the offshore circalittoral sand extended along 112 291 km^2, followed by the offshore circalittoral coarse sediment with 94 269 Km^2 and upper bathyal sediment with 87 307 Km^2. The 86% (intensity avg: 0.58) of the offshore circalittoral sand habitat area is swept by a mobile contact fishing gear, 70% (intensity avg: 0.67) of the offshore circalittoral coarse sediment area and upper bathyal is swept up to the 43% (intensity avg: 0.66) of its area. However, the most intensively impacted habitat by fishing activity is the Offshore circalittoral mud, with 95% of its area been contacted by a bottom fishing gear and with an intensity average of 0.77 y-1. This habitat type is extended along 61 528 km2 within the Celtic Seas ecoregion.

Table 12. MSFD broad habitat types and the area within ICES Celtic Seas ecoregion.

MSFD BHT	Area Km2
Abyssal	1540.550174
Circalittoral coarse sediment	8011.154774
Circalittoral mixed sediment	527.2127223
Circalittoral mud	2759.348177
Circalittoral rock and biogenic reef	3494.198364
Circalittoral sand	4808.428059
Infralittoral coarse sediment	250.4222158
Infralittoral mud	108.6420669
Infralittoral rock and biogenic reef	342.1139021
Infralittoral sand	346.4645262
Lower bathyal sediment	2247.513423
Na	17348.72249
Offshore circalittoral coarse sediment	94269.02375
Offshore circalittoral mixed sediment	4955.155975
Offshore circalittoral mud	61528.47691
Offshore circalittoral rock and biogenic reef	3743.810954
Offshore circalittoral sand	112291.9299
Upper bathyal rock and biogenic reef	202.8114799
Upper bathyal sediment	87307.77467

Table 13. MSFD BBHT with the related fishing activity footprint and average intensity.

MSFD BBHT	Footprint (%)	Intensity
Abyssal	1.14	0.16
Circalittoral coarse sediment	44.4	0.24
Circalittoral mixed sediment	53.7	0.21
Circalittoral mud	59	0.48
Circalittoral rock and biogenic reef	39.03	0.33
Circalittoral sand	43.24	0.26
Infralittoral coarse sediment	31.11	0.1
Infralittoral mud	30	0.13
Infralittoral rock and biogenic reef	25.97	0.34
Infralittoral sand	25	0.1
Lower bathyal sediment	1.33	0.11
Na	41.15	0.37
Offshore circalittoral coarse sediment	69.62	0.67
Offshore circalittoral mixed sediment	53.63	0.51
Offshore circalittoral mud	94.09	0.77
Offshore circalittoral rock and biogenic reef	53.58	0.68
Offshore circalittoral sand	85.91	0.58
Upper bathyal rock and biogenic reef	22.64	0.42
Upper bathyal sediment	43.03	0.66

MSFD BBHT	Metier Level 4	Footprint (%)	Intensity
Abyssal	OTB_DEF	0.88	0.16
Abyssal	OTB_SPF	0.09	0.07
Abyssal	SSC_DEF	0.09	0.35
Circalittoral coarse sediment	DRB_MOL	21.48	0.13
Circalittoral coarse sediment	OTB_DEF	15.72	0.53
Circalittoral coarse sediment	TBB_DEF	11.72	0.11
Circalittoral mixed sediment	DRB_MOL	33.33	0.11
Circalittoral mixed sediment	OTB_CRU	22.22	0.15
Circalittoral mixed sediment	OTB_DEF	14.81	0.83
Circalittoral mud	OTB_CRU	39.85	0.56
Circalittoral mud	OTB_DEF	31.8	0.39
Circalittoral mud	OTT_CRU	19.16	0.74
Circalittoral rock and biogenic reef	OTB_DEF	24.55	0.42
Circalittoral rock and biogenic reef	DRB_MOL	8.45	0.1
Circalittoral rock and biogenic reef	TBB_DEF	7.85	0.09
Circalittoral sand	OTB_DEF	20.95	0.35
Circalittoral sand	DRB_MOL	17.06	0.12
Circalittoral sand	OTB_CRU	10.98	0.25
Infralittoral coarse sediment	DRB_MOL	20	0.12
Infralittoral coarse sediment	OTB_MOL	13.33	0.05
Infralittoral coarse sediment	OTB_DEF	6.67	0.08
Infralittoral mud	DRB_MOL	20	0.16
Infralittoral mud	OTB_CRU	10	0.1

MSFD BBHT	Metier Level 4	Footprint (%)	Intensity
Infralittoral mud	OTB_DEF	5	0.03
Infralittoral rock and biogenic reef	OTB_DEF	10.39	0.42
Infralittoral rock and biogenic reef	DRB_MOL	9.09	0.08
Infralittoral rock and biogenic reef	OTB_CRU	3.9	0.7
Infralittoral sand	TBB_CRU	9.21	0.03
Infralittoral sand	DRB_MOL	7.89	0.11
Infralittoral sand	OTB_CRU	7.89	0.2
Lower bathyal sediment	OTB_DEF	0.6	0.13
Lower bathyal sediment	OTB_CEP	0.34	0.01
Lower bathyal sediment	OTT_DEF	0.32	0.19
Na	OTB_DEF	29.04	0.41
Na	OTB_CRU	8.53	0.3
Na	DRB_MOL	6.08	0.08
Offshore circalittoral coarse sediment	OTB_DEF	58.72	0.99
Offshore circalittoral coarse sediment	TBB_DEF	25.65	0.2
Offshore circalittoral coarse sediment	OTT_DEF	21.78	0.86
Offshore circalittoral mixed sediment	OTB_DEF	28.49	0.92
Offshore circalittoral mixed sediment	DRB_MOL	19.84	0.2
Offshore circalittoral mixed sediment	TBB_DEF	13.56	0.09
Offshore circalittoral mud	OTB_DEF	83.37	0.69
Offshore circalittoral mud	OTB_CRU	44.43	1.22
Offshore circalittoral mud	OTT_DEF	38.26	0.54
Offshore circalittoral rock and biogenic reef	OTB_DEF	41.91	1.05
Offshore circalittoral rock and biogenic reef	OTB_CRU	15.65	0.26
Offshore circalittoral rock and biogenic reef	DRB_MOL	8.75	0.09
Offshore circalittoral sand	OTB_DEF	76.73	0.53
Offshore circalittoral sand	OTT_DEF	41.41	0.94
Offshore circalittoral sand	TBB_DEF	16.14	0.2
Upper bathyal rock and biogenic reef	OTB_DEF	18.87	0.42
Upper bathyal rock and biogenic reef	OTB_DWS	13.21	0.52
Upper bathyal rock and biogenic reef	OTT_DEF	5.66	0.1
Upper bathyal sediment	OTB_DEF	36.54	0.66
Upper bathyal sediment	OTB_DWS	13.98	0.28
Upper bathyal sediment	OTT_DEF	13.08	0.71

Biological extensions

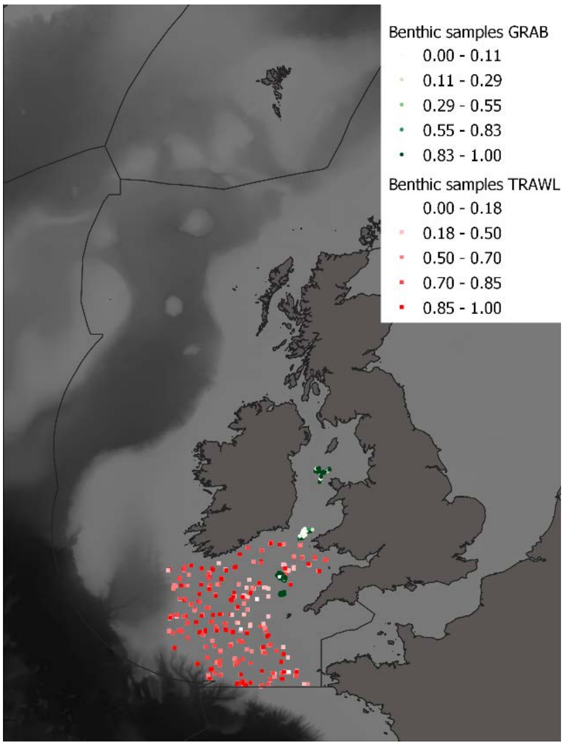

Figure 15. Distribution of sampled stations from grabs (UK Marine Protected Area survey programme) and fisheries trawling survey (IBTS EVHOE).

Within UK waters, several grab sample datasets (Figure 16, Table 14) 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. Surveys were undertaken in February, March and July 2012. As the samples were collected within MPAs, the points are clustered around a small area and therefore may not cover all habitat types present in the UK part of the Celtic Seas. There may be other UK datasets available. Trawl samples from IBTS fisheries survey (Figure 17, Table 14) were also available (French EVHOE or potentially from the Irish IGFS). Within the Celtic area, the coverage of habitats significantly differ depending on the types of biological dataset with trawl datasets covering more habitats and often more intensely than the grabs dataset. However, the data from trawl samples have not yet been used in the context of this assessment. They must be the subject of further information (complements and verification of longevity matrices) and tests (indicator responsiveness) before they can be validated and utilized within this assessment framework.

Table 14. Biological stations distribution by habitat type for available macrofauna (grabs) and epi-megafauna (trawls from 2008–2015 EVHOE survey) datasets.

	Number of stations	
MSFD BBHT	**Macrofauna**	**Epi-megafauna**
Na	0	24
Offshore circalittoral coarse sediment	97	71
Offshore circalittoral mixed sediment	7	0
Offshore circalittoral mud	0	170
Offshore circalittoral rock and biogenic reef	0	2
Offshore circalittoral sand	17	218
Upper bathyal sediment	0	65

Step 4: Estimate of longevity relationship

From the biological dataset, longevity classes as been assigned to each species by observed station. The "standard longevity matrix provided by WGFBIT (Emodnet dataset from Beauchard, 2018)" has been utilized, the species longevity matrix being attributed mostly at the genus level. The longevity matrix didn't cover the entire regional species list. The median proportion of covered biomass per station was above 90% for stations and habitats covered by trawls samples whereas the coverage appeared much lower for the macrofauna species list of grabs samples (Figure 18 and Figure 19). Moreover, depending on the dataset (macrofauna or megafauna), the relative distribution of biomass among longevity classes was significantly different (Figure 20). The Megafauna dataset had a dominant proportion of biomass in the longevity class 3–10 years, regardless of the habitat considered. In addition, the lower longevity class (>1year) was missing from the megafauna dataset.

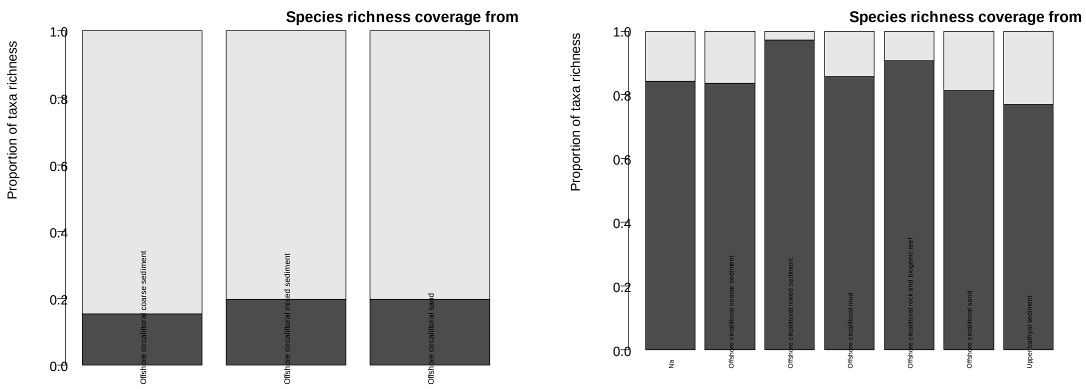

Figure 18. Taxa richness proportion covered (black) or not (grey) into the longevity matrix at the genus level for macrofauna (grabs samples) or epi-megafauna (trawl samples) datasets and for each habitat types.

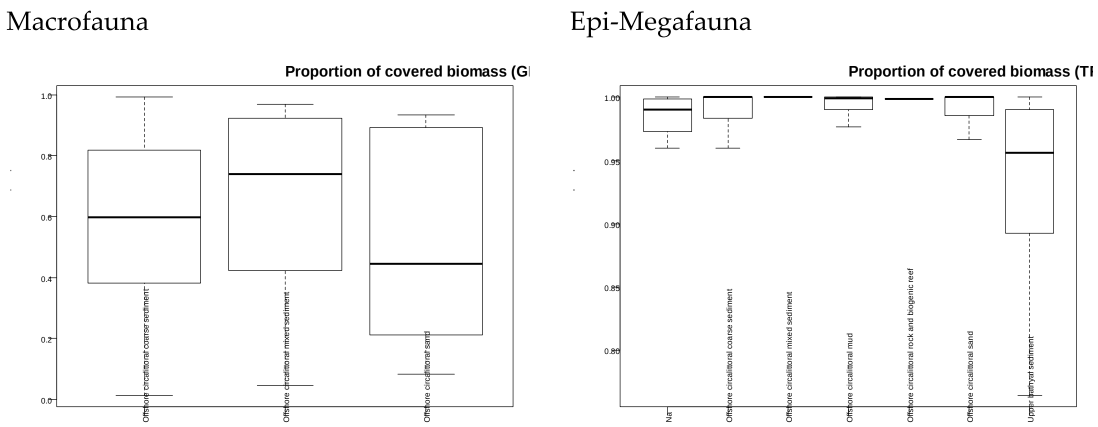

Figure 19. Covered biomass (log+1 transformed) proportion among stations for macrofauna (grabs samples) or epi-megafauna (trawl samples) datasets per habitat types.

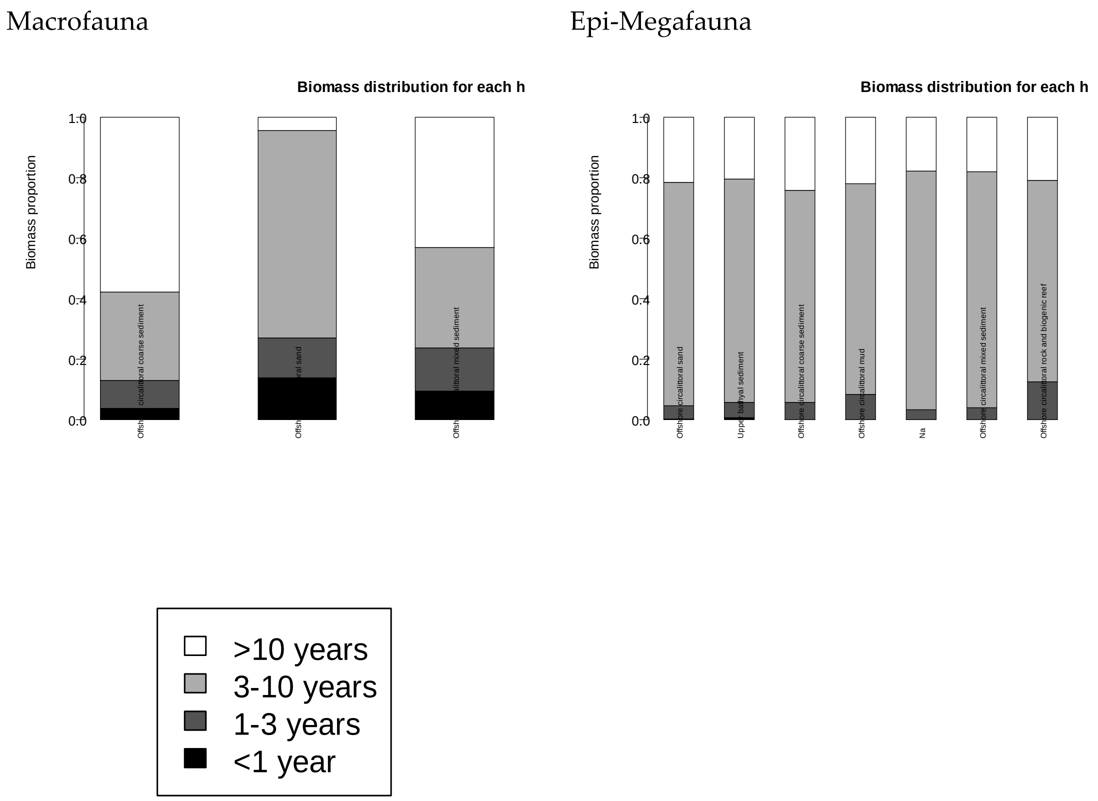

Figure 20. Distribution of biomass (log+1 transformed) within longevity classes for macrofauna (grabs samples) or epi-megafauna (trawl samples) datasets per habitat types.

In order to calculate the cumulative biomass (Cumb) by station the proportion of each longevity class by station was summed (Longevity <- statEnv$L1, (statEnv$L1+statEnv$L1_3), (statEnv$L1+statEnv$L1_3+statEnv$L3_10)) and then logarithm transformed (ll <- log(Longevity)).

The three Generalized Linear Mixed Models (GLMMs) were defined to identify which parameters have larger influence in the variability of cumulative biomass . Model #1 include the logarithm transformed longevity and its interaction with the MSFD broad habitat types as explanatory variables. The Model #2 doesn't take in account the interaction between longevity and broad habitat types and the Model #3 only includes longevity as explanatory variable. The three models performance was measured using the Akaike Information Criterion (AIC), consequently the model #1 was selected.

Table 15. Model formulations and measures of goodness of fit.

Model formulations and measures of goodness of fit. Model	R^2	AIC	P
#1 **glmer(Cumb ~ ll + MSFD*ll + (1 | ID)**	NA	903.3872	NA
#2 **glmer(Cumb ~ ll + MSFD + (1 | ID)**	NA	973.5639	NA
#3 **glmer(Cumb ~ ll + (1 | ID)**	NA	1005.0851	NA

Figure 21. Median of longevity across habitats in the Celtic Seas ICES ecoregion.

The model coefficients were used to estimate the sensitivity of the habitats within the ecoregion. At each grid cell we can predict longevity at a certain cumulative biomass (e.g. show median longevity (50% of biomass is longer-living)). Longevity is back-transformed using the exponential function and calculated the median longevity by c-square based in the presence of certain habitat type. The median of the longevity shors longevity distribution across the ices ecoregion and the sensitivity of each habitat type (Figure 21).

Step 5: Impact assessment

The biomass depletion by fishing gear type was provided in a look up table (Hiddink *et al.*, 2018) and multiplied by the fishing intensity within the c-square. The fishing intensity value represents the number of passes of a bottom contact gear by c-square, then it was possible to calculate the associated cumulative biomass depletion by grid cell.

The depletion, model slope and intercept parameters by c-quare were inputted in the Relative Benthic Status (RBS) functions available in the Github WG material and the RBS calculated by grid cell.

Table 16. Look up table used to assign the depletion to the bottom contact fishing gear types.

Gear type	Depletion
TBB	0.14
OT	0.06
TD	0.2
Seine	0.06

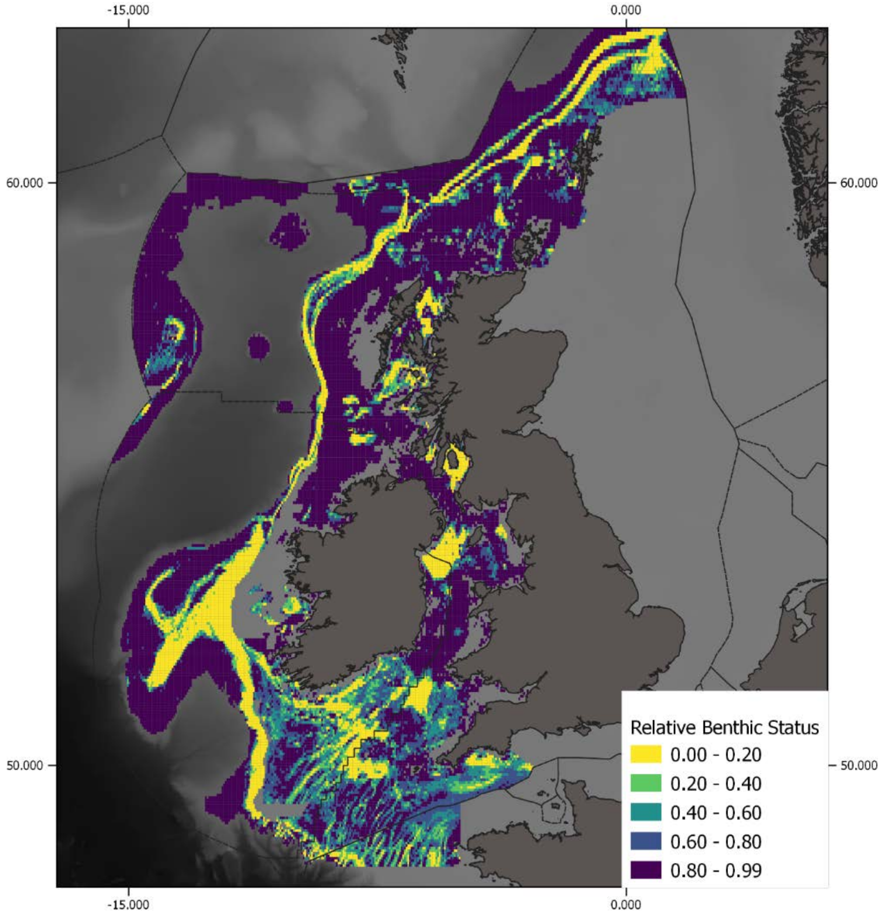

Figure 22. Relative benthic status (RBS) for the Celtic sea Ecoregion (map resulting from preliminary results that cannot be used for assessing the status of the region).

The Figure 22 show the distribution of the RBS indicator across the Celtic Seas ecoregion and how it reflect relationship between the fishing intensity and the habitat-specific sensitivity. The relative benthic status value ranges between 0 and 1, it is equivalent to a the biomass over carrying capacity (B/K) indicating the state of the biomass over the habitat carrying capacity (1).

The results presented in the map (Figure 22) and the Table 17 are preliminary results that cannot be used for assessing the status of the Celtic sea region. The relative biomass status by habitat type is shown in the Table 17 together with fishing intensity mean occurring within these habitats. Although there are habitat types intensively fished, the RBS value is high indicating a high recovery values and consequently a good status of the benthic biomass (e.g. offshore circalittoral mixed sediment or offshore circalittoral coarse sediment are near 1 RBS) .

Table 17. MSFD broad habitat type and the mean RBS and fishing intensity.

MSFD BBHT	RBS	Fishing Intensity
Circalittoral sand	0.95	0.34
Offshore circalittoral coarse sediment	0.84	1.8
Offshore circalittoral mixed sediment	0.9	1.12
Offshore circalittoral mud	0.41	3.73
Offshore circalittoral sand	0.68	1.79
Upper bathyal sediment	0.66	1.07

Step 6: Validation

Taken from other ecoregions in the report:

Data from national monitoring programmes, individual research projects and environmental assessments could be used for ground truthing of the longevity estimates.

Step 7: Confidence

This aspect is not yet taken forward.

Step 8: Trade-off

This aspect is not yet taken forward.

Gaps identified

The longevity data matrix has to be completed especially for species list of macrofauna from grabs samples. The influence on the longevity indicator responsiveness of the distribution among longevity classes for macrofauna or megafauna dataset must be better evaluated (e.g. probably fewer taxa representatives of strategy r and very short-lived species in the mega fauna component compared to macrofauna). Regarding megafauna, it will probably be necessary to revise the longevity matrix by subdividing or extending in particular the 2 higher longevity classes. This proposal is in line with the findings for other sub-regions (e.g. Eastern Mediterranean). A problem also exists concerning the validity of biomass as measured from gear such as trawls. They are not suitable for sampling efficiently the benthic invertebrates and create a strong divergence in catchability depending on the species. So the tests must be continued to assess the compatibility of megafauna component use from trawl samples with the longevity indicator assessment framework.

The geographic area covered should be extended to the Bay of Biscay but the available dataset is based primarily on the megafauna as collected from fisheries trawling survey.

Some habitats, little or not covered in other sub-regions (e.g. Upper bathyal sediment), require definition of reference points and longevity distribution models. These references must be based on zones with zero or very low fishing pressure, which could be problematic in fully exploited areas or habitats. Moreover, these habitats have few macrofauna data to calibrate the models. This reinforces the need to test and develop the assessment framework from megafauna dataset.

3.4 North Sea

General info

Original Code

https://github.com/ices-eg/FBIT/tree/dev

Adapted code for North Sea

The code is stored on the WGFBIT sharepoint at

https://community.ices.dk/ExpertGroups/WGFBIT/

under '0.7 Software/NorthSea'

Contributors *(in alphabetic order)*

Stefan Bolam, Daniel van Denderen, Jochen Depestele, Dario Fiorentino, Jan Geert Hiddink & Tobias van Kooten.

Datasets

Seabed Sampling: Benthis project data (UK, the Netherlands).

Seabed Habitat: EMODnet seabed habitat data portal (EUSeamap 2019).

Fishing Effort: Extraction from ICES VMS/Logbook data call made for WGFBIT 2019.

Step 1: Assign region of interest

For the Greater North Sea, no further method development was needed to run the assessment, as this was already completed in the 2018 report (ICES, 2018). However, an update to the MSFD broad habitat map (EUSeamap 2019) has recently become available, as well as recent data on the distribution of the fishing fleet. In light of this, the assessment for the Greater North Sea was run using the most recent data. Below follows a brief summary of the output of the 2018 assessment. The main concern of WGFBIT in this update was that the existing North Sea assessment code and procedures were robust to the addition of novel VMS data and a new habitat map. This was found generally to be the case. With minor streamlining it has been possible to re-run the assessment for the Greater North Sea. Finally, a first exploration of the uncertainty underlying the assessment was conducted. This was aimed primarily at developing a working procedure to estimate sensitivity.

Step 2: Pressure layer information

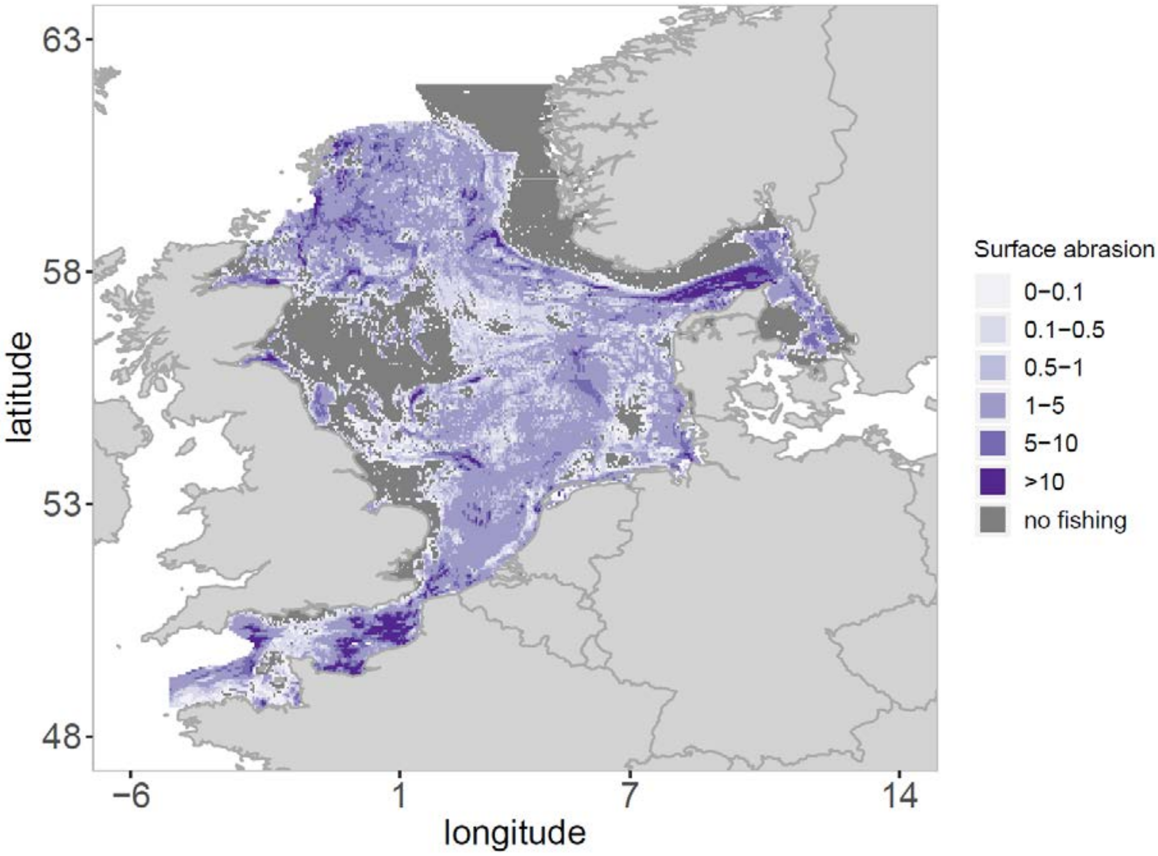

Figure 23. Extent of surface abrasion in the Greater North Sea area in 2018, plotted on a 0.05° × 0.05° grid. Abrasion is based only on data from bottom trawl fisheries.

The main source of abrasion in the North Sea is bottom fishing. Other activities are sand extraction and coastal sand nourishments, but these cover orders of magnitude smaller areas than fishing. It is important to note that the North Sea is a highly dynamic and as a result, abrasion from natural (tidal, wave) sources is significant and has strong implications for the seafloor ecosystem and the effects of bottom trawling (van Denderen *et al.*, 2015).

The map of surface abrasion (Figure 23) is constructed by combining the gear-specific effects of a number of métiers into a single Swept Area Ratio (SAR), following the method in (Eigaard *et al.*, 2016). This SAR is the number of times the entire cell area has been trawled in a given year, so that high values indicate high trawling frequency. The inverse of SAR is an estimate of the number of years between consecutive trawling events.

The current abrasion map (Figure 23) includes the effects of the three main bottom fishing métiers. These are otter trawls for crustaceans, otter trawls for demersal fish and beam trawls for demersal fish. In the future, other abrasive activities (particularly sand extraction) can also be included so that a truly integrated view of the intensity of abrasion across the Greater North Sea ecoregion can be obtained.

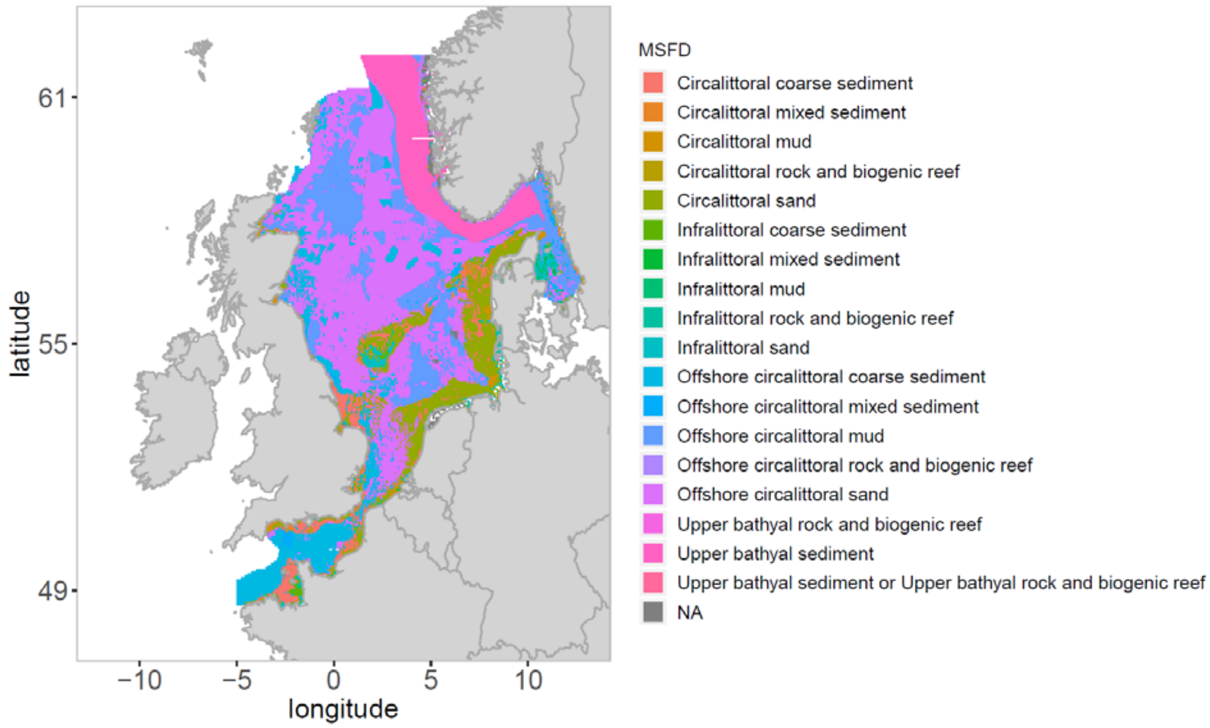

Figure 24. Broad-scale (2019 Level 3 EUNIS) habitats of the Greater North Sea ecoregion.

Step 3: Habitats of the Greater North Sea ecoregion

Habitats in the North Sea are subjected to high variability due to natural disturbance. For example, some areas of the English Channel are covered by rock with a thin layer of sediment which is affected by local currents which could cause the exposure of rock or a decrease of the sediment layer (Diesing, *et al.* 2015). This means that the same location could be typified as a sediment area, or a rocky habitats, depending on sampling time and exact location.

Generally, the seabed of the Greater North Sea is dominated by soft sediments (Figure 24). The four main habitats (A5.1 – circalittoral coarse sediment, A5.2 – circalittoral sand, A5.3 – circalittoral mud, and A5.4 – circalittoral mixed sediment) comprise 93% of the total surface area between 0 and 200 m depth. Deeper waters are dominated by muddy sediments.

Step 4: Estimate of the longevity relationship

The accuracy of the benthic sensitivity layer depends on how well it describes the benthic invertebrate community in an unfished state. The North Sea benthic sensitivity layer is based on a statistical analysis on a dataset that was a collation of box corer and Day grab samples from around the North Sea (Rijnsdorp *et al.*, 2018). These gears are generally considered to mostly sampling small infaunal invertebrates and probably undersample the fraction of larger and mobile epifaunal organisms. This sensitivity layer therefore represents the sensitivity of infauna and smaller epifauna. There were no samples in the collation from the north-eastern part of the area that was predicted to be most vulnerable, and these predictions are therefore extrapolations and least certain. There are no extensive unfished areas in the North Sea (about 20% of the North Sea has consistently not been fished but some habitats such as muddy grounds have much lower unfished fractions (Amoroso *et al.*, 2018)). The longevity distribution was therefore predicted by fitting a model that including fishing effort, and subsequently using this model to predict the longevity distribution at no fishing (Rijnsdorp *et al.*, 2018). This approach is considered to be the best available method to estimate the longevity composition of an unfished community, and given the lack of an abundance of samples from unfished areas, we cannot be certain that the longevity layer is accurate.

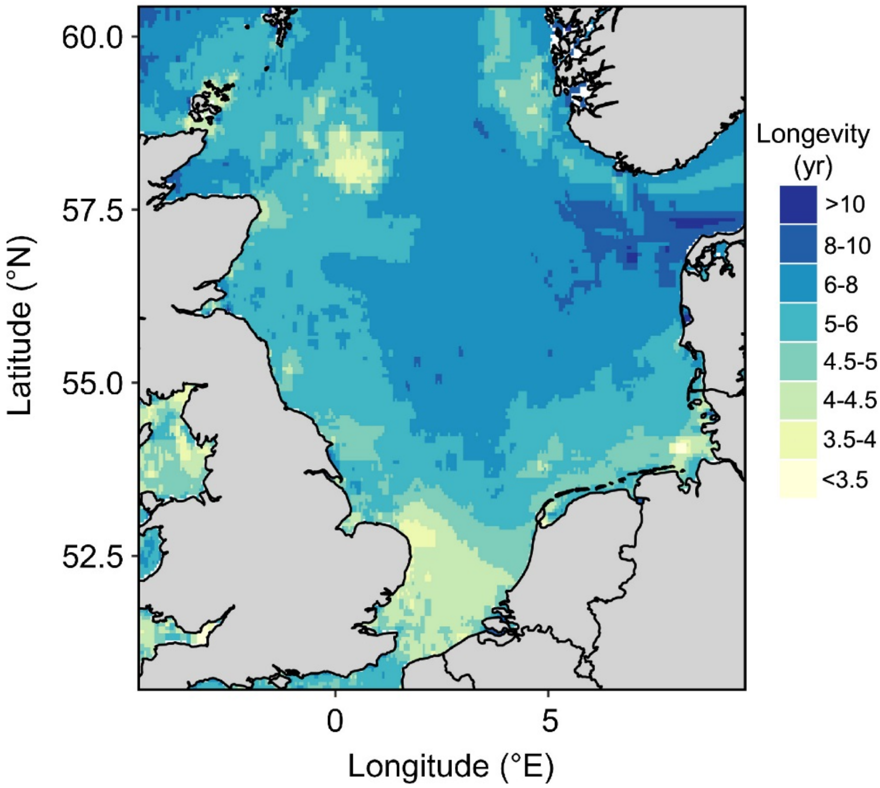

Figure 25. Biomass-weighted median longevity of the benthos in the Greater North Sea region, figure from (Rijnsdorp *et al.*, 2018).

Habitat sensitivity to abrasion is defined in the current assessment as the median longevity of the benthic biomass at each location. This information is obtained for the Greater North Sea ecoregion by combining data on species-specific longevity with (box-core) sampling data, local depth and sediment data and bottom trawling intensity (Rijnsdorp *et al.*, 2018). The resulting statistical model can then be used to infer longevity biomass distributions in unfished areas, from which the median values plotted in Figure 25 are calculated. This sensitivity is used in the assessment to determine the rate of recovery of the (local) benthic community following abrasion.

Step 5: Impact assessment

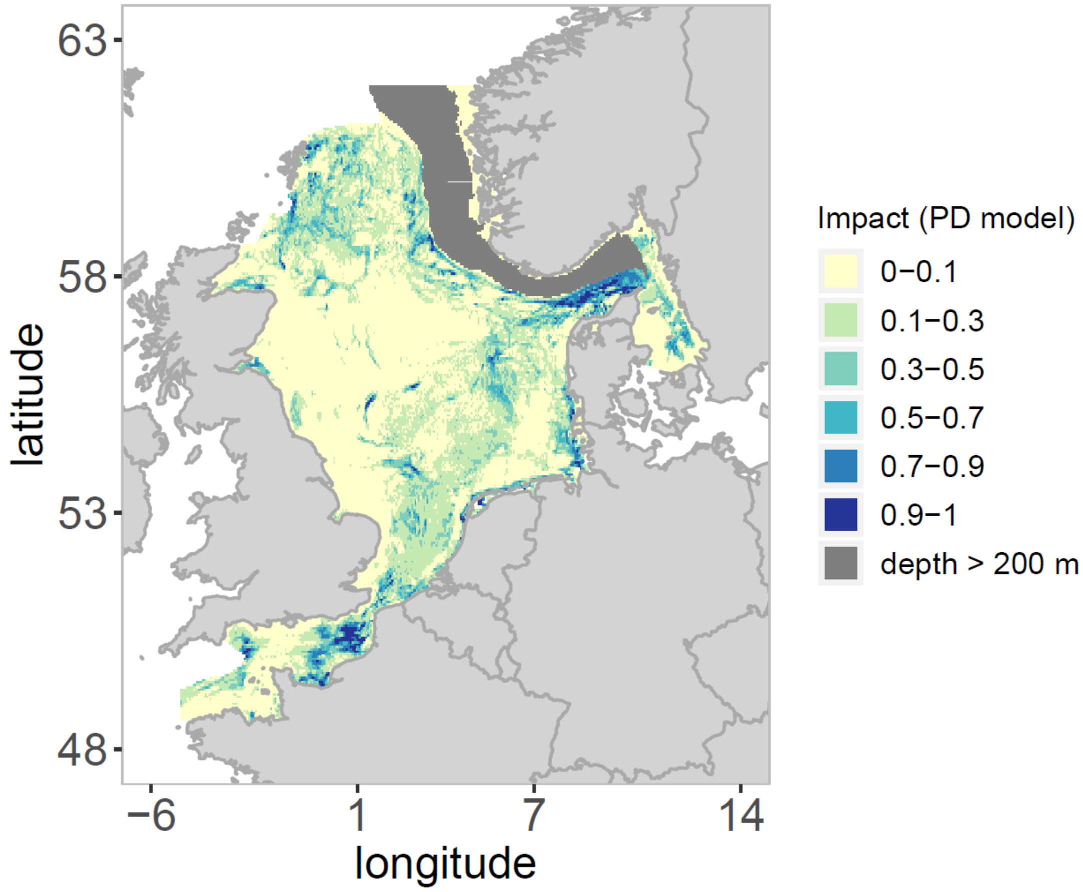

Figure 26. Impact of abrasion on the benthic biomass. Impact is calculated following the PD method. Highest impact is found in areas with high sensitivity and high abrasion. Low impact means low abrasion, low sensitivity or both.

Impact is expressed as the reduction of the maximum benthic biomass which would result if current levels of abrasion would continue for a long time (i.e. the equilibrium reduction). A value of 0 means abrasion has zero impact on the benthos, which can occur only if no abrasion occurs. A value of 1 means that if current abrasion continues, the assessment predicts that no benthic biomass can survive. An overview for the Greater North Sea is visualized in Figure 26.

Time trends in impact

Time trends (Figure 27) indicate that impact is relatively stable. The impact in circalittoral sand was reduced in 2017, but has returned to close a value close to its long-term mean in 2018. The proportion of the habitat with impact scores below 0.2 (which we use as an arbitrary placeholder for a favourable state here) is slightly more dynamic over time. The extent of impact <0.2 has decreased since 2015 for circalittoral course sediment, and has been quite variable for circalittoral sand.

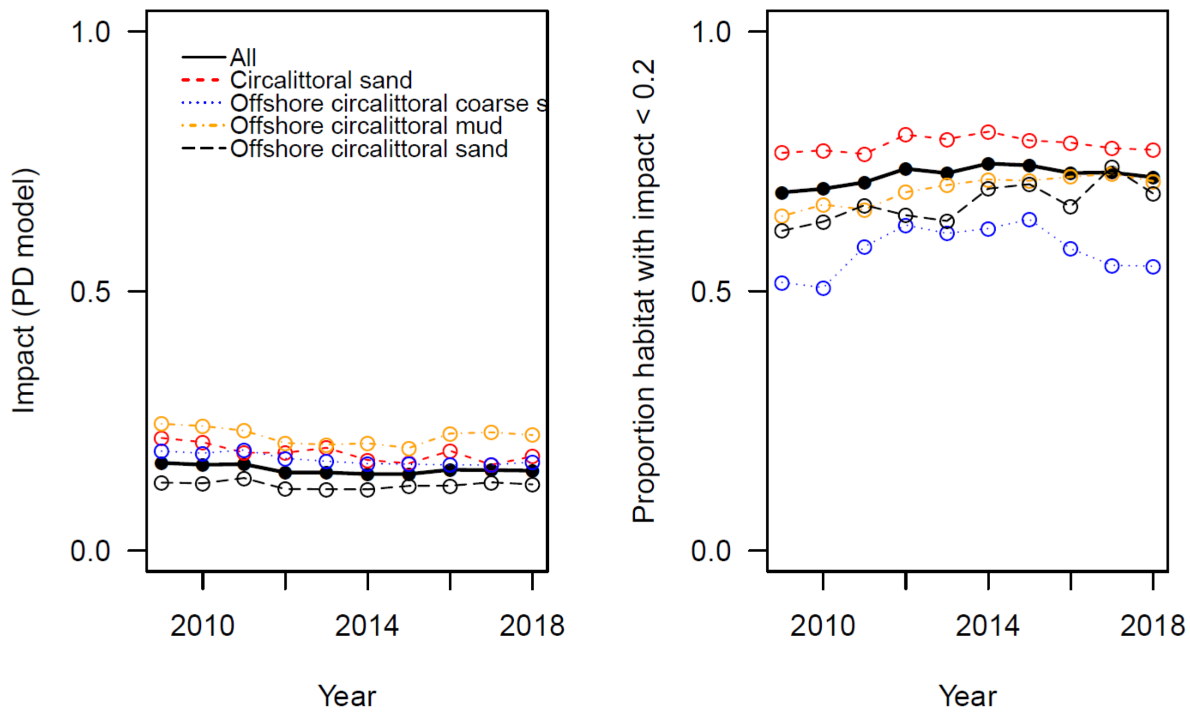

Figure 27. Time trends in impact (Left panel) and state above a hypothetical threshold value (Right panel) overall and in each of the 4 most dominant habitat types in the Greater North Sea ecosystem.

Issues encountered in the North Sea ecoregion assessment case study

The North Sea is heavily trawled, and there are virtually no untrawled areas. As a result, the untrawled state of the benthic community used in this assessment has been derived from the longevity distribution model. Empirical validation of the untrawled state can only be achieved when areas (for each habitat type) have been closed to trawling for a long time (and have been properly sampled).

The derivation of longevity distributions is done using only grab/boxcore samples which underestimate the larger long-lived epifauna. This could lead to an underestimate of the effect of trawling. However, these large-bodied species generally contribute little to the total biomass-longevity distribution.

Step 6: Validation

The PD assessment method is strongly based on conceptual ecological principles. This has many advantages. For example, the results are comparable across regions, and can be adapted to situations where data is scarce (Hiddink *et al.*, 2017). However, this also makes it difficult to directly validate the outcome using empirical data. The calculated impact reflects an equilibrium state which the benthic biomass is predicted to attain if the current fishing practice would be continued indefinitely. Fishing pressure varies from year to year at any given location, so that testing this for fished areas using empirical data is difficult. Nonetheless, an analysis comparing predicted impact versus observed biomass in samples confirmed a clear positive relationship between the two (Hiddink *et al.*, 2019). This clearly indicates that the PD assessment method can pick up real differences between locations related to trawling intensity. Another independent test showed that relative shifts in abundance of longevity classes along productivity gradients corresponded to the pattern predicted by the PB method (van Denderen *et al.*, 2015)

Other empirical or experimental validations of specific parameters used in the PD method can also be carried out. The installation of Marine Protected Areas offers one opportunity. Following the benthos recovery trajectory after trawling stops would yield an independent estimate of the recovery rate, and ultimately, as benthic biomass approaches equilibrium, of the carrying capacity as well.

Step 7: Uncertainty in relative benthic state

The propagation of uncertainty in relative benthic state (RBS, which equals one minus the impact) estimates was based on bootstrapping depletion estimates from the logitnormal distribution, based on parameters taken from S4 Tables in Hiddink *et al.* (2017) for three fishing gears (beam trawl TBB, otter trawls OTB, dredges TD). Depletion estimates for seines were approximated by using the otter trawl parameters. The uncertainty in RBS estimates was also based on bootstrapping recovery from the normal distribution. Uncertainty was calculated as the difference between the upper and lower limit, being the size of the 95% confidence interval. The resulting maps are presented for illustrative purposes for 2015 (Figure 28, Figure 29). The uncertainty resulting from bootstrapping depletion is higher than from the bootstrapping procedure for recovery (Figure 30, Figure 31).

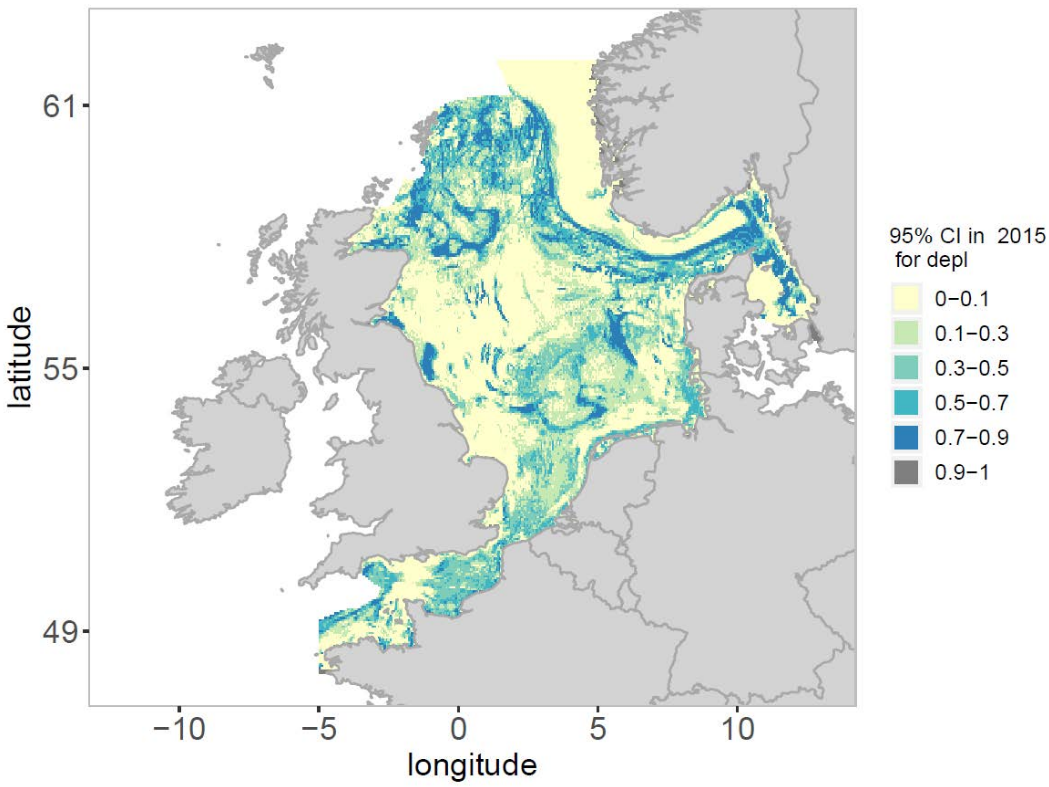

Figure 28. Size of 95% Confidence interval for estimating state using bootstrapped depletion estimates (Size = Q97.5 – Q2.5, being the difference between upper minus lower limit of the 95% CI).

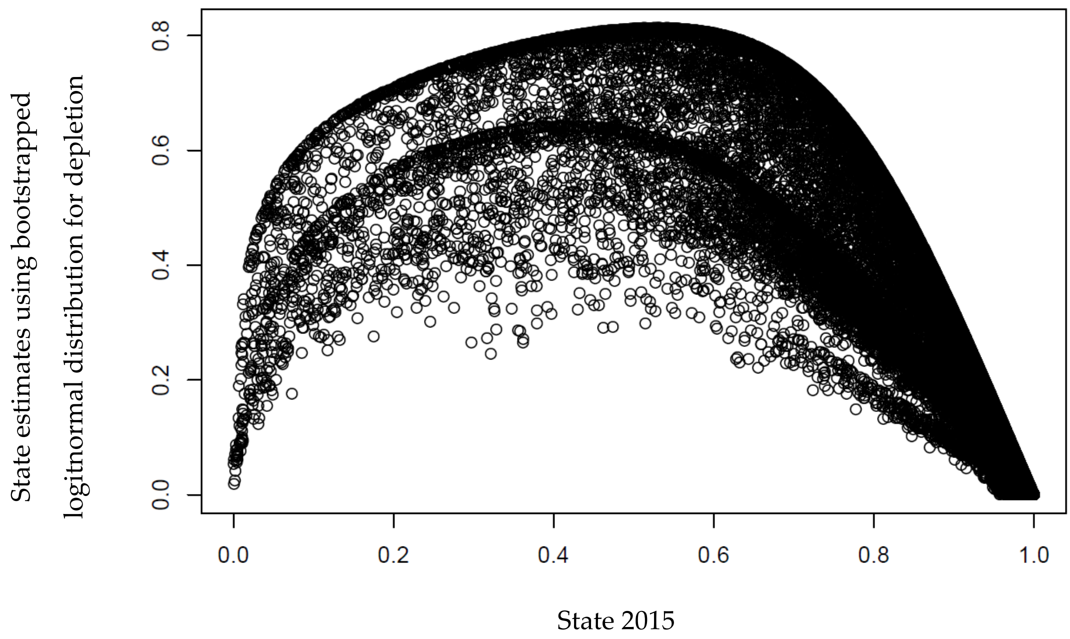

Figure 29. State estimates using the bootstrapped logitnormal distribution for depletion in function of the Relative Benthic State in 2015.

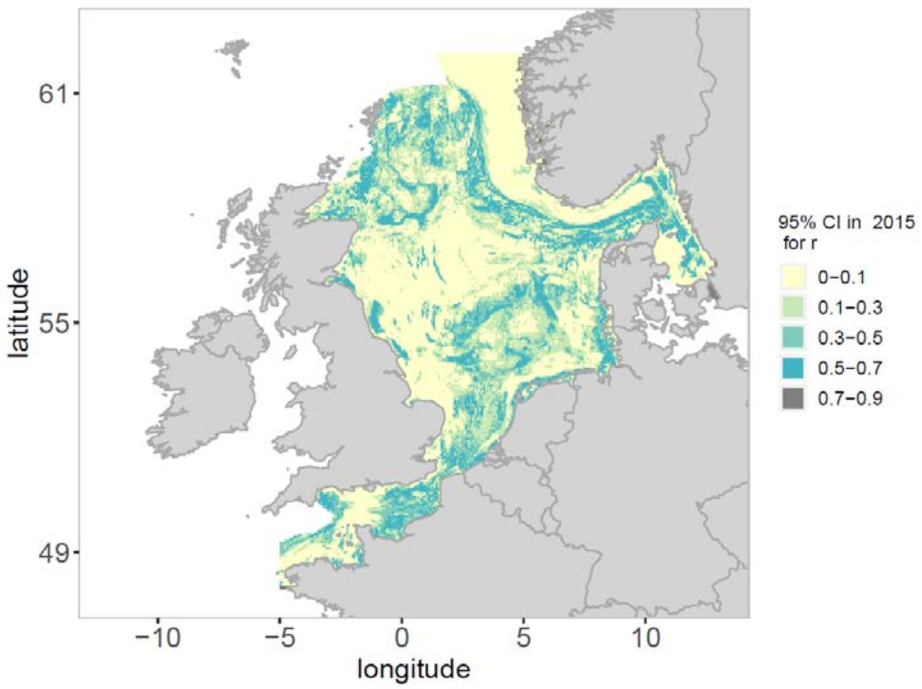

Figure 30. Size of the 95% Confidence interval for estimating state using bootstrapped recovery estimates (Size = Q97.5 – Q2.5, being the difference between upper minus lower limit of the 95% CI).

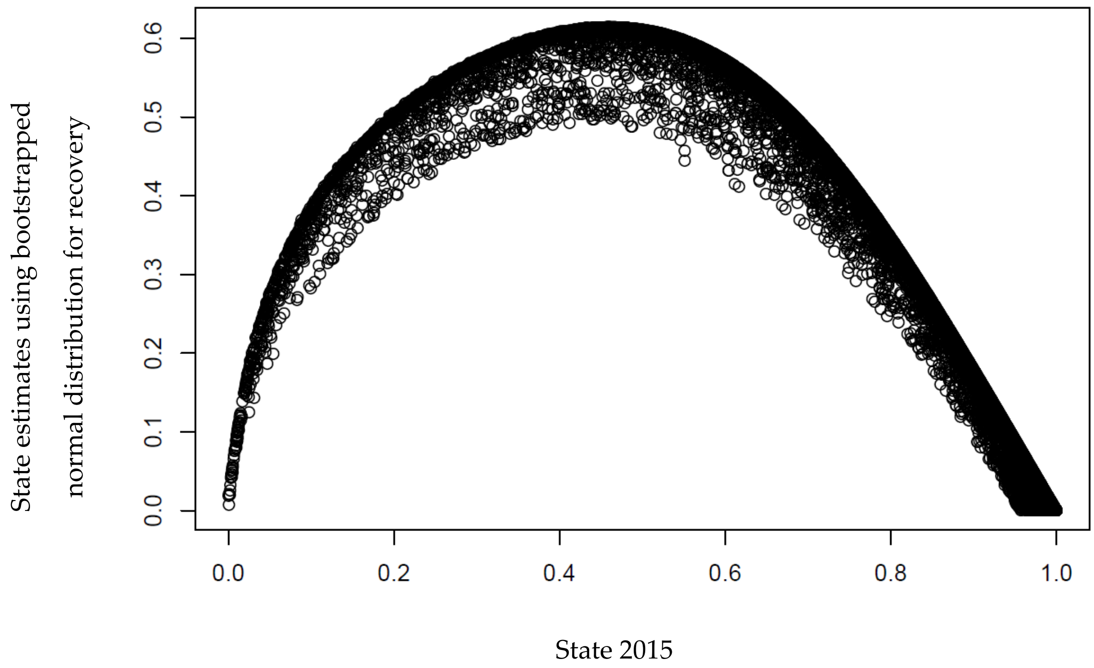

Figure 31. State estimates using the bootstrapped normal distribution for recovery in function of the Relative Benthic State in 2015.

Conclusions

The method and associated code established and adopted by WGFBIT in 2018 has proven to be robust to updated input data.

Impact, as measured by the PD method, has been relatively stable in the Greater North Sea as a whole, and within the main habitat types present. The extent of a (hypothetical) favourable environmental state has been more variable, in particular within specific habitats.

A first exploration of uncertainty in the input parameters to the assessment indicated that uncertainty in the depletion rates has a larger effect on the assessment outcome than uncertainty in benthic sensitivity.

3.5 Mediterranean Sea

General info

Original Code

https://github.com/ices-eg/FBIT/tree/dev

Adapted code for MedSea

https://github.com/d-lorenz/ICES_FBIT

Contributors *(in alphabetic order)*

Fabio Badalamenti, Alessandro Colombelli, Igor Cvitković, Lorenzo D'Andrea, Giovanni D'Anna, Maria Despalatović, Gianna Fabi, Emanuela Fanelli, Fabio Grati, Cristina Mangano, Bojan Marceta, Carlo Pipitone, Elisa Punzo, Saša Raicevich, Chiara Romano, Tommaso Russo, Antonello Sala, Angela Santelli, Giuseppe Scarcella, Alessandra Spagnolo, Pierluigi Strafella, Anna Nora Tassetti

Datasets

Seabed Sampling: Santelli *et al.* (2017)

Seabed Habitat: EMODnet seabed habitat data portal (EUSeamap 2017)

Fishing Effort: Eigaard, *et al.* (2017)

Step 1: Assign region of interest

The working group tested the feasibility of employing a single region of interest for the entire Mediterranean Sea. The reference 3x3 nm grid was successfully created but it was computationally heavy to handle. We decided to reduce the extent of the area of interest and consider only the Italian waters. Several GFCM recommendations regard the development and establishment by parties of the appropriate legal framework defining access to the fisheries resources and fishing grounds, as well as the implementation of management measures and the activities on monitoring, control and surveillance. They relate, inter alia, to driftnets, closed seasons, mesh size, management of demersal fisheries, plans of actions, red coral, incidental by-catch of seabirds or turtles, conservation of monk seal, records of vessels, port State control, lists of IUU vessels, logbooks, vessel monitoring systems.

Particularly notable are the GFCM measures on the establishment of fisheries restricted areas in order to protect deep sea sensitive habitats (namely Recommendation 30/2006/3, which prohibits fishing with towed dredges and bottom trawl nets within "*Lophelia* reef off Capo Santa Maria di Leuca", "The Nile delta area cold hydrocarbon seeps" and "The Eratosthenes Seamount", as well as recommendation 33/2009/1, on the fisheries restricted area in the Gulf of Lions. Additionally, recommendation 2005/1 on the management of certain fisheries exploiting demersal and deep water species, prohibits the use of towed dredges and trawl nets fisheries at depths beyond 1000 m (Figure 32).

Figure 32. Bathymetry shapefile with isobaths <1000 m.

The Gebco shapefile (www.gebco.net) for bathymetry (Figure 32) was used to clip the 3x3 nm grid. The resulting grid was made of 6363 single cells (Figure 33). Following the FBIT tutorial, we downloaded the EUSeaMAP 2019 (version July 2019) from the EMODnet Seabed Habitat portal (www.emodnet-seabedhabitats.eu/access-data/download-data).

Likewise, the 3x3 nm grid, the EUSeaMAP shapefile was clipped to exclude depths below 1000 m (Figure 34). Each cell of the 3x3 grid was matched with the corresponding MSFD predominant habitat types from the EMODnet dataset along with the depth values from the GEBCO bathymetry data.

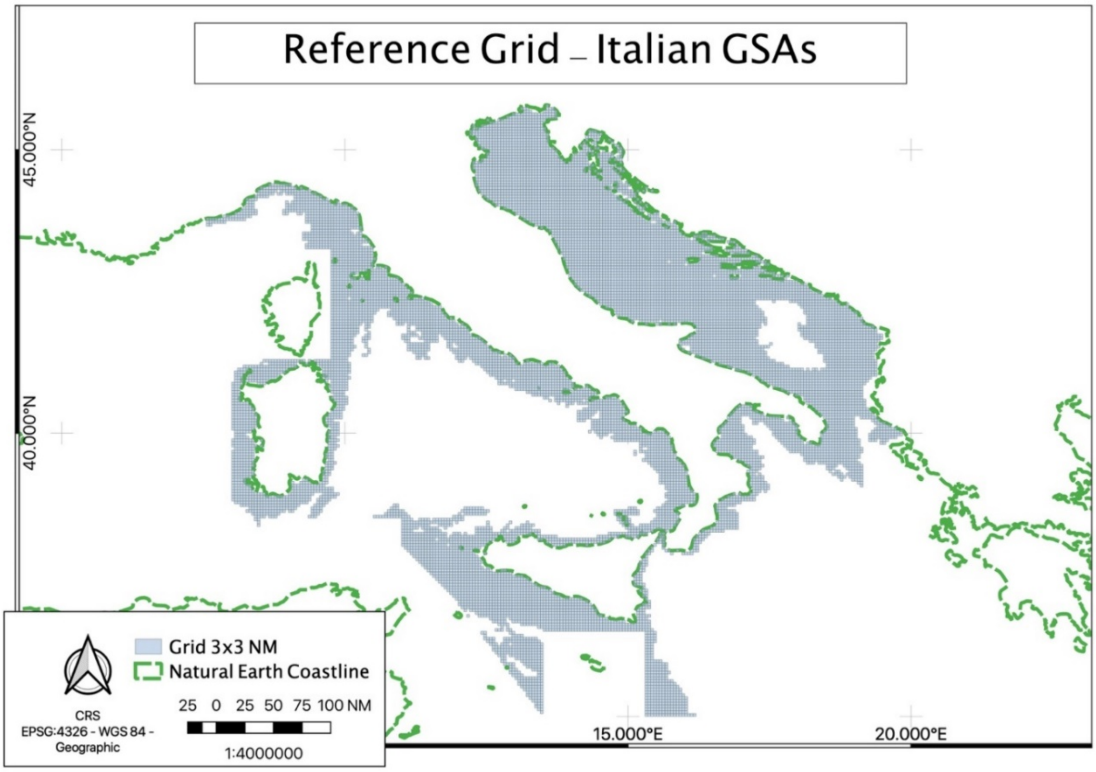

Figure 33. Grid 3x3 nm for the Mediterranean region, restricted to only the Italian waters. Depths below 1000 m are excluded from the analysis.

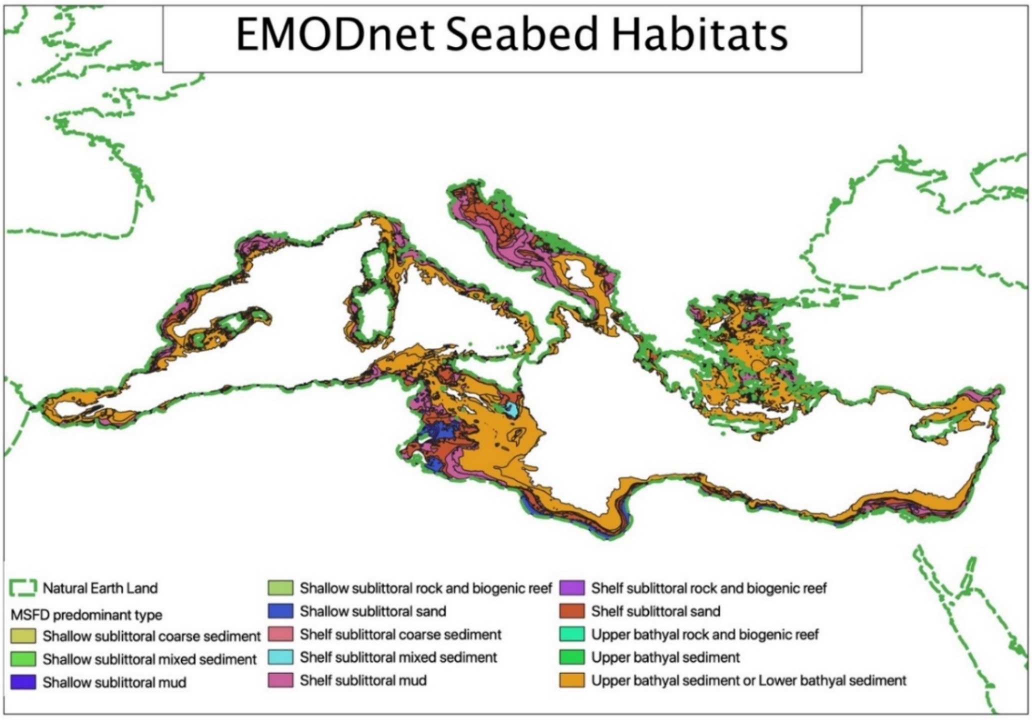

Figure 34. EMODnet seabed habitats for the Mediterranean representing only waters falling within depth 0–1000 m range.

Step 2: Pressure layer information

Figure 35 shows the information on swept area by gear calculated by Eigaard *et al.* (2017). Table 18 and Table 19 report the SAR (Swept Area Ratio) and depletion of community biomass for otter trawl (OT) and beam trawl (TBB) gears.

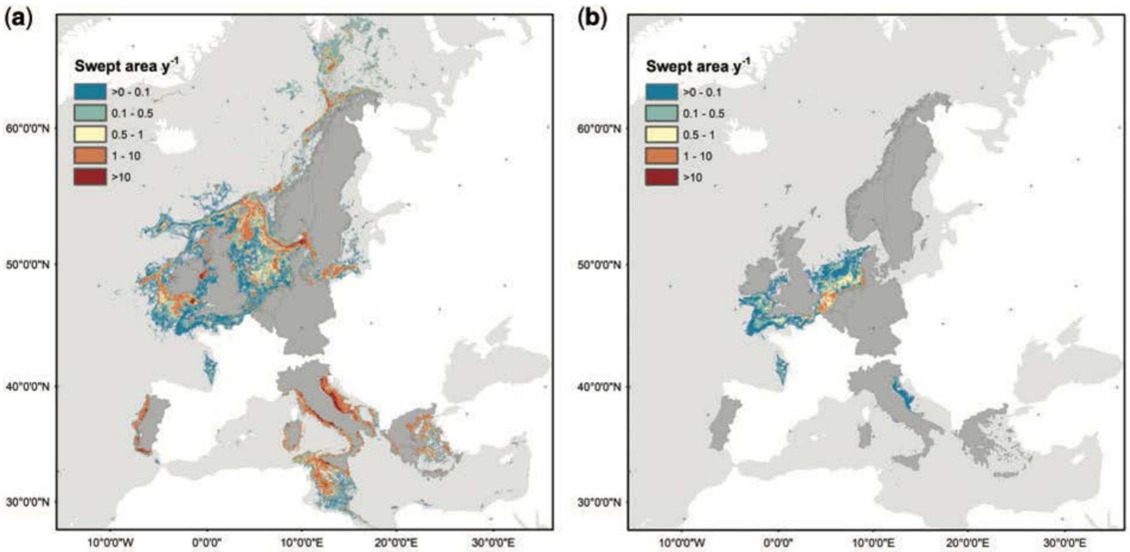

Figure 35. Fishing intensity at the surface level by main gear groups (a: demersal otter trawls, b: beam trawls). Note: the Italian "Rapido" trawl belong to the beam trawl gear category.

Table 18. SAR (Swept Area Ratio) of the Mediterranean fishery metiers analysed separately by main habitat types. TBB: Rapido beam trawl; OT: otter trawl.

Habitat type **(MSFDhab)**	TBB SAR **(TBB_SurfSAR)**	OT SAR **(OT_SurfSAR)**
Shallow_sublittoral_mud	0.02539177	11.051143
Shallow_sublittoral_sand	0.06158087	9.731274
Shelf_sublittoral_mud	0.17397265	13.498598
Shelf_sublittoral_sand	0.15257053	8.528516

Table 19. Depletion of community biomass and abundance for different trawling gears (see Hiddink *et al.*, 2017). Gear types are otter trawls (OT), and Rapido beam trawls (TBB).

Gear	Depl_TBB	Depl_OT
Depletion rate (d)	0.14	0.06

Step 3: Estimate longevity relationships

Two case studies were here analysed, by considering two datasets available for Italian waters and already published (see below). Tthese concerned the Northern and Central Adriatic Sea (Figure 25) and the Northern coasts of Sicily (Figure 26), from the Gulf of Castellammare on the west to the Gulf of Patti on the west, up to 80 m depth. Data from the Adriatic Sea (GSA1 17) were derived from the SoleMon project (Figure 36). 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. Two Rapido trawls were towed simultaneously during each haul. Average speed was 5.5 knots and average haul duration was 30 min; at a small number of stations, haul duration had to be modified due to seabed texture and to the accumulation of excessive weight in the net. After the commercial catch was sorted, biological samples of megazoobenthos, which acounted to 15–80 kg (in line with the SoleMon protocol; Grati *et al.*, 2013), depending on the weight of the fraction of epibenthic/benthic species and of debris in the catch, were randomly collected from the total discard and immediately classified on board. Each specimen was identified to the lowest possible taxonomic level. The specimens of each species were counted and weighed (g).

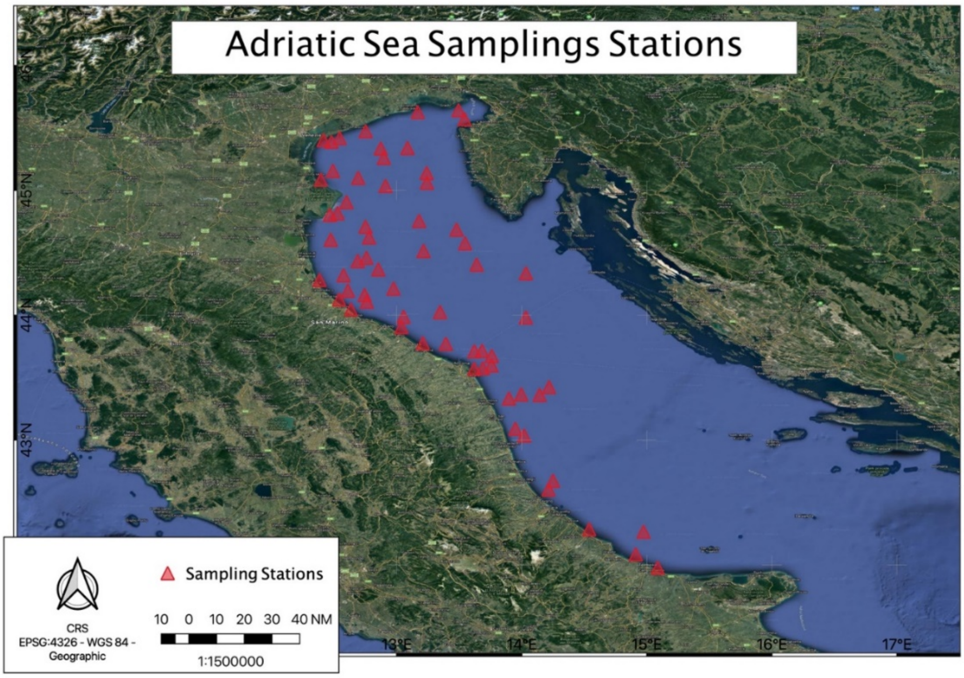

Figure 36. Overview of sampling stations Adriatic Sea.

Data from the Northern Sicily (Western Mediterranean) were derived from Romano *et al.* (2016), this study was carried out in four areas off the coast of northern Sicily, two untrawled (Gulf of Castellammare, GCAST, 38_040N, 12_560E; Gulf of Patti, GPATT, 38_100N, 15_060E), and two trawled (Gulf of Termini Imerese, GTERM, 38_020N, 13_460E; Gulf of Sant'Agata, GSANT, 38_040N, 14_200E) (Figure 37). GCAST and GPATT are fishery exclusion zones where trawling has been banned since 1990 on the continental shelf and the upper slope under Regional Act 25/ 1990 (200 and 242 km^2 no-trawl area, respectively). The fishing activity inside these gulfs is restricted to artisanal fishing that extends over the continental shelf and upper slope and includes mainly static gears and small purse seines. GTERM and GSANT are characterized by a medium-large trawling fleet resulting in an intensive multispecies demersal fishery (target species: Mediterranean hake, red mullet, anglerfishes, red and pink shrimps, cephalopods), and by an artisanal fleet (Mangano *et al.*, 2014). In these two gulfs trawl fishing is allowed at >50 m depth.

Eighteen replicate sediment samples were collected with a 0.4 m2 Van Veen grab in each gulf (total n. 72) in 2005. Sampling was limited to the 40–0 m depth range over the coastal terrigenous mud assemblages (sensu Pérès, 1982) identified with the aid of previous literature (see Romano *et al.* 2016 for further details and literature references). For each sampling site, three grabs were sampled and pooled in order to standardize the collected volume of mud to a total of about 40 l of sediment, which is considered an adequate sample volume to represent the benthic community in this type of assemblages. The presence of species characteristic of this biocenosis (Pérès and Picard, 1964) such as the polychaete *Sternaspis scutata*, the crab *Goneplax rhomboides* and the sea cucumber *Labidoplax digitata* allowed us to confirm the type of benthic assemblage in each sampling area.

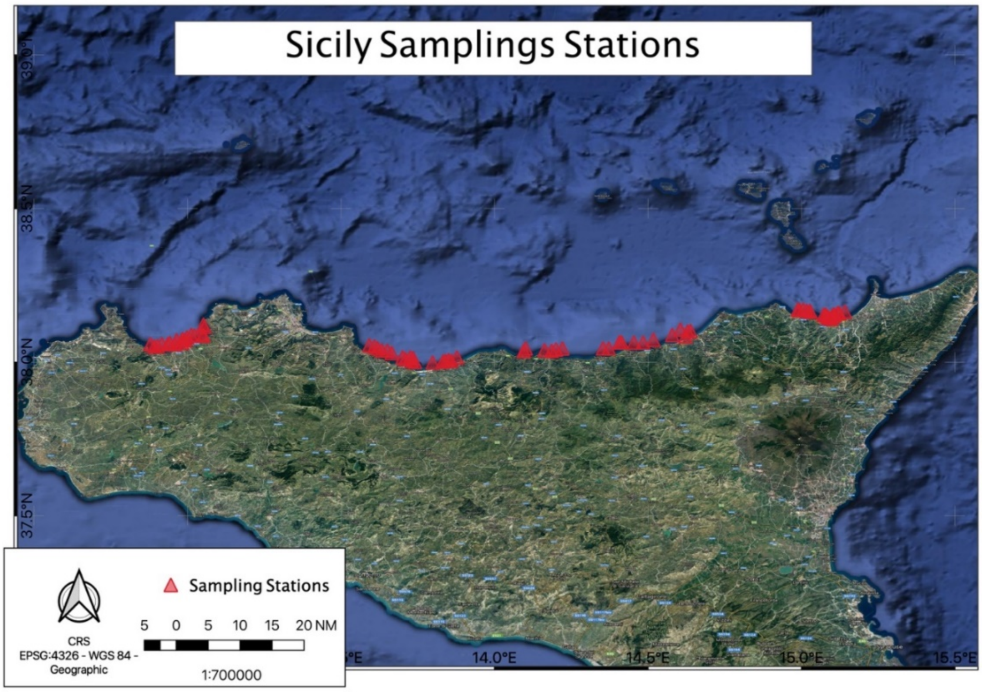

Figure 37. Overview of the Sicily sampling stations.

Potential benthic data sources from EMODNET Biology portal in Mediterranean for WGFBIT purpose

Regular benthic surveys on large spatial scale are scarce for the Mediterranean area. For a proper execution of the FBIT framework, the habitat specific recovery estimates, derived from the longevity curves need to be based on benthic data. Therefore, potential data sources were searched for in the EMODNET biology portal, besides data from FBIT participants. This was done by using the search term “Mediterranean” under theme “Benthos”, including all data origins. From this search 101 potential datasets were retrieved (see document “Emodnet Med dataset analyses” on sharepoint), whereof at the end 20 were maybe relevant (Table 20). Seven of those are worthwhile to further explore or compile in the near future. The majority of the 101 datasets, were not relevant, due to there are not focusing on macrobenthos, epifauna or megabenthos; are being from Black Sea or lagoon systems or contain a fraction of the benthic fauna (e.g. only Crustacea).

Table 20. Overview of the Emodnet Med benthic datasets, that maybe of importance for the FBIT framework.

EMODNET Search on Mediterranean benthic datasets	**yes(1)/ no(0)**	REMARK
Aegean Polychaetes, more	1	HCMR (Christos A.); shallow
Aegean Sea Cruise Benthos, more	1	2000m)
REBENT: Benthic Network, more	**1**	included, shallow area
MEDITS-Spain: Demersal and mega-benthic species from the MEDITS (Mediterranean International Trawl Survey) project on the Spanish continental shelf between 1994 and 2010, more	**1**	Megabenthos part?; but no fishery pressure data
Fauna Bentonica, more	1	coverage
Trawl-survey data from the Pipeta Expedition in the Adriatic Sea (Mediterranean) collected in 1982, more	1	covered adriatic; trawl, but major taxa
Trawl-survey data from the Pipeta programme in the Northern Adriatic Sea (Mediterranean) collected in 1988 and 1991, more	1	only North
LBMRev, more	[1]	1985-2004University Trieste, trieste area
Macrobenthos North Adriatic-ALPE ADRIA Project, more	[1]	1990-1993; Trieste
Macrobenthos collected in the Po River Delta - North Adriatic Sea (RITMARE Project) in December 2014, more	[1]	Po Delta, transect data 2014
Macrofauna Bahia de Blanes, more	[1]	1992-1997; two coastal points
Megafaunal data from the 2009 BIOFUN trans-Mediterranean deep-sea cruise, more	[1]	Mollusca, fish); cross-Med area
Polychaete Study in Northeastern Mediterranean Coast of Egypt, more	[1]	6 locations, 2008
SARONIKOS, more	[1]	restricted; 6 locations; 1999 on
Trawl survey data from the Jabuka Pit area (central-eastern Adriatic Sea, Mediterranean) collected between 1956 and 1971, more	[1]	Crustacea, Mollusca
Benthos Cretan Continental Shelf, more	[1]	Dounas C., 1988; shallow
Kalamitsi, more	[1]	Ionean Sea, 1991
Kerkyra, more	[1]	Ionean Sea, 1991
Kyklades, more	[1]	1986, central aegan sea
Macrobenthos North Adriatic-INTERREG-FVG Project, more	[1]	99-2005; Trieste
Marine biodiversity atlas of the Balearic Sea, more	[1]	observation methods

Step 3: Predict sensitivity

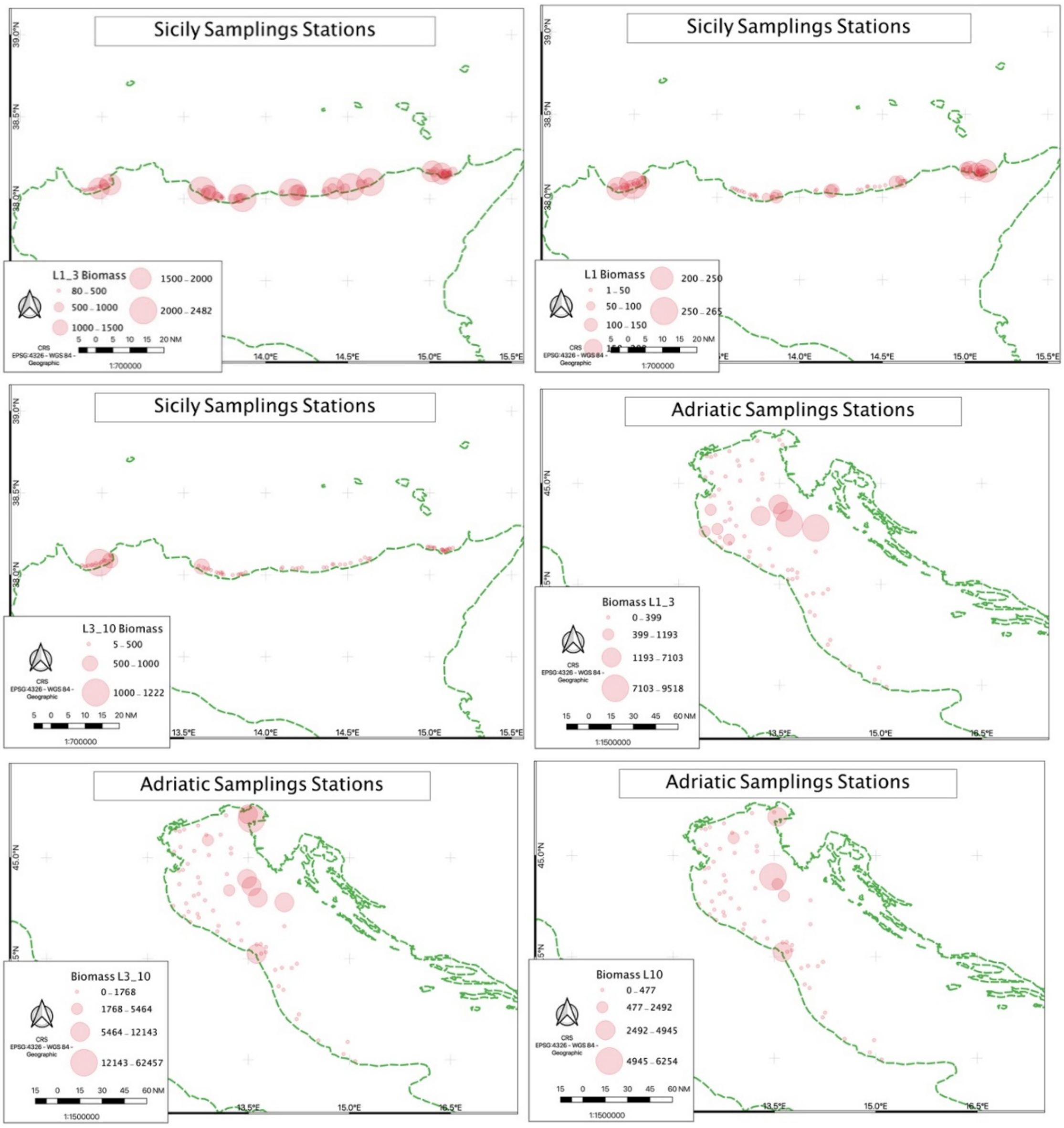

Figure 38. Overview of the Biomass for the different longevity classed in the Adriatic and Sicily sampling stations.

Benthic sensitivity

For testing the methodology to calculate the recovery based on longevity from Adriatic benthic data, all data from both fished and unfished arear, are included. This aspect need of course to be tackled in the near future.

Tested Models for the Benthic Sensitivity regression (see Table 21):

- mod1 <- glmer(Cumb ~ ll + MSFD*ll + Depth + (1 | ID), data=fulldat, family=binomial)
- mod2 <- glmer(Cumb ~ ll + MSFD + Depth + (1 | ID), data=fulldat, family=binomial)
- mod3 <- glmer(Cumb ~ ll + (1 | ID), data=fulldat, family=binomial)
- mod4 <- glmer(Cumb ~ ll + Depth + (1 | ID), data=fulldat, family=binomial)

- mod5 <- glmer(Cumb ~ ll + Depth*ll + (1 | ID), data=fulldat, family=binomial)
- mod6 <- glmer(Cumb ~ ll + MSFD + (1 | ID), data=fulldat, family=binomial)
- mod7 <- glmer(Cumb ~ ll + MSFD*Depth + (1 | ID), data=fulldat, family=binomial)

Table 21. Output of tested models, with df and AIC indicated.

	df	AIC
mod1	6	171.3285
mod2	7	174.8225
mod3	3	174.1549
mod4	4	170.5583
mod5	5	172.4647
mod6	6	176.9239
mod7	10	172.4067

Regression versus Depth

Generalized linear mixed model fit by maximum likelihood (Laplace Approximation) ['glmer-Mod']
Family: binomial (logit)
Formula: Cumb ~ ll + Depth + (1 | ID)
Data: fulldat

```
  AIC      BIC   logLik deviance df.resid
 170.6    185.8    -81.3    162.6      332
Scaled residuals:
    Min       1Q   Median       3Q      Max
-14.1558  -0.0794   0.0216   0.2146   5.1910
Random effects:
 Groups Name        Variance  Std.Dev.
 ID     (Intercept) 1.157e-09 3.401e-05
Number of obs: 336, groups:  ID, 112
Fixed effects:
```

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	**-5.811481**	**1.030366**	**-5.640**	**1.70e-08**	***
ll	**4.808707**	**0.867020**	**5.546**	**2.92e-08**	***
Depth	**-0.018402**	**0.008176**	**-2.251**	**0.0244**	*

```
---Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
      (Intr) ll
ll    -0.943
Depth  0.381 -0.114
convergence code: 0
boundary (singular) fit: see ?is Singular
```

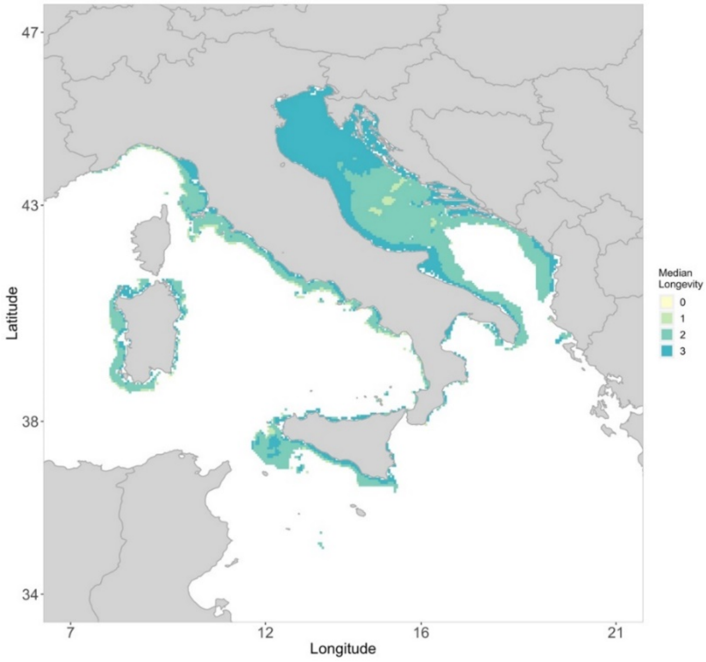

Figure 39. Median longevity of benthic communities in the Italian seas.

Step 4: Impact assessment

Surface SAR

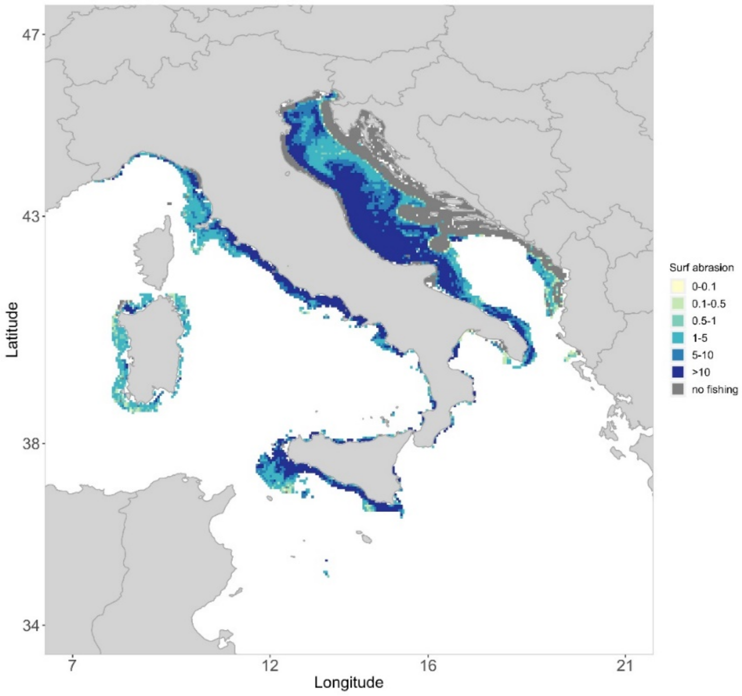

Figure 40. Prevision of sea bottom abrasion (expressed as SAR) in the Italian Seas for otter trawl (OT) data.

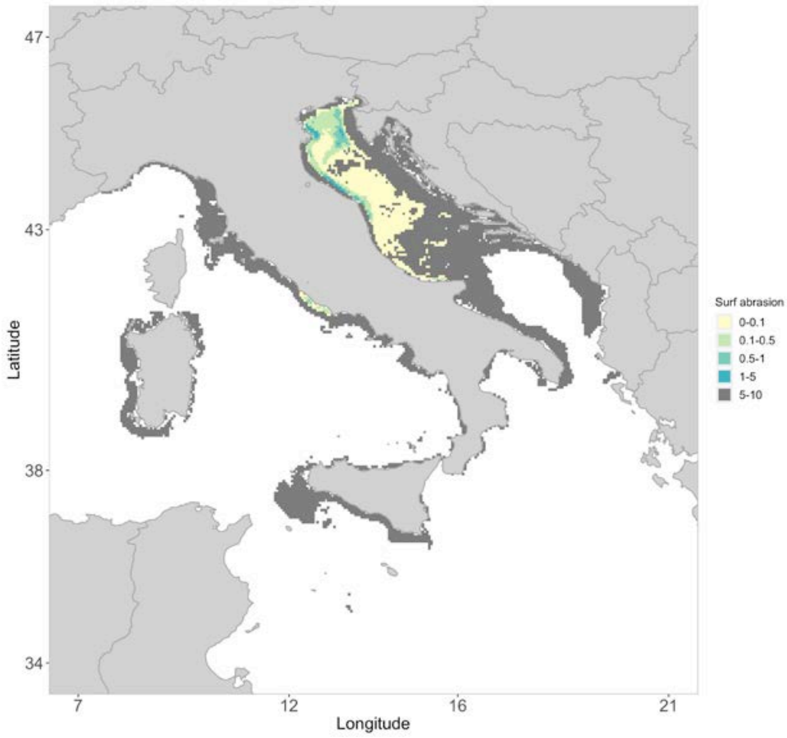

Figure 41. Prevision of sea bottom abrasion (expressed as SAR) in the Italian Seas for beam trawl (TBB) data.

Seabed state

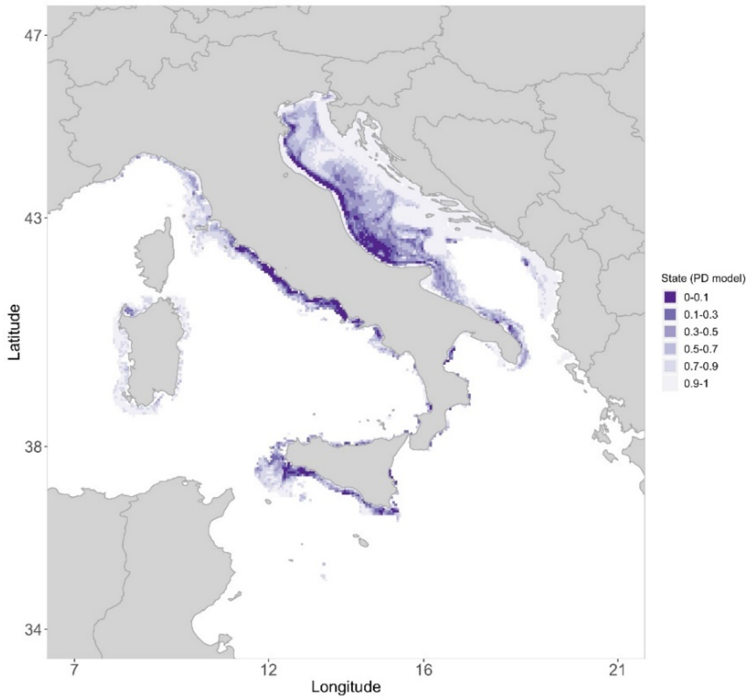

Figure 42. State (one minus impact) based on PD model of Italian Seas.

Table 22. State Estimate by MSFD habitat.

Habitat type	Impact
Shallow_sublittoral_mud	0.9173496
Shallow_sublittoral_sand	0.8683704
Shelf_sublittoral_mud	0.6280393
Shelf_sublittoral_sand	0.7707954

Step 6, 7 and 8: Validation, confidence and trade off

These aspects were not yet tackled.

Gaps

- Other environmental variables from EMODnet:
  - Kinetic energy at the seabed due to currents (Mediterranean)
  - Fraction of surface light reaching the seabed (Europe-wide)
  - Light (PAR) at the seabed (Europe-wide)
  - Modelled occurrence probability for Maerl habitats across the Mediterranean Sea
  - Modelled occurrence probability for Posidonia oceanica meadows across the Mediterranean Sea

Conclusions / take home message

SoleMon survey is carried out every year in November. A systematic sampling strategy was adopted during the first exploratory survey in 2005 and a randomly stratified sampling is performed in subsequent years. Three depth strata were identified: 0–30 m; 30–50 m and 50–100 m. During the survey both commercial and discards are identified, weighted and counted.

SoleMon participation in the next WGFBIT meetings should be desirable in order to provide data for the Adriatic Sea.

The MEDITS program in the Mediterranean Sea, funded by DG-MARE is aimed at the assessment of demersal resources of Mediterranean European countries from 10 to 800 m depths. During the survey, carried out usually in all the EU countries, between May and July, in order to represent a snapshot on the late spring-early summer situation, trawl hauls are carried out, with a random stratified sampling design (see MEDITS Handbook 2017), on sandy-muddy bottoms and both commercial, by-catch and discards are identified, weighted and whenever possible (commercial and by-catch species) counted. Thus, although data useful for the scope of WGFBIT concerns epi- megafauna, they can provide a long-term data series (MEDITS is active since 1984) and a wide spatial coverture across the Mediterranean. Therefore, MEDITS community (i.e. through the General Assembly or single State contact point) should be invited in the next WGFBIT meeting.

Further, in order to gather data from non-EU Mediterranean members an involvement of GFCM is also desirable. GFCM is organizing a MEDITS-like program in different Eastern Mediterranean countries such as Lebanon.

Finally, other EU project such as INTERREG, with WGFBIT-related activities, could be followed and coordinators and/or partners invited to the group (i.e. HARMONY, an Italy-Malta INTERREG or BLUE-ADAPT, an Italy-Tunisia INTERREG).

The last consideration concerns the decommissioning of EU Mediterranean fleet that took place in the last 20 years. The data here processed are from 2005 (data on N Sicily) and 2012 (data from the Adriatic), so when the effort was probably considerably higher than what was estimated in this exercise. In addition, whilst the fishing capacity of EU Mediterranean countries decreased as effects of the decommissioning scheme with a subsequent reduction in landings, an increasing in fishing capacity cannot be excluded in other Mediterranean (not belong to EU) areas (Samy-Kamal, 2015).

4 Methodological issues

Existing collations of longevity data

Collations of longevity estimates exist for bivalves and sessile invertebrates, containing >600 species (Ridgway *et al.*, 2011; Moss *et al.*, 2016; Montero-Serra *et al.*, 2018). Olivier Beauchard has also collated a large number of longevity estimates.

How to interpret the value of Relative Benthic State (RBS)?

The assessment results in an RBS value between 0 and 1 for each c-square, and a mean RBS value per broad habitat type. Trawled cells will have a RBS<1, while untrawled cells have RBS=1. The estimated RBS is for the benthic community composition present in unfished habitats. Thus, RBS=0 does not imply that no biota are left in on the seabed; rather, the biota typically present in unimpacted habitats would be entirely depleted whereas more resilient biota may have increased in abundance and would remain.

How does it relate to function?

A good indicator to assess GES for D6 of the MSFD should relate to the biodiversity, structure and function of the benthic community (ICES, 2016, 2017). The PD method combines information on total benthic biomass (which is linked to the overall functioning of the ecosystem) with the relative abundance of different longevity classes (that in turn relates to the structure and biodiversity). A 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. Community biomass correlates to the energy flow through food webs and other ecosystem processes (e.g. nutrient cycling, bioturbation and food provisioning for fish and sea birds).

What sampling data is appropriate for fitting the biomass-longevity curves by habitat?

In practice, assessments will need to use the data currently available. However, it is worthwhile considering the kind of sampling data which is preferred. Benthic communities can be sampled using different gears, e.g. box corers, dredges, small mesh trawls and commercial size trawls. Each of these gears will capture a different component of the benthic community. Grabs and corers are more suited for sampling small fauna living in and on the seabed, dredges obtain a larger fraction of large infauna, and trawls obtain more mobile epifauna.

After correcting for differences in efficiency of different gears, the biomass of benthic biota per m2 in the size range that is sampled well by grabs (10-3 to 101 g WW) is about 1.25 times higher than the size range sampled well by 2m-beam trawl with a 2mm mesh line (10-1 to 103 g WW). This in turn is about a factor 2.4 higher than the faunal component sampled by a 4m-beam trawl with a 8cm mesh (102 to 104 g WW) (Howarth *et al.*, 2018b). Combining grab/core with 2m-beam trawl samples will therefore be useful, but further inclusions of 4m-beam trawl samples will not necessarily substantially change biomass-longevity distributions.

Because a correlation exists between longevity and body-size (significant yet highly variable, e.g. for bivalves (Ridgway *et al.*, 2011)), gears that sample large fauna will catch a larger fraction of long-lived fauna. Assessments using only grab or core samples will, therefore, underestimate the real fraction of long-lived fauna and underestimate the impact of bottom trawling on RBS. Assessments using only trawl samples, or video or stills, will probably overestimate the real fraction of long-lived fauna and overestimate the impact of bottom trawling on RBS.

Therefore, ideally the assessment will use biomass-longevity distributions that are representative of the whole community, ranging from sessile infauna to mobile epifauna. It is likely that such an approach will require combining data from different sampling gears by correcting for gear efficiency.

Abundance to biomass conversions

The parameterisation of the PD model requires a biomass-longevity distribution curves. However, many benthic surveys have only quantified numerical abundance of fauna and not biomass, which means that this data cannot be directly used to fit these curves. It may however be possible to convert abundance to biomass by using estimates of mean weights of individual animals for genera from other datasets. Analyses were performed to compare the mean wet weight of individuals per genera from 7 different surveys using a variety of sampling gears (grab, box corer, dredge, 2m beam trawl, 4m beam trawl) from the Celtic Sea (Howarth *et al.*, 2018a; Waggitt *et al.*, 2018), 5 surveys in the North Sea (Tillin *et al.*, 2006; van Denderen *et al.*, 2015), the Kattegat (Hiddink *et al.*, 2016) and the eastern Baltic Sea (Oxytrawl survey, Hiddink and Van Denderen). All surveys occurred between April and September. The mean wet weight of individuals per genus was compared for all genera that occurred in at least two of these surveys. The mean wet weight per species correlated tightly between surveys (t1599 =39.99, p<0.0001, R2=0.80), and this suggests that mean wet weight per individual per genus from one area may be used to estimate mean wet weight per genus for surveys where only abundance was measured. A table of mean wet weights for 348 benthic invertebrates from this analysis is provided in Annex 5.

Obtaining precise mean wet weight estimates from reference areas will require samples for which large numbers of individuals have been measured. A good estimate of maximum body size may be more quickly obtained, and may be used as a proxy for mean body size if a strong correlation exists between them, as can be expected from life-history theory (Charnov, 1993). An analysis using the same dataset show that maximum body size, estimated as the 95th quantile of wet weight, correlates tightly with mean body size (maximum wet weight = 2.34245 x mean wet weight, t103=62.4, p<0.0001, R2=0.974, for genera with n>50 only).

This suggests that measures of both mean and maximum body size from other areas may be used to convert abundance to biomass estimates for the fitting of longevity biomass distributions.

Seasonality in ratio of different longevity biomass

It is important that the benthic sample data that is used to estimate the biomass-longevity distribution is representative and comparable between and within ecoregions. It is conceivable that this distribution varies with the seasons (e.g. short-lived species are likely to show larger variations in biomass with the seasons than long-lived species). WGFBIT tested whether the longevity distribution seasonally varies based on a dataset for the Celtic Sea, where 20 stations were sampled twice, in contrasting seasons (September 2015 and April 2016). Although there was a larger fraction of short-lived biota in September than in April (particularly in the 1-3yr trait class; Figure 32), as one may have predicted, this difference was not significant for combined gears(AIC for model with season = 7.52, AIC for model without season = 5.51), nor for any of the individual gears. This suggests that it is not necessary standardize the sampling season for data used for the fitting of longevity distributions.

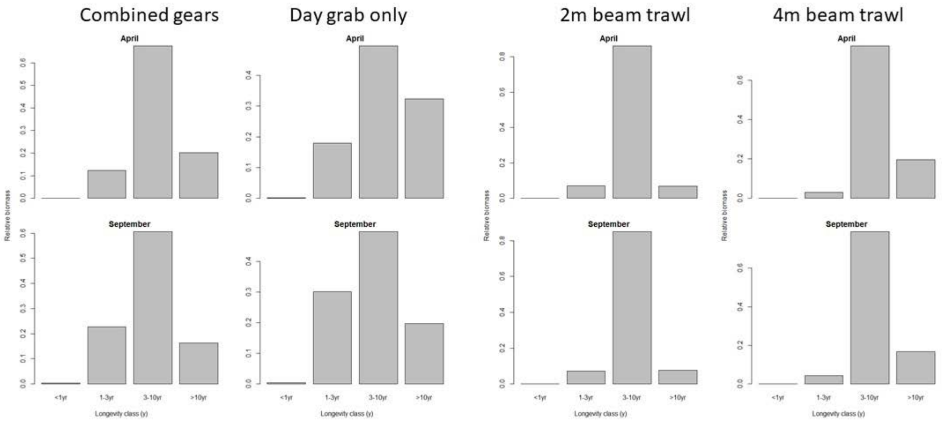

Figure 43. Biomass-longevity distribution of benthic invertebrates in the Celtic Sea in April 2016 and September 2015. Mean over 20 stations that were sampled using grabs and trawls, data corrected for differences in gear efficiencies. Data from (Howarth *et al.*, 2018a; Howarth *et al.*, 2018b).

This analysis also 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.

Other pressures: FBIT framework for estimating disturbance from human activities resulting in abrasion, removal and deposition

Over the past 2 years, an ICES advice process has been working towards advising the EU with regard to a seafloor assessment process for physical loss and physical disturbance on benthic habitats (ICES 2019). This ICES advice relates to criteria D6C1 (physical loss pressure) and D6C4 (habitat loss), as well as D6C2 (physical disturbance pressure) as laid down in Commission Decision (EU) 2017/848 (EU, 2017) under Descriptor 6 (D6 seafloor integrity) of the Marine Strategy Framework Directive (EU, 2008) that sets out the requirement that "sea-floor integrity is at a level that ensures that the structure and functions of ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected."

In this work, ICES has advised the use of a single assessment process (Figure 44). This assessment process expresses the spatial extent and distribution of these pressures, both separately and in combination, and can be applied in MSFD marine waters per subdivision and (where possible) per MSFD broad habitat type. The assessment process presented in the ICES advice facilitates the development of an overarching regional framework that also allows for the benchmarking of national assessments against regional assessments, thereby providing further consistency.

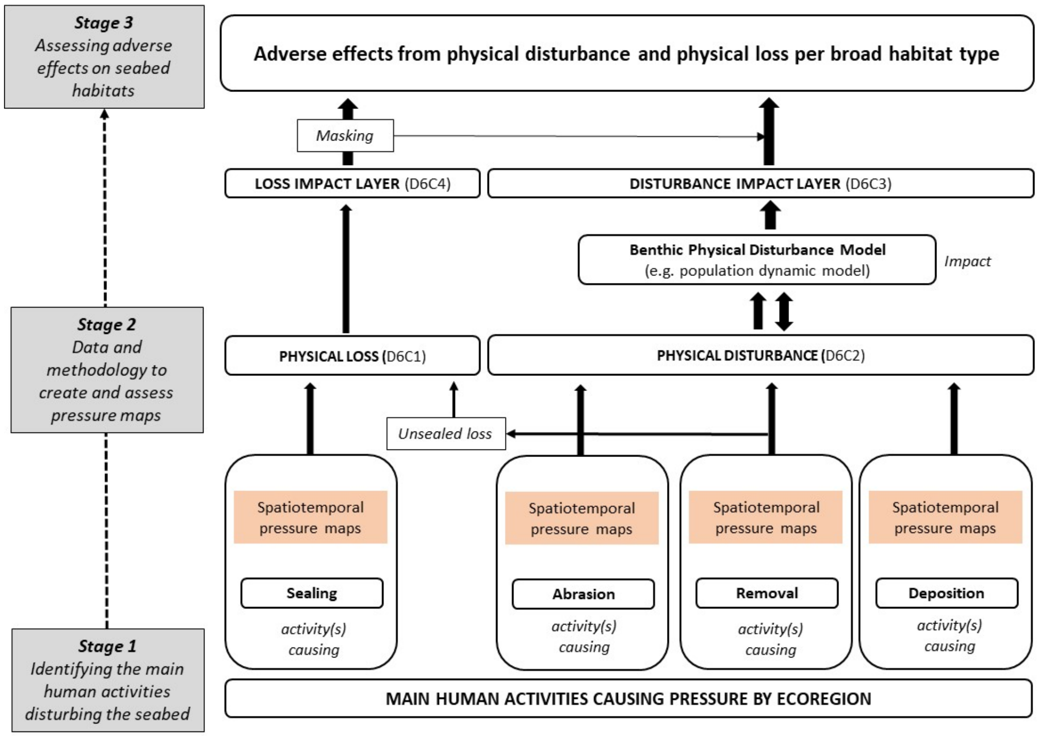

Figure 44. Seafloor assessment process (from ICES 2019).

The assessment process consists of three stages to assess the criteria D6C1, D6C2, and D6C4 and is designed to accommodate for the assessment of criterion D6C3.

- Stage 1. Identifying the main human activities disturbing the seabed
- Stage 2. Data and methodology to create and assess pressure maps
- Stage 3. Assessing adverse effects on seabed habitat

The 2019 ICES advice also highlighted that key to the process of translating from pressure into adverse effects is to define and quantify pressures, in a way that allows their use in the assessment of impacts on seabed integrity. At the heart of this process is a benthic physical disturbance model, or a series of such models which translate various pressure subtypes into impact in a biologically meaningful way.

As such the ongoing WGFBIT work will serve to operationalize the assessment procedure initially for looking at the impact from abrasion using the PD model, and can be used to accommodate other pressures in future iterations of the assessment. Some of these key steps in terms of parameterizing the PD model for removal and deposition are discussed in the 2019 Advice and the WKBEDPRES2 report.

Abrasion of the seabed results primarily from mobile bottom-contacting fishing gears, but other activities, such as aggregate extraction, can also result in abrasion. All activities that result in abrasion of the seabed can be combined into a single pressure through the mapping of the footprint of the activities on the seabed, and the intensity of the abrasion within this footprint can be quantified as the depletion of benthic fauna within this footprint (where depletion is defined as the fraction of benthic fauna killed or removed by a single pass within the footprint (Pitcher *et al.*, 2017; Sciberras *et al.*, 2018; Hiddink *et al.*, 2019). These methods can be integrated in a benthic physical disturbance model (e.g. the Population Dynamic Model, see Annex 4 in ICES, 2018b) with subsequent indicators, that ICES has advised the EU could be used (ICES, 2017) to assess benthic impacts. Such a model can be extended to include abrasion by other activities where a footprint and depletion rate can be quantified.

Similarly the assessment methodology of FBIT has been used in this ICES advice process (namely in WKBEDPRES1 and WKBEDPRES2) to determine the data products needed to assess other human activities than bottom fishing that cause physical abrasion to the seabed, e.g. aggregate extraction. The methodology has furthermore been used to produce a demonstration product showing the spatial extent of physical loss and cumulative disturbance pressures in the North Sea ecoregion.

Fundamental aspects for this wider application of the FBIT framework is the determination of pressure-activity specific depletion and recovery values to run the benthic model for impact estimation within the FBIT framework. For example, currently no values were available about depletion caused by physical abrasion caused by sand extraction, for how fauna is depleted in relation to smothering caused by dredge disposal. In the future, after specific research or workshops, the aim for the FBIT framework to be expanded to incorporate these other pressures in the assessment of seafloor integrity.

5 Science contributions

During the meeting, ongoing research work was presented by several participants.

Towards the assessment of North Atlantic deep-sea ecosystems' status: opportunities and challenges unravelled by the ATLAS project

Georgios Kazanidis, Covadonga Orejas, Angel Borja, Lea-Anne Henry, Oisin Callery, Marina Carreiro-Silva, Hrönn Egilsdóttir, Anthony Grehan, Ellen Kenchington, Lenaick Menot, Telmo Morato, Stefan Aki Ragnarsson, Steve Ross, Christopher Roterman, José Luis Rueda, David Stirling, Tanja Stratmann, Javier Urra, Dick van Oevelen, J Murray Roberts

The H2020 ATLAS project (https://www.eu-atlas.org/) aims to improve our understanding of complex deep-sea ecosystems informing the development of international policies to ensure deep-sea Atlantic resources are managed effectively. As part of this, ATLAS has assembled an international group of experts aiming to facilitate the implementation of the Marine Strategy Framework Directive and achieve Good Environmental Status (GES) in the deep-sea ecosystems of the North Atlantic. The ATLAS work on GES has four objectives: 1) to propose scientific indicators for the assessment of deep-sea environmental status & identify the MSFD Criteria that could be addressed by those indicators, 2) to evaluate the usefulness of the Nested Environmental Status Assessment Tool (http://www.devotes-project.eu/neat/) for the assessment of deep-sea environmental status, 3) to identify the challenges and opportunities in the assessment of deep-sea environmental status and 4) to propose guidelines and recommendations for the assessment of the deep-sea status. The GES work in ATLAS has focused on four MSFD Descriptors (D1: Biodiversity, D3: Commercial fish and shellfish, D6: Seafloor integrity, D10: Marine litter) as they are particularly relevant for the deep sea. The work has focused on 9 case studies: LoVe Observatory, Faroe-Shetland Channel, Reykjanes Ridge, Mingulay Reef Complex, Rockall Bank, Porcupine Seabight, Bay of Biscay, Azores and Gulf of Cadiz. 24 indicators were selected in total (3 in D1, 5 in D3, 14 in D6 and 2 in D10) mainly based on data availability. Each of the indicators was linked to spatial assessment units, habitats and ecosystem components in each of the ATLAS case studies. This was followed by the supply of data and the setup of boundary values (each of them representing a different environmental status) for each of the indicators. The potential of each of the 24 indicators to be used in the assessment of deep-sea environmental status was evaluated based on data availability and data quality. In 4 of the ATLAS case studies there was a moderate agreement between the NEAT results and expert judgement, in 2 there was good, in 2 there was complete agreement while in 1 case an opinion was not expressed. Major challenges for the assessment of environmental status in the deep sea are the limited knowledge (in space and time) of the structure and functioning of ecosystems, the limited understanding about the role of natural variability, the lack of standardization and the almost absence of historic data that can serve the establishment of baselines. Technological advances (e.g. species distribution models, use of autonomous underwater vehicles, artificial intelligence), intersectoral collaboration (industry-academia), improved use of already available and new data (e.g. deposition in online archives) will advance our understanding about the structure and functioning of deep-sea ecosystems as well as their response to human activities serving thus the implementation of Marine Strategy Framework Directive and achievement of Good Environmental Status in deep-sea regions.

Vulnerability of benthic habitats to trawling in the English Channel, the North Sea and the Mediterranean Sea (Cyrielle Jac, Nicolas Desroy, Sandrine Vaz); (presented by P. Laffarque)

The European Union drew up the Marine Strategy Framework Directive (MSFD) in 2008 to achieve or to maintain good environmental status in the marine environment in 2020 at the latest. To control degradation factors and manage the consequences, the MSFD is divided in descriptors and criterias for which indicators and threshold values must be defined. Bottom trawling being the main source of shelf continental disturbance, the goal of this study is to evaluate the vulnerability of each benthic habitat to trawling in three areas: the English Channel, the North Sea and the Mediterranean Sea. Trawling impacts are dependent of the spatial and temporal distribution of the fishing effort, the habitat type, the fishing gear and the degree of natural perturbation. Benthic community structures present in these areas were studied using data of by-catch non-commercial benthic invertebrates collected during scientific bottom trawling surveys: MEDITS, IBTS, CGFS and CAMANOC. The percentage of abrasion was evaluated using VMS data and allowed to highlight a very important heterogeneity in the spatial distribution of the fishing effort. To studied the benthic communities' status along the trawling gradient in each encountered habitat, 14 different indicators (univariate or functional) were used and compared. After determining which indicators could be used to study the impact of trawling on epifauna, a modeling approach was used to determine abrasion threshold values on each habitat of the classification EUNIS level 4. Values, beyond which trawling has a negative impact on benthic communities, have been determined in this study. The result of this work is a map of the potential impact of trawling in these three areas, which we hope may prove useful for the D6 (seabed integrity) MFSD descriptor.

Does fishing impact ecological process?? (**Dario Fiorentino**, C Kraan, O R Eigaard, W Armonies, U Gräwe, S Kadar Badesab, F Bas-tardie, G E Dinesen, H Gislason, J Dannheim, T Brey)

Bottom trawling is damaging the fauna living at the seafloor. Few studies have investigated the impact on spatial structure benthic organisms. We think that the spatial structure of benthic organisms informs on connectivity across an area, which is very useful to understand ecological processes such as dispersion and recruitment.

Here, we 1) identified the spatial scales at which trawling indirectly affects macrozoobenthos, 2) investigated the interactions between such impact and environmental conditions and 3) mapped the impact of this fishing on macrozoobenthos.

The analysis relied on high quality Vessel Monitoring System (VMS) data of swept area for individual vessels and 20 environmental descriptors. Biotic data consisted of 140 macrozoobenthos species from 300 grab-samples taken in the German Bight (North Sea), collected on an area of about 8000 km2.

We used Moran Eigenvector Maps (MEM) to model connectivity between locations and identify the relevant spatial scales of macrozoobenthos distribution. Partial Redundancy Analysis (pRDA) identified the spatial scales at which fishing affects macrozoobenthos. Random Forest was used to map the impact of fishing and investigate the interactions with environmental parameters at each scale.

We identified the fauna structured in three spatial scales and the fishing paramenters significantly impacting the connectivity between locations. Furthermore, we found non-linear correlation between the impact and environmental parameters. Finally, we could map fishing impact on location connectivity, also highlighting areas where fishing impacts connectivity.

Our novel approach integrates spatial components of the ecosystem to advance our understanding of the processes that shape ecosystems and diversity distribution. We think that taking care of those areas specifically impacting connectivity will support benthic communities' recovery in the future as depletion of fishing in those areas may put back locations in connection.

Spatial distribution of megazoobenthic assemblages in the Adriatic Sea (**Elisa Punzo**, Fabio Grati, Gianna Fabi, Vera Salvalaggio, Angela Santelli, Pierluigi Strafella, Anna Nora Tassetti, Giuseppe Scarcella)

The study describes the composition, spatial distribution and persistence of invertebrate megazoobenthic assemblages in the Adriatic Sea. Within Solemon project, samples were collected during rapido trawl. A total of 4 main megazoobenthic assemblages were identified and were designated as A, B, C and D. Group A assemblages were detected in the northern and central offshore area, Group B assemblages occupied the northernmost part of the basin, Group C assemblages were predominantly found along the western coast and Group D assemblages were detected in the deepest parts of the northern and central basin. A degree of spatial overlap in the northern Adriatic was probably due to the physical and chemical characteristics of the area, which is characterized by strong river runoff, hence by changes in sediment composition from sandy mud to muddy sand.

The present findings may help to devise integrated management strategies of fishing activities, especially trawling, in view of the implementation of the Ecosystem Approach to Fisheries Management, and may help to define some descriptors of the Marine Strategy Framework Directive.

Among the others, this study supports the proposal to establish a Fisheries Restricted Area, called «Sole sanctuary» in the northern Adriatic Sea (Scarcella *et al.*, 2014 and Bastardie *et al.*, 2017), where the adults of Solea solea are concentrated.

In fact, the proposed area is characterized by the presence of holothurians (mainly Holothuria forskali, H. tubulosa and Stichopus regalis) and bryozoans (Amathia semiconvoluta), which strongly reduces the efficiency of towed gears and damages the catch (evisceration of holothurians), favoring the use of set nets (gillnets), which are not spatially compatible with active gears.

How does bottom trawling affect seafloor integrity, water quality and protected areas in the Baltic Sea? (Mathias Skold *et al.*)

The effect of bottom trawling on Baltic Sea seabeds is poorly understood. Evidence from other seas shows that benthic fauna and sediments may be severely disturbed by this fishing method. Suspended sediment can also increase turbidity and be transported by currents into other less disturbed areas. In the southern Baltic, where there is intensive bottom trawling for cod, there is a risk that trawl-suspended sediment could drift into cod spawning areas at a sensitive time of this species' life cycle. Also, the Baltic ecosystem has been a recipient for anthropgenic contaminants during the 1900 century and the sediment is now the main source for contaminants to the biota in the Baltic. However, this has not been quantified, despite this information being essential in the effective planning of MPAs, ecosystem-based sustainable fisheries management and assessment of seafloor integrity and ecological status of benthic ecosystems in the Baltic Sea.

This project will: a) quantify how seafloor integrity is altered by bottom trawling; b) quantify the amount of sediment, nutrients and contaminants suspended by bottom trawling; c) quantify and model the distance suspended sediment is transported before settling; d) provide concrete recommendations to managers and policy makers on the optimisation of marine protected areas and fisheries closed areas. These questions will be addressed by field measurements of the extent and effects of experimental and commercial trawling (using state-of-the-art acoustic methods), modelling of the spread of sediment suspended by trawling, and lab experiments.

There is lack of knowledge about the extent to which bottom trawling disturbs the Baltic seafloor by stirring up sediment, and re-mobilizing nutrients and contaminants. This information is essential in the effective planning of marine protected areas (MPAs), ecosystem-based sustainable management of fisheries and assessment of seafloor integrity and Good environmental status (GES) of benthic ecosystems.

The project is a collaboration between Stockholm University (Professor Clare Bradshaw coordinator), the Swedish University of Agricultural Sciences, and Norwegian Institute For Water Research (NIVA), and funded by Formas, a government research council for sustainable development.

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6 General issues

6.1 Trade-off

Better indicators of socio-economic impact

As part of the 2018 WGFBIT working group, trade-offs were established to compare the effects of a number of scenarios to reduce fishing intensity by 10%. The approach used the expression of 'cost' to the fishery (to be traded off against gain in benthic state) as either biomass or monetary value of fish not caught as a consequence of the reduction. This was considered an important weakness of the approach. This was an important reason to call for the workshop 'WKTRADE2', which was held in September 2019. An important aim of that workshop was to study further the possible implementation of the variable cost of fishing in each location. This cost could then be used to offset the revenues per location to yield the so-called contribution margin, which can be mapped. The contribution margin is a better estimator of the real value to the fishery, and hence is a better indicator of the socio-economic impact of closing areas to fishing.

WKTRADE2 proposed two approaches: the (1) disaggregation and the (2) mechanistic approach (ICES, 2019).

The disaggregation approach implies that the economic data reported in the Annual Economic Report (AER data) are disaggregated from fleet segment to metier scale, and from annual costs at metier scale at fleet-wide spatial scale to annual costs are fine-scale spatial resolution of an assessed region (c-squares). The disaggregation from metier scale to fine-scale spatial resolution requires a match of the FDI, VMS and AER data to be able to disaggregate the costs. The cost structure from the AER data can then be disaggregated according to fishing effort (e.g. fishing hours), but the nominal cost of a c-square grid cell will not be different in space. The actual differentiation in costs will be a differentiation on the metier level that is presented at fine-scale spatial resolution, but it will not account for the nominal differences in costs. Therefore WKTRADE2, in its report suggested that the cost structure is also assessed following the mechanistic approach to costs.

The mechanistic approach to estimate costs in space requires development and it is unlikely that this will be addressed within the WGFBIT group. Therefore WGFBIT is looking towards other ICES Working Groups (e.g. WGECON) to assess the potential of the mechanistic approach within the WGFBIT tool. An example of the logic of this approach is shown in Equation 1 for the estimation of fuel costs in one grid cell (Figure 33).

$$C_{f,i} = D_i * U_f * P_f \qquad \text{Eq. (1)}$$

Where

$C_{f,i}$ is the fuel costs of one passage during fishing trip in grid cell i

D_i is the distance travelled to get to grid cell i

U_f is the fuel use (consumption) per unit of distance travelled

P_f is the unit price of fuel

Fuel use is a function of metier, and relates to the applied fishing gear, the engine power (kW) and the vessel size (LOA).

While this approach seems promising, WKTRADE2 in its report noted two potential caveats. The first potential caveat is the assumed linearity to get to grid cell i. The cost to get to grid cell i should take into account that a fishing vessel may also be fishing in the areas between the fishing harbour and the grid cell, so that the actual cost of the travelled distance is not varying with the generated revenues along the way and not solely with distance. The second caveat to implement this approach in the FBIT tool is the requirement of data at the national level.

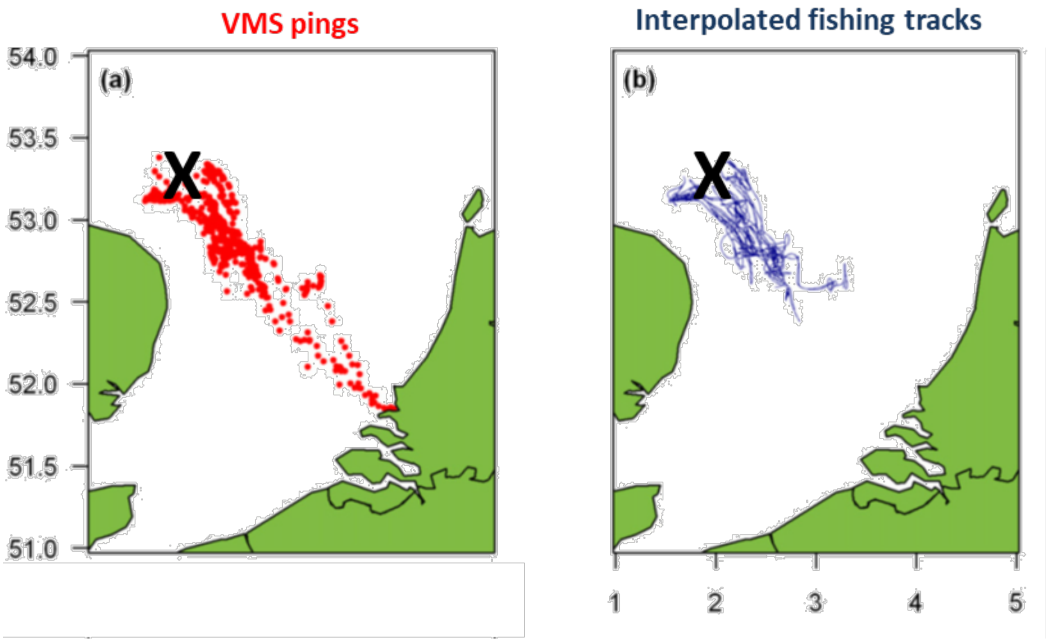


Figure 45. Available data from VMS data at national level. VMS pings can be used to estimate the locations of steaming and fishing (based on speed). The interpolation method from Hintzen *et al.* (2010) can be used to track the travelled distance for both steaming and fishing. The cost of fishing in location X is not linear with the distance from the coast, because revenues can be generated prior to getting to location X.

A WGFBIT subgroup discussed the work of WKTRADE2. WGFBIT considers the proposed refinement of the location-specific socio-economic value of high importance, and recommends further development. The progress made in WTRADE2 is promising, but not yet applicable in the FBIT assessment framework. However, it is important for the FBIT assessment development that there is now a report clearly highlighting the complexity of developing strong socio-economic indicators. Therefore, it was decided that until better indicators become operationally available, the FBIT framework will continue to use fish biomass and its value as its socio-economic indicator. WGFBIT considers changes in these quantities, in absence of a better alternative, a reasonable approximation of the relative economic impact of seafloor conservation measures on the fishing industry and the metiers it is made up of.

Better implementation of displacement from closed areas

A second goal of the WKTRADE2 workshop was to explore better ways to implement the adaptation (displacement) of the fleet after areas are closed. The scenarios studied in 2018 (ICES, 2018) only looked at area closures where the closing of areas led to a reduction in fishing effort. However, many spatial management regulations are not associated with effort reduction, so that the displaced effort is likely to be added in another location. The current FBIT assessment framework uses a simple reallocation of displaced effort to all grid cells, in proportion to their prevailing fishing effort. However, this is generally deemed unrealistic – displaced fishermen are likely to explore specific new fishing grounds, not fish slightly more in other areas they already used.

Fishermen may even relocate to formerly unfished areas, reducing or theoretically even reversing the net effect of area closures on a larger spatial scale.

WKTRADE2 showed the need to address knock-on effects from displacement of fishing effort due to the proposed measures to improve the benthic status (ICES, 2019). Applying predictive modelling techniques adds to assessing a static picture (current fishing activity) because it considers displacement effects which may elucidate increased pressure on essential fish habitats, sensitive vulnerable habitats, or previously untrawled areas.

WGFBIT acknowledges the burden of complexity in applying bio-economic dynamic models and suggests to first use the static approaches as an intermediate step to elucidate the key trade-offs between fisheries and benthic protection. However, WGFBIT also acknowledged that an incremental increase in spatial restriction to achieve GES for benthic communities does not relate linearly to effects on fisheries values (and other knock-on effects).

WGFBIT has installed a subgroup whose task is to work, inter-sessionally, on developing useful management scenarios, to be used to feed into the ICES ecosystem overviews, as well as address a potential DGENV trade-off request. Such scenarios can include assumptions about displacement which can be accommodated in the FBIT framework, in 2020. FBIT considers this outside the scope of the current 3-year working group cycle. However, WGFBIT considers the work on displacement of very high importance and it is highly desirable that a mechanistic framework to accommodate displacement becomes available.

6.2 Deep-sea

Application of the FBIT framework to the deep sea

A subgroup met to discuss how to apply the FBIT approach to the deep sea, taking account of the WGDEC progress with this topic. Aims were:

- Further links between WGDEC and WGFBIT to benefit both groups' work towards jointly developing an ICES approach to assess GES that covers both shallow and deep sea areas.
- Noting that such an assessment will be well suited for future iterations of the ICES Ecosystem Overviews advice.
- Work towards this could include consideration of the current state of play, the specific characteristics of both realms, as well as drawing on data sets collected in targeted projects (i.e. ATLAS and IDEM) for assessing GES in the deep-sea, and any forthcoming developments of the assessment methods by WGFBIT.

The principal current human activity resulting in physical disturbance spatially in the deep sea is fishing, in particular bottom trawling (Benn *et al.*, 2010), but also long-lining (Pham *et al.*, 2014). There are also other pressures related to non-renewable resource extraction occurring in the deep sea (e.g. oil and gas exploitation and potentially deep-sea mining in the future, Ragnarsson *et al.*, 2017).

Like on the continental shelf, the deep sea habitats include sedimentary substrates (mostly mud) as well as biogenic habitats, defined here as habitats characterized by high densities of epibenthic organisms that form emergent three-dimensional structures (Morrison *et al.* 2014). Examples of biogenic habitats include cold-water coral reefs and deep-sea sponge aggregations. Some of these habitats are considered as Vulnerable Marine Ecosystems (VMEs), due to their high vulnerability to bottom trawling and slow recovery rates.

The main limitation for the application of the WGFBIT framework in the deep sea, both in sedimentary substrates and in biogenic habitats, is the scarcity of the necessary data on diversity, biomass and longevity.

Information on the composition and distribution of deep-sea ecosystems arise from two main sources. First, from scientific surveys that normally apply non-invasive methods and supply visual observations made by underwater cameras and/or Remotely Operated Vehicles (ROVs). In general, deep sea surveys collecting visual observations have mainly focused on areas of high biogenic complexity and, to date, there is lack of research on the more common and widespread habitat types. An important exception are national mapping programmes like MAREANO in Norway and the Icelandic Habitat Mapping Programme that obtain visual observations in all habitat types (see also Parry *et al.* 2015; OSPAR 2017). Surveys using visual observations provide an accurate description of the species composition and the abundance or density of organisms. Visual observations do not provide biomass estimations directly, and therefore they will require conversions of estimates of density or coverage to community biomass indicators in order to use them within the WGFBIT framework.

At broader spatial scales, information on the distribution of deep-sea benthic ecosystems can be obtained from the analysis of by-catch from dedicated bottom trawl surveys. These data are already being collected in several areas, including Rockall Bank, Bay of Biscay, the Barents Sea, and the Icelandic shelf. By-catch data provides direct estimations of the biomass of benthic organisms, although catchability for some taxa may be low, in particular for organisms with small body sizes. WGFBIT already using these types of data in application of their framework in shallower areas, as it is the case of the Barents Sea (Jørgensen *et al.*, 2019) and the Bay of Biscay.

The fauna living in sedimentary habitats live in cold waters with a relatively low supply of food, and therefore have a slow life-history, with low population growth and recovery rates and long lifespans (Gage and Tyler, 1991; but see also Billett *et al.*, 2001, 2010). There is no reason to assume that the relationship between *r* and longevity that was estimated for continental shelf biota is not applicable to fauna in the deep sea. Similarly, there is no reason to assume that the estimate for depletion *d* from the continental shelf are not applicable to deep-sea fauna. However, to be able to capture the biomass-longevity distribution for these longer-lived fauna, the approach will probably need to use more longevity classes extending into higher ages to be able to characterise the sensitivity of these habitats properly.

Biogenic habitats are likely to suffer high depletion rates as the result of a trawl pass, and biogenic habitats that are made up out of complex and long-lived structures are likely to have very low recovery rates. This means that even low fishing efforts may result in removal of the structures, although untrawled patches may remain even on intensely trawled grounds because of the patchiness of trawling activities. For some of these structures, the longevity of the structure may be much longer than the longevity of the organisms that create the structure, and the recovery rate of the structure may therefore not be well estimated based on the longevity of the biota building the structures. These structures can also support a large variety of epifaunal organisms, that themselves may be short-lived and able to colonize quickly, but that will not recover without recovery of the biogenic structure. Estimates of the recovery rate of biogenic deep-sea biota are not currently available and would be highly valuable.

A final issue is that in many areas of the deep-sea only a small proportion of biogenic habitats have been directly observed, and maps of the distribution of habitats rely heavily on distribution models. Models can be used to predict the distribution of the habitats themselves (e.g. Howell *et al.* 2011, Gonzalez-Mirelis *et al.* 2015), or to predict the presence (Buhl-Mortensen *et al.* 2019, Ramiro-Sanchez *et al.* 2019) or abundance of indicator taxa (e.g. Ruiz-Pico *et al.* 2017). All model predictions have varying degrees of uncertainty, and particular locations can be considered as suitable for more than one habitat type or indicator taxa. Therefore, it is necessary to incorporate into the assessment the predicted distribution of biogenic habitats with their associated uncertainty.

This combination of habitats with very different sensitivities makes a unified assessment under the FBIT framework more difficult. The most practical approach to solve this problem is to assess the impact of trawling in the deep sea in two steps.

In step 1, an assessment is performed based on the sensitivity of the sedimentary habitats only (and the presence of biogenic habitats in the deep sea is effectively ignored). The assessment produces outputs using longevity and depletion values that are appropriate for sedimentary deep-sea biota, and reports these per broad-scale habitat.

In step 2, all actual and potential biogenic habitats as mapped using surveys and species-distribution models is assessed separately. For biogenic structures that may take centuries to recovery, a recovery rate of r ~ 0 may be appropriate to use in the assessment, which means that the state is purely driven by the fishing effort and the depletion rate. This depletion rate will be close to 1 for cold-water hard coral reefs, but closer to the values for continental shelf biota for flexible biota such as sea pens and can be chosen using the values presented in Sciberras *et al.* (2018). This assessment will result in in an estimate of the trawl impacts for biogenic habitats separately from the sedimentary habitats.

This proposed approach is very similar to the approach that was proposed by WKBEDLOSS for assessing the effect of trawling on biogenic habitats.

It will be highly informative to derive *r* estimates for deep-sea biota, using studies that have sample fauna over gradients of trawling intensity.

The first steps needed for the assessment are these.

For sedimentary habitats:

1. Focus initially on regions with a high availability of fishing effort, benthic survey and environmental data layers. The Nordic Seas are a good candidate region.
2. Collate benthic sampling data sets that allow the generation of longevity-biomass distributions. If biomass has not been measured, conversions from abundance, size and or coverage to biomass need to be developed.
3. Update the longevity traits database to include the genera in these samples, and add more longevity modalities to effectively capture high longer-lived nature of these communities
4. Collate environmental data layers that allow the prediction of longevity-biomass distributions. This needs to focus on the drivers of population growth rates, such a depth.
5. Apply the FBIT approach to estimate trawling impact for sedimentary habitats.

For biogenic habitats:

1. Provide maps of the actual and potential distribution of biogenic habitats. These maps are likely to be at spatial resolutions higher than the c-square resolution used in the WGFBIT approach. Identify areas in which multiple biogenic habitats are likely to occur.
2. Estimate *d* for each habitat using the study of (Sciberras *et al.*, 2018) and other sources. Depletion is likely to be close to 1 for fragile hard structures but closer to 0.1 for flexible biota.
3. Evaluate if *r* is likely to be substantially > 0 for each habitat. If recovery is not considered likely over the time-scale of decades, it can be assumed that r = 0 for the purpose of the assessment. If recovery is likely to be faster, it can be estimated from the longevity of the biogenic structure using the relationship in (Hiddink *et al.*, 2019).

4. Apply the FBIT approach to estimate trawling impact for the mapped biogenic habitats.

The impact on sedimentary and biogenic habitats can then be reported together.

Steps to be taken before WGFBIT 2020

For sedimentary habitats, steps 1-4 should be completed, so that step 5 can be completed at the meeting. For biogenic habitats, steps 1 should be completed, so that step 2-4 can be completed at the meeting.

Initial estimates of *r* for biogenic deep-sea fauna

Our understanding of the population dynamics of biogenic and deep-sea biota is very limited, and any estimates of r for these fauna is very valuable. An estimate of *r* for cold-water sponges was generated by combining the data collected for a recent paper from the ATLAS project (Kazanidis *et al.*, 2019) with SAR estimates available through FBIT.

The collection of data on sponge density and biomass was based on 13 towed-camera transects carried out inside or outside the Faroe-Shetland Channel Nature Conservation Marine Protected Area (North-East Atlantic) in 2014 (Figure 34). Sponges recorded in high-quality images were assigned to 5 morphotype categories i.e. 1) encrusting, 2) arborescent, 3) massive/spherical/papillate, 4) flabellate/caliculate and 5) stipitate/clavate (Boury-Esnault and Rützler, 1997). For full details of the sampling protocols and locations see (Kazanidis *et al.*, 2019).

Measurements on sponge body size were carried out for the massive/spherical/papillate and flabellate/caliculate morphotype categories as they dominated the sponge aggregations. The measurements were carried out across the sponge body axes (cm) using the image analysis software ImageJ (see Kazanidis *et al.,* 2019 for details). Sponge body size was measured for each of the transects and for each of the two main morphotype categories mentioned above. Body size measurements were converted to volume assuming that massive/spherical/caliculate sponges resembled a sphere and the flabellate sponges resembled an isosceles triangle with a thickness of 0.5 cm. Sponge volume values were converted to sponge dry biomass (g) based on previous work for the massive cold-water sponge *Spongosorites coralliophaga* assuming that all sponges have the same body density (Kazanidis and Witte, 2016). Dry biomass was estimated for massive/spherical/papillate, flabellate/caliculate sponges as well as for the sum of these two morphotype categories, for each transect.

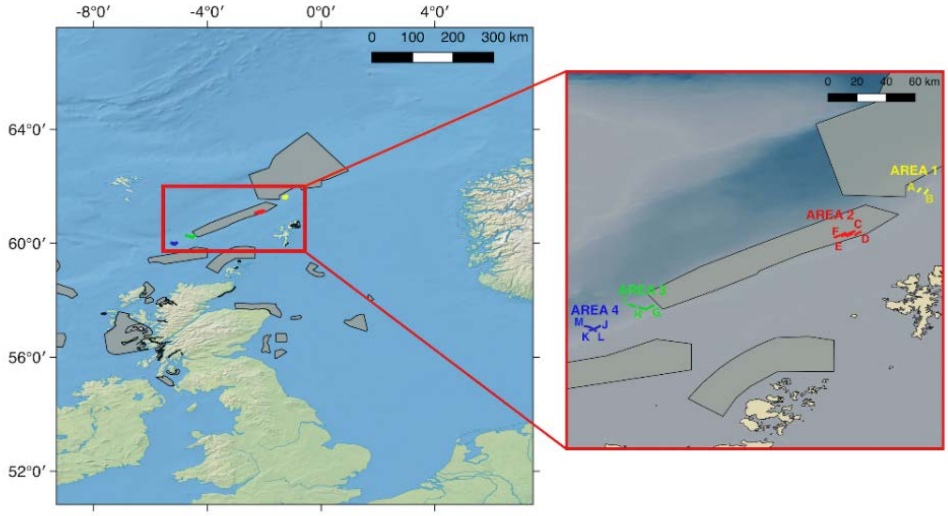


Figure 46. Wider study area (left) and camera transects inside (Area 2: transects C-F) and outside the Faroe-Shetland Channel Nature Conservation Marine Protected Area (FSC NC MPA) (Area 1: transects A, B; Area 3: transects G-I; Area 4: transects J-M). Image: Kazanidis *et al.* 2019.

The original paper did not quantify the fishing pressure as a SAR, and therefore bottom trawl fishing intensity estimates were taken from an OSPAR request on the production of spatial data layers of fishing intensity/pressure (2017) http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2017/Special_requests/OSPAR.2017.17.pdf. Fishing intensity was represented as the swept area ratio, the ratio between the area of a site that is trawled each year and the total area. During the WGFBIT, data on surface Swept Area Ratio (SAR) over the period 2009-2016 were extracted from the ICES data base for the areas inside and outside the Faroe-Shetland Channel Nature Conservation Marine Protected Area (FSC NCMPA hereafter; Figure 1). Only surface SAR values over the period 2009-2014 were used in the analysis to match the 5 years before sampling. Areas inside the FSC NCMPA had much lower values of Surface SAR compared to areas outside the FSC NCMPA.

The resulting relationship between sponge biomass and SAR was used to estimate the population recovery rate *r* for deep sea sponges using the approach of Hiddink *et al.* (2017). It was assumed that depletion d = 0.10 following the value for sponges from Sciberras *et al.* (2018) with SD = 0.078 following (Hiddink *et al.*, 2017). There were a few transects with biomass = 0 (2 transects for flabellate/caliculate sponges and 4 transects for massive/spherical/papillate sponges), but the analysis was not designed to deal with these and therefore 0-values were converted to ½ of the minimum non-zero value before estimating *r*. This may have resulted in an overestimate of *r*.

Sponge community biomass showed very strong, and highly significant, declines with increase swept area ratio, with > 10 fold declines in biomass at SAR < 1 (Figure 35, Figure 36, Figure 37). Massive/spherical/papillate sponges showed an even stronger response than flabellate/caliculate sponges. The estimates were *r* = 0.039 for all sponges, *r* = 0.045 for flabellate/caliculate sponges, and *r* = 0.041 for massive/spherical/papillate sponges. For comparison, the mean *r* for biota with a longevity of 3-10 years is several orders of magnitude higher at *r* = 1.24 (Hiddink *et al.*, 2019). This therefore makes deep-sea sponges very sensitive to bottom trawling. At *r* = 0.039, all sponges are predicted to disappear at SAR = *r*/*d* = 0.037/0.10 = 0.39.

Because of the patchy nature of bottom trawling, it is conceivable that the remaining sponges biomass simply reflects the remaining untrawled patches of the seabed, rather than the balance between trawling mortality and population recovery as assumed by Hiddink *et al.* (2017). An analysis of the mean individual biomass of sponges showed that sponge individual size decreased with increasing SAR, which is the pattern that is expected when the observed sponge biomass represents the balance between trawling mortality and population recovery.

If we assume that the relationship between r and longevity from (Hiddink *et al.*, 2019) holds (r = 5.31/longevity), at r = 0.039 (5-95% range = 0.0074 – 0.169) the sponges in this area would be expected to have a longevity of 136 years (5-95% range = 31 – 711 years). This seems a plausible estimate (Figure 38). For now it therefore seems reasonable to assume that r = 5.31/longevity can be used for deep-sea fauna.

In conclusion, using the SAR estimates available through FBIT allowed us to obtain a first estimate of r for biogenic deep-sea biota, which shows that they are highly sensitive to bottom trawling activity and likely to go extinct even at low fishing intensities. This r estimate can be used in the assessment of trawl impacts for deep-sea VMEs.

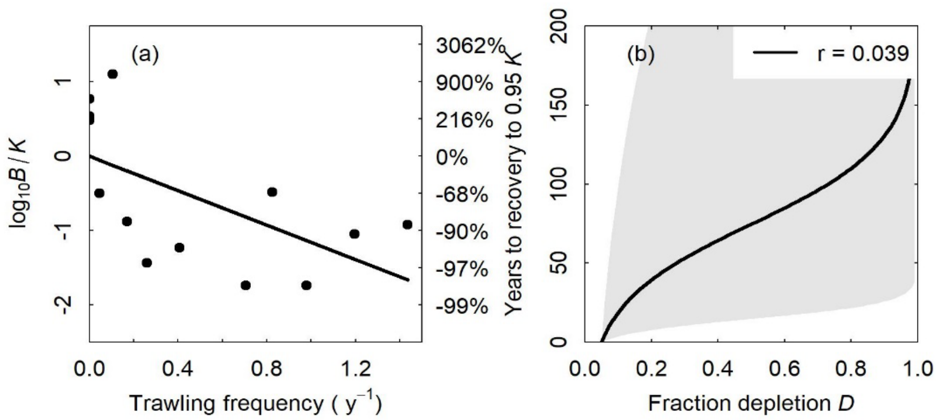


Figure 47. The relationship between trawling frequency and total sponge biomass community (A). Recovery time to 0.95K for depleted total community biomass as a function of estimated r and initial depletion D. The shaded areas indicate the 5–95% uncertainty intervals for estimates.

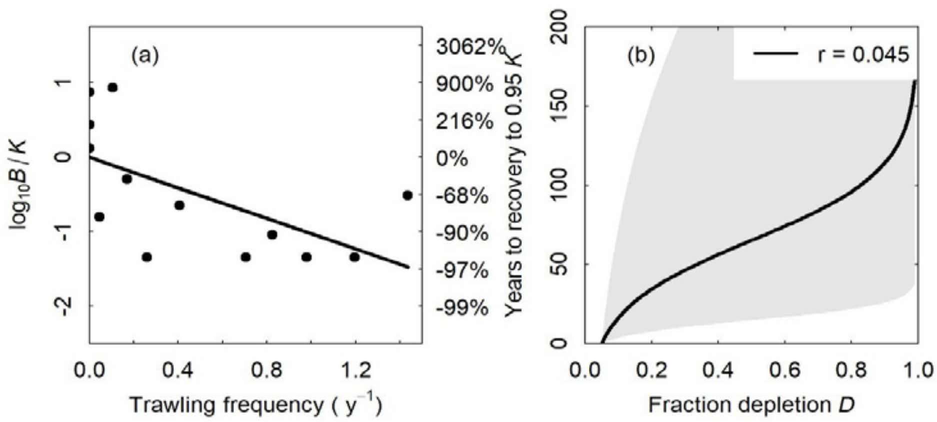


Figure 48. The relationship between trawling frequency and flabellate/caliculate sponge community biomass (A). Recovery time to 0.95K for depleted total community biomass as a function of estimated r and initial depletion D. The shaded areas indicate the 5–95% uncertainty intervals for estimates.

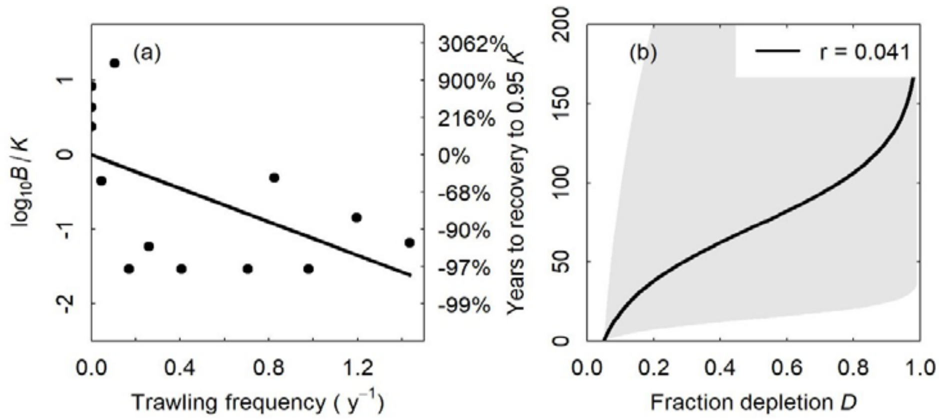


Figure 49. The relationship between trawling frequency and massive/spherical/papillate sponge community biomass (A). Recovery time to 0.95K for depleted total community biomass as a function of estimated r and initial depletion D. The shaded areas indicate the 5–95% uncertainty intervals for estimates.

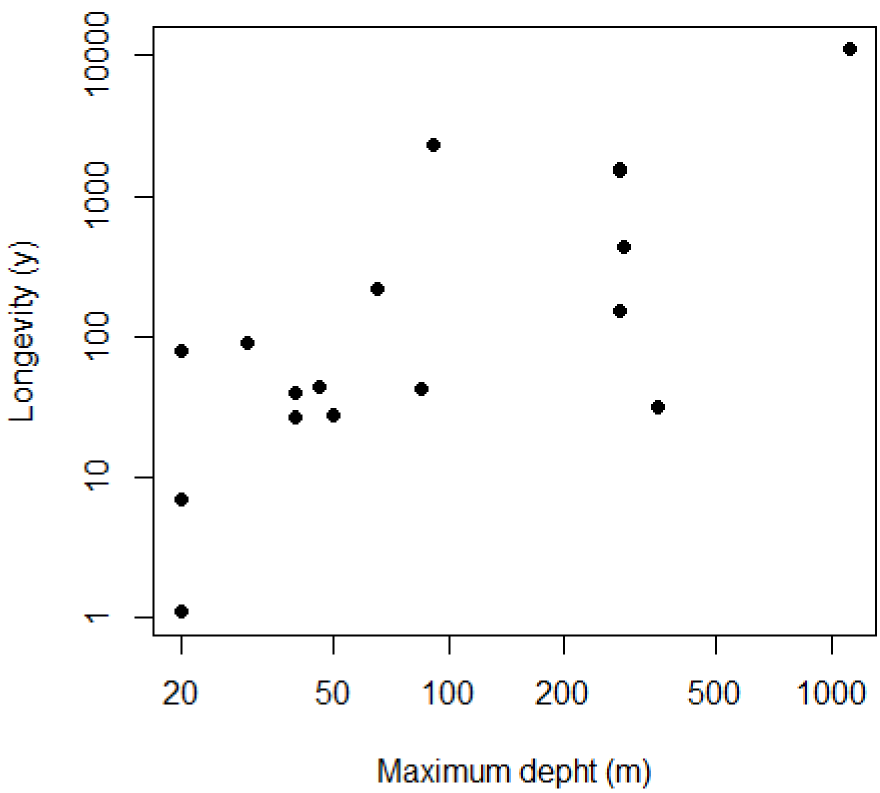
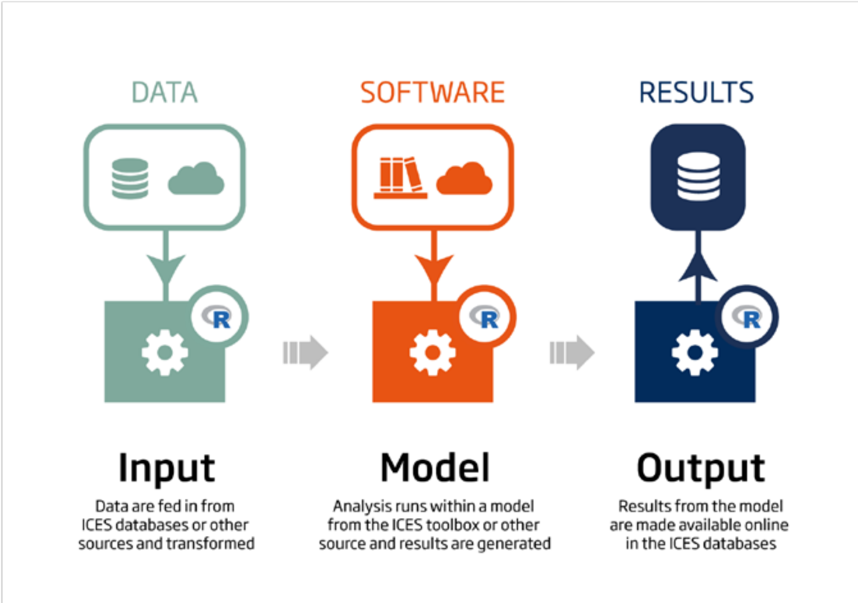


Figure 50. The relationship between maximum depth and longevity for sponges. Data from (Montero-Serra *et al.*, 2018)

6.3 Data/script management

During the WGFBIT meeting, the different regional groups were executing the FBIT assessment framework based on regional-specific data and settings, and making small adaptations to the general script. Therefore, a proper standardised data/script management practice and protocol is necessary. The working group aims to have all code and data products leading to the assessment product managed on GitHub: https://github.com/ices-eg/FBIT in a structured and transparent way. This is a basic requirement if the assessment outcome is to comply with TAF rules and allow FBIT members to share and implement new developments.. Another aspect that needs to be formalized is ownership of methodological developments as well as analyses and assessment outputs. Therefore, an intersessional subgroup is started to tackle those aspects towards the next meeting and to develop a flow diagram illustrating this data/script management aspect.

The data governance and scripting sub group of WGFBIT will work towards structuring the way individual ecoregions assessment scripts are updated, and how they stem from the same overall framework script ensuring that when general improvements are made they can be applied consistently across assessments. The organizing of this work of WGFBIT will use the guiding principles of ICES's TAF (transparent assessment framework), allowing respective assessments per ecoregion to be re-run when new data becomes available or criteria change. Such a way of working will contribute towards a seafloor assessment framework that can be run using FAIR data principles - Findable, Accessible, Interoperable, Reusable.



To begin their work the subgroup will look into similarities within the ICES Fisheries Overview assessments process and how it is are run with its respective six ecoregions in TAF with respective repositories:

- https://github.com/ices-taf/2019_NwS_FisheriesOverview
- https://github.com/ices-taf/2019_BrS_FisheriesOverview
- https://github.com/ices-taf/2019_BI_FisheriesOverview
- https://github.com/ices-taf/2019_BtS_FisheriesOverview
- https://github.com/ices-taf/2019_CS_FisheriesOverview
- https://github.com/ices-taf/2019_NrS_FisheriesOverview

In these repositories of the ICES Fisheries Overviews assessments, the full process of creation/ update of the plots and annexes in the documents is described. There are three main scripts: data.R, model.R and report.R. In data.R, the raw data is cleaned and prepared for that specific ecoregion. In the model.R some intermediate formatting is performed and in the report.R all graphs and related data tables are produced and saved in the same folder, ready for its use in the document. The report.R script is modified following the feedback from experts on different issues (number of species to be shown, wrong namings, etc.), ensuring that the final product is fully reproducible with all its details. This process uses a significant amount of the ices R packages to function (icesTAF, icesSAG, icesSD and icesFO). In the 2020 update, these 2019 repositories will be used as template for the 2020 TAF repositories for each of the FOs to be updated.

6.4 Dissemination and communication work

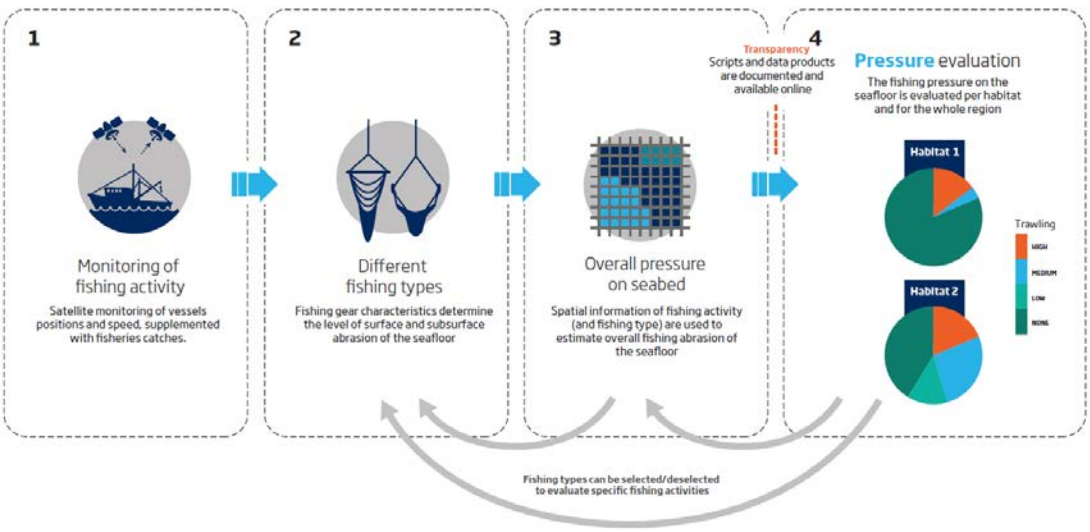
Ultimately, the FBIT assessment could serve as input for the ICES Fisheries Overviews (FOs, *link*) and Ecosystems Overviews (EOs, *link*). Therefore, an inter-sessional communications and advice sub-group was formed at the 2019 WGFBIT meeting. It was discussed how to produce an advisory based on the approaches and pilots presented in the demonstration advice of the North Sea on page 9–17 in the 2017 ICES advice on benthic pressure and impact indicators (ICES, 2017 *link*). This intersessional subgroup will further develop and discuss the content of this advisory sheet. At the meeting, it was assessed essential to strike the right balance between adequate outputs (tables, graphs) and a clear formulation of the main assessment outcomes (key messages) for each step in the FBIT framework.

The assessment methodologies and outputs are still to some extent under development and to be considered as relatively complex pioneer work, where practitioners and end-users will have little or no acquired knowledge. Therefore, explaining the assessment method at the correct level of detail is still a key challenge that needs further and continuous development.

WGFBIT felt that the developed infographics used to explain the assessment framework (role-up poster and flyers, see Figure below) would be useful communications tool. The material can be used to get new members of FBIT on board as to what the assessment framework as a whole is aiming at, and how to run/calibrate the assessments for respective ecoregions. The communication materials so far with respective icons are uploaded on the SharePoint for wider use in relation to FBIT work. The meeting approved the material agreeing that a communications sub-group of FBIT would further develop the material. In addition to providing feedback to the ICES communications department on font size and FBIT branding the sub-group would explore how to use the material to help further disseminate the assessment framework (and its results). As such, in the coming year a “4 page explainer”, with managers as the target audience would be developed. This can draw on the developed infographics as well as the more detailed method description (Annex 4 technical guidelines) agreed by FBIT in last year’s report.

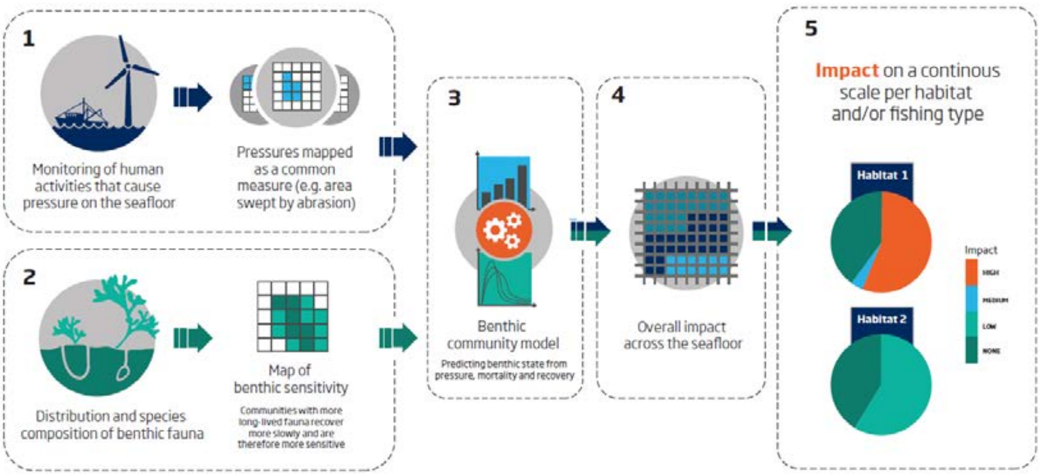
Pressure

Translating human activities (e.g. different fishing types) into a common measure of pressure on the seafloor and its seafloor habitats



Impact

Evaluating seafloor impact and benthic habitats that are at greatest risk from human activities disturbing the seafloor



7 Other issues

7.1 Feedback from FBIT session at ICES Annual Science conference

Feedback form the ICES Annual science session (Gert Van Hoey, Jan-Geert Hiddink, Roland Pitcher): Quantifying human footprints, indicators and reference points for seabed impacts
The short report, summarizing the contributions and conclusions.

Bottom fishing is the most widespread direct human disturbance on the seabed. However, bottom trawling is also important for global food security, providing about a quarter of the world's seafood catch. While there is much debate about the severity of bottom fishing impacts, there is a void of large-scale quantitative investigations of the actual extent and risks bottom fishing poses to the marine environment. Quantitative tools, indicators and reference points are needed to assess the status of the seabed to support management practices that ensure fisheries are sustainable. This theme session addressed and discussed recent progress with synthesising and mapping bottom fishing footprints (e.g. from satellite and logbook monitoring of fishing effort) and quantifying their impacts around the globe, as well as statistical modelling methods and approaches for assessing the state of seabed habitats and fauna. The talks and posters in the session grouped in 5 broad themes:

Ways of estimating the footprint of human activity (e.g. fishing gear, dredging operations) (Collie *et al.*: Modelling the intensity of bottom trawling footprints; van der Reijden *et al.* (poster): North Sea demersal fisheries prefer specific benthic habitats).

Methods to quantify the sensitivity of seabed habitats to human activities / Ground truthing of indicators that assess the impact on benthic ecosystems (Dinesen *et al.*: bottom trawling impacts on marine macrobenthos: Changes in ecological functioning and seafloor integrity interpreted by a biological multiple traits approach; Van Denderen *et al.*: Identifying benthic vulnerability, predicted fishing impact and values in a warming Barents sea; Atkinson *et al.*: Demersal trawl interactions with South African ecosystem types: spatial analyses and potential management actions; Hiddink *et al.*: Testing and selection of indicators for assessing and managing the bottom trawling impacts on seabed habitats; Bradshaw *et al.*: Effects of bottom trawling on benthic processes, sediment suspension and seafloor integrity; Cyrielle *et al.* (poster): Vulnerability of benthic habitats to trawling in the English Channel, the North Sea and the Mediterranean Sea).

Approaches that allow spatial upscaling of local findings to regional scale (Pitcher *et al.*: Assessing seabed status in 24 trawled regions of the world).

Management actions/plans that reduce the footprint of human activities or establish trade-offs between impact and economic revenue (Breen *et al.*: A Bayesian network model for assessing ecological risk and economic impacts for spatial marine management options; Evans *et al.*: Testing uncertainty within a method to assess the impact of bottom towed fishing gear on sedimentary habitats: Defining data thresholds, limitations and resolution; Danto *et al.*: Identification of effective measures to reduce fisheries impacts on the seafloor: a bio-economic evaluation in the Baltic Sea; McConnaughey *et al.*: Best practices for managing impacts of trawl fishing on seabed habitats and biota).

We specifically asked for talks on this topic too: **Methods to establish threshold values for impact indicators, indicating adverse impacts or habitat degradation**, but no talks on this topic were received. This overview of the talks therefore clearly shows that this field of research requires further studies on how to scale up assessments, and studies on how to set ecologically relevant thresholds for determining what are acceptable impacts and what are not. How much of specific habitats we need to protect in order to preserve proper functioning of the benthic (seafloor) ecosystem, and what intensity of an activity is acceptable, therefore remains an unanswered question that needs to be addressed by ICES in order to inform Good Environmental Status.

Much of the presented work originated from research that was performed under the FP7 BENTHIS project and the Trawling Best Practices projects. The session showcased the work that is being carried out in WGFBIT, and that is contributing to guiding the development of standardized methods to assess EU's MSFD D1 habitat/D6 benthic, as well as in providing further guidance to member states for determining relevant indicator threshold values. This theme session provided an opportunity to review the applied assessment frameworks and showcasing the state of the art in this field.

Discussion focused on the importance of providing assessments for guiding management decisions, the applicability of approaches in data-limited situations and the application of such tools for the sustainability certification of fisheries. There are clear indications that good management for ensuring that exploitation of trawl fish stocks is sustainable is also very likely to result in a good state of the seabed, and fisheries with limited benthic data may be able to achieve a good benthic status simply by managing their commercial stocks sustainably (e.g. F<Fmsy and/or B>Bmsy).

Other knowledge gaps that became evident during the session are:

- The limited number of studies of trawling impacts in tropical areas, in deep water and in the southern hemisphere limits our ability to generalise impacts globally.
- Effects of trawling on functioning of ecosystems is often inferred but hardly ever directly measured. More studies of effects on biogeochemistry and food webs, e.g. food supply for higher trophic levels, are needed. If this is achieved, these approaches may also be able to feed in to D4 in the MFSD.
- The effect of smothering by resuspension of sediment on benthic ecosystems is barely known.
- Large areas globally have no trawling effort data at all at any resolution.
- Related to the threshold setting problem, a definition or description of how a good functioning benthic system has to be, is lacking. Such baseline need ideally be based on scientific research, which is the major problem for the majority of investigated areas.
- In impact or status assessments, the quality and resolution of the data plays a very important role in the outcome. Therefore, much more attention need to be provided on this uncertainty-confidence aspect in assessments.
- Quantifying the trade-off between ecological impacts vs. economic benefits is only just starting and could be developed much more, particularly the inclusion of quantitative and/or dynamics operational model for the ecosystem (rather than qualitative/scoring system currently prevalent). This field of study would particularly benefits from a better understanding of the patterns of effort redistribution in response to management measures.

Some discussion focused whether we have to accept that some marine areas are managed primarily for producing food rather than for combined nature conservation and food production, just like some agricultural areas on land are highly or completely modified from their original ecosystem.

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Annex 2: WGFBIT Resolutions

The **Working Group on Fisheries Benthic Impact and Trade-offs (WGFBIT)**, chaired by Tobias van Kooten, Netherlands; Ole Ritzau Eigaard, Denmark; and Gert van Hoey, Belgium, will work on ToRs and generate deliverables as listed in the Table below.

	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2018	12–16 November	ICES HQ, Copenhagen, Denmark	Interim report by 14 December	
Year 2019	7–11 October	Ancona, Italy (tbc)	Interim report by 1 December	
Year 2020	14–18 September	Barcelona, Spain	Final report by 1 November	

ToR descriptors

ToR	Description	Background	Science Plan codes	Duration	Expected Deliverables
a	Building from 2017 ICES work (WKTRADE, WKBENTH, and WKSTAKE) produce a framework for MSFD D6/D1 assessment related to bottom abrasion of fishing activity at the regional / subregional scale and identify key ecological processes input requirements.	Provide a worked example on how science can operationalize EBM (ecosystem based management) and contribute towards IEAs (intergrated ecosystem assessment) as ICES advice products. Links (avoiding overlaps) will be established with key experts also attending WGECO, WGDEC, WGSFD, BEWG, WGMHM, WGIMM, WGMBRED, and WGMPCZM	2.1; 2.4; 2.7	Year 1, reviewed in year 3	A worked example with guidng principles, that can be reviewed by ACOM leadership and SCICOM chair/SSGs for feedback. Specific action points, to ensure year 2 assessments can be conduccted by appropriate sub region for the N. Sea, Celtic, Baltic and Barrents Seas
b	Apply the framework to make a regional assessment for the North Sea, Celtic, Baltic and Barents Seas	EU MSFD D6/D1 assessment and providing management options that can be applied also by non-EU ICES countries.	2.7; 6.3	Year 2	Regional assessments of the impact of bottom abrasing fisheries

Summary of the Work Plan

Year 1	For an EU MSFD D6/D1 assessment related to bottom abrasion of fishing activity at the regional / subregional scale identify key ecological processes required as input. Priority should be given to decide on a quantitative framework based on biological processes, and to improve the parameterisation of framework components. The framework should allow for an overall assessment of benthic status and for the exploration of alternative management options to improve GES. Worked-out examples (and findings from WKTRADE 2017) should be used to ensure that a framework for addressing the above is established. The framework should be 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). The framework should take into account complementarity to the ICES Fisheries Overviews (FOs) and Ecosystems Overviews (EOs), and provide input to overviews. The group will work between sessions to ensure required information is worked up to conduct assessments using the suggested framework (in preparation for year 2 meeting and advisory products).
Year 2	Using the framework, produce aassessment (draft advice) for the Celtic Seas, Greater North Sea, Barents Sea and Baltic Sea by subregion. Consider how other ecoregions can be incorporated (e.g. Mediterranean, Black Sea, Bay of Biscay and Iberian Coast). Assessments should be conducted using the guiding principles of TAF (transparent assessment framework).
Year 3	Update advice from previous year, and produce new (draft) assessments for 3 other ecoregions (and associated sub-regions). Review framework produced in year 1, and produce technical guidelines for "a standard" ICES advice product for MSFD D6/D1 and alternative management options to improve GES. Technical guidelines for the assesment will be produced to support TAF (transparent assessment framework).

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 some 20–25 members and guests.
Secretariat facilities	Meeting room facilities, as well as Assisting Sectrariat help, Data Centre support, and Professional Officer shadowing and attendance of working group meeting.
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: Terminology and definitions

WGFBIT 2019 agreed to revise their definitions with regard to 2019 ICES advice to the EU on a seafloor assessment process for physical loss (D6C1, D6C4) and physical disturbance (D6C2) on benthic habitats, and the respective workshops (WKBEDPRES1, WKBEDLOSS, and WKBEDPRES2).

Central to the construction of the WGFBIT framework is a common understanding of how benthic species respond to disturbance in order to know the status of the benthic community as a whole, including the associated habitat (see Figure 39). Below we describe the definitions related to benthic impact from trawling and we describe how to differentiate between physical loss and physical disturbance.

Within WGFBIT it was further agreed that the EU's WG GES document (GES_20-2018-06), describing the policy and ecological context within which to consider "good environmental status" for MSFD Descriptor 1 (seabed habitats) and Descriptor 6 (sea-floor integrity), will be a useful source of information when defining and revisiting definitions.

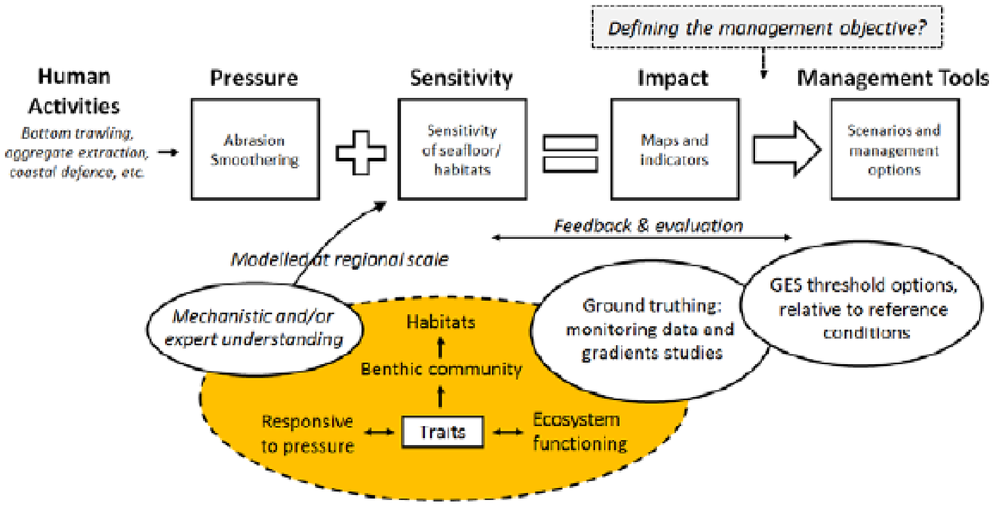

Figure 51. Conceptual diagram of the steps taken in developing management tools for assessing pressure and impact on the seafloor from human activity. Benthic community component is highlighted in orange.

Definitions related to benthic impact from trawling

The differing responses of species to disturbance over time can be defined. In the context of bottom trawl fishing, an important parameter is trawling frequency as this modulates each specific species response. Instantaneously, a haul can damage or kill an organism depending on its <u>sensitivity</u> to the gear (e.g. degree of body fragility) and the magnitude of the disturbance. Then, in case of consequent demographic or biomass depletion, another type of response is <u>recovery</u> through adult migration or offspring settlement. Recovery depends on trawling frequency, so that the higher the frequency, the slower the recovery. In case of a null degree of sensitivity, organisms are resistant, i.e. no damage or population depletion is consequent from a trawl disturbance. In the case where species are sensitive to disturbance, two types of species can be characterised with reference to their sensitivity and recovery. A resilient species is primarily characterised by a fast recovery following damage or depletion, independent of sensitivity, so that juvenile or adult mortality do not impair population survival over time under a disturbance regime. By contrast, a vulnerable species experiences substantial damage or depletion following a minimum disturbance with a recovery time influenced by maintained or increased disturbance frequency.

Within the above context, and to ensure common understanding, WGFBIT have proposed the below set of definitions:

Activity: basic human activities to satisfy the needs of societal drivers; e.g. aquaculture or tourism. One activity may cause many different pressures with different scales of impacts (as defined below).

Pressure: is considered as the mechanism through which an activity has an actual or potential effect on any part of the ecosystem, e.g. for demersal trawling activity, one pressure would be abrasion of the seabed. It should be noted that one pressure may be caused by many different activities (e.g. abrasion from fishing, aggregate extraction, dredging) with different extents, frequencies, and impacts, and that one activity may be responsible for multiple pressures (e.g. other non-physical pressures by fishing such as spread of non-indigenous species, mortality/injury to wild species, and inputs of litter). Pressures can cause multiple and progressive biological (e.g. lethal and various sub-lethal changes through damage and stress) and physio-chemical state changes (e.g. sediment homogenization, changes in sediment topography, and compaction) at any level (e.g. communities and habitats).

Adverse effect: within the assessment process ICES defines adverse effects as a possible change, influencing or affecting an environmental component, caused by a pressure related to one or more anthropogenic activities.

To identify the main human activities that disturb the seabed, four pressure subtypes were identified as the pathways through which physical loss and physical disturbance operate. These physical pressure subtypes were identified by ICES as the only pathways from activities to physical loss or physical disturbance. ICES defines these four pressure subtypes as:

Abrasion: the scraping of the substrate (e.g. by a trawl door or an anchor). Whilst abrasion could result in the mixing of sedimentary substrates, any sediment removal is considered a "Removal" pressure subtype. The abrasion pressure subtype can result in physical loss and/or physical disturbance.

Removal: the net transference of substrate away from the seabed resulting from human activities (e.g. either directly by human activities or indirectly through the modification of hydrodynamics). This pressure subtype can result in physical loss and/or physical disturbance.

Deposition: the movement of sediment and/or particulates to a new position on top of or in existing substrates (e.g. directly by human activities such as dredge disposal or indirectly through the modification of hydrodynamics). This pressure subtype can result in physical disturbance.

Sealing: the capping of the original substrate with structures (e.g. metal pilings, concrete footings, or blankets) or substrates (e.g. rock or stone fills, dredge disposal) which in and of themselves change the physical habitat. This pressure subtype can result in physical loss.

Fishing pressure: The physical abrasion of the seabed by bottom-contacting fishing gears. The pressure is expressed as the ratio between the sum of the area swept by the fishing gear (with components having a surface or subsurface penetration) per year to the total area of the site (swept-area ratio - SAR).

Species sensitivity: The intolerance of a species or habitat to damage from an external factor and the time taken for its subsequent recovery.

Resistance: The ability of a receptor to tolerate a pressure without changing its character

Impact: The effects (or consequences) of a pressure on an ecosystem component. The impact is determined by both exposure and sensitivity to a pressure (ICES 2016).

Degree of impact: The level of impact on the seabed should be considered in the ranking, where low impact activities are ranked below high impact activities for the same level of spatial/temporal coverage. Low impact activities are those that cause minor direct mortality/damage on benthic organisms, resulting in adverse effects/impacts that lie within the bounds evidenced across cycles of natural variation. High levels of impact can be considered to have occurred where the activity results in adverse effects/impacts to the benthic habitat and its communities beyond what might be expected from natural disturbances. Issues on sensitivity/resilience/recovery of specific benthic groups (faunal or traits) and functional habitats are discussed in section 3.2 of the 2018 WGFBIT report on modelling and smothering.

Areal coverage: This must consider two aspects: the spread of the activities footprint at a regional scale and its spatial coverage within the footprint. For example, for a given degree of impact, if an activity occurring throughout the region is split into small, discrete areas, this would rank lower than similarly impactful activities that have a higher areal coverage but are not as widespread across the region. Activities that occur over the entire region, and are continuously distributed throughout this area, would be regarded as having the maximum areal coverage possible.

Recoverability (or resilience): The time that a receptor needs to recover from a pressure, once that pressure has been alleviated.

Impact: a possible change (adverse or beneficial) influencing or affecting an environmental component, caused by a pressure related to one or more anthropogenic activities.

Fishing impact: The effects (or consequences) of fishing pressure on an ecosystem component. The impact is determined by both exposure and sensitivity to a pressure.

Fishing intensity indicator: A characteristic of the footprint of the fisheries, expressed either on spatial or temporal scale (or both).

Benthic impact indicator: A characteristic of a benthic habitat that can provide information on ecological structure and function.

Differentiating between physical disturbance and physical loss (ICES 2019)

In the 2019 ICES advice to the EU on a seafloor assessment process for physical loss (D6C1, D6C4) and physical disturbance (D6C2) on benthic habitats the following definitions of physical disturbance and physical loss were established:

Physical loss is defined as any human-induced permanent alteration of the physical habitat from which recovery is impossible without further human intervention. An alteration of the physical habitat refers to a change from one EUNIS level 2 habitat type to another EUNIS level 2 habitat type. Recovery indicates the re-establishment of the original natural EUNIS level 2 habitat by means of a human intervention. Two types of physical loss are identified:

- Sealed physical loss results from the placement of structures in the marine environment (e.g. wind turbines, port infrastructure) and from the introduction of substrates that seal off the seabed (e.g. dredge disposal).
- Unsealed physical loss results from changes in physical habitat, either from human activities or from the indirect effects of the placement of man-made structures (e.g. aggregate extraction or a structure causing changes in water flows, ultimately changing the EUNIS level 2 habitat type).

Physical disturbance is defined as a pressure that disturbs benthic biota but does not permanently change the habitat from one EUNIS level 2 habitat type to another EUNIS level 2 habitat type. With sufficient time, recovery can be expected without human intervention.

Physical disturbance to physical loss can be regarded as a continuum, where the intensity of a physical disturbance may lead, in time, to a permanent change from one EUNIS level 2 habitat type to another and hence physical loss.

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Annex 5: Wet weight info

Table 23. Wet weight of individuals (g) per genus estimated from 7 surveys. N indicates the number of individuals on which the estimate is based.

Genus	n	Mean	Median	95th quantile	Maximum
Abra	1456	0.108429	0.047	0.347	6.932
Acanthocardia	45	28.20069	13.15	76.88	85.306
Acanthomysis	1	0.001	0.001	0.001	0.001
Acholoe	2	0.174	0.174	0.2379	0.245
Acrocnida	14	0.67581	0.6995	1.185	1.471
Acteon	5	0.0326	0.027	0.067	0.073
Actinauge	9	21.7	3.1	104.8	171
Adamsia	1109	3.970149	3.5	8.856	42
Aequipecten	440	31.70078	24	44.22	2951
Alcyonidium	115	18.04838	8	68.5	234
Alcyonium	1293	21.67117	5.007605	27.08	10150
Allomelita	2	0.063	0.063	0.0675	0.068
Alloteuthis	14	8.571429	8	12.35	13
Ampelisca	216	0.019903	0.01	0.049	0.106
Ampharete	7	0.008886	0.001	0.0269	0.032
Amphicteis	7	0.010286	0.012	0.0204	0.021
Amphipholis	64	0.048213	0.024167	0.0682	0.77
Amphiura	267	0.183002	0.1473	0.459276	1
Ampithoe	2	0.0365	0.0365	0.05675	0.059
Anapagurus	578	0.674875	0.3	2.015	31.5
Anseropoda	42	12.40476	8	36	40
Antalis	106	0.45616	0.5	0.9745	1.226
Apherusa	1	1.00E-04	1.00E-04	1.00E-04	1.00E-04
Aphrodita	321	23.52658	21.1	48	377
Aporrhais	250	3.357196	3	6.89065	9.5
Arcopagia	3	2.164333	2.27	3.6632	3.818
Arcopella	1	3.132	3.132	3.132	3.132
Arctica	57	43.18304	23.331	99.105	293
Argissa	4	0.003	0.0025	0.00655	0.007
Ariadnaria	1	1.756	1.756	1.756	1.756
Aricidea	78	0.001716	0.00135	0.004615	0.0063
Armina	8	0.375	0.5	0.825	1
Arrhis	4	0.012063	0.012	0.022587	0.02325
Ascidiella	21	9.552095	9	22	32
Aspidosiphon	17	0.414588	0.126	1.3362	4.545
Astacilla	4	0.15	0.15	0.2	0.2
Astarte	1529	0.94463	0.482684	3.1	179
Asterias	1598	14.63634	8	53.45357	213
Astropecten	1420	7.318335	6	21	60
Atelecyclus	90	10.76911	11	25	29

Atlantopanda-lus	1	2.792	2.792	2.792	2.792
Axinella	1	34	34	34	34
Bathyporeia	25	0.002435	5.00E-04	0.007	0.018
Bela	2	0.1185	0.1185	0.13695	0.139
Bolocera	2	361.55	361.55	442.955	452
Branchiostoma	3	0.045	0.012	0.1092	0.12
Brissopsis	887	4.186912	1.32	18	72
Buccinum	481	65.5249	62	138	202
Calliactis	195	9.012721	8	21	36
Callianassa	13	0.346692	0.108	0.9188	1.07
Calliostoma	10	2.3685	1.351	5.11	5.2
Callista	6	30.33333	23.5	52.5	53
Calocaris	1	1	1	1	1
Cancer	22	647.8	630	1092.6	1157.5
Capitella	2	0.3225	0.3225	0.61275	0.645
Carcinus	1	0.206	0.206	0.206	0.206
Caryophyllia	74	1.820503	1.6	3.61	7
Cellaria	6	141.8462	10.5185	605.5	796
Cerastoderma	6	0.107722	0.0075	0.42525	0.54
Cerebratulus	11	0.012182	0.0063	0.03505	0.0447
Cereus	1	0.802	0.802	0.802	0.802
Cerianthus	11	1.490562	1.016	4.781	4.781
Chaetopterus	11	8.56103	4.333333	22.95	24.4
Chaetozone	3	0.003	0.003	0.0048	0.005
Chamelea	351	1.745892	1.196	4.2715	35
Cheirocratus	1	0.002	0.002	0.002	0.002
Chlamys	12	1.893833	1.413	4.41	5.4
Chrysaora	1	5	5	5	5
Ciona	1	0.049	0.049	0.049	0.049
Cirolana	3	0.007	0.007	0.0088	0.009
Clausinella	3	0.768	0.5	1.5431	1.659
Colus	111	8.015505	3.361	24.9	106
Comarmondia	15	0.032067	0.025	0.074	0.095
Corbula	127	0.075093	0.011	0.4305	1.125
Corella	3	3.289333	1	7.3	8
Corophium	2	0.00365	0.00365	0.004235	0.0043
Corystes	81	7.542185	6	18	40
Crangon	275	0.6754	0.6	1.5	6.6
Crepidula	7	4.928571	4.5	8.4	9
Crisia	8	2.111	1.6465	5.464	6.255
Crossaster	36	28.62778	17.6	112.475	162.1
Cumella	1	0.001	0.001	0.001	0.001
Cuspidaria	12	0.241333	0.155	0.6069	0.608
Cylichna	21	0.011129	0.006	0.03	0.064
Dendronotus	1	5	5	5	5
Diastylis	135	0.007603	0.0043	0.02571	0.0335
Dichelopanda-lus	26	1.626282	1.366667	4	5

Dikoleps	4	0.000788	0.00055	0.00185	0.002
Diplocirrus	122	0.007795	0.004	0.016	0.21
Ditrupa	1974	0.118443	0.11	0.18	0.43
Donax	8	0.089792	0.007	0.441033	0.666667
Doris	69	11.07971	10	20.6	26
Dosina	1	4.998	4.998	4.998	4.998
Dosinia	205	2.703434	1.333	9.76676	15.526
Ebalia	302	0.279113	0.1135	1	2
Echinocardium	695	7.331204	0.03	37	90.947
Echinocyamus	92	0.080818	0.007	0.04235	4.293
Echinus	55	230.7964	145.2	661.6	1044
Echiurus	2	11.517	11.517	17.9394	18.653
Edwardsia	3	0.002333	0.003	0.003	0.003
Elasmopus	3	0.046167	0.0145	0.11125	0.122
Eledone	35	131.9314	76	445.8	511
Emarginula	4	0.43625	0.2	1.15	1.3
Ensis	48	0.485542	0.0975	3.6561	5.039
Epilepton	1	1.00E-04	1.00E-04	1.00E-04	1.00E-04
Epimeria	37	0.162162	0.1	0.3	0.3
Epitonium	11	0.340545	0.061	1.541	2.556
Epizoanthus	498	1.240015	0.856485	3.184046	23
Ericthonius	1	1.00E-04	1.00E-04	1.00E-04	1.00E-04
Eriopisa	4	0.00575	0.0025	0.0149	0.017
Erythrops	2	0.00155	0.00155	0.002855	0.003
Eteone	1	0.008	0.008	0.008	0.008
Euclymene	23	0.038522	0.031	0.102	0.122
Eumida	2	0.007	0.007	0.0079	0.008
Eunicella	49	4.091538	3	9.2	30
Eurydice	11	0.01803	0.006	0.081	0.1
Eurynome	46	1.035355	1	2	8
Eurytemora	9	6.67E-05	5.00E-05	1.00E-04	1.00E-04
Euspira	47	0.166255	0.048	0.6388	2.506
Fabulina	23	0.039217	0.02	0.1651	0.173
Flustra	35	409.7983	180	1696	3258
Galathea	1439	0.071957	0.038	0.2751	3
Gari	83	1.252711	0.4	4	10.56
Gastrosaccus	2	0.0115	0.0115	0.02095	0.022
Geryon	1	26.7	26.7	26.7	26.7
Gibberula	1	0.22	0.22	0.22	0.22
Gibbula	1	0.069	0.069	0.069	0.069
Glycera	91	0.127903	0.024	0.774	2.4
Glycymeris	52	34.88861	42	59.45	106
Golfingia	4	0.69975	0.338	1.8571	2.098
Goneplax	52	5.855673	5	10.9	16
Goniada	52	0.047282	0.0185	0.231	0.582
Goodallia	6	0.00285	0.003	0.00475	0.005
Gouldia	1	0.058	0.058	0.058	0.058
Halicryptus	71	0.064074	0.0347	0.215969	0.545795

Harmothoe	133	0.008326	0.0038	0.02226	0.1693
Polynoe	5	0.047	0.055	0.07	0.073
Harpinia	5	0.00142	0.002	0.002	0.002
Hemimysis	2	0.0225	0.0225	0.04005	0.042
Henricia	39	4.471795	4	8.05	10
Heteromastus	587	0.002128	0.002	0.004	0.118
Heteromysis	1	0.006	0.006	0.006	0.006
Hiatella	12	0.114917	0.0365	0.5094	1
Hippasteria	2	41.35	41.35	77.845	81.9
Hippolyte	3	0.033667	0.028	0.046	0.048
Hippomedon	3	0.016	0.017	0.0215	0.022
Hyalinoecia	478	0.460207	0.364	1	3
Hyas	335	0.638149	0.4	1.63	16
Hydrobia	15	0.090964	0.01	0.2894	0.290333
Hydrobius	30	1.423833	0.214	5.03355	28.1
Hyperia	2	0.0235	0.0235	0.02575	0.026
Inachus	472	4.770388	3	12	120
Iphinoe	123	0.001975	0.002	0.0049	0.012
Irus	1	0.012	0.012	0.012	0.012
Jaxea	1	2	2	2	2
Jujubinus	1	0.157	0.157	0.157	0.157
Kefersteinia	8	0.009833	0.0105	0.01965	0.02
Kurtiella	31	0.001748	0.0015	0.004	0.005
Lacuna	3	0.589	0.721	1.0126	1.045
Laetmonice	13	3.194769	3	6	6
Laevicardium	20	4.4534	0.045	36.7	50
Lagis	93	0.085236	0.032	0.3368	1.301
Lanice	2	0.0095	0.0095	0.01085	0.011
Laonice	19	0.032368	0.01	0.0953	0.224
Lembos	5	0.002	0.001	0.004	0.004
Lepidasthenia	1	0.006	0.006	0.006	0.006
Lepidonotus	9	0.022992	0.010167	0.081633	0.1185
Leptasterias	6	0.6	0.65	0.95	1
Leptochiton	1	0.1	0.1	0.1	0.1
Leptomysis	3	0.002367	0.002	0.0047	0.005
Levinsenia	255	0.001012	0.001	0.002	0.002
Ligia	1	0.008	0.008	0.008	0.008
Limaria	1	0.152	0.152	0.152	0.152
Liocarcinus	1722	3.351901	0.5	16	38.9
Lithodes	2	1.15	1.15	2.005	2.1
Littorina	12	4.949333	2.5	15.95	22
Loligo	13	10.99902	2	30.2	32
Lucinoma	4	1.57175	0.624	4.2862	4.924
Luidia	1179	18.05113	6.652941	81	476
Lumbrineris	144	0.03016	0.014	0.0587	1
Lutraria	10	25.84383	5.64	86.1	96
Lysidice	2	0.003	0.003	0.0048	0.005
Macoma	577	0.262771	0.2272	0.636896	1.173297

Macropodia	416	1.367834	0.7	5	12
Mactra	2	1.255	1.255	2.2945	2.41
Maera	231	0.019905	0.012	0.116	0.249
Magelona	61	0.011557	0.01	0.022	0.043
Maja	143	385.9649	390	853	1220
Malacoceros	1	0.004	0.004	0.004	0.004
Maldane	139	0.064436	0.052	0.142	0.232
Mangelia	4	0.08525	0.0915	0.1517	0.155
Marenzelleria	1	0.0019	0.0019	0.0019	0.0019
Margarites	1	0.022	0.022	0.022	0.022
Marphysa	1	0.922	0.922	0.922	0.922
Marshallora	2	0.0105	0.0105	0.01635	0.017
Marthasterias	772	98.33534	69.83165	277.8	594
Melinna	23	0.163798	0.118	0.4585	0.523
Melita	3	0.007333	0.006	0.0114	0.012
Mercenaria	3	0.300333	0.315	0.3474	0.351
Metridium	303	22.82259	20	52.9	105
Microprotopus	1	1.00E-04	1.00E-04	1.00E-04	1.00E-04
Mimachlamys	13	2.297923	1	6.8	11
Modiolula	4	0.1545	0.008	0.51135	0.6
Modiolus	1	1.00E-04	1.00E-04	1.00E-04	1.00E-04
Moerella	23	1.351004	0.87	3.574	5.303
Monoporeia	4	0.014475	0.0142	0.024395	0.0257
Munida	74	3.38965	1	21.2	45
Musculus	2	1.0845	1.0845	2.02365	2.128
Mya	1	24	24	24	24
Myriochele	143	0.000734	0.001	0.002	0.003
Myrtea	5	0.294	0.222	0.5548	0.58
Mysia	1	1.747	1.747	1.747	1.747
Mysta	4	0.00075	5.00E-04	0.00185	0.002
Mytilus	317	0.455588	0.2862	1.528272	5.391421
Nassarius	59	0.650836	0.116	3.033333	4
Natica	50	1.231935	0.2145	6	7
Neanthes	79	1.684768	1.4	4	5.6
Nebalia	2	0.0045	0.0045	0.00765	0.008
Necora	22	27.27273	20.5	81.55	97
Nemertesia	1	7.1	7.1	7.1	7.1
Neomysis	1	0.041	0.041	0.041	0.041
Nephrops	238	19.63403	15	53.75	95
Nephtys	328	0.115905	0.0235	0.446	4
Neptunea	104	51.29336	19.5905	155.005	337.8
Nereis	13	0.324577	0.089	1.3098	2.457
Notomastus	10	0.069934	0.021071	0.23075	0.233
Nucula	256	0.115255	0.007	0.574	4
Nuculana	8	0.180438	0.028	0.712575	0.9175
Nuculoma	1	0.23	0.23	0.23	0.23
Oestergrenia	2	0.1925	0.1925	0.27665	0.286
Onchidella	6	0.001533	0.0015	0.003	0.003

Ophelia	48	0.148709	0.059	0.36265	2.223
Ophelina	69	0.102775	0.045	0.1614	3.164
Ophiocomina	31	4.518869	4.4	9	10
Ophiocten	33	0.170205	0.159	0.3876	0.673
Ophiopholis	4	0.0805	0.041	0.2044	0.232
Ophiothrix	165	0.802362	0.3	2.98	5.5
Ophiura	1720	2.293698	0.8665	8	61
Orbinia	110	0.130391	0.1275	0.2898	0.38
Orchomene	3	0.005537	0.0035	0.01035	0.011111
Owenia	36	0.023301	0.0155	0.079	0.132
Oxydromus	2	0.0045	0.0045	0.00585	0.006
Oxypolia	2	0.1435	0.1435	0.17005	0.173
Pachymatisma	1	41	41	41	41
Pagurus	2777	6.657558	5	18	134
Palliolum	4	1.25	1	1.85	2
Pandalina	2441	0.04001	0.037	0.079	0.17
Pandalus	5562	1.910798	1.66	5	16
Pandora	2	0.036	0.036	0.0423	0.043
Paramphinome	220	0.001086	0.001	0.002	0.004
Paramysis	2	0.00105	0.00105	0.001905	0.002
Parvicardium	25	0.0992	0.022	0.6276	1.018
Pasiphaea	3	0.022667	0.022	0.0292	0.03
Peachia	1	1.00E-04	1.00E-04	1.00E-04	1.00E-04
Pecten	515	136.3328	139	222.9	309
Pectinaria	46	0.308803	0.005976	1.94325	3.74
Pennatula	83	1.166831	0.9	3	19
Pentapora	16	398.0063	58	1583.5	4150
Peronidia	1	0.704	0.704	0.704	0.704
Phascolion	19	0.094147	0.065	0.3345	0.366
Phaxas	12	0.108083	0.1055	0.24995	0.256
Pherusa	3	0.13	0.114	0.2418	0.256
Philine	4	5.775	1.5	17.3	20
Philocheras	395	0.01561	0.012	0.042	0.135
Pholoe	74	0.100164	0.001	0.014	2.879
Phoxocephalus	4	0.00225	0.002	0.0037	0.004
Pilumnus	27	1.158654	1	3	4.064
Pinna	1	0.1	0.1	0.1	0.1
Pinnotheres	3	0.027667	0.034	0.0394	0.04
Pisidia	43	1.095483	0.095	0.966667	37
Pista	3	0.173	0.25	0.2527	0.253
Poecilochaetus	1	0.005	0.005	0.005	0.005
Polinices	85	0.418744	0.037	3.116	6.8
Poliopsis	3	0.298	0.238	0.607	0.648
Polyodontes	1	1.821	1.821	1.821	1.821
Polyphysia	16	1.6395	2.0835	2.567	2.738
Pontocrates	2	0.001	0.001	0.001	0.001
Pontophilus	213	0.065103	0.026	0.38	1
Pontoporeia	21	0.008633	0.0042	0.0187	0.0254

Porania	17	50.47059	47.2	111.96	116.2
Porcellana	1	0.05	0.05	0.05	0.05
Praunus	3	0.003667	0.004	0.0058	0.006
Processa	128	0.202047	0.05	1	2
Psammechinus	698	1.270495	0.2	6	39.7
Pseudamuss-ium	17	5.472294	3	17	17
Pygospio	49	0.001267	9.00E-04	0.00348	0.007
Reteporella	4	0.41025	0.063	1.2894	1.5
Rhodine	51	0.067397	0.049	0.173833	0.282
Rhopalomenia	23	0.002087	0.002	0.0039	0.006
Rissoa	1	0.024	0.024	0.024	0.024
Ruditapes	2	0.5195	0.5195	0.95195	1
Sacculina	2	1.6	1.6	2.5	2.6
Saduria	151	0.286379	0.1809	0.865729	2.2433
Sagartia	3	3	2	4.7	5
Samytha	1	0.006	0.006	0.006	0.006
Sarcodictyon	1	0.492	0.492	0.492	0.492
Sarsia	5	0.364444	0.2	0.844444	1
Scalibregma	40	0.063001	0.025	0.3321	0.829
Scalpellum	54	0.286767	0.1195	1	3
Scaphander	89	19.20202	17	42	55
Schistomysis	1	0.011	0.011	0.011	0.011
Scolelepis	8	0.0715	0.0645	0.13785	0.155
Scoloplos	197	0.006305	0.0051	0.01378	0.0334
Sepia	29	395.4483	430	862	1175
Sepiola	77	1.399362	1	3.06	9.888889
Sigalion	8	0.15675	0.082	0.41415	0.488
Simnia	9	0.324815	0.3	0.66	0.7
Solaster	2	1.7	1.7	2.78	2.9
Solecurtus	1	0.05	0.05	0.05	0.05
Spatangus	89	31.48209	19.414	79.28	179
Spio	1	0.006	0.006	0.006	0.006
Spiophanes	183	0.007817	0.005	0.024	0.049
Spirontocaris	5	1.02	1	1.7	1.8
Spisula	125	0.755456	0.318	2.84	4.4
Stenella	3	0.002667	0.003	0.003	0.003
Sthenelais	2	0.045	0.045	0.0576	0.059
Stichastrella	25	9.856	0.9	29.8	40
Suberites	250	3.051696	1.8	9.32	44
Syllis	3	0.267333	0.312	0.3264	0.328
Talochlamys	1	0.014	0.014	0.014	0.014
Tapes	1	0.04	0.04	0.04	0.04
Tellimya	21	0.002571	0.002	0.005	0.006
Tellina	1	0.557	0.557	0.557	0.557
Terebellides	121	0.018875	0.009	0.0393	0.435
Thia	7	1.103714	1	1.7823	1.806
Thoralus	1	0.1	0.1	0.1	0.1
Thracia	9	2.931556	0.3	10.9622	13.521

Thyasira	225	0.008758	0.007	0.025	0.036
Timoclea	28	0.770757	0.8	1.9	2
Trichobranchus	1	0.0023	0.0023	0.0023	0.0023
Tridonta	94	0.538117	0.518	0.95235	2.6
Tritonia	1	0.03	0.03	0.03	0.03
Trivia	3	0.446	0.188	0.9188	1
Trophonopsis	2	0.257	0.257	0.4046	0.421
Tubulanus	4	0.178	0.184	0.1952	0.197
Turritella	808	0.513362	0.25	2	5.878
Turtonia	6	0.075517	0.0155	0.30275	0.395
Upogebia	28	1.925123	0.781	7.08515	7.537
Urothoe	10	0.00485	0.00105	0.02215	0.037
Urticina	3	0.730333	1	1.0819	1.091
Venus	7	5.996307	0.032	26.53	34.9
Virgularia	181	0.12474	0.002	0.701	1.522
Vitreolina	2	0.203	0.203	0.3569	0.374
Westwoodilla	100	0.02059	0.015	0.038	0.038