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Background

The general objective of the BalticBOOST project is to enhance regional coherence in the accomplishment of marine strategies through improved data flow, assessments, and knowledge base for development of measures. The WP 3.1 of the project has the objective of developing joint principles to define environmental targets for pressures affecting seabed habitats. HELCOM GEAR is the advisory body for the work.

This document presents interim results of the WP 3.1 and will be a background document for the HELCOM workshop on 'the development of joint principles to define environmental targets for pressures affecting the seabed to be 28-29 November 2016 at the premises of the HELCOM Secretariat, Helsinki. At the workshop where the synthesis and the guidelines will be discussed and the contents of the final BalticBOOST project report agreed. The results comprise a literature synthesis of non-fishery impacts of human activities on benthic habitats and conclusions on the basis of case studies of fishery and non-fishery impacts on benthic habitats. Guidelines for setting environmental targets are being developed on the basis of the results. The project ends in mid-December 2016.

Action required

The Meeting is invited to provide feed-back to the document, guide the finalization of the guidelines, and agree what should be the next appropriate action.

Contents

1. Introduction

The WP 3.1 of the BalticBOOST project has the objective of developing joint principles to define environmental targets for pressures affecting seabed habitats. At GEAR 14-2016 it was decided to call these joint principles as 'guidelines', as this term better indicates what the project is developing (Outcome GEAR 14-2016, para 3.3). The work began in December 2015 and will end in mid-December 2016. The WP 3.1 partners are SYKE (Finland, WP leader), IOW (Germany), SLU (Sweden), DTU Aqua (Denmark) and ICES.

The work is based on a literature study of reported impacts of human activities on benthic species and habitats as well as a series of case studies where more data-driven approaches have been used to analyze the relationship between impacts and the state of environment. SYKE and IOW focused on non-fishery pressures, SLU and DTU Aqua focused on fishery pressures and ICES encompassed all pressures.

2. The BalticBOOST approach in evaluating human activities, pressures and impacts

The starting point for the approach to environmental targets has been to establish how much pressure an activity can produce without causing significant impacts on the marine ecosystem. In Figure 1 this is expressed as Maximum allowable pressure that is (more or less) consistent with GES. In this scheme, the environmental target (blue line) is placed near GES and the GES is presented as a 'fuzzy area' on the pressure scale. This is considered to reflect the reality where it is extremely difficult to define the exact dependency between a pressure and state. The WP 3.1 has worked to find this answer with the use of explorative analyses of the dependency, multivariate analyses and simple correlations of pressures and state parameters (incl. GES indicators). However, in practice, many simplifications and assumptions based on expert knowledge were needed and there have been difficulties to distinguish the impacts of physical pressures from other pressures, such as eutrophication, hypoxia, chemical pollution, changes in food web structure as well as natural pressures.

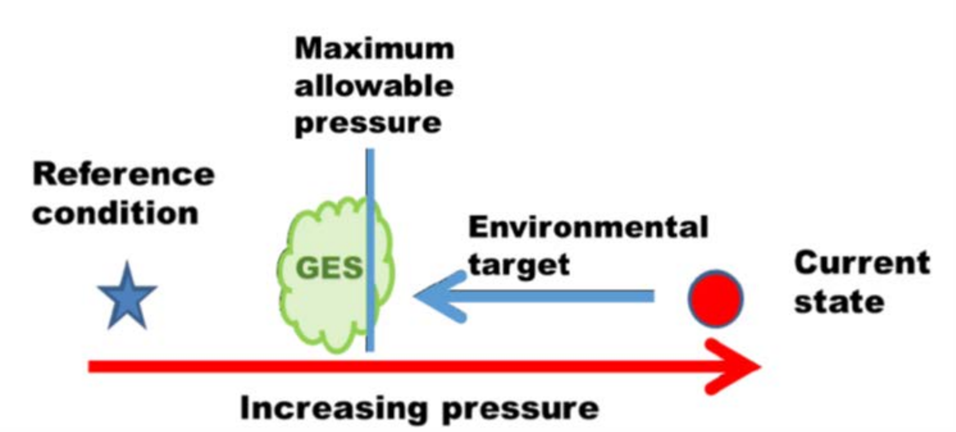

Figure 1. Schematic figure of the relations of GES (green fuzzy area), maximum allowable pressure which is at GES (vertical line) and the environmental target (blue arrow of reduced pressure) on the horizontal pressure gradient (red arrow).

2.1 Impact chains from activities to pressures and impacts

The WP 3.1 started by building a linkage framework which allows impacts to be back-tracked to pressures, human activities and activity sectors. The linkages help to identify which activities cause the pressures on benthic habitats. The linkage frameworks were compiled in co-operation with the HELCOM TAPAS[1] projects on the basis of the works made in the FP7 ODEMM project[2], OSPAR[3], JNCC[4] and INPN[5]. The linkages are referred to as impact chains[6]. In the HOLAS II assessment of activities, pressures and impacts, these chains allow a flexibility to perform assessments for different purposes (e.g. an assessment of pressures stemming from a selected activity or vice versa). An interim HELCOM linkage framework is available at the HELCOM web site (http://www.helcom.fi/action-areas/maritime-spatial-planning/human-activities-and-pressures) and a finalized version for the HOLAS II purposes will be ready by the end of November 2016.

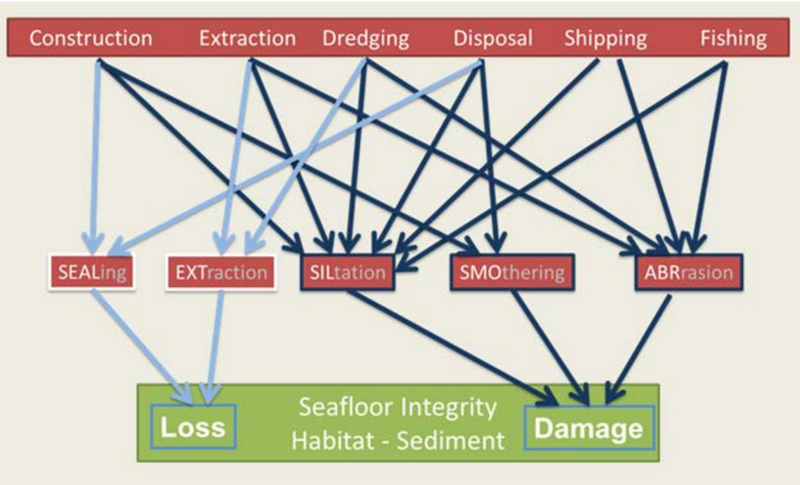

Figure 2. Links between generalized activity types and the physical pressures they exert on the seabed.

The linkage chains can also be visualized as in Figure 2, but more detailed information is given in Table 1 which presents interim results of the activities causing physical disturbance and physical loss to seabed. The activities in the table act on very different magnitudes and scales (spatial and temporal). There are also other pressures affecting benthic habitats and these are listed in Annex 1. In these 'other pressures' the impacts are either indirect (e.g. changes in water flows), chemical (e.g. causing eutrophication, hypoxia, contamination) or spatially very limited (e.g. input of heat, seismic waves, impulsive sounds). We have not considered eutrophication or hypoxia/anoxia in the WP 3.1 work as other reports give more comprehensive estimates of their impacts (e.g. HELCOM 2009[7], 2013[8]).

[1] The HELCOM coordinated EU co-finance project: Development of HELCOM tools and approaches for the Second Holistic Assessment of the Ecosystem Health of the Baltic Sea

[2] http://odemm.com/content/linkage-framework

[3] http://qsr2010.ospar.org/media/assessments/p00443_BA6_assessment-final.pdf

[4] http://jncc.defra.gov.uk/pdf/Final_HBDSEG_P-A_Matrix_Paper_28b_Website_edit%5b1%5d.pdf

[5] https://inpn.mnhn.fr/programme/sensibilite-ecologique?lg=en

[6] Knights, A., Koss, R.S. and Robinson, L. (2013). Identifying common pressure pathways from a complex network of human activities to support ecosystem-based management. Ecological Applications 23: 755-765.

[7] HELCOM 2009. Eutrophication in the Baltic Sea – An integrated thematic assessment of the effects of nutrient enrichment and eutrophication in the Baltic Sea region. Balt. Sea Environ. Proc. No. 115B.

[8] HELCOM 2013. Approaches and methods for eutrophication target setting in the Baltic Sea region. Balt. Sea Environ. Proc. No. 133

Table 1. Lists of human activities causing the main pressures affecting benthic habitats. Part A: physical loss and Part B: physical disturbance or damage. The lists of human activities are from the linkage framework.

PART A. Change of seabed substrate or morphology (~ physical loss)		PART B. Physical disturbance or damage to the seabed
Finfish mariculture		Finfish mariculture
Shellfish mariculture		Shellfish mariculture
Wind energy production: wind farms under construction		Wind energy production: wind farms under construction
Wave energy production		Wave energy production
Cables, incl. placement		Cables, incl. placement
Fishery: Benthic trawling		Fishery: Potting/Creeling
Fishery: Mussels and scallop dredging		Fishery: Netting
Marine plant harvesting: Maerl and Furcellaria harvesting		Fishery: Demersal long lining
Marine plant harvesting: Reed harvesting		Fishery: Benthic trawling
Extraction of sand and gravel		Fishery: Benthic seining
Pipelines, incl. placement		Fishery: Mussels and scallop dredging
Permanent land claim (urban, industrial, leisure, agriculture purposes)		Marine plant harvesting: Machine collection (fucoids, kelp)
Large-scale water deviation		Marine plant harvesting: Maerl and Furcellaria harvesting
Canalisation		Marine plant harvesting: Reed harvesting
Culverting/trenching		Extraction of metal ores
Coastal dams, weirs		Extraction of sand and gravel
Sea walls		Oil and gas industry infrastructure (Oil platforms)
Breakwaters		Pipelines, incl. placement
Groynes		Coastal dams, weirs
Flood protection		Sea walls
Tidal barrages		Breakwaters
Artificial reefs and islands		Groynes
Dredging (Capital/maintenance)		Flood protection
Beach replenishment/ nourishment		Tidal barrages
Tourism and leisure infrastructure: Piers		Dredging (Capital/maintenance)
Tourism and leisure infrastructure: Marinas and leisure harbours		Beach replenishment/ nourishment
Tourism and leisure infrastructure: Slipways		Tourism and leisure infrastructure: Marinas and leisure harbours
Transport infrastructure: Fishing harbours		Tourism and leisure activities: Recreational boating, yachting
Transport infrastructure: Industrial and ferry ports (harbours, bunkering points at sea; oil terminals)		Tourism and leisure activities: Beach use (bathing sites, beaches)
Transport infrastructure: Bridges and causeways		Tourism and leisure activities: Wildlife watching
Transport infrastructure: Tunnels		Tourism and leisure activities: Underwater cultural heritage
Solid waste disposal, incl. deposit of dredged material		Transport infrastructure: Industrial and ferry ports (harbours, bunkering points at sea; oil terminals)
Carbon capture and storage (Carbon sequestration)		Transport infrastructure: Ship/boat-building facilities
Military infrastructure (e.g. military firing ranges)		Transport: Passage of ships/boats
Waste disposal (munitions)		Transport: Mooring, anchoring, beaching, launching
		Solid waste disposal, incl. deposit of dredged material
		Military infrastructure (e.g. military firing ranges)
		Waste disposal (munitions)
		Research and survey: Fish surveys
		Research and survey: Environmental monitoring stations

2.2 Catalogue of activities, pressures and impacts

The WP 3.1 collected a catalogue of circa 120 studies with >380 hits for different impacts on benthic habitats. The catalogue includes only non-fishery impacts as the fishery impacts were evaluated separately in the WP 3.2. Both of these were, however, synthesized in the WP 3.1. The catalogue includes information of the type of activity, pressure it is causing, intensity of the pressure, lasting of the pressure, target of the impact, type of impact, magnitude of the impact, spatial extent of the impact, recovery from the impact, region of the study, type of study and reference. The catalogue was synthesized into a table summarizing the level of activity and magnitude of pressure and impact on different benthic habitats and species. The synthesis also summarizes recoverability from the pressure and the spatial extents. The catalogue and the synthesis are still developing and will be made available later in 2016.

2.3 Spatial extent of pressures

As our environmental monitoring programmes rarely have spatial components that cover local, regional and national scales, it is necessary to develop estimates of the spatial extent of different pressures. These estimates will form an important component in the process to judge whether an activity and its pressures cause significant harm to the benthic habitats (and hence whether environmental targets are needed to be established). The WP 3.1 included the spatial extents of pressures to the literature study and the case studies. Also in WP 3.2 spatial extents were added to the analyses of the impacts of fishing gears on seabed. In addition, for pressures that diminish at increasing distances from their source, the spatial representation of the pressures needs to incorporate the correct form of this decline. This gradient was also studied in the project (see Figure 3). The synthesis report will include detailed results of the spatial extents, but typical non-fishery extents were 1-3 km from the pressure source (Table 3).

Another aspect of spatial extent is the distribution of the human activities. While non-fishery activities are typically spatially limited, fishery with demersal gears is widespread. The case studies showed however that the Baltic bottom trawl fishery is very conservative in nature when it comes to choice of fishing grounds and tends to fish the same grid cells across years (the analysis limited to 2010-2012).

Table 3. Spatial extents of pressures from their source (km). The extents are estimated to the distance where impacts are considered negligible. Note that hydrographic conditions affect the distances.

Activity	Pressure extent (km)
Capital dredging	4 km (fish), 3 km (benthos), 3 km (vegetation), 3 km (water turbidity)
Maintenance dredging	4 km (fish), 3 km (benthos), 3 km (vegetation), 3 km (water turbidity)
Sand extraction	5 km (water turbidity), 4 km (fish), 3 km (vegetation), 2 km (benthos)
Disposal of dredged matter	4 km (fish), 3 km (benthos), 3 km (vegetation), 2 km (water turbidity)
Shipping and ferry traffic	1 km (fish), 1 km (water turbidity, 30 m in depth), 0.5 km (vegetation), 0.3 km abrasion (substrate change)
Boating	0.5 km (water turbidity, 4 m in depth),
Marinas	0.5 km (fish), 0.5 km (vegetation)
Wind turbines (operational)	0.1 km (abrasion effect)

2.4 Correlations between amount of human activities, associated pressures and their impacts

An important part of the WP 3.1 was the dependency of pressures and impacts on the magnitude of a human activity. For this work, the catalogue separated different human activities causing pressures and impacts on benthic habitats. As this dependency is affected by the distance from the pressure source, it was important to record also this distance in the catalogue. For many human activities and pressures such detailed information was not available, but Figure 3 presents an example of such a result related to dredging. On the basis of the figure, one can make at least three observations: (1) the pressure increase is not linear but logarithmic (i.e. high pressures are caused already at low activities and the increased activity increase the pressure only marginally), (2) the turbidity pressure decreases away from the 'core zone', and (3) the turbidity pressure is mostly limited to 2 km distance. Although as detailed figures were not available for many cases, similar conclusions were also made for other activities and pressures.

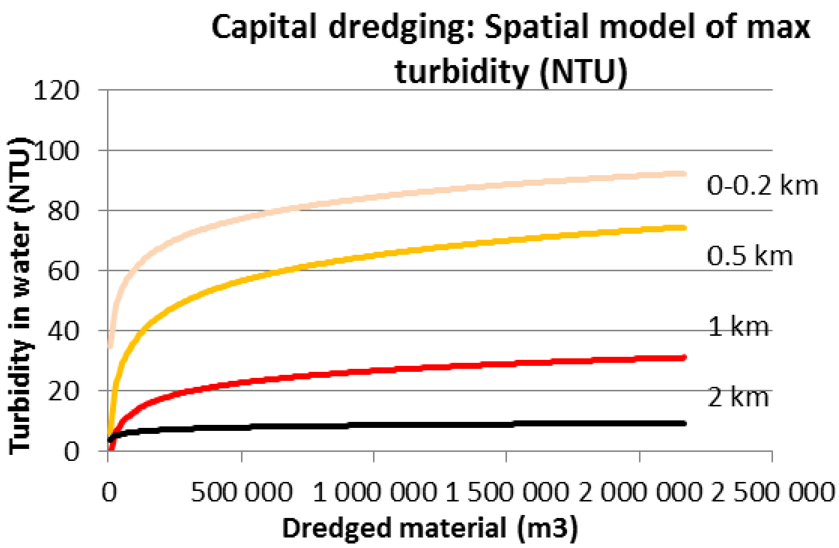

Figure 3. Dependence of water turbidity on dredging activity at different distances from the dredging site. Data is from the Vuosaari harbor construction case study in Finland.

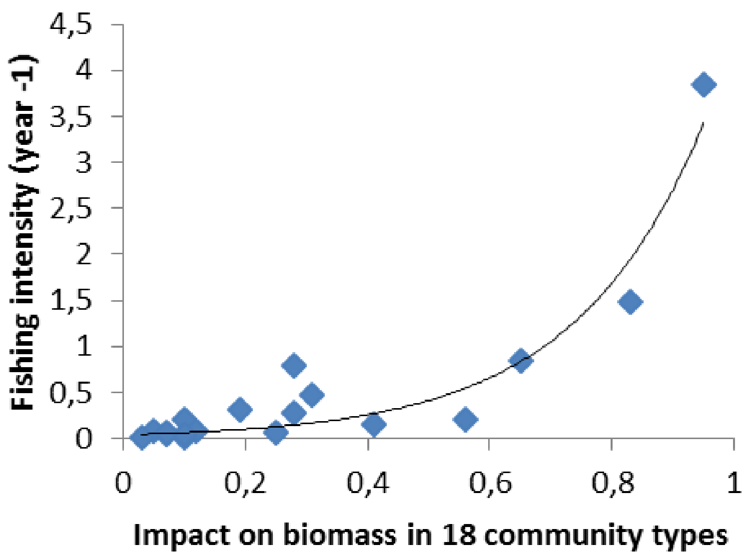

Figure 4. Impact of bottom-trawling fishing on benthic biomass in 18 benthic communities. The fishing intensity is an average value over all occurrences of that community type in the Baltic Sea and the impact on biomass is modelled for each community type in the Baltic Sea scale.

2.5 Recoverability from a pressure

The catalogue recorded also observed recoveries of the benthic features (species and habitat parameters). Typical recovery times were between 1-10 years depending on the feature. Table 4 gives a synthesis of the recoverability of benthic habitats. In the table, the habitat recoverability is a combined value of different features. Also the features with longest recovery times are mentioned.

Table 4. Recoverability of benthic broad habitat types from the physical disturbance pressure. The values comprise a synthesis of several studies. Note also that hydrographic conditions affect the recovery time.

Broad benthic habitat type	Typical recovery time in years	Features of longest recovery times
Infralittoral hard bottom	Disposal, dredging, sand extraction: >5 years	Herring spawning, Vegetation
Infralittoral mud bottom	Disposal and dredging: 5-10 y (in exposed areas faster)	Vegetation
Infralittoral sand bottom	Sand extraction: >6 y at the site, 2 y at 0.5-1km.	Benthic fauna
Circalittoral hard bottom		
Circalittoral mud bottom	Disposal of dredged matter: 4 y at the site; Capital dredging: 4-6 y at the site (1 y on exposed sites).	Benthic fauna
Circalittoral sand bottom	Sand extraction: >6 y at the site, 2 y at 0.5-1km.	Benthic fauna
Pelagic habitats	1 day – 1 week	turbidity

2.6 Ranking the impacts of human activities

The synthesis of the human activities allowed ranking them according to the amounts of pressures they cause and impacts on the benthic habitats. As only a few of the pressures could be compared on a same scale (i.e. same parameter, same units) and impacts on different species or environmental parameters cannot be directly compared, the WP 3.1 synthesis relied on a qualitative analysis of the activities, where the magnitudes were compared. For example, if capital dredging caused predominantly >75% mortality in benthic fauna (in near vicinity around the core zone) and wind turbine construction caused only 30% mortality at the same distance, one can rank them. Similarly, one can compare other impacts. The catalogue and the synthesis are meant to be kept together in order to ensure transparency in the interpretation. Table 5 lists a general ranking for physical disturbance pressure, but the project aims at more specific rankings per broad habitat type. At this stage, all the rankings are temporary and need to be finalized with the BalticBOOST WP 3.1 work by the end of November 2016.

Table 5. Ranking of human activities on the basis of their pressures and impacts. The activities are categorized into six categories on the basis of the magnitude of pressures and severity of impacts they cause. The ranking may differ between benthic habitat types and therefore the final WP 3.1 product will separate the benthic habitats. [The fishery activities need to be yet confirmed]

Rank	Activity causing physical disturbance
High pressures and impacts	Bottom-trawling, Demersal seining (Danish and Scottish), Scallop and blue mussel dredging, Maintenance and capital dredging (incl. harbours), Sand extraction and Sediment disposal
Moderate to high	Construction of water course modification and Coastal defence and flood protection, Finfish mariculture, Shellfish mariculture
Moderate	Demersal long-lining, Wind turbine construction, Contaminated sediments, Shipping, Marinas
Low to moderate	Boating, Pipeline placement, Maerl and furcellaria harvesting
Low	Cable placement
No	

2.7 How much human activities benthic habitats can tolerate and still be in GES?

One of the WP 3.1 objectives was to analyze the amount of human activities (and associated pressures) in marine areas and estimate how the benthic habitats respond to these activities. This task has proven to be very complex and clear dependencies have been difficult to find. The main reasons for this are:

1. the spatially limited impact from the non-fishery activities: benthic monitoring sites do not capture local impacts;
2. temporally limited impacts do not overlap with the benthic monitoring frequency;
3. physical impacts are difficult to distinguish from eutrophication, contamination or natural processes (e.g. upwelling, wind-forced resuspension, etc.);
4. indicators with GES thresholds are typically spatially and temporally aggregated and hence not adequate for this analysis;
5. pressure gradients and impact gradients are too narrow for statistical analyses;
6. often several impacts take place at the same time which makes it difficult to allocate the correct magnitude to specific impacts.

In this document, we do not yet present final results for this objective but present some interim findings in Section 3.3. Our ambition is to propose ranges of harmful activity levels for a couple of activity-pressure-impact chains.

3. Towards common guidelines in setting environmental targets for pressures affecting the benthic habitats

3.1 Starting points for the guidelines

The WP 3.1 approach to compare pressures and impacts from human activities allows a concrete basis for setting environmental targets. Our starting points for an environmental target (ET) are the following:

- ET is defined for a measurable pressure, often identifiable to a specific activity or sector;
- ET is necessary if GES has not been reached (or there is a risk for sub-GES) and reduction of a pressure can improve the GES status;
- ET may be necessary for a habitat type if an activity is causing physical loss and especially if the loss is not reversible (e.g. removal of a specific substrate, land filling of marine area, covering a habitat with disposed sediment, etc.);
- ET is necessary if a significant proportion of benthic habitat is affected or lost due to the pressure (also at more detailed levels of EUNIS classification);
- ET's necessity should be considered if the spatial extent of pressure impact is wide;
- ET's necessity should be considered if the pressure lasts for a long time or is continuous;
- ET's necessity should be considered if sensitive or threatened features are at risk;
- ET's necessity should be considered if recovery from the pressure takes a long time.

The WP 3.1 synthesis particularly showed that the concepts of physical loss and physical disturbance are not simple. These observations are given in Table 6.

Table 6. Difficulties in assessments of human impacts on benthic habitats.

The physical loss pressure is defined in the proposed GES decision as 'Change of seabed substrate or morphology' lasting at least 12 years. For sand extraction, dredging and disposal of dredged matter this is not a simple definition and therefore the BalticBOOST project defined this more carefully: - the core zone of the activity (extraction/ dredging site, disposal site) is considered 'lost' because the seabed morphology has been changed for at least 12 years; - the core zone may be lost forever, if the site is emptied of the particular substrate (e.g. extracting specific grain size) or covered by a new substrate (depositing dredged matter over a different substrate type);

- these activities also cause physical disturbance in the form of sedimentation to nearby areas and turbidity of the adjacent water areas.
An activity causing physical loss of a habitat may be limited to a small area (e.g. the dredged spot), whereas the adjacent areas are affected by a gradually decreasing pressure which is only disturbance.
Permanent hydrographical alterations due to construction of wind turbines, platforms or other obstacles take place in the vicinity of the object. If these cause changes in water flows, they may exert physical disturbance (i.e. abrasion, resuspension and sedimentation) to the seabed, but these are difficult to assess and approximations are needed.
In case of physical loss, it is necessary to consider also the potential to reverse the loss in the longer perspective, i.e. remove an obstacle (e.g. wind turbine or sea wall), compensate for the loss by building a new habitat (e.g. an artificial reef), or restore a habitat (e.g. restore a sill to an semi enclosed bay).
There are several different techniques on how specific human activities are carried out in practice. For instance, a construction project can be planned to cause minimal impacts to the environment, or a dredging or a sand extraction technique can be less impacting than another one. As a result of this, assessments of human impacts can overestimate impacts from environmentally friendly projects. No method exists to include such information into the region-wide guidelines.
Pressures and impacts from an activity depend strongly on the hydrography of the site. Exposed areas will have weaker effects than sheltered areas, but generalizations are difficult.
Seasonality of a feature (habitat or species) affects the impact: impacts can be high on a sensitive season, whereas pressures acting on other seasons may cause negligible impacts. The data is, however, often annual, and therefore the seasonality can be difficult to observe.
Temporal extents of the activities vary greatly. A long lasting pressure can cause higher impacts than single occurrences of that pressure.

While the synthesis focused mostly on two pressures – physical loss and physical disturbance – and the activities causing them, there are other pressures (mostly of minor or local importance) which affect the benthic habitats and which should be considered when identifying environmental targets (Table 2). The interim guidelines presented in Section 3.2 are applicable also to these pressures.

The geographical scale of the environmental targets is not defined in the EU MSFD (except that they are set for marine regions by Member States), but the project proposes that the HELCOM sub-basins are a suitable scale in case of the benthic habitats for the following reasons:

- The proposed GES decision has identified 'subdivision of region or subregion, reflecting biogeographic differences in species composition of the broad habitat type' as the relevant scale for the assessment of descriptor six criteria.
- The Benthic Quality Index, which has been proposed as a core indicator for benthic faunal communities, is assessed for sub-basins.
- The cumulative benthic impact indicator, which has been proposed as a core indicator for impacts on sea bed, is assessed for sub-basins.

As environmental targets aim to guide progress towards GES in the area by reducing pressures, they should not be conceptually too limited. It is beneficial for their purpose that they can encompass a pressure type in general, a pressure affecting a certain habitat type or even a pressure type in a certain time period, depending on the need. Hence, the environmental targets could be used as a tailor-made tool.

3.2 Interim guidelines

The interim guidelines are in the form of steps which give a general framework for setting of environmental targets for benthic habitats (Figure 5). The guidelines take into account the starting points listed in the previous section but do not, as such, include proposals for any pressure thresholds or any activity-specific details. More specific information of potential thresholds or details and examples for the guideline steps are given in Section 3.3 on the basis of the catalogue and the case studies.

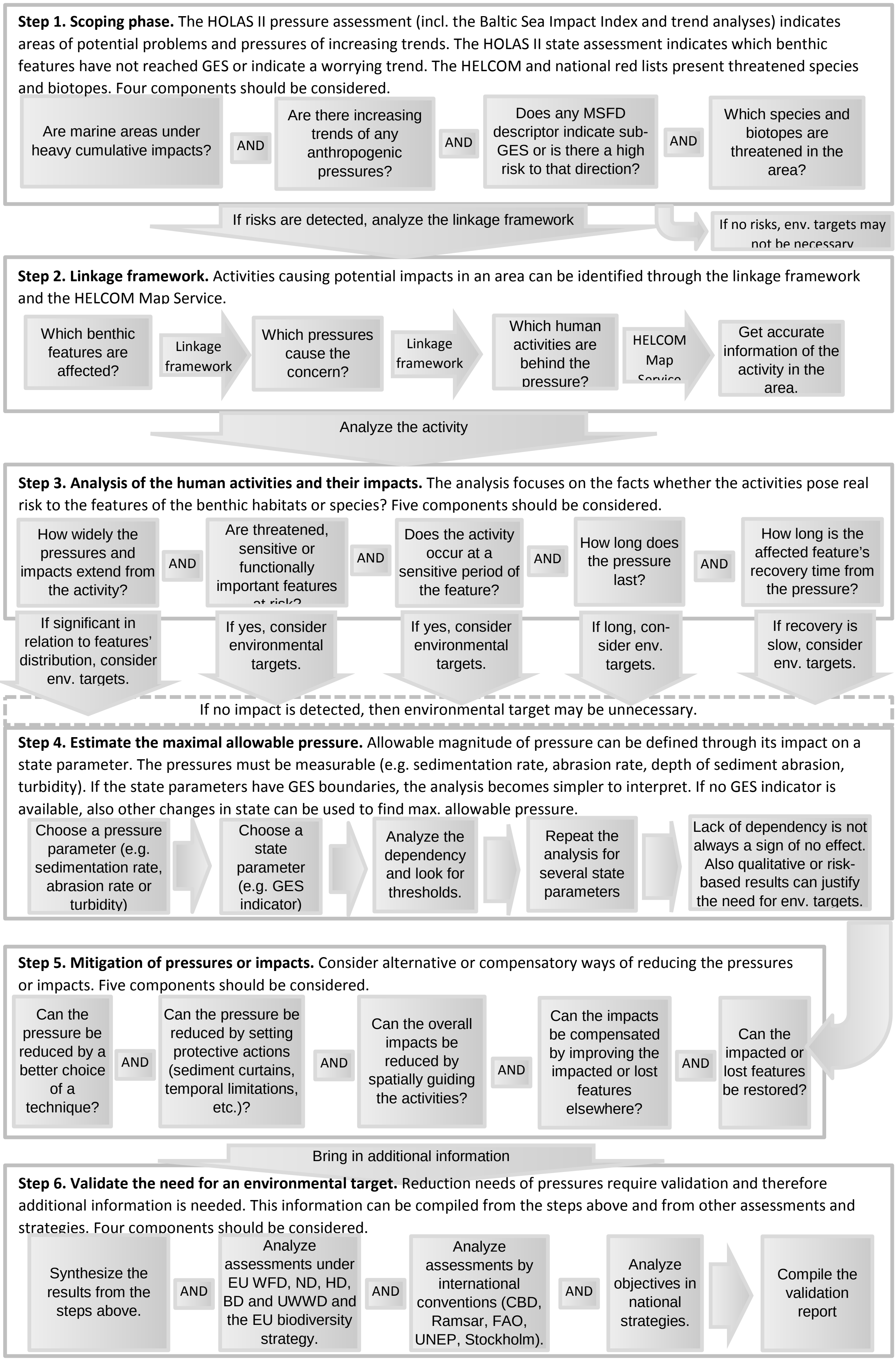

Figure 5. Interim guidelines for the setting of environmental targets for pressures affecting benthic habitats.

3.3 Experience from the WP 3.1 work

In this section more concrete proposals for the setting of environmental targets are presented. They are given in the order of the six steps of the interim guidelines (Figure 5) and also more practical explanations of the steps are given.

Step 1: Scoping phase. In this step, one becomes familiar with the most recent assessment results and identifies potential problem areas where environmental targets may be required. In addition to the HOLAS II results, also other information sources can be used.

Step 2: Linkage framework. Linkage frameworks are presented in Section 2.1. At present the interim linkage framework indicates only on/off linkages, but the project aims to include also the strength of the linkage into the final product. This would be based on the ranking of the activities (see Section 2.6). Confidence of the linkages can be retrieved from the number of information sources where the link has been identified.

Step 3: Analysis of the human activities. Spatial extents of human activities are given in Section 2.3 and will be also complemented by the TAPAS project's expert survey. This information can be included in any spatial assessment of physical disturbance and physical loss. GIS data layers including this information will be available on the HELCOM Map Service. Spatial overlay analysis of species and habitats and the pressures could be made available as a HOLAS II product and, at minimum, GIS data layers of benthic habitats and some species are available on the HELCOM Map Service. Recoverability information of benthic features is given in the synthesis (see table 3) and will be complemented by the TAPAS expert survey. The step 3 also proposes that duration of the pressure and sensitive seasons should be considered as long-lasting pressure or a pressure taking place in a sensitive time period for a species or habitat will likely affect the benthic features more significantly. Unfortunately the WP 3.1 synthesis did not include sufficient temporal information to allow any conclusion on these matters. However, Table 7 gives some preliminary considerations on sensitive periods in benthic habitats.

Table 7. Potential overlaps of pressures and sensitive time periods of species. The table is interim and more thorough analysis of this is needed.

Habitat type	Physical disturbance		
	Sedimentation	**Turbidity**	**Abrasion, changes in water flow**
Infralittoral hard bottom	Late spring -early summer is sensitive time for Fucus recruitment, and spring for herring spawning.	Summer time vegetation growth affected.	
Infralittoral mud bottom	Summer is sensitive for vegetated enclosed bays.	Summer is sensitive for vegetated enclosed bays.	
Infralittoral sand bottom	Eelgrass is sensitive year round	Eelgrass is sensitive year round	Eelgrass is sensitive year round
Circalittoral hard bottom	Red algae are sensitive year round.	Red algae are sensitive year round.	Mussel beds are sensitive to abrasion year round.
Circalittoral mud bottom			
Circalittoral sand bottom			

Step 4: Estimate the maximal allowable pressure. The WP 3.1 case studies aimed to find simple answers to the question 'How much pressure a benthic feature can tolerate and still be in GES?'. In Section 2.7 this matter was discussed and only partial answers can be provided. In case of benthic trawling fishery, the longevity models predict that the most impacted benthic communities were in muddy bottoms in salinity 2.4-9.6 at depth 10-46 m, salinity 19.4-30.8 at depths 12-24 m and salinity 23.2-34.7 at 13-49m (community

types 3, 7 and 14 in Gogina et al. 2016[9]) and in gravelly sand bottoms in salinity 20.9-30.7 at <21 m depth (community type 10 in Gogina et al. 2016) (Table 8). The project made scenarios how to best decrease the impacted area. The best result was achieved by focusing to grid cells that are fished less than once a year and decreasing fishing in 95% of them and, additionally, decreasing fishing in the remaining grid cells by 15%. This scenario results in less impact in almost all communities. This occurs since there is non-linearity between impact and fishing intensity and the frequency of fishing intensity becomes much lower in this scenario compared to other scenarios where reductions were made also in the fishery core areas (i.e. areas of high fishing frequency). Still, impact remains high in community 14, as most of the grid cells that cover this community have a high fishing intensity. This suggests that community 14 could best be protected spatially (marine protected area).

Table 8. Management scenarios for reduced fishing for 18 benthic communities. The 'no change' column shows the bottom-trawling impact without any further management, the 'scenario 1' reduces fishing in all cells with 30% and the best scenario ('scenario 2') reduces 95% fishing in areas which are only rarely trawled and 15% elsewhere. The shades of green and red indicate impacts on the scale from 0 (low) to 1 (high). The community types (1-18) are given in Gogina et al. 2016.

Community	No change	Scenario 1 (all intensities in grid cells reduced with 30%)	Scenario 2 (95% reduction in marginal fishing areas and 15% reduction elsewhere)
1	0.10	0.09	0.06
2	0.28	0.25	0.10
3	0.83	0.80	0.59
4	0.05	0.04	0.03
5	0.19	0.17	0.09
6	0.12	0.10	0.01
7	0.65	0.64	0.54
8	0.07	0.04	0.00
9	0.10	0.09	0.08
10	0.56	0.54	0.49
11	0.25	0.24	0.21
12	0.10	0.09	0.01
13	0.07	0.05	0.01
14	0.95	0.95	0.89
15	0.28	0.26	0.20
16	0.41	0.39	0.30
17	0.03	0.03	0.03
18	0.31	0.27	0.16

[9] Gogina, M., H. Nygård, M. Blomqvist, D. Daunys, A. B. Josefson, J. Kotta, A. Maximov, et al. 2016. The Baltic Sea scale inventory of benthic faunal communities. ICES Journal of Marine Science 73:1196–1213.

Tables 9 and 10 give an interim summary of the findings and the project's final report will give more examples of the maximal allowable pressures (see Figure 1 for this concept).

Table 9. Estimates of maximal allowable pressures on some state parameters. The results are preliminary and will be corrected in the project. The pressure amounts are measured at 0.2-0.9 km distance but the amounts still depend on local environmental factors. The numbers are from semi-exposed coast.

State parameter	Physical disturbance
Fucus coverage	20-30 g/m²/d sediment
Fucus depth limit	
Fucus colonization	0.2 cm burial
Fucus growth	7 g/m² sediment
Red algae growth	
Seagrasses in bays	1 marina, 10 ferries/day
Herring fry mortality (detachment)	40-60 g/m²/d
Pike juvenile mortality	1 marina
Benthic fauna mortality	10-40 cm burial in mud, 1-2 cm burial in hard bottom
Mortality of juvenile Macoma balthica	40-60 g/m²/d
Benthic fauna community (Benthic Quality Index)	

Table 10. Amounts of human activities causing the maximal allowable physical disturbance pressures. The pressure amounts are measured at 0.2-0.9 km distance but the amounts still depend on local environmental factors. The numbers are from semi-exposed coast.

Activity	Physical disturbance		
	Sedimentation	Turbidity	Abrasion, changes in water flow
Capital dredging	~8000 m³	~8000 m³	
Maintenance dredging		8000-12000 m³	
Disposal of dredged matter	500-3000 m³		
Sand extraction			
Wind turbine construction	1 turbine	1 turbine	1 turbine
Pipeline construction			
Cable placement			
Shipping and ferry traffic		1 ship	
Boating		1 ferry	
Marinas			

Step 5: Mitigation of pressures or impacts. Environmental targets do not need to reduce the activities but can also influence the way of carrying out the activity. Requiring environmentally friendly techniques (e.g. a change of fishing gear), protective actions (e.g. sediment curtains) and precautionary planning (e.g. avoiding sensitive time periods and areas) one can sufficiently reduce the impacts. Marine spatial planning could reduce impacts by guiding activities away from sensitive areas (e.g. disposal of dredged matter) or concentrating them to some areas (e.g. fishery). The fishery case studies showed that large areas are trawled much less (i.e. trawling concentrates on some areas) and overall fishery impacts would be significantly reduced by preventing fishery from these areas. Environmental targets could also be 'positive', i.e. improving the state of environment, by a number of potential ways. Enhanced protection of features (e.g. MPAs, other protection measures) can compensate for the degradation or loss of a feature elsewhere. Other compensation measures could be artificially improving the state of a feature (e.g. restocking a species, restoring a lost habitat such as a coastal wetland or vegetated bay, introducing an artificial reef). Restoration actions can also take place at the site after cessation of the pressure.

Step 6: Validate the need for an environmental target. As environmental targets mean usually increased costs, sufficient validation is needed to back up the target. This includes a comprehensive synthesis of the analyses (steps 1-5) but also results from other assessments, studies and strategies. For instance, results and recommendations arising from the assessments under the EU Water Framework Directive, Habitats Directive, Birds Directive, Urban Waste Water Directive and Nitrate Directive may provide good argumentation. Moreover, assessment results and recommendations from international conventions such as CBD, Ramsar, Stockholm Convention or UN bodies may give additional information. The EU biodiversity Strategy, Baltic Sea Action Plan and national strategies give important support for setting the environmental targets and may also guide towards the quantitative target (e.g. how many restored salmon or trout rivers are aimed at, etc.).

4. Other results from the BalticBOOST WP 3.1

Even though the project objective is rather clear – to develop joint principles (or guidelines) – several synergies have been identified with the other HOLAS II development and therefore BalticBOOST WP 3.1 has produced a couple of spin-off products which have supported the HOLAS II progress.

The WP 3.1 has supported the development of sensitivity estimates which are needed in the Baltic Sea Impact Index, being developed in the HELCOM TAPAS project. These sensitivity estimates were developed as a side product of the synthesis and will be presented in the final report of the WP 3.1. Interim values are given in Annex 2. The method for this has been presented in a document for the fifth State & Conservation meeting (7-11 November 2016).

Moreover, the synthesis also provided important information for the production of the HOLAS II spatial pressure data layers. For these layers, WP 3.1 has provided information of the spatial extent of pressures as well as support for aggregation of pressure data from different human activities. This latter work benefited from the ranking process presented in Section 2.6 of this document. The method for this has been presented in a document for the fifth State & Conservation meeting (7-11 November 2016).

Annex 1. Other pressures affecting benthic habitats and human activities causing these pressures.

Selected activities affecting only benthic habitats have been included from the linkage framework.

Changes to hydrological conditions	**Input of nutrients**	**Input of litter, incl. micro litter**	**Input of heat**	**Deposit of contaminated dredged material at sea**	**Impulsive noise**	**Input of organic matter**	**Input of seismic waves**
Wind energy production: operational wind farms	Finfish mariculture	Netting	Fossil fuel energy production	Dredging (capital/ maintenance)	Wind farms under construction	Finfish mari-culture	Seismic surveys
Wave energy production	Shellfish mariculture	Benthic trawling	Nuclear energy production	Solid waste disposal, incl. deposit of dredged material	Military infrastructure (e.g. military firing ranges)	Shellfish mari-culture	
Oil and gas industry infrastructure (Oil platforms)	Urban waste water treatment	Benthic seining					
Breakwaters	Industrial waste water treatment						
Groynes	Industrial animal farming						
Artificial reefs and islands							
Piers							
Marinas and leisure harbours							
Coastal dams, weirs							

Annex 2. Preliminary results of the literature survey to assess impacts of non-fishery pressures on seafloor habitats

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Introduction

BalticBOOST WP3.1 has the task to develop common principles to define environmental targets for pressures affecting the seabed habitats. Environmental targets need to ensure sustainable levels of human activities without compromising the achievement of good environmental status (GES). Whereas many human activities cause same kind of pressure, e.g. physical disturbance on seabed habitats, the setting of environmental targets will have to consider effects of multiple human activities in order to be useful. The intensity, frequency and magnitude of the different human activities vary and thus the impact on seabed habitats will also vary among the human activities. To assess the impacts of human activities causing physical disturbance on seabed habitats a literature survey was carried out. The aim of the literature survey was to quantify the impacts of different human activities causing physical disturbance on seabed habitats and based on this information rank the activities based on the severity of the impacts they are causing.

Methods

In BalticBOOST WP3.1 impacts of pressures impacting the seabed habitats are assessed. However, here we only consider non-fishery pressures, as the fishery pressure will be assessed in WP3.2.

To collect the information on impacts a template form was developed. The input column in the form were:

- Activity
- Pressure (MSFD Annex III)
- Intensity of pressure
- Frequency of pressure
- Vertical impact in the sediment
- Target
- Respective habitat
- Impact
- Quantified impact
- Spatial extent gradient of the impact
- Recovery
- Type of study
- Region
- Reference

In total >130 articles were reviewed, resulting in a total of >380 recorded impacts. The reviewed literature included both peer-reviewed articles as grey literature (e.g. scientific reports and environmental impact assessments).

The target in the reviewed studies varied from species to community to habitat impacts. The collected information was synthesized according to activity, pressure and habitat, taking into account the reported intensities and type of impact. In addition, impacts on vascular plants and fish recruitment were treated separately. In the synthesis, the magnitude of the impact of different activities was estimated and the activities were ranked in five categories (high impact, moderate to high impact, moderate impact, moderate to low impact, and low impact). Similarly recoverability of habitats/communities from the pressure was categorized based on the literature survey (slow recoverability, moderate recoverability, high recoverability, and immediate recovery). Habitat sensitivity to the activities was based on the impact and recoverability, according to table 1.

Table 1. Cross-table to assess sensitivity based on impact and recoverability.

	immediate recoverability	high recoverability	moderate recoverability	slow recoverability
no impact	very low sensitivity	low sensitivity	low sensitivity	low sensitivity
low impact	low sensitivity	low sensitivity	moderate sensitivity	moderate sensitivity
moderate impact	low sensitivity	moderate sensitivity	moderate sensitivity	high sensitivity
high impact	moderate sensitivity	moderate sensitivity	high sensitivity	high sensitivity

To assess the confidence of the impacts and habitat sensitivities derived from the literature survey a categorical approach will be used. The exact definitions of confidence categories are not yet settled, but a proposal is to use categories as following:

High = Several studies showing similar magnitude of impacts

Intermediate = Single studies verified by expert judgment

Low = Studies not consistent or expert judgment

Results

Impacts

Based on the literature survey, dredging (both capital and maintenance), extraction and disposal have the highest impacts on all types of seabed habitats. Wind turbine construction and contamination of sediments have moderate impacts, whereas cable placement have low impact on all habitat types. Shipping and boating were considered to have a moderate impact on hard bottoms, but a low impact on sandy and muddy bottoms. The water column was considered to be most impacted by disposal and dredging, followed by sand extraction and shipping in the Moderate to high-category. In sheltered areas, marinas and boating were considered to have moderate impact on the water column, whereas elsewhere boating was considered to have low to moderate impacts. Dredging and disposal have high impact on vascular plants and fish recruitment. Additionally small-scale dredging in sheltered areas have a high impact on vascular plants.

HARD BOTTOM SEABED

Rank	Activity causing physical disturbance	Category	Weight
High pressures and impacts	Maintenance and capital dredging (incl. harbours), sand extraction and sediment disposal	80-100%	1
Moderate to high		60- <80%	0,8
Moderate	wind turbine construction and contaminated sediments, boating	40- <60%	0,6
Low to moderate		20- <40%	0,4
Low	Cable placement	0- <20%	0,2
No		0	0

SANDY SEABED

Rank	Activity causing physical disturbance	Category	Weight
High pressures and impacts	Maintenance and capital dredging (incl. harbours), sand extraction and sediment disposal	80-100%	1
Moderate to high		60- <80%	0,8
Moderate	wind turbine construction and contaminated sediments	40- <60%	0,6
Low to moderate		20- <40%	0,4
Low	Cable placement, boating	0- <20%	0,2
No		0	0

MUDDY SEABED

Rank	Activity causing physical disturbance	Category	Weight
High pressures and impacts	Maintenance and capital dredging (incl. harbours), sand extraction and sediment disposal	80-100%	1
Moderate to high		60- <80%	0,8
Moderate	wind turbine construction and contaminated sediments	40- <60%	0,6
Low to moderate		20- <40%	0,4
Low	Cable placement, boating	0- <20%	0,2
No		0	0

WATER COLUMN

Rank	Activity causing physical disturbance	Category	Weight
High pressures and impacts	Disposal, capital dredging, maintenance dredging	80-100%	1
Moderate to high	Sand extraction, shipping	60- <80%	0,8
Moderate	Marinas and boating in sheltered sites	40- <60%	0,6
Low to moderate	boating	20- <40%	0,4
Low		0- <20%	0,2
No		0	0

FISH RECRUITMENT

Rank	Activity causing physical disturbance	Category	Weight
High pressures and impacts	maintenance and capital dredging (incl. harbours), sand extraction, sediment disposal	80-100%	1
Moderate to high	marinas and boating (in sheltered sites) and shipping	60-<80%	0,8
Moderate		40-<60%	0,6
Low to moderate		20-<40%	0,4
Low	wind turbine construction	0- <20%	0,2
No		0	0

VASCULAR PLANTS

Rank	Activity causing physical disturbance	Category	Weight
High pressures and impacts	maintenance and capital dredging, sediment disposal, small-scale dredging in sheltered areas	80-100%	1
Moderate to high	sand extraction, marinas (in sheltered areas), ship traffic, boating (in sheltered areas)	60-<80%	0,8
Moderate		40-<60%	0,6
Low to moderate		20-<40%	0,4
Low		0- <20%	0,2
No		0	0

Habitat sensitivity

Based on the intensity of the impacts and the recoverability of habitats, the sensitivity of habitats to different human activities were estimated. Impacts and recoverability were assessed in the literature survey and complemented by expert judgment where this information was lacking. Generally, hard bottoms are most sensitive to human activities, followed by sandy bottoms. Mud bottom habitats seem to be least sensitive to pressures from human activities. The results will be complemented with sensitivity estimates for habitat forming species if time allows.

Infralittoral hard bottoms

	impact	recoverability	sensitivity	remarks
Construction	moderate	slow	high	Loss, damage from abrasion and smothering during work on site plus siltation in adjacent areas
Extraction	high	moderate	high	Loss, otherwise damage from siltation in nearby areas
Dumping	high	slow	high	Loss from periodical (maintenance) dumping
Dredging	low	n/a	low	No dredging on rocks, but damage from siltation from nearby areas
Shipping	low to moderate	slow	moderate	Possible damage from constant resuspension of fine sediments
Sum of "adversely affected"	moderate to high	slow	**high**	Sensitivity even higher with perennial algae or biogenic reefs

Circalittoral hard bottoms

	Impact	recoverability	sensitivity	remarks
Construction	moderate	slow	high	Loss, damage from abrasion and smothering during work on site plus siltation in adjacent areas
Extraction	High	moderate	high	Loss, otherwise damage from siltation in nearby areas
Dumping	High	slow	high	Loss from periodical (maintenance) dumping
Dredging	Low	n/a	low	No dredging on rocks, but damage from siltation from nearby areas
Shipping	Low	slow	moderate	Possible damage from constant resuspension of fine sediments
Sum of "adversely affected"	moderate to high	slow	**high**	Lower hydrological impacts in deeper water lead to more sensitive communities

Infralittoral sand bottoms

activity	Impact	recoverability	sensitivity	Remarks
Construction	Moderate	moderate	moderate	Loss, damage from abrasion and smothering during work on site plus siltation in adjacent areas
Extraction	moderate to high	moderate	moderate to high	Loss, damage from abrasion and smothering during work on site plus siltation in adjacent areas
Dumping	moderate to high	moderate	high	Loss from periodical (maintenance) dumping, depending on material and contamination
Dredging	moderate to high	moderate	moderate	Loss from periodical (maintenance) dredging
Shipping	Low	moderate	low	Possible damage from constant resuspension of fine sediments

Sum of “adversely affected”	Moderate	moderate (high in exposed areas with sediment transport)	**moderate to high**	Sensitivity even higher with perennial algae or biogenic reefs

Circalittoral sand bottoms

activity	**Impact**	**recoverability**	**sensitivity**	**Remarks**
Construction	Moderate	moderate	moderate	Loss, damage from abrasion and smothering during work on site plus siltation in adjacent areas
Extraction	moderate to high	moderate	moderate to high	Loss, damage from abrasion and smothering during work on site plus siltation in adjacent areas
Dumping	moderate to high	moderate	high	Loss from periodical (maintenance) dumping, depending on material and contamination
Dredging	moderate to high	moderate	moderate	Loss from periodical (maintenance) dredging
Shipping	Low	moderate	low	Possible damage from constant resuspension of fine sediments
Sum of “adversely affected”	Moderate	moderate (high in exposed areas with sediment transport)	**moderate to high**	Lower hydrological impacts in deeper water lead to more sensitive communities

Infralittoral mud bottoms

	Impact	**recoverability**	**sensitivity**	**Remarks**
Construction	moderate	high	low	Loss, damage from abrasion and smothering during work on site plus siltation in adjacent areas
Extraction	moderate	high	low	Loss, damage from abrasion and smothering during work on site plus siltation in adjacent areas
Dumping	moderate	high	moderate	Loss from periodical (maintenance) dumping, depending on material and contamination
Dredging	moderate	high	moderate	Loss from periodical (maintenance) dredging
Shipping	low	moderate	low	Possible damage from constant resuspension of fine sediments
“adversely affected”	moderate	high	**low to moderate**	Areas with high natural sedimentation are less, but areas with perennial macrophytes or biogenic reefs are more sensitive

Circalittoral mud bottoms

	impact	**recoverability**	**sensitivity**	**Remarks**
Construction	moderate	high	low	Loss, damage from abrasion and smothering during work on site plus siltation in adjacent areas

Extraction	moderate	high	low	Loss, damage from abrasion and smothering during work on site plus siltation in adjacent areas
Dumping	moderate	high	moderate	Loss from periodical (maintenance) dumping, depending on material and contamination
Dredging	moderate	high	moderate	Loss from periodical (maintenance) dredging
Shipping	low	moderate	low	Possible damage from constant resuspension of fine sediments
“adversely affected”	moderate	high	**low to moderate**	Areas with high natural sedimentation are less sensitive