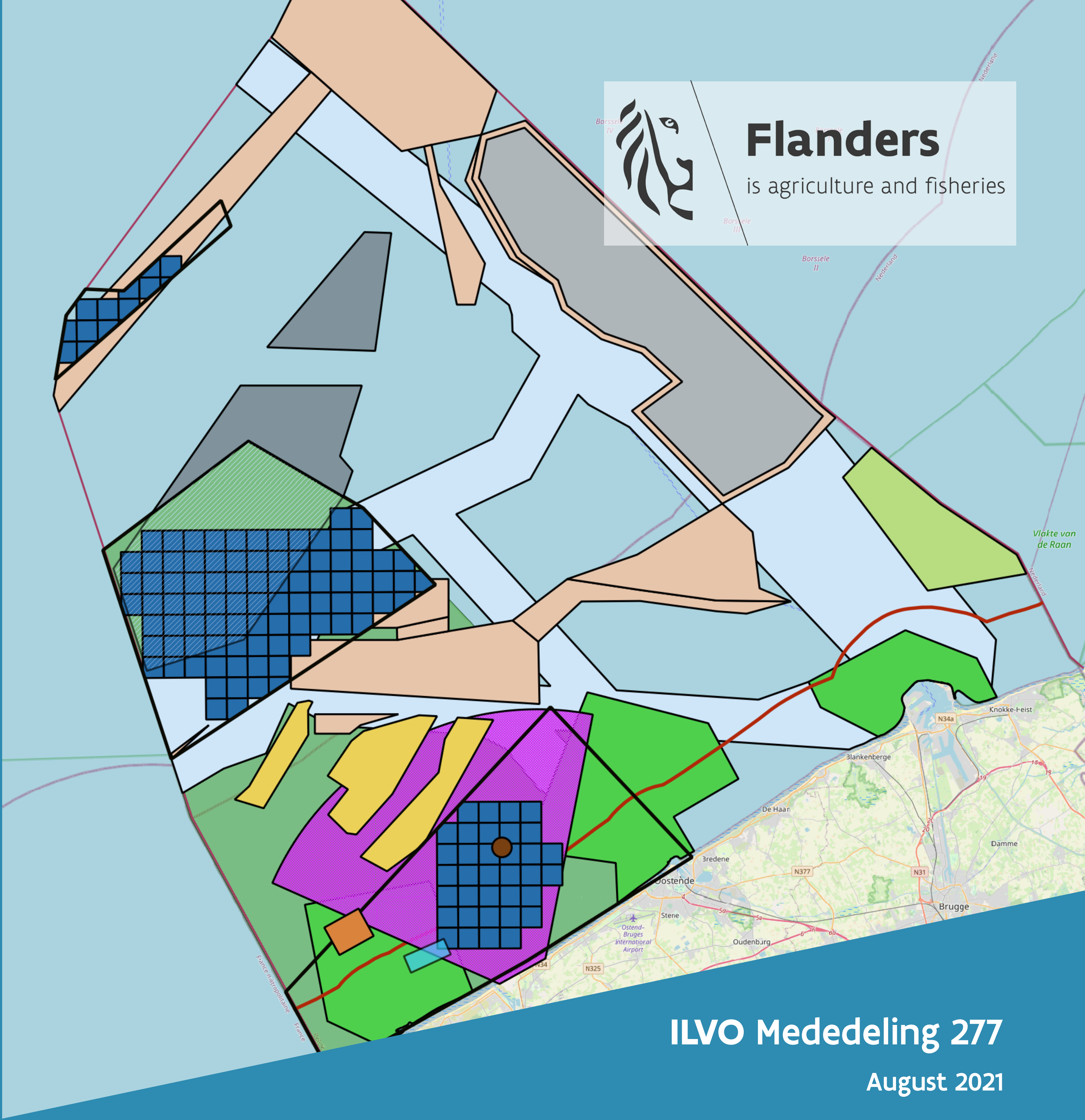

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SCIENTIFIC BACKGROUND REPORT IN PREPARATION OF FISHERIES MEASURES TO PROTECT THE BOTTOM INTEGRITY AND THE DIFFERENT HABITATS WITHIN THE BELGIAN PART OF THE NORTH SEA

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Scientific background report in preparation of fisheries measures to protect the bottom integrity and the different habitats within the Belgian part of the North Sea

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Scientific background report in preparation of fisheries measures to protect the bottom integrity and the different habitats within the Belgian part of the North Sea

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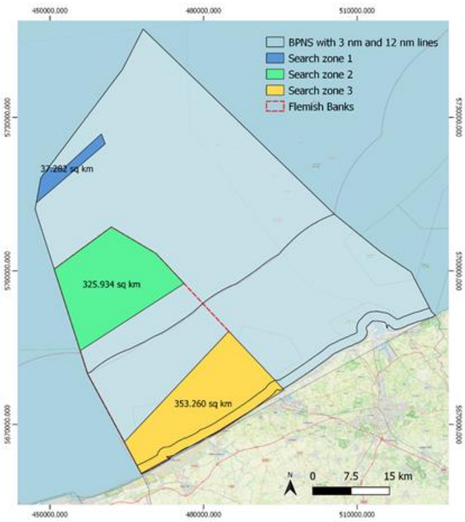
Executive summary

In the European Union, two key legal instruments exist for the protection of marine habitats: the EU Habitats Directive (HD) and the EU Marine Strategy Framework Directive (MSFD). Under MSFD the aim is to protect the marine environment and to reach a good environmental status (GES). The implementation of MSFD focuses on 11 descriptors including “Biodiversity and “Sea floor integrity”. The EU Habitats Directive requires Member States to aim for the conservation and protection of important or threatened species and habitat types, for which a network of marine protected areas, the Natura 2000 network, is designated. In Belgium, the zone ‘Vlaamse Banken’ was designated as a marine protected area and there are two habitat types that need protection. The first habitat - type 1110 “Sandbanks which are slightly covered by sea water all the time” - represents the main habitat type of the Belgian part of the North Sea (BPNS) covering its entire surface area with a geologically unique sandbank system. Gravel beds and *Lanice conchilega* biogenic aggregations, that can be found within sandbank systems, are classified as habitat type 1170 “Reefs”, which is the second habitat type to protect. For both habitat types, specific conservation objectives, which were aligned with the environmental targets as set under the MSFD, were adopted in 2017 and revised in 2021. Hence, the Belgian implementation of both directives is done by translating the requirements into one integrated approach.



The evaluation of the environmental targets and the conservation objectives under the MSFD and HD has revealed that the GES (as evaluated by MSFD) or the favourable conservation status (as evaluated by HD) is not reached for the benthic habitats. To accomplish GES and favourable conservation status, sufficient areas of both habitats (habitat 1110 and habitat 1170) need to be protected. In this report, we focus on the restrictions for bottom disturbing fishery (see 5.3) that need to be taken as they pose one of the main threats to restoring and preserving bottom integrity which is essential in order to reach GES and the conservation objectives under the HD. Other restrictions for bottom disturbing activities (e.g aggregate extraction, construction works, cable laying) need to be considered, but they need to be applied within the federal Marine Spatial Planning (MSP) procedure, and are therefore not further discussed in this report.

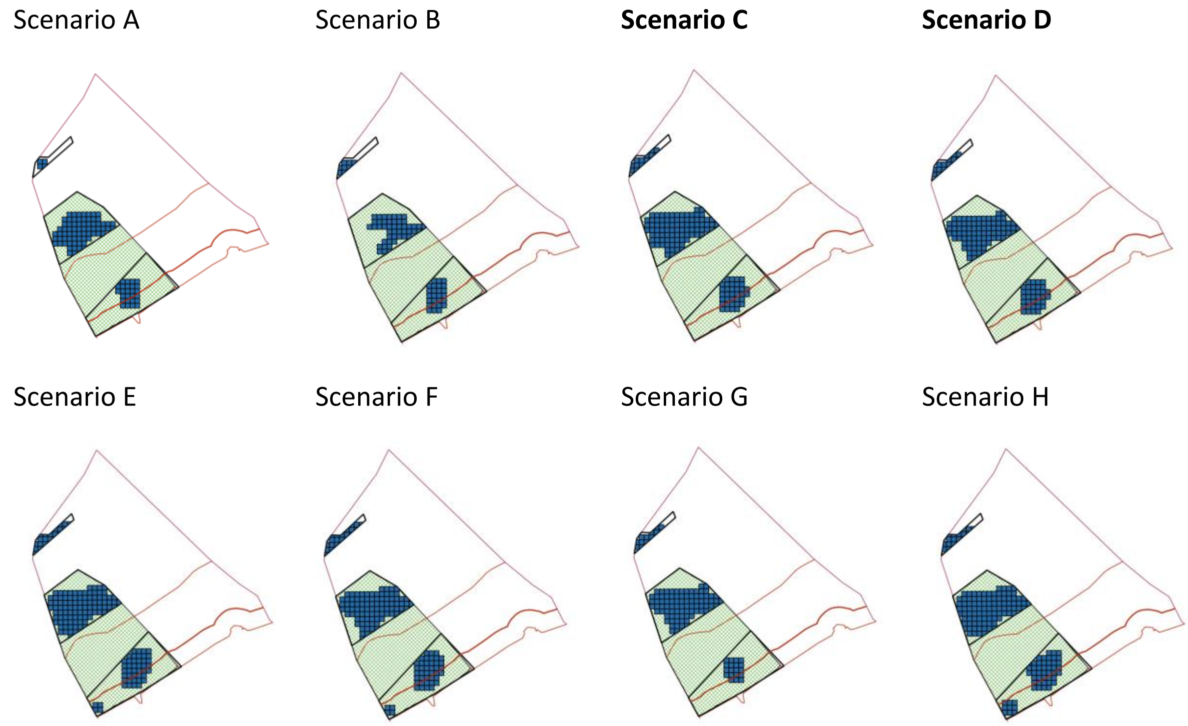
Based on scientific knowledge on the habitat type three Search Zones were established in the MSP 2020-2026 in which taking measures to restrict bottom disturbing activities (e.g. fishery) are expected to be necessary and effective. The MSP 2020-2026 (art 6.) provides a legal basis for spatial restriction to fisheries within these search zones. Subsequent measures need to comply with the European procedures (Regulation (EU) No. 1380/2013 of the European Parliament and of the Council of 11 December 2013 on the Common Fisheries Policy).

This report describes and covers most of the input required for the background document that is needed for taking conservation measures under the Common Fishery Policy and contains:

- An overview of the conservation objectives and environmental targets of relevance
- Scenarios to select key areas for restrictions of bottom disturbing activities

- An up-to-date distribution map of the benthic habitats and their biological value
- A sensitivity evaluation of the benthic habitats
- A review on the sea-bottom impact of the different fishing métiers
- Conservation measures (e.g. fishery, other bottom disturbing activities) to take
- Detailed socio-economic analyses of the fishery activities within the BPNS

Selection of key areas for restrictions of sea bottom disturbing activities



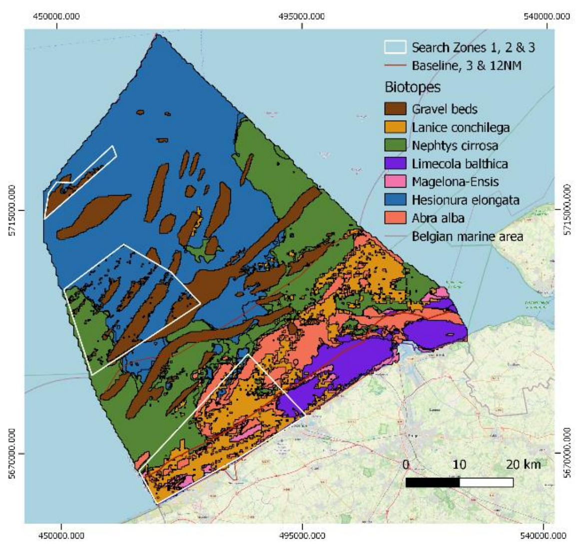
Several scenarios (A to H) for the delineation of zones that would benefit most from a ban of bottom disturbing fisheries were developed using Marxan, a software-based decision support tool. Marxan is one of the most widely used spatial planning tools, and is especially suited to suggest zones where the predefined environmental targets can be achieved at the lowest cost. In this case, the aim is to delineate a sufficiently large area to allow preservation and restoration of the seabed while also taking into account the potential impact for the commercial fishery sector. To translate the conservation objectives into concrete targets, the different habitat features that are recognized within the habitat types 1110 and 1170 (i.e. 5 macrobenthic communities[1], gravel beds and *Lanice* aggregations) were ranked based on the sum of their sensitivity for abrasion and their biological value score (scoring explained in next sections). This one score allowed us to determine the proportion to protect of each habitat feature (more valuable and sensitive habitat features get more protected area). To explore how much we want and can protect of each habitat feature, different ambition levels (15, 20, 25% protected) for gravel beds (highest biological value, most sensitive) were tested. The biological value-sensitivity ranking was then used to determine the relative proportion of each of the other habitat features to protect. This determined the outcome of scenarios A, C and E. A test was also carried out for each ambition level to see what happens if less important habitat features (lowest ranking) were excluded from the initial targets (scenarios B, D and E). Finally, a scenario (G) was tested in which only

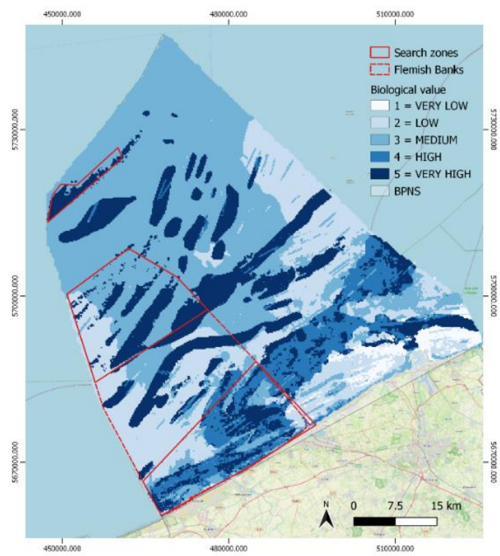
[1] The 5 macrobenhic communities are: *Abra alba, Nephtys cirrosa, Magelona-Ensis, Hesionura elongate and Macoma balthica*

the sensitivity to bottom fisheries was taken into account. In scenario H, only the biological value was considered. These last two scenarios were mainly included as a comparison. The evaluation of the various scenarios shows that scenario C and D score the best. Primarily with regard to conservation objectives, but also in terms of enforceability (minimal fragmentation) and favorable spatial overlap with other sectors. Within these scenarios, the ambition level of 20% protection was pursued for gravel beds, 14% for *Abra* and *Lanice*, 8% for *Hesionura* and *Magelona-Ensis* (only scenario C) and 6% for *Nephtys* (only scenario C). Those targets were almost reached (gravel beds: 18.43%); exactly reached (*Abra, Lanice, Nephtys*) or exceeded (*Hesionura* [11.54%], *Magelona-Ensis* [14.35%]). Scenario A got third place, but in this scenario the environmental objectives were fulfilled to a lesser degree.

An up-to-date distribution map of the benthic habitats and their biological value

The biological value and the distribution maps of seafloor habitats were updated to build a solid scientific basis to guide the delineation of fishery restriction areas. A compilation of over 3000 macrobenthos community samples from 1994 and 2018 was used to map the distribution of the five identified macrobenthos communities in the BPNS by habitat suitability modelling using R-INLA-SPDE (a Bayesian geospatial modelling approach specific for geographically referenced data, advantageous in ecology as it accounts for spatial effects). The macrobenthos samples and 1400 epibenthos and demersal fish samples from the same period, together with the updated distribution map of gravel beds and the distribution map of *Lanice conchilega* aggregations were used to produce an updated biological valuation of the BPNS as described in Derous *et al.* (2007b). The data were used to answer a series of assessment questions based on values of biodiversity, rarity, aggregation, and key-species occurrence. The results of the biological valuation indicated that all gravel beds have a very high biological value (5 on a scale of 1 to 5). Very High biological values (value 5) were also assigned to the rich and dense *Abra alba* community and to the *Lanice conchilega* reefs.





In total, 31% of the BPNS was classified as value 4 or 5, with much of this surface lying within the three defined search zones. In search zones 1 and 2, very high value gravel beds are found within sediments hosting the *Hesionura elongata* community, which was classified as medium value (value 3) because of its biodiversity. In search zone 3, a large seabed surface of very high and high biological value is found because the zone hosts both the *Abra alba* community and *L. conchilega* reefs, interspaced by the *Magelona-Ensis* community (value 3). Low and very low biological values (values 2 and 1) were assigned to the *Nephtys cirrosa* and *Limecola balthica* communities due to lower densities and biodiversity.

A sensitivity evaluation of the benthic habitats

The sensitivity classification of the habitat features of the BPNS was based on information available on MarLIN (marlin.ac.uk), a site that hosts the largest review yet of the effects of human activities and natural events on marine species and habitats. MarLin defines sensitivity as a product of (1) the likelihood of damage (intolerance or resistance) due to a pressure and (2) the rate of (or time taken for) recovery (recoverability or resilience) once the pressure has been reduced or been removed. It is a 'relative' concept as it depends on the degree of the effect on the feature. For this report, we determined a sensitivity score (1: low sensitivity; 2: low to medium sensitivity; 3: medium sensitivity; 4: medium to high sensitivity and 5: high sensitivity) of each benthic habitat feature based on the impact of abrasion/removal of substratum.

The sandy habitats (*Nephtys cirrosa, Hesionura elongata*) received score 1 (low sensitivity), due to their high resilience. The *Magelona-Ensis leei* habitat is also not very sensitive to abrasion (score 1). The *Abra alba* and *Limecola balthica* habitats received a sensitivity score of 2 (low to medium sensitivity). The *Lanice conchilega* habitat received score 2 due to the fact that the sensitivity of *L. conchilega* itself is low, as the majority of individual worms can survive a single trawl passage, and they can quickly recover (1-2 days) their 3D structures. However, the associated community and species are more sensitive to disturbance. Based on the MarLin classification, gravel biotopes have a medium sensitivity. In the past, however, boulders and gravel have been removed by fishing activity, creating loss of the habitat (physical change of the seabed/sediment). In combination with the low or non-resistance of many species within this habitat, this has led to a score 5 (highly sensitive) for gravel beds in the BPNS.

A review on the sea-bottom impact of the different fishing metiers

A literature study and the results of two ongoing Belgian research projects (Visserij Verduurzaamt and Benthis Nationaal) gave an overview of the impact of different fishing gears on the seabed.

In the project 'Visserij Verduurzaamt', the 'Valduvis' tool is used to assess the sustainability of the Belgian fleet based on 11 indicators. One of the ecological indicators assesses seabed disturbance by combining the fished area with an abrasion factor between 0 and 1. This factor takes into account the percentage of the fishing gear that has a penetration depth of more than 2 cm.

- For the demersal beam trawl and the mechanical dredge, the full width of the fishing gear goes deeper than 2 cm, so the abrasion factor is 1. Many adjustments were made to the demersal beam trawl in the past such as roller shoes, ecoroll, sum wing, aquaplaning gear or the pulse trawl. All these adjustments resulted in fuel savings and are a step towards a higher sustainability, but have no demonstrable effect on the reduction of seabed disturbance. Only with the pulse trawl, a significant decrease in seabed disturbance was observed. However, this technique has recently been banned by the European Commission.
- The shrimp trawl is a lighter beam trawl using a footrope with small rolling bobbin wheels, which means that the abrasion factor is much lower than that of the demersal beam trawl.
- For the otter trawl fishery, only the otter boards penetrate deeper than 2 cm so the abrasion factor is also lower than that of the demersal beam trawl. On the other hand, the fished area is usually much larger for otter trawls compared to demersal beam trawls.

- The degree of bottom disturbance in seine fishery is not yet known, and needs further investigation. No boards are used but the thickness of the seine rope does affect the seafloor. This fishing technique also has a large fished area.
- Passive fishing has the lowest bottom disturbance. Only the anchors penetrate the seabed; the net slightly sweeps over the seabed.

Within the project 'Benthis Nationaal', seafloor impact was not only evaluated based on fishing pressure, but the sensitivity of the seabed was also taken into account. According to the project outcome, a more sustainable fishing practice in relation to reducing seafloor disturbance can grow when

- Fisheries mainly concentrate in areas where there is a lot of fishing activity or in areas where there is a quick recovery (less sensitive areas).
- Areas with high biological value and sensitive areas are avoided in order to allow recovery.
- Effort is made to reduce the impact by the choice of the fishing gear and the fished area.

Conservation measures to take

To accomplish GES and favourable conservation status for benthic habitats a complete closure for bottom disturbing activities (fishery with mobile contacting gears, constructions, cable digging, aggregate extraction, anchoring, …) in the proposed areas is needed. For most activities, this needs to be regulated through the MSP, whereas for fishery this needs to be complied with the CFP. With regards to fishing, there is currently no mobile fishing technique targeting demersal fish that does not impact the seafloor integrity (see previous section). They all cause a certain disturbance of the top-layer of sediment and are removing benthic fauna (attached, non-attached species, infauna) on top and in the sediments. Therefore, those mobile fishing gear groups should be banned from biological valuable and sensitive areas. Passive fishing techniques can be seen as least disturbing for the sediment surface, as only a minor part of the fishing equipment impact the bottom and the extent of disturbance is also the lowest of all bottom disturbing fishing techniques. Too which degree (fishing intensity), extent and types (nets, traps, …) this passive fishing techniques can be allowed in the proposed closed areas need to be considered based on the specific circumstances of an area. For example, it is possible that it is not opportune to execute passive fishing in areas where reef restoration actions are undertaken, as any impact should be avoided. For managing the passive fisheries, a kind of license system can be developed, wherein the operational context is defined. A part of this, can be for example the cooperation that could be sought in which fisherman also provide an important contribution to the monitoring of the area (data collection).

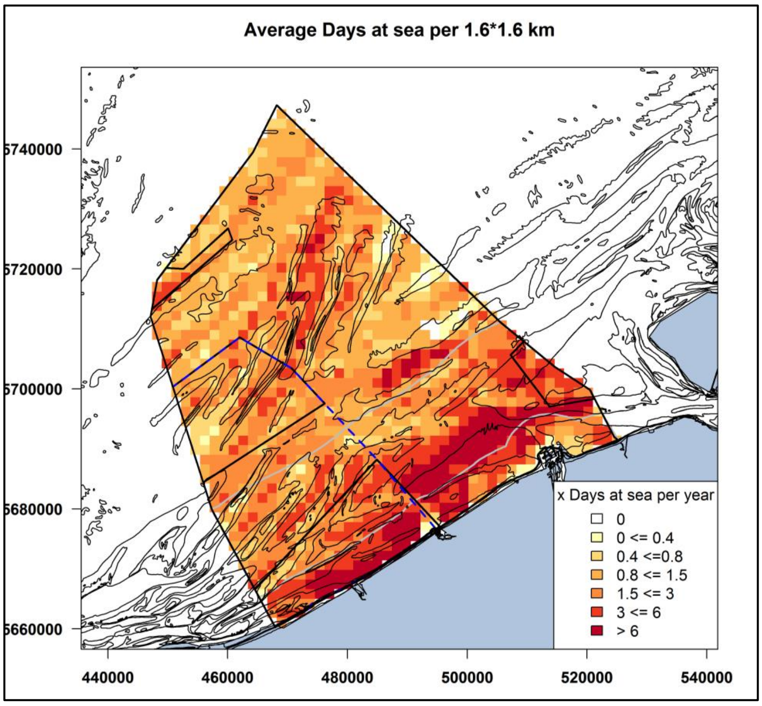
Detailed socio-economic analyses of the fishery activities within the BPNS

Fishing activities within the Belgian part of the North Sea were investigated focusing on the Natura 2000 areas ('Vlaamse Banken' and 'Vlakte van de Raan') and the three search zones. For this study, both effort (days at sea), landing value and landing weight from 2013-2019 were used for all the European member states active in the region.

- In the Natura2000 area 'Vlakte van de Raan', only Dutch and Belgian fishing activity was recorded, mainly by pulse trawlers and shrimp trawlers.
- In the 'Vlaamse Banken' the effort was highest for the Belgian fleet, followed by the Dutch fleet. France, Germany, Great Britain and Denmark represented on average less than 5% of the total effort in the area. In terms of landed value, the Dutch fleet was the most important in the area.

The majority of the fishing activity between 2013 and 2019 was carried out by pulse trawls and demersal beam trawls.

- Search zone 1 is an important area for several countries and multiple gear types. Based on the relative importance per km², Search zone 1 is the most important area for otter trawlers and seiners. For seiners especially the western part of the area is a hotspot.
- Search zone 2 is an important fishing ground, but without clear differences between countries or between gear types except for the French otter trawlers. These group is slightly more active here compared to the rest of the BPNS.
- Search zone 3 shows a complex pattern of spatially distributed gear types with different member state interests. Based on the relative importance per km², this area is the most important for beam trawlers, shrimp trawlers and passive gear fishery. Based on overall effort (DAS), this zone is intensively fished. However, landings (both in value and weight) for all gears combined were relatively low.



Conclusion

1/ We have compiled the necessary information in order to assess which measures need to be taken in order to protect bottom integrity allowing us to reach the environmental targets of MSFD and the conservation objectives of the HD.

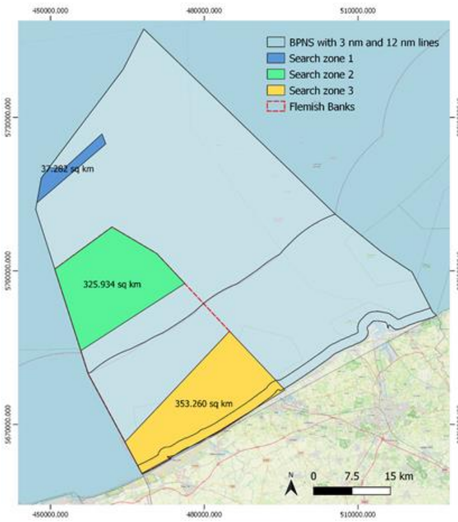
2/ The followed procedure is unique within Europe and combines different concepts (biological value, sensitivity, space usage (e.g. fishery economics)) to come to an integrated and scientific based allocation of the protected areas. These concepts were taken into account in different scenarios developed in the Marxan decision support tool. The scenario based approach was flexible and allows us to prioritize and nuance with regards to the target settings for each habitat feature.

3/ Based on all gathered information and the evaluation of the different Marxan scenarios exclusion of fishing with mobile bottom contacting gears for the areas as indicated in the scenarios C & D should allow to reach the environmental targets of MSFD and the conservation objectives of the HD.

4/ The information gathered within this report will provide a sound scientific basis for policy makers allowing them to make informed decisions when delineating the final boundaries of the zones restricting fishing with mobile bottom contacting gears in consultation with the involved stakeholders.

Uitgebreide samenvatting

In de Europese Unie gelden twee belangrijke juridische instrumenten voor de bescherming van mariene leefgebieden of habitats: de Europese Habitatrichtlijn (HD) en de Europese Kaderrichtlijn Mariene Strategie (MSFD). Onder de MSFD wordt gestreefd naar de bescherming van het mariene milieu en het bereiken van een goede milieutoestand (GES). De implementatie van de MSFD richt zich op 11 descriptoren, waaronder ‘biodiversiteit en zeebodemintegriteit’. De Europese Habitatrichtlijn verplicht de lidstaten om te streven naar de instandhouding en de bescherming van belangrijke of bedreigde soorten en habitattypes, via een netwerk van beschermde mariene gebieden - het Natura2000 netwerk. In België werd het zuidwestelijke gebied ‘Vlaamse Banken’ aangeduid als marien beschermd gebied, met twee habitattypes die beschermd dienen te worden. Het eerste habitattype 1110 “Zandbanken die voortdurend oppervlakkig met zeewater bedekt zijn” vertegenwoordigt het belangrijkste habitattype van het Belgisch deel van de Noordzee (BNZ) en omvat het volledige oppervlak met een geologisch uniek zandbanksysteem. Grindbedden en biogene aggregaties van de schelpkokerworm *Lanice conchilega*, die te vinden zijn binnen deze zandbanksystemen, worden geclassificeerd als habitattype 1170 “Riffen”. Dit is het tweede habitattype dat moet worden beschermd. Voor beide habitattypes werden in 2017 specifieke instandhoudingsdoelstellingen vastgelegd, die in lijn waren met de milieudoelstellingen zoals vastgelegd in de MSFD en die herzien werden in 2021. De Belgische implementatie van beide richtlijnen, HD en MSFD, gebeurt dus volgens een geïntegreerde aanpak.



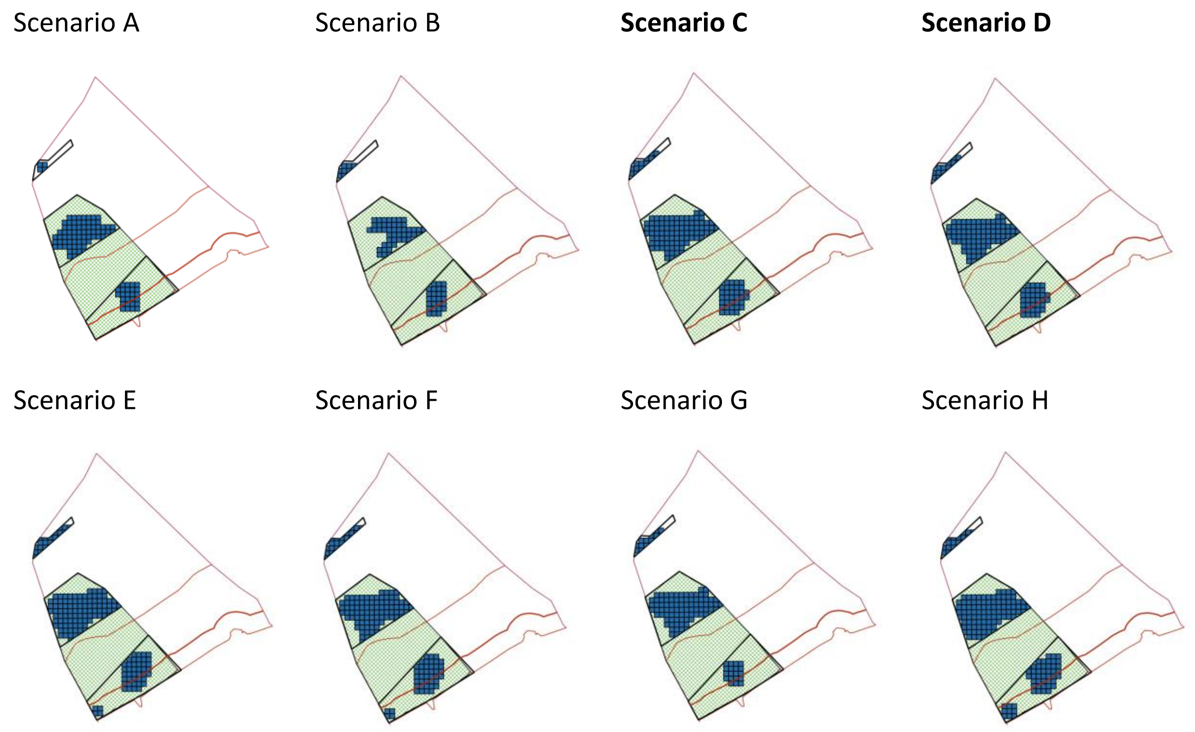
Uit de evaluatie van de milieudoelen en de instandhoudingsdoelstellingen onder de MSFD en de HD is gebleken dat de GES (zoals beoordeeld door de MSFD) of de gunstige staat van instandhouding (zoals beoordeeld door HD) voor de bodemgebonden habitattypes niet wordt bereikt. Om een GES en een gunstige staat van instandhouding te bereiken, moeten voldoende gebieden van beide habitattypes (H1110 en H1170) worden beschermd. In dit rapport richten we ons op de beperkingen voor bodemberoerende visserij (zie 5.3) die moeten worden opgelegd, aangezien ze een van de grootse bedreigingen vormen voor het herstel en het behoud van de integriteit van de bodem. Dit herstel en behoud van de bodemintegriteit is essentieel om de GES en de instandhoudingsdoelstellingen onder de HD te bereiken. Ook andere beperkingen voor bodemverstorende activiteiten zoals zandontginning, constructiewerken en het aanleggen van kabels moeten worden overwogen, maar deze vallen binnen de federale procedure voor Mariene Ruimtelijke Planning (MRP) en worden daarom niet verder besproken in dit rapport.

Op basis van wetenschappelijke kennis over elk habitattype zijn in het MRP 2020-2026 drie zoekzones ingesteld waarin maatregelen ter beperking van bodemverstorende activiteiten (bijvoorbeeld visserij) noodzakelijk en effectief kunnen zijn. Het MRP 2020-2026 (art.6) geeft een wettelijke basis voor ruimtelijke beperking voor visserij binnen deze zoekzones. Daaropvolgende maatregelen moeten voldoen aan de Europese procedures (Verordening (EU) nr. 1380/2013 van het Europees Parlement van 11 december 2013 betreffende het gemeenschappelijk visserijbeleid).

Dit rapport beschrijft en omvat de meeste gevraagde input voor het achtergronddocument dat nodig is om instandhoudingsdoelstellingen te stellen in het kader van het gemeenschappelijk visserijbeleid (GVB) en bevat:

- Een overzicht van de instandhoudingsdoelstellingen en milieudoelstellingen die van belang zijn
- Scenario’s om belangrijke gebieden te selecteren voor het beperken van bodemverstorende activiteiten
- Een actuele verspreidingskaart van de leefgebieden op de zeebodem en hun biologische waarde
- Een overzicht van de impact op de zeebodem van de verschillende visserijmethodes
- De te nemen instandhoudingsmaatregelen (bijvoorbeeld visserij, andere bodemverstorende activiteiten)
- Gedetailleerde socio-economische analyses van de visserijactiviteiten binnen het BNZ.

Selectie van kerngebieden voor het beperken van bodemverstorende activiteiten



Met behulp van de software Marxan werden verschillende scenario’s (A-H) ontwikkeld voor de afbakening van zones die het meeste baat zouden hebben bij een verbod op bodemverstorende activiteiten. Marxan is wereldwijd een van de meest gebruikte ruimtelijke planningstools en is vooral geschikt om zones voor te stellen waar de vooraf gedefinieerde doelstellingen worden bereikt tegen de laagst mogelijke kost. In dit geval is het de bedoeling om een voldoende groot gebied af te bakenen om het behoud en herstel van de zeebodem mogelijk te maken en tegelijkertijd rekening te houden met de mogelijke impact voor de commerciële visserijsector. Om de instandhoudingsdoelstellingen te vertalen naar concrete doelen, zijn de verschillende habitatgemeenschappen die worden herkend binnen de habitattypes 1110 en 1170 (namelijk 5 macrobenthos gemeenschappen[2], grindbedden en *Lanice conchilega* aggregaties) gerangschikt. Deze rangschikking gebeurt op basis van de som van hun gevoeligheid voor bodemverstoring en hun biologische waarde (dit wordt verder uitgelegd in de volgende paragrafen). Met deze ene score konden we het te beschermen aandeel van elke habitatgemeenschap bepalen (meer waardevolle en gevoelige habitatgemeenschappen krijgen een

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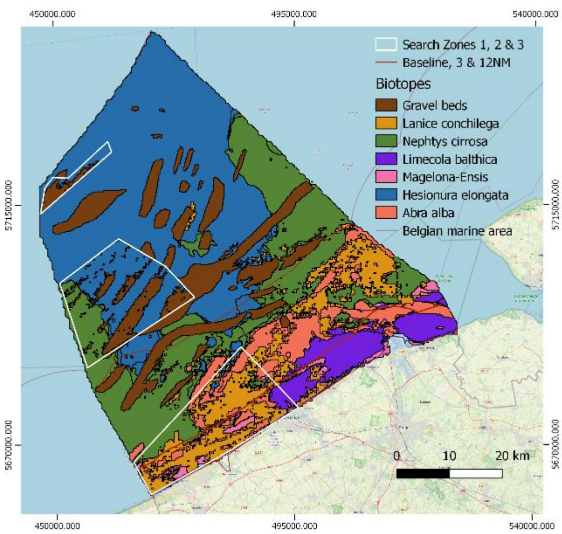
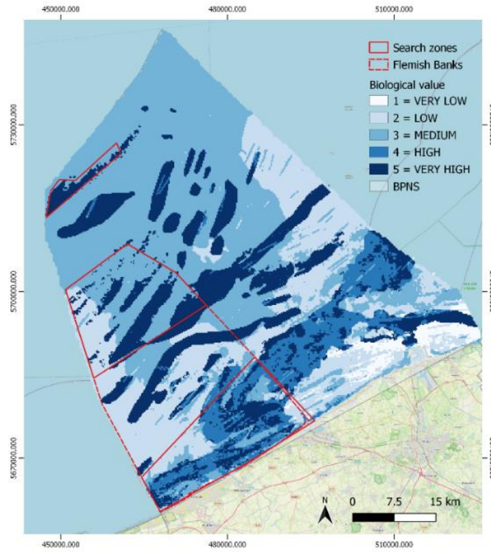
[2] De 5 macrobenthosgemeenschappen zijn: *Abra alba, Nephtys cirrosa, Magelona-Ensis, Hesionura elongate and Macoma balthica*

groter beschermd gebied). Om te onderzoeken hoeveel we van elke habitatgemeenschap willen en kunnen beschermen, werden verschillende ambitieniveaus (15, 20, 25% beschermd) getest. Deze ambitieniveaus werden bepaald voor de grindbedden aangezien deze de hoogste biologische waarde hebben en het meest gevoelig zijn. De biologische waarde/gevoeligheid score werd vervolgens gebruikt om het relatieve aandeel van elk van de andere te beschermen habitatgemeenschappen te bepalen. Dit bepaalde de uitkomst van scenario's A, C en E. Daarnaast is er per ambitieniveau getoetst wat er gebeurt als de minder belangrijke habitatgemeenschappen (met de laagste scores) worden uitgesloten van de initiële doelen (scenario's B, D en E). Tot slot is een scenario (G) getest waarin alleen rekening gehouden wordt met de gevoeligheid voor bodemberoerende visserij. In scenario H is alleen gekeken naar de biologische waarde. Deze laatste twee scenario's zijn voornamelijk ter vergelijking meegenomen. Uit de evaluatie van de verschillende scenario's blijkt dat scenario C en D het beste scoren. Die goede scores hebben voornamelijk betrekking op het behalen van de instandhoudingsdoelstellingen, maar ook op vlak van handhaafbaarheid (minimale versnippering) en gunstig ruimtelijk overlap met de andere sectoren. Binnen deze scenario's is het ambitieniveau van 20% bescherming nagestreefd voor de grindbedden, 14% voor de *Abra alba*-gemeenschap en *Lanice conchilega*, 8% voor de *Hesionura elongata* en *Magelona-Ensis* gemeenschap (alleen scenario C) en 6% voor de *Nephtys cirrosa* gemeenschap (alleen scenario C). Deze doelstellingen werden bijna bereikt (grindbedden 18, 43%), exact bereikt (voor *Abra alba, Lanice conchilega en Nepthys cirrosa*) of overschreden (*Hesionura elongata*: 11, 54% en *Magelona-Ensis*: 14,35%). Scenario A behaalde de derde plaats, maar in dit scenario werd in mindere mate voldaan aan de instandhoudingsdoelstellingen.

Een actuele verspreidingskaart van de leefgebieden op de zeebodem - benthische habitats - en hun biologische waarde

De biologische waarde- en verspreidingskaarten van leefgebieden op de zeebodem die oorspronkelijk opgemaakt werden in 2007 werden bijgewerkt om een solide wetenschappelijke basis te hebben voor de afbakening van gebieden met visserijbeperkingen. Een compilatie van meer dan 3000 bodemmonsters uit 1994 en 2018 werd gebruikt om de verspreiding van de vijf geïdentificeerde macrobenthosgemeenschappen in het BNZ in kaart te brengen. Dat gebeurde door middel van modellering van habitatgeschiktheid met behulp van R-INLA-SPDE. De gegevens van de bodemmonsters werden samengenomen met de gegevens uit dezelfde periode van 1400 monsters van ongewervelden en vissen die op of net boven de bodem leven (epibenthos en demersale vis). Daarbovenop kwamen nog de bijgewerkte verspreidingskaart voor grindbedden en *Lanice conchilega* werden gebruikt, hetgeen resulteerde in een bijgewerkte biologische waarderingskaart voor de BNZ te maken zoals beschreven in Derous *et al*. (2007b). De data werden gebruikt om een reeks beoordelingsvragen te beantwoorden op basis van biodiversiteit, zeldzaamheid, aggregatie en het voorkomen van sleutelsoorten. De resultaten van de biologische waardering gaven aan dat alle grindbedden een zeer hoge biologische waarde hebben (score 5 op een schaal van 1 tot 5). Zeer hoge biologische waarden (score 5) werden ook toegekend aan de rijke en dichtbevolkte *Abra alba*-gemeenschap en aan de *Lanice conchilega* riffen.





In totaal werd 31% van het BNZ geclassificeerd als waarde 4 of 5, waarbij een groot deel van dit oppervlak binnen de 3 gedefinieerde zoekzones ligt. In zoekzones 1 en 2 worden grindbedden van zeer hoge waarde gevonden in sedimenten die de *Hesionura elongata* gemeenschap huisvesten. Deze laatste gemeenschap heeft een middelmatige biologische waarde (score 3) vanwege zijn biodiversiteit. In zoekzone 3 wordt een groot gebied van zeer hoge biologische waarde en van hoge biologische waarde gevonden omdat het zowel de *Abra alba*-gemeenschap bevat als de biogene riffen gevormd door de schelpkokerworm *L. conchilega.* Daarnaast bevat het ook gebieden van *Magelona-Ensis* (score 3). Lage en zeer lage biologische waarde (score 2 en 1) werden toegewezen aan de gemeenschappen *Nephtys cirrosa* en *Limecola balthica* vanwege lagere dichtheden en biodiversiteit.

Een gevoeligheidsevaluatie van de benthische gemeenschappen

De gevoeligheidsclassificatie van de habitatgemeenschappen van het BNZ is gebaseerd op informatie die beschikbaar is op MarLIN (marlin.ac.uk), een site die het grootste overzicht tot nu toe bevat van de effecten van menselijke activiteiten en natuurlijke gebeurtenissen op mariene soorten en habitats. MarLin definieert gevoeligheid als een product van 1) de kans op schade (intolerantie of weerstand) als gevolg van een druk en 2) de snelheid van (of de tijd die nodig is voor) herstel (herstelbaarheid of veerkracht) zodra de druk is verminderd of is verdwenen. Het is een ‘relatief’ concept omdat het afhangt van de mate van effect op het kenmerk. Voor dit rapport hebben we een gevoeligheidsscore bepaald (1= lage gevoeligheid; 2= lage tot matige gevoeligheid; 3= gemiddelde gevoeligheid: 4 = gemiddelde tot hoge gevoeligheid en 5 = hoge gevoeligheid) van elke benthische habitatgemeenschap op basis van de impact van bodemschade en verwijdering van het zeebodemoppervlak.

De zandige gemeenschappen (*Nephtys cirrosa, Hesionura elongata*) kregen vanwege hun hoge veerkracht een score 1 (lage gevoeligheid). Ook de *Magelona-Ensis* gemeenschap is niet erg gevoelig voor bodemschade (score 1). De gemeenschappen *Abra alba* en *Limecola balthica* kregen een gevoeligheidsscore van 2 (lage tot gemiddelde gevoeligheid). De *L. conchilega* aggregaties kregen score 2 vanwege het feit dat de gevoeligheid van *L. conchilega* zelf laag is. De meeste individuele wormen kunnen namelijk een eenmalige passage van een vissersvaartuig overleven, en de kokers worden snel hersteld (1-2 dagen). Op basis van de MarLin-classificatie hebben grindbiotopen een gemiddelde gevoeligheid. In het verleden zijn echter keien en grind verwijderd door visserij, waardoor het leefgebied verloren is gegaan (fysieke verandering van de zeebodem/sediment). In combinatie met de lage of niet-resistentie van veel soorten binnen die leefgebied heeft dit geleid tot een score 5 (zeer gevoelig) voor grindbedden in de BNZ.

Een overzicht van de impact op de zeebodem van de verschillende visserijtechnieken

Een literatuurstudie en de resultaten van twee lopende Belgische onderzoeksprojecten (Visserij Verduurzaamt en Benthis Nationaal) gaven een overzicht van de impact van verschillende vistuigen op de zeebodem. In het project 'Visserij Verduurzaamt' wordt de tool 'Valduvis' gebruikt om de duurzaamheid van de Belgische vloot te beoordelen op basis van 11 indicatoren. Een van de ecologische indicatoren beoordeelt bodemverstoring door het beviste gebied te combineren met een factor voor bodemschade (de zogenaamde 'Abrasionfactor' tussen 0 en 1. Deze factor houdt rekening met het percentage van het vistuig met een penetratiediepte van meer dan 2 cm.

- Voor de demersale boomkor en de mechanische dreg gaat de volle breedte van het vistuig dieper dan 2 cm en is deze abrasionfactor dus 1. Er zijn in het verleden veel aanpassingen gedaan aan de demersale boomkor zoals rolsloffen, ecorol, sumwing, aquaplaning gear of de pulskor. Al deze aanpassingen hebben geleid tot brandstofbesparing en zijn een stap in de richting naar meer duurzaamheid. Deze veranderingen hebben echter geen aantoonbaar effect op het verminderen van bodemberoering. Alleen bij de pulskor werd een significante daling in bodemberoering waargenomen. Deze techniek is evenwel onlangs door de Europese Commissie verboden.
- De garnaalkor is een lichtere boomkor waarbij gebruik gemaakt wordt van een klossenpees waardoor de abrasion factor veel lager is dan die van de demersale boomkor.
- Voor de bordenvisserij gaan alleen de borden dieper dan 2cm waardoor de abrasion factor ook lager is dan bij de demersale boomkor. Bij deze visserij is de beviste oppervlakte doorgaans wel groter dan bij de demersale boomkor.
- De mate van bodemberoering in de zegenvisserij is nog ongekend en vraagt verder onderzoek. Er worden bij deze techniek geen planken gebruikt maar de dikte van het zegentouw heeft wel een invloed op de bodemberoering. Deze vistechniek heeft vaak ook een groot bevist oppervlak.
- Passief vissen heeft de minste bodemberoering. Alleen de ankers dringen in de zeebodem; het net veegt door de stroming heel oppervlakkig over de zeebodem.

Binnen het project 'Benthis Nationaal' werd niet alleen de impact op de zeebodem geëvalueerd op basis van de visserijdruk, maar werd ook rekening gehouden met de gevoeligheid van de zeebodem. Volgens het projectresultaat kan een duurzamere visserijpraktijk met betrekking tot het verminderen van bodemverstoring groeien wanneer:

- de visserij zich vooral concentreert op gebieden waar veel gevist wordt of gebieden waar sprake is van snel herstel (minder kwetsbare gebieden).
- gebieden met een hoge biologische waarde en kwetsbare gebieden vermeden worden om herstel mogelijk te maken.
- door de keuze van het vistuig en het beviste gebied wordt geprobeerd om de impact te verminderen.

Te nemen instandhoudingsdoelstellingen

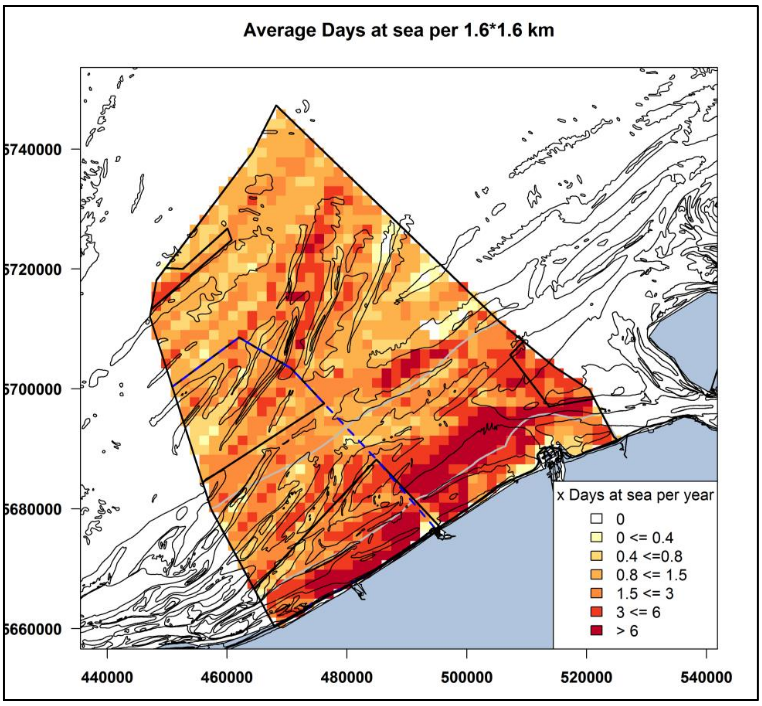
Om GES en een gunstige staat van instandhouding voor benthische gemeenschappen te bereiken, is volledige afsluiting voor bodemverstorende activiteiten (visserij met mobiele, bodemverstorende vistuigen, constructies, graven van kabels, zand en aggregaat extractie, verankering,…) in de voorgestelde gebieden nodig. Voor de meeste activiteiten moet dit worden geregeld via het Marien

Ruimtelijk Plan; voor de visserij moet dat via het Gemeenschappelijk Visserijbeleid (GVB). Met betrekking tot de visserij bestaat er momenteel geen mobiele visserijtechniek gericht op demersale vis die geen invloed heeft op de integriteit van de zeebodem (zie vorige paragraaf). Ze veroorzaken allemaal een zekere verstoring van de bovenste sedimentlaag en verwijderen bodemfauna (aangehechte, niet-aangesloten soorten, infauna) bovenop en in de sedimenten. Daarom moeten deze mobiele vistuigen geweerd worden uit biologisch waardevolle en kwetsbare gebieden. Passieve visserijtechnieken kunnen als minst bodemverstorend worden beschouwd, aangezien slechts een klein deel van de visuitrusting de bodem beïnvloedt en de mate van verstoring ook de laagste is van alle bodemverstorende visserijtechnieken. In welke mate (bevissingsintensiteit, omvang en soorten (netten, vallen,…) deze passieve visserijtechnieken kunnen worden toegestaan in de voorgestelde gesloten gebieden moet worden bekeken op basis van de specifieke omstandigheden binnen een gebied. Het is bijvoorbeeld niet aan te raden om passief te vissen in gebieden waar herstelacties voor een rif worden genomen; in dat geval moet elke impact worden vermeden. Voor het beheer van de passieve visserij kan een soort vergunningensysteem worden ontwikkeld, waarin de operationele context wordt gedefinieerd. Onderdeel hiervan kan bijvoorbeeld een samenwerking zijn waarbij vissers ook een belangrijke bijdrage leveren aan de monitoring van het gebied (dataverzameling).

Gedetailleerde socio-economische analyses van de visserijactiviteiten binnen het BNZ.

De visserijactiviteiten binnen het Belgisch deel van de Noordzee werden onderzocht met de nadruk op de Natura 2000-gebieden (Vlaamse Banken en Vlakte van de Raan) en de drie zoekzones. Voor dit onderzoek zijn zowel inspanning (dagen op zee), en besomming en aanvoer uit 2013-2019 gebruikt voor alle Europese lidstaten die actief zijn in de regio.

- In het Natura2000 gebied 'Vlakte van de Raan' werd alleen Nederlandse en Belgische visserij geregistreerd, voornamelijk met pulskor en garnaalboomkor.
- In het gebied 'Vlaamse Banken' was de inspanning het hoogst voor de Belgische vloot gevolgd door de Nederlandse vloot. Frankrijk, Duitsland, Groot-Brittannië en Denemarken vertegenwoordigen gemiddeld minder dan 5% van de totale inspanning in het gebied. Op basis van de besomming was de Nederlands vloot het belangrijkste in het gebied. Het merendeel van de visserijactiviteit tussen 2013 en 2019 werd uitgevoerd met pulskorren en demersale boomkorren.



- Zoekzone 1 is een belangrijk gebied voor verschillende landen en verschillende vistuigtypes. Op basis van het relatieve aandeel per km² is zoekzone 1 het belangrijkste gebied voor bordenvissers en zegenvissers. Voor de zegenvissers is vooral het westelijke deel van het gebied een hotspot.

- Zoekzone 2 is een belangrijke visgrond, maar heeft geen duidelijke verschillen tussen landen of tussen vistuigtypes. Franse bordenvissers komen hier iets meer voor dan in de rest van het BNZ.
- Zoekzone 3 vertoont een complex patroon van ruimtelijk verspreide vistuigtypes met verschillende belangen voor de verschillende lidstaten. Op basis van het relatieve belang per km² is dit gebied het belangrijkste voor boomkor-, garnalen- en passieve visserij. Op basis van de totale inspanning (dagen op zee) wordt er intensief gevist in deze zone. De aanvoer en de besomming voor alle visserijactiviteit samen was relatief laag.

Conclusie

1/ We hebben de nodige informatie verzameld om te beoordelen welke maatregelen moeten genomen worden om de integriteit van de bodem te beschermen, zodat we de milieudoelstellingen van de MSFD en de instandhoudingsdoelstellingen van de HD kunnen halen.

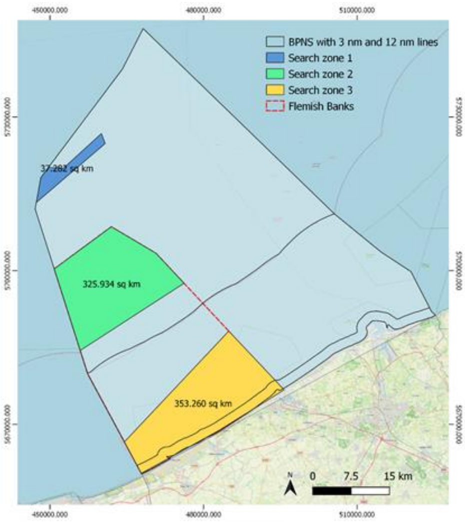
2/ De gevolgde procedure is uniek binnen Europa en combineert verschillende concepten (biologische waarde, gevoeligheid, ruimtegebruik (bijvoorbeeld visserij-economie)) om te komen tot een geïntegreerde en wetenschappelijk onderbouwde toewijzing van de beschermde gebieden. Met deze concepten is rekening gehouden in verschillende scenario's die ontwikkeld zijn met de beslissingsondersteunende tool Marxan. De op scenario's gebaseerde aanpak was flexibel en stelt ons in staat om prioriteiten te stellen en te nuanceren met betrekking tot de doelstellingen voor elke habitatgemeenschap.

3/ Op basis van alle verzamelde informatie en de evaluatie van de verschillende Marxan scenario's, uitsluiting van bodem beroerende visserij voor gebieden zoals aangegeven in scenario C en D moet toelaten om de milieudoelstellingen van de MSFD en de instandhoudingsdoelstellingen van de HD te bereiken.

4/ De informatie die in dit rapport verzameld wordt, zal beleidsmakers een degelijke wetenschappelijke basis bieden, zodat ze weloverwogen beslissingen kunnen nemen bij het afbakenen van de definitieve grenzen van de zones waar bodemberoerende visserij geweerd wordt, in overleg met de betrokken belanghebbenden.

Resumé

L’Union européenne a établi deux instruments juridiques clés pour assurer la protection des habitats marins : la directive habitats (DH) et la directive-cadre « stratégie pour le milieu marin » (DCSMM). L'objectif de la DCSMM est de protéger le milieu marin et d’y réaliser un bon état écologique (BEE). La mise en œuvre de la DCSMM s’articule autour de 11 descripteurs, parmi lesquels la « biodiversité » et l’« intégrité des fonds marins ». Quant à la directive habitats de l’UE, elle exige des États membres qu’ils visent à conserver et à protéger des espèces et des types d’habitat importants ou menacés, en faveur desquels un réseau de zones marines protégées, le réseau Natura 2000, a été constitué. En Belgique, la zone « Vlaamse Banken » a été définie comme zone marine protégée. Elle renferme deux types d’habitat à protéger. Le premier habitat – type 1110 « Bancs de sable à faible couverture permanente d'eau marine » – représente le principal type d’habitat de la partie belge de la mer du Nord (PBMN), dont la totalité de la superficie se caractérise par un système de bancs de sable géologiquement unique. Les lits de gravier et les agrégations biogènes de *Lanice conchilega*, que l’on trouve dans les systèmes de bancs de sable, sont classifiés comme type d’habitat 1170 « Récifs », le second type d’habitat à protéger. Pour les deux types d’habitat, des objectifs de conservation spécifiques, qui ont été alignés sur les objectifs environnementaux au titre de la DCSMM, ont été adoptés en 2017 et revus en 2021. En conséquence, la mise en œuvre par la Belgique de ces deux directives s’effectue en traduisant ces exigences par une approche intégrée.



L’évaluation des objectifs environnementaux et des objectifs de conservation au titre de la DCSMM et de la DH a révélé que le BEE (tel qu’évalué par la DCSMM) ou l’état de conservation favorable (tel qu’évalué par la DH) n’étaient pas atteints dans les habitats benthiques. Pour réaliser un BEE et un état de conservation favorable, des superficies suffisantes des deux habitats (habitats 1110 et 1170) doivent être protégées. Le présent rapport est centré sur les restrictions qui doivent être imposées à la pêche perturbant les fonds marins (voir point 5.3), qui constitue l’une des menaces majeures pour la restauration et la préservation de l’intégrité des fonds marins, deux actions cruciales pour atteindre le BEE et les objectifs de conservation au titre de la DH. D’autres restrictions visant les activités perturbant les fonds marins (par ex. extraction de granulat, travaux de construction ou pose de câbles) sont à envisager, mais comme elles relèvent du plan fédéral d’aménagement des espaces marins (PAEM), elles ne sont pas abordées dans ce rapport.

Sur la base des connaissances scientifiques en matière de types d’habitat, le PAEM 2020-2026 a délimité trois zones de recherche dans lesquelles des mesures de restriction des activités perturbant les fonds marins, dont la pêche, sont jugées nécessaires et devraient être appliquées. Le PAEM 2020-2026 (art. 6) apporte une base juridique pour les restrictions spatiales à imposer à la pêche dans ces zones de recherche. Les mesures qui en découleront devront être conformes aux procédures européennes (règlement (UE) n° 1380/2013 du Parlement européen et du Conseil du 11 décembre 2013 relatif à la politique commune de la pêche).

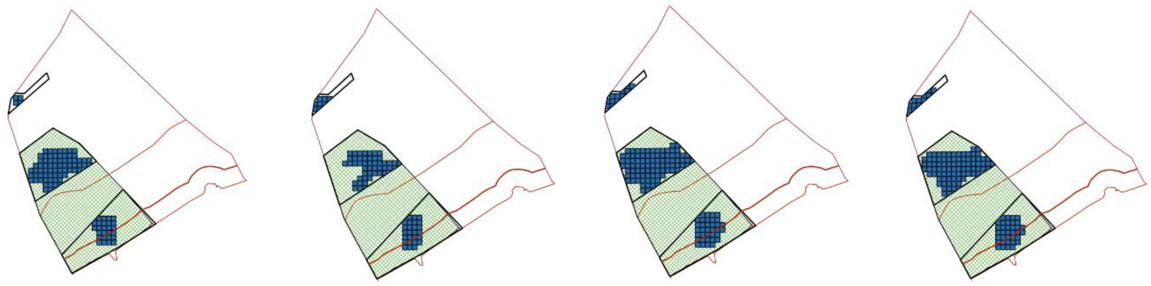
Le présent rapport aborde et décrit la majorité des éléments du document de référence qui devra être élaboré afin de prendre les mesures de conservation au titre de la politique commune de la pêche. Il contient :

- un aperçu des objectifs de conservation et des objectifs environnementaux concernés ;
- des scénarios permettant de sélectionner les zones clés où imposer des restrictions aux activités perturbant les fonds marins ;
- une carte de répartition actualisée des habitats benthiques et de leur valeur biologique ;
- une évaluation de la sensibilité des habitats benthiques ;
- un passage en revue de l'impact des différents métiers de la pêche sur les fonds marins ;
- les mesures de conservation (par ex. à l'égard de la pêche ou d'autres activités perturbant les fonds marins) à adopter ;
- des analyses socioéconomiques détaillées des activités de pêche dans la PBMN.

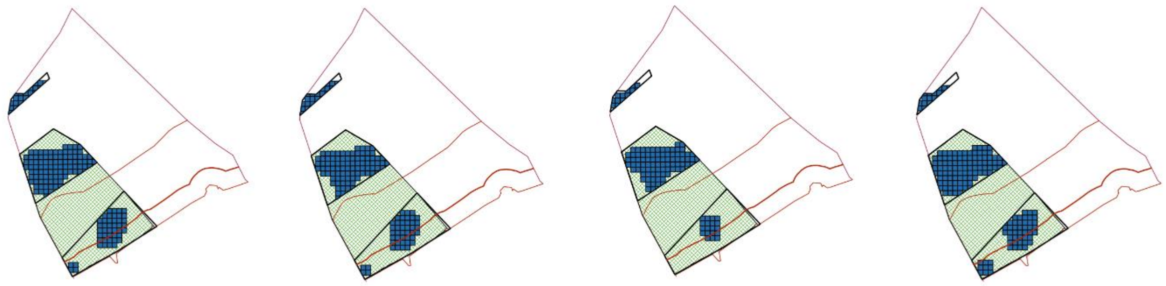
Sélection des zones clés pour les restrictions des activités perturbant les fonds marins

Plusieurs scénarios (du A au H) de délimitation des zones qui bénéficieraient d'une interdiction de la pêche perturbant les fonds marins ont été élaborés à l'aide de Marxan, un outil logiciel d'aide à la décision. Marxan est un des outils d'aménagement spatial les plus couramment utilisés. Il convient particulièrement pour suggérer des zones où les objectifs environnementaux prédéfinis peuvent être atteints au moindre coût. Dans le cas qui nous occupe, le but est de délimiter une zone suffisamment vaste pour permettre la préservation et la restauration des fonds marins, tout en tenant compte de l'impact potentiel des mesures sur le secteur de la pêche commerciale. Afin de traduire les objectifs de conservation en objectifs concrets, les diverses caractéristiques d'habitat qui sont reconnues au sein des types d'habitat 1110 et 1170 (à savoir cinq communautés macrobenthiques, les lits de gravier et les agrégations de *Lanice*) ont été classifiées sur la base d'une note obtenue en conjuguant la sensibilité à l'abrasion à la valeur biologique (système de notation expliqué dans les sections suivantes). Cette note nous a permis de déterminer la proportion de chaque caractéristique d'habitat à protéger (les caractéristiques d'habitat plus sensibles et de plus grande valeur reçoivent davantage de superficie protégée). Différents niveaux d'ambition (15, 20 et 25 % de superficie protégée) applicables aux lits de gravier (plus haute valeur biologique et plus grande sensibilité) ont été testés afin de voir quelle superficie de chaque habitat nous voulons et pouvons protéger. Ce classement basé sur la valeur biologique et la sensibilité a ensuite servi à déterminer la proportion relative de chacune des autres caractéristiques d'habitat à protéger. Cette opération a fait ressortir les résultats des scénarios A, C et E. Par ailleurs, pour chaque niveau d'ambition, un test a été réalisé afin de voir ce qui se passerait si des caractéristiques d'habitat moins importantes (classement plus bas) étaient exclues des objectifs initiaux (scénarios B, D et E). Enfin, un scénario (G) a subi un test dans lequel la sensibilité à la pêche de fond a seule été prise en compte. Dans ce scénario H, seule la valeur biologique a été considérée. Ces deux derniers scénarios ont surtout été établis à titre de comparaison. L'évaluation des différents scénarios indique que les scénarios C et D sont les mieux notés. Cela d'abord à l'égard des objectifs de conservation, mais aussi en termes de mise en œuvre (fragmentation minimale) et de chevauchement spatial favorable avec d'autres secteurs. Dans ces scénarios, un niveau d'ambition de 20 % de protection a été recherché pour les lits de gravier, de 14 % pour *Abra* et *Lanice*, de 8 % pour *Hesionura* et *Magelona-Ensis* (uniquement scénario C) et de 6 % pour *Nephtys* (uniquement scénario C). Ces objectifs ont été presque atteints (lits de gravier : 18,43 %) ; précisément atteints (Abra, Lanice, Nephtys) ou dépassés (Hesionura [11,54 %], Magelona-Ensis [14,35 %]). Le scénario A a obtenu la troisième place, mais en ne permettant d'atteindre les objectifs environnementaux que dans une moindre mesure.

Scénario A Scénario B **Scénario C** **Scénario D**

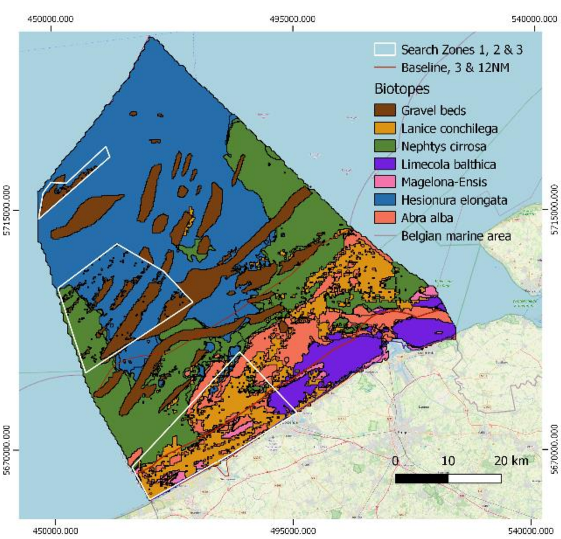


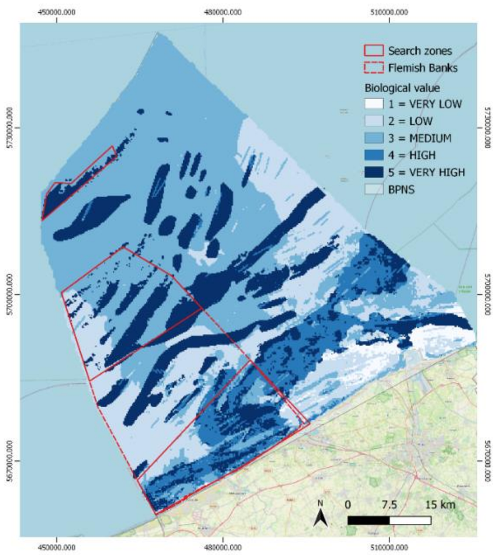
Scénario E Scénario F Scénario G Scénario H



Carte de répartition actualisée des habitats benthiques et de leur valeur biologique

La valeur biologique et les cartes de répartition des habitats des fonds marins ont été actualisées afin de constituer une base scientifique solide pour guider la délimitation des zones de restriction de la pêche. Une compilation de plus de 3 000 échantillons de la communauté de macrobenthos recueillis entre 1994 et 2018 a été utilisée pour cartographier la répartition des cinq communautés de macrobenthos identifiées dans la PBMN grâce à une modélisation de l'adéquation de l'habitat réalisée au moyen de l'approche R-INLA-SPDE. Ces échantillons de macrobenthos et 1 400 échantillons d'épibenthos et de poissons de fond prélevés dans la même période, ainsi que la carte de répartition actualisée des lits de gravier et celle des agrégations de *Lanice conchilega* ont permis d'élaborer une évaluation biologique actualisée de la PBMN, telle que décrite dans Derous *et al.* (2007b). Ces données ont servi à répondre à une série de questions évaluatives basées sur des valeurs en termes de biodiversité, de rareté, d'agrégation et de prévalence d'espèces clés. Selon les résultats de cette évaluation biologique, tous les lits de gravier présentent une valeur biologique très élevée (5 sur une échelle de 1 à 5). Des valeurs biologiques très élevées (de 5) ont également été attribuées à la riche et dense communauté d'*Abra alba* et aux récifs de *Lanice conchilega*.





Au total, 31 % de la PBMN ont été classifiés de valeur 4 ou 5, avec une grande partie de cette superficie comprise dans les trois zones de recherche définies. Dans les zones de recherche 1 et 2, des lits de gravier de valeur très élevée se trouvent parmi les sédiments qui hébergent la communauté de *Hesionura elongata*, qui a été classifiée de valeur moyenne (valeur 3) du fait de sa biodiversité. Dans la zone de recherche 3, une valeur biologique élevée à très élevée a été attribuée à une vaste superficie de fond marin parce qu'elle héberge à la fois une communauté d'*Abra alba* et des récifs de *L. conchilega*, espacés par une communauté de *Magelona-Ensis* (valeur 3). Des valeurs biologiques faibles à très faibles (valeurs 2 et 1) ont été attribuées aux communautés de *Nephtys cirrosa* et de *Limecola balthica* en raison de leur densité et de leur biodiversité plus basses.

Évaluation de la sensibilité des habitats benthiques

La classification de sensibilité des caractéristiques d'habitat de la PBMN a été déterminée sur la base d'informations disponibles sur MarLIN (marlin.ac.uk), un site Web qui héberge la plus grande étude à ce jour des effets des activités humaines et des événements naturels sur les espèces et les habitats marins. MarLIN définit la sensibilité comme une résultante (1) de la probabilité d'un dommage (intolérance ou résistance) dû à une pression et (2) du rythme de (ou du temps nécessaire à la) récupération (capacité de récupération ou résilience) après que la pression a été réduite ou supprimée. La sensibilité est un concept « relatif » car elle dépend du degré d'intensité de l'effet sur la caractéristique. Aux fins du présent rapport, nous avons déterminé une note de sensibilité (1 : sensibilité faible ; 2 : sensibilité faible à moyenne ; 3 : sensibilité moyenne ; 4 : sensibilité moyenne à élevée et 5 : sensibilité élevée) de chaque caractéristique d'habitant benthique en nous basant sur l'impact en termes d'abrasion/élimination du substrat.

Les habitats sablonneux (*Nephtys cirrosa, Hesionura elongata*) ont reçu une note de 1 (sensibilité faible) en raison de leur forte résilience. L'habitat de *Magelona-Ensis leei* n'est pas non plus très sensible à l'abrasion (note de 1). Les habitats d'*Abra alba* et de *Limecola balthica* ont eu une note de sensibilité de 2 (sensibilité faible à moyenne). L'habitat de *Lanice conchilega* a reçu une note de 2 car l'espèce *L. conchilega* elle-même présente une sensibilité faible. En effet, la majorité des vers individuels peuvent survivre à un passage unique de chalut et restaurer rapidement (en un ou deux jours) leur structure tridimensionnelle. Toutefois, la communauté et l'espèce qui y sont associées sont plus sensibles aux perturbations. Selon la classification MarLIN, les biotopes de gravier présentent une sensibilité moyenne. Pourtant, par le passé, des rochers et du gravier ont été retirés pour les besoins de la pêche, causant la disparition de l'habitat (modification physique du fond marin/sédiment). Conjugué à la résistance faible ou inexistante de nombreuses espèces de cet habitat, ce fait donne une note de 5 (sensibilité élevée) aux lits de gravier de la PBMN.

Passage en revue de l'impact des différents métiers de la pêche sur les fonds marins

Une recherche bibliographique et les résultats de deux projets de recherche belges en cours (« Vers une pêche durable » et « Benthis Nationaal ») nous ont permis d'élaborer un passage en revue de l'impact des différents engins de pêche sur les fonds marins.

Dans le projet « Vers une pêche durable », l'outil « Valduvis » est utilisé pour évaluer la durabilité de la flotte belge en fonction de 11 indicateurs. L'un de ces indicateurs écologiques évalue les perturbations du fond marin en combinant la zone de pêche avec un facteur d'abrasion compris entre 0 et 1. Ce facteur prend en compte le pourcentage des engins de pêche dont la profondeur de pénétration est supérieure à 2 cm.

- Pour le chalut de fond à perche et la drague mécanique, la largeur totale de l'engin de pêche pénètre au-delà de 2 cm, ce qui donne un facteur d'abrasion de 1. De nombreuses améliorations ont par le passé été apportées au chalut de fond à perche, notamment le guidage à galets, l'Ecoroll, le SumWing, l'engin aquaplane ou le chalut à impulsion. Toutes ces modifications se sont traduites par des économies de carburant et constituent des progrès vers une plus grande durabilité, mais n'ont pas entraîné de réduction démontrable des perturbations des fonds marins. Une diminution significative de ces perturbations a seulement été observée avec le chalut à impulsion. Cependant, cette technique a été récemment interdite par la Commission européenne.
- Le chalut à crevettes est un chalut à perche plus léger qui fait appel à une ralingue de fond dotée de petites roues à bobine, ce qui donne un facteur d'abrasion beaucoup plus bas que celui du chalut de fond à perche.
- Dans le cas de la pêche au chalut à panneaux, seuls les panneaux pénètrent à une profondeur de plus de 2 cm, produisant aussi un facteur d'abrasion plus bas que celui du chalut de fond à perche. En revanche, la zone de pêche est habituellement beaucoup plus étendue pour les chaluts à panneaux que pour les chaluts de fond à perche.
- Le degré de perturbation des fonds marins causée par la pêche à la senne n'est pas encore connu et nécessite des études plus poussées. Cette technique de pêche n'utilise pas de panneaux, mais l'épaisseur de la ralingue de la senne affecte le fond marin. De plus, la zone de pêche concernée est également plus étendue.
- La pêche passive est celle qui perturbe le moins le fond marin. Seules les ancres pénètrent dans le fond, que le filet balaie légèrement.

Dans le cadre du projet « Benthis Nationaal », l'impact sur les fonds marins a été évalué en termes de pression de la pêche mais la sensibilité du fond marin a aussi été prise en compte. Au vu des résultats de ce projet, des pratiques de pêche plus durables en matière de perturbations du fond marin peuvent être développées si :

- la pêche se concentre sur les zones où elle est pratiquée intensivement ou les zones à récupération rapide (zones moins sensibles) ;
- l'on évite les zones à valeur biologique élevée et les zones sensibles pour permettre leur restauration ;
- l'on accomplit des efforts pour réduire l'impact par le choix des engins et des zones de pêche.

Mesures de conservation à adopter

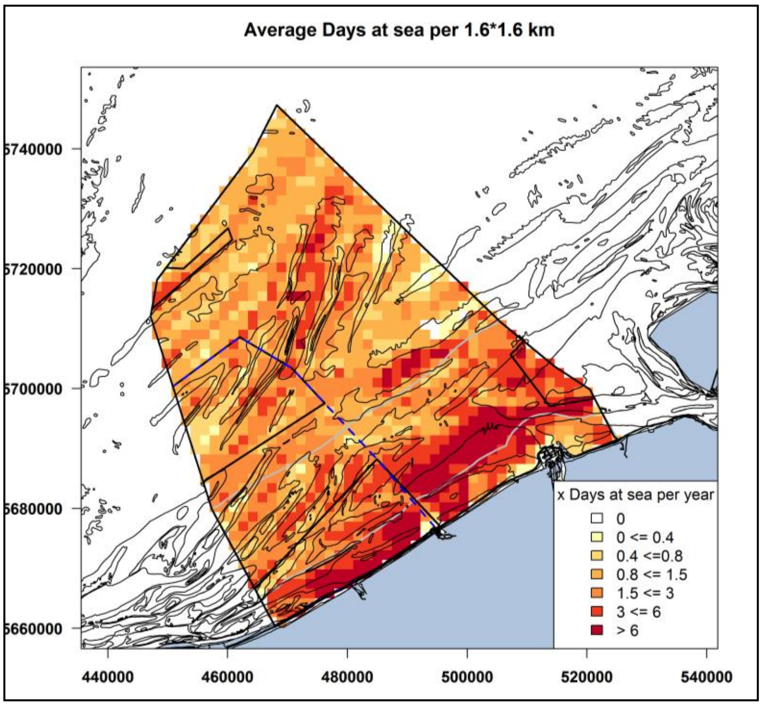
Pour réaliser un BEE et un état de conservation favorable dans les habitats benthiques, il est nécessaire de fermer totalement les zones proposées aux activités perturbant les fonds marins (pêche avec engins mobiles à contact, construction, enfouissement de câbles, extraction de granulat, ancrage, etc.). Pour la majorité des activités, cette fermeture doit être réglementée par le PAEM, tandis que dans le cas de la pêche, elle doit être conforme à la PCP. Il n'existe actuellement pas de technique de pêche mobile des poissons de fond qui n'affecte pas l'intégrité des fonds marins (voir la section précédente). Toutes les techniques causent certaines perturbations de la couche supérieure du sédiment et ont pour effet de retirer une partie de la faune benthique (espèces fixées ou non fixées, endofaune) du dessus et de l'intérieur du sédiment. C'est pourquoi l'utilisation de ces groupes d'engins de pêche mobiles devrait être interdite dans les zones sensibles et à valeur biologique. Les techniques de pêche passive peuvent être considérées comme moins perturbantes pour la surface du sédiment, car seule une petite partie des engins de pêche affectent le fond et l'ampleur des perturbations est également la plus limitée parmi toutes les techniques de pêche responsables de perturbations. Il conviendra d'étudier les conditions spécifiques de chaque zone afin de déterminer à quel degré (intensité de la pêche), avec quelle ampleur et avec quels types d'engins (filets, nasses, etc.) ces techniques de pêche passive peuvent être autorisées dans les zones dont la fermeture est proposée. Par exemple, il pourrait s'avérer inopportun de pratiquer une pêche passive dans les zones où des mesures de restauration des récifs sont en cours et où tout impact est à éviter. Une sorte de système de licence définissant le contexte opérationnel pourrait être mis en place pour gérer la pêche passive. Dans ce cadre, l'on pourrait par exemple rechercher la coopération des pêcheurs en leur demandant une contribution importante au suivi des zones (collecte de données).

Analyses socioéconomiques détaillées des activités de pêche dans la PBMN

Nous avons étudié les activités de pêche dans la partie belge de la mer du Nord en nous focalisant sur les sites Natura 2000 (« Vlaamse Banken » et « Vlakte van de Raan ») et les trois zones de recherche. Aux fins de la présente étude, les données sur la durée des activités de pêche (jours en mer), la valeur de débarquement et le poids à l'atterrissage entre 2013 et 2019 ont été utilisées pour tous les États membres de l'UE actifs dans la région.

- Sur le site Natura 2000 « Vlakte van de Raan », seules des activités de pêche néerlandaises et belges ont été enregistrées, essentiellement par des chalutiers à chalut à impulsion et des crevettiers.
- Dans les « Vlaamse Banken », les activités étaient les plus intenses de la part de la flotte belge, suivie de la flotte néerlandaise. La France, l'Allemagne, le Royaume-Uni et le Danemark représentaient en moyenne moins de 5 % du total des activités de pêche dans la zone. En termes de valeur débarquée, la flotte néerlandaise était la plus importante de la zone. Entre 2013 et 2019, la majeure partie des activités de pêche ont été réalisées au moyen de chaluts à impulsion et de chaluts à perche.
- La zone de recherche 1 est une zone importante pour plusieurs pays et types d'engins de pêche. Sur la base de l'importance relative par km², cette zone est la plus importante pour les bateaux équipés de chaluts à panneaux et les senneurs. La partie occidentale de la zone revêt une importance particulière pour les senneurs.

- La zone de recherche 2 est une zone de pêche importante, mais sans différences marquées entre les pays ou entre les types d'engins, à l'exception des bateaux français à chaluts à panneaux.
- La zone de recherche 3 montre un schéma complexe de répartition spatiale des types d'engins et d'intérêts différents des États membres. Sur la base de l'importance relative par km², cette zone est la plus importante pour les chalutiers à perche, les crevettiers et la pêche à engins passifs. Cette zone fait en générale l'objet d'une pêche intensive. Néanmoins, tous engins confondus, les débarquements (tant en valeur qu'en poids) y sont relativement faibles.



Conclusion

1/ Nous avons compilé les informations nécessaires pour déterminer quelles mesures sont à adopter afin de protéger l'intégrité des fonds marins en nous permettant d'atteindre les objectifs environnementaux de la DCSMM et les objectifs de conservation de la DH.

2/ La procédure que nous avons suivie est unique en Europe : elle combine différents concepts (valeur biologique, sensibilité, utilisation de l'espace (par ex. économie de la pêche) afin de parvenir à une attribution des zones protégées qui soit intégrée et fondée sur des données scientifiques. Ces concepts ont été pris en compte dans différents scénarios construits à l'aide de l'outil d'aide à la décision Marxan. Cette approche à base de scénarios étant flexible, elle nous permet de prioriser et de nuancer la fixation d'objectifs pour chaque caractéristique d'habitat.

3/ En nous basant sur l'ensemble des informations collectées et sur l'évaluation des différents scénarios élaborés dans Marxan, l'interdiction de la pêche avec équipement mobile de contact de fond, comme indiqué dans les scénarios C et D, devrait permettre d'atteindre les objectifs environnementaux de la DCSMM et les objectifs de conservation de la DH.

4/ Les informations rassemblées dans ce rapport offriront aux responsables politiques une base scientifique solide qui leur permettra de prendre des décisions en connaissance de cause, en consultation avec les parties prenantes concernées, pour délimiter les limites finales des zones d'interdiction de la pêche avec équipement mobile de contact de fond.

1. Introduction

1.1. The importance and need for marine habitat protection

A healthy seafloor is fundamental for a marine ecosystem to function as it hosts numerous microbial and animal communities spanning several trophic levels at the base of the food web (e.g. Vanaverbeke *et al.*, 2000; Griffiths *et al.*, 2017; Breine *et al.*, 2018; Gogina *et al.*, 2020). Along a gradient of environmental conditions and habitat features, microbial and animal communities have evolved and diversified to inhabit the entire seafloor, occupying specific realized niches (Guisan and Thuiller, 2005). Such structural diversification corresponds in turn to a functional diversity that guarantees fundamental ecological processes for the ecosystem functioning (Bolam *et al.*, 2017). For example, highly diversified macrobenthos communities (organisms > 1 mm) have important roles in biogeochemical cycles, in providing nutrients for higher trophic levels and in creating habitat and substrates through ecosystem engineering (Degraer *et al.*, 2008; Birchenough *et al.*, 2011; Breine at al., 2018; de la Torriente *et al.*, 2020). Ecosystem engineering species in particular have been recognized as exceptionally important for the ecosystems thanks to their contribution to e.g. the modulation of hydrodynamics, reworking of sediments and the creation of nursery habitats (Braeckman *et al.*, 2014; Van Hoey *et al.*, 2008; Rabaut *et al.* 2007). Nevertheless, seafloor communities, adapted to specific environmental conditions, are sensitive to changes and therefore vulnerable (despite in different extents) to human activities that directly and indirectly impact the seafloor. In a busy marine environment like the Belgian part of the North Sea (BPNS) where numerous human activities are undertaken in a relatively small area, seafloor integrity needs special attention (MSP 2020-2026; Vanden Eede *et al.*, 2014; Belgian State, 2018). Bottom disturbing fisheries are one of the activities that are known to negatively affect the seafloor, especially when the frequency of the disturbance does not allow benthos recovery (Mazor *et al.*, 2020; Rijnsdorp *et al.*, 2020; McConnaughey *et al.*, 2019; Amoroso *et al.*, 2018; Hiddink *et al.*, 2017). Fishing effort is seldom homogeneously distributed but rather concentrates at fishing hotspots in which specific environmental conditions favour the aggregation of target species and underlying benthic communities (van der Reijden *et al.*, 2018). Fisheries disturbance over time in the BPNS resulted in the disappearance of oyster beds and fragmented, dislocated or destroyed gravel bed ecosystems (Kerckhof *et al.*, 2018; Degraer *et al.*, 2010; Houziaux *et al.*, 2007, 2008, 2011). However, the creation of areas where human activities are restricted and habitats are protected and allowed to recover (i.e. marine protected areas (MPAs)) have been chosen around the world as one of the management measures to tackle habitat degradation (McConnaughey *et al.*, 2019; Ban *et al.*, 2019; Sala and Giakoumi, 2018; Pecceu *et al.*, 2015; Rabaut *et al.*, 2009). Several MPAs are targeting benefits that may be gained from a partially or fully protected seafloor as these may induce e.g. increased benthic habitat complexity and the return of long-lived sessile species (Gonzalez-Irusta *et al.*, 2018), increased sediment carbon storage and restored biogeochemical recycling properties (van de Velde *et al.*, 2018; De Borger *et al.*, 2020), and increased food availability to sustain food web interactions (Hiddink *et al.*, 2011, 2017). Despite the restrictions for fisheries activities within the area, spatial restrictions have often proven beneficial for fisheries as the habitat recovery also contributes to replenished stocks, restored resource biomasses and increased resilience of populations to other pressures, positively affecting not only the area where the measures are implemented but also its surroundings thanks to the spill-over effect (Cullis-Suzuki and Pauly, 2010; Marshall *et al.*, 2019; Ban *et al.*, 2019; Leleu *et al.*, 2012; Rabaut *et al.*, 2009). The long-term benefits of fully protected MPAs (i.e. no-take zones) have long been argued as more cost-effective compared to poorly managed and permissive MPAs that risk to become hotspots for fisheries due to their high natural value and rather serve as examples of failures (Sciberras *et al.*, 2013; van der Reijden *et al.*, 2018; WWF, 2019).

Because of the small but busy nature of the BPNS, the designation of bottom fisheries exclusion zones must be part of an integrated management that accounts for all natural and human needs (Olsen *et al.*, 2014). Therefore, the identification of areas with high ecological value, and/or in serious need for protection, is crucial. The prioritization of areas for conservation is essential to ensure a strategic management that persues the protection of the seafloor and the associated habitats in an efficient and effective manner.

1.2. Framework for marine habitat protection in Belgium

In the European Union, two key legal instruments exist for the protection of marine habitats; the EU Habitats Directive (1992/43/EEC) and the EU Marine Strategy Framework Directive (2008/56/EC). The EU Habitats Directive requires Member States to aim for the conservation and protection of important or threatened species and habitat types, for which a network of Natura 2000 sites was designated (*Council Directive 92/43/EEC*; Rees *et al.*, 2013). Within the HD for Belgium, we are obliged to maintain or achieve a favorable conservation status for habitat type 1110 (sandbanks permanently flooded with seawater) and habitat type 1170 (reefs). The habitat type 1110 represents the main habitat type of the BPNS covering its entire surface area with a geologically unique sandbank system. The habitat hosts a rich and highly productive benthic ecosystem diversified in several communities that play fundamental roles at the base of food webs and ecosystem functioning (Van Hoey *et al.*, 2005; Breine *et al.*, 2018). Within this sandbank system, gravel beds and *Lanice conchilega* biogenic aggregations are present, which are classified as habitat type 1170 “Reefs”. This habitat type 1170 serves numerous important functions representing a hotspot for biodiversity, a nursery and shelter location for several species and a key ground for ecosystem engineering species (Houziaux *et al.*, 2008, 2011; Braeckman *et al.*, 2014; Van Hoey *et al.*, 2008). Gravel beds are classified as highly sensitive to degradation from human disturbance, whereas the *Lanice conchilega* aggregations less.

The second legal tool and framework for habitat and species protection is the Marine Strategy Framework Directive (MSFD 2008/56/EC). The main goal of the MSFD is to achieve and maintain a “Good Environmental Status” across the marine environment maintaining biodiversity and productivity, preventing adverse impacts to natural habitat structures and functions, and promoting a healthy and integrous ecosystem functioning; thus, requiring action for coordinated and sustainable management (MSFD Task Group 6 Report, 2010). Targets are defined based on a series of descriptors, where descriptor 6 targets seafloor integrity, while descriptors 1 and 4 target biodiversity and foodwebs (Rice *et al.*, 2012), also in Belgian waters (Belgian State, 2008). Seafloor integrity is achieved when the habitats are not fragmented and the characteristic ecosystem processes are well functioning which may be monitored with several indicators and key species (Rice *et al.*, 2012; Braeckman *et al.*, 2014).

The assessment under the MSFD reveals that GES is not reached within the Belgian part of the North Sea (Belgische Staat, 2018c) and that Habitat 1110 and 1170 are classified as being in an unfavourable status under the Habitat Directive (HD) (Belgische staat, 2016a; Degraer *et al.*, 2010; https://nature-art17.eionet.europa.eu/article17/; https://nature-art.12.eionet.europa.eu/article12). Under the obligations that each Member State has in habitat and species protection and conservation within the HD and the MSFD, the establishment of conservation measures can be pursued and fisheries measures can be envisaged under the Common Fishery Policy (CFP, 2004/585/EC), in accordance with Article 11 and/or Article 20 (Regulation (EU) No 1380/2013). The European Commission is empowered to adopt conservation measures that may limit or fully restrict fisheries activities in proposed areas if scientific substantiation, conservation objectives, expected costs and benefits, implementation and monitoring plans are comprehensively provided. Therefore the lead Member State has to develop a Joint Recommendation and an accompanying background document that must be adopted by the other concerned Member States.

In 2012, under the Habitat Directive, Belgium established the Vlaamse Banken Special Area of Conservation (1111.9 km^2) comprising 32% of its waters (Pecceu *et al.*, 2015). In the new Marine Spatial Plan, Belgium decided to define areas where protection of the seafloor integrity is most likely to be necessary and effective (search zones). Those areas provide the legal framework for the designation of spatial restrictions for fishing techniques to maintain bottom integrity in order to achieve good environmental status. Pertaining seafloor integrity, restrictions particularly concern fishery with mobile bottom contacting gears. Three search zones (two of which are within the Vlaamse Banken, and one at the top-left corner of the Belgian EEZ) have been indicated as the potential focus for such restrictions (MSP 2020-2026, article 6) (Figure 1). The search zones were indicated as areas potentially containing large extents of biologically valuable habitats and species based on expert knowledge of the Belgian marine environment and available maps at that moment. Taking measures to restrict fishing with mobile bottom contacting gear in those search areas are expected to be necessary and most effective.

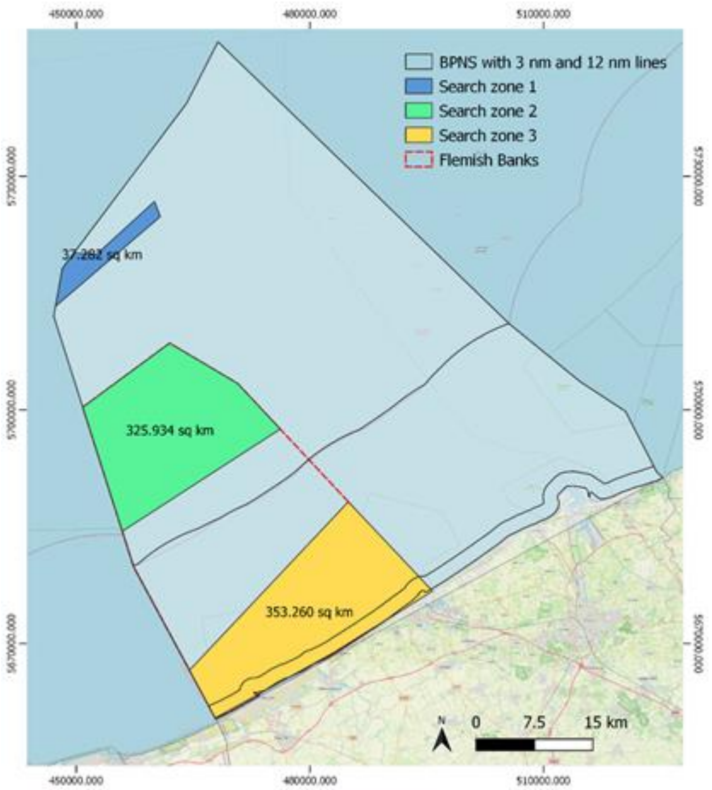


Figure 1. The three search zones indicated in the MSP 2020-2026 in which areas to conserve bottom integrity may be foreseen. The search areas were defined based on scientific knowledge on the habitat type in which taking measures for bottom disturbing fishery are expected to be necessary and effective.

1.3. Joint recommendation requirements

This report describes and covers most of the input required for the background document that is needed for taking conservation measures under the Common Fishery Policy. In line with the guidelines from the EC, the following input is required (it is indicated where this information is provided):

1. The conservation status of the protected habitats and/or species and the conservation objectives of the Natura 2000 site should be clearly set out. Under MSFD, this would be the assessment of environmental status (Art. 8(1)(a)) and the establishment of environmental targets (Art. 10) to achieve good environmental status. Measures need to be based on conservation objectives for the area.

This is outlined in detail in chapter 2.1, where an overview is given of the defined conservation objectives for the HD and good environmental status assessment under the MSFD (Table I).

2. Scientific advice accompanying the joint recommendations should be reliable and where appropriate include a detailed mapping of the protected habitats.

The procedure to define fishery restriction measures in order to protect bottom integrity within the BPNS is completely based on scientific knowledge at all levels:

- The most recent ecological and sedimentological data is used to map the protected habitats and their biological value within the BPNS (see chapter 0)
- Up-to-date modelling exercises are performed to map the benthic habitats and determine their biological value (see chapter 0)
- Socio-economic analyses of fishery activity are based on VMS data analysis (see chapter 6)
- A decision support tool is used to have an objective, scientific based determination of the areas where to take measures in order to protect bottom integrity and to achieve the goals set under the HD and MSFD (see chapter 2.3)

3. Fishing activities should be adequately described.

The fishery activities within the BPNS are analyzed in detail and are described in chapter 6. All countries fishing in the BPNS are included and have delivered the required fishery data (VMS, logbook) to perform these analyses.

4. The effects of fishing activities on the protected habitats and/or species should be adequately described and assessed.

In chapter 4, the sensitivity of the benthic habitats is outlined, based on the Marlin evaluation (MarSea approach). Besides, in chapter 5, it is explained how the current fishing activities hamper in reaching the conservation goals for the habitats and species.

5. The expected conservation benefits of the proposed measures on the protected areas (in terms of favorable conservation status of habitats and/or species or good environmental status under the MSFD) should be described.

This is outlined in detail in chapter 2.1, where an overview is given of the defined conservation objectives for the habitat directive and good environmental status assessment under the MSFD (Table I). The expected benefit for the conservation goals by applying a certain scenario is explained in chapter 2.5. The report of Van Hoey *et al.* (2020) gives insight in the recovery potential of the benthic habitats in the BPNS in case of fishery exclusion.

6. The expected impacts of the proposed measures on fishing activities, including socio-economic impacts, should be described. For new measures falling under the MSFD programme of measures, the cost-benefit analyses or impact assessment carried out in accordance with Article 13(3) of the MSFD should be included.

The expected impact on the fishing activities is in detail (per fishing activity type) described for each scenario in chapter 2.4.

7. Adequate monitoring of the implementation of measures, in relation to the fisheries affected and the environmental objectives to be achieved as well as their periodical review should be foreseen, e.g. measures to monitor and assess the maintenance and/or recovery of the habitats and/or species within the site including a timeframe for review of measures.

Specific monitoring program is not outlined in this report, but the monitoring of the conservation objectives and good environmental status is covered under the MSFD monitoring program. The review of this program is following the MSFD cycle.

8. The possible displacement of the fishing effort and its impact on new areas should be evaluated and reported accordingly.

When closing areas for mobile bottom contacting gear some fishery displacement is likely to happen. Displacement is difficult to quantify, and it is impossible to predict where exactly activities will be displaced to. Nevertheless, some considerations and assumptions on fishery displacement are described in chapter 5.5.

9. The proposed control and enforcement measures should be clearly set out. Examples of information that can be included are: control measures envisaged by the Member State or regional organisations, possible ecological and buffer zones to ensure site protection and/or effective control measures.

Control and enforcement measures were not considered within this report as they are part of a separate study by IMDC (2021).

10. Information on the coordination with neighbouring Member States should be provided, as appropriate. Information on the consultation of the respective Advisory Council(s) should also be provided.

The neigbouring member states are informed about this project during a consultation meeting on 21 September 2020.

2. Delineation of the restriction areas for bottom disturbing activities

In order to comply with the EU Habitats directive and the Marine Strategy Framework Directive (MSFD) (CEC 2008) some areas in and around the Natura 2000 area 'Vlaamse Banken' will have to be protected more adequately by implementing fisheries restrictions. Planners should seek for reaching the conservation objectives and the environmental targets (highest priority) while taking into account the socio-economic importance of the area (Grantham *et al.* 2013; Klein *et al.* 2013 in Metcalfe *et al.*, 2015). This should be a target-based approach that helps to identify priority areas that adequately represent species and habitats whilst minimizing impacts on fisheries and other sectors (Klein *et al.*, 2013). This generally involves the use of spatial prioritization software tools, such as Marxan, which has been developed to identify priority areas efficiently (Ball, Possingham & Watts 2009). We used the Marxan software (see 2.3), as a decision support tool to select suitable areas for reaching our conservation objectives and environmental targets (see 2.1).

2.1. Conservation objectives and environmental targets

The MSFD aims to maintain or achieve good environmental status (GES) for its marine waters and to use the marine resources in a sustainable way. The evaluation of the benthic seafloor ecosystem is an important part of the MSFD and therefore specific goals are set for sea-floor integrity, soft substrates (sandbanks) and gravel beds (Belgische staat, 2018a). The Habitats Directive (HD) obliges Member States to maintain or achieve a favorable conservation status for certain habitats including habitat type 1110 (sandbanks permanently flooded with seawater) and habitat type 1170 (reefs). In the BPNS habitat type 1170 consists of gravel beds and *Lanice conchilega* aggregations. habitat type 1110 consist of 5 defined benthic communities. On order to reach the favorable conservation status mariene protected areas have to be designated and site specific conservation objectives have to be adopted. Conservation objectives for the 'Vlaamse Banken' were first adopted in 2017 and revised in 2021 (Belgische staat, 2021). Due to the overlap in the implementation of both directives, Belgium strived to formulate the environmental targets and the conservation objectives in a consistent way (Belgische staat, 2018b). Consequently, the environental targets (MSFD) and the conservation objectives (HD) are in line with each other, with some specific accents in certain cases (see Table I).

To reach good environmental status and the favorable conservation status, we need to accomplish the following targets:

- **The spatial range of habitat type 1110 does not change meaningfully**
- **The function of shallow sandbanks as spawning and nursery areas is maintained or enhanced**
- **The frequency of occurrence of vulnerable and benthic key-species increases**
- **The benthic ecosystem provides sufficient food for higher trophic levels**
- **The ecological qualities of each occurring community are preserved.**
- **The autonomous development of *Lanice conchilega* aggregations is not prevented.**
- **There is at least a conservation of the surface area of naturally occurring hard substrates**
- **There is a recovery of the natural benthic communities in the gravel beds**

The assessment under the MSFD reveals that GES is not reached (Belgische Staat, 2018c). Habitats 1110 and 1170 are classified as being in an unfavourable conservation status (Belgische staat, 2016a;

Degraer *et al.*, 2010 https://nature-art17.eionet.europa.eu/article17/; https://nature-art.12.eionet.europa.eu/article12). Those habitats are impoverished by decades of impact. Bottom disturbing activities (beam trawling; sand extraction) are the mean impacts. Bottom disturbing fisheries have shown to have a significant impact on the ecological integrity of sea floor ecosystems (benthic communities, biogenic reefs, gravel beds). For the benthos community within the BPNS, it can be generally stated that the high frequency of bottom disturbing fisheries has led to a shift from species that live long, reproduce more slowly, and can usually grow relatively large (K-strategy; highly sensitive to disturbance) to species that can reproduce quickly and massively (r-strategy, less sensitive to disturbance). The K-strategy species have become rare or have disappeared within the benthic communities.

Within the sandbanks (habitat 1110) gravel beds and *Lanice conchilega* biogenic aggregations are present which are classified as habitat type 1170 "Reefs". *Lanice conchilega* aggregations provide a niche for a different and generally more species rich and abundant faunal community than the adjacent tube-free sands in both inter- and subtidal areas (Rabaut *et al.* 2007; Van Hoey *et al.* 2008). The species inhabits a permanent tube, slightly protruding from the sediment and is likely to be damaged by any activity that penetrates the sediment. Following the passage of the fishing gear, *L. conchilega* itself can survive and it may recover fast (1-2 days) in their 3D structures. However, the associated community and species are more sensitive to disturbance and may disappear or remain present at lower densities for a long period of time even after just a single passage (Degraer *et al.*, 2010; Rabaut *et al.*, 2008).

In the BPNS, especially when referring to gravel beds, the conservation status of the habitat 1170 is highly unfavourable with risk of disappearance because of historical damage from bottom trawling and fisheries activity in general (Houziaux *et al.*, 2011). The natural oyster beds that used to occur in association with these gravel beds have completely disappeared and it could not be demonstrated that the area is still used as a spawning area by herring either. The physical habitat is still (at least partially) present; as it could be shown that boulders and larger rocks are still there in the area (Houziaux *et al.*, 2007, 2008, 2011). However, the associated sessile epifauna has not been able to develop fully, mainly due to the intensive fishing with bottom contacting gear that is carried out in the area. This undoubtedly also affects the more mobile fauna of the hard substrates, and the fauna found in the mobile matrix (surrounding soft sediments) (Houziaux *et al.*, 2007, 2008, 2011).

The evaluation of the environmental targets and the conservation objectives under the MSFD and HD has revealed that the benthic habitats are not in GES or in favourable conditions and that bottom disturbing fisheries is one of the main treats for reaching these goals. To turn this around, sufficient surface of habitat type 1110 and habitat type 1170 need to be effectively protected. Already in 2014, Belgium has proposed to take fishery restriction measures in the marine spatial plan. These measures were also included in the management plans for Natura 2000 (Belgische staat, 2018b) and the program of measures for MSFD (Belgische staat, 2016b). Although these measures were rejected at the European level, the need to limit these pressures remains and a new proposal for measures is being prepared. The legal basis for this is defined in the MSP 2020-2026 (article 6), which makes it possible to delineate areas where restrictions for bottom disturbing fishery can be implemented to maintain and restore sea-bottom integrity in order to achieve good environmental status. The determination of concrete measures and their entry into force is subject to ratification within the applicable European procedures, determined by Regulation (EU) No. 1380/2013 of the European Parliament and of the Council of 11 December 2013 on the Common Fisheries Policy. This establishment of sea-bottom protection zones will be included as an important measure in the new MSFD - Natura 2000 program of measures, which will be adopted in early 2022 (March).

Therefore, this study will develop scenarios that allow to select key areas for fishery restriction measures in order to protect bottom integrity within the BPNS to contribute to the conservation targets for the benthic habitats.

Table I. Overview of the conservation objectives as defined under the Habitat Directive (HD) for the Vlaamse Banken (Belgische staat 2021) and for the Marine Strategy Framework Directive (MSFD) in the BPNS (Belgische staat, 2018).

	Objectives	HD	MSFD
1	**The spatial range of habitat type 1110 does not change meaningfully**	x	x
1.1	Positive trend in terms of seabed area permanently spared from disturbance by fishing gear hitting the bottom within the different benthic habitat types (= pressure indicator), which in turn results in a natural development of the benthic fauna and flora and minimizes the artificial division of the seabed (= desired situation).		x
1.2	The spatial range and distribution of Level 2 EUNIS physical habitats (sandy mud to mud, muddy sand to sand and gravel-containing sediment) fluctuates - in relation to the reference status as described in the 'Initial Assessment' (KRMS) - within a margin limited to the accuracy of the current distribution folders	x	x
1.3	The spatial range and distribution of the *Abra alba* community is maintained	x	
2	**Function of shallow sandbanks as spawning and nursery areas is maintained or enhanced**	x	
3	**The frequency of occurrence of vulnerable and benthic key-species increases.**	x	x
3.1	The ratio of benthic R-strategists to K-strategists (at species level) is decreasing	x	
3.2	The number of K-strategists (at species level) is increasing	x	
3.3	There is a positive trend in the mean density of adult specimens (or frequency of occurrence) of a selection of long-lived and/or slow reproducing species and the major structuring benthic species groups in mud to muddy sands and pure fine to gravelly sands	x	x
3.4	The densities of tube-building polycheates that have a habitat-structuring function are high within the *Abra alba* community (*Lanice conchilega, Owenia fusiformis, Lagis koreni*)	x	
4	**The benthic ecosystem provides sufficient food for higher trophic levels**	x	
5	**The ecological qualities of each occurring community are preserved.**	x	x
5.1	The Benthic Ecosystem Quality Indicator as determined by BEQI tool is a minimum value of 0.60 for each occurring community	x	x
5.2	The bioturbation potential (BPc), an indicator for evaluating the functioning of the ecosystem has a minimum value of 331 for the Abra alba community	x	x
6	**The autonomous development of *Lanice conchilega* aggregations is not prevented.**	x	
6.1	The 3D structures formed by Lanice conchilega are preserved	x	

6.2	The densities of the Lanice reef-associated species (e.g. *Eumida sanguinea, Pariambus typicus, Microprotopus maculatus* and *Phyllodoce* spp.) do not show a downward trend	x	
7	**There is at least a conservation of the surface area of naturally occurring hard substrates**	x	
7.1	For gravel beds, the ratio of hard substrate surfaces (specifically, surfaces colonized by hard substrate epifauna) to soft sediment surfaces (specifically, surfaces on top of the hard substrate and preventing the development of substrate fauna) should not show a negative trend in predefined test zones	x	x
8	**There is a recovery of the natural benthic communities in the gravel beds**	x	x
8.1	There has been an increase in species richness within taxa typically associated with hard substrates (specifically *Porifera, Cnidaria, Bryozoa, Polychaeta, Malacostraca, Maxillopoda, Gastropoda, Bivalvia, Echinodermata* and *Ascidiacea*)	x	x
8.2	There is an increase in the frequency of occurrence or median density of adult or mature colonies of at least half of the most important and long-lived species within gravel beds: native Flat oyster (*Ostrea edulis*), Mussel (*Mytilus edulis*), Whelk (*Buccinum undatum*), Dead man's thumb (*Alcyonium digitatum*), erected sponges (such as Geweis sponge (*Haliclona oculata*)) and erected Bryozoa (such as Sea fingerlings (*Alcyonidium spp*.) and Leafy hornwort (*Flustra foliacea*)	x	x
8.3	There is an increase in the median body size of the larger benthic species: Whelk (*Buccinum undatum*) and Spider Crabs (Majidae spp.)	x	x
8.4	There is an increase in the number and size of sand tubeworm (*Sabellaria spinulosa*) reefs and the number of clusters of triangular tubeworms (*Pomatoceros (Spirobranchus) triqueter*). - Type 1	x	
8.5	There is recovery of gravel beds as spawning areas for Herring (*Clupea harengus*) and as sites for egg deposition by rays and sharks	x	
9	**Positive trend in seabed area permanently protected from bottom disturbance by fishing gear within the different benthic habitat types (=pressure indicator) which in turn results in natural development of benthic fauna and flora and minimizes artificial subdivision of the seabed (=desired situation)**		x

2.2. Methodology for the scenario settings

Exclusion of disturbing activities from key areas is necessary to reach the environmental targets and the conservation objectives. Therefore, we want to protect sufficient surface area of habitat type 1110 and habitat type 1170 from bottom disturbing activities. Detailed scientific research of the BPNS area revealed 5 macrobenthic communities, geogenic reefs (gravel beds) and biogenic aggregations (*Lanice conchilega*) as important features included within the habitat types 1110 and 1170 (Van Hoey *et al.*, 2004; Degraer *et al.*, 2008; Houziaux *et al.*, 2007, 2008, 2011; Breine *et al.*, 2018). For reaching the conservation objectives we need to strive to protect a sufficient amount of those habitat features. At this point, no scientific method exists for defining the amount of surface area that needs to be protected in order to reach the conservation objectives. Therefore, we have developed an objective reasoning, as explained in this section and as reflected in the scenario settings, to come to a sufficient protection of the different habitat features and this in a balanced way.

Our methodological approach used a 10% protection target value for the habitattype 1110 (including Habitattype 1170) as a guidance in developing and evaluating the scenarios for defining the fishery restriction areas (basic scenario, see further). This 10% protection value is in line with several conventions or strategies, targeting such 10% protection value (box 1). This 10% is a policy driven target value and not specifically defined on habitat level. To come to surface area values on habitat level, we relied on their biological value characteristics (see chapter 0) and their sensitivity classification to bottom disturbing fisheries (see chapter 4). We have used a combination (sum) of these characteristics in order to prioritize the different habitat features and in order to rank them according to their need of protection against bottom disturbing fisheries. This means that the areal extent to protect was estimated higher for habitat features characterized by a higher biological value and/or sensitivity to bottom abrasion.

Box 1.

Convention of Biological Diversity (CBD), Target 11:

By 2020, at least … **10 per cent** of coastal and marine areas, **especially areas of particular importance for biodiversity and ecosystem services**, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area based conservation measures, and integrated into the wider landscape and seascape.

UN Sustainable Development Goal 14, Target 14.2 and 14.5:

By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans. By 2020, **conserve at least 10 per cent of coastal and marine areas**, consistent with national and international law and based on the best available scientific information.

EU Biodiversity Strategy for 2030:

The Strategy sets an ambitious objective of establishing a truly coherent Trans European Nature Network, to include legal protection for at least … 30 per cent of the sea in the EU, of which … **10 per cent of sea to be under strict protection**.

The weighed sum of biological value and sensitivity (see Table II) was used as a measure to determine the relative proportions of the different habitat features to be protected in order to prioritize the protection of the features with the highest biological value that are most sensitive to bottom disturbing. The biological value characterization of the different habitat features is described in chapter 0 (habitat suitability and biological value mapping). The sensitivity classification, based on the MarESA approach (*www.marlin.ac.uk*) is described in chapter 4 (Sensitivity classification of the habitat features in the BPNS to physical disturbance (abrasion)). In summary, the gravel habitat is determined as priority one, as it has a very high biological value and is highly sensitive to fishery (overall score of 10). The *Lanice conchilega* and *Abra alba* habitat are also characterized with a high biological value, but the sensitivity to fishery is low to medium (score 1-3) whereby these habitats end up with an overall score of 7. The sensitivity to bottom abrasion is also low (score 1) for the other habitat features (*Hesionura, Magelona-Ensis, Nephtys*). Nevertheless, those habitat features are differing in their biological value, leading to some differentiation between them in the overall scoring. *Hesionura* and *Magelona-Ensis* have a medium biological value, (score 3), whereas *Nephtys* has a low biological value (score 2). The overall score for those habitat features is hence respectively 4 and 3. The *Limecola* habitat feature has a very low biological value (score 1) and medium sensitivity (score 2). This habitat feature is not prioritized in the scenario settings because the *Limecola* habitat has a limited occurrence within the Flemish bank area (small patch in the coastal area of Oostende) and has a very low biological value.

Table II. Overview of the Habitat 1110 and Habitat 1170 features, their biological value and sensitivity classification. The sum determines the ranking of the habitat features, based on biological value and sensitivity. For each habitat feature the surface area (in m² and relative %) of each habitat features within the BPNS and the search areas (SA) is given.

Habitat type	Habitat Features	Biological value	Sensitivity	Sum	Total Area (m²) BPNS	Area (m²) in SA	Relative availability in search zones (%)
1170	**Gravel beds**	5	5	10	503 200 000	102 711 424	20.41
1170	***Lanice conchilega***	5	2	7	360 160 000	169 405 106	47.04
1110	***Abra alba***	5	2	7	523 800 000	201 129 649	38.40
1110	***Hesionura elongata***	3	1	4	1 654 799 928	287 161 913	17.35
1110	***Magelona-Ensis***	3	1	4	82 800 000	51 240 442	61.88
1110	***Nephtys cirrosa***	2	1	3	961 244 145	146 926 169	15.29
1110	***Limecola balthica***	1	2	3	196 720 000	13 354 028	6.79

A set of scenarios was developed (Table III). First, we included a basic scenario, where this prioritization is not taken into account and where we strive for an equal habitat feature inclusion (10% each).

Subsequently three sets of scenarios (A&B; C&D; E&F) were developed using the prioritization based on biological value and sensitivity (Table II) including an increasing target for gravel beds: 15% (scenario A&B), 20% (scenario C&D) and 25% (scenario E&F).

- For scenarios A, C and E, the target for the other habitat features is determined relative to the target set for gravel beds. The relative proportions of the targets (percentages of total surface area of the habitats within the BPNS to be protected) set for the different habitats within the different scenarios are based on the sum score of the biological value and sensitivity score for each of those habitat features (Table II).
- For scenarios B, D and F, we followed the same procedure, but any habitat feature (*Hesionura, Nephtys, Magelona*) with a total score less than 5 was set to a 0% threshold. Within these scenarios, a score less than 5 was seen as a habitat feature with a lower priority. This was done in order to see if by removing such targets, the priority targets for gravel, *Lanice* and *Abra alba* could be reached easier. Nevertheless, these habitat features will be included with a certain percentage in the selected areas anyway.
- The last two scenarios (G and H), were included to see which areas are selected when only taking into account the sensitivity of the habitats (Scenario G) or only taking ino account the biological value of the habitats (Scenario H). For those scenarios, we have taken the 20% protection target as starting point for the gravel beds and calculated the other percentages accordingly. This 20% protection target is the intermediate target from the other scenarios and leans towards the maximal available surface area of gravel within the search zones.

These predesigned scenarios have determined the Marxan tool settings, which strived for each scenario to find optimal areas able to best satisfy the targets set for each habitat feature.

Table III. Overview of the scenarios and the selected strategies.

	HA1110						
	HA1170						
	Gravel	***Lanice***	***Abra***	***Hesionura***	***Nephtys***	***Magelona***	
	5	2	2	1	1	1	Sensitivity to bottom fishery
	5	5	5	3	2	3	Biological value
	10	7	7	4	3	4	SUM (sensitivity to fishery and biological value)
Basic scenario	**10**	**10**	**10**	**10**	**10**	**10**	
Scenario A	**15**	**10.5**	**10.5**	**6**	**4.5**	**6**	Weighed according to the sum
Scenario B	**15**	**10.5**	**10.5**	**0**	**0**	**0**	Weighed according to the sum (anything less than score 4 set to 0% threshold)
Scenario C	**20**	**14**	**14**	**8**	**6**	**8**	Weighed according to the sum
Scenario D	**20**	**14**	**14**	**0**	**0**	**0**	Weighed according to the sum (anything less than score 4 set to 0% threshold)
Scenario E	**25**	**17.5**	**17.5**	**10**	**7.5**	**10**	Weighed according to the sum
Scenario F	**25**	**17.5**	**17.5**	**0**	**0**	**0**	Weighed according to the sum (anything less than score 4 set to 0% threshold)
Scenario G	**20**	**8**	**8**	**4**	**4**	**4**	Weighed according to sensitivity to bottom fisheries
Scenario H	**20**	**20**	**20**	**12**	**8**	**12**	Weighed according to biological value

The protected surface area (m²) that was strived for in each scenario for each habitat feature is given in Table IV.

Table IV. Overview of the surface area (km²) per habitat feature for each scenario.

	HA1110					
km²	HA1170					
	Gravel	*Lanice*	*Abra*	*Hesionura*	*Nephtys*	*Magelona*
Basic scenario	50.32	36.02	52.38	165.48	96.12	8.28
Scenario A	75.48	37.82	55.00	99.29	43.26	4.97
Scenario B	75.48	37.82	55.00	0	0	0
Scenario C	100.64	50.42	73.33	132.38	57.67	6.62
Scenario D	100.64	50.42	73.33	0	0	0
Scenario E	125.80	63.03	91.67	165.48	72.09	8.28
Scenario F	125.80	63.03	91.67	0	0	0
Scenario G	100.64	28.81	41.90	66.19	38.45	3.31
Scenario H	100.64	72.03	104.76	198.58	76.90	9.94

When looking at Table II, one can note that some of the targets (cf scenario E and F) are higher than the available area for certain biotopes (f.e. there is a maximum of 20.4% of gravel available within the search zone and the target was put at 25%). Even when it is known that this target for gravel cannot be reached a certain scenario we kept it in order to see what was the outcome is.

2.3. Marxan: what is it and why is it used?

Marxan is a problem solving tool that is used to support decisions on spatial conservation planning. As part of a systematic planning process, Marxan contributes towards a transparent, inclusive and defensible decision making process.
It provides zoning options that meet biodiversity targets and are relatively cost-effective for conservation management by minimizing impact on other activities.
In this study, the outcome of the Marxan tool is in the first place based on the targets defined in the scenariosetting, whereas thereafter the enforceability and socio-economic aspects are taken into account.
This provided us with scenarios on where to implement fisheries restrictions, taking into account biological valueand detailed information of fishering activities (Ball, Possingham & Watts 2009). One of the advantages of using this tool is the fact that it facilitates inclusivity and transparency. As Marxan provides different possible solutions, the scenarios are a good starting point to engage stakeholders. It also helps to visualize how objectives translate spatially (Marxan tutorial, 2015).

2.3.1. Key concepts of the Marxan tool

The Marxan tool is based on certain key concepts such as the study area and its defined planning units, the cost layer, the environmental target layers, the connectivity and boundary length.

Study area

The Belgian Marine Spatial Plan 2020-2026 has designated 3 areas for the research into the possibility of enacting spatial measures with regards to fishing techniques (search zones). Two of these zones are located within the Natura 2000 area 'Vlaamse Banken' (Figure 2). These 3 search zones were selected as areas potentially containing large extents of biologically valuable habitats and species based on expert knowledge. To confirm the appropriateness of those search zones, a MARXAN test run was executed to allow the tool to select areas within the entire 'Vlaamse Banken' and Search Zone 1 (see Annex).This test shows that the majority of the preferred areas for protection were located within the Search zones.

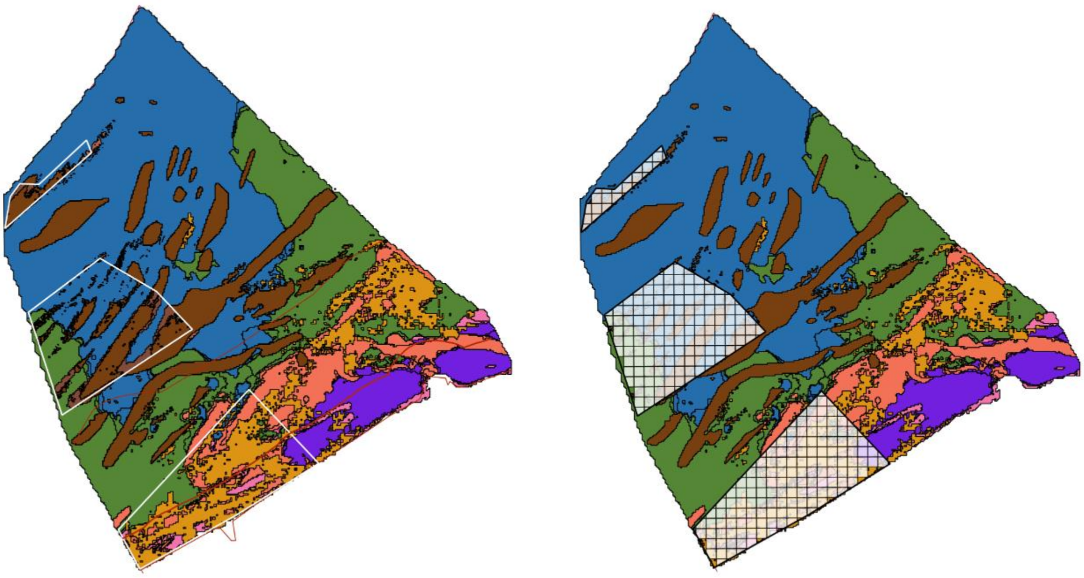


*Figure 2. Left: The three delineated areas (white) wherein the fishery restriction measures for protecting bottom integrity will be taken. Right: Map of the 3 search zones divided in 336 Planning Units of 1.6*1.6 km*

Planning Units

The study area is divided in grid cells. These grid cells are called Planning Units (PUs) (Figure 2) and were chosen to have the same size as the grid cells used for the fisheries data (Chapter 5). In total the study area (= 3 search zones) counts 336 planning units; each with a maximum surface area of 2,56 km². The planning unit layer (PU-layer) consists of all planning units with a unique number (PUID) and its associated status and cost (see further).

Ecological layers

Four different layers of biological information were produced or updated as described in Chapter 3 and were used to set the biological targets in the scenario analyses in Marxan.

The distribution of the five macrobenthic communities that occur within habitat type 1110 was obtained through a habitat suitability modelling exercise using presence-absence data collected between 1998 and 2018.

To set the targets for the protection of habitat type 1170 including both geogenic and biogenic reefs, the potential distribution of gravel beds and of *Lanice conchilega* aggregations were included. The distribution of gravel beds was obtained compiling different sources of data and observations including sediments samples, acoustic seabed classification, video footages, and expert knowledge. The distribution of *Lanice conchilega* aggregations was obtained through a habitat suitability modelling exercise developed using observed densities above 500 ind/m^2. For the Marxan analyses, only the areas with a suitability percentage >50% were retained for the *Lanice conchilega* aggregations.

Finally, the biological valuation map was used to drive the biological targets towards surfaces assigned to very high and high biological value. The latter map was developed combining all biological and ecological properties from the several layers of information following a protocol of assessment questions drawn in the Belspo BWZee Project in Derous *et al.* (2007) providing a distribution of five classes of biological value between very high and very low (See Section 0).

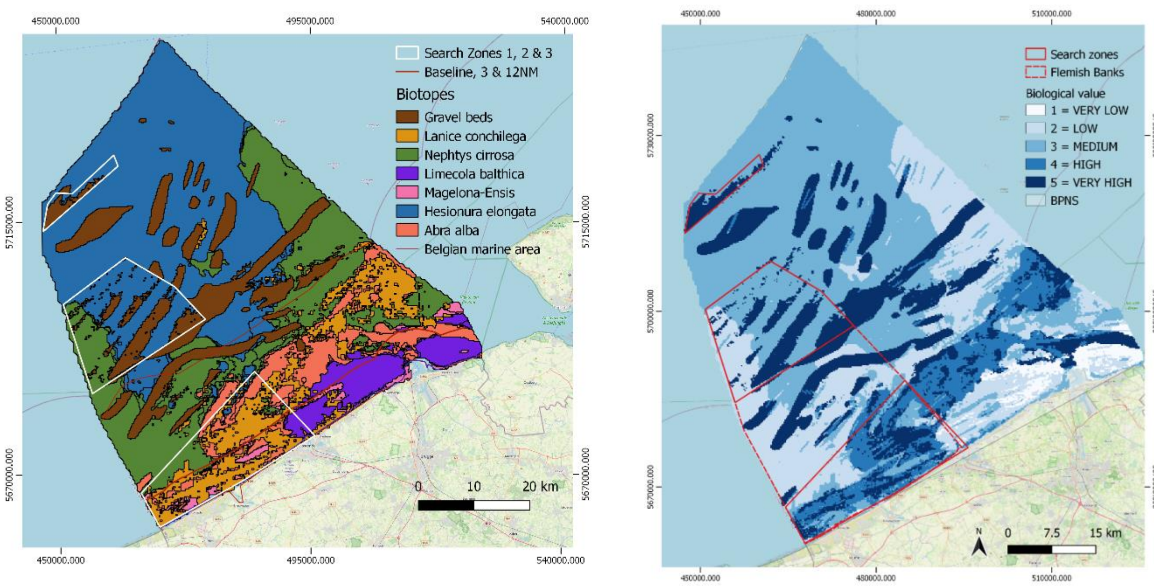


Figure 3. Map of the five macrobenthic communities, Lanice conchilega aggregations and gravel beds, (left) and the biological value (right) in the BPNS.

Cost layer

Depending on the nature of the project, 'cost' can be calculated in different ways within Marxan: the area of planning units, the cost of displaced commercial activities, cost of tourism and industry. In this study, the cost was defined as the possible loss of socio-economic value in fishery. In our case, we wanted to reach our selected scenarios with the least consequences for the fisheries sector. This was done by including the spatial distribution of average landings from commercial fisheries.

Each planning unit contains a certain cost. Here, we used the average landings (€)/year of all the fishery activities in the area between 2013-2019. Cost is included for each grid cell in the PU-layer (See fisheries chapter 6).

After the scenarios were chosen, we also calculated the average landings for the Belgian fleet only and divided per gear group. This analysis was performed via the clipping tool in QGIS.

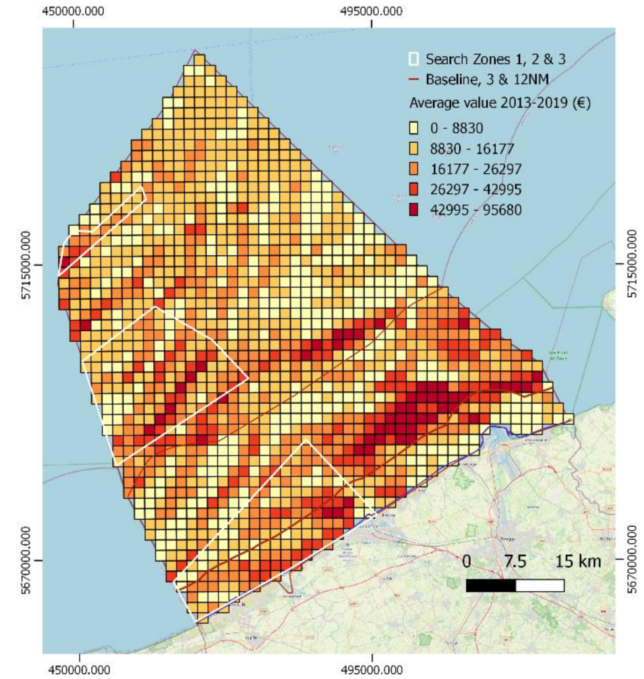


Figure 4 Average landings of all fishery activities between 2013-2019 (the darker the color, the higher the value of landings in the grid cell; black lines are the contour lines of the search zones, red lines are the 3 and 12NM-line)

Connectivity and Boundary Length

The boundary length of a selected area is a way of quantifying the connectivity of a group of planning units. It is a combination of the total length of the edges of the selected planning units, and the weight that you choose to give to this value. This weighing is known as the boundary length modifier (BLM) (Game *et al.*, 2008). In this case, we set the BLM on 5 in all scenarios. Marxan tries to find the solution with the lowest score, so your selected area will have a more clumped distribution. Here, we strived for a maximum of 3 or 4 potential areas for management measures as more areas makes it difficult in terms of enforceability.

2.3.2. How does Marxan work

Marxan identifies sets of areas that meet the predetermined targets at a minimal "cost". After the specification of the targets (surface area for each feature), Marxan will start by assigning scores to planning unit configurations in the sample space. This score is based on that particular configuration's ability to meet the targets while minimizing the cost: the lower the score, the better. Marxan will then compare a huge number of configurations (it would be virtually impossible to compare them all) and find the one with the lowest overall score. This is the proposed solution. You can repeat the process as many times as you want: the more times you do, the more confident you can be that a near optimal solution is found (Marxan tutorial, 2015).

Preparation

After defining our overall starting guideline to select 10% of each feature (5 macrobenthic communities, gravel beds & *Lanice* aggregations), all geographic data were included in QGIS. Next, the study area (the 3 search zones) was divided into planning units.

The following step was to tally the amount of each feature in each PU. Via the clipping tool in QGIS, we calculated for each planning unit what amount (area in m²) of each habitat feature was present. For the Marxan program, these files must be transferred to .qmd format. In QGIS (version 2.18), there is a plugin Marxan toolbox to make these calculations but we discovered that this plugin gave an incorrect output so we calculated the surface area manually in QGIS with the clipping tool as described above.

Before running Marxan, we needed to prepare the input folder. The files in this folder were generated via the Marxan toolbox in QGIS. The Planning Unit layer (PU.dat) contains all the planning units with a unique ID, the cost (here average value of landings) and the status where you can specify whether the planning unit is free to be selected, or must be either excluded or included in the solution. In this case all the Pus were free to be selected. The species file (spec.dat file) contains all habitat features. In this file, we needed to set the target for each feature. Based on the % in Table III, we calculate the surface area for each of the features (Figure 5)

```
id    prop  target       targetocc  spf   name
1     0.0   52380000     0      1.0   Abra alba
2     0.0   0.0          0      1.0   BVM_4&5
3     0.0   0.0          0      1.0   BVM_5
4     0.0   165479992.80        1.0   Hesionura
5     0.0   36016000     0      1.0   Lanice
6     0.0   0.0          0      1.0   Limecola
7     0.0   8280000      0      1.0   Magelona-Ensis
8     0.0   96124414.5   0      1.0   Nephtys
9     0.0   50320000     0      1.0   gravel_new
```

Figure 5. Example of a spec.dat file

In Marxan, there is also the possibility to include a Species Penalty Factor (SPF). This is a measure of how important it is to meet the target for the feature. By increasing this number, the program can be forced to reach the target. In this study, we didn't increase the SPF for any target. The Puvsp.dat file describes how much of each feature is included in each planning unit and incorporates the species (.gmd files) in the PU-layer. The boundary file (Bound.dat) contains the boundary cost which is usually quantified as the length of the PU edge. Unconnected PUs will incur a large cost. The boundary cost is multiplied by the Boundary Length Modifier (BLM), a user-defined value. This BLM can be modified in the input.dat file. We have adjusted the BLM to 5 in all scenarios, which gave us a result of 3-5 areas.

In the input.dat folder, it could also be specified how many solutions for the scenario needed to be displayed. With 100 runs for each scenario, a near optimal solution was obtained. Some tests were done with 500 and 1000 solutions but this only slowed down the process and resulted in similar solutions. This is in line with the expectations as the study area is rather small.

Run Marxan

Marxan has no graphical interface; it just does the computing. In this case, Marxan was used in combination with QGIS (version 2.18). All geographic data were compiled and prepared in the correct format for Marxan (see preparation).

After running Marxan, the output folder is filled with output files. First the output_log.dat file was consulted. In this file the cost, number of planning units and in what extent targets are met can be found for each of the runs. Each of the runs also have individual output files. In the output_mvbest file, more information can be found on the targets of the best solution.

Besides that, there is also a file called 'output_best'. This output is considered by Marxan as the best solution of all the runs. This output was displayed in QGIS by combining it with the PU-file (join function in QGIS). All the maps under section 'Scenario results' are the best solution of the scenario runs.

2.4. Scenario results

In this section, the different scenarios are discussed. For each scenario a map of the selected planning units is provided. The selected area is indicated in blue; the rest of the search zones are in white. On the map, the overlap with the area for renewable energy (RE) and the seafarm Nieuwpoort (near the coast) is indicated in opaque. The red lines are the 3 & 12 NM. In the first part of the table, an overview is given of the amount of each of the habitat features and each of the habitat types (HA1170 & HA1110) in relation to the available amount in the entire BPNS. Also the percentage of biological value high (BV4) and biological value very high (BV5) is included. Besides that, the number of planning units (PU); the area and the overlap with the area for renewable energy (RE) was provided. The catch (landing value) is given in total and split for the Belgian fishery and the rest. Finally, the catch is divided per gear type. Both the total value and the relative amount (in relation to the entire BPNS) was added.

2.4.1. Basic scenario

In this scenario the target for all important biotopes is to protect 10% of the biotope present at the BPNS. This basic scenario is included as a comparison for the next scenarios that are based on the prioritization of the specific habitat features (See section 2.2). In total 130 planning units were selected with an area of 323.63km². The selected units are displayed in blue. This scenario largely overlaps with the area for renewable energy (144,42 km² or about 44,6%).

In Table V the amount of habitat protected per biotope in this basic scenario is given. With this scenario 10.5% of habitat type 1170 is protected and 9.7% of habitat type 1110. This scenario leads to the determination of two areas for fishery restriction measures. In terms of biological value, the scenario protects 6.7% of high biological value (score 4) and 10.6% of very high biological value (score 5).

The average value of landings within the selected area for this scenario was 1.87 mill.€ or 8.5% of the yearly value of landings in the entire BPNS. This scenario largely overlaps with the area for renewable energy where fisheries will most likely be excluded for safety reasons in the near future. The average landings within the overlapping area amounts to 940 000€ or more than half the average landings for the entire selected area.

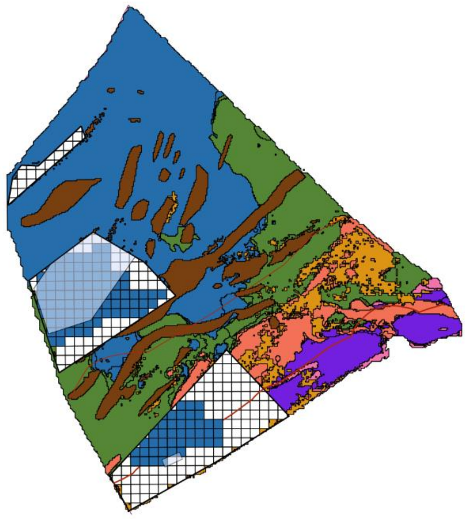


Figure 6 Map of the output of the basic scenario

For the Belgian fleet, the average value of landings/year for the selected area was around 213 500€ or 6% of the total landing value of the BPNS.

If we look at gear type level, the area was the most important for the passive fishers (19.4% of the total value of landings in the BPNS for this gear type) followed by the bottom beam trawl (11.7%) and the pulse trawl (10.1%).

Table V. Overview of the output of the basic scenario. Left: percentage of the habitat features, habitat types & biological value (BV) in relation to the entire BPNS.; Right: number of Planning Units, area, landings (in general and in overlap with the area for Renewable energy (RE). Landings are also provided per gear type.

Basic scenario	**% tov BPNS**
Abra	10.00
Hesionura	9.99
Magelona-Ensis	11.84
Nephtys	10.00
Limecola	0.00
gravel	10.18
Lanice	11.02
HA1170	**10.53**
HA1110	**9.68**
BV4	6.71
BV5	10.63

PU (n)	130
Area (km²)	323.63
Landings (€)	1 867 116.91
Relative landings (% BPNS)	8.50
Landings (€) / km²	5 769.29
Area within RE (km²)	144.42
Landings within RE (€)	940 182.10
Landings (€) outside RE	926 934.81
Landings_BE (€)	213 582.44
Relative landings_BE (% BPNS)	6.02
Landings_Rest (€)	1 653 534.47
Relative landings_rest (% BPNS)	8.98
Landings_shrimp (€)	36 079.47
Landings_TBB (€)	294 209.90
Landings _PUL (€)	1 391 305.02
Landings _SSC (€)	63 018.98
Landings_OTB (€)	1 520.42

Landings_PAS (€)	80 983.12
Rel_Landings_shrimp (%)	0.87
Rel_Landings_TBB(%)	11.66
Rel_Landings _PUL (%)	10.17
Rel_Landings _SSC (%)	6.39
Rel_Landings_OTB (%)	0.82
Rel_Landings_PAS(%)	19.42

2.4.2. Scenario A and B

In scenario A, the target for gravel was set at a protection of 15% of the total gravel area. Next, all other communities got a percentage weighed according to the sum of sensitivity to fisheries and biological value. Scenario B has the same targets for gravel, *L. conchilega* and *A. alba* but the targets for the rest of the communities were put on zero.

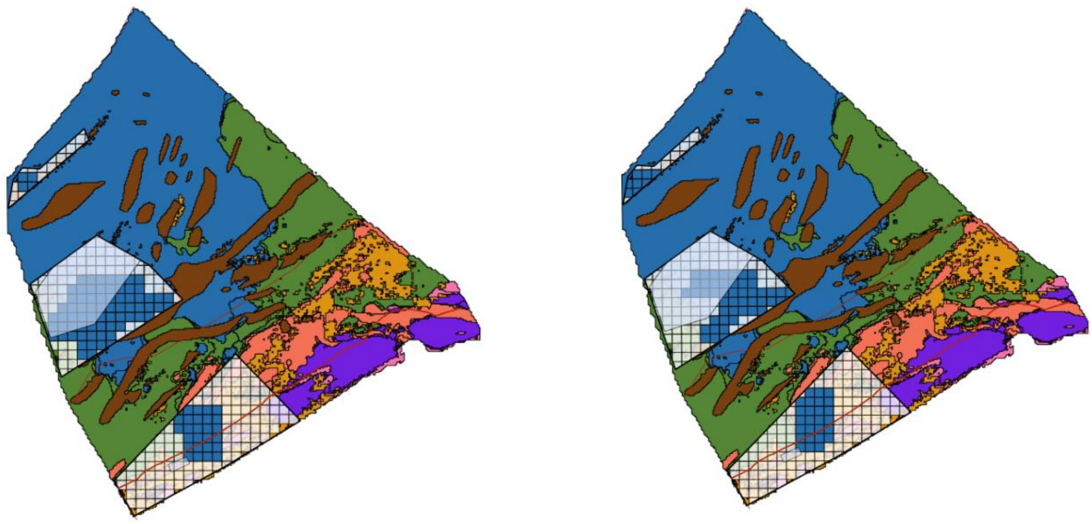


Figure 7. Map of the output of scenario A (left) and scenario B (right)

Both scenarios protect around 13% of habitat type 1170. In scenario A 8.6% of habitat type 1110 is protected; in scenario B 7.3%. All predefined targets are met for the different features. The included zones with biological value 4 and 5 are similar in both scenarios.

Scenario A includes a much larger area than scenario B (252 km² vs 199 km²). The overlap with the area for renewable energy is larger in scenario A (77.9 km²) than in B (37.7 km²) Both scenarios propose 3 areas where fishery restrictions should be implemented.

The landing value is larger in scenario A than in B but when looking at the value of landings/km² the value in scenario B is higher than in A (8800 €/km² vs 7800 €/km²). For the Belgian fleet, the average landings/year is around 6% of the total for the BPNS in scenario A and 4.8% in scenario B.

When looking at the absolute number of the value of landings, the pulse fisheries had the highest average landings (> 1 mill. €) followed by the beam trawlers (300 000€). Relative to the entire BPNS, the value of landings is the highest for the passive fishers and the demersal beam trawlers in scenario A and for the flyshooters and passive fishers in scenario B (Table VI).

Table VI. Overview of the output of scecnario A & B First: percentage of the habitat features, habitat types & biological value (BV) in relation to the entire BPNS.; Next: number of Planning Units, area, landings (in general and in overlap with the area for Renewable energy (RE). Landings are also provided per gear type.

Scenario A	% tov BPNS
Abra	10.58
Hesionura	8.85
Magelona-Ensis	7.87
Nephtys	4.56
Limecola	0.00
gravel	15.01
Lanice	10.75
HA1170	**13.23**
HA1110	**8.56**
BV4	7.87
BV5	13.50

Scenario B	% tov BPNS
Abra	10.61
Hesionura	7.95
Magelona-Ensis	8.84
Nephtys	0.52
Limecola	0.00
gravel	14.96
Lanice	10.54
HA1170	**13.12**
HA1110	**7.30**
BV4	7.12
BV5	13.04

Scenario A	
PU (n)	101
Area (km²)	252.24
Landings (€)	1 969 534.50
Relative landings (% BPNS)	8.97
Landings (€) / km²	7 808.18
Area within RE (km²)	77.86
Landings within RE (€)	575 589.07
Landings (€) outside RE	1 393 945.43
Landings_BE (€)	217 644.90
Relative landings_BE (% BPNS)	6.14
Landings_Rest (€)	1 751 889.60
Relative landings_rest (%)	9.52
Landings_shrimp (€)	31 624.04
Landings_TBB (€)	321 495.62
Landings _PUL (€)	1 440 936.71
Landings _SSC (€)	96 781.24
Landings_OTB (€)	6 973.11
Landings_PAS (€)	71 723.78
Rel_Landings_shrimp (%)	0.76
Rel_Landings_TBB(%)	12.74
Rel_Landings _PUL (%)	10.54
Rel_Landings _SSC (%)	9.81
Rel_Landings_OTB (%)	3.75
Rel_Landings_PAS(%)	17.20

Scenario B	
PU (n)	81
Area (km²)	199.42
Landings (€)	1 771 305.20
Relative landings (% BPNS)	8.07
Landings (€) / km²	8 882.28
Area within RE (km²)	37.07
Landings within RE (€)	341 197.40
Landings (€) outside RE	1 430 107.80
Landings_BE (€)	169 460.18
Relative landings_BE (% BPNS)	4.78
Landings_Rest (€)	1 601 845.02
Relative landings_rest (%)	8.70
Landings_shrimp (€)	27 770.25
Landings_TBB (€)	267 198.15
Landings _PUL (€)	1 281 383.98
Landings _SSC (€)	133 129.31
Landings_OTB (€)	8 015.85
Landings_PAS (€)	53 807.67
Rel_Landings_shrimp (%)	0.67
Rel_Landings_TBB(%)	10.59
Rel_Landings _PUL (%)	9.37
Rel_Landings _SSC (%)	13.50
Rel_Landings_OTB (%)	4.31
Rel_Landings_PAS(%)	12.91

2.4.3. Scenario C and D

In scenario C the target for gravel was set on 20% and the targets for all other features were weighed according to the sum of sensitivity to fisheries and biological value. Scenario D has the same targets for gravel*, L. conchilega* and *A. alba* but the targets for the other 3 communities (*Hesionura, Nephtys and Magelona*) were put on zero. The targets for gravel were not met (18.43% in the selected zones instead of the target of 20%).

The differences in the output of these two scenarios are minimal. Scenario C selects 136 planning units or 333.9km² whilst Scenario D selects 132 planning units or 323.7km². In both scenarios the same percentage of habitat type 1170 is protected (16.59%) and for habitat type 1110 11.14% in C and 10.9% in D is protected (Table VII). On community level, there is only a difference for the *Nephtys cirrosa* community: in scenario C 5.99% is protected, while in scenario D 4.93% is protected. These scenarios lead to 3 areas where fishery restrictions would be implemented.

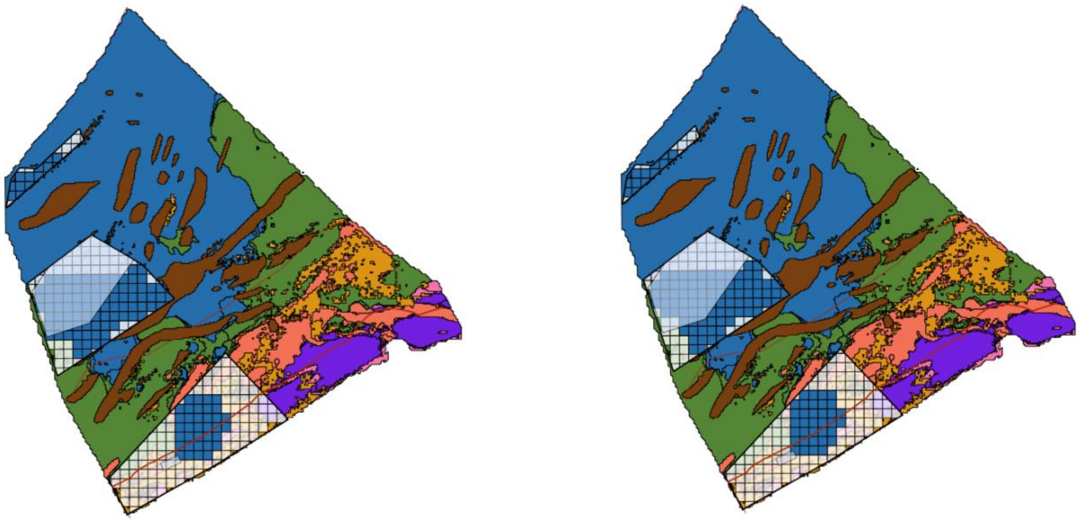


Figure 8. Map of the output of scenario C (left) & D (right)

The value of landings is slightly larger in scenario C than in D but when looking at the value of landings/km² the value in scenario D is higher than in C (7750 €/km² vs 7924 €/km²). For the Belgian fleet, the average landings/year is around 7.6% of the total for the BPNS in both scenarios.

When looking at the absolute number of the value of landings, the pulse fisheries had the highest average landings (> 1 mill. €) followed by the beam trawlers (almost 400 000€). Relative to the entire BPNS, the value of landings is the highest for the passive fishers, the seine fishery and the demersal beam trawlers in both scenarios (Table VII).

Table VII. Overview of the output of scenario C & D First: percentage of the habitat features, habitat types & biological value (BV) in relation to the entire BPNS.; Next: number of Planning Units, area, landings (in general and in overlap with the area for Renewable energy). Landings are also provided per gear type.

Scenario C	**% tov BPNS**
Abra	14.01
Hesionura	11.54
Magelona-Ensis	14.35
Nephtys	5.99
Limecola	0.00
gravel	18.43
Lanice	14.02
HA1170	**16.59**
HA1110	**11.14**
BV4	8.15
BV5	18.23

Scenario D	**% tov BPNS**
Abra	14.01
Hesionura	11.54
Magelona-Ensis	14.35
Nephtys	4.93
Limecola	0.00
gravel	18.43
Lanice	14.02
HA1170	**16.59**
HA1110	**10.90**
BV4	8.15
BV5	18.23

Scenario C	
PU (n)	136
Area (km²)	333.88
Landings (€)	2 587 749.35
Relative landings (%)	11.79
Landings (€) / km²	7 750.54
Area within RE (km²)	105.54
Landings within RE (€)	730 296.70
Landings (€) outside RE	1 857 452.65
Landings_BE (€)	273 126.27
Relative landings_BE (%)	7.70
Landings_Rest (€)	2 314 623.08
Relative landings_rest (%)	12.57
Landings_shrimp (€)	62 456.74
Landings_TBB (€)	397 963.22
Landings _PUL (€)	1 875 741.19
Landings _SSC (€)	158 364.47
Landings_OTB (€)	8 752.81
Landings_PAS (€)	84 470.92
Rel_Landings_shrimp (%)	1.50
Rel_Landings_TBB(%)	15.77
Rel_Landings _PUL (%)	13.72
Rel_Landings _SSC (%)	16.06
Rel_Landings_OTB (%)	4.71
Rel_Landings_PAS(%)	20.26

Scenario D	
PU (n)	132
Area (km²)	323.67
Landings (€)	2 564 751.31
Relative landings (%)	11.68
Landings (€) / km²	7 923.97
Area within RE (km²)	98.44
Landings within RE (€)	707 298.66
Landings (€) outside RE	1 857 452.65
Landings_BE (€)	268 366.41
Relative landings_BE (%)	7.57
Landings_Rest (€)	2 296 384.90
Relative landings_rest (%)	12.47
Landings_shrimp (€)	62 456.74
Landings_TBB (€)	391 853.26
Landings _PUL (€)	1 858 956.22
Landings _SSC (€)	158 364.47
Landings_OTB (€)	8 752.81
Landings PAS (€)	84 367.82
Rel_Landings_shrimp (%)	1.50
Rel_Landings_TBB(%)	15.53
Rel_Landings _PUL (%)	13.59
Rel_Landings _SSC (%)	16.06
Rel_Landings_OTB (%)	4.71
Rel_Landings_PAS(%)	20.23

2.4.4. Scenario E and F

In scenario E the target for gravel was set on 25% and all other features were weighed according to the sum of sensitivity to fisheries and biological value. Scenario F is equal for gravel, *Lanice* and *Abra* but the targets for the other 3 communities (*Hesionura, Nephtys* and *Magelona*) were put on zero.

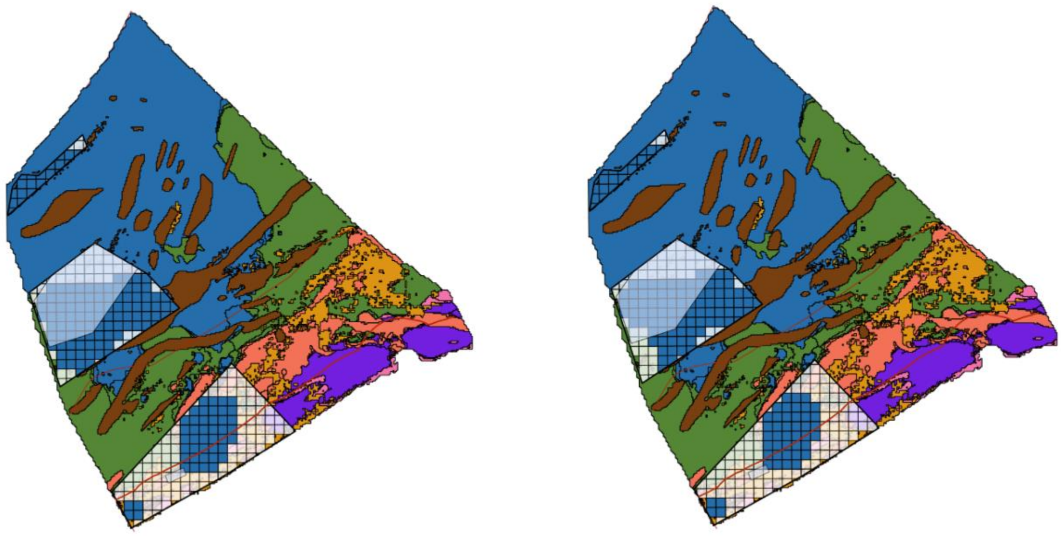


Figure 9. Map of the outputs of scenario E (left) and F (right)

Scenario E has a total area of 384.3 km² or 161 planning units. Almost one third of this area overlaps with the area for renewable energy (110 km²). Scenario F has a total area of 361.22 km² or 152 planning units. In this scenario 103 km² overlaps with the area for renewable energy. In scenario E 19.2% of habitat type 1170 and 12.84% of habitat type 1110 is included. In scenario F a total of 18.8% of habitat type 1110 and 12.2% of habitat type 1110 is covered in this scenario. For both scenarios all predefined targets were met except for the target for gravel (target 25% vs 19% in result). These scenarios lead to 4 areas where fishery restrictions would be implemented.

The average value of landings for all fishing activities in scenario E was 3.04 mill. € and in scenario F 2.9 mill.€. Nevertheless, the landings per km² is higher in scenario F compared to scenario E. For both scenarios the relative value of landings is around 13%. The landings (€) for the Belgian fleet were only slightly higher in scenario E than in scenario F. Based on the absolute value of landings per gear type, pulse fisheries was the most important in both scenarios. Relatively, the passive fishers had the largest landings in both scenarios (22% of the BPNS). Also, the relative landings of bottom beam trawl fishery, pulse fishery and flyshoot fishery were not negligible (average landings between 15 and 19% of the entire BPNS).

Table VIII. Overview of the output of scenario E & F First: percentage of the habitat features, habitat types & biological value (BV) in relation to the entire BPNS.; Next: number of Planning Units, area, landings (in general and in overlap with the area for Renewable energy).Landings are also provided per gear type.

Scenario E	% tov BPNS
Abra	17.51
Hesionura	12.43
Magelona-Ensis	16.52
Nephtys	7.59
Limecola	0.00
gravel	19.45
Lanice	18.87
HA1170	**19.21**
HA1110	**12.84**
BV4	9.88
BV5	20.47

Scenario F	% tov BPNS
Abra	17.50
Hesionura	12.43
Magelona-Ensis	16.33
Nephtys	5.23
Limecola	0.00
gravel	19.27
Lanice	18.23
HA1170	**18.83**
HA1110	**12.23**
BV4	9.82
BV5	20.26

Scenario E	
PU (n)	161
Area (km²)	384.23
Landings (€)	3 043 667.71
Relative landings (%)	13.86
Landings (€) / km²	7 921.47
Area within RE (km²)	110.24
Landings within RE (€)	773 974.92
Landings (€) outside RE	2 269 692.79
Landings_BE (€)	348 366.13
Relative landings_BE (%)	9.82
Landings_Rest (€)	2 695 301.58
Relative landings_rest (%)	14.64
Landings_shrimp (€)	87 357.29
Landings_TBB (€)	479 499.05
Landings _PUL (€)	2 194 072.70
Landings _SSC (€)	177 991.16
Landings_OTB (€)	9 412.26
Landings_PAS (€)	95 335.25
Rel_Landings_shrimp (%)	2.10
Rel_Landings_TBB (%)	19.00
Rel_Landings _PUL (%)	16.05
Rel_Landings _SSC (%)	18.05
Rel_Landings_OTB (%)	5.06
Rel_Landings_PAS (%)	22.87

Scenario F	
PU (n)	152
Area (km²)	361.22
Landings (€)	2 933 038.26
Relative landings (%)	13.36
Landings (€) / km²	8 119.81
Area within RE (km²)	103.14
Landings within RE (€)	750 976.87
Landings (€) outside RE	2 182 061.38
Landings_BE (€)	336 932.48
Relative landings_BE (%)	9.50
Landings_Rest (€)	2 596 105.78
Relative landings_rest (%)	14.10
Landings_shrimp (€)	86 089.47
Landings_TBB (€)	459 668.33
Landings _PUL (€)	2 107 406.94
Landings _SSC (€)	175 700.41
Landings_OTB (€)	9 410.20
Landings PAS (€)	94 762.90
Rel_Landings_shrimp (%)	2.07
Rel_Landings_TBB (%)	18.21
Rel_Landings _PUL (%)	15.41
Rel_Landings _SSC (%)	17.81
Rel_Landings_OTB (%)	5.06
Rel_Landings_PAS (%)	22.73

2.4.5. Scenario G and H

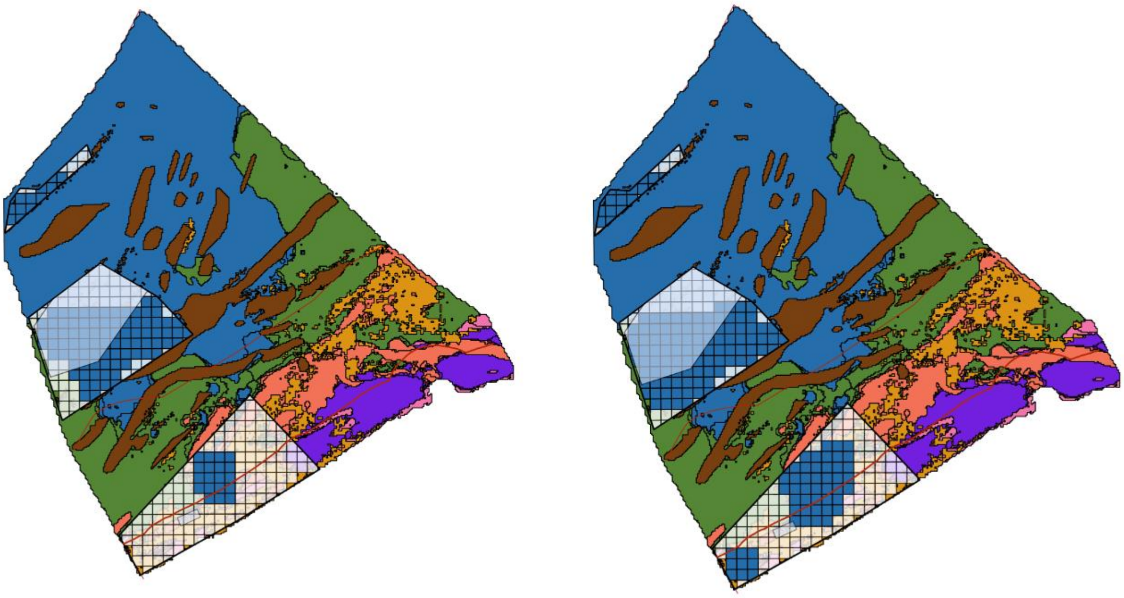


Figure 10. Map of the outputs of scenario G (left) and H (right)

In scenario G, gravel was put at 20% and all other features were weighed according to their sensitivity to fisheries while the biological value is not taken into account. In scenario H, gravel was again put at 20% but all other communities were weighed according to their biological value; sensitivity to fisheries is not taken into account.

Scenario G selects an area of 282.8 km² or 116 planning units. More than one third of the scenario overlaps with the area for renewable energy (98.44 km²). This scenario results in 3 areas for fishery restriction measures. It covers the protection of 14.18% of habitat type 1170 and 9.46% of habitat type 1110. The predefined targets were met for all the features except for gravel (target 20% vs result 18.4%). Scenario H covers an area of 396.42% or 164 planning units over 4 areas. Almost one third lays within the area of renewable energy (111.5km²). Within scenario H, 19.92% of habitat type 1170 and 13.26% of habitat type 1110 is included. The predefined targets were met for all the features except for gravel (target 20% vs result 18.9%).

Scenario G has a relative landing value of 10.58% of the BPNS or 2.3 mill.€. Within the area for renewable energy the landings account for around 707 000€. The landings for the Belgian fleet are 141 000€ or 3.98% of the entire BPNS. Scenario H has for all fisheries activities a relative landing of 13.77% of the BPNS or 3.02 mill. €. The landing for the Belgian fleet is 428 514€ which is 12% of the Belgian landings in the BPNS. The landings/km² is lower for scenario H than for scenario G.

In terms of absolute landings, the pulse fisheries had the largest value in this area. This is the case for both scenarios. In terms of relative landings, some differences between the scenarios can be noticed. Relatively the area G is most important for the fly shoot fishery (16.05%) followed by the passive fishery (14.9%). In scenario H, the area is even more important for the passive fishery (24.6%) and is also important for beam trawl fishery and pulse fishery (both 21%).

Table IX. Overview of the output of scenario G & H. First: percentage of the habitat features, habitat types & biological value (BV) in relation to the entire BPNS.; Next: number of Planning Units, area, landings (in general and in overlap with the area for Renewable energy).Landings are also provided per gear type.

Scenario G	% tov BPNS
Abra	8.07
Hesionura	11.51
Magelona-Ensis	7.29
Nephtys	4.58
Limecola	0.00
gravel	18.43
Lanice	8.23
HA1170	**14.18**
HA1110	**9.46**
BV4	5.13
BV5	16.34

Scenario H	% tov BPNS
Abra	19.93
Hesionura	12.01
Magelona-Ensis	18.99
Nephtys	8.03
Limecola	0.00
gravel	18.93
Lanice	21.30
HA1170	**19.92**
HA1110	**13.26**
BV4	12.05
BV5	20.33

Scenario G	
PU (n)	116
Area (km²)	282.77
Landings (€)	2 323 840.98
Relative landings (% BPNS)	10.58
Landings (€) / km²	8 218.13
Area within RE (km²)	98.44
Landings within RE (€)	707 298.66
Landings (€) outside RE	1 616 542.32
Landings_BE (€)	141 120.74
Relative landings_BE (% BPNS)	3.98
Landings_Rest (€)	2 182 720.24
Relative landings_rest (%)	11.86
Landings_shrimp (€)	21 932.37
Landings_TBB (€)	316 670.14
Landings _PUL (€)	1 757 336.06
Landings _SSC (€)	158 323.18
Landings_OTB (€)	7 303.05
Landings_PAS (€)	62 276.18
Rel_Landings_shrimp (%)	0.53
Rel_Landings_TBB(%)	12.55
Rel_Landings _PUL (%)	12.85
Rel_Landings _SSC (%)	16.05
Rel_Landings_OTB (%)	3.93
Rel_Landings_PAS(%)	14.94

Scenario H	
PU (n)	164
Area (km²)	396.42
Landings (€)	3 022 403.33
Relative landings (% BPNS)	13.77
Landings (€) / km²	7 624.25
Area within RE (km²)	111.50
Landings within RE (€)	786 612.91
Landings (€) outside RE	2 235 790.42
Landings_BE (€)	428 514.61
Relative landings_BE (% BPNS)	12.08
Landings_Rest (€)	2 593 888.72
Relative landings_rest (%)	14.09
Landings_shrimp (€)	93 461.32
Landings_TBB (€)	530 421.33
Landings _PUL (€)	2 873 870.55
Landings _SSC (€)	165 549.21
Landings_OTB (€)	9 644.10
Landings PAS (€)	102 704.12
Rel_Landings_shrimp (%)	2.24
Rel_Landings_TBB(%)	21.02
Rel_Landings _PUL (%)	21.02
Rel_Landings _SSC (%)	16.78
Rel_Landings_OTB (%)	5.19
Rel_Landings_PAS(%)	24.63

Table X. Overview summary of the strengths and weakness of the different scenarios. (-) not optimal scenario; (*) this scenario is less optimal, but still justifiable for reaching conservation objectives; (**) this scenario is optimal for reaching conservation objectives.

	A	B	C	D	E	F	G	H	Basic
Evaluation conservation objectives									
Reaching 10% H1110 (incl. H1170)	No	No	**yes**	**yes**	**yes**	**yes**	No	**yes**	No
All habitat features weighted according to biological value and sensitivity	**yes**	partly	**yes**	partly	**yes**	partly	partly	partly	No
Gravel beds	*	*	**	**	**	**	**	**	-
Lanice aggregations	*	*	**	**	**	**	-	**	**
Abra	*	*	**	**	**	**	-	**	**
Hesionura	*	*	**	**	**	**	**	**	-
Magelona – Ensis	**	**	**	**	**	**	**	**	**
Nephtys	**	-	**	**	**	**	**	**	**
Biological value high & very high (4 and 5) (%)	21.37	20.16	26.38	26.38	30.35	30.08	21.47	32.38	17.34
Enforceability									
Amount of areas	**3**	**3**	**3**	**3**	4	4	**3**	4	2

% overlap with area for renewable energy (Princes Elisabeth Zone)	30.87	18.59	31.61	30.41	28.69	28.55	34.81	28.13	44.63
Overlap with seafarm Nieuwpoort	yes	yes	yes	yes	yes	yes	no	yes	yes
Overlap with military use	yes	yes	yes	yes	yes	yes	yes	yes	yes
Socio-economic									
Landings (€)/km²	7808	8882	7750	7923	7921	8120	8218	7624	5769
Proposed total area for protection for bottom disturbing activities (MSP)									
Total area	252	199	333	323	384	361	282	396	323

2.5. Evaluation of the scenarios (Ranking)

Based on the weight of each habitat feature in relation to biological value and sensitivity to fishery abrasion, multiple scenarios were tested. We chose to prioritize certain habitat features in our scenario settings, instead of trying to allocate 10% for each habitat feature. The main reason is that some habitat features are biologically more valuable and more sensitive to bottom disturbing activities. Therefore, it is advisable to protect a larger area for those features to reach the conservation objectives and the environmental targets. Further, in the scenarios we tested increasing ambition levels for the habitat features to evaluate how much of each habitat feature can be optimally protected in relation to the available surface area. This scenario based approach was flexible and allowed us to prioritize and nuance with regards to the target settings for each habitat feature. It delivered consequent results and allowed us to visualize the key areas to protect.

Each of the scenarios has some strengths and weaknesses in relation to the following policy criteria: (1) conservation targets, (2) enforceability and (3) socio-economic impact. The highest priority is given to the conservation targets followed by enforceability and socio-economic impact. This means that if different scenarios are valid for reaching the conservation targets, further prioritization can be based on enforceability or socio-economic impact.

Conservation objectives and environmental targets

Several conservation targets (conservation objectives as defined in HD and environmental targets as defined in MSFD; see Table I) were defined, which benefit from protection of sufficient surface area of the defined habitat features. The potential conservation benefits derived from seafloor protection and fisheries exclusion were discussed for the different scenarios in relation to the conservation targets listed for each habitat feature. For each habitat feature in each scenario, a qualitative score (not optimal, justifiable or optimal) was given that indicated whether these scenario settings allowed the conservation targets to be reached (Table X). A scenario was scored as not optimal when the proposed target for surface area of a habitat feature as defined in the scenario settings (Table III) was not reached. A scenario was scored as justifiable if it reached the proposed target for surface area, but other scenarios were more suited in relation to surface area and the proposed surface area is around the 10% target protection value (cf Box 1). A scenario was scored as optimal when it clearly reached the proposed target for surface area and proposed a surface area well above the 10% for the biologically most valuable habitat features (gravel beds, *Lanice* aggregations, *Hesionura* and *Abra* habitat). Besides, when different scenarios were reaching the same score, we define the scenario reaching a similar protection level (around 1% difference) for the habitat features with less total surface area to protect as most optimal.

Gravel beds

Based on the HD and MSFD status reports, gravel beds are in poor condition. For this, and in combination with the high biological value and the high sensitivity of the gravel beds for fisheries, we propose to allocate most of the protected surface area to this habitat feature. This should at least allow to conserve the surface area where naturally occurring hard substrates are present (objective 7; Table I) and to allow recovery of the natural benthic communities in the gravel beds (objective 8; Table I). Scenarios C, D, E and F were considered as optimal scenarios, as they allow to protect 18.5 to 19.5% of the gravel beds on the BPNS and as they are covering almost all naturally occurring hard substrates within the search zones (20.4%) and ¼ of the gravel beds on the BPNS. The proposed PU's within those scenarios are almost identical and are covering all the key areas for gravel beds. Scenarios C and D can be considered as the scenarios to take forward in relation to gravel bed protection as they are protecting the gravel beds with a lower total protection area surface (40 km² less) in comparison to the other scenario's. They allocated only 1% less gravel bed surface as in scenario E and F and are still including the key gravel areas. Nevertheless, also scenario A and B are justifiable, as 15% of the total gravel bed surface in the BPNS is protected. In those scenarios, a smaller area in search zone 1 and at the French border in zone 2 (scenario B) is assigned for gravel beds. Scenarios G and H propose a similar area (surface area and location) as scenario C and D for protecting the gravel beds. As those scenarios are respectively based on sensitivity and biological value only, it support the fact that the key-areas (sensitive and biological value ones) are properly assigned with scenario C and D.

Lanice aggregations

Lanice conchilega may recover fast after fishery disturbance, but the associated community is more sensitive and needs a longer recovery time (Degraer *et al.*, 2010; Rabaut *et al.*, 2008). Therefore, the conservation target is to preserve the 3D structures (objective 6.1; Table I) and to ensure that the *Lanice* reef-associated species do not show a downward trend (objective 6.2; Table I). *Lanice conchilega* aggregations show a patchy distribution pattern, with the highest habitat suitability found within the *Abra alba* community (fine muddy sands). The Marxan scenarios clearly indicated the Nieuwpoort-Stroombank up to the Oostende bank area as the area most preferred to protect sufficient surface of this habitat feature. Only for the scenarios E, F and H an additional potential area for protection is defined nearby the coast and the French border (Potje – Trapegeer bank). The difference between the scenarios is that more surface area is allocated for the protection of this habitat feature from scenario A towards F, related to the increased ambition level of the scenarios. We can assume that the proposed surface area (about 10% of the surface of suitable locations for *L. conchilega* within the BNPS) in scenario A and B is rather low (justifiable, but not optimal), in relation to the importance of *Lanice* aggregations for conservation. Therefore, scenarios C, D, E and F are probably more suitable, as we preserve 16 to 18% of this habitat feature, which creates a better opportunity to reach the conservation targets for *Lanice* aggregations. In scenario H, the surface area goes up to 21% and this is the scenario where there are additional PU's allocated to the area at the coast with the French border. Nevertheless, scenario H allocated based on biological value the same area (Nieuwpoort-Stroombank up to the Oostende bank area) as for scenarios C, D, E and F, indicating that this is the key area and the rest additional. Scenario G is not optimal, as it does not allocate enough area (<10%) in relation to *Lanice* aggregations. In this case, scenarios Cand D can also be considered as the scenarios to take forward. This because, E, F and H, compared to C and D, are adding relatively less additional surface area for *Lanice* aggregations in relation to the total surface area to protect (40 to 60km² more).

Benthic communities

The protection of the *Hesionura elongata* community is linked with the protection of the gravel beds. The soft-sediments in the potential gravel bed areas are characterized as *Hesionura* community, which therefore ensure that protection of certain areas is in the benefit of both habitat features. The same accounts for the *Abra alba* community and *Lanice* aggregations. The conservation target for benthic communities is to increase the frequency of occurrence of vulnerable and benthic key-species (objective 3; Table I; Table XI). Based on Table XI, it is clear that the habitat preference of most of these species is associated with the *Abra* and *Hesionura* community, stressing the importance to protect those communities. Based on the scenario target settings (Table III), 10.5 (scenario A), 14 (scenario C) and 17.5 % (scenario E) of the *Abra* community is targeted to protect. For the *Hesionura* community, a target of 6 (scenario A), 8 (scenario C) and 10 % (scenario E) is proposed in the scenario target settings. All scenarios reach the target for the *Abra* community exactly, whereas for the *Hesionura* community the proposed area is covering a higher surface area (+ 2% on average) than targeted. For the scenarios (B, D and F), where no specific target was set for the *Hesionura* community, a similar surface area for the *Hesionura* community to protect was proposed as in scenarios (A, C and E). Probably, to restore the populations of the vulnerable and benthic key species in both communities, we should allow to protected enough surface, ideally well above 10%. This target is clearly reached for scenarios (C, D, E, F and H), which protect 11 to 12% of the *Hesinura* habitat and 14.5 to 17.5% of the *Abra* habitat and those values are all above the 10% target protection value.

Table XI. Overview of habitat preference for the vulnerable and benthic key species as defined for the MSFD (Belgische Staat, 2018b) and HD (Belgische staat, 2021).

	Abra	*Magelona-Ensis*	*Nephtys*	*Hesionura*
Aphrodite aculeata	x	x	x	x
Chaetopterus variopedatus				x
Branchiostoma lanceolatum				x
Buccinum undatum				x
Corystes cassivelaunus			x	x
Dosinia exoleta				x
Echinocardium cordatum	x		x	
Glycymeris glycymeris				x
Laevicardium crassum				x
Lagis koreni	x	x		
Lanice conchilega	x			
Lutraria lutraria	x			
Mya spp	x			
Owenia fusiformis	x			
Venerupis corrugata	x			

In relation to the conservation of the *Magelona-Ensis* community, all scenarios fit as they all reach the minimal proposed target for surface area, as defined in the scenario settings (Table III). In scenario A-B, it is 1% above the proposed 6% scenario target, whereas with scenario C, D, E and F even a surface area up to 16.5% is proposed. Scenario G and H are also reaching the scenario target clearly (up to 19%

in scenario H). For the scenarios (B, D and F), where no target is set for this community, the scenarios still ensure the protection of similar surface areas as in scenarios (A, C and E). Any of those scenarios were optimal for the conservation of the *Magelona-Ensis* community, as for this less biological valuable and less sensitive community a general 10% target protection value is not necessary for reaching the conservation targets for benthic habitats.

For the *Nephtys cirrosa* community, it is clear that it is incorporated in a (much) lower amount in the proposed areas when no specific target is set for this community (scenario B, D and F). Especially, in scenario B, this community is not protected at all (only 0.5%), which is not optimal. Protection of the *Nephtys cirrosa* community is not a priority, as it has a low sensitivity to fishery and only a few key species (Table XI) are present. Therefore, the proposed target is low and a 10% target protection values is not necessary. Nevertheless, a low amount (at least 4%) should be considered as the protection of all habitat features will ensure that the benthic ecosystem provides sufficient food for higher trophic levels (objective 4;Table I). This target is reached with all scenarios, except scenario B.

In conclusion, for reaching the conservation objective of preserving the ecological quality of each occurring habitat feature (objective 5; Table I), only scenario B and G are not optimal. The other scenarios include sufficient surface area (reaching the proposed targets) in the proposed protection zones to serve in reaching the conservation objectives. Nevertheless, we can put scenario C and D forward as the most optimal scenarios for reaching the conservation goals, based on the fact that they clearly reach the proposed targets for all habitat features with the lowest total surface to protect.

Overarching conservation objectives

Some of the conservation objectives will be reached in all areas closed for bottom disturbing activities.
As to maintain or enhance the function of shallow sandbanks as spawning and nursery areas (objective 2; Table I), it is important to protect an area offshore and one within the coastal area of the BPNS. The offshore area and more specifically the gravel beds are for example important for herring (Houziaux *et al.*, 2007, 2008, 2011). The coastal area is for example important as nursery area for flatfish like sole (Pecceu *et al.*, 2020; *www.geofish.be*).
The protection of all habitat features will ensure that the benthic ecosystem provides sufficient food for higher trophic levels (objective 4; Table I; Table III**Error! Reference source not found.**).
Another general conservation objective is that “The spatial range of habitat type 1110 does not change meaningfully” (objective 1; Table I). This relates to spatially-explicit abrasion that may uncover coarser sediment layers, or to smothering which may lead to burial of coarser substrates. It is unlikely that fishing activities would change the distribution of soft sediment habitats. For gravel beds, the primary concern is loss of structure and function by the removal of pebbles and cobles, but also burial is of concern and may be caused by several human activities, whether or not in concert (e.g., cumulative impact). This burial aspect is evaluated in objective 7, as the ratio of soft versus hard substrate. Therefore, the high surface area targets set for gravel beds will contribute strongly in reaching those conservation targets.
In relation to the MSFD, there is a pressure indicator striving for more seabed area, which is permanently protected from bottom disturbance by fishing gear (objective 9; Table I). Obviously, closing areas for bottom disturbing fisheries are needed to reach this target.

Enforceability and synergy with other bottom disturbing activities

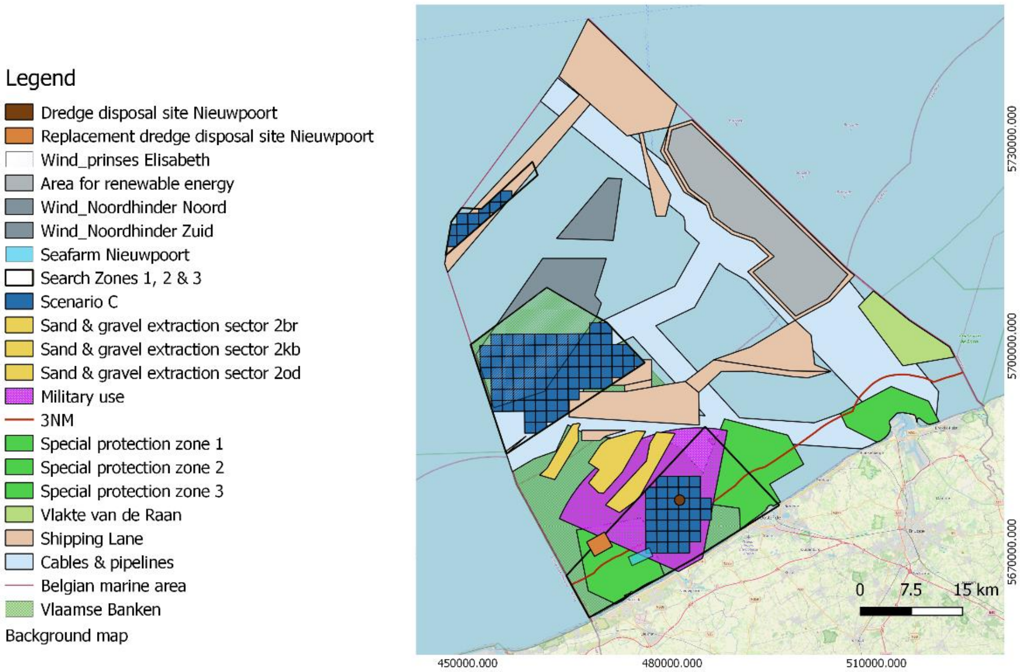


Figure 11. Map of scenario C in combination with the activities from the MSP 2020-2026 in and around 'Vlaamse Banken'

In relation to enforcebality, it is more optimal to protect a few larger areas compared to several smaller areas. This aspect is already taken forward in the scenario development with forcing Marxan to highly connect the planning units and keep the boundary length as low as possible. Scenarios A, B, C, D and G have appointed 3 potential areas for fisheries measures. This makes them slightly more enforceable (and optimal) than scenarios E, F and H where 4 areas were selected.

If bottom disturbing fischeries are excluded form an area in order to protect the seafloor and the hatitats are also impacted by other human activities, it will need carefull management or it will have to be excluded.

The current areas for sand extraction are located outside the search zones but search zone 1 overlaps with a zone for research of the potential for exploitation for aggregate extraction. In all the scenarios, planning units in search zone 1 are selected. If bottom disturbing fishing techniques are excluded form (parts of) this zone to protect bottom integrity and the gravel beds also sand extraction needs to be banded.

For the selected units in search zone 1, there is also overlapping with the shipping lane, but this has no consequence for seabottom protection measures.

All the scenarios overlap with the dredge disposal site of Nieuwpoort (Dredge disposal Nieuwpoort), but none of the scenarios overlap with the proposed replacement area included in the MRP 2021-2026. Thereforeit will be needed to carefully look at the current dredge disposal site and develop a strategy to to halt his use, as dredge disposal is seafloor disturbing.

All the scenarios except G overlap very slightly with the 'seafarm Nieuwpoort' area. As aquaculture activities can influence the bottom integrity (e.g. organic enrichment, species dropp-off), this aspect need also to be taken into account in the management of this 'seafarm Nieuwpoort' area.

All the scenarios also overlap with the potential area for renewable energy (Princess Elisabeth area). The smallest overlap with the renewable energy zone is in scenario B (18.6% of the total scenario area), whereas the largest overlap is in scenario G (34.8%). In scenario E, F and G around 28% of the total selected area is lying in the area for renewable energy; scenario A, C and D have respectively 30.8, 31.6 and 30.4% overlap. A high overlap can be preferable (cf respectively scenarios G, C, A and D) as this Princess Elisabeth area will most likely be closed for fishing with mobile bottom contacting gears for security reasons (MSP 2021-2026). Of course, this under the restriction that the planned offshore windpark will not hamper in reaching the conservation targets, which is currently investigated by RBINS.

The protection zone in search zone 3 also overlaps completely with the area for military activities in all scenarios, therefore also possible effects of the military activities need to be analysed and mitigation measures should be proposed where necessary.

Socio-economic

For evaluating the socio-economic difference between the scenarios, the total landings (€) per km² is the most valuable summarizing parameter. The importance for fishery for each search zone is described in detail in chapter 6.

The total landings per km² was the highest in scenario B (8882€/km²) and the lowest for scenario H (7624 €/km²). The Dutch fishers were mostly active in search zones 1 and 2 ; the Belgian fishers were mostly active in search zone 3, near the coast and a bit in search zone 2. The shrimp fishery is active near the coast (search zone 3) but the proposed area within this zone only have has a limited impact (maximum 2.2% of the landings in the BPNS). The flyshoot fishery was more active offshore especially in search zone 1. As all scenarios propose to close areas in zone 1, they all have a clear consequence for the flyshoot fishery.

MSP proposed total area for protection for bottom disturbing activities

In the Marine Spatial plan, it is included that measures to conserve bottom integrity would not exceed 285km². Only scenario A, B and G stay below this 285km² limit. Scenario C and Dare larger than initially proposed in the MSP (respectively 48 or 38km² more). The other scenarios are much larger than the proposed total surface area and probably need to be reduced for the final delineation.

2.6. Monetary valuation of ecosystem services, in relation to conservation measures

The total economic value (TEV) of an ecosystem is not only given by the direct use value, but also by optional and indirect use values, and importantly, also by non-use values (Bertram and Rehdanz, 2013) (Figure 12). Within the use value of an ecosystem, indirect uses and optional uses are allowed, and restored, only when pressure from direct use is lifted. Within the indirect uses of an ecosystem, the ecosystem services are included. Ecosystem services are the benefits that society obtains from natural ecosystems, and that sustain, improve and allow human wellbeing (Millennium Ecosystem

Assessment, 2005). They comprise both consumptive goods provisions, but also the maintenance of ecosystem functions and processes driven by natural resources left untouched.

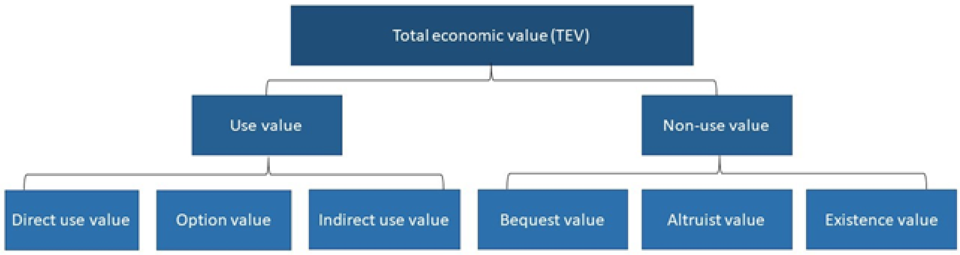


Figure 12. Scheme of the several subcategories identifying the use and non-use value of the environment contributing to its total economic value. Use value includes direct use value (removable products in nature), indirect use value (non-removable products and services), and option value (the potential future availability of a resource to be used). Non-use value includes bequest value (the satisfaction from preserving a natural resource or ecosystem), altruist value (the preservation for future generation), and the existence value (the value of knowing a certain natural resource or ecosystem exist).

Therefore, when assessing the socio-economic costs derived from the restriction of human activities from a natural area for protection, the economic values of the natural resources in the area left untouched should also be considered in the total sum. In fact, natural resources left in the water, including those with no commercial value, hold an underestimated monetary value. It is difficult to estimate the monetary value of ecosystem services, and previous studies on global valuations have turned out to have continuously and greatly undervalued ecosystem services across the world (Costanza *et al.*, 1997; Costanza *et al.*, 2014). However, approximations are evolving as more knowledge is being gathered and average numbers are available in literature. The areas delineated for the implementation of fisheries measures in the BPNS may be considered part of the open waters or the coastal systems, each type of ecosystem providing a series of ecosystem services (Table XII). Open water environments are food sources and carbon sinks, of which conservation guarantees food security and climate regulation. Furthermore, open waters ecosystems hold a great recreational value (De Groot *et al.*, 2012; Costanza *et al.*, 2014). Coastal systems provide a larger and more profitable variety of ecosystem services, additionally representing nursery habitats and reserves of genetic diversity. The most economically valuable service provided by coastal system is erosion prevention, which develops its potential only when the ecological integrity is maintained as well (De Groot *et al.*, 2012; Costanza *et al.*, 2014).

Finally, another potential economic value to consider in the trade-off is the public willingness to pay (WTP) for marine conservation. The public WTP represents the money that societal members (often under the form of household units) would be willing to spend for the conservation of nature (Bertram and Rehdanz, 2013). The indicator is especially suitable to capture a part of the monetary value hold within an ecosystem non-use value (Brouwer *et al.*, 2016). As an example, in the Netherlands the public WTP for the conservation and management of remote MPAs in the Dutch part of the North Sea was estimated in 2016 by means of surveys carried to more than 1200 coastal and non-coastal households, highlighting a range of WTP between 56 and 170 euro per household per year.

Therefore, when considering the implementation of restrictions on human activities and extractions from the marine environment (e.g. fisheries measures) the cost-benefit analysis should not only account for the socio-economic losses due to restriction on fisheries activities but also account for the socio-economic gains obtained through the preservation of the other economic values that are not linked to the direct use of the marine resources.

Table XII. Monetary value of main ecosystem services provided by marine ecosystems expressed in dollars per hectare per year. Values represent global averages of the considered marine ecosystem calculated with the market status of 2012 by De Groot et al. (2012) and Costanza et al. (2014).

Services	Open waters	Coastal systems
Food	93	2384
Climate regulation	65	479
Erosion prevention	-	25368
Nursery	-	194
Genetic diversity	5	180
Recreation	319	256
Total	**491 $/ha/year**	**28'917 $/ha/year**

2.7. Additional reflections of the science community

On the 14th of June 2021, a meeting was organized within the science community to collect some additional knowledge on the study area. The entire process is based on a high amount of data, which is transformed into models to give us the best insights in where the valuable habitat features are expected. This process is complemented with some reflections from the stakeholders knowing the area. Validation of the process by expert knowledge is very valuable and creates a wider support base.

Following major suggestions were raised:

1) Validation of the gravel bed areas in terms of their biodiversity potential, including occurrences of relict fauna (input delivered by Giacomo Montereale-Gavazzi, RBINS ODNature)

An extra validation exercise was executed on the areas that resulted from the Marxan analyses with the goal of further prioritization of gravel bed areas. Therefore, the selected Planning Units (PU) as described in this report were further scrutinized against multiple analyses and disparate datasets, acquired and produced in the framework of the research summarized in Montereale-Gavazzi (2019; *et al.*, 2020a; b, and Montereale-Gavazzi *et al.*, (in prep.), and references therein). This included both state-of-the-art 1) high resolution seafloor predictive models and 2) ground truth data (i.e., video and Hamon grab samples) that spatially constrain gravel bed areas.

A data overlay in a geographical information system environment (Figure 13) enables the sub selection of the PU file, selecting locations coinciding with areas of high ecological value, defined in terms of e.g., presence of MSFD monitoring indicator species (as observed from video and/or grab sample data; see monitoring program (*https://odnature.naturalsciences.be/msfd/nl/monitoring/2020/#ANSBE-P9-Benthos-4-hard-substrate*), and modelled predictions of abiotic parameters of key interest (i.e., by means of acoustic seafloor classification) i.e., geogenic and/or coarse bioclastic resources, providing the means for biological colonization by gravel bed fauna.

Furthermore, the prioritization of the selected PU units is also based on consideration relating the potential for habitat restoration (i.e., search zone 2; Hinder bank area). Indeed, besides the exclusion of active bottom disturbing practices (i.e., bottom trawling), restoration landings would considerably benefit the ecological value of part of the units selected within search zone 2 (coincident with large scale depressions), where, besides *refugium* (i.e., gravel bed biodiversity hotspots) areas, the ecological preconditions required for the establishment of the typical gravel bed community have been historically depauperated.
The units selected within search zone 1 (northwesternmost area of the Belgian continental shelf), coincide with relatively rich and diverse natural hard substrate epibenthic communities with abundant and well-developed (i.e., adult colonies/individuals, vertically and horizontally developed, arborescent fauna) key focal species such as the soft coral *Alcyonium digitatum*. The presence of such species, in such configuration, confirms the relative absence of bottom fishing activities, hence providing an invaluable "regional biological status reference" for an ecologically sound design and implementation of gravel bed habitat restoration landings elsewhere.

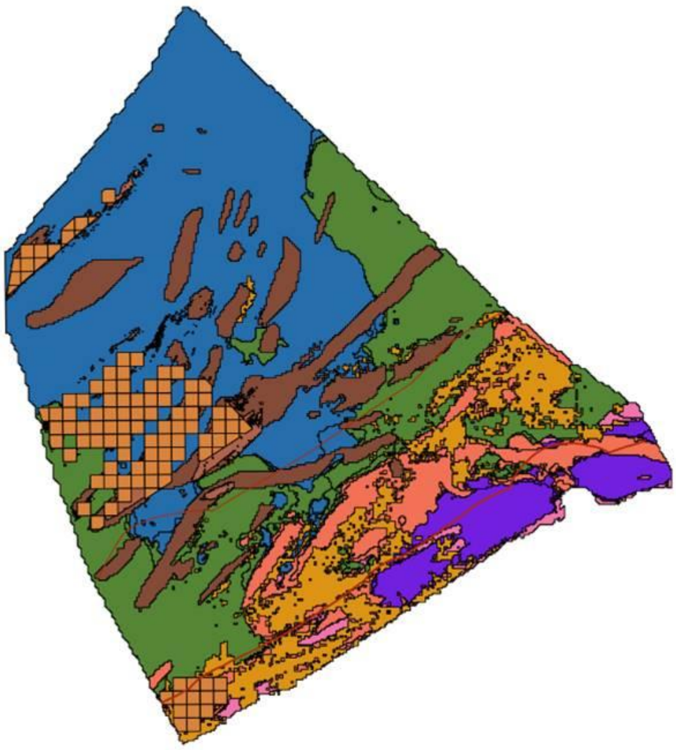


Figure 13. Confirmation of the PU units (orange cells) with ecologically-relevant gravel occurrences as provided by Giacomo Montereale Gavazzi (RBINS ODNature).

2) In the previous process (MSP 2014-2020), the coastal area from the French border to Nieuwpoort (named Zone 1 in the previous process) was considered as a protection zone, but seems not to pop-up any more in most scenarios (except E, F). Why?

The coastal area from the French border to Nieuwpoort is known for its heterogeneous habitat mixture and is indeed containing a lot of the important benthic habitat features (*Lanice, Abra, Nephtys, Magelona-Ensis*). Nevertheless, when we want to reach the conservation targets of those habitat features, based on the Marxan analysis, it can be reached more optimally when selecting the area between Nieuwpoort and Oostende. This area contains more of the desired habitat features so the conservations objectives can be reached in a consistent way. A part of this area is also overlapping with the previous zone 2 of the MRP of 2014-2020, where only alternative fishing gear was allowed. The proposed area in Search zone 3 seems to contain the required habitat features and has therefore the right potential to reach the conservation targets, when bottom disturbing activities are banned.

3) Required size of the protection areas?

The strategy followed here is to strive for a few larger areas rather than several small ones. This strategy was also endorsed by the stakeholders. Due to the habitat patchiness in the Belgian Part of the North Sea, it is advisable to protect larger areas, which include the mosaic of habitats and its gradients. Therefore, the selection of 3 to 4 larger areas is well supported.

2.8. Preferred allocation of the protection zones for bottom disturbing activities

The followed procedure is unique within Europe and combines different concepts (biological value, sensitivity, space usage (e.g. fishery economics), the Marxan decision support tool) to come to an integrated and scientific based allocation of the areas to protect. Based on this procedure, we prefer to put scenario C-D forward as protection zones.

Scenario C-D are the scenarios which are combining most strengths in relation to reaching the conservation objectives following the evaluation criteria. Scenario A is considered as the third relevant scenario.

- Scenario D is identical to C as it only includes the *Nephtys cirrosa* community a little bit less.
- Conservation targets have a high potential to be reached when following scenarios C-D, as key areas for each habitat feature are sufficiently included. For the most sensitive (gravel beds) and biological most valuable habitat features (gravel bed, *Lanice* aggregations, *Abra* habitat and *Hesionura* habitat) more than 10% of their surface area on the BPNS will be protected. And for all habitat features the proposed scenario targets (Table III) are met with scenario C-D.
- Three protection areas are defined: one in each search zone. It is important to cover all habitat features. All habitat features are present within the search zones 2 and 3 area, but an area in zone 1 is also needed to protect enough gravel beds (> 10%).
- There is a relatively high overlap with the renewable energy area (second highest scenario). A high overlap can be preferred as this area will be closed for fishing with mobile bottom disturbing gear for security reasons.
- The socio-economic consequence (landings (€)/km²) is ranked medium in comparison to the others.

Therefore, the grid file of scenario C-D can be used as basis to shape the areas that will be closed for bottom disturbing activities. This will be done in relation to the marine spatial plan and stakeholder consultations.

3. Habitat suitability and biological value mapping

3.1. Introduction

3.1.1. Scientific tools for protected area delineation

The BPNS is a small but extremely busy area which requires a highly strategic and comprehensive management in order to regulate human activities, resolve spatial conflicts while ensuring marine conservation (MSP 2020-2026). The identification of areas with high natural value and consequently high priority for conservation is fundamental to promote solutions that gain the best ecological outcome with the least socio-economical cost. A delineation procedure that set the biological value as the first and most important criteria to identify such areas is meant to succeed in representing the different habitats and ensure that nature conservation and restoration is pursued at best. The biological valuation map (BVM) is a map showing the intrinsic biological value of each area, thus independently from its socio-economic benefits, in relation to the value of any other area therefore highlighting the relative importance of an area. The intrinsic biological value is based on a series of assessment questions quantifying rarity, aggregation, fitness consequences, naturalness, and proportional importance in samples and habitats. Different ecosystem components can be assessed and integrated into a final product of total biological value that is very well suited for uses in habitat delineation and prioritization in conservation. Furthermore, the results of the analyses of available observations and samples from monitoring programmes can be combined with habitat suitability mapping of benthic communities and species obtaining a map with full-coverage model predictions supplemented by additional insights and ground truthing. This integrated assessment approach has already been used for the development of a marine BVM of the BPNS and the Belgian coastal zone (Derous *et al.*, 2007a; Vanden Eede *et al.*, 2014). The assessment concept behind the BVM was described by Derous *et al.* (2007a, 2007b) and was originally applied to the BPNS. The standardization of the tool facilitated its successful application in other European waters (Gomes *et al.*, 2018; Pascual *et al.*, 2011; Weslawski *et al.*, 2009). The objectivity of the biological valuation is beneficial in protected area delineation as it avoids that the area selection is steered by several marine users towards a less costly but less effective choice. However, the marine BVM should be considered as an information tool with no attribute on potential recovery and implementation success, and that therefore needs to be accompanied by decision-making tools and criteria if used in the context of seafloor prioritization for conservation.

Seafloor integrity is not evident to assess through sampling and monitoring, and good environmental status indicators may change according to scale and conditions. Both human impact and benthic features are patchy and heterogenous, making samples alone unrepresentative of the reality unless they are supported and integrated into predictive models (MSFD Task Group 6 Report; Reiss *et al.*, 2015). Predictive modelling methods (also called *habitat suitability models (HSM)*) have increasingly played important roles in ecosystem management and habitat assessment because of their capacity to overcome the difficulties related to sampling representativeness and because their application in the North Sea have proved useful (Degraer *et al.*, 2008, 2009; Reiss *et al.*, 2011, 2015; Gogina *et al.*, 2010, 2020). One of the greatest values of habitat and species distribution modelling is the production of full coverage maps at the level of the study area considered. Distribution maps virtually visualize the occurrence of a resource or a feature representing an easy tool for different stakeholders in nature conservation, sustainable management, and conflict resolution at sea. The modelling products identify the spatial range and most suitable distribution area for a certain species, community or ecological feature given the environmental variables that influences its distribution acting like limiting factors, disturbances or resources and are often cost-effective making use of large-scale high-resolution environmental data obtained from available remote sensing tools (Thuiller & Münkemüller, 2010; Reiss *et al.*, 2015; Birchenough *et al.*, 2010). Small-scale heterogeneity and morphological features have proven to be crucial descriptors of benthos distribution (Degraer *et al.*, 2008; Merckx, 2011; Reiss *et al.*, 2015; Van Lancker, 2012, 2017; Breine *et al.*, 2018). Furthermore, benthic ecosystems are well suited for habitat suitability modelling because several benthic species are long-living, sessile/low mobility species with specific environmental requirements that highly represents their habitat surroundings (i.e. bioindicators) (Birchenough *et al.*, 2011).

3.1.2. Aim of the chapter and specific goals

The aim of this project chapter is to identify the most biologically valuable zones within the BPNS evaluating the distribution and the ecological characteristics of the seabed inhabiting macrobenthic, epibenthic and demersal fish communities. The focus of the research strategy is given to seafloor integrity, mapping the updated habitat suitability of the different macrobenthos communities, the occurrence of gravel beds and the habitat suitability of *Lanice conchilega* aggregations, and updating the biological valuation map of the BPNS reviewing the assessment questions used for its development.

The specific goals of this project chapter are the following:

- Update the habitat suitability maps of each macrobenthos community
- Update the potential distribution of gravel beds
- Update the habitat suitability map of *Lanice conchilega* aggregations
- Update the habitat suitability map of epibenthos and demersal fish communities
- Update the assessment questions for the biological valuation map development
- Update the total marine biological valuation map
- Identify and describe the most biologically valuable areas

3.2. Material and methods

3.2.1. Data availability

3.2.1.1. Biological data

A total of 2943 macrobenthos samples collected in the BPNS between 1994 and 2018 within the framework of several projects were compiled in this study selecting only one autumn sample replicate per sampling location in case more than one replicate was collected during the same year. All samples were collected with a Van Veen grab and sieved through 1 mm mesh-size roughly sampling 0.1 m^2 surface area and penetrating ~10 cm. Organisms were identified up to the species level when possible and counted for species-specific densities (ind/m^2). The entire dataset was used for the BVM exercise where species number per sample and density values were used to answer the different assessment questions. Within the BVM exercise an additional 1408 epibenthos and demersal fish samples collected in autumn in the BPNS between 1994 and 2018 were compiled and added to the dataset. Epibenthos and demersal fish samples were retrieved trawling for 30 (before 2010) and 15 (after 2010) minutes at 3.5 knots using an 8 meters beam trawl with a mesh size of 22 mm (stretched). Organisms were identified up to the species level when possible and counted for species-specific densities standardized to a surface area of 1000 m^2.

For the HSM exercise, only the samples that were consistently classified into one of the five recognized macrobenthos communities (see section 3.2.2.1 on cluster analysis) and that were accompanied by all the associated environmental variables were retained. This corresponds to a final dataset of 1412 macrobenthos samples.

3.2.1.2. Environmental data

Median grain size (µm), sediment mud content (% < 63 µm), water depth (m), rugosity, bathymetric position index (BPI), salinity (PSS), chlorophyll (CHL) P10, P50 and P90 concentrations (µg/L), suspended particulate matter (SPM) P10, P50 and P90 concentrations (mg/L), and sea surface temperature (SST) P10, P50 and P90 (°C) were tested as potential environmental predictors of the macrobenthos community distribution within the HSM exercise. *In situ* measurements for median grain size and sediment mud content were available for most of the macrobenthos samples (see section 2.1.1) after sediment analyses through a sieving tower or via laser diffraction (Malvern Mastersizer 2000G hydro version 5.40). Fractions were determined as volume percentages according to the Wentworth scale. The median grain size was calculated excluding fractions above 2 mm in samples after 2008, while before 2008 the calculation was limited to fractions below 850 µm. Full-coverage maps were available for all environmental predictors and were first used to extract values at sampling locations for the model development (except for median grain size and sediment mud content available as *in situ* measurements), and later used as environmental input layers for the map projection. A high resolution (20 m) bathymetric map was used from Flemish Hydrography (*https://www.afdelingkust.be/en/flemish-hydrography*). Since the digital terrain model is compiled from single- and multibeam datasets, a resampling was done to a 200 m resolution, after which rugosity was calculated (method: nearest neighbour using a 3x3 neighbourhood size). Rugosity is expressed between 0 (no terrain variation) and 1 (complete terrain variation) and is a proxy of benthic diversity (Lauria *et al.*, 2015). Benthic position index was available from broad-scale (inner radius 1 m; outer radius 80 m; scale factor 1600), and fine-scale calculations (inner radius 1 m; outer radius 12 m; scale factor 240) using the 20 m bathymetry grid (RBINS contribution to EMODnet-Geology project, Kint *et al.*, 2019). RBINS further provided maps of median grain size and sediment mud content at a resolution of 200 m following updates of the Belspo TILES seabed substrate knowledge base (Van Lancker *et al.*, 2019). Most recent sediment data were incorporated, standardized and interpolated geostatistically following the approach of Verfaillie *et al.* (2006). Salinity was retrieved at sampling locations through the LifeWatch program (*www.vliz.be*). Finally, satellite data after 1998 were available for CHL, SPM and SST at the Remote Sensing and Ecosystem Modelling team of RBINS. Values before 2017 were interpolated using the technique called Data *Interpolating* Empirical Orthogonal Functions (DINEOF) at a resolution of 1 km, while values from 2017 are extracted from the Sentinel-3 satellite archive and have a resolution of 300 m. Variables represent values at surface, but we assumed proportionality with water column values. No satellite data were available before 1998, therefore the samples collected before 1998 were not used for the habitat suitability modelling exercise but only for the biological valuation.

3.2.2. Habitat suitability modelling

3.2.2.1. Updated community classification

The distribution of distinct macrobenthos communities in the BPNS was mapped by Degraer *et al.* in 2008. Recently, the classification and the features of the macrobenthos communities in the BPNS was updated and an additional community was distinguished thanks to a large number of standardized samples compiled over time (Breine *et al.*, 2018). As the current dataset additionally includes data until 2018, the classification into five communities was updated again and performed over the entire dataset following the same methodology. As in Breine *et al.* (2018) few rounds of cluster analysis were first performed to exclude extreme outliers which were located far apart from any cluster group. Furthermore, only samples that were consistently assigned to a certain community in both the previous and updated cluster analyses (which thus have a higher probability of being correctly classified) were retained from the final cluster groups in order to enhance the discrimination among communities and improve the predictive power of the habitat suitability model. From the initial 2943 macrobenthos sample, this corresponded to 841 samples being excluded and 2102 samples classified into five communities: the *Abra alba* community, the *Hesionura elongata* community, the *Limecola balthica* community, the *Magelona-Ensis* community and the *Nephtys cirrosa* community. After further exclusion of samples incomplete of environmental predictors, a final dataset of 1412 samples classified in communities was used for the modelling exercise (Figure 14).

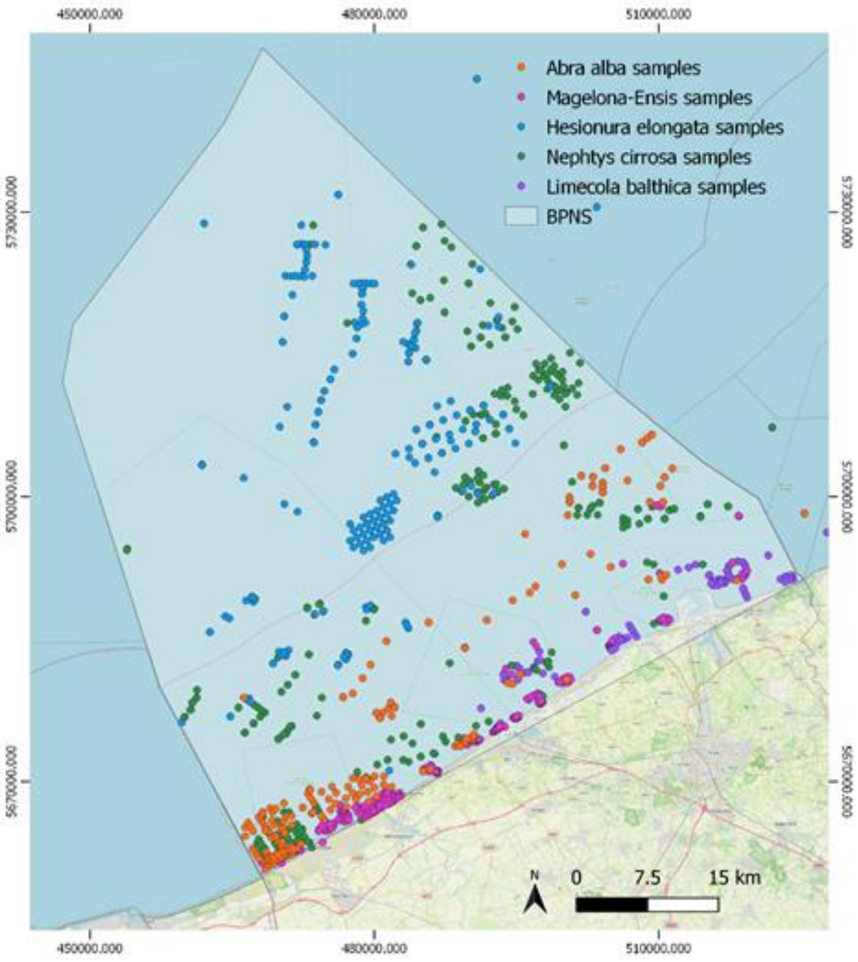


Figure 14. Macrobenthos samples per community collected across in the Belgian part of the North Sea between 1994-2018 selected for the habitat suitability modelling exercise after exclusion of samples with uncertain assignment and incomplete of environmental predictors.

3.2.2.2. *Data exploration*

Potential collinearity among all environmental predictors was tested calculating pairwise Spearman's rank correlation coefficients and the variance inflation factor (VIF) in the statistical environment R. A threshold of 0.70 and 3 was applied, respectively. High collinearity was found between salinity and the SPM percentiles (> 0.90 correlation coefficients and >10 VIF). SPM is known to be an environmental driver in community distribution, while salinity is not expected to shape benthic assemblages in the BPNS as the water column is locally well mixed and species are adapted to tide-induced changes (Gogina *et al.*, 2020). Thus, salinity has been excluded from the list of potential environmental predictors. Percentiles of SPM, CHL and SST were also collinear among each other within each variable. Therefore, each percentile was tested separately in both univariate and multivariate models, and the best explanatory percentile was retained for the model selection.

3.2.2.3. *Modelling techniques, model selection and validation across techniques*

Generalized linear models (GLMs) and generalized additive models (GAMs) were used and developed using the Integrated Nested Laplace Approximation with Stochastic Partial Differential Equation (INLA-SPDE) Bayesian approach in R to construct binomial models predicting the occurrence of each community using presence-absence data in relation to given explanatory variables (*www.r-inla.org*). The two statistical regression modelling techniques are not new in habitat suitability modelling because they allow for a transparent stepped model construction and an easy outcome interpretation (Gogina *et al.*, 2010; Furey and Rooker, 2013). GLMs are similar to the statistical methods used in linear modelling but may also use parametric functions in a combination of linear, quadratic and cubic terms. GAMs are a non-parametric form of GLMs where the relationship between response and explanatory variables are predicted without specifying the underlying regression functions nor the distribution of the data. The use of smooth functions as regression makes GAMs flexible in modelling non-linear or non-monotonic response curves highlighted by GLMs, as long as an excessive smoothening of the regression functions and overfitting are prevented by using selection and validation metrics (Furey and Rooker, 2013). Furthermore, the frequentist approach of Bayesian statistics outcomes probability distribution instead of fixed parameters for the estimated relationships among variables. However, regression methods that assume data independency may be inappropriate in species distribution modelling if spatial or temporal dependency are not considered (Dyer *et al.*, 2017). In fact, a well-known problem in species distribution modelling is spatio-temporal autocorrelation. Temporal autocorrelation arises from seasonal and time-series sample design, but in this study it was minimized by selecting one sample replicate per year during the autumn collection. On the other hand, spatial autocorrelation is an inherent problem of ecological data as it represents the higher similarity of variables at nearby sites compared to sites that are further away (Guélat and Kéry, 2018; Dyer *et al.*, 2017; Record *et al.*, 2013). Furthermore, some spatial correlation between observations and their geographical distance may derive from asymmetric sampling distribution and landings in the dataset as a consequence of the compilation of different studies and monitoring campaigns. In order to account for model residual spatial autocorrelation (i.e. spatial structure in residuals after the covariates effect have been accounted) and reduce the chances of misleading estimations and predictions, a spatial random effect was included in each model (Lezama-Ochoa *et al.*, 2020). The spatial effect is a Gaussian random field that is fit to the data to approximate the effects of spatial correlation building a numeric vector that pairs observations to location to account for the variance not explained by covariates (Lezama-Ochoa *et al.*, 2020; Dyer *et al.*, 2017). The construction of the spatial random field around the meshed data and its inclusion in the model development and fitting followed the detailed instruction presented in the books of Zuur, Ieno and Saliev (2017) and of Blangiardo and Cameletti (2015). Specific functions of the package INLA in R were used. Firstly, a mesh was fitted through Delaunay triangulation around the data locations and a spatial random field was created using a parametrization dependent on the dimensions of the study area. As the BPNS has a similar extent to the study case presented in Chapter 21 of Zuur *et al.* (2017), the same parameters were chosen. Secondly, environmental factors and the spatial random field are stacked together to be tested against the response variable. The best and most parsimonious GAM and GLM INLA-SPDE models were selected for each community by retaining only significant environmental predictors and minimizing the Deviance Information Criterion (DIC). Model diagnostics and 10-fold cross-validation were applied on the selected models to evaluate their fit. Finally, the performances of both selected models per community were compared looking at the average accuracy (i.e. the ratio between correct assignment of predictions over total observations in a test dataset), the average area under the receiver operating characteristic curve (AUC) (i.e. area below the True Positive rate over False Positive rate function; good above 0.7), and the pseudo-R^2 (i.e. McFadden's goodness-of-fit and proportion of variance explained by the model). Therefore, the habitat suitability modelling exercise resulted in the selection of one best model per community.

3.2.2.4. *Habitat suitability mapping*

Habitat suitability maps were produced for each community by projecting the posterior means of the fitted values predicted as probability of occurrence (between 0 and 1) by the best models. Projection was done over the BPNS full coverage maps of the environmental predictors using a combination of the *raster* package in R and the geographical information system QGIS. All environmental layers were aligned to be stacked together prior to predict full-coverage probabilities. The final resolution for all habitat suitability maps is 200 x 200 m.

3.2.3. Marine biological valuation map

3.2.3.1. *Framework and development from previous work*

The BVM shows the intrinsic biological value of each study area unit (i.e. a grid cell of a resolution of 200 x 200 m) relative to the value of any other study area unit within the BPNS. Therefore, the BVM is a tool to display relative biological importance of areas, highlighting both units with higher and lower than average values based on a series of assessment questions which aim at displaying information on the criteria of rarity, aggregation, fitness consequences, naturalness, and proportional importance (Derous *et al.*, 2007a). The justification for the selection of the criteria, the protocol for performing a marine biological valuation, and its application to various ecosystem components of the BPNS are thoroughly explained in the BWZee project report where the BVM was originally developed (Derous *et al.*, 2007b). The set of assessment questions were decided by Derous *et al.* (2007b) after an extensive review and judgement based on literature and experts' input. The BVM of the BPNS was updated in this study following in detail the guideline and procedure explained in the report. Only the macrobenthos, the epibenthos and the demersal fish components were updated as the focus of the research strategy and the prioritization for conservation is given to seafloor integrity. The set of assessment questions were scrutinized for relevance and adaptations were made according to the current study (Table XIII). Furthermore, updated information was available for habitat type 1170 and was included during the compilation into the marine BVM of the BPNS.

3.2.3.2. Habitat type 1110

For the biological valuation of the macrobenthos, the eight assessment questions provided by Derous *et al.* (2007b) were included but the assessment question *"Is the abundance of ecologically significant species high in the subzone?"* was updated. The ecologically important species considered in the current study are the key benthic species listed in the MSFD under two qualitative descriptors for determining good environmental status in Belgian waters: the D1 for biological diversity and the D6 for seafloor integrity (Belgian State, 2008; Berg *et al.*, 2015). Under this framework, species are not classified by habitat type (Belgian State, 2008). Therefore, benthic key species associated to habitat type 1170 are also included in this exercise. The key species included are listed in Table XIV. For the biological valuation of the epibenthos, the first four assessment questions provided by Derous *et al.* (2007b) were included but the assessment question *"Is the subzone highly productive?"* was removed as data were not available to be answered (Table XIII). To answer the assessment question *"Is the abundance of ecologically significant species high in the subzone?"* the brown shrimp *Crangon crangon* was considered in addition to the MSFD benthic species in Table XIII found in the epibenthos samples and classified as such (i.e. *Buccinum undatum, Aphrodita aculeata*). For the biological valuation of the demersal fish, all three assessment questions were included (Table XIII). The continuous response variables assessed by each question were first log transformed to reduce the influence of outliers, and afterwards categorized into five equal classes of values as presented in Derous *et al.* (2007b). Full-coverage habitat suitability distribution maps of epibenthos and demersal fish communities were not included in the biological valuation as the results could not be made available in the timeframe of the current study, thus only sample observations are included in the study with regards to the two seafloor communities.

Table XIII. The set of assessment questions for the biological valuation selected and adapted for this study from the original list decided by Derous et al. (2007b) after an extensive review and judgement based on literature and experts' input.

Ecosystem component	Assessment question
Macrobenthos	*Is the subzone characterized by high counts of many species?*
	Is the abundance of a certain species very high in the subzone?
	Is the subzone characterized by the presence of many rare species?
	Is the abundance of rare species high in the subzone?
	Is the abundance of habitat-forming species high in the subzone?
	Is the abundance of ecologically significant species high in the subzone?
	Is the species richness in the subzone high?
	Are there distinctive/unique communities present in the subzone?
Epibenthos	*Is the subzone characterized by high counts of many species?*
	Is the abundance of a certain species very high in the subzone?
	Is the abundance of ecologically significant species high in the subzone?
	Is the species richness in the subzone high?

Demersal fish species	*Is the subzone characterized by high counts of many species?* *Is the abundance of a certain species very high in the subzone?* *Is the species richness in the subzone high?*

Table XIV. List of key benthic species listed in the MSFD description 1 and 6 for determining good environmental status in Belgian waters and used to answer two of the assessment questions of the BVM.

Species	
Abra alba *Alcyonium digitatum*	*Lagis koreni* *Lanice conchilega*
Aphrodita aculeata *Branchiostoma lanceolatum*	*Lutraria angustior* *Mya* spp.
Buccinum undatum *Cancer pagurus*	*Mytilus edilus* *Ostrea edulis*
Callianassa spp. *Corystes cassivelaunus*	*Owenia fusiformis* *Pestarella*
Dosinia exoleta *Echinocardium cordatum*	*Pomatoceros triqueter* *Sabellaria spinulosa*
Glycymeris glycymeris *Laevicardium crassum*	*Upogebia deltaura* *Venerupis senegalensis*

3.2.3.3. Habitat type 1170

The potential gravel beds distribution in the BPNS, as available from Van Lancker *et al.* (2007, with subsequent updates in Degraer *et al.*, 2009 and Belgische Staat, 2012), was supplemented with higher resolution data in the northwest of the BPNS and the Hinder Banks (Van Lancker *et al.*, in prep.). In the BVM both maps are combined. The 2007 map represents an insightful compilation of different sources of data and observations derived from geological information, sediment databases, stone samples, acoustic seabed classification, bathymetric position index and bathymetry digital terrain models and determined the boundaries of gravel bed potential areas at a resolution of 200 m. This resulted in large areas with a potential for gravel occurrences. Strictly for the evaluation of ecological value, only areas where gravel is surfacing is of importance which is difficult to assess from the older data. Therefore, for search zone 1 and 2, most recent very-high resolution (i.e., 1m) data from Flemish Hydrography were analysed spatially for gravel presence (Van Lancker *et al.*, in prep.). The resulting map complies with the results of Montereale-Gavazzi *et al.* (2020) developed for a subset of search zone 2, and based on acoustic imagery, video footage and sampling.

The habitat suitability distribution of *Lanice conchilega* aggregation presented in Degraer *et al.* (2009) was included in the marine biological valuation of the BPNS. After a review of up-to-date literature and knowledge on the impact of the sand mason worm aggregations on habitat complexity and biodiversity, the threshold of 500 ind/m^2 as chosen in Merckx *et al.* (2011) was still considered adequate for the biological valuation. Such threshold is used because the species has a low habitat specialization and a wide distribution in the BPNS but reaches optimal aggregations only in shallow fine sands. It is when forming such aggregations that the presence of *Lanice conchilega* becomes important as ecosystem engineer and positively correlates with benthos richness and density (Van Hoey *et al.*, 2008; Braeckman *et al.*, 2014). However, an asymptotic relationship was observed when *L. conchilega* densities exceed >1000 ind/m^2 (Van Hoey *et al.*, 2008). The habitat suitability model highlighted the contribution of mud content, maximum current velocity at the bottom layer, mean bottom shear stress, slope, and bathymetric position index to the occurrence of *L. conchilega* aggregations (Merckx *et al.*, 2011). The gradient of occurrence probability from 0 to 100 % was categorized into five equal classes from 1 to 5 to integrate the map into the biological valuation.

3.2.3.4. Compilation

The total biological value per each grid cell was determined averaging all available values obtained from the assessment questions applied to each ecosystem component (i.e. macrobenthos, epibenthos and demersal fish) and projected to the entire BPNS. However, as in the previous marine biological valuation map (Derous *et al.*, 2007b), the majority of grid cells values were determined by the overlaying of three full-coverage potential distribution maps (macrobenthos communities, gravel beds and *Lanice conchilega* aggregations) while only a limited number of grid cells values were determined by the results of the assessment questions based on the sample observations. Therefore, a specific reliability score was assigned to each grid cell in order to differentiate the certainty of the assessment. Areas only covered by habitat suitability modelling predictions were assigned to very low or low reliability scores when probability of occurrence was below or above 50%, respectively. The certainty score of areas additionally covered by gravel beds and *Lanice conchilega* distribution predictions was increased by one level to low or medium reliability. Within the gravel bed distribution, a distinction was made for the updated high-resolution map within the search zone 1 and 2 that was assigned to a higher level of certainty (one score more in the reliability scale). Finally, grid cells covered by observations were assigned to high or very high reliability scores when less than 10 samples or more than 10 samples were averaged, respectively.

3.3. Results

3.3.1. Macrobenthic community distribution

Spatial autocorrelation among residuals was detected in GAMs and GLMs of all macrobenthos communities when models were developed without including a spatial random term (called SPDE in INLA) that accounts for such variance. The improvement was visualized using variograms, plots that display the variance between residuals as a function of distance (package *gstat* in R) before and after the introduction of an SPDE in the model that was built around a mesh imposed over the study area (Figure 15).

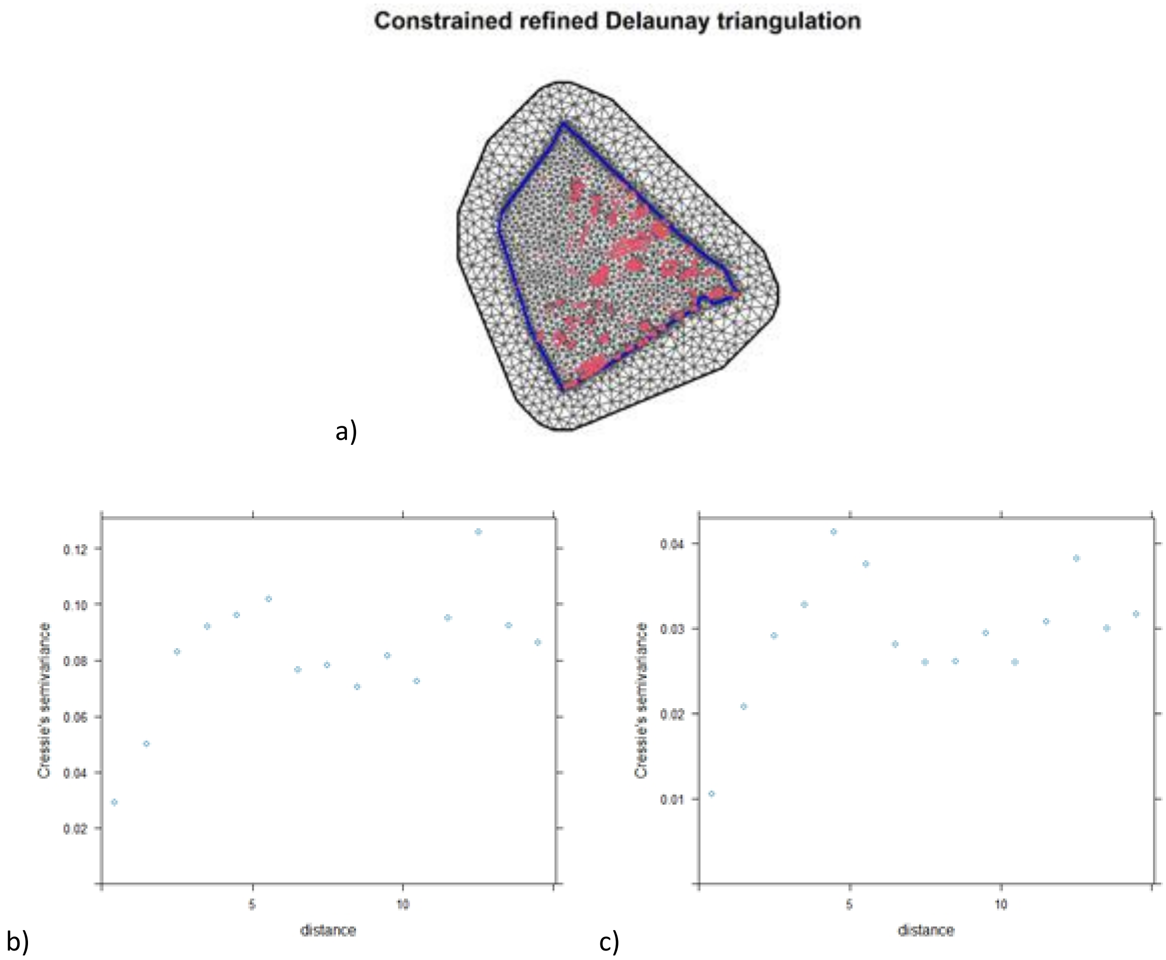


Figure 15. (a) Mesh constructed around the samples on which the spatial random field was developed. (b, c) Example of spatial autocorrelation among model residuals for the Abra alba community before and after the inclusion of a spatial random field in the model, respectively.

Therefore, all five final best parsimonious models for the macrobenthos communities contained the spatial effect and showed the lowest DIC (Table XV). Median grain size, mud %, depth, CHL and SPM were significant explanatory variables in most of the models, while temperature and rugosity were never retained in multivariable models. For all five communities, distributions were best predicted by binomial GLMs. The *Abra alba* community distribution was best predicted by quadratic relationships with median grain size, mud content and depth, underlying higher probability of occurrence at intermediate values. Despite the *Abra alba* community displayed a unimodal relationship with SPM in an univariable model, the best parsimonious model only includes a linear term for SPM. The model predicts the top 10% highest probability of occurrence at an average 246.98 ± 36.92 µm of median grain size, 9.37 ± 8.10 mud content %, 14.37 ± 3.90 meters depth and 5.88 ± 2.73 mg/L of SPM concentrations. After a 10-fold cross-validation, the accuracy of the model was quantified at 0.97 (sensitivity of 0.91 ± 0.03; specificity of 0.99 ± 0.01) with an AUC of 0.92. The model explained 74% of the total deviance. When the model predictions are projected over the environmental features of the BPNS, the most suitable areas for the *Abra alba* community are predicted along an intermediate zone between the coast and the offshore area (Figure 16A). On the West side, higher suitability is predicted in the flanks and gullies of the Flemish and Coastal banks. Towards the East side, highly suitable locations can be found below the Akkaert Bank and north of Vlakte van de Raan.

The suitable habitats for the *Hesionura elongata* community were best identified by a positive linear relationship with median grain size, and a negative linear relationship with chlorophyll concentrations, while a small part of the variance was captured by the spatial random field. The model predicts the top 10% highest probability of occurrence at an average 425.84 ± 37.70 µm of median grain size and 1.70 ± 0.24 µg/L of CHL concentrations. Model performances using a 10-fold cross validation were quantified with accuracy of the model was quantified at 0.94 accuracy (sensitivity of 0.874 ± 0.031; specificity of 0.951 ± 0.011) and an AUC of 0.92. The model explained 70% of the total deviance. The suitable area for the *Hesionura elongata* community in the BPNS was the most extended as it was predicted for almost the entire offshore area beyond the 12 nm line with an increasing probability of occurrence as distance from the coast increases (Figure 16B).

The best parsimonious model to predict the suitable areas of the *Nephtys cirrosa* community included median grain size, mud % and chlorophyll. The model included a quadratic relationship with median grain size and CHL, and a negative linear relationship with mud. The community shares part of the environmental conditions with the other communities and has a wider potentially suitable area as visible from the samples distribution (Figure 14). The average environmental characteristics predicted within the top 10% suitable habitat were 302.15 ± 50.87 µm of median grain size, 0.30 ± 0.62 mud % and 3.08 ± 1.55 µg/L of CHL concentrations. Accordingly, suitable locations for the *Nephtys cirrosa* community were predicted in a transitional area and as a gradient between coastal and offshore communities (Figure 16C). Furthermore, the community is predicted to occur in the central part of the Vlaamse Banken and across the Thornton Bank where the wind farms concession areas are located. The 10-fold cross validation highlighted a model accuracy of 0.93 (sensitivity 0.869 ± 0.027; specificity 0.949 ± 0.012) and an AUC of 0.86 with a total variance explained of 62% when the spatial random field is included.

The suitable areas for the *Magelona-Ensis* community were best identified by a model that included a negative linear relationship with mud % and SPM, and a positive linear relationship with depth. The model predicted the top 10% highest probability of occurrence for the community at an average 4.46 ± 8.90 mud %, 2.90 ± 2.50 meters depth and 12.14 ± 3.48 mg/L of SPM concentrations. The model performances following 10-fold cross validation highlighted a 0.97 accuracy (sensitivity 0.833 ± 0.034; specificity 0.982 ± 0.003), an AUC of 0.84 and a total variance explained of 60%. The projection of suitable habitats in the BPNS exposed high probability of occurrence in between the biotopes likely for the *Abra alba* community to occur, possibly extending on top of the sand banks crests. Furthermore, the *Magelona-Ensis* community may found highly suitable habitats along the coast, close to the beach (Figure 16D).

Finally, the best parsimonious model predicting the *Limecola balthica* community habitat suitability included mud %, depth, CHL and SPM. The community occurrence was positively correlated with mud %, CHL and SPM and has a quadratic relationship with depth. The average environmental values within the top 10% suitable habitat corresponded to a 36.18 ± 12. 92 mud %, 6.27 ± 1.21 meters depth, 9.60 ± 1.67 µg/L of CHL concentrations and 15.47 ± 1.69 mg/L of SPM concentrations. Accordingly, the most suitable habitat for the community was predicted within the mud fields and turbidity maxima area surrounding the Ostend and Zeebrugge harbours with the exclusion of the manmade shipping channel (Figure 16E). The best parsimonious model had an accuracy of 0.96 (sensitivity 0.858 ± 0.038; specificity 0.981 ± 0.007) an AUC of 0.86 and explained of the total variance of 72%.

Table XV. Best parsimonious binomial generalized linear models predicting the distribution of the five macrobenthos communities of the Belgian Part of the North Sea including parameter estimates, 95% confidence intervals (CI), model accuracy, area under the curve (AUC) and explained variance percentage.

Community	Best model	Parameter	Estimate (mean ± SD)	CI 95% (Q0.025; Q0.975)	Accuracy	AUC	Pseudo R^2
Abra alba	*A. alba$_i$ ~ binomial (μ_i)*	Intercept	-12.4 ± 3.7	-19.8; -5.0	0.97	0.92	0.74
	E(A. alba) = μ_i	mgs	0.006 ± 0.017	-0.03; 0.04			
	log(μ_i) = *Intercept + mgs$_i$ + mgs$_i^2$ + mud$_i$ + mud$_i^2$ + depth$_i$ + depth$_i^2$ + SPM$_i$ + u$_i$*	mgs^2	-0.00004 ± 0.00003	-0.00006; -0.00002			
		mud	0.15 ± 0.05	0.05; 0.26			
		mud^2	-0.004 ± 0.001	-0.006; -0.002			
		depth	-0.91 ± 0.26	-1.4; -0.38			
		$depth^2$	-0.02 ± 0.01	-0.04; -0.005			
		SPM	0.82 ± 0.40	0.02; 1.58			
		spatial random field	11445 ± 3333	6697; 19447			
Hesionura elongata	*H. elongata$_i$ ~ binomial (μ_i)*	Intercept	-4.3 ± 1.27	-6.99; -1.91	0.94	0.92	0.70
	E(H. elongata) = μ_i	mgs	0.020 ± 0.003	0.014; 0.025			
	log(μ_i) = *Intercept + mgs$_i$ + CHL$_i$ + u$_i$*	CHL	-1.25 ± 0.24	-1.71; -0.78			
		spatial random field	11848 ± 2726	8086; 19091			
Nephtys cirrosa	*N. cirrosa$_i$ ~ binomial (μ_i)*	Intercept	-12.3 ± 2.9	-17.9; -6.5	0.93	0.86	0.62
	E(N. cirrosa) = μ_i	mgs	0.07 ± 0.02	0.003; 0.09			
	log(μ_i) = *Intercept + mgs$_i$ + mgs$_i^2$ + mud$_i$ + CHL$_i$ + CHL$_i^2$ + u$_i$*	mgs^2	-0.00011 ± 0.00002	-0.0002; -0.00006			

		mud	-0.7 ± 0.1	-0.95; -0.40			
		CHL	0.9 ± 0.3	0.24; 1.56			
		CHL^2	-0.07 ± 0.03	-0.12; -0.02			
		spatial random field	9674 ± 1593	7557; 14201			
Magelona-Ensis	*Magelona-Ensis$_i$* ~ *binomial* (μ_i)	Intercept	5.36 ± 1.18	2.57; 8.11			
	E(Magelona-Ensis) = μ_i	mud	-0.08 ± 0.03	-0.13; -0.03			
	$\log(\mu_i) = Intercept + mud_i + depth_i + SPM_i + u_i$	depth	0.87 ± 0.14	0.60; 1.13	0.97	0.85	0.60
		SPM	-0.23 ± 0.10	-0.42; -0.04			
		spatial random field	17719 ± 10100	6364; 43637			
Limecola balthica	*L. balthica$_i$* ~ *binomial* (μ_i)	Intercept	-17.53 ± 3.52	-24.41; -10.61			
	E(L. balthica) = μ_i	mud	0.056 ± 0.009	0.038; 0.074			
	$\log(\mu_i) = Intercept + mud_i + depth_i + depth_i^2 + CHL_i + SPM_i + u_i$	depth	-3.39 ± 0.98	-5.30; -1.46			
		$depth^2$	-0.24 ± 0.08	-0.39; -0.098	0.96	0.86	0.72
		CHL	0.28 ± 0.11	0.07; 0.48			
		SPM	0.19 ± 0.09	0.006; 0.36			
		spatial random field	11973 ± 49	11689; 12192			

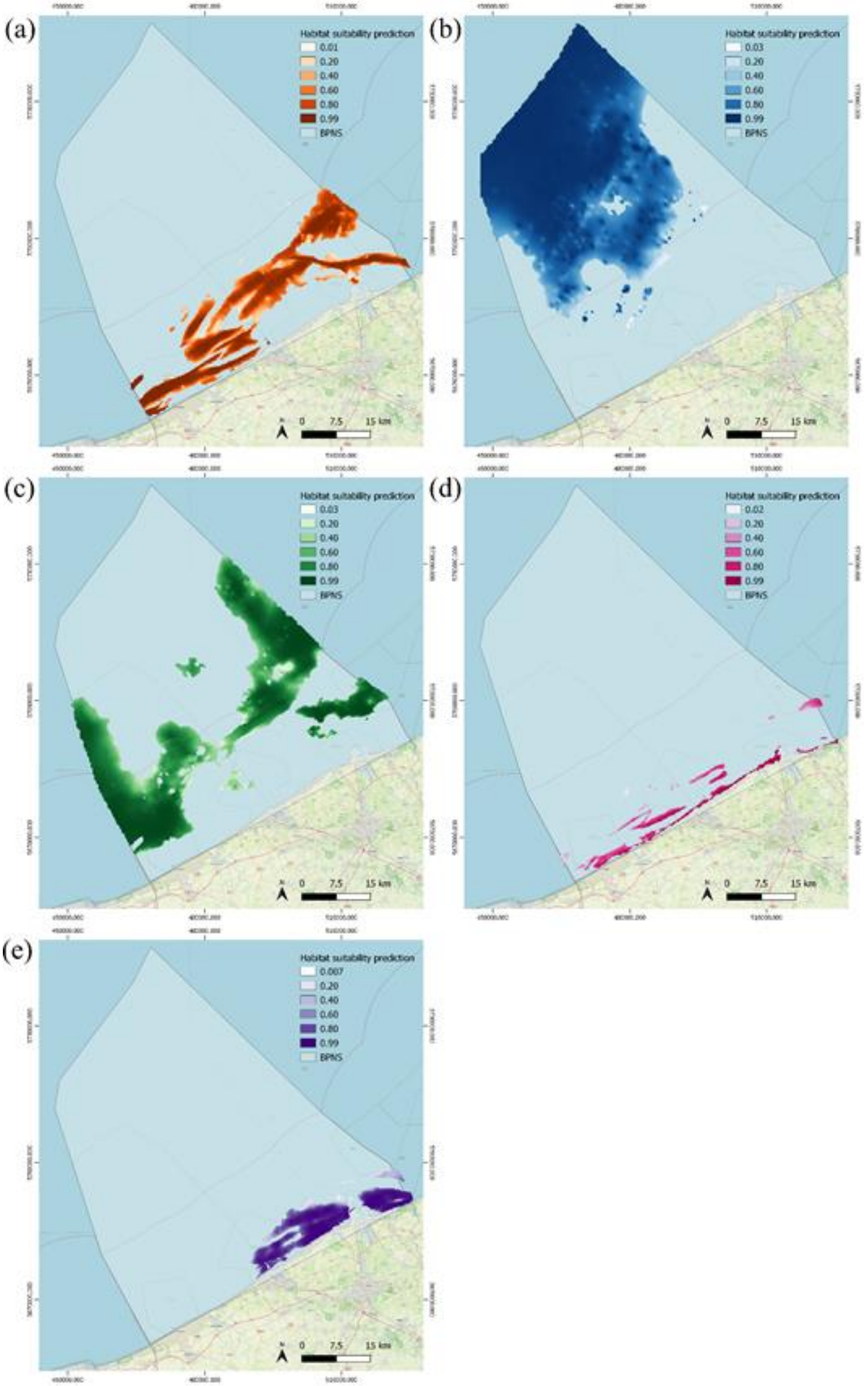


Figure 16. Full-coverage habitat suitability distribution at a resolution of 200 x 200 m for each macrobenthos community found in the Belgian Part of the North Sea. Probability of occurrence is expressed from 0 to 1 and displayed as increasing colour intensity. a) Abra alba community; b) Hesionura elongata community; c) Nephtys cirrosa community; d) Magelona-Ensis community; e) Limecola balthica community.

3.3.2. Marine biological valuation map

The analysis of the biological samples of macrobenthos, epibenthos and demersal fish according to the assessment questions presented in Derous *et al.* (2007b) produced 16 maps of relative biological values, where each grid cell was assigned to 0 (if *in-situ* observations were not available, and therefore not considered in the next averaging step) or to a score from 1 (very low value) to 5 (very high value) in case *in-situ* observations were available. A total of 883 grid cells were scored using macrobenthos samples, while a total of 4073 grid cells were scored using epibenthos and demersal fish tracks. To answer the assessment question "*Are there distinctive/unique macrobenthos communities present in the subzone?*" the average observed number of species and densities per macrobenthos community were calculated and log-transformed, divided by the log-transformed BPNS global average, and multiplied together (Table XVI). Based on the values, the *Abra alba* community was ranked with a very high value (5), the *Magelona-Ensis* and the *Hesionura elongata* communities with a medium value (3), the *Nephtys cirrosa* community with a low value (2) and the *Limecola balthica* community with a very low value (1).

Table XVI. Mean richness and density values per community and their logarithmic ratio with average macrobenthos richness and density in the Belgian Part of the North Sea used to determine community relative biological value.

Community	Richness (N_0)	Density (ind/m^2)	Richness ratio	Density ratio	Product	Class
Abra alba	27.25 ± 9.17	5422.389 ± 7235.47	1.226	1.150	1.410	5
Hesionura elongata	14.83 ± 4.89	859.41 ± 493.71	1.00	0.904	0.904	3
Nephtys cirrosa	9.73 ± 4.40	389.90 ± 347.70	0.846	0.799	0.676	2
Magelona-Ensis	11.76 ± 4.43	2797.25 ± 5064.61	0.917	1.062	0.974	3
Limecola balthica	6.46 ± 2.91	868.94 ± 1916.40	0.694	0.906	0.623	1
BPNS	14.70 ± 9.22	1755.96 ± 3957.89				

For the integration of habitat type 1170 in the total marine biological valuation map, the potential distribution of gravel beds was classified into two classes of biological value: 5 in case of presence, 0 in case of absence (Figure 17a). The potential distribution of *Lanice conchilega* aggregations was classified into five classes of biological value based on probability of occurrence (Figure 17b). Only the suitable areas with biological value 5 were retained from the potential distribution map of gravel bed in order to be averaged with the other maps in the total biological valuation map. For the same reason¸ only the suitable areas with a value above 1 (predicted occurrence above 20%) were retained for the habitat suitability map of *Lanice conchilega*.

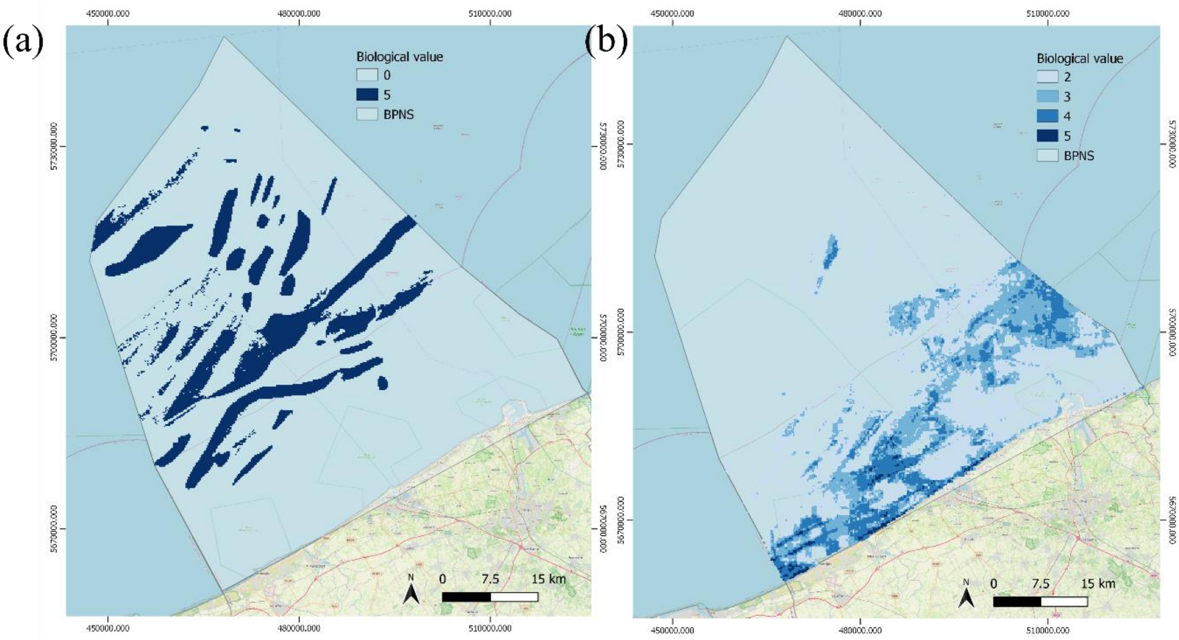


Figure 17. a) Potential gravel beds presence-absence distribution classified in very high and very low biological value, respectively. b) Habitat suitability above 20% probability of Lanice conchilega aggregations above 500 ind/m² classified into biological values based on % of occurrence.

The 16 individual biological value maps of macrobenthos, epibenthos, demersal fish, gravel beds and biogenic reefs were integrated by averaging the values of the different ecosystem components into a total biological value map of the BPNS (Figure 18). The map has a resolution of 200 x 200 m in which each grid cell derived from the average of the available set of biological values for such location, which may be a different number of values for each. A score of "five" corresponds to very high biological value. Most valuable areas are found within two predicted biotopes: 1) within all areas where gravel beds occurrence is expected, and 2) within a stripe of coastal area where the *Abra alba* community and high-probability (>60% habitat suitability) *Lanice conchilega* aggregations are predicted to co-occur. High biological value areas, corresponding to the score "four", are also found within the *Abra alba* community but including areas with a probability of occurrence of *Lanice conchilega* aggregations between 40 and 60%. Areas with a medium biological value are sparsely located in the BPNS. They include the offshore habitats likely hosting the *Hesionura elongata* community, the coastal habitats likely hosting the *Magelona-Ensis* community, and the coastal habitats likely hosting the *Abra alba* community but less likely to be suitable for *Lanice conchilega* aggregations (suitability 20 and 40%). Medium value areas also include locations where the value was either lowered or increased by the analyses made on the samples. Low biological value areas are represented by habitats suitable for the *Nephtys cirrosa* community, including the Eastern and Western sides of the BPNS and the transitional area between the coastal and the offshore environment. Some areas between the harbours of Ostend and Zeebrugge were assigned to very low biological value and they correspond to habitats likely hosting the *Limecola balthica* community.

As the biological value assigned to each grid cell derives from a different number of averaged values and from different types of assessment (i.e. from habitat suitability modelling or biological samples analyses), the reliability underlying each grid cell is different. As a result, the reliability map displaying the level of certainty associated with each prediction is provided in Figure 19. Very high reliability with a score of "five" was only assigned to locations with the number of samples exceeding ten. The corresponding grid cells serve as ground truthing locations for the habitat suitability modelling exercises. Similarly, locations including the presence of one to ten samples were considered of high reliability. High reliability can also be found in areas that are represented by the predictions of macrobenthos community distribution, gravel beds occurrence and *Lanice conchilega* aggregations. Within the gravel beds, high reliability is assigned to the area where additional analyses were performed and the distribution was updated from the original map. A large portion of the BPNS was valued with a medium level of reliability, but majority of the total area remains valued with low certainty. Only few transitional areas in between highly suitable areas for macrobenthos communities were not strongly predicted by the habitat suitability modelling (suitability <50%) and were those considered valued with very low reliability.

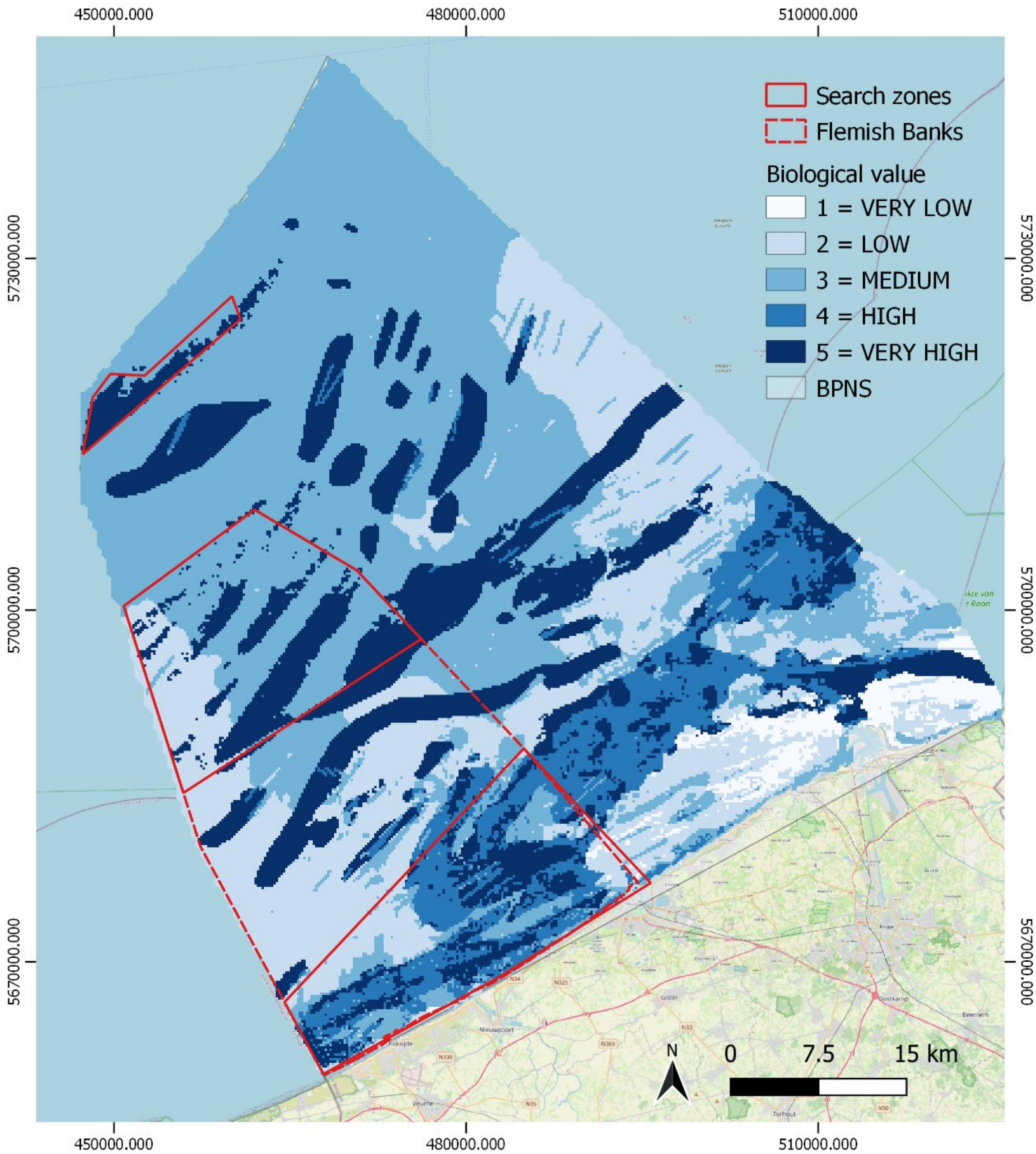


Figure 18. Total marine biological valuation map of the Belgian part of the North Sea at a resolution of 200 x 200 m obtained by averaging all ecosystem components considered. Biological value goes from very high (5) to high (4), medium (3), low (2) and very low (1).

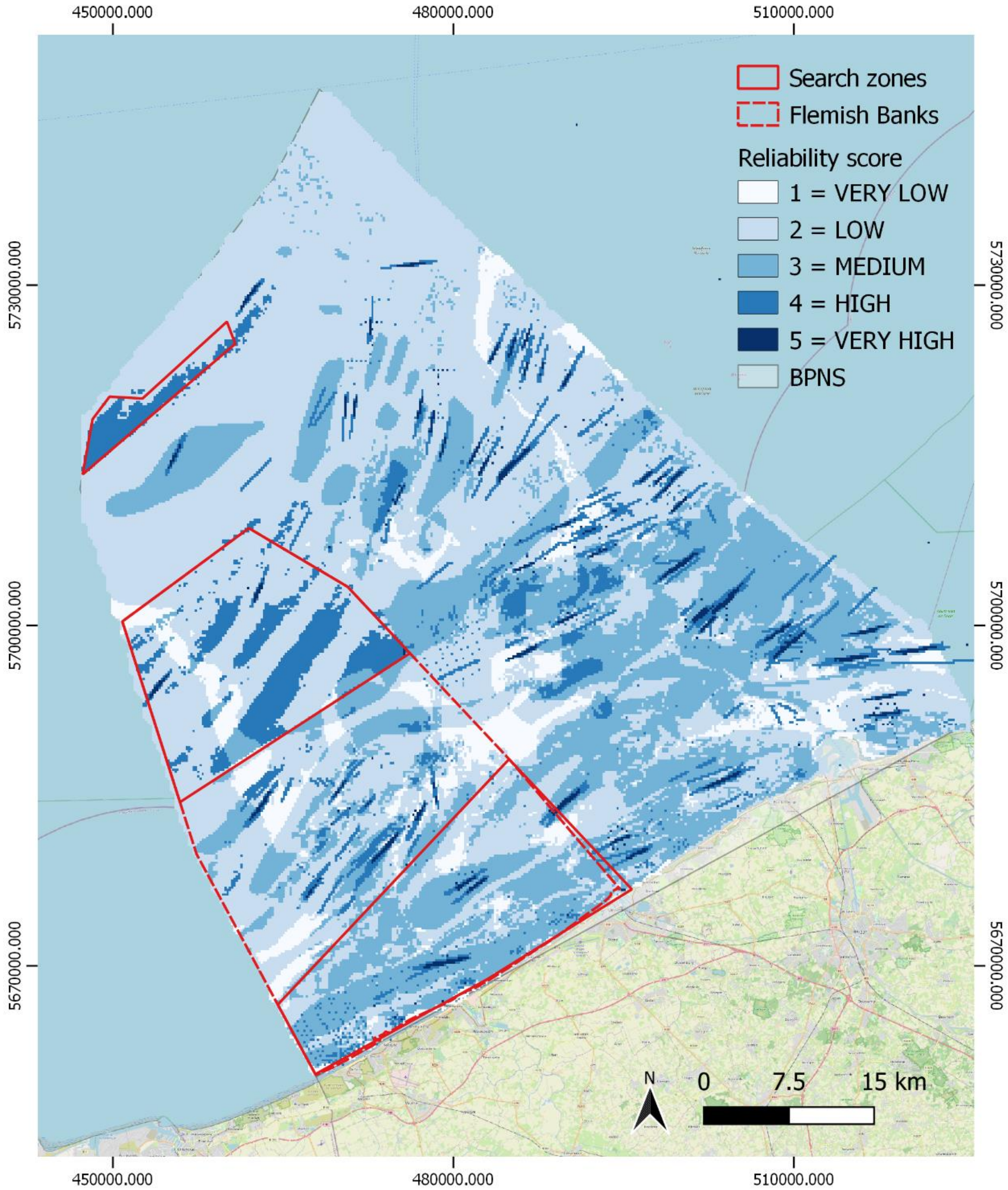


Figure 19. Reliability associated to each biological value displayed in the marine biological valuation map determined by the number of layers/samples available per location. Reliability score goes from very high (5) to high (4), medium (3), low (2) and very low (1).

3.4. Discussion and conclusion

3.4.1. Application of the biological valuation map in the development of fisheries measures

The biological valuation protocol (Derous *et al.*, 2007b) proved to be flexible and data-inclusive, successfully updating the marine biological valuation of the BPNS with the most recent data collections. As such, the biological valuation map serves as a greatly informative tool in the context of marine conservation and protection as it assesses and supports the implementation of the obligations imposed by the Habitat Directive, the MSFD and Biodiversity Strategy, the main tools that address marine environmental protection in European waters (Derous *et al.*, 2007c). By its very nature, the biological valuation protocol can evaluate the network of Natura 2000 areas, it can represent a baseline map for the assessment of GES within the MSFD by incorporating biological and physical characteristics (Vanden Eede *et al.*, 2014), and it can advise for the extension of seafloor protection towards the new Biodiversity Strategy targets. Therefore, the use of the biological valuation map to guide spatial management options, e.g. fisheries restriction measures is relevant for two main reasons: 1) the biological valuation comprehends several scientifically sound analyses and considerations serving as the evidence base necessary for the identification of priority areas and 2) it supports MPA and MSP decision-making by highlighting the distribution of lower, intermediate and higher biological values within and beyond existing protected networks. It functions as a first layer of a sound and transparent decision support system that can be complemented with a second layer displaying the distribution of bottom-disturbing fisheries activities in terms of days at sea, landings and value. In the context of the request for fisheries measures in the BPNS, these two layers support the use of the Marxan software for the identification of potential areas that me*et al.*l the biological targets at the least costs in terms of implementation landingss and economic losses.

The total marine BVM of the BPNS is the result of a combination of full-coverage data and discrete data point information. The full-coverage distribution of the three Habitat Directive Annex I habitat types present in Belgian waters (1110: *Sandbanks which are slightly covered by sea water all the time*, 1170: *Reefs - Gravel beds*, 1170: *Reefs - Lanice conchilega aggregations*) are included in the biological valuation as three separately modelled distributions developed using independent data collections. The BVM is strongly influenced by the full-coverage data as most of the area value was determined by their modelled distribution rather than sample observations. Areas where discrete data point information were collected were further substantiated by the analysis of assemblages and ecological indicators of bottom communities. Despite the fragmented and the small-scale information provided by the point information, the discrete data proved useful to locally enhance scientific knowledge and increase the accuracy of the results. Often the discrete data harmonized with the full-coverage information, but sometimes highlighted locations with relative higher or lower biological value. As a result, most of the BPNS seafloor biological values are derived from habitat suitability modelling exercises (i.e. interpolation) and are thus indicated with a correspondent low to high reliability, where increasing reliability is given by a greater number of information layers determining the value of the area. However, locations with high to very high reliability are patchily distributed along the BPNS in correspondence with empirical observations.

3.4.2. Biological justification behind the total marine biological valuation map

A total of 742 km^2 (~21% of BPNS) of the BPNS surface were assigned to very high biological value and 360 km^2 (~10% of BPNS) to high biological value. The process of prioritization for the selection of areas to be assigned for seabed protection and fisheries exclusion focuses on the localization of these two highest classes of value. Very high biological value areas are located where the probabilities of occurrence of gravel beds, *Abra alba* community or *Lanice conchilega* aggregations are the highest. However, the distribution of the three habitats is segregated in space, highlighting a very highly valuable area offshore, and a very highly valuable area closer to the coast. The mosaic of values displayed in the map relates to the spatial heterogeneity of sediment types in the BPNS shaping the habitat variability necessary to support a variety of benthic species assemblages (Vanden Eede *et al.*, 2014).

Offshore located gravel beds (habitat type 1170: *Geogenic reefs*) are considered of very high biological value. Gravel beds (*sensu* Wentworth classification sediments with a median grain size of >2 mm) may comprise up to 487 km^2 unique habitats in the BPNS (13.7% of its surface). They represent subtidal natural hard substrates in a sand-dominated area suitable for an array of species that cannot occur in soft-bottom habitats (Houziaux *et al.*, 2008). As such, they naturally host rich macro- and epibenthos communities that include sessile and/or long-lived species (i.e. >5 yrs.) (e.g. *Pomatoceros triqueter, Sabellaria spinulosa, Haliclona oculata, Flustra foliacea, Alcyonium digitatum, Sertularia cupressina*, *Ostrea edulis, Buccinum undatum*) (Houziaux *et al.*, 2008). The heterogeneous environment creates high-quality habitats for many juvenile species from higher trophic levels. However, such features make the habitat extremely sensitive and not resilient to physical seafloor disturbance but at the same time, attractive for fisheries activities (Houziaux *et al.*, 2011). Nowadays, large parts of gravel beds are found to be in a highly unfavourable status of conservation with many typical species being rare due to the historical damage caused by bottom trawling, which includes cobble and boulder displacement and reef destruction (Houziaux *et al.*, 2011; Degraer *et al.*, 2010; Belgische Staat, 2018). The remaining sheltered healthy patches of gravel beds pinpoint towards the possibility for habitat restoration and underline the great benefit that the habitat would gain from seafloor protection and active bottom fisheries exclusion (Kerckhof *et al.*, 2018). The map used in this study (Van Lancker *et al.*, 2007 and Van Lancker *et al.*, in prep.) displays the potential gravel bed distribution in a binary way, as it is mostly based on a compilation of several sources of information resulting in a seabed discrimination into either presence or absence of gravel beds. Therefore, the biological valuation map shows a net contrast in biological value in the offshore areas as no gradient of values was available within the gravel beds distribution, and co-habiting macrobenthos communities were classified to medium or low biological value. Overall, potential gravel beds may be found offshore in the gullies of the Flemish Banks, Hinderbanks and Zeelandbanks (Figure 17a). With increasing sampling and visual observation landings, in combination with full-coverage acoustic remote sensing, and predictive modelling, maps are getting increasingly enriched withspatially-explicit ecological knowledge of gravel beds (as in Montereale-Gavazzi *et al.*, 2020).

In the total biological valuation map, very high biological value was assigned to areas where the *Lanice conchilega* aggregations (i.e. *L. conchilega* densities of more than 500 ind/m^2) co-occurred at high probability (above 60%) with the entire *Abra alba* community distribution. Alike, high biological value was assigned to areas where the dense patches of *L. conchilega* co-occured with a probability between 40-60% with the *Abra alba* community. The *Abra alba* community was confirmed as the most biologically valuable among the five identified macrobenthos communities of the BPNS as it displayed the highest values of species richness and density (Table 3). The community is acknowledged to be the ecologically most important macrobenthos community of shallow soft-bottom sediments in the southern North Sea (Van Hoey *et al.*, 2005, 2007) as it hosts the highest biodiversity (up to 60 species per sample recorded in this study) and abundances (up to per 53900 ind/m^2 recorded in this study). The distribution was predicted close to the coast in the gullies of the Coastal Banks and the Flemish Banks continuing up to the northern part of the Vlakte van de Raan for a total of 533 km^2 (15.0% of the BPNS surface). The distribution correlated with intermediate depth and environmental conditions, slow hydrodynamics and muddy fine sandy sediments in alignment with previous findings (Van Hoey *et al.*, 2005; Breine at al., 2018). It revealed to host several key-species for seafloor integrity such as the ecosystem-engineers and habitat forming species *Owenia fusiformis*, *Lagis koreni* and *Lanice conchilega*, and large long-lived species as *Echinocardium cordatum*, *Venerupis corrugata* and *Mya* spp. The sand mason worm *Lanice conchilega* is found in high numbers within the *Abra alba* community but only thrives and aggregates in dense fields at optimal environmental features. Here, species richness, densities and biomasses reach their peak because of the additional habitat structure, shelter and food sources provided to the associated species at the various trophic levels (Braeckman *et al.*, 2014; Van Hoey *et al.*, 2008; Rabaut *et al.* 2007).

The remainder of the BPNS was assigned to medium biological value for a total of 1525 km^2 (43% of the BPNS) and a total of 914 km^2 (26%) with low and very low biological value. Medium biological value was mainly linked to the presence of two macrobenthos communities found at very different locations; the *Hesionura elongata* community and the *Magelona-Ensis* community. Samples of the offshore *Hesionura elongata* community revealed a higher biological value than previously thought (Derous *et al.*, 2007b) thanks to the second highest average species richness detected within the community. On the other hand, the medium biological value assigned to the *Magelona-Ensis* community was due to the second highest average species density recorded in the samples. This may be due to the similarity shared with the *Abra alba* community against which it differs by the high percentage of *Magelona* and *Ensis* species (Breine *et al.*, 2018). Accordingly, the community was predicted to share close locations with the *Abra alba* community inhabiting the Coastal Banks tops but further distributing along the coast. Additional medium biological value was detected at locations within the low-value *Nephtys cirrosa* community distribution by epibenthos and demersal fish samples. Previously thought to host intermediate species richness and abundances (Derous *et al.*, 2007b), this transitional community dominated by the opportunistic polychaete species *Nephtys cirrosa* displayed the lowest average species density. The lowest biological value was confirmed for the muddy sediments *Limecola balthica* community.

A large portion of the very high and high biological value areas fall within the search zones delimitations. The search zone 3 is the largest (353 km^2; 10% of the BPNS) and the closest to the coast. This search zone satisfies two of the requirements for the area to identify as it includes 40% of the *Abra alba* community surface area (habitat type 1110) and 47% of the *Lanice conchilega* aggregation distribution above 60% probability (habitat type 1170: *Reefs – Lanice conchilega aggregations*). This corresponded to a total of 62% of the search zone 3 being assigned to high/very high value. Furthermore, the area has been the most heavily sampled over time making the reliability behind the biological valuation very high at certain locations. However, the search zone 3 does not host any potential gravel beds. The search zone 2 is the second largest (326 km^2; 9.2% of the BPNS). The area includes 23% of the potential gravel beds surface area, including the area where their presence is the most certain. Accordingly, the search zone 2 satisfies the requirement for protection of the habitat type 1170 *Reefs – Gravel beds* with 35% of its surface being assigned to very high biological value. Finally, the search zone 1 is the smallest of the three covering 37 km^2 of the northwesternmost part of the BPNS (1%). However, 73% of the area was assigned to very high value as it includes 27 km^2 of potential gravel bed surface area.

3.4.3. Comparison of the updated macrobenthos habitat suitability map with the previous version

The macrobenthos habitat suitability map was updated by using up-to-date data of macrobenthos samples and environmental variables. Therefore, a comparison can be made observing the similarities and discrepancies found with the same map produced in Degraer et al. (2008). The modelling method was updated using a Bayesian modelling approach (R INLA-SPDE) which is best suited to account for spatial effects and dependencies present in geographically referenced ecological data. In the previous habitat suitability modelling exercise, a total of 773 samples were used and two environmental variables were significantly describing the distribution: median grain size and mud content. In the updated exercise, a total of 1412 samples were used and a larger set of environmental variables was found significant, including median grain size, mud content, bathymetry, suspended particulate matter and chlorophyll content. The classification of the samples themselves into macrobenthos communities was refined thanks to the larger database. The distribution of the *Hesionura elongata* community is predicted in the offshore part of the BPNS as in Degraer et al. (2008), including the added top right corner of the map, but it is predicted to extend also along the Hinder banks, and near the Goote Bank where several such samples were collected. The community distribution is majorly determined by large median grain size and low chlorophyll concentrations. As in Degraer et al. (2008), the *Nephtys cirrosa* community is still predicted for the intermediate and transitional areas between coastal and offshore environments. The extent is updated as being explained by median grain size and chlorophyll content and resulted to have the largest surfaces being predicted within the offshore wind farm zone and in the intermediate part of the Natura 2000 area Vlaamse Banken. The distribution of the *Limecola balthica* community was predicted over a smaller surface in comparison to Degraer et al. (2008) and localized between Ostend, Zeebrugge and the Western Scheldt in relation to high mud content, suspended particulate matter and chlorophyll content. This because the area around the Wandelaar were assigned to *Abra alba*, while in the areas in proximity of the coast and on top of the coastal sandbanks the model predicted the occurrence of the newly identified *Magelona-Ensis* community, informed by the updated samples classified as such and described by mud content, suspended particulate matter and depth. Finally, the most ecologically important *Abra alba* community follows the same general distribution as in Degraer et al. (2008) but displays a more defined distribution that goes from the gullies of the western Coastal Banks to the northern part of the Vlakte van de Raan, areas of maximum observed richness and densities, passing through the coastal Flemish Banks. Such distribution is explained by the optimal conditions of median grain size, mud content, bathymetry and suspended particulate matter that characterize the coastal zone just after the maximum turbidity zone. As this area holds intermediate levels of mud content and suspended fines, it supports a rich and dense community that includes suspension and deposit feeders even under heavy trawling regimes. In the areas where suitability is predicted, the *Abra alba* community may further develop into an even more diversified and rich community if disturbance is removed. In addition to the previous habitat suitability map, the *Abra alba* community is also predicted to inhabit the manmade channels that connect to the Zeebrugge harbour and the Western Scheldt. Here the artificial conditions recreated in the channels by dredging the sediments may have created potentially suitable conditions for the community in terms of sediments and depths that the model has detected as no counteracting disturbance factor is included in the analysis. Therefore, the realized distribution in the channels should be verified as no sample was available to inform the model there. As artificial disturbance will not be reduced in the channels, the *Abra alba* community may not further evolve to the undisturbed form as in other suitable areas, but the channels will preserve the potential for the community to occur at present day richness and density values.

4. Sensitivity classification of the habitat features in the BPNS to physical disturbance (abrasion)

For the sensitivity classification of the habitat features of the BPNS, we have based our evaluation on the information available on MarLIN. MarLIN (marlin.ac.uk) provides information to support marine conservation, management and planning. It hosts the largest review of the effects of human activities and natural events on marine species and habitats yet undertaken. Therefore, it is a relevant source for determining the sensitivity of our habitat features. On the MarLIN website (www.marlin.ac.uk), the sensitivity of selected habitats is determined based on the MarESA approach (Marine Evidence based Sensitivity Assessment; *https://www.marlin.ac.uk/sensitivity/sensitivity_rationale*; Tyler-Walters *et al.*, 2018). The 'concept' of sensitivity is mostly defined as a product of (1) the likelihood of damage (termed intolerance or resistance) due to a pressure and (2) the rate of (or time taken for) recovery (termed recoverability, or resilience) once the pressure has been reduced or been removed (Tyler-Walters *et al.*, 2018). Sensitivity is an inherent characteristic determined by the biology/ecology of the feature (species or habitat) in question. But it is a 'relative' concept as it depends on the degree (expressed as magnitude, extent, frequency or duration) of the effect on the feature. For this report, we determine the sensitivity of the benthic communities and some benthic key species based on the impact of abrasion on them. For the gravel beds, habitat structure changes – removal of substratum and physical abrasion were taken into account.

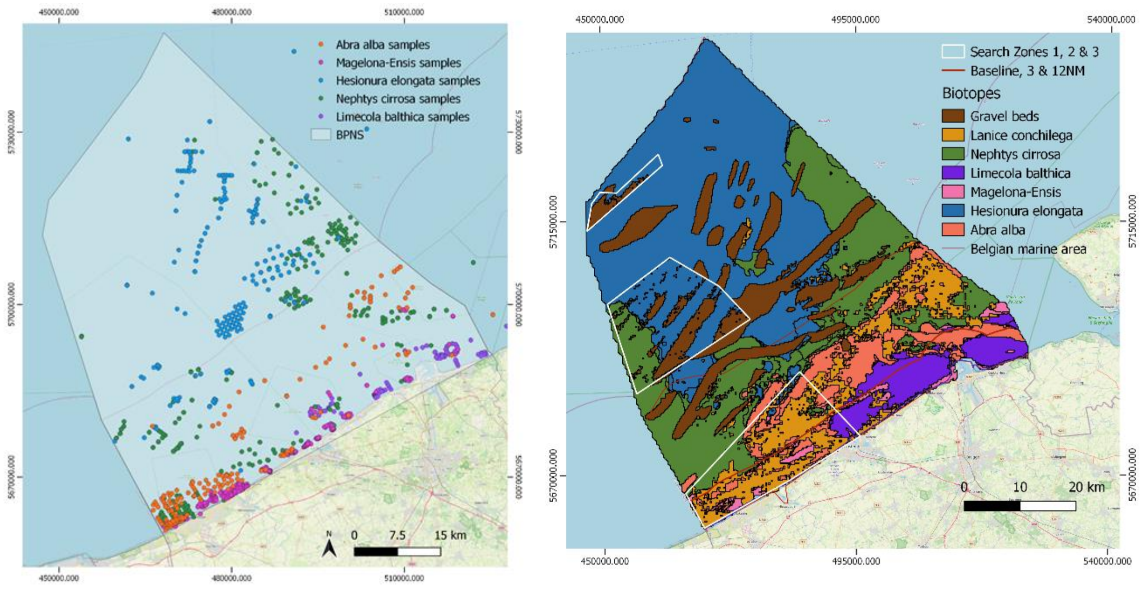


Figure 20. (left) Benthic sampling locations with indication of the macrobenthic community to which they belong (chapter 3.3.1); (right) habitat suitability map of the benthic communities, Lanice conchilega aggregations and gravel beds (chapter 3.3.1).

On the MarLin website, the habitat classification is based on the EUNIS system, which is a comprehensive pan-European system for habitat identification. The classification is hierarchical and covers all types of habitats from natural to artificial, from terrestrial to freshwater and marine. The habitat types are identified by specific codes, names and descriptions. The EUNIS biotope classifications (level 5) that relate best (based on key species) to each of the identified habitat features of the BPNS. For certain communities, several EUNIS biotope types can be identified as is indicated in table XVII .

In Breine *et al.*, 2018, the five communities of the BPNS were identified and described, each with their own structural characteristics, indicator species, sediment properties and spatial distribution. The spatial distribution of those communities is modelled, based on the Breine *et al.* (2018) data, as outlined in chapter 3.3.1. In summary, the offshore area was dominated by the *Hesionura elongata* community which has the second highest sample diversity and moderate densities. Also, a new community (compared to Van Hoey *et al.*, 2004), the *Magelona-Ensis leei* community, was found in very shallow water and characterized by low diversity and the dominance of the non-indigenous species *E. leei*. The structural characteristics and spatial distribution of the *Limecola balthica*, *Abra alba* and *Nephtys cirrosa* community remained largely unchanged, compared to the earlier description in Van Hoey *et al.*, 2004. Though structurally distinct, the communities overlap in some of their functional attributes. Analysis of biological traits revealed that in the coarser permeable sands, both the *N. cirrosa* and *H. elongata* community harbor more free living mobile individuals, causing diffusive mixing. The finer sand (*A. alba, Magelona- Ensis leei*) and muddy (*L. balthica*) communities hold more sessile, tube building and burrow dwelling species. Beside the 5 soft sediment communities occuring within the sand banks (habitat type 1110), two distinct habitat features are recognized as reefs (habitat type 1170) within the BPNS: *Lanice conchilega* aggregations and gravel beds. *Lanice conchilega* aggregation provide a niche for a different and generally more species rich and abundant faunal community than the adjacent tube-free sands in both inter- and subtidal areas (Rabaut *et al.* 2007; Van Hoey *et al.* 2008). These aggregations are mainly found within the *Abra alba* community. The gravel beds are geogenic reefs, made up of stones and pebbles. The typical species of this habitat feature, which are still found at some gravel relict spots are whelks, top shells, spider crabs and long-legged spider crabs, sea beards and dead man's fingers. Hundred years ago, those gravel beds in the BPNS were also characterized by flat oyster and recognized as breeding grounds for fish.

4.1. Sensitivity classification overview

For every biotope the sensitivity assessment as published on the MarLIN website was copied (see chapter 4.2), is summarized in this chapter and was used in the Marxan scenario setting (see Table XVII). Based on this sensitivity assessment, we give the habitat features of the BPNS a sensitivity score (see chapter 2.2), ranging from 1 to 5 (1: low sensitivity; 2: low to medium sensitivity; 3: medium sensitivity; 4: medium to high sensitivity and 5: high sensitivity).

Table XVII. Summary of the sensitivity classification of the 5 benthic communities, Lanice conchilega aggregations and gravel beds in relation to the marlin classification.

		Sensitivity review		
Community	**EUNIS classification**	**Resistence**	**Resilience**	**Sensitivity**
Limecola balthica	A5.331	Low	Medium	Medium
Abra alba	A5.261	Medium	High	Low
	A5.241	Low	Medium	Medium
	A5.351	Low	Medium	Medium
	A5.137	High	High	Not sensitive
Magelona-Ensis leei	A5.242	Medium	High	Low
	A5.241	Low	Medium	Medium
Nephtys cirrosa	A5.233	Low	High	Low

Hesionura elongata	A5.134	Medium	High	Low
	A5.152	Medium	High	Low
Lanice conchilega	A5.137	High	High	Not sensitive
gravel beds	A5.611	Low	Medium	Medium
	A4.232	None	High	Medium
		None	Very Low	High
	A4.135	Low	Medium	Medium
		None	Medium	Medium
	A4.221	Low	Medium	Medium
	A4.2142	Medium	High	Low

In general, the sensitivity to abrasion is lower in coarser permeable sands compared to the communities living in finer sand and muddy sediments (Rijnsdorp *et al.*, 2020). The sandy habitats (*Nephtys cirrosa, Hesionura elongata*) are classified under low sensitivity (score 1), due to their high resilience. The *Magelona-Ensis leei* habitat, occurring in shallow muddy sands, is also classified as low sensitive to abrasion (score 1). The *Abra alba* habitat on the BPNS, occurring in muddy sands corresponds with different EUNIS biotope classes, with a variable sensitivity classification ranging from not sensitive to medium. Therefore, we give the *Abra alba* habitat of the BPNS a sensitivity score of 2 (low to medium sensitive), as some species groups are determined as medium sensitive. The *Limecola balthica* habitat, occurring in sandy mud is in EUNIS classified as medium sensitive, due to higher sensitivity of *Nephtys hombergii.* Nevertheless, the dominant species *L. balthica* has a low sensitivity (see chapter 4.2.1). Therefore, we give the *Limecola balthica* habitat of the BPNS a sensitivity score of 2 (low to medium sensitive).

For the *Lanice conchilega* habitat in EUNIS the sensitivity is low as *L. conchilega* itself can survive a single trawl passage, and it may recover fast (1-2 days) in their 3D structures. However, the associated community and species are more sensitive to disturbance and may disappear or remain present at lower densities for a long period of time even after just a single passage (Degraer *et al.*, 2010; Rabaut *et al.*, 2008). Therefore, the *Lanice conchilega* aggregations in the BPNS are scored as 2 (low to medium sensitive).

In accordance to the MarESA classification, gravel biotopes are classified mainly as medium sensitive. But, in the past boulders and gravel have been removed by fishing activity, creating loss of the habitat (physical change of the seabed/sediment). In areas with a relatively high gravel content and a lower level of natural disturbance, the benthos is expected to have a higher sensitivity to trawl disturbance as compared to the more sandy habitats that are exposed to higher shear bed stress. Therefore, gravel beds in the BPNS are assessed as being highly sensitive (score 5) to all types of bottom contacting gear, even gears with small subsurface impact, and larger surface impact.

4.2. Biotope descriptions and their sensitivity classifications: the details

Note for the readers:

In this chapter, the details about the habitats/biotopes and its sensitivity classification is outlined, which is summarised in chapter 4.1. It gives a description of the structural and functional characteristics of the different habitat features as described in Breine *et al.* (2018) and for the two features recognized as reefs: the *L. conchilega* aggregations and the gravel beds. For those habitat features the linked EUNIS biotopes for each habitat features is given, accompagned with their description of the MarLin website. The sensitivity classification of those EUNIS biotopes is copied from the MarLin website, accompagned with their description.

4.2.1. Limecola balthica community

4.2.1.1. Biotope information

The biotope ***Limecola balthica* community on the BPNS** is described in Breine *et al.* (2018) as follows: The *L. balthica* community is found in areas characterized by sandy mud (mud content (45 $\pm$ 29%); median grain size (184 $\pm$ 72 μm)). It is dominated by Cirratulidae spp., followed by *L. balthica*. Other characterizing species/taxa were Oligochaeta spp., *Nephtys hombergii* and *A. alba*. This community typically has very low densities (N=580 $\pm$ 1206 individuals per m2), biomass (40 $\pm$ 101 g m^{-2}), and the lowest number of taxa (7 $\pm$ 3 per 0.1m^2, d=0.9 $\pm$ 0.5) and diversity values (H= 1.8 $\pm$ 0.7, Simpson = 0.6 $\pm$ 0.2) compared to the other communities.
Bioturbation potential (BPc) is very low (42 $\pm$ 107 per 0.1m^2), with *L. balthica*, *A. alba* and *N. hombergii* contributing most to the BPc value. This is the only community where the trait ʻlarval development' showed a more or less equal distribution of taxa over the three trait modalities: planktotrophic (39%), lecithotrophic (38%, mostly due to Cirratulidae spp.) and direct development (22%). Trait analysis further pointed out that maximum size is 11‑20mm for 53% of all individuals, and for 95% of all individuals, maximum longevity is between 1 and 10 years. Burrow dwelling (67% of abundances) is the most important living habit, and the most common feeding mode is subsurface deposit feeding (45% of abundances). Furthermore, most individuals are sessile (71%), and the most important modalities for bioturbation are diffusive mixing (48%) and surface deposition (36%).

In relation to the EUNIS classification system, this community is catalogued under EUNIS level 3 (habitat complex level) to the category A5.3: Sublittoral mud and can be associate with the following EUNIS level 5 (biotopes level).

A5.331 - *Nephtys hombergii* and *Limecola*(*Macoma) balthica* in infralittoral sandy mud
Near-shore shallow sandy muds and muds, and sometimes mixed sediments, may be characterised by the presence of the polychaete *Nephtys hombergii* and the bivalve *Limecola balthica*. *Abra alba*, and *Nucula nitidosa* may also be important although they may not necessarily occur simultaneously or in high numbers. Other taxa include *Spiophanes bombyx*, *Lagis koreni*, and *Echinocardium cordatum*. In some areas *Scoloplos armiger* and *Crangon crangon* may also be present. The community appears to be quite stable (Dewarumez *et al.* 1992) and the substratum is typically rich in organic content. This community has been included in the 'Boreal Offshore Muddy Sand Association' of Jones (1950) and is also described by several other authors (Petersen 1918; Cabioch & Gla‡on 1975). A similar community may occur in deep water in the Baltic (Thorson 1957). This biotope may occur in slightly reduced salinity estuarine conditions where *Mya* sp. may become a significant member of the community (Thorson 1957).
Situation: The community may occur in small patches or swathes in shallow waters parallel to the shore (Jones 1950; Cabioch & Gla‡on 1975) or in shallow nearshore depressions or trenches where finer material collects e.g. off the Suffolk coast (IECS 1991). This biotope is known to occur in patches between Denmark and the western English Channel.

4.2.1.2. Sensitivity to abrasion

Summary:
The *Limecola balthica* habitat in EUNIS is classified as medium sensitive, due to higher sensitivity of *Nephtys hombergii.* On the other site, a lot of opportunistic species (E.g. oligochaeta spp., Cirratulidae spp.) are also present, which are less sensitive. Besides that, the dominant species *L. balthica* has a low sensitivity in accordance to MarLin. Due to the combination of those factors, the *Limecola balthica* habitat of the BPNS gets a sensitivity score of 2 (low to medium sensitive).

A5.331 - *Nephtys hombergii* and *Macoma balthica* in infralittoral sandy mud

(*https://www.marlin.ac.uk/habitats/detail/173#sensitivity_review*) + additional info in Annex 1.

	Resistence	Resilience	Sensitivity
Abrasion/disturbance of the surface of the substratum or seabed	Low	Medium	Medium
	Q: High A: Medium C: Medium	Q: High A: Medium C: Medium	Q: High A: Medium C: Medium

The biotope will be impacted if damage to seabed surface features is widespread, as, although, motile and opportunistic fauna, such as *Streblospio shrubsolii* and Tubificoides benedii may recover quickly *Nephtys hombergii* shows a greater negative impact (Collie *et al.*, 2000, Ferns *et al.*, 2000, Kaiser *et al.*, 2001). Resistance is assessed as 'Low', Resilience is assessed as 'Medium', providing a sensitivity assessment of 'Medium'.

Key species for BPNS: *Limecola balthica*

	Intolerance	*Recoverability*	*Sensitivity*	*Evidence/confidence*
Abrasion & physical disturbance	Intermediate	High	Low	Very low

No evidence was found concerning the effect of physical abrasion on *Limecola balthica*. However, the species is not mobile enough to be able to avoid an object such as a dragging anchor or a scallop dredge and the shell is relatively thin and would probably be damaged by such an impact. It is expected that some mortality would result and therefore intolerance is assessed as intermediate. Recoverability is recorded as high (see additional information below).

4.2.2. *Abra alba* community

4.2.2.1. Biotope information

The biotope ***Abra alba* community on the BPNS** is described in Breine *et al.* (2018) as follow.
In the *A. alba* community, the median grain size is 211 ± 44 µm and mud content 12 ± 14%. The taxa contributing most to within-group similarity were *A. alba* and Oligochaeta spp. (9 and 7%, respectively). Other dominant species are *Spiophanes bombyx, Cirratulidae spp., Scoloplos armiger, Kurtiella bidentata, Magelona spp* and *Lanice conchilega*. This community has the highest densities (5563 ± 7694 individuals per m2), biomass (669 ± 878 g m^{-2}), diversity (H' =3.1 ± 0.8, Simpson=0.77 ± 0.15), number of taxa (26 ± 9 per $0.1m^2$, d=3.02 ± 0.8), and BPc (431 ± 415 per $0.1m^2$) (Table 1). The species contributing most to BPc are *A. alba*, *Echinocardium cordatum* and *Lanice conchilega*.

With respect to bioturbation modalities, both downward convection and surface deposition made up 34% of densities, while 28% of all individuals are diffusive mixers. Maximum longevity is between 1 and 10 years for 88% of all individuals, but the 5% of individuals that live>10 years are responsible for 43% of the community biomass. With respect to mobility, sessile organisms (67%) dominated this community. The modalities of the other traits are more or less equally represented (Annex, table A1), as can be seen for living habit (tube dwelling (34%), burrow dwelling (38%) and free living (27%)), and feeding mode (suspension feeding (24%), surface deposit feeding (29%), and subsurface deposit feeding (33%)).

In relation to the EUNIS classification system, this community is catalogued under EUNIS level 3 (habitat complex level) to the category A5.2: Sublittoral sand and can be associate with the following four EUNIS level 5 (biotopes level).

A5.261 *Abra alba* & *Nucula nitidosa* in circalittoral muddy sand or slightly mixed sediment

Non-cohesive muddy sands or slightly shelly/gravelly muddy sand characterized by the bivalves *Abra alba* and *Nucula nitidosa*. Other important taxa include *Nephtys* spp., *Chaetozone setosa* and *Spiophanes bombyx* with *Fabulina fabula* also common in many areas. The echinoderms *Ophiura albida* and *Asterias rubens* may also be present. The epibiotic biotope EcorEns may overlap this biotope. This biotope is part of the *Abra* community defined by Thorson (1957) and the infralittoral etage described by Glemarec (1973) (JNCC, 2015).

A5.241 - Echinocardium cordatum and Ensis spp. in lower shore and shallow sublittoral slightly muddy fine sand

Sheltered lower shore and shallow sublittoral sediments of sand or muddy fine sand in fully marine conditions, supporting populations of the urchin *Echinocardium cordatum* and the razor shell *Ensis siliqua* or *Ensis ensis*. Other notable taxa within this biotope include occasional *Lanice conchilega, Pagurus* and *Liocarcinus* spp. and *Asterias rubens*. This biotope has primarily been recorded by epifaunal dive, video or trawl surveys where the presence of relatively conspicuous taxa such as *Echinocardium cordatum* and *Ensis* spp. have been recorded as characteristic of the community. However, these species, particularly *Echinocardium cordatum* have a wide distribution and are not necessarily the best choice for a characteristic taxa (Thorson, 1957). Furthermore, detailed quantitative infaunal data for this biotope is often rather scarce, possibly as a result of survey method as remote grab sampling is likely to under-estimate deep-burrowing species such as *Ensis* sp. (Warwick & Davis, 1977). Consequently, it may be better to treat this biotope as an epibiotic overlay which is likely to overlap a number of other biotopes such as FfabMag, NcirBat and AalbNuc with infaunal components of these biotopes occurring within EcorEns. The precise nature of this infaunal community will be related to the nature of the substratum, in particular the quantity of silt/clay present. Infaunal species may include the polychaetes *Spiophanes bombyx, Magelona mirabilis, Nephtys cirrosa* and *Chaetozone setosa* and the amphipod *Bathyporeia* spp. This biotope is currently broadly defined and needs further consideration as to whether it should be placed at biotope or biotope complex level. AreISa is another biotope based primarily on epibiotic data. It is likely that this biotope and EcorEns form a wider epibiotic sand /muddy sand community with EcorEns biased towards sandier areas and SSA.AreISa towards slightly muddier areas (this description was taken from Connor *et al.*, 2004: JNCC).

A5.351 - Amphiura filiformis, Mysella bidentata and Abra nitida in circalittoral sandy mud

Cohesive sandy mud off wave exposed coasts with weak tidal streams can be characterized by super-abundant *Amphiura filiformis* with *Kurtiella bidentata* (syn. *Mysella bidentata)* and *Abra nitida*. This community occurs in muddy sands in moderately deep water (Hiscock 1984; Picton *et al.*, 1994) and may be related to the 'off-shore muddy sand association' described by other workers (Jones, 1951; Thorson, 1957; Mackie, 1990) and is part of the infralittoral etage described by Glemarec. This community is also characterized by the sipunculid *Thysanocardia procera* and the polychaetes *Nephtys incisa, Phoronis* sp. and *Pholoe* sp., with cirratulids also common in some areas. Other taxa such as *Nephtys hombergii*, *Echinocardium cordatum, Nucula nitidosa, Callianassa subterranea* and *Eudorella truncatula* may also occur in offshore examples of this biotope (e.g. K�nitzer *et al.,* 1992). (Information taken from Connor *et al.*, 2004).

A5.137 Dense Lanice conchilega and other polychaetes in tide-swept infralittoral sand and mixed gravelly sand

Dense beds of *Lanice conchilega* occur in coarse to medium fine gravelly sand in the shallow sublittoral, where there are strong tidal streams or wave action. Several other species of polychaete also occur as infauna e.g. *Spiophanes bombyx*,*Scoloplos armiger*, *Chaetozone setosa* and *Magelona mirabilis*. *Lanice* beds are found in a wide range of habitats including muddier mixed sediment. The dense *Lanice* biotope (LGS.Lan) on certain lower shores may be a littoral extension of the current biotope. The presence of *L. conchilega* in high numbers may, over time, stabilise the sediment to the extent where a more diverse community may develop (Wood, 1987). Possibly as a result of this, there is a high level of variation with regard the infauna found in SCS.SLan. It is likely that a number of sub-biotopes may subsequently be identified for this biotope. Offshore from the Wash and the North Norfolk coast *Lanice* beds are often found intermixed with *Sabellaria spinulosa* beds in muddier mixed sediment, particularly in the channels between the shallow sandbanks, which are so prevalent in this area (IECS, 1995; NRA, 1995). It is possible that the presence of *Lanice* has stabilised the habitat sufficiently to allow the deposition of finer material, which has subsequently assisted the development of *S. spinulosa*. It may be more accurate to define SLan as an epibiotic biotope which overlays a variety of infaunal biotopes (e.g. NcirBat in finer sands and AalbNuc or FfabMag in slightly muddier areas) (JNCC, 2015).

4.2.2.2. Sensitivity to abrasion

Summary:

The *Abra alba* habitat on the BPNS corresponds with different EUNIS biotope classes, with a variable sensitivity classification ranging from not sensitive to medium sensitive. In most cases, the characterizing fauna is suffering depletion after abrasion events, leading to a low to medium resistance to abrasion. At the opposite, most fauna is characterized as highly resilient, due to its rapid recruitment. Overall, this leads to a low to medium sensitivity to abrasion. Therefore, the *Abra alba* habitat of the BPNS gets a sensitivity score of 2 (low to medium sensitive), as some species groups are determined as medium sensitive.

A5.261 Abra alba & Nucula nitidosa in circalittoral muddy sand or slightly mixed sediment

Circalittoral muddy sand

https://www.marlin.ac.uk/habitats/detail/62#sensitivity_review

	Resistence	Resilience	Sensitivity
Abrasion/disturbance of the surface of the substratum or seabed	Medium	High	Low
	Q: Low A: NR C: NR	Q: High A: Medium C: High	Q: Low A: Low C: Low

Sensitivity assessment: Abrasion is likely to damage epifauna and flora and may damage a proportion of the characterizing species, biotope resistance is therefore assessed as ‘Medium’. Resilience is assessed as ‘High’ as opportunistic species are likely to recruit rapidly and some damaged characterizing species may recover or recolonize. Biotope sensitivity is assessed as ‘Low’.

A5.241 - *Echinocardium cordatum* and *Ensis* spp. in lower shore and shallow sublittoral slightly muddy fine sand

Infralittoral muddy sand

https://www.marlin.ac.uk/habitats/detail/124#sensitivity_review

	Resistence	Resilience	Sensitivity
Abrasion/disturbance of the surface of the substratum or seabed	Low	Medium	Medium
	Q: High A: High C: High	Q: High A: High C: High	Q: High A: High C: High

Sensitivity assessment: The infaunal position provides some protection but the characterizing species of the biotope may suffer some damage as a result of surface abrasion. Resistance is therefore assessed as Low and resilience as Medium so the biotope’s sensitivity is assessed as Medium.

A5.351 - *Amphiura filiformis*, *Mysella bidentata* and *Abra nitida* in circalittoral sandy mud

Circalittoral sandy mud

https://www.marlin.ac.uk/habitats/detail/368#sensitivity_review

	Resistence	Resilience	Sensitivity
Abrasion/disturbance of the surface of the substratum or seabed	Low	Medium	Medium
	Q: High A: High C: Medium	Q: Low A: NR C: NR	Q: Low A: NR C: NR

Sensitivity assessment: Although burrowing life habits may provide some protection from damage by abrasion at the surface, a proportion of the population is likely to be damaged or removed. Significant impacts in population density would be expected if such physical disturbance were repeated at regular intervals. Furthermore, the nature of the soft sediment where the biotopes occur means that objects causing abrasion, such as fishing gears (including pots and creels) are likely to penetrate the surface and cause further damage to the characterizing species. Resistance is therefore assessed as Low and resilience as Medium, so sensitivity is assessed as Medium.

A5.137 Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand and mixed gravelly sand

Part of: Infralittoral coarse sediment

https://www.marlin.ac.uk/habitats/detail/116#sensitivity_review

	Resistence	Resilience	Sensitivity
Abrasion/disturbance of the surface of the substratum or seabed	High Q: High A: High C: High	High Q: High A: High C: High	Not sensitive Q: High A: High C: High

Sensitivity assessment: The experiments by Rabaut *et al.* (2008) suggest that *Lanice conchilega* has 'High' resistance to abrasion, however, other associated species may be more impacted but species may be able to repair and recover from damage. Biotope resistance to a single abrasion event is assessed as 'High' based on the key characterizing species Lanice conchilega. There may be some damage to Lanice conchilega tubes and some reduction in abundances of the associated polychaete species but this unlikely to significantly alter the character of the biotope. Recovery from impacts of associated species is predicted to be 'High' and the biotope is assessed as 'Not sensitive'.

Key species for the BPNS: Abra alba

	Intolerance	*Recoverability*	*Sensitivity*	*Evidence/confidence*
Abrasion & physical disturbance	Intermediate	Very high	Low	Moderate

Despite their robust body form, bivalves are vulnerable to physical abrasion. For example, as a result of dredging activity, mortality and shell damage has been reported in *Mya arenaria* and *Cerastoderma edule* (Cotter *et al.*, 1997). *Abra alba* is a shallow burrower and has a fragile shell (Tebble, 1976) and may be damaged by impact Bergmann & Santbrink (2000) reported between <0.5%and 18% mortality of *Abra alba* due to trawling in the southern North Sea, depending on the type of trawl (12 m or 6 m beam trawl or otter trawl). They included *Abra alba* amongst their list of bivalve species most vulnerable to trawling. However, they noted that many bivalve species were able to maintain a population in the face of fishing landings, depending on their life history characteristics. Therefore, intolerance has been assessed to be intermediate. Recoverability has been assessed to be very high.

4.2.3. Magelona-Ensis leei community

4.2.3.1. Biotope information

The biotope ***Magelona-Ensis leei* community on the BPNS** is described in Breine *et al.* (2018) as follows:

The sedimentology of this community is characterized by a median grain size of 199 ± 29 µm and a mud content of 7% ± 13%. This community was dominated by *Magelona spp.* (14.21%) and *E. leei* (12.19%), as they contributed most to the within-group similarity. Other frequent occurring species are *Nepthys cirrosa, Donax vitatus, Spio spp, Nephtys hombergii, Cirratulidae, L. balthica, Abra alba, Spiophanes bombyx, Tellina fabula.* Densities (2511 ± 4682 individuals per m^2) and biomass (269 ± 556 g m^{-2}) were relatively high, whereas number of taxa (S=12 $\pm$ 5 taxa per 0.1m^2) and diversity (d= 1.6 $\pm$ 0.6, H' = 2.2 $\pm$ 0.8, and Simpson= 0.64 $\pm$ 0.23) were low.

BPc averages at 254 $\pm$ 400 per 0.1m^2, with *E. leei*, *L. balthica*, and *N. cirrosa* being the most important bioturbators. Since *E. leei*, apart from other bivalves (*Donax vittatus, L. balthica, A. alba* and *Tellina fabula*), dominate density and biomass, it has the main influence on trait modality distribution. Consequently, 70% of all organisms had an exoskeleton, 58% of all individuals reached a maximum size of 101‑200 mm, and 54% lived longer than 10 years. Living habit was mainly burrow dwelling (84%), and the most important feeding mode was suspension feeding (72% of all abundances). This community was also dominated by sessile organisms (65%) and it was the only community where bioturbation was mainly due to surface deposition (69% of abundances).

In relation to the EUNIS classification system, this community is catalogued under EUNIS level 3 (habitat complex level) to the category A5.2: Sublittoral sand and can be associate with the following two EUNIS level 5 (biotopes level).

A5.242 - *Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand

Part of: Infralittoral muddy sand

In stable, fine, compacted sands and slightly muddy sands in the infralittoral and littoral fringe, communities occur that are dominated by venerid bivalves such as *Chamelea gallina*. This biotope may be characterized by a prevalence of *Fabulina fabula* and *Magelona mirabilis* or other species of Magelona (e.g. *Magelona filiformis*). Other taxa, including the amphipod Bathyporeia spp. and polychaetes such as *Chaetozone setosa, Spiophanes bombyx* and Nephtys spp. are also commonly recorded. In some areas the bivalve Spisula elliptica may also occur in this biotope in low numbers. The community is relatively stable in its species composition, however, numbers of *Magelona* and *Fabulina fabula* tend to fluctuate. Around the Scilly Isles numbers of Fabulina fabula in this biotope are uncommonly low whilst these taxa are often found in higher abundances in muddier communities (presumably due to the higher organic content). Consequently it may be better to revise this biotope on the basis of less ubiquitous taxa such as key amphipod species (E.I.S. Rees pers. comm. 2002) although more data is required to test this. FfabMag and MoeVen are collectively considered to be the 'shallow Venus community' or 'boreal off-shore sand association' of previous workers (see Petersen 1918; Jones 1950; Thorson 1957). These communities have been shown to correlate well with particular levels of current induced 'bed-stress' (Warwick & Uncles 1980). The 'Arctic Venus Community' and 'Mediterranean Venus Community' described to the north and south of the UK (Thorson 1957) probably occur in the same habitat and appears to be the same biotope described as the *Ophelia borealis* community in northern France and the central North Sea (Künitzer et al. 1992). Sites with this biotope may undergo transitions in community composition. The epibiotic biotopes EcorEns and AreISa may also overlay this biotope in some areas (*JNCC, 2015*).

A5.241 - Echinocardium cordatum and Ensis spp. in lower shore and shallow sublittoral slightly muddy fine sand

Sheltered lower shore and shallow sublittoral sediments of sand or muddy fine sand in fully marine conditions, supporting populations of the urchin *Echinocardium cordatum* and the razor shell *Ensis siliqua* or *Ensis ensis*. Other notable taxa within this biotope include occasional *Lanice conchilega, Pagurus* and *Liocarcinus* spp. and *Asterias rubens*. This biotope has primarily been recorded by epifaunal dive, video or trawl surveys where the presence of relatively conspicuous taxa such as *Echinocardium cordatum* and *Ensis* spp. have been recorded as characteristic of the community. However, these species, particularly *Echinocardium cordatum* have a wide distribution and are not necessarily the best choice for a characteristic taxa (Thorson, 1957). Furthermore, detailed quantitative infaunal data for this biotope is often rather scarce, possibly as a result of survey method as remote grab sampling is likely to under-estimate deep-burrowing species such as *Ensis* sp. (Warwick & Davis, 1977). Consequently, it may be better to treat this biotope as an epibiotic overlay which is likely to overlap a number of other biotopes such as FfabMag, NcirBat and AalbNuc with infaunal components of these biotopes occurring within EcorEns. The precise nature of this infaunal community will be related to the nature of the substratum, in particular the quantity of silt/clay present. Infaunal species may include the polychaetes *Spiophanes bombyx, Magelona mirabilis, Nephtys cirrosa* and *Chaetozone setosa* and the amphipod *Bathyporeia* spp. This biotope is currently broadly defined and needs further consideration as to whether it should be placed at biotope or biotope complex level. ArelSa is another biotope based primarily on epibiotic data. It is likely that this biotope and EcorEns form a wider epibiotic sand /muddy sand community with EcorEns biased towards sandier areas and SSA.ArelSa towards slightly muddier areas (this description was taken from Connor *et al.*, 2004: JNCC).

4.2.3.2. Sensitivity to abrasion

Summary:

The *Magelona-Ensis leei* community on the BPNS is more related to what is described for biotope A5.242, as for A5.241. This because *Echinocardium cordatum* is not frequently occurring within this community on the BPNS (more frequent occuring in Abra and Nephtys community). Therefore, the sensitivity classification for the BPNS corresponds best with A5.242 and the sensitivity evaluation of *Magelona* (low sensitivity). Therefore, the *Magelona-Ensis leei* habitat is classified as low sensitive to abrasion (score 1).

A5.242 - *Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand

https://www.marlin.ac.uk/habitats/detail/142

	Resistence	Resilience	Sensitivity
Abrasion/disturbance of the surface of the substratum or seabed	Medium	High	Low
	Q: Low A: NR C: NR	Q: High A: Medium C: High	Q: Low A: Low C: Low

Abrasion is likely to damage epifauna and flora and may damage a proportion of the characterizing species, biotope resistance is therefore assessed as 'Medium'. Resilience is assessed as 'High' as opportunistic species are likely to recruit rapidly and some damaged characterizing species may recover or recolonize. Biotope sensitivity is assessed as 'Low'.

A5.241 - *Echinocardium cordatum* and *Ensis* spp. in lower shore and shallow sublittoral slightly muddy fine sand

Infralittoral muddy sand

https://www.marlin.ac.uk/habitats/detail/124#sensitivity_review

Resistence Resilience Sensitivity

	Low	Medium	Medium
Abrasion/disturbance of the surface of the substratum or seabed	Q: High A: High C: High	Q: High A: High C: High	Q: High A: High C: High

Sensitivity assessment: The infaunal position provides some protection but the characterizing species of the biotope may suffer some damage as a result of surface abrasion. Resistance is therefore assessed as Low and resilience as Medium so the biotope's sensitivity is assessed as Medium.

Key species BPNS: *Magelona mirabilis*

	Intolerance	*Recoverability*	*Sensitivity*	*Evidence/confidence*
Abrasion & physical disturbance	Intermediate	High	Low	Low

Magelona mirabilis is a soft bodied organism which exposes its palps at the surface while feeding. The species lives infaunally in sandy sediment, usually within a few centimetres of the sediment surface. Physical disturbance, such as dredging or dragging an anchor, would be likely to penetrate the upper few centimetres of the sediment and cause physical damage to *Magelona mirabilis*. An intermediate intolerance is therefore recorded. Recoverability is recorded as high (see additional information in annex).

No specific sensitivity information available on *Ensis leei* in Marlin.

4.2.4. Nephtys cirrosa community

4.2.4.1. Biotope information

The biotope ***Nephtys cirrosa* community on the BPNS** is described in Breine *et al.* (2018) as follows:
The *Nephtys cirrosa* community is characterized by a median grain size of 297 $\pm$ 71 μm and<1% mud content (0.4 $\pm$ 1.8%). The most characteristic taxa are *N. cirrosa* and *Spio spp.* that contributed respectively 46 and 11% to the within-group similarity. Other frequent occurring species are *Spiophanes bombyx, Urothoe brevicornis, Magelona, Bathyporeia guilliamsoniana, Ophelia borealis, Echinocardium cordatum, Scoloples armiger*. Mean macrobenthos density (N=368 $\pm$ 360 ind. m^{-2}), biomass (123 $\pm$ 367 g m^{-2}), number of taxa (9 $\pm$ 4 per $0.1m^2$ and d=1.4 $\pm$ 0.6), diversity (H' = 2.4 $\pm$ 0.6, Simpson=0.73 $\pm$ 0.13) and BPc (71.4 $\pm$ 118.2 per $0.1m^2$) are all low in comparison to the other communities.
The most important bioturbators are *E. cordatum, N. cirrosa* and *E. leei*. Apart from planktotrophic larval development (66%), there is also a substantial proportion of organisms that use direct development in this habitat (30% of all individuals). Free living species are the most abundant, encompassing 76% of all individuals. For the trait 'feeding mode' there is a rather equal distribution over all modalities, but with the highest relative amount of predators (22% of individuals) compared to the other communities. In the mobility trait, a dominance of burrowing (49%), swimming (22%), and crawling/creeping/climbing organisms (18%) is observed. Regarding bioturbation, diffusive mixing is the dominant trait modality (75%).

In relation to the EUNIS classification system, this community is catalogued under EUNIS level 3 (habitat complex level) to the category A5.1: Sublittoral coarse sand and can be associate with the following EUNIS level 5 (biotopes level).

A5.233 *Nephtys cirrosa* and *Bathyporeia* spp in infralittoral sand
Part of: Infralittoral fine sand
Well-sorted medium and fine sands characterised by Nephtys cirrosa and Bathyporeia spp. (and sometimes Pontocrates spp.) which occur in the shallow sublittoral to at least 30 m depth. This biotope occurs in sediments subject to physical disturbance, as a result of wave action (and occasionally strong tidal streams). The magelonid polychaete *Magelona mirabilis* may be frequent in this biotope in more sheltered, less tideswept areas whilst in coarser sediments the opportunistic polychaete Chaetozone setosa may be commonly found. The faunal diversity of this biotope is considerably reduced compared to less disturbed biotopes (such as unit A5.242) and for the most part consists of the more actively-swimming amphipods. Sand eels Ammodytes sp. may occasionally be observed in association with this biotope (and others) and spionid polychaetes such as Spio filicornis and S. martinensis may also be present. Occasional Lanice conchilega may be visible at the sediment surface. Temporal variation: Stochastic recruitment events in the *Nephtys cirrosa* populations may be very important to the population size of other polychaetes present and may therefore create a degree of variation in community composition (Bamber 1994).

4.2.4.2. Sensitivity to abrasion

Summary:
The sandy habitat, characterized by *Nephtys cirrosa* is classified under low sensitivity (score 1), due to their high resilience and low resistence. This community is also characterized by mobile amphipods, which have indeed a high survivability and recovery potential.

A5.233 *Nephtys cirrosa* and *Bathyporeia* spp in infralittoral sand
https://www.marlin.ac.uk/habitats/detail/154/nephtys_cirrosa_and_bathyporeia_spp_in_infralittoral_sand

	Resistence	Resilience	Sensitivity
Abrasion/disturbance of the surface of the substratum or seabed	Low	High	Low
	Q: High A: High C: High	Q: High A: Low C: High	Q: High A: Low C: High

Sensitivity assessment. Resistance to a single abrasion event is assessed as ‘Low’ based on the evidence for trampling from Reyes-Martínez *et al.* (2015). Resilience is assessed as ‘High’, based on migration from adjacent populations and in-situ reproduction by surviving amphipods. Sensitivity is therefore assessed as ‘Low’. This assessment may underestimate sensitivity to high-levels of abrasion (repeated events within a short period). The trampling evidence and the evidence for penetration from mobile gears (see below) differ in the severity (resistance) of impact. This may be due to different levels of intensity (multiple trampling/abrasion events vs single penetration/towed gear impacts) or the nature of the pressure. Abrasion from trampling also involves a level of compaction that could collapse burrows and damage species through compression. Penetration may, however, break sediments open allowing mobile species to escape or species may be pushed forwards from towed gear by a pressure wave where this is deployed subtidally (Gilkinson *et al.,* 1998). Both risk assessments are considered applicable to single events based on the evidence and the sensitivity assessment for both pressures is the same although resistance differs.

4.2.5. Hesionura *elongata* community

4.2.5.1. Biotope information

The biotope ***Hesionura elongata* community on the BPNS** is described in Breine *et al.* (2018) as follow: This community occurred in sediments with the highest average median grain size (387 ± 94 µm) and a low mud content (0.9 ± 5.7%). *N. cirrosa* contributed 18% to within-group similarity and *H. elongata* 16%. Besides, this community was characterized by several interstitial polychaete species (*Polygordius spp., Protodrillus spp.* and *Microphthalmus spp.*). Some other frequent occurring species are Oligochaeta spp., Spio spp., *Spiophanes bombyx, Ophelia borealis, Bathyporeia guiliamsoniana*, Gastrosaccus, *Urothoe brevicornis, Bathyporeia elegans, Aonides paucibranchiata*. Density (724 ± 746 ind. m^{-2}), number of taxa (14 ± 5.4 species per $0.1m^2$and d=2.03 ± 0.7) and diversity (H' =2.9 ± 0.6, Simpson=0.79 ± 0.12) were relatively high, while biomass (56.7 ± 142.8 g m^{-2}) and BPc (43.1 ± 40.5 per $0.1m^2$) were low. Most important bioturbators were *N. cirrosa, E. cordatum* and *Ophelia borealis*.
Looking at biological traits, egg development occurred in 53% of all individuals by brooding under adult protection. Larval development is mainly planktotrophic (50%) or lacking (i.e. direct development, 42%). The maximum size was distributed over the three smallest modalities (< 10-100 mm), and 60% of all individuals reached a maximum age between 1 and 2 years. For the remaining traits (living habit, feeding mode, and bioturbation), the trait modalities showed a high similarity with the values observed for the *N. cirrose* community.

In relation to the EUNIS classification system, this community is catalogued under EUNIS level 3 (habitat complex level) to the category A5.1: Sublittoral coarse sand and can be associate with the following EUNIS level 5 (biotopes level).

A5.134 *Hesionura elongata* & *Microphthalmus similis* with other interstitial polychaetes in infralittoral mobile coarse sand
Part of: Infralittoral coarse sediment
On infralittoral sandbanks and sandwaves and other areas of mobile medium-coarse sand, populations of interstitial polychaetes may be found. These habitats consist of loosely packed grains of sand forming waves up to several metres high often with gravel, or occasionally silt, in the troughs of the waves. This biotope is commonly found both inshore along the east coast of the UK e.g. around the Race Bank, Docking Shoal and Inner Dowsing banks (IECS, 1995; IECS, 1999), and in the Southern Bight of the North Sea and off the Belgian coast (Degraer *et al.* 1999; Vanosmael *et al.* 1982). These habitats support interstitial communities living in the spaces between the grains of sand, in particular hesionurid polychaetes such as Hesionura elongata and Microphthalmus similis, along with protodrilid polychaetes such as Protodrilus spp. and Protodriloides spp. Other important species may include Turbellaria spp. and larger deposit feeding polychaetes such as Travisia forbesii. An important feature of this biotope which is not reflected in much of the available data is the importance of the meiofaunal population which may exceed the macrofaunal population both in terms of abundance and biomass (Willems *et al.* 1982).

Situation: This biotope is commonly found both in shore adjacent to the coast, and further away from the coast.

A5.152 *Hesionura elongata* and *Protodorvillea kefersteini* in offshore coarse sand
Part of: Deep circalittoral coarse sediment
Offshore (deep) circalittoral habitats with coarse sand may support populations of the interstitial polychaete *Hesionura elongata* with *Protodorvillea kefersteini*. Other notable species include the phyllodocid polychaete *Protomystides limbata* and the bivalve *Moerella pygmaea*. This biotope was reported in the offshore northern North Sea by Eleftheriou & Basford (1989). Relatively little data exists for this biotope (Information from Connor et al., 2004; JNCC, 2015).

4.2.5.2. Sensitivity to abrasion

Summary:
The coarse sandy habitat, characterized by interstitial polychaetes is classified under low sensitivity (score 1), due to their high resilience and medium resistence. The evidence for the sensitivity assessment of those biotopes is limited.

A5.134 *Hesionura elongata* & *Microphthalmus similis* with other interstitial polychaetes in infralittoral mobile coarse sand
(*https://www.marlin.ac.uk/habitats/detail/379#sensitivity_review*

	Resistence	Resilience	Sensitivity
Abrasion/disturbance of the surface of the substratum or seabed	Medium	High	Low
	Q: High A: Medium C: Medium	Q: High A: Medium C: Medium	Q: High A: Medium C: Medium

Sensitivity assessment: Different sediment types and associated species communities will occur in association with aggregate extraction, scouring around renewable energy device bases and anchoring sites. Penetration and or disturbance of the substratum would result in similar effects as 'abrasion'. As the characterizing species are burrowing species the impact from damage to the sub-surface sea bed would be greater than damage to the sea bed surface. Where coarser sediment is exposed abundance of characterizing species will display limited impact. Where deposition of fine sediment occurs, typically further away from an obstruction such as a wind farm tower, or from deposition of aggregate or drilling waste will be likely to lead to reduction in abundance of characterizing species. Resistance to damage to seabed surface features is assessed as 'Medium'. The species community displays high recoverability and Resilience is 'High' and Sensitivity is assessed as 'Low.'

A5.152 *Hesionura elongata and Protodorvillea kefersteini* in offshore coarse sand
https://www.marlin.ac.uk/habitats/detail/1113/hesionura_elongata_and_protodorvillea_kefersteini_in_offshore_coarse_sand

Resistence	Resilience	Sensitivity

Abrasion/disturbance of the surface of the substratum or seabed	Medium Q: Low A: NR C: NR	High Q: High A: Low C: Medium	Low Q: Low A: Low C: Low

Sensitivity assessment. Evidence is limited but the biological assemblage present in this biotope is characterized by species that are likely to be relatively tolerant of penetration and disturbance of the sediments. Either species are robust or buried within sediments or are adapted to habitats with frequent disturbance (natural or anthropogenic) and recover quickly. The characterizing species are infaunal and likely to be protected from abrasion, although movement of sediments may damage a proportion of the population. Biotope resistance is assessed as 'Medium' as some species will be displaced and may be predated or injured and killed. Biotope resilience is assessed as 'High' as most species will recover rapidly. Biotope sensitivity is therefore assessed as 'Low'.

4.2.6. Lanice conchilega aggregations

4.2.6.1. Biotope information

Lanice conchilega has a wide geographical distribution and a low habitat specialization, but optimally occurs in shallow fine sands. In Van Hoey *et al.* (2008), based on a North Sea wide benthic dataset, the presence of *L. conchilega* resulted in a density increase and a signicant (positive) correlation of the benthos density with the density of *L. conchilega*. Furthermore, the species richness (number of species) increased with increasing density of *L. conchilega*. This trend was, however, not consistent: the number of species reached more orless an asymptotic value or even decreased after reaching a critical density of *L. conchilega* (>500–1,000 ind/m²), as observed in shallow sands. From the results of the community analysis, it can be concluded that the species, which were responsible for the increase of the diversity, belonged to the overall species-pool of that habitat. The effects on density and diversity differed between the four discerned habitats (shallow muddy sand, shallow fine sand, shallow medium sand and deep fine sand), and were most pronounced in shallow fine sands. Therefore, the *Lanice conchilega* aggregations were mostly associated with the *Abra alba* community. And due to the relation of density to the other benthic characteristics (density, diversity), *Lanice conchilega* aggregations were seen as optimal from >500 ind/m² in relation to conservation.
These patterns can be attributed to the habitat structuring capacity of *L. conchilega*. The mechanisms responsible for the increase of the habitat quality in patches of *L. conchilega* can be summarized as (1) changes in the hydrodynamics, (2) increases of the habitat stability and oxygen supply, and (3) a creation of habitat heterogeneity in a uniform environment. In this way, *L. conchilega* alters the habitat characteristics and affects other organisms, and can therefore be considered as an ecosystem engineer. In other words, *L. conchilega* patches are responsible for an increased habitat quality in an otherwise uniform habitat, which results in a higher survival of the surrounding benthic species. A detailed list of associated species of Lanice patches is described in Rabout *et al.* (2007). Positively associated bivalves were *Donax vittatus*, *Ensis spp.*, *Mysella bidentata*, *Spisula subtruncata, Abra alba*, Tellina fabula and others. For polychaetes, *Pygospio elegans, Eumida sanguinea, Harmothoe spp., Spiophanes bombyx*, etc. were found to be strongly associated, whereas some of the most associated amphipods were *Pariambus typicus, Urothoe poseidonis, Gammarus spp.*, etc. Based on association degree only, eight species were exclusively associated (100%) with *L. conchilega* tubes: *Gattyana*

cirrhosa, Asterias rubens, Bodotria arenosa, Gammarus spp., Leucothoe lilljeborgii, Liocarcinus arcuatus, Amphilochus neopolitanus and *Pagurus bernhardus*.

A5.137 Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand and mixed gravelly sand

Dense beds of *Lanice conchilega* occur in coarse to medium fine gravelly sand in the shallow sublittoral, where there are strong tidal streams or wave action. Several other species of polychaete also occur as infauna e.g. *Spiophanes bombyx, Scoloplos armiger, Chaetozone setosa* and *Magelona mirabilis*. Lanice beds are found in a wide range of habitats including muddier mixed sediment. The dense Lanice biotope (LGS.Lan) on certain lower shores may be a littoral extension of the current biotope. The presence of *L. conchilega* in high numbersmay, over time, stabilise the sediment to the extent where a more diverse community may develop (Wood, 1987). Possibly as a result of this, there is a high level of variation with regard the infauna found in SCS.SLan. It is likely that a number of sub-biotopes may subsequently be identified for this biotope. Offshore from the Wash and the North Norfolk coast *Lanice* beds are often found intermixed with Sabellaria spinulosa beds in muddier mixed sediment, particularly in the channels between the shallow sandbanks, which are so prevalent in this area (IECS, 1995; NRA, 1995). It is possible that the presence of *Lanice* has stabilised the habitat sufficiently to allow the deposition of finer material, which has subsequently assisted the development of *S. spinulosa*. It may be more accurate to define SLan as an epibiotic biotope which overlays a variety of infaunal biotopes (e.g. NcirBat in finer sands and AalbNuc or FfabMag in slightly muddier areas) (*JNCC, 2015*).

4.2.6.2. Sensitivity to abrasion

Summary:

For the *Lanice conchilega* habitat in EUNIS the sensitivity is low as *L. conchilega* itself can survive a single trawl passage, and it may recover fast (1-2 days) in their 3D structures. However, the associated community and species are more sensitive to disturbance and may disappear or remain present at lower densities for a long period of time even after just a single passage (Degraer *et al.*, 2010; Rabaut *et al.*, 2008). Therefore, the *Lanice conchilega* aggregations sensitivity for the BPNS is scored as 2 (low to medium sensitive).

A5.137 Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand and mixed gravelly sand

https://www.marlin.ac.uk/habitats/detail/116

Resistence Resilience Sensitivity

Sensitivity assessment. The experiments by Rabaut *et al.* (2008) suggest that *Lanice conchilega* has 'High' resistance to abrasion, however, other associated species may be more impacted but species may be able to repair and recover from damage. Biotope resistance to a single abrasion event is assessed as 'High' based on the key characterizing species *Lanice conchilega*. There may be some damage to *Lanice conchilega* tubes and some reduction in abundances of the associated polychaete species but this unlikely to significantly alter the character of the biotope. Recovery from impacts of associated species is predicted to be 'High' and the biotope is assessed as 'Not sensitive'.

Benthic key species BPNS: *Lanice conchilega*

	Intolerance	Recoverability	Sensitivity	Evidence/confidence
Abrasion & physical disturbance	Intermediate	Very high	Low	Low

Lanice conchilega inhabits a permanent tube and is likely to be damaged by any activity that penetrates the sediment. Ferns *et al.* (2000) investigated the effect of mechanical cockle harvesting (see extraction below). The tubes of *Lanice conchilega* were damaged but this damage was seen to be repaired. An intolerance of intermediate has therefore been recorded. A recoverability of very high has been recorded (see additional information below). This assessment is for minor abrasion or disturbance, major abrasion, or disturbance would be similar to substratum removal.

4.2.7. Gravel beds

4.2.7.1. Biotope information

The biotope **gravel beds on the BPNS** as described for the MSFD assessment (Belgische staat, 2018) is as follows:
Gravel beds are valuable habitats in the mainly sandy sediments of the southern North Sea. Historical data from the Hinderbanks have shown that until the early 20th century, a rich fauna was present in the gravel beds of the BPNS, characterized by erected species typical of hard substrates, such as sponges, bryozoa and hydrozoa, but flat oysters also once formed banks there. However, due to the increasing magnitude of bottom trawling, the gravel beds became highly pressurized. Even today, frequent fishing occurs in the gravel beds, mainly by a foreign fleet (see chapter 6). Stones are overturned or removed, destroying the often fragile typical hard substrate fauna and the habitat is reduced in size. The indicator species on which the environmental targets are based are species that are typically expected in a gravel habitat, but at the same time are sensitive to disturbance. *Buccinum undatum* (whelk) is a snail that deposits egg packets, deposited on the hard substrate. Fishing physically removes the animals and destroys the eggs. *Mytilus edulis* (mussel) settles as spat on the stones. They are crushed when the bottom is stirred up. *Alcyonium digitatum* (dead man's thumb), *Flustra foliacea* (Bryozoa), *Haliclona oculate* (antler sponge) and *Alcyonidium* sp. are fragile erected organisms that are destroyed by trawling and do not have given the chance to grow to their maximum colony size. *Ostrea edulis* (oyster), *Sabellaria spinulosa* and *Pomatoceros triqueter* build three-dimensional reefs in undisturbed conditions over the years on which a rich associated fauna can develop.
Key species summary (Montereale-Gavazzi G; 2021 Personal communication): *Alcyonium digitatum, Alcyonidium diaphanum, Haliclona oculata, Sabellaria spinulosa, Spirobrancus triqueter, Ostrea edulis, Buccinum undatum, Majidae spp., Mytilus edulis, Flustra foliacea*,..

In relation to the EUNIS classification system, this community is catalogued under EUNIS level 3 (habitat complex level) to the category A4: Atlantic and Mediterranean moderate energy circalittoral rock and A5.2: Sublittoral biogenic reefs and can be associated with the following EUNIS level 5 (biotopes level).

A5.611: *Sabellaria spinulosa* on stable circalittoral mixed sediment

The tube-building polychaete *Sabellaria spinulosa* has high abundances on mixed sediment. These species typically form loose agglomerations of tubes forming a low lying matrix of sand, gravel, mud and tubes on the seabed. The infauna comprises typical sublittoral polychaete species such as Protodorvillea kefersteini, Pholoe synophthalmica, Harmothoe spp, Scoloplos armiger, Mediomastus fragilis, *Lanice conchilega* and cirratulids, together with the bivalve *Abra alba*, and tube building amphipods such as *Ampelisca* spp. The epifauna comprise a variety of bryozoans including Flustra foliacea, *Alcyonidium diaphanum* and *Cellepora pumicosa*, in addition to calcareous tubeworms, pycnogonids, hermit crabs and amphipods. The reefs formed by Sabellaria consolidate the sediment and allow the settlement of other species not found in adjacent habitats leading to a diverse community of epifaunal and infauna species. The development of such reefs is assisted by the settlement behaviour of larval Sabellaria which are known to selectively settle in areas of suitable sediment and particularly on existing Sabellaria tubes (Tait and Dipper, 1998; Wilson, 1929). These reefs are particularly affected by dredging or trawling and in heavily dredged or disturbed areas an impoverished community may be left (e.g. SS.SCS.CCS.Pkef) particularly if the activity or disturbance is prolonged. However, it is likely that reefs of Sabellaria spinulosa can recover quite quickly from short-term or intermediate levels of disturbance as found by Vorberg (2000) in the case of disturbance from shrimp fisheries. Recovery will be accelerated if some of the reef is left intact following disturbance as this will assist larval settlement of the species. (Information from Connor *et al.,* 2004; JNCC, 2015).

A4.232: Polydora sp. Tubes on moderately exposed sublittoral soft rock

Large patches of chalk and soft limestone are occasionally covered entirely by *Polydora* sp. tubes to the exclusion of almost all other species. This tends to occur in highly turbid conditions and spans the infralittoral and circalittoral in limestone areas such as the Great and Little Ormes (North Wales) and Gower (South Wales). It is even present on the lower shore in the Severn estuary. The boring form of the sponge *Cliona celata* often riddles the surface layer of the stone. Other sponges present include *Halichondria panicea, Haliclona oculata* and *Hymeniacidon perlevis* (syn. *Hymeniacidon perleve*). *Polydora* sp. also frequently occurs in small patches as part of other biotopes (e.g. FluCoAs). Other species present include *Alcyonium digitatum, Sarcodictyon roseum*, the hydroids *Halecium halecinum, Abietinaria abietina* and *Tubularia indivisa*, the ascidians C*lavelina lepadiformis, Botryllus schlosseri* and *Morchellium argus*, the anemones *Urticina felina*, *Metridium dianthus* (syn. *Metridium senile)* and *Sagartia elegans* and the bryozoans *Flustra foliacea* and a crisiid turf. The starfish *Asterias rubens*, the crabs *Inachus phalangium* and *Carcinus maenas*, the polychaete *Spirobranchus triqueter* (syn. *Spirobranchus triqueter)*, the barnacle *Balanus crenatus* and the brittlestar *Ophiothrix fragilis* may also be seen. **Please note**: this biotope may extend into the infralittoral and littoral zone in areas where water turbidity is sufficiently high. (Information taken from Connor *et al.*, 2004).

A4.135: Sparse sponges, Nemertesia spp., and *Alcyonidium diaphanum* on circalittoral mixed substrata

This biotope is found on moderately wave-exposed sand-scoured, circalittoral boulders, cobbles and pebbles that are subject to moderately strong tidal streams (referred to as lag-cobbles locally). It is characterized by sparse sponges and a diverse bryozoan and hydroid turf. The sparse sponge community is primarily composed of *Dysidea fragilis* and*Scypha ciliata*. The mixed faunal turf is composed of *Nemertesia antennina*, *Nemertesia ramosa*, *Halecium halecinum*,*Sertularia argentea*, *Alcyonium digitatum*, *Bugulina flabellata*, *Bugulina turbinata*, *Crisularia plumosa*, *Flustra foliacea*, *Cellepora pumicosa*, *Alcyonidium diaphanum*, *Cellaria fistulosa* and crisiid bryozoans. The anemones *Epizoanthus couchii*, *Sagartia elegans* and *Cerianthus lloydii* may also be recorded. Echinoderms such as the starfish *Asterias rubens*, *Crossaster papposus*, *Henricia oculata* and the crinoid *Antedon bifida*. Other species present include the colonial ascidian *Clavelina lepadiformis*, the barnacle *Balanus crenatus*, the top shell *Gibbula cineraria*, the polychaete*Spirobranchus triqueter*, the ascidian *Morchellium argus*, *Prosthecareus vittatus* and the crab *Cancer pagurus*. It is distributed off Pen Llyn and over considerable areas of the Irish Sea.

A4.221 *Sabellaria spinulosa* encrusted circalittoral rock
This variant is typically found on tide-swept, moderately wave-exposed circalittoral bedrock, boulders and cobbles subject to slight sand-scour. It occurs predominantly in the lower circalittoral. This variant normally appears as a bedrock/boulder outcrop or reef with a dense crust of the polychaete *Sabellaria spinulosa* and a dense turf of didemnid ascidians and scour-tolerant bryozoans such as *Flustra foliacea*, *Pentapora foliacea* and *Cellaria* species. There may be discreet clumps of *Alcyonium digitatum* and sparse sponges such as *Tethya aurantium* and *Phorbas fictitius*. Patchy occurrences of the small ascidians *Polycarpa scuba*, *Polycarpa pomaria* and *Distomus variolosus* may be present on the tops of rocks and boulders whilst in crevices between, the anemone *Urticina felina* may be found. Species such as *Asterias rubens*,*Crossaster papposus*, the serpulid worm *Salmacina dysteri* and the anemone *Sagartia elegans* are occasionally seen on the rock surface. This variant has been recorded from the Lleyn Peninsula, the Skerries and around Pembrokeshire in Wales. (Information from Connor *et al.*, 2004; JNCC, 2015).

A4.2142: Alcyonium digitatum, Spirobranchus triqueter, algal and bryozoan crust on wave-exposed circalittoral rock
This variant is typically found on the vertical, steep and upper faces of wave-exposed circalittoral bedrock or boulders subject to varying amounts of current. The variant has a very grazed, sparse appearance, dominated only by the presence of *Alcyonium digitatum* and large expanses of encrusting red alage and bryozoan crusts particularly (*Parasmittina trispinosa*). The sparse appearance can be attributed to the frequently observed sea urchin *Echinus esculentus*. The polychaete *Spirobranchus triqueter* can be locally abundant, and may in some cases cover far more rock surface than *A. digitatum*, especially on vertical faces. Clumps of robust hydroids such as *Abietinaria abietina* occur occasionally. Other species present include the echinoderms *Asterias rubens*, *Henricia sanguinolenta*, *Ophiothrix fragilis*, the anemone *Urticina felina*, *Calliostoma zizyphinum* and *Cancer pagurus*. (Information from Connor *et al.,* 2004; JNCC,2015).

4.2.7.2. Sensitivity to abrasion

The gravel beds are currently in an unfavorable status. In the past boulders and gravel have been removed by fishing nets. In this sensitivity review, we therefore also take into account extraction and physical change of seabed/sediment.

Summary:

In accordance to the MarESA classification, gravel biotopes are classified mainly as medium sensitive. But, in the past boulders and gravel have been removed by fishing activity, creating loss of the habitat (physical change of the seabed/sediment). In areas with a relatively high gravel content and a lower level of natural disturbance, the benthos is expected to have a higher sensitivity to trawl disturbance as compared to the more sandy habitats that are exposed to higher bed shear stress. Therefore, gravel beds in the BPNS are assessed as being highly sensitive (score 5) to all types of bottom contacting gear, even gears with small subsurface impact, and larger surface impact.

A5.611: *Sabellaria spinulosa* on stable circalittoral mixed sediment

https://www.marlin.ac.uk/habitats/detail/377/sabellaria_spinulosa_on_stable_circalittoral_mixed_sediment

	Resistence	Resilience	Sensitivity
Abrasion/disturbance of the surface of the substratum or seabed	Low Q: Low A: NR C: NR	Medium Q: Medium A: High C: Medium	Medium Q: Low A: Low C: Low

Sensitivity assessment: Based on the evidence discussed under this assessment (see annex 1), abrasion at the surface of Sabellaria spinulosa reefs is considered likely to damage the tubes and result in sub-lethal and lethal damage to the worms. Resistance is therefore assessed as 'Low' (loss of 25-75% of tubes and worms within the impact footprint). Resilience is therefore assessed as 'Medium' (within 2 years) and sensitivity is therefore assessed as 'Medium'. This assessment is relatively precautionary and it should be noted the degree of resilience will be mediated by the character of the impact. The recovery of small areas of surficial damage in thick reefs is likely to occur through tube repair and may be relatively rapid.

A4.232: Polydora sp. Tubes on moderately exposed sublittoral soft rock

https://www.marlin.ac.uk/habitats/detail/247/polydora_sp_tubes_on_moderately_exposed_sublittoral_soft_rock

- Abrasion

	Resistence	Resilience	Sensitivity
Abrasion/disturbance of the surface of the substratum or seabed	None Q: High A: High C: High	High Q: High A: Medium C: High	Medium Q: High A: Medium C: High

Sensitivity assessment: The characterizing Polydora community in this biotope, is considered likely to be damaged and removed by abrasion. As a soft bodied species, Polydora ciliata is likely to be crushed and killed by an abrasive force or physical blow. Erect epifauna are directly exposed to this pressure which would displace, damage and remove individuals. Resistance to abrasion is considered None. However, Polydora is likely to be able to re-establish the lost community rapidly, so resilience of the biotope is assessed as High with the biotope considered to have Medium sensitivity to abrasion or disturbance of the surface of the seabed. The substratum is unable to recover from damage and therefore the biotope would be considered highly sensitivity to abrasion that damaged or removed the soft rock substratum.

- Extraction

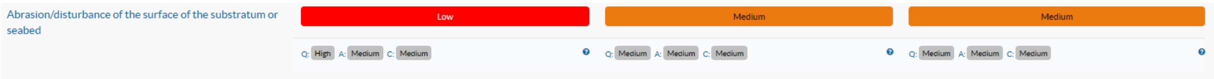
	Resistence	Resilience	Sensitivity
Habitat structure changes - removal of substratum (extraction)	None Q: High A: High C: High	Very Low Q: High A: High C: High	High Q: High A: High C: High

Removal of the substratum to 30 cm would result in the loss of *Polydora* sp. tubes. Resistance to the pressure is considered None, and resilience Very Low based on the loss of suitable substratum to support the community of the characterizing species of *Polydora*. Sensitivity has been assessed as High. Although no specific evidence is described confidence in this assessment is ‘High’, due to the incontrovertible nature of this pressure.

A4.135: Sparse sponges, Nemertesia spp., and *Alcyonidium diaphanum* on circalittoral mixed substrata

- Abrasion

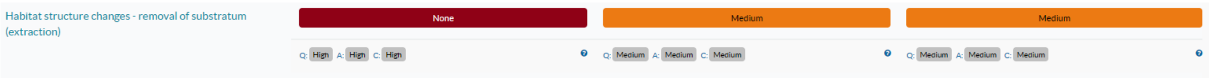
Resistence Resilience Sensitivity



Sensitivity assessment: Given the sessile, erect nature of the sponges, hydroids and bryozoans, damage and mortality following a physical disturbance effect are likely to be significant, however some studies have brought into question the extent of damage to the faunal turf. A proportion of the biotope occurs on cobbles, pebbles and mobile substrata, which could result in increased damage in abrasion events. The physiology of the bryozoans affords some protection in the event of abrasion events and recovery is likely to be rapid if stolons remain undamaged. Based on the potential damage to sponges, resistance is assessed as ‘Low’, resilience as ‘Medium’, and sensitivity is assessed as ‘Medium’.

- Extraction

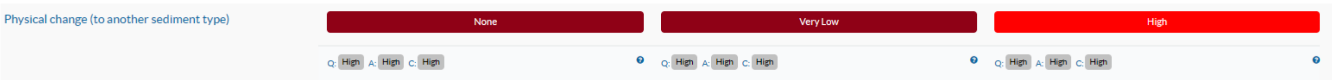
Resistence Resilience Sensitivity



Sensitivity assessment. Biotope resistance is assessed as ‘None’ (in the extraction footprint), resilience (following habitat restoration, or where the underlying substratum remains the same) is assessed as ‘Medium’. Sensitivity is, therefore, assessed as ‘Medium’. Recovery will be prolonged (and sensitivity greater) where the entire habitat is removed and restoration (artificial or natural) to the previous state does not occur.

- Physical change (to another sediment type)

Resistence Resilience Sensitivity



The biotope is considered to have no resistance to this pressure as change to a soft sediment substratum (e.g., by burial) may be irreversible. Recovery of the biological assemblage (following habitat restoration) is generally still considered to be 'High'. However, the pressure benchmark is considered to refer to a permanent change and recovery is therefore ‘Very low’. Sensitivity is therefore assessed as 'High'.

A4.221: *Sabellaria spinulosa* encrusted circalittoral rock

https://www.marlin.ac.uk/habitats/detail/348

	Resistence	Resilience	Sensitivity
Abrasion/disturbance of the surface of the substratum or seabed	Low	Medium	Medium
	Q: Low A: NR C: NR	Q: Medium A: Medium C: Medium	Q: Low A: Low C: Low

Sensitivity assessment: Based on the evidence discussed above, abrasion at the surface of Sabellaria spinulosa reefs is considered likely to damage the tubes and result in sub-lethal and lethal damage to the worms. Resistance is therefore assessed as ‘Low’ (loss of 25-75% of tubes and worms within the impact footprint). Resilience is therefore assessed as ‘Medium’ (within 2 years) and sensitivity is therefore assessed as ‘Medium’. This assessment is relatively precautionary and it should be noted the degree of resilience will be mediated by the character of the impact. The recovery of small areas of surficial damage in thick reefs is likely to occur through tube repair and may be relatively rapid.

A4.2142: *Alcyonium digitatum*, *Spirobranchus triqueter*, algal and bryozoan crust on wave-exposed circalittoral rock

	Resistence	Resilience	Sensitivity
Abrasion/disturbance of the surface of the substratum or seabed	Medium	High	Low
	Q: High A: High C: High	Q: High A: High C: High	Q: High A: High C: High

Sensitivity assessment: Resistance has been assessed ‘Medium’, resilience has been assessed as ‘High’. Sensitivity has been assessed as ‘Low’.

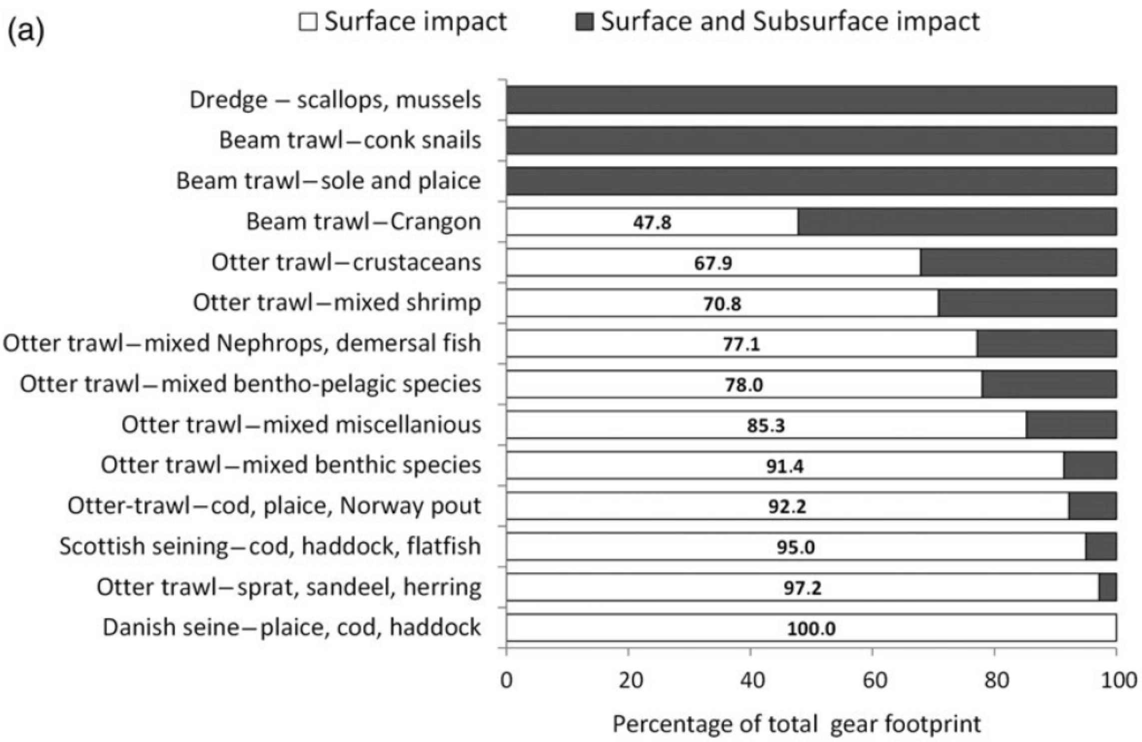
5. Fishery measures

5.1. Summary on bottom disturbance caused by different fishery gears

Bottom distrubing fisheries may damage biogenic structures and deplete benthic invertebrates, resulting in alterations in the structure and functioning of the benthic ecosystem (Kaiser, 1998; Rijnsdorp *et al.*, 2020).

In this chapter, we give an overview of the difference in seafloor pressure created by different bottom-disturbing fishing techniques. To evaluate this, we consider for each gear type the trawled area and the penetration depth of the different gear components. The impact of trawling is determined by its footprint (the geographical area that is directly contacted by trawls at least once in a specified time period) and trawling intensity, and differs between gear types due to variations in the penetration depth of the gear components (Eigaard *et al.*, 2016; O'Neill and Ivanovic, 2016; Rijnsdorp *et al.*, 2016; Hiddink *et al.*, 2017). Eigaard *et al.* (2016) estimates the seabed pressure from demersal trawls, seines and dredges based on gear design and dimensions (Eigaard *et al.*, 2016; Figure 21). The impact is further governed by the sensitivity of the seafloor habitat, which is related to the resistance of the community to trawling, the recovery rate after trawling (Collie *et al.*, 2000; Kaiser *et al.*, 2006; Hiddink *et al.*, 2020) and the degree of natural disturbance (Hall, 1994; Diesing *et al.*, 2013; van Denderen *et al.*, 2015a in Rijnsdorp *et al.* 2020).

The Belgian part of the North sea (BPNS) is a shallow, hydrodynamic area, which leads to the fact that most habitat communities are subjected to a high degree of natural disturbance. The sensitivity of the habitat communities occurring on the BPNS is presented in Chapter 4 based on the MarLin methodology.



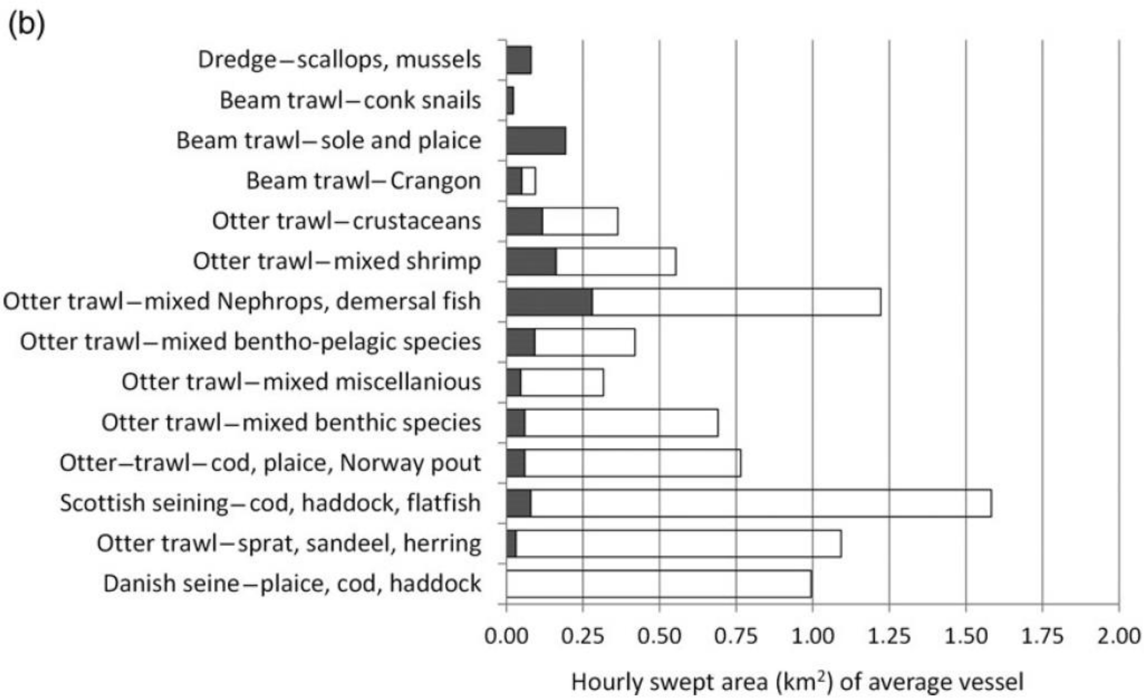


Figure 21. Proportion of total gear footprint (a) and the area of seabed swept in 1 h of fishing with an average-sized vessel (b) with impact at the surface level and at both the surface and the subsurface level for the 14 BENTHIS metiers (copied from Eigaard et al., 2016).

5.2. Indicators for seafloor disturbance / impact

The evaluation of the seafloor disturbance and benthic impact from fishing gears is taken forward into two EFMZV projects, 'Visserij Verduurzaamt' and 'Benthis Nationaal'. In 'Visserij Verduurzaamt', the tool 'Valduvis' is used to assess the sustainability of the fishing fleet. One of the indicators is 'Seafloor disturbance' and is based on the fished area and an abrasion factor. In Benthis Nationaal, the impact on the benthic ecosystem is estimated based on the fishery footprint and depletion/recovery rate of the benthic fauna. With the VALDUVIS indicator, only the physical disturbance of certain fishing gear is taken into account, whereas in Benthis Nationaal we also evaluate the impact on the sea bottom ecosystem itself.

Current knowledge on differences in seafloor pressure created by bottom-disturbing techniques relevant for this study area is evaluated based on these project insights and scientific literature.

5.2.1. VALDUVIS

VALDUVIS (www.valduvis.be) is a tool that resulted from a collaborative landings between various Belgian stakeholders to assess the sustainability of the Belgian fishery. It is based on 11 indicators that describe economic, ecological and social parameters. One of the ecological indicators describes the seafloor disturbance as the physical pressure of the fishing gear of the seabed. The indicator combines the fished area and an abrasion factor relative to the landing value.

The fished area (FA) or swept area indicates how large the area is where fishing occurred. It is a combination of the width of the fishing gear and the towing speed. Sometimes, the penetration depth can be small but the surface fished can be very large (e.g. Seine fishery).

The **Abrasion factor** is a factor based on Eigaard *et al.* (2016). This factor differentiates the swept area of each bottom trawling method by considering the penetration depth of each gear component. The **Penetration Depth** of a fishing gear is the sum of the penetration depths of its gear components standardised by the width of each component. The penetration depth of the gear depends on the weight and dimensions of the components, the length of the fishing line, the towing speed and the characteristics of the seabed (sediment). The depth of penetration is well known for some fishing gears, for other gear types expert judgment is used. In the sections below, it is explained what parts of the gear were taken into account in the calculation of the abrasion factor.

Each gear type has its own 'footprint'. In order to discriminate between superficial and deep penetration, a threshold has been defined at 2cm penetration. For Valduvis, the assumption was made that all penetration deeper than 2 cm is harmful for the ecosystem (Eigaard *et al.*, 2016).

An overview of the used Abrasion Factor is given in Table XVIII and is based on the study of Eigaard *et al.*, 2016.

The used formula for seafloor disturbance in Valduvis is:

$$\textbf{Seafloor disturbance} = \textbf{landings} / (FA_{\text{fishing gear}} * \textbf{AbrasionFactor}) * 1.000.000$$

With:

$FA_{\text{fishing gear}}$: fished area which differs according to the métier and is specified further below (Table XVIII).

AbrasionFactor: differs according to the métier (Table XVIII)

Table XVIII. Overview of the fished area, abrasion factor and seafloor disturbance in VALDUVIS for the different gear types

Gear type	**Fished area:** Total width of the fishing gear * towing speed*number of fishing hours*1000	**Abrasion factor**
Traditional beam trawl	Width = length of the beams Average towing speed: 8.3 km/h	1
Shrimp trawl (lighter beam trawl)	Width= length of the beams Average towing speed: 7.4 km/h	0.522
Otter trawl_shrimp	Width= length of the beams Average towing speed: NN	0.321
Bottom otter trawl	Average width: varies but usually larger than beam trawl (f.e 4x30m) Average towing speed: 5.6 km/h	0.229
Scottish seine (or flyshoot)	fixed: 22,100,000 m^2 / day (3.4km^2 with an average of 6.5 hauls/day)	0.05
Mechanical dredge (molluscs)	Width: length of the dredge Average towing speed: 5.6 knots	1

Passive fishing gear	NA	0

5.2.2. Benthis Nationaal

To support the MSFD assessment of seafloor integrity, an assessment methodology is needed to estimate the impact of the different bottom trawling gears on the various seafloor habitats across the European shelf. The methodology to assess trawling impact has traditionally used expert judgement to derive the sensitivity of different habitats for specific bottom trawl fisheries (Eno *et al.*, 2013; Grabowski *et al.*, 2014). In the Horizon 2020 project Benthis, a more quantitative methodology is developed (Rijnsdorp *et al.*, 2020; Figure 22)) and currently taken forward within ICES. Within the Belgian Benthis Nationaal project, it is being assessed how this evaluation methodology can be applied specifically for the Belgian fishery and how it can be taken forward in the future as an indicator for bottom impact evaluation of the Belgian fishery métiers. This evaluation methodology (indicator) is currently named as relative benthic state.

The relative benthic state is determined based on the trawling pressure (footprint, as swept area; Eigaard *et al.*, 2016), depletion and recovery rates for benthic habitats. Depletion of the biota and trawl penetration in the seabed are highly correlated (Hiddink *et al.* 2017). The depletion rates of Hiddink *et al.* (2017) were estimated for a generic beam trawl and a generic otter trawl. The depletion rates of the otter trawls were more recently updated for a range of specific otter trawl types (Rijnsdorp *et al.*, 2020b), but for beam trawls a distinction was only made between the flatfish and shrimp directed beam trawls (Rijnsdorp *et al.* 2020b) and between the beam trawl and the pulse trawl (Rijnsdorp *et al.* 2020a). Recovery rates are estimated based on the longevity composition of the benthic fauna. Habitats with more longer living benthic species recover more slowly from bottom disturbance. Consequently, such habitats are evaluated as more sensitive to bottom disturbance compared to habitats with more shorter living species.

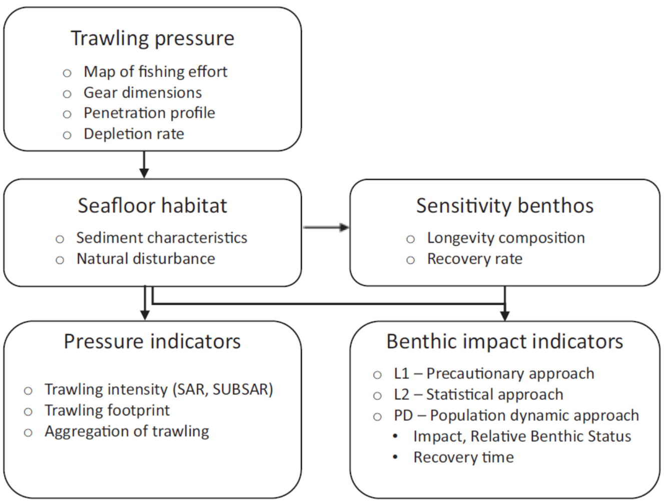


Figure 22. Evaluation framework for fishery induced benthic impact (Rijnsdorp et al., 2020)

In this indicator, the type of fishing ground (sensitivity of the habitat) is an important element in the assessment, something that was not taken into account in the past. Although there are fishing grounds where bottom disturbance is a problem, there are many fishing grounds where towing a fishing gear has a more limited influence. Nevertheless, the impact of trawling is still strongly driven by the trawling pressure, as high fishing intensities are still responsible for high benthic depletion in all habitats and deterioration of the benthic seafloor ecosystem.

The basic intention of this ongoing Benthis Nationaal research is to give fishers more insight in how they can reduce their bottom disturbance. In order to achieve this, they can use three different tactics: (1) Fish in areas with frequent fishing (e.g. core fishing grounds); (2) Fish in areas that allow a quick recovery of the benthic fauna (avoid sensitive habitats); (3) Fish with less impact (e.g. adapt the gear to reduce bottom penetration).

5.3. Sea-bottom disturbing fishing techniques

5.3.1. The traditional beam trawl

The beam trawl is constructed of a funnel-shaped net, opened horizontally by a steel beam and vertically through the beam trawl shoes. Traditional flatfish beam trawlers can be equipped with two types of nets: the 'V-net' with tickler chains and the 'R-net' with a chain matrix. Rarely, an R-net is also rigged with tickler chains. (Lenoir *et al.*, in prep.)

The V-net is mostly used on flat sandy bottoms without obstacles such as stones and boulders. The tickler chains are attached to the beam trawl shoes. (Lenoir *et al.*, in prep) These chains are made of metalchains that are intended to drive flatfish out of the seabed.

In R-nets the flatfish are stimulated by a chain mat comprising of a matrix of longitudinal and transverse chains between the ground rope and the beam. R-nets are used on rough grounds and the chain matrix prevents large stones from entering the net (Rijnsdorp *et al.*, 2008; Rijnsdorp *et al.* 2021).

When fishing with a beam trawl, different parts of the gear come in contact with the seabed. The components that make the most contact with the seabed are the shoes, the tickler chains or chain matrix and the ground rope. Both tickler chains and beam shoes have been demonstrated to generate furrows in the sediment of up to 10cm deep (Paschen *et al.*, 2000; Depestele *et al.*, 2016; Eigaard *et al.* 2016). The scientific literature identified significant differences in the sediment penetration depths of gears and their components. The penetration into the seabed is depending on beam trawl weight, towing speed, and sediment type (Paschen *et al.*, 2000; Depestele *et al.*, 2016; Eigaard *et al.*, 2016). Currently, the penetration depth of a beam trawl is estimated as on average 2.72 cm (SD=1.24) (varying between 0 to 6, Hiddink *et al.*, 2017 - PNAS).

5.3.2. Adaptations of the traditional beam trawl

The design of the beam trawl has slightly changed over time by adapting certain aspects of the beam or beam trawl shoes (

Table XIX). The main driver for those changes is the reduction of fuel consumption. Some designers also claim to have developed alterations with less impact on the bottom but very few of these statements have been scientifically proven or even investigated. More details on these adaptations can be found in Lenoir *et al.* (in prep.).

Table XIX. Different types of beam trawls used in the Belgian fisheries and their adaptations in relation to the traditional beam trawl (Source: ILVO VV) (From Lenoir et al., in prep.)

Type beam trawl	**Adaptations compared to the traditional beam trawl**
Sumwing	Wing profile instead of beam Runner instead of traditional shoes
Aqua Planning Gear	Wing profile instead of beam Adapted shoes
Ecoroll beam	Wing profile instead of beam
Beam trawl with roller shoes	Roller shoes instead of traditional shoes
Pulse trawl	Tickler chains replaced by rubber coated electrodes

From the overview in alternative fishing techniques (Table XX), and as outlined below, we recognize that modifications to the traditional beam trawl contribute considerably in reducing fuel consumption. In this way, the sector reduces its carbon emission clearly. Secondly, some net adaptations (benthos release panels, sieve nets …) have contributed to reduce by-catch (not focused on here). These efforts have clearly helped to make the fishery sector more sustainable on various aspects but not in the light of reducing bottom disturbance. Therefore, the current effort by the fishery sector is not enough in order to be able to be compatible with zones designated to protect bottom integrity and the benthic habitats.

5.3.2.1. Sumwing

The so called Sumwing was developed by a Dutch company, 'HfK Engineering' with the aim to decrease the hydrodynamic resistance of the trawl during fishing (Leijzer & Bult, 2008). The Sumwing is a hydrodynamic type of beam trawl and has the beam replaced by a wing shaped profile that provides the horizontal opening of the net. The Sumwing functions best when it is rigged with a V-net and tickler chains. The Sumwing is not used in combination with a chain matrix due to stability issues that can cause damage to the gear. The Sumwing is neither used in the shrimp fishery because of stability issues due to the low towing speed. (Lenoir *et al.*, in prep.)

In the Belgian fisheries the Sumwing is used by a number of vessels the whole year round. In addition, a number of vessels are rigged with a Sumwing during the annual fishing campaign in the Bay of Biscay.

For Valduvis, this gear type is currently scored as a traditional beam trawl. In the ongoing research of the Benthis Nationaal project it is estimated that the penetration depth of a Sumwing beam trawl (2.50cm) is ~9 % less compared to the traditional beam trawl (2.72 cm), following the assumption that the removal of the trawl shoes reduces penetration depth proportionally to the gear width and accounting for the deeper penetration of the shoes with respect to tickler chains (Depestele *et al.*, 2021). A lower penetration depth leads to a reduced depletion of benthic biomass (Hiddink *et al.*, 2017).

5.3.2.2. Aqua Planning Gear

The Aqua planning Gear was invented by the owner of the Z.201 Job Schot, and was realized in cooperation with 'Van Wijk Installations and Constructions'. In the Aqua Planning Gear the beam is replaced by a wing profile but unlike the Sumwing, the beam trawl shoes are still present. A reduced drag is assumed due to the customized design of the shoes and the altered shape of the beam. There is a longitudinal opening in the shoe plate, which reduces the bottom contact surface of the shoe. (Lenoir *et al.*, in prep.) Nevertheless, there is currently no scientific proof that Aqua Planning Gear creates less seafloor disturbance compared to the traditional beam trawl. In the Belgian fisheries the use of Aqua Planning Gear is limited.

In Valduvis, bottom disturbance of the Aqua Planning Gear is scored as the traditional beam trawl.

5.3.2.3. Hydrorig

The HydroRig was a fishing gear that was developed in the Netherlands as an alternative for the traditional beam trawl by using waterjets. The results (Van Marlen *et al.*, 2011) showed fuel reduction but the landings was also much lower (32%). Therefore this idea wasn't commercially viable.

5.3.2.4. Ecoroll Beam

The Ecoroll Beam is an alternative for the traditional beam trawl with the beam being replaced by a wing profile. The trawl shoes are replaced by wheels and the wing is, just like for the Sumwing, rigged with a central runner which, unlike the Sumwing, is equipped with a wheel. The Ecoroll Beam was designed and built by the owner of the beam trawler Z 53, Steve Savels and Joël Snauwaert of Maritime Constructions in Zeebrugge. The Ecoroll beam still has 3 contact points with the seafloor, due to the three wheels. Currently, there is no scientific evidence that wheels creates less bottom disturbance (penetration) than beam shoes. Therefore, this technique does not seem to reduce the surface area (Table XX). In Valduvis it gets the same abrasion factor as the traditional beam trawl.

5.3.2.5. Beam trawl with roller shoes

The trawl shoes of a beam trawl can be fitted with or replaced by wheels. With this adaptation the sliding resistance of the shoes is replaced by a rolling resistance of the wheels. Different configurations (single large wheel, large wheel with one or two smaller wheels, two large wheels) of wheeled trawl shoes have been tested and are used on board of commercial vessels (Van Craeynest *et al.*, 2013)**.**

Skippers taking part in a research project complained about the poor performance (operability) of the wheeled beam trawl on soft sediments. The use of roller shoes can lead to fuel savings, mainly on hard sediments (Bult, 2007, Van Craeynest *et al.*, 2013). Another advantage reported was that repair and maintenance costs for the wheels appear to be lower than for the trawl shoes.

5.3.2.6. Sole pulse trawl

A pulse trawl is a demersal trawl with a net opening rigged with electrodes, generating an electric pulse field that causes a cramp response in the target species. The sole pulse trawl used in the North Sea is a demersal trawl, where the horizontal spread during trawling is maintained by a horizontal beam or wing across the net mouth (www.wur.nl).

Pulse trawls were introduced as a replacement of the tickler chain beam trawls in the fishery for sole to reduce the impact on the ecosystem and environment and improve its ecological and economic sustainability. Because the EU legislation prohibits the use of electricity to capture fish, the beam trawl vessels that switched to pulse trawling operated under a (temporary) derogation. Pulse trawling became a controversial fishery that was heavily criticized for its supposed detrimental impact on marine life and threatening the livelihood of other fisheries, in particular small scale fisheries (Haasnoot et al., 2016; Stokstad, 2018; Le Manach et al., 2019). In absence of a comprehensive scientific advice, the public campaign against pulse fishing in 2017 culminated in a decision of the EU parliament for a ban on pulse trawling in January 2018. Despite of a positive advice of ICES (2018), the EU maintained its ban on pulse fishing in the revised regulation on technical measures (European parliament; *https://www.pulsefishing.eu/*) (Rijnsdorp et al., 2020c). The main bottleneck for the majority of European member states was the limited controllability of the technology and the potential environmental impact that comes with it (Kraan *et al.*, 2015) (Lenoir *et al.* 2021).

The ICES advice, 2020, concludes however that pulse fishing on sole in the North Sea scores better on relevant sustainability aspects than fishing with the traditional beam trawl. For example, there is less bottom disturbance, less by-catch of undersized fish and less fuel consumption (ICES advice, 2020). Less bycatch and less seabed impact has been demonstrated in certain experimental set-ups (Depestele *et al.*, 2019, Rijnsdorp *et al.*, 2020b).

Following the ban on pulse trawling, a gradual out phasing of the pulse trawl fleet in the North Sea is going on. Although some vessels explore the feasibility of alternative, innovative fishing gears to catch flatfish, the majority of vessel owners replaced the pulse gear by conventional beam trawls equipped with tickler chains. This transition is likely to have an impact on allocation of fishing effort at a very fine spatial scales with a reduction of fishing effort on those grounds that cannot be exploited by heavier fishing gear. This includes a shift from fishing grounds with coarser sediment types to fishing grounds with finer sediment such as sand and mud, but also a shift away from the very soft sediment types. For the Flemish bank area, the shift will be minimal, as very soft sediment types are not really occurring and the area is dominated by sand to muddy sand. Moreover, the fishing speed maintained during beam trawling is higher than the fishing speed during pulse trawling, as a result, the total fished area is expected to increase following the out phasing of the pulse trawl. Besides technical reasons, effort allocation is also expected to alter due to changes in catch composition related to the switch from pulse to beam trawling. Compared to pulse trawlers, conventional beam trawls with tickler chains have a lower and higher catch efficiency for sole and plaice, respectively. Therefore, it is expected that the vessels will allocate more fishing effort on those fishing grounds with higher abundance of plaice which are situated in the central and northern part of the North Sea, in contrast to the sole fishing grounds that are mainly situated in the southern part of the North Sea. To conclude, the ban for pulse trawl will minimally affect the trawl effort (the same or maybe even a bit lower) within the Flemisch bank area. Nevertheless, this is difficult to predict, so future VMS analyses has to confirm this.

5.3.2.7. Shrimp pulse trawl

Besides the pulse trawl for sole, the pulse technique was also used in the shrimp trawl fishery. In the Belgian fishing fleet, the few pulse trawlers were targeting shrimps. Verscheuren et al. (2019) is the first study in which a direct catch comparison between a traditional beam trawl and a pulse trawl is executed over an entire fishing season. The results illustrate that pulse stimulation enables a discard reduction of small shrimp of up to 35% and a reduction of benthos and fish discards of up to 76%, with no loss of commercial shrimp. In addition, contact of the groundgear with the seabed is reduced by using a straight bobbin rope with less bobbins. The reduction in seabed contact was not quantified, but assumed based on the beam configuration. Also this technique is banned from 1 July 2021 (European Parliament).

Table XX. Overview of the effect of adaptations to the classic beam trawl on the fuel reduction, bottom disturbance.

Technique	Fuel reduction	Reduction in bottom disturbance?		References
		In theory	Measurements available (lab, field test, camera, …)	
Sumwing	yes	Minor reduction (ongoing research Benthis Nationaal)	Camera observations Comparative study of pulsewing and sumwing beam trawl with tickler chains	Depestele *et al.* 2019; Depestele *et al.* 2021; Marlen and Berghe 2013; Polet and Depestele 2010; Taal and Klok 2012
Aqua Planing Gear	yes	Reduced drag assumed	No direct measurements	
Hydrorig	yes	Not commercially viable, Less bycatch of benthos, variable results	No direct measurements	Polet & Depestele, 2010; Polet *et al.* 2010
Ecoroll Beam	yes	Wheels are maybe less penetrating certain sediments compared to shoes.	No direct measurements	
Beam trawl with roller shoes	yes	No, as still shoes are present, it shall perform as the traditional beam trawl	No direct measurements	Bult, 2007**,** Van Craeynest *et al.*, 2013
Pulse trawl (4m pulse trawl with trawl shoes;	yes	Less bycatch and less seabed impact. However there is an EU-wide ban on	BACI experiment using Multibeam echosounder, SPI and box corer.	Depestele et al. 2019; Verscheuren et al., 2019; Depestele et al. 2016; Rijnsdorp et al.

12m pulse wing trawl)		pulse trawling from 2021.	Modelling exercise of sediment resuspension with experimental verification	2020b; Rijnsdorp *et al.* 2021 Rijnsdorp *et al.*, 2020, ICES WGELECTRA 2020

5.3.3. Shrimp trawl (with sieve net)

A shrimp trawl is similar to the traditional beam trawl but is much lighter. Shrimp trawlers mainly operate near the coast. The footrope has small rolling bobbin wheels fitted to help the net travel over the seabed. The abrasion factor (factor_CRU= 0.522) is only half of the factor of the traditional flatfish beam trawl (factor TBB_DEF= 1) (Table XVIII). The beam, the beam trawl shoes and the bobbin rope (groundgear) are significantly lighter compared to flatfish beam trawls.

To retain the shrimps, this gear has to use small mesh netting. This is liable to catch and retail high quantities of fish by-catch. Therefore the so-called sieve net was developed. This can be incorporated to reduce bycatch (Polet *et al.* 2004, Revill & Holst 2004b, Verschueren *et al.*, 2014). The use of the sieve net is mandatory for brown shrimp fishing in all EU waters (EC No. 850/98). Several countries provide an exemption for the use of the sieve net at times when algae and jellyfish occur in large quantities and clog the sieve net.

In Belgian waters, the sieve net is mandatory for shrimp trawl gears between December and the end of May (RD 8jul 2002). For otter trawls targeting shrimps, sievenets should be used yearround (RD 24dec 2020)

5.3.4. Bottom otter trawl

The otter trawl is a fishing gear of which the net is opened by the hydrodynamic forces of the water on the otter boards that are rigged to the front part of the gear. Together with the ground rope the otter boards usually do not leave the seabed while fishing (Anon, 1992; Nédélec & Prado, 1990). Depending on the type of substrate, there are different types of ground rope, which are intended to protect the lower part of the trawl for damage by bottom contact and to enable the net to travel over the bottom. There are different types of otter boards on the market that differ in weight, size and design. The desired horizontal opening of the net determines the type of board that is used. The bridles are cables connecting the boards to the net.

Depending on the number of nets, there are single otter trawls (1 net), twinrig (two nets attached to each other) or multirigs (with 3, 4 or more nets). The quadrig consists of four nets. The horizontal gear opening as used in the Belgian fishery is on average 110 meters.

A beam trawler is usually not designed to tow otter trawls but with an adapted technique and a skilled skipper and crew, it is possible to tow two otter trawls, one at each side of the vessel. The method is called outrigger fishing. The horizontal net opening as used in Belgium is between 15 and 17 m (Vanderperren, 2008). Because of the lower weight of the gear compared to the beam trawl and the lower towing speed, there is a significant fuel saving. The target species are sole, plaice and skate. The outriggers are allowed to fish within the 12 miles zone. Because of safety issues, this technique is limited to the season with prevalence of calm weather.

For a traditional single otter trawl (OT), there are three main gear components creating seabed disturbance during a haul: (i) from the otter boards, (ii) from the sweeps and bridles, and (iii) from the trawl groundgear, which together define the footprint of an OT fishing operation. Of these three impacts, the otter boards have the highest penetration depth but only have a narrow track/path. Depending on the sediment type, the otter trawl can dig up a trench/furrow of on average down to 2.4cm deep (Hiddinck *et al.* 2017), which is a bit lower compared to the traditional beam trawl. Nevertheless, the fished area is usually much larger than for the traditional beam trawl (Eigaard *et al.* 2016).

For Valduvis, the scoring method is the same as for the traditional beam trawl. The abrasion factor is lower as only the boards are taken into account.

5.3.5. Flyshoot fishery

The flyshoot fishery, as used today in the southern North Sea and the English Channel, is based on the Scottish seine fishery. First a buoy is thrown overboard with the flyshoot rope attached to it. The vessel usually performs a circa rectangular trajectory while shooting the flyshoot rope. Halfway, the net is released into the water. At the end of the encircling operation, the crew picks up the end with the buoy and hauls in the two ropes and finally the net. The flyshoot ropes roll over the seabed and cause dust clouds that startle the fish. During the operation, the fish are herded between the flyshoot ropes to be caught by the approaching net. That is why this fishery is only carried out during the day because at night the dust clouds and the flyshoot rope are not visible to the fish. Also during winter months the flyshoot fishery deceases because the days are short and the light intensity is low. Flyshoot fishing can only be practiced in areas without obstacles such as rocks and wrecks, because the fishing line would get stuck on them. Flyshooting is therefore both area-specific and seasonal. However, this disadvantage is offset by a higher selling price, lower fuel consumption and the possibility of fishing for non-quota fish species (Geeraert, 2008; Den Heijer and Keus, 2001).

The physical impact of the Danish seine on seabed habitats is not documented in the scientific literature, but presumably for Danish seines the impact is less than for bottom otter trawling, since there are no trawl doors and the groundgear is lighter. The impact of Scottish seining (flyshooting) is somewhere in-between, as flyshooting can be considered a hybrid between anchored seining and demersal otter trawling. This was recently confirmed (Rijnsdorp *et al.*, 2020) and will also be integrated in the revised Valduvis indicator (2022).

5.3.6. Mechanical dredge

A dredge is a fishing gear usually designed to target shellfish like scallops. There are hydraulic and mechanical dredges. Mechanical dredges are dragged across the sea floor, scraping or penetrating the bottom to catch shellfish. To catch shellfish that live in or on the seabed, it takes some force to detach these organisms. The vessel sets the dredge to the sea bottom and drags it over the seabed. A dredge consists of a metal framework, which is usually triangular (Pitel *et al.*, 2001). At the lower part of this framework a scraping plate is secured. This plate, with or without teeth, digs into the sediment in order to extract and to collect organisms. A heavy network or metal rings form a bag in which the catch is retained. The bag allows the water, sand and mud to wash out.

Usually more than one dredge is used. Larger vessels generally tow two sets of dredges. Beam trawlers do this by securing the dredges on a beam with wheels. These beams are dragged from the outrigger booms. The number of dredges that can be used varies with the strength of the vessel, the possibilities for manipulation of the fishing vessel and the area. Usually four to sixteen dredges are towed, but this number can be as high as 36.

In Valduvis, the calculation of the indicator is equal as for traditional beam trawls. Nevertheless, hydraulic dredges caused the most depletion and penetrating the seabed on average 16.1cm (Hiddink *et al.* 2017).

5.3.7. Passive gear: set nets

Set nets are passive fishing gears and are used in the Belgian fishery as vertical net panels fixed to the seafloor by anchors and weights and held vertically by buoys or floats. There are two types of set nets used in the Belgian fisheries: gillnets and trammel nets (Depestele *et al.,* 2006). The naming of the different types of set nets varies from country to country. In Belgium, the single layer net is a gillnet and a triple layer net is a trammel net.

The direct physical disruption of the seabed can be considered minimal as the lead line is not penetrating into the seabed. Direct damage to the benthos could however originate from the sweeping movements of the nets, which were found to be higher than usually estimated by experts, up to about 2 m. The sweeping movements were for the most part in the order of magnitude of 10 cm, and resulted in a total swept area per fishing operation lower than any of the hourly swept area estimated for active fishing gears (Savina *et al.* 2018).

5.4. Conservatoin measures to implement (e.g. fishery measures).

To reach the conservation objectives and environmental goals for seafloor integrity, there is a need to limit bottom disturbing activities (fishing, construction, cables, aggregate extraction, …) to a minimum and to avoid them to take place in the proposed areas. Recovery and restoration of habitat types 1110 and 1170 is only possible when anthropogenic disturbance of the seafloor is excluded completely in certain areas. This closure of certain areas for all bottom disturbing activities is also considered as more cost-effective compared to poorly managed areas (partial closure, reduced extent of activities). The benefits from a fully protected seafloor are extensive, as increased benthic habitat complexity and the return of long-lived sessile species (Gonzalez-Irusta *et al.*, 2018), increased sediment carbon storage and restored biogeochemical recycling properties (van de Velde *et al.*, 2018; De Borger *et al.*, 2020), and increased food availability to sustain food web interactions (Hiddink *et al.*, 2011, 2017). This habitat recovery shall also contribute to replenished stocks, restored resource biomasses and increased resilience of populations to other pressures, positively affecting not only the area where the measures are implemented but also its surroundings thanks to the spill-over effect (Cullis-Suzuki and Pauly, 2010; Marshall *et al.*, 2019; Ban *et al.*, 2019; Leleu *et al.*, 2012; Rabaut *et al.*, 2009). Closed areas act as recovery spots, where the marine fauna get the chance to grow larger, which on their turn lead to increased production (e.g. larger individuals produce proportionally more eggs). Therefore, the recovery and restoration of habitat types 1110 and 1170 in certain areas will contribute to the creation of a healthy seafloor ecosystem in the Southern Bight of the North Sea. This should also ensure the stability of exploiting the ecosystem goods and services, as for example in food supply (fishery). A collapse of the ecosystem needs to be avoided, as this would be catastrophic among others for the fishery sector. A diverse and stable ecosystem shall ensure future exploitation of diverse sources.

In relation to managing fishery activities within closed areas, following questions are relevant to consider and discuss.

- **Which activities and fishery techniques need to be forbidden or can be allowed?**

Ideally all bottom disturbing activities (constructions, cable digging, aggregate extraction, anchoring, …) should be banned form the proposedareas. Specifically with regards to fishing, there is currently no mobile fishing technique targeting demersal fish that does not impact the seafloor integrity. They all cause a certain disturbance of the top-layer of sediment and are removing benthic fauna (attached, non-attached species, infauna) on top and in the sediments. Therefore, those mobile fishing gear groups should be banned from the proposed areas (Table XXI). Except passive fishing techniques, which can be seen as least disturbing for the sediment surface, as only a minor part of the fishing equipment impact the bottom and the extent of disturbance is also the lowest of all bottom disturbing fishing techniques. Too which degree (fishing intensity), extent and types (nets, traps, …) this passive fishing techniques can be allowed in the proposed areas need to be considered based on the specific circumstances of an area. For example, it is possible that it is not opportune to execute it in areas where reef restoration actions are undertaken, as any impact should be avoided. For managing the passive fisheries, a kind of licence system can be developed, wherein the operational context is defined, but wherein the fisherman can also contribute to the monitoring of the area (data collection).

Table XXI. Overview of the gear groups (with gear type code) that should be banned or could be allowed in the closed areas. The gear types are defined based on the current fishing metiers active in our waters (see chapter 6).

	Gear type code	**Remark**
Gear groups that should be banned in the closed area		
Beam trawl	TBB	
Shrimp trawl	TBS, TBC	
Pulse trawl	PUL	Under EU ban, forbidden
Otter trawl	OTB, OTM, OTT, PTB	
Seiners	SDN, SSC, PS	
Other gears	AG, DRB, HMD, MIS, PTM	
Gear groups that could be allowed in the closed area		
Passive fishing techniques	FPN, FPO, FYK, GN, GND, GNS, GTR, LHM, LHP	Need to be evaluated in which circumstance allowed or not.

- **Is a periodic closure enough?**

A periodic closure is not an option here as the goal is not only to preserve seafloor integrity but also to restore populations of typical longlived, slow growing species. The first disturbance is considered to create the highest impact on the seabottom fauna (Rijnsdorp, 2000). In relation to gravel beds, the epifauna on the boulders and pebbles will be destroyed by a first passage of a trawl or by dredging activities. For *Lanice conchilega* aggregations, the species itself will survive (but maybe in reduced numbers), whereas the associated fauna is removed after a first disturbance. The slow growing, long lived fauna recovers slowly and will be replaced by oppurtunistic species. Therefore, a periodic closure for the closed areas is not advised.

- **Could certain adaptations of traditional beam trawl or other less bottom disturbing fishery techniques be stimulated or investigated for later implementation in certain areas?**

As there is currently no evidence that adaptations of the traditional beamtrawl reduce the seafloor disturbance significantly, it is currently not a management option to stimulate these techniques in the proposed areas. Only the pulse trawl has shown to reduce the sediment penetration significantly compared to a conventional beam trawl. Nevertheless, this technique is neither acceptable in the proposed areas, as there is the need to exclude all bottom disturbanceto reach the conservation objectives.

5.5. Evaluation of possible displacement of fishing effort

Some fishery displacement is likely to happen as a consequence of closing areas for mobile bottom contacting gear in the Natura 2000 area 'Vlaamse Banken'. Displacement is difficult to quantify, and it is impossible to predict where exactly activities will be displaced to. This displacement of fishing effort may have economic effects for the fishery sector, because steaming to and from the fishing grounds may take longer, new fishing grounds have to be explored, and competition for resources may increase. The effects of the displacment on catch and revenue are less well understood and are also not necessarily negative. Important to mention is that even if the effects on the entire fleet are small, this does not imply that individual fishers will not be affected substantially by a closure of a specific area at sea. The effects of closing a specific area are generally thought to have less effect on fishing fleet level than on specific individuals or fishing companies. Especially for coastal fisheries this can have clear consequences and they need to have enough alternative fishing opportunities. In the case of the closed areas in the 'Vlaamse banken' following consequences in relation to displacement of fishery practices can be assumed:

- In general, the fishery measures will impact all countries and gear types, which will have to displace a part of their activities to other areas. The importance of each area is clearly described in the socio-economic analysis of chapter 6.
- The proposed area in Search Zone 1 is small and has an elongate shape, so fishery can displace their activities nearby. Of course, it is not guaranteed that these neighbouring areas have the

same fishing potential (effort, catch composition). Specifically for the flyshoot fishery, for which this area was a clear fishing spot in the BPNS (besides the Goote bank area).

- For the closed area in Search Zone 2, it is mainly the Dutch beam trawl fishery that is influenced, but all countries and metiers were clearly active in this zone. A sidenote is that a part of this proposed area is foreseen to be used for renewable energy what will probably imply a ban frombottom contacting fishing gears for safety reasons. Nevertheless, closing of this area will almost certainly lead to fishery displacement for all countries and metiers, which can currently not be predicted.
- For the proposed area in Search Zone 3, the coastal fishery activities will be influenced. However, based on the detailed socio-economic analyses, it is clear that the majority of this area is not a hotspot for them. Therefore, the coastal fishery (eg. Shrimp fishery) will not severly be affected and consequently displacement estimate is probably minimal.

As not the entire Natura 2000 area will be closed, some displacement will occur in areas within the Natura 2000 area itself. Increased effort in lightly- or unfished areas would cause substantial additional mortality, whereas increased effort to an already heavily fished area causes relatively little additional mortality of benthic invertebrates (Rijnsdorp et al., 2020). In case of the ‘Vlaamse banken’, there are no lightly- or unfished areas, so the expected ecological effects ofincreased fishery pressure in certain areas, will rather be limited. Therefore it is considered that positive effects of banning fisheries form some key areas will outweigh, these limited effects of displacement.

On top, as the closed areas will benefit from the prohibition of certain gears (“spillover” effects (Buxton *et al.*, 2014), improved ecosystem status), the potential increased pressure in the rest of the ‘Vlaamse banken’ will maybe somehow be compensated. Nevertheless, assessing or predicting the ecological improvement or deterioration is extremely difficult. In any case, such developments are dependent on the fishing intensity and distribution before the closure, the added fishing activity caused by displacement and external factors (such as fish distribution, TAC/quota, fuel prices, other spatial claims).

Therefore, this fishery displacement effects on the ecology (conservation objectives) and socio-economic fishery activity need to be part of the monitoring programmes.

6. Socio-economic analyses of fishery activity

6.1. Introduction

6.1.1. Study area & context setting

The Belgian part of the North Sea (BPNS) is a relatively small (3454 km²) and shallow area with a coastal length of 66km. Nevertheless, this area is intensively used by various activities such as renewable energy development, shipping, dredging and fisheries. The BPNS is characterized by a unique complex of sandbanks and contains valuable habitats such as gravel beds and biogenic reefs formed by aggregated soft bristleworms (e.g. sandmason *Lanice conchilega*) (Van Hoey *et al.*, 2004; Rabaut *et al.*, 2007, Degraer *et al.*, 2010).
In line with the European Habitats Directive (HD) (92/43/EEG) and the Birds directive (BD) (79/409/EEG) Member States must take the necessary measures to maintain the species and habitats in a favorable conservation status and restore them when necessary in designated protected areas.

In the BPNS, there are three bird directive areas and two special areas for conservation (SACs) (HD) ('Vlaamse Banken' and '*Vlakte van de Raan'*). The 'Vlaamse Banken' is an extension of a previously designated SAC, *Trapegeer-Stroombank* (KB October 16th 2012). The *Vlakte van de Raan* was first designated as a SAC in 2005. However, in 2008 this designation was annulled after a series of court cases before the Belgian Council of State. Nevertheless, this area has to remain a Natura 2000 area for the EU. Therefore, in the current Marine Spatial Plan (MSP) (2020-2026), *Vlakte van de Raan* has now been included as a SAC. These areas are designated to protect sandbanks (habitat type 1110), gravel beds and biogenic *Lanice conchilega* reefs (habitat type 1170) (Degraer *et al.*, 2010; KB 22 mei 2019)

Belgium is in the process of implementing management measures (fisheries restrictions) in these marine protected areas. In the recently approved MSP (2020-2026), three 'Seach Zones' for the protection of the seabed in and around the SAC 'Vlaamse Banken' were identified, based on the previously defined areas for fishery measures in the previous MSP (2014-2020) and one additional area (Seach Zone 1) (Figure 1). They include the coastal area (potential for *L. conchilega* reefs) as well as an offshore area (potential for gravel beds) and several sandbank systems. Within these areas, a maximum of 285km² will be designated and will come under additional fishery management measures. This represents the same size as the 4 fisheries areas that were appointed in the previous MSP (2014-2020). It is noteworthy that Seach Zone *2* and Seach Zone *3* fall entirely within 'Vlaamse Banken', while Seach Zone *1* is further offshore (see Figure 23). Seach Zone *1* was added after recent research conducted by RBINS (Royal Belgian Institute of Natural Sciences) indicated that relict gravel beds occur within this area.

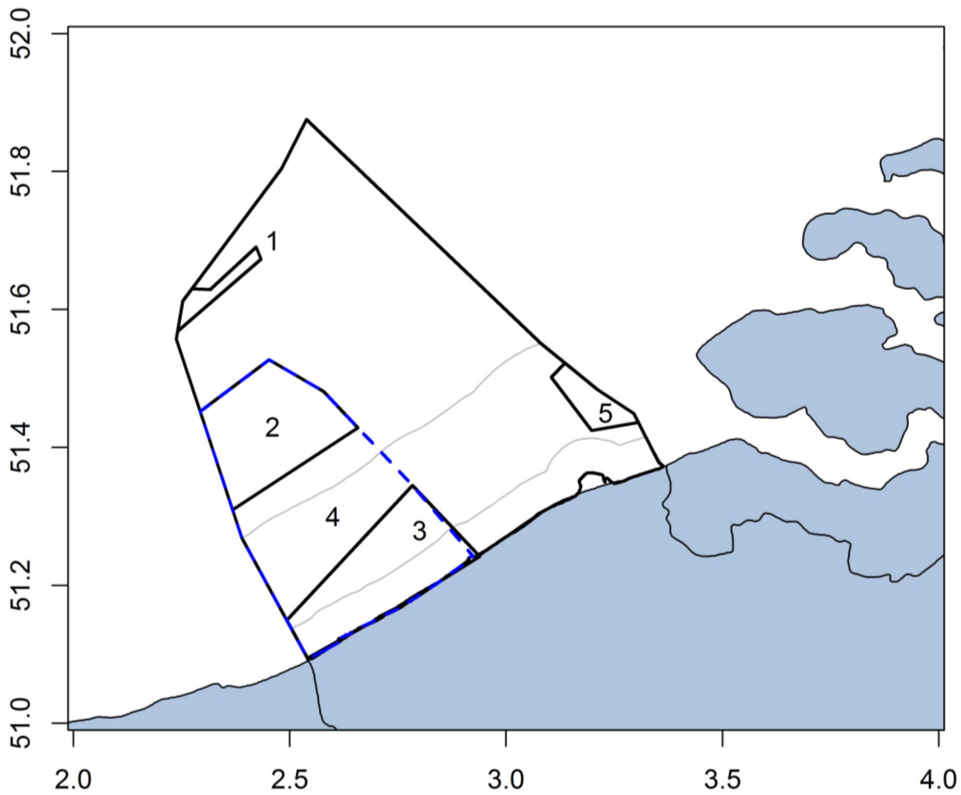


Figure 23 Map of the proposed closed areas in the Belgian part of the North Sea. 1= Seach Zone 1, 2= Seach Zone 2, 3= Seach Zone 3, 4= 'Vlaamse Banken' (indicated with dashed blue lines), 5= Vlakte Van De Raan, grey lines are 3NM and 12NM.

6.1.2. Objectives

This report/chapter gives an overview of the fishing activities in the BPNS in the three identified 'Seach Zones', as well as in the Natura2000 areas 'Vlaamse Banken' and *Vlakte van de Raan*. The overall goal of the analysis is to support decision-making in the allocation of areas where additional fishery measures are to be implemented in order to protect valuable habitats. The aim is to provide options that meet biodiversity targets, but are also relatively socially and economically cost-effective by minimizing conflicts with other activities.

To determine those areas in an optimal and objective way, we will combine updated biological value maps (representing the ecology: *www.bwzee.be*), fishing activity over several years and impact maps and the Marine Spatial Plan (RD MSP 2020-2026). In a later stage a decision support tool (Marxan) that is designed for solving complex conservation planning problems in landscapes and seascapes will be used. This report describes the fishing activities of Belgium, Great Britain, Demark, Germany, France and the Netherlands in the above mentioned five areas (three 'Seach Zones', 'Vlaamse Banken' and *Vlakte van de Raan*).

6.1.3. Fisheries regulations in the BPNS

The BPNS can be divided into two zones: the territorial sea (the zone from the baseline to 12 nautical miles offshore) and the rest of the Belgian Exclusive Economic Zone (EEZ).
The Common Fisheries Policy (CFP) is a set of rules for managing European fishing fleets and for conserving fish stocks. Designed to manage a common resource, it gives all European fishing fleets

equal access to European waters and fishing grounds and allows fishers to compete fairly (REF: EU website). This policy also applies in the Belgian EEZ (law of 10 October 1978).
In the Belgian EEZ, the practicing of fishing activities is subject to Belgian jurisdiction, taking into account the rights of foreign vessels in the context of the CFP and the relevant international regulations (article 5 and appendix I) (Polet *et al.*, 2018). All member states in this report (Belgium, the Netherlands, Germany, France, UK and Denmark) have unlimited and free access to the Belgian EEZ.

In the territorial waters, fisheries are regulated by the national legislation (law of 19 August 1891). Fisheries are exclusively reserved for Belgian fishers, although multilateral conventions and European legislation allow some other member states to fish in this area. Based on the CFP, between 3 and 12 NM the Dutch fishing vessels have unlimited fishing rights and the French fishing vessels have fishing rights for Herring. The German, Danish and British fleets are not allowed in the Belgian territorial sea. Within 0-3 NM vessels sailing under a Dutch flag with a gross tonnage <70 may conduct fishing activities based on the Benelux convention (Douvere F and Maes F, 2005).

In August 2019, the Flemish government also decided that vessels with a pulse gear were no longer allowed within Belgian territorial waters. This in compliance with the decision of the European Parliament that voted to pass the 'Technical Measures' regulation, which want to see electric pulse trawling to be banned from July 1, 2021 (EU Regulation 2019/1241).

6.2. Methodology

6.2.1. Fishing activity data

6.2.1.1. Source and data

Acknowledgement

This report was written with the data provided by Torsten Schultze (Thunen Institute, Germany), Roi Martinez (CEFAS, England), Mads Nørgaard Larsen (Ministry of Environment and Food, Denmark) and Jeppe Olsen (DTU-Aqua, Denmark), Aurore Chassanite (IFREMER, France) and Laureline Gauthier (Ministère de l'agriculture et de l'alimentation, France), and Niels Hintzen (WUR, The Netherlands).

Vessel Monitoring by Satellite (VMS) and catch data from fishers logbooks were used to analyze the fishing activities. VMS is a satellite-based monitoring system which provides data on the location, time, course and speed of vessels at regular intervals and is transmitted to the fisheries authorities. The time interval between two original VMS pings is on average 2 hours, but may vary from a few minutes up to 4 hours. Within the European Framework, logbooks are compulsory for most commercial fishing vessels and contain information on the daily catch composition, the type of fishing gear used as well as the departure and arrival times in harbours. Belgian VMS and logbook data are collected by the Flemish authorities (Departement Landbouw en Visserij; Afdeling landbouw- en visserijbeleid) and ILVO has the permission to conduct analyses on these data.

Research institutes of Great Britain (CEFAS), Denmark (DTU-AQUA), Germany (TI), France (IFREMER) and the Netherlands (WUR) were asked to provide data on the fishing activities of their countries in the 3 searching areas, *the* 'Vlaamse Banken' and *Vlakte van de Raan* as well as in the BPNS. The same standardized R-script developed by ILVO was sent out to these institutes. The rationale was that the same methods (and script) to processes VMS and logbook data could then be used by all countries as they use the same data format and type of data. France is an exception and used their own scripts or software to process the data, but followed similar steps as outlined in the ILVO script.

The script calculates the number of vessel-gear combinations, the effort (days at sea) and landings (weight and value) by gear and vessels length class in the 5 areas based on VMS and logbook data for 2013-2019.

Next to the 5 selected areas, we also calculated the fishing activities of different member states (except France, which was not able to provide the data in the specified format) in a grid (size: 1.6km by 1.6km) covering the Belgian part of the North sea (Figure 24). We determined effort (fishing hours and days at sea) and total landings (in weight and value) by gear, by year and grid cell for 2013-2019. This data allowed for relative comparison of the fishing intensities in the different areas as well as other spatial analyses.

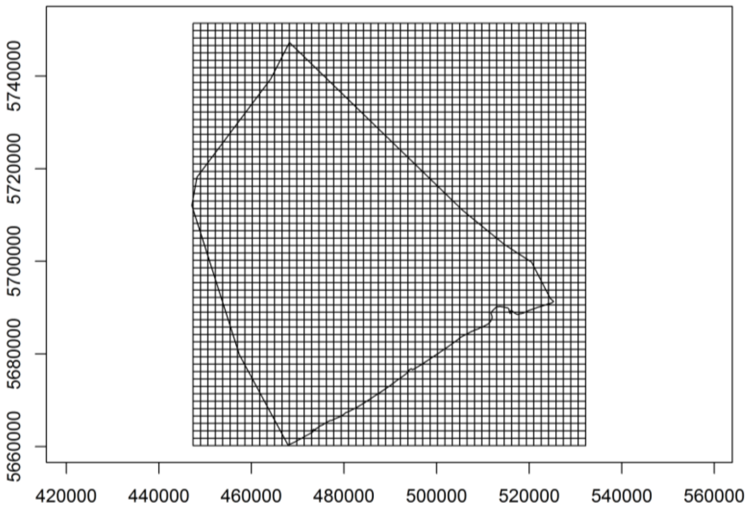


*Figure 24 1.6 * 1.6 km grid cells from which fisheries data were requested*

6.2.1.2. Linking VMS and logbook data & defining fishing effort

All data processing of VMS and logbook data was done in R using the vmstools package (Hintzen *et al.* 2012). An extensive quality control of the data was performed, checking for duplicated data, locations inside the harbours or on land and impossible times, dates, headings and locations. Data quality checks for the logbook records included removal of duplicates, arrival times before departure times and overlap with other trips.

VMS and logbook data were linked based on vessel identity and date-time. As such, data on fishing location, fishing time, fishing speed, fishing gear and the resulting catch can be combined. Therefore, for each trip that is linked to VMS data, the landings and days at sea are allocated to all VMS pings of that trip for which we expect fishing activity based on speed. If a match cannot be found, the record is left out. On average 12.6% (± 7.8 %) of the Belgian landing weights in ICES rectangles 31F2, 31F3, 32F2 and 32F3 in the logbook data could not be coupled to VMS pings for the Belgian fleet. On average 5.4% (± 4.0) of the Dutch landing weights in ICES rectangles 31F2, 31F3, 32F2 and 32F3 in the logbook data could not be coupled to VMS pings for the Dutch fleet. For each VMS ping, the activity of the vessel (floating, fishing or steaming) is defined based on the speed at that time and the gear type associated with the VMS ping as is presented in Table 1. Only VMS records with speeds that correspond to fishing activities were selected. To derive the total landings weight, landings value and fishing hours within each selected area, we checked if VMS pings were located inside or outside the 5 selected areas (Seach Zones 1,2 and 3, the Vlakte van de Raan and the 'Vlaamse Banken', fig. 1) using a point-in-polygon routine in R. Effort was expressed in terms of days at sea. Landings weight and value are expressed in tonnes and euro and were based on a combination of logbook data and sales data.

Table XXII. Determination of fishing activity based on the vessel speed for different types of gear.

Gear code	Gear type	Min fishing speed	Max fishing speed
AG		4	7
BTF	Live-bait gear	0	5
DRB	Boat dredge	1	5
FPO	Pots and traps	0	20
GN	Gillnets (not specified)	0	20
GNS	Set gillnets	0	20
GTN	Combined gillnets- trammel nets	0	20
GTR	Trammel nets	0	20
HMD	Mechanized dredges	0	3
LHM	Mechanized handlines and pole-lines	0	4
LHP	Hand-operated handlines and pole-lines	0	5
MIS	Miscellaneous gear	0.5	5
NK	Gear not known	2	5
OTB	Otter trawls	1	5
OFG	Other static and other gears	2	3
OTM	Midwater otter trawls	1	7
OTT	Otter twin trawls	1	5
PS	Purse seines	0	4
PTM	Midwater pair trawls	1	6
PTB	Bottom pair trawl	1	5
SDN	Danish seines	0.5	6
SSC	Scottish seines	0.5	6
TBB	Beam trawls	2	7.5
TBS	Shrimp trawls	2	6

The resulted data was combined for analyses and gear types were grouped into more generic categories (Table XXIII). The total fishing activity in the BPNS (days at sea, landings weight and value) was derived from the data by grid cell.

Table XXIII. Relation between gear groups and gear codes in this analysis.

Group	Gear type code
Passive	FPN, FPO, FYK, GN, GND, GNS, GTR, LHM, LHP
Beam trawl	TBB

Shrimp trawl	TBS, TBC
Pulse trawl (flatfish)	PUL
Otter trawl	OTB, OTM, OTT, PTB
Seiners	SDN, SSC, PS
Other gears	AG, DRB, HMD, MIS, PTM

6.2.2. Seabed impact

Seabed impact of trawling was calculated as swept area in a grid cell divided by surface area of a grid cell (Eigaard *et al.* 2016) for each grid cell and year. Swept area data for the German, Dutch and Belgian fleet were combined into one grid. We retained only towed and seine gears (beam trawls, twin trawls, otter trawls, seines, bottom paired trawls and dregdes) to calculate swept area. Given the small spatial scales at which the data are processed, some sort of interpolation is required to obtain higher-resolution data for the seabed impact. We used the cubic Hermite spline (cHs) interpolation method described by Hintzen *et al.* (2010) to interpolate vessel trajectories from VMS data points. This cHs method uses position, heading and speed to interpolate the track of a vessel between two succeeding data points. Hintzen *et al.* (2010) showed that this cHS method approximated the real vessel track markedly better than a straight line interpolation. For each gear group, a vessel size-gear size relationship was estimated to enable the prediction of gear footprint area and sediment penetration from vessel size. Application of these relationships with vessel size and towing speeds provided swept-area estimates by gear.

6.2.3. Remark/Uncertainty of the analyses:

VMS and logbooks

The analyses requires making a number of assumptions related to fishing activity and linking catches to VMS pings. One of the main assumptions is the use of speed to determine the activity of a vessel. We used speed thresholds by gear, VMS records with speeds between these thresholds were assumed to represent fishing. The speed thresholds are based on observations at sea on commercial vessels. This method will not result in a perfect identification of fishing behavior, but it provides us a much finer spatial resolution of fishing activities (Hintzen *et al.* 2012).

By linking VMS pings with the logbook records, we can assign individual VMS pings to logbook records. The landings data of these logbook records recorded at 24h intervals are then equally distributed among the linked VMS positions. Here we assume equal catch rates on the different VMS positions. In reality, one vessel fishing may encounter different fishing grounds with different yields during one day, but since the lack of more detailed catch records, we can only assume equal catches for the different VMS records of a certain day and corresponding logbook record.

The temporal resolution of VMS data is relatively low, usually with a 1 or 2 interval time between two VMS pings.

Vessels with a length above 12 meters are obliged to comply with the VMS requirements since 1 January 2012 (EC 2009 and EC 2011). All Belgian vessels have a VMS-system on board. However, this may not be the case for other non-Belgian vessels under 12 m and active in the BPNS.

This means that the final results contain a degree of uncertainty and that numeric values presented in these results are subjected to change if assumptions change.

Vessel Lengths

The vessel length categories used in this analysis follow the same division as is done within the European Data Collection Framework, where it forms the basis to define a fleet segment in combination with a particular fishing technique (*https://datacollection.jrc.ec.europa.eu/wordef/fleet-segment-dcf*). This allows for a means of comparison across member states. In this report we did not consider keeping different categories for vessels under 12 meters or over 24 meters. Very small and very large vessels are rare in these areas. Furthermore, the EU defines small-scale fisheries as vessels with an overall length < 12 m and not using towed gears (Council Regulation (EC) No 1198/2006). This definition is applied in the Data Collection Framework as well as in the current CFP.

Days at sea

Days at sea were calculated as the differences between departure date and time and arrival date and time, expressed as days. These 'Days at sea' of the different logbook records are then equally distributed of the VMS pings that were linked to this logbook record. On average, one day at sea equals 20 fishing hours in the different datasets that were used in this study. Days at sea were requested in the 5 areas as well as for the grid covering the BPNS. However, France provided this variable as fishing hours. This variable was divided by 24 as a means of correction, but is likely an underestimation of the effort in terms of days at sea when comparing it with the data provided by the other member states. Denmark also provided data using hours as a unit.

Number of vessel-gear combinations

The number of vessel-gear combinations in an area gives a proxy for the number of vessels in this area. It represents the number of vessels using a particular gear type code and not the actual number of vessels. It may well be that the same vessel used a gear with a different gear type code on a different fishing occasion in the area (E.g. periodic switch between beam trawl and shrimp trawl). Gear type codes were later pooled per gear group. Therefore, it is possible that some vessels are represented more than once and the number of actual distinct vessels in the area will likely be lower.

6.3. Commercial fisheries results

6.3.1. General overview

Between 2013 and 2019, the fishing activities in the different areas considered in this document have varied. Overall, 2019 seems to have been a year with exceptionally low activity in *Vlakte van de Raan* as well as in 'Vlaamse Banken', however this was not observed in Seach Zone *2* or Seach Zone *1*. This lower activity within the territorial sea is mainly attributed to fishing activities of the Dutch fleet and to a lesser extent, in some areas, to the Belgian fleet.

Not surprisingly, most activity occurred in the 'Vlaamse Banken', the largest subarea considered in this document ranging from 89 **vessel-gear combinations** (2019) to 139 vessel-gear combinations (2017) (Figure 25). In Seach Zone *1* on average 40 vessel-gear combinations were observed in the area, in Seach Zone *2* this was 60 on average and 71 on average in Seach Zone *3*. In *Vlakte van de Raan,* the average was 62 vessel-gear combinations. All different gear groups occurred in the 'Vlaamse Banken' area. In *Vlakte van de Raan* and Seach Zone *3*, shrimp trawls were dominant, as well as pulse trawls, beam trawls and otter trawls (although not in the last 3 years in *Vlakte van de Raan*). In Seach Zone *1* and Seach Zone *2*, besides all trawl gear types, seiners were also active. Passive fishing was executed in all Seach Zones, but mainly in Seach Zone *2* and Seach Zone *3*.

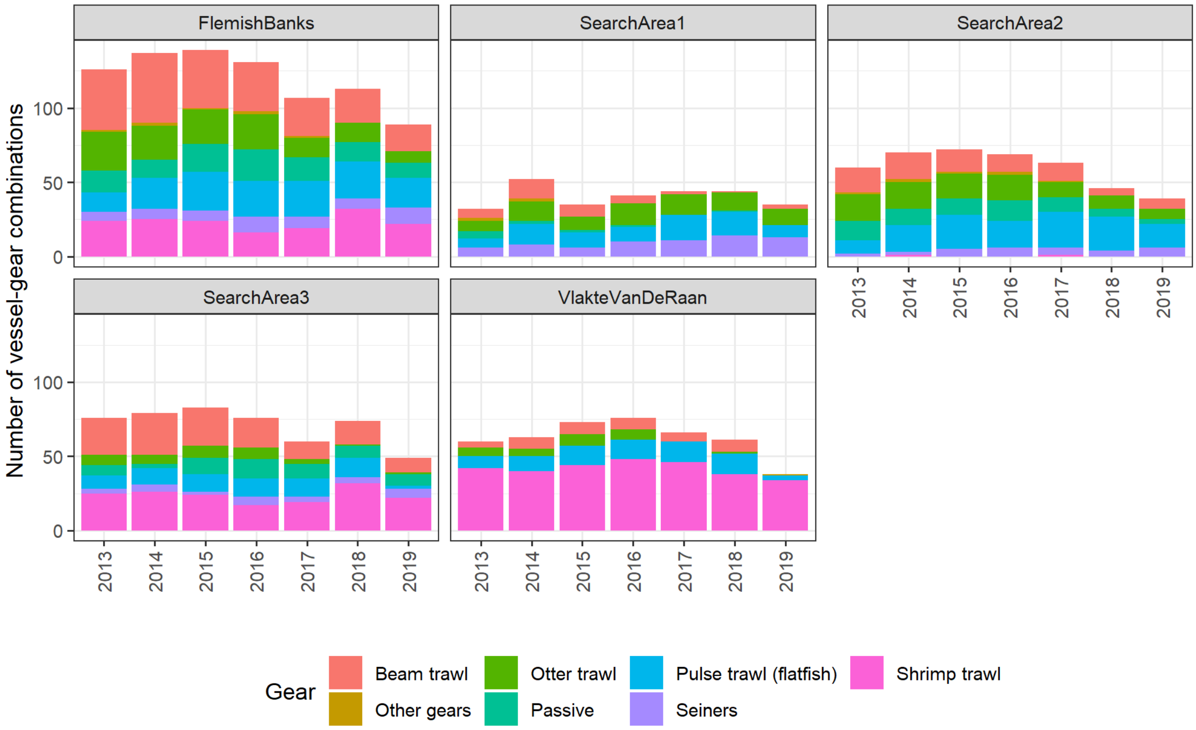


Figure 25 Overview of the number of vessel-gear combinations per year in each subarea. The data is divided per gear type.

Based on the number of **days at sea** (Figure 26) larger vessels - 18-24m and larger than 24 m - were dominant in the study area. In Seach Zone *1* and Seach Zone *2*, almost exclusively the largest ones (>24m) were observed; whereas in Seach Zone 3 and *Vlakte van de Raan* had more of the 18-24m category. In Seach Zone 3, also smaller vessels (12-18m) conducted fishing activities. Some fishing activities was observed for vessels < 12 m, but this is likely to be an under representation as these vessels do not require VMS-system on board.

The pulse trawl targeting flatfish was the most important gear used, both in terms of effort as well as in terms of landings (weight and value). A shift from beam trawls to pulse trawling is noticeable in Seach Zone *2* in 2013 and 2014. In 2019, pulse trawl activity was much lower, in 'Vlaamse Banken' and *Vlakte van de Raan*.

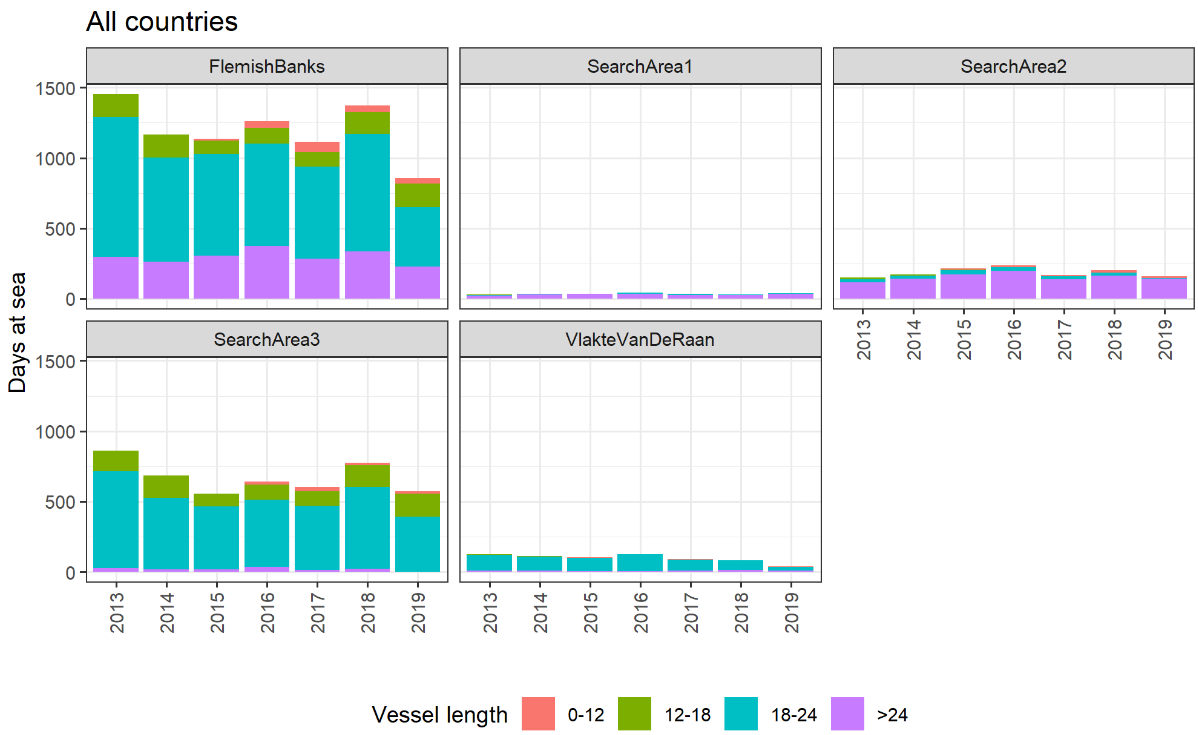


Figure 26 Overview of effort (in days at sea) for all countries in each sub area. Data divided per vessel length

In the next figure (Figure 27) an overview is given of the **effort** in **days at sea** for each subarea and each member state. The data is divided per gear type.

The Dutch fleet was a major player in all areas, using pulse trawls, shrimp trawls, beam trawls and seines. The 'Vlaamse Banken' was important for the Belgian fleet and especially Seach Zone *3* where shrimp trawls, beam trawls and passive gear were used. Seach Zone *2* also holds some significance for passive gears. In the *Vlakte van de Raan*, shrimp trawls were the dominant gear used by the Belgian fleet.

Seach Zone *2* was of importance to the French otter trawls and vessels using passive gears. Fishing activity of French otter trawls also occurred in Seach Zone *1* (more offshore), where additionally seines were used. There was also low fishing activity (maximum of 6 days) of the Danish fleet with passive gears in the years 2013-2015. The German fleet mostly operated with passive gears within Seach Zone*s* *1* and *2*, but with a decreasing trend (from 6 to 2 days a year) over the study period. Great-Brittan occasionally (maximum 1.5 day) used a beam trawl (and in 2016 also passive gear).

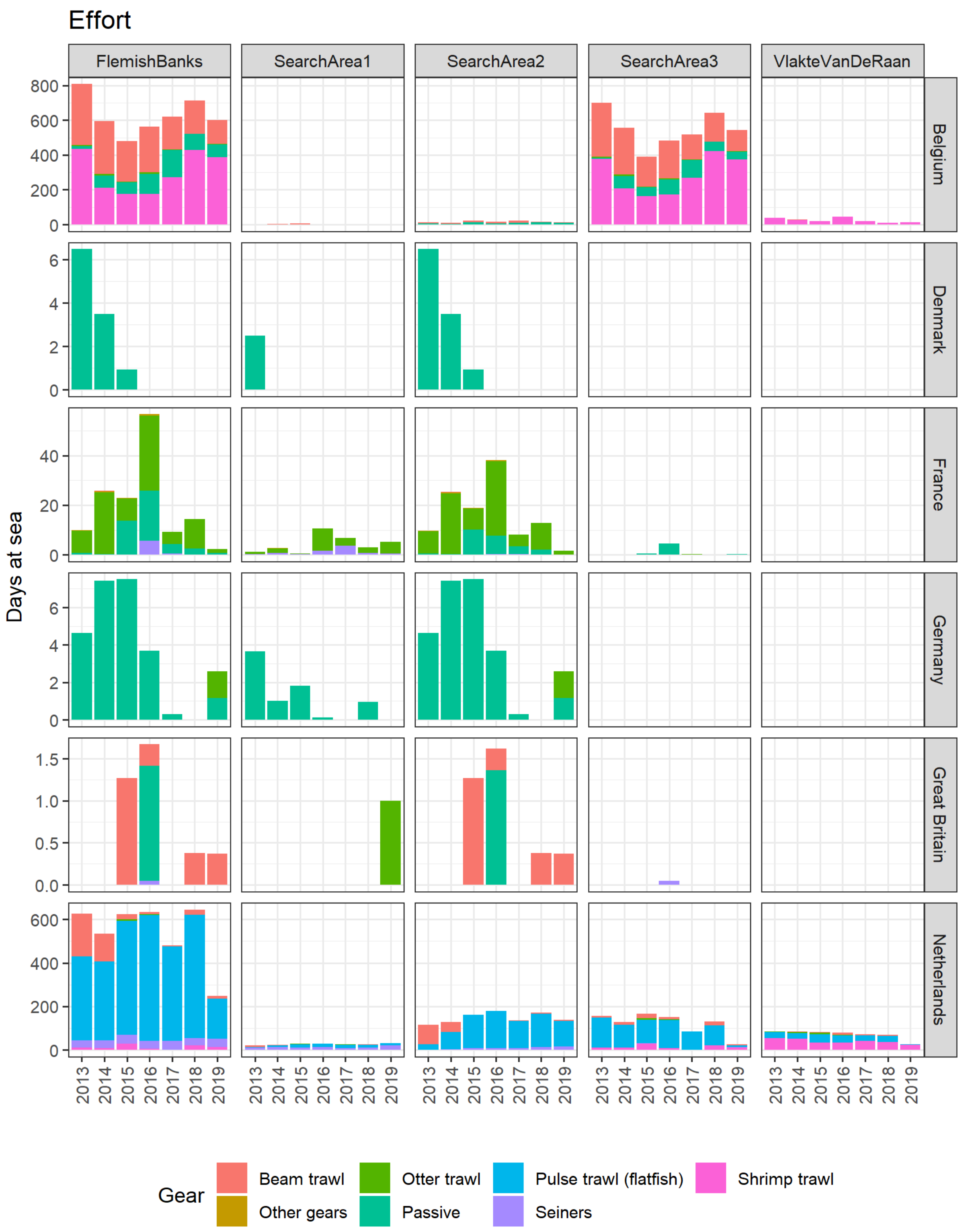


Figure 27 Overview of effort (in days at sea) for each subarea and each member state. The data is divided per gear type

There seems to be a decreasing trend in terms of **landings weight** in the 'Vlaamse Banken', which was also observed in Seach Zone *3* (Figure 28). This overlap, must be considered when comparing results across areas. No clear trend was observed in Seach Zone *2*, Seach Zone *1* or *Vlakte van de Raan*.

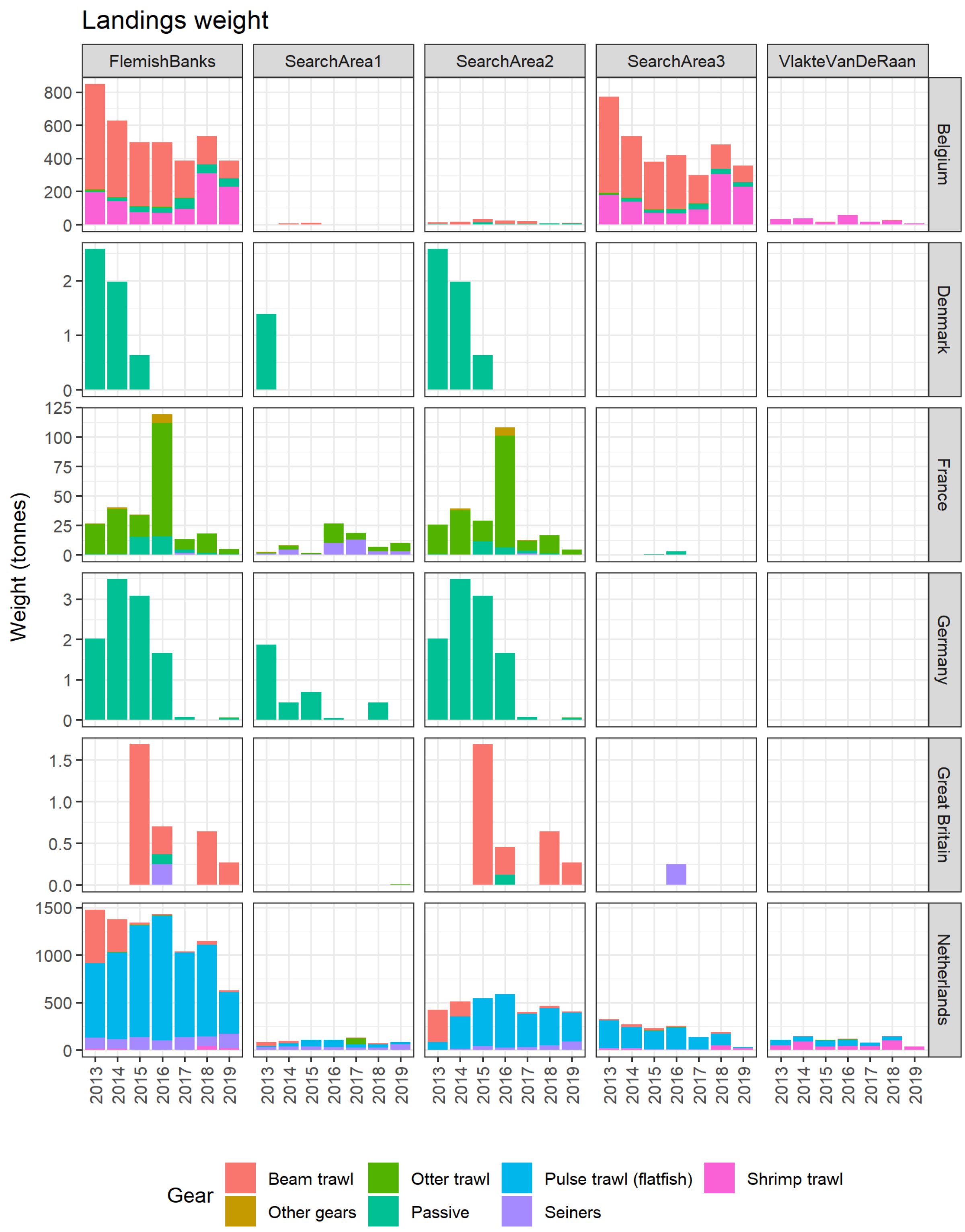


Figure 28 Overview of the weight (tonnes) for each subarea and each member state. The data is divided per gear type

In terms of **value** most fishing activity can be observed in Seach Zone *3* for Belgium, and to a lesser extent Seach Zone *2* (Figure 29). For all other countries, Seach Zone *2* seems to be the most important area.

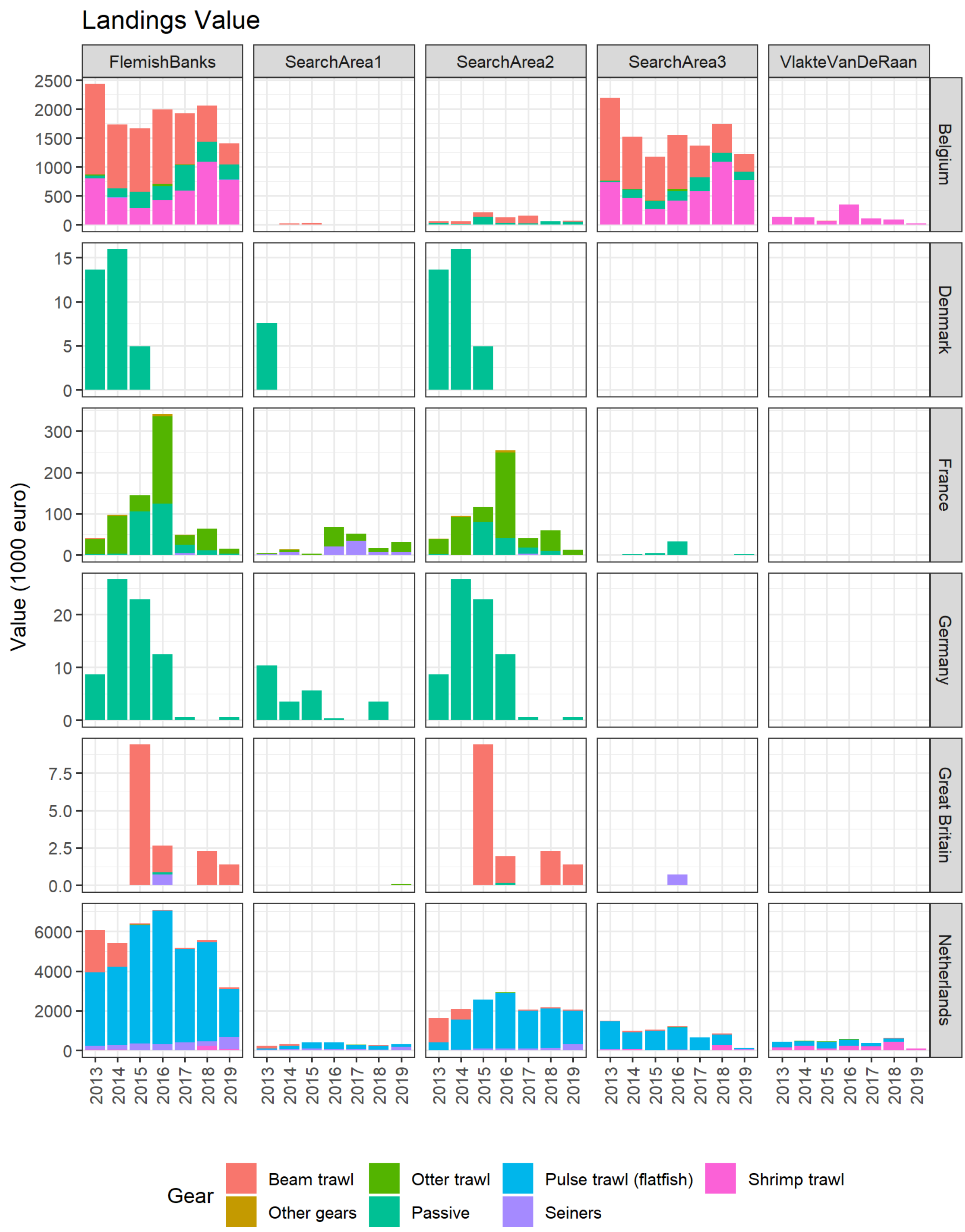


Figure 29 Overview of the landing value for each subarea and each member state. The data is divided per gear type

6.3.2. Fishing activity in area ''Vlaamse Banken''

This Natura2000 area comprises about one third of the BPNS (1106.64 km²) and is located in the western part of the Belgian EEZ, bordering France (see Figure 1).

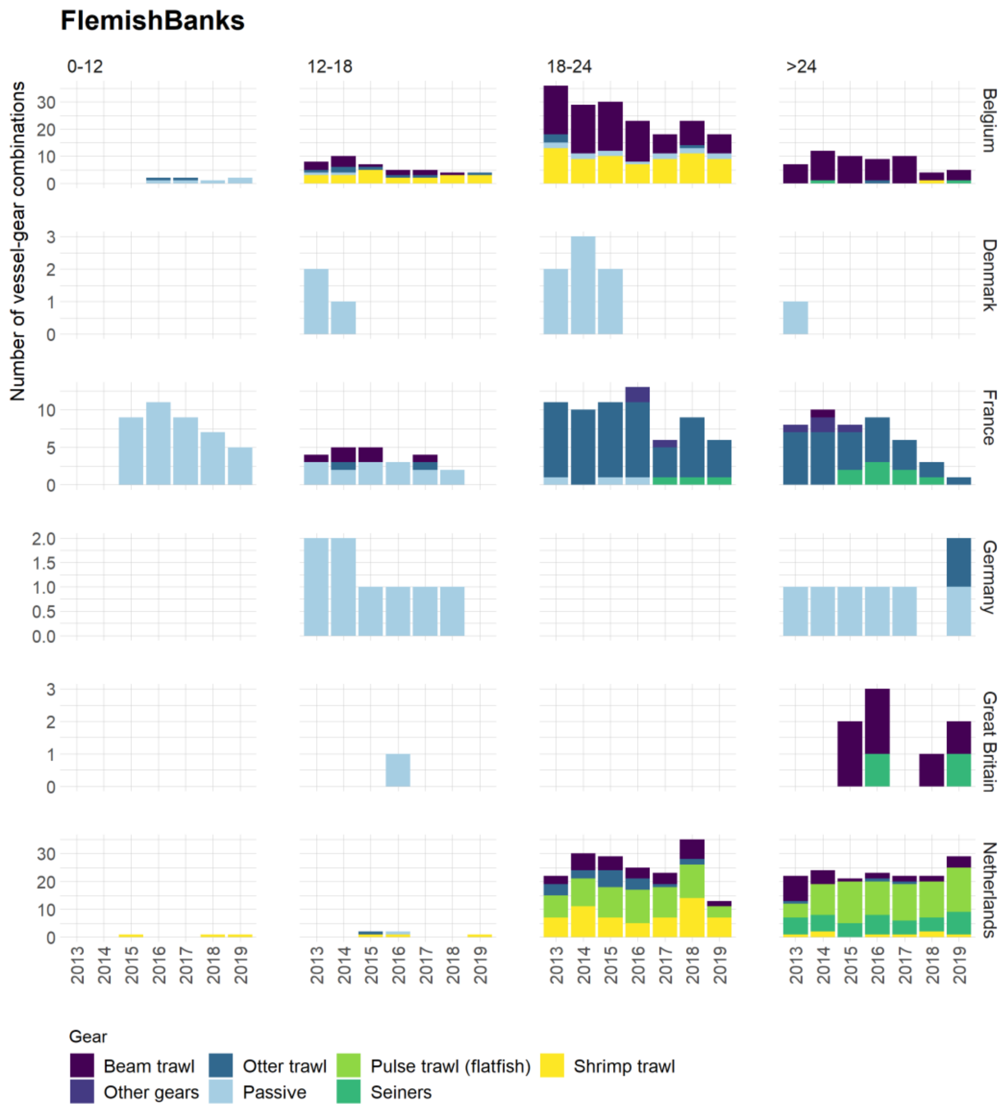


Figure 30 Number of vessel-gear combinations per vessel length class, per country and per type of fishing gear in area ''Vlaamse Banken''

The **number of vessel-gear combinations** in the area gives a proxy for the number of vessels in the area (Figure 30). The Dutch fleet had the largest number of vessel-gear combinations (on average 50) followed by the Belgian fleet (on average 41) and the French fleet (on average 25). The number of vessel-gear combinations for the other member states was very low (average <5 vessel-gear combinations).

The Belgian fleet was mainly composed of large vessels using shrimp trawls or demersal beam trawls. The Danish and German vessels in the area used passive gears, with the exception of one German otter trawler. The French fleet consisted of both small vessels (< 12m) using passive gears as well larger vessels using otter trawls and seines, but also employed a few beam trawls in the area. The British fleet operated with larger vessels (> 24m): seiners or demersal beam trawlers. The Dutch fleet was most present in the area, operating with vessels of 18-24 m or > 24m using demersal trawls, shrimp trawls and pulse trawls.

*Table XXIV. Overview of the effort (days at sea), landed weight (tonnes) and value (*1000€) per country in the period 2013-2019 in the Natura2000 site ''Vlaamse Banken''*

Effort (days at sea)

Country	2013	2014	2015	2016	2017	2018	2019	Average
France	9.9	25.8	23.0	56.7	9.2	14.4	2.3	20.2
Belgium	808.6	596.1	479.2	563.5	621.8	713.4	601.2	626.3
Denmark	6.5	3.5	0.9	0.0	0.0	0.0	0.0	1.6
Germany	4.6	7.4	7.5	3.7	0.3	0.0	2.6	3.7
Great Britain	0.0	0.0	1.3	1.7	0.0	0.4	0.4	0.5
Netherlands	626.5	533.3	622.9	633.4	481.0	645.1	248.9	541.6
Total	1456.1	1166.2	1134.8	1259.0	1112.2	1373.3	855.3	1193.8

Landings (tonnes)

Country	2013	2014	2015	2016	2017	2018	2019	Average
France	26.38	40.18	33.89	119.17	13.34	17.79	4.85	36.51
Belgium	848.07	628.84	495.37	495.21	384.24	532.94	385.88	538.65
Denmark	2.58	1.98	0.63	0.00	0.00	0.00	0.00	0.74
Germany	2.02	3.49	3.08	1.65	0.07	0.00	0.05	1.48
Great Britain	0.00	0.00	1.69	0.70	0.00	0.64	0.27	0.47
Netherlands	1477.55	1377.03	1340.05	1429.11	1039.17	1146.78	626.40	1205.16
Total	2356.60	2051.52	1874.71	2045.84	1436.82	1698.15	1017.45	1783.01

Value (1,000 euros)

Country	2013	2014	2015	2016	2017	2018	2019	Average
France	39.96	97.60	144.85	340.49	48.14	63.86	15.32	107.17
Belgium	2432.62	1730.79	1662.05	1992.74	1928.16	2062.03	1403.13	1887.36
Denmark	13.66	15.95	4.94	0.00	0.00	0.00	0.00	4.94
Germany	8.63	26.64	22.85	12.42	0.59	0.00	0.53	10.24
Great Britain	0.00	0.00	9.39	2.65	0.00	2.29	1.39	2.25
Netherlands	6062.48	5414.07	6387.19	7081.44	5163.27	5566.23	3169.30	5549.14
Total	8557.35	7285.04	8231.28	9429.74	7140.16	7694.41	4589.67	7561.09

On average, **the effort** in the area was highest for the Belgian fleet (626 days at sea or 50% of the total average effort in the area), followed by the Dutch fleet (524 days at sea). France, Germany, Great Britain and Denmark represented on average less than 5% of the total effort in the area.

On average, the **amount of fish** landed from the 'Vlaamse Banken', amounted to 1,783 tonnes, representing a value of €7.56 million. The largest contribution was accounted for by the Dutch fleet, representing about 67.4% of the total landings (in tonnes), followed by the Belgian fleet with 30% (Figure 31). France took up less than 2% on average, while the share of the other countries (Germany, Denmark and Great Britain) was even lower (0.1 %).

In terms of landed **value**, the Dutch fleet was the most important in the area. The yearly average in the period 2013-2019 was €5.5 million with the highest value in 2016 (€7.1 million) and the lowest in 2019 (€3.2 million). The Belgian fleet, landed on average a value of €1.9 million, or 25% of the total value landed from this area. France landed on average €107 thousand from the 'Vlaamse Banken' with the highest value (€340 thousand) in 2016 and the lowest value in 2019 (€15 thousand). The landed value from Denmark, Germany and Great Britain is very low (< 0.1% of the total landed value).

The majority of the fishing activity between 2013 and 2019 was carried out by pulse trawls and demersal beam trawls. The presence of the pulse fishers increased over the years in the area and so did their share in the overall effort and landings, except in 2019 (Figure 31). Overall, both pulse trawls and demersal beam trawls had lower values in 2019 than in the period before. This observation is not apparent for shrimp trawls and seines.

Figure 31 Overview of effort (days at sea), landed weight (tonnes) and value (thousand euro) per country (left) and per gear (right) for the period 2013-2019 in area ''Vlaamse Banken''

6.3.3. Fishing activity in searching areas

6.3.3.1. Search Zone 1

This area is located further offshore, and contrary to Seach Zone *2* and Seach Zone *3*, it is not located within the Natura2000 area 'Vlaamse Banken' (see Figure 23). This area is 37.28 km².

The Dutch fleet had the highest **vessel-gear combinations** in the area, consisting of mainly large pulse trawlers, seiners and beam trawlers (on average 21 vessels, ranging from 28 vessels in 2017 to 15 vessels in 2013). France had on average 14 vessel-gear combinations, mainly otter trawls and seiners. Belgium had on average 5 active vessels in the area, mainly large vessels using beam trawls, with a range from 11 in 2014 to none in 2018. Some fishers (Denmark or Germany) used passive gears in the area. Denmark and Great Britain were only active during one year in the period considered here, with a low number of vessels (<3). The German fleet was active in area 1 almost every year, but with a low number of vessels. No small vessels (<12m) were operating in this area.

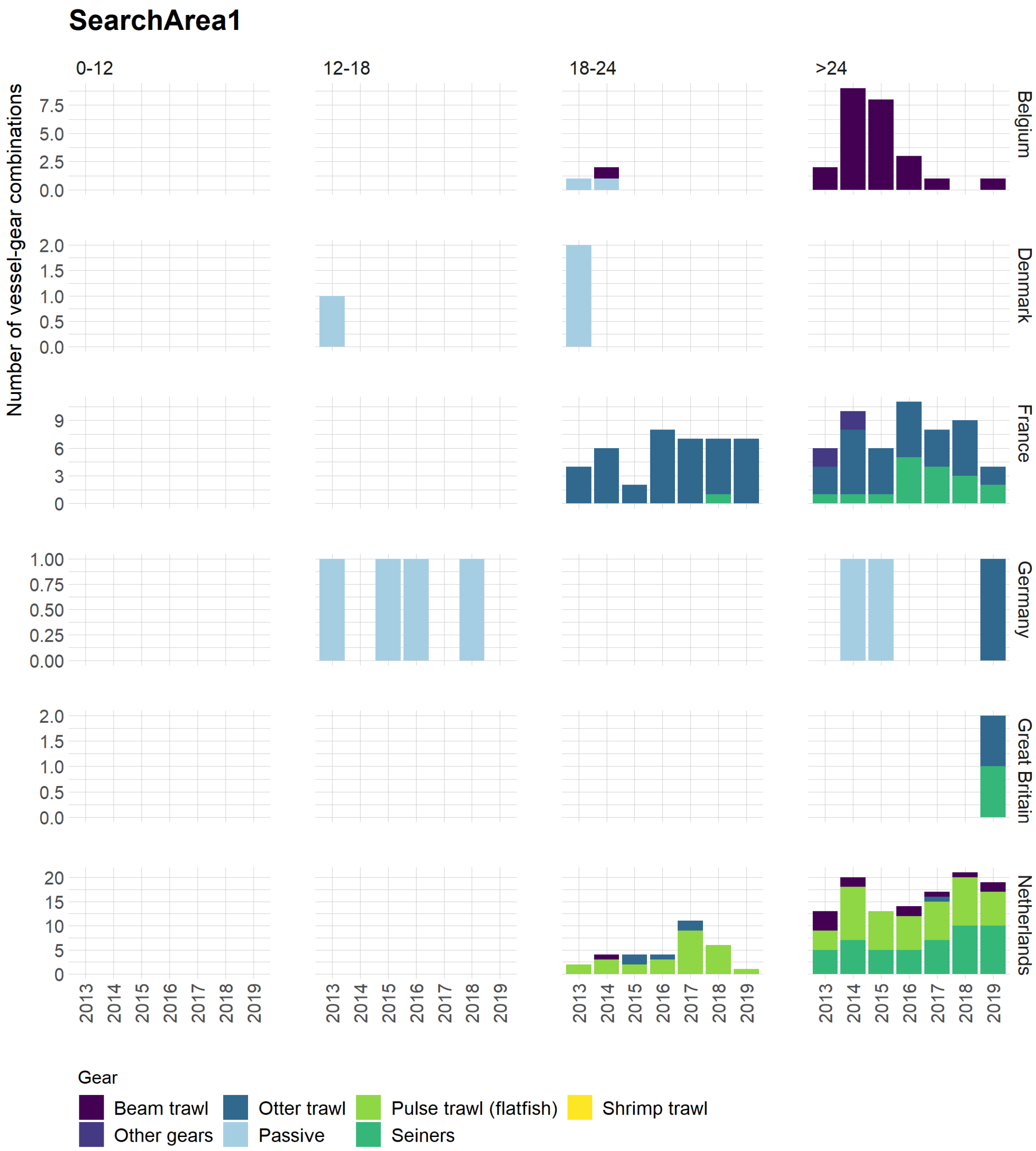


Figure 32 Number of vessel-gear combinations per vessel length class, per country and per type of fishing gear in 'Seach Zone 1'

On average, **the effort** in the area was highest for the Dutch fleet (27 days at sea or about 80% of the total average effort in the area), followed by the French fleet (4 days at sea). The effort for Belgium, Germany and Denmark seems to have more or less ceased in the last 3-4 years in the considered period (Figure 12).

On average, the **amount of fish** landed from Seach Zone *1*, amounted to 111 tonnes, representing a **value** of €356 thousand. The largest contribution was accounted for by the Dutch fleet, representing on average 87.4% of the **total landings** in tonnes (or 97 tonnes). On average 9% of the landings was caught by the French fleet and 1.8% by Belgian vessels. Germany, Denmark and Great Britain only had little activity in this area. Overall, the landed weight increased until 2017, but was lower in 2018 and 2019.

The value of landings in Seach Zone *1* generally increased between 2013 and 2016. Between 2016 and 2017 it decreased and remained more or less stable over the last three years. The majority of the landed value was caught by Dutch vessels (average of 89% or €318 thousand); France caught on average €27 thousand, while Belgium had no fishing activity in the area between 2017 and 2019. Between 2013 and 2016, the average value was €7 thousand.

The majority of the fishing activity between 2013 and 2019 was carried out by pulse trawls and seiners. The presence of the pulse fishers increased over the years in the area and so did their share in the overall effort and landings untill 2016, and then gradually decreased again (Figure 33). The fishing activity of seiners showed a gradually increase, with 2019 being higher than previous years. In 2013 and 2014 there is also a part of the landings caught by demersal beam trawlers and in 2017 the largest amount of landings was caught by vessels with an otter trawl gear. Overall fishing activity in the area increased until 2016, decreased in 2017, but remained comparable since.

*Table XXV. Overview of the effort (days at sea), landed weight (tonnes) and value (*1000€) per country in the period 2013-2019 in 'Seach Zone 1'*

Effort (days at sea) Search Zone 1

Country	2013	2014	2015	2016	2017	2018	2019	Average
France	1.2	2.8	0.4	10.5	6.6	2.9	5.1	4.2
Belgium	0.9	4.1	5.3	0.2	0.0	0.0	0.1	1.5
Denmark	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Germany	3.7	1.0	1.8	0.1	0.0	0.9	0.0	1.1
Great Britain	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.1
Netherlands	21.7	24.9	27.8	29.9	26.1	25.6	30.8	26.7
Total	29.9	32.7	35.4	40.7	32.8	29.4	37.0	34.0

Landings (tonnes) Search Zone 1

Country	2013	2014	2015	2016	2017	2018	2019	Average
France	2.35	7.93	1.62	26.69	18.47	6.48	10.14	10.53
Belgium	0.71	6.14	9.78	0.49	0.00	0.00	0.12	2.46
Denmark	1.39	0.00	0.00	0.00	0.00	0.00	0.00	0.20
Germany	1.86	0.42	0.69	0.04	0.00	0.43	0.00	0.49
Great Britain	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Netherlands	83.46	94.35	109.47	105.46	130.03	72.80	84.34	97.13
Total	89.76	108.84	121.55	132.68	148.50	79.71	94.60	110.81

Value (1,000 euros) Search Zone 1

Country	2013	2014	2015	2016	2017	2018	2019	Average
France	3.80	13.77	2.50	66.86	50.73	16.73	30.51	26.41
Belgium	3.24	15.94	30.83	1.63	0.00	0.00	0.44	7.44
Denmark	7.56	0.00	0.00	0.00	0.00	0.00	0.00	1.08

Germany	10.35	3.49	5.60	0.35	0.00	3.50	0.00	3.33
Great Britain	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.01
Netherlands	227.09	312.48	394.13	411.36	299.55	265.46	317.08	318.16
Total	252.04	345.69	433.06	480.20	350.28	285.69	348.09	356.44

Figure 33 Overview of effort (days at sea), landed weight (tonnes) and value (thousand euro) per country (left) and per gear (right) for the period 2013-2019 in area Seach Zone 1.

6.3.4. Search Zone 2

This area is located within the Northern part of the Natura2000 area ‘Vlaamse Banken’. This area is 325.93km².

In Seach Zone *2* the average **number of vessel gear combinations** was the highest for the Dutch fleet (26 vessels), followed by the French fleet (on average 18 vessels) and the Belgian fleet (on average 11 vessels). Denmark, Great Britain and Germany had low fishing activity in the area (2-3 vessel-gear combinations).

Figure 34 Number of vessel-gear combinations per vessel length class, per country and per type of fishing gear in 'Seach Zone 2'

On average, **the effort** in the area was highest for the Dutch fleet (147 days at sea or about 80% of the total average effort in the area), followed by the French fleet (16 days at sea) and the Belgian fleet (16 days at sea). The effort for Germany, Great Britain and Denmark was low during the considered time period (< 3%) and even seems to have more or less ceased for Denmark and Great Britain in the last 3-4 years of the considered time period (Figure 35)

On average, the **amount of fish** landed from Seach Zone *2*, amounted to 531 tonnes, representing a **value** of €2.4 million. The largest contribution was accounted for by the Dutch fleet, representing on average 89% of the **total landings** (or 476 tonnes), followed by the French (6% or 33 tonnes) and Belgian (3% or 18 tonnes) fleet. Germany, Denmark and Great Britain had only little activity in this area (≤ 1 tonnes).

Overall, the **value of landings** from Seach Zone *2* showed an increasing trend between 2013 and 2016. In 2017 it decreased by 32% compared to the previous year and remained somewhat stable since. Of the overall average, 91% accounted for by the Dutch fleet.

The majority of the fishing activity between 2013 and 2019 was carried out by pulse trawls, followed by seiners, demersal beam trawls and to a lesser extent otter trawlers. The presence of the pulse fishers increased over the years in the area and so did their share in the overall effort and landings. A possible shift from beam trawling to pulse trawling can be observed in 2013 and 2014. Belgian beam trawl fishing activity decreased in this area over the time series, perhaps as a consequence of competing for the same target species.

Since 2014-2015 the share of seiners also seems to have increased, while the activity of otter trawlers seems to have decreased since 2016. As in Seach Zone *1*, but contrarily to observations in other areas of this study, 2019 does not appear to be considerably different from previous years.

*Table XXVI. Overview of the effort (days at sea), landed weight (tonnes) and value (*1000€) per country in the period 2013-2019 in Seach Zone 2*

Effort (days at sea) Search Zone 2

Country	2013	2014	2015	2016	2017	2018	2019	Average
France	9.6	25.4	18.8	38.2	8.1	12.9	1.6	16.4
Belgium	13.8	8.5	23.5	14.7	22.5	14.8	13.7	15.9
Denmark	6.5	3.5	0.9	0.0	0.0	0.0	0.0	1.6
Germany	4.6	7.4	7.5	3.7	0.3	0.0	2.6	3.7
Great Britain	0.0	0.0	1.3	1.6	0.0	0.4	0.4	0.5
Netherlands	114.3	127.3	161.9	179.5	135.8	172.7	138.2	147.1
Total	148.8	172.1	213.9	237.7	166.7	200.7	156.5	185.2

Landings (tonnes) Search Zone 2

Country	2013	2014	2015	2016	2017	2018	2019	Average
France	25.74	39.37	29.02	108.08	12.08	16.45	4.46	33.60
Belgium	14.53	18.11	35.15	22.41	19.55	7.94	8.90	18.08
Denmark	2.58	1.98	0.63	0.00	0.00	0.00	0.00	0.74
Germany	2.02	3.49	3.08	1.65	0.07	0.00	0.05	1.48
Great Britain	0.00	0.00	1.69	0.45	0.00	0.64	0.27	0.44
Netherlands	425.34	510.84	547.34	588.94	397.47	460.73	403.53	476.31
Total	470.21	573.79	616.90	721.53	429.18	485.76	417.21	530.65

Value (1,000 euros) Search Zone 2

Country	2013	2014	2015	2016	2017	2018	2019	Average
France	38.65	94.28	116.31	253.11	40.27	58.87	12.67	87.74
Belgium	61.23	53.07	213.11	124.71	150.12	56.16	66.74	103.59
Denmark	13.66	15.95	4.94	0.00	0.00	0.00	0.00	4.94
Germany	8.63	26.64	22.85	12.42	0.59	0.00	0.53	10.24

Great Britain	0.00	0.00	9.39	1.94	0.00	2.29	1.39	2.14
Netherlands	1632.87	2093.64	2560.50	2918.49	2059.45	2168.13	2052.13	2212.17
Total	1755.04	2283.57	2927.10	3310.67	2250.43	2285.45	2133.47	2420.82

Figure 35 Overview of effort (days at sea), landed weight (tonnes) and value (thousand euro) per country (left) and per gear (right) for the period 2013-2019 in area Seach Zone 2

6.3.4.1. Search Zone 3

This area is located within southern (coastal) part of the Natura2000 area Vlaamse Banken. This area is 353.26 km² and falls within 12NM from the coastline.

Both the Dutch fleet and the Belgian fleet had the highest **vessel-gear combinations** (32 on average) in the area. France had on average 7 vessel-gear combinations in the area, mainly small vessels (<12m). Their activity decreased towards 2019. Germany, Denmark had no activity in the area. This is in line with the regulations as they are not allowed to fish within the 12 NM. These regulations normally also apply to Great Britain, but a seiner vessel was recorded in two different years.

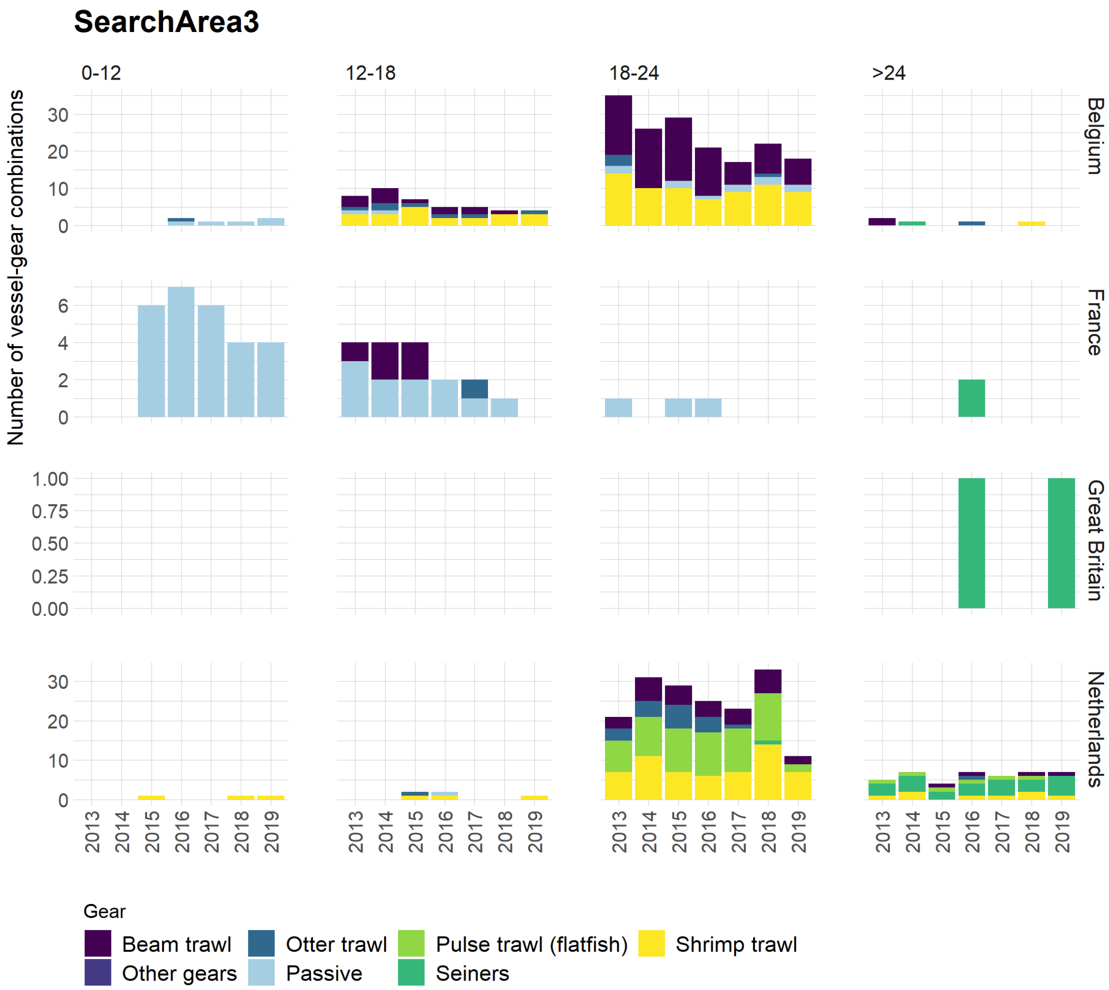


Figure 36 Number of vessel-gear combinations per vessel length class, per country and per type of fishing gear in 'Seach Zone 3'

On average, the effort in the area was highest for the Belgian fleet (548 days at sea or about 82% of the total average effort in the area), followed by the Dutch fleet (121 days at sea). The effort for Great Britain and France was less than 1% (Figure 36).

On average, the **amount of fish** landed from Seach Zone *3*, amounted to 668 tonnes, representing a **value** of €2.45 million. The main players were the Belgian and Dutch fleet, accounting for 69 % and 30.6 % of the **landed weight** on average. The French fleet had a low fishing activity in this area (0.1%). Overall the **value of landings** from this area seems to follow a decreasing trend between 2013 and 2019. Of the overall average, 63% was accounted for by the Belgian fleet.

The overall trend in fishing activity seems to be decreasing. In particular, 2019 seems to have been an unfavorable year, with considerable lower landings (49% lower value of landings than the average of 2013-2018).

The majority of the fishing activity between 2013 and 2019 was carried out by pulse trawlers beam trawlers and shrimp trawlers. There was also some fishing with passive gears (Belgian fleet; on average

3 vessel-gear combinations). The presence of the pulse fishers increased over the years in the area and so did their share in the overall effort and landings untill 2016, and then gradually decreased. The fishing activity of shrimp trawlers seems to have increased, with 2018 being higher than previous years.

*Table XXVII. Overview of the effort (days at sea), landed weight (tonnes) and value (*1000€) per country in the period 2013-2019 in 'Seach Zone 3'*

Effort (days at sea) Search Zone 3

Country	2013	2014	2015	2016	2017	2018	2019	Average
France	0.1	0.1	0.4	4.5	0.1	0.1	0.3	0.8
Belgium	702.0	555.4	389.3	483.8	517.5	642.0	544.9	547.8
Great Britain	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Netherlands	156.9	127.8	166.7	151.2	85.1	130.8	26.4	120.7
Total	858.9	683.2	556.5	639.6	602.8	772.9	571.6	669.4

Landings (tonnes) Search Zone 3

Country	2013	2014	2015	2016	2017	2018	2019	Average
France	0.08	0.21	0.53	2.83	0.07	0.06	0.19	0.57
Belgium	771.17	534.84	380.49	417.87	298.56	482.40	354.47	462.83
Great Britain	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.04
Netherlands	325.03	270.98	227.97	252.73	135.80	187.62	32.72	204.69
Total	1096.28	806.03	608.99	673.67	434.43	670.08	387.38	668.12

Value (1,000 euros) Search Zone 3

Country	2013	2014	2015	2016	2017	2018	2019	Average
France	0.31	1.61	3.58	32.33	0.65	0.36	1.30	5.73
Belgium	2193.06	1519.14	1175.38	1552.25	1363.74	1744.10	1223.23	1538.70
Great Britain	0.00	0.00	0.00	0.71	0.00	0.00	0.00	0.10
Netherlands	1499.66	1000.02	1046.38	1201.34	659.39	844.13	118.56	909.93
Total	3693.02	2520.77	2225.34	2786.63	2023.78	2588.59	1343.09	2454.46

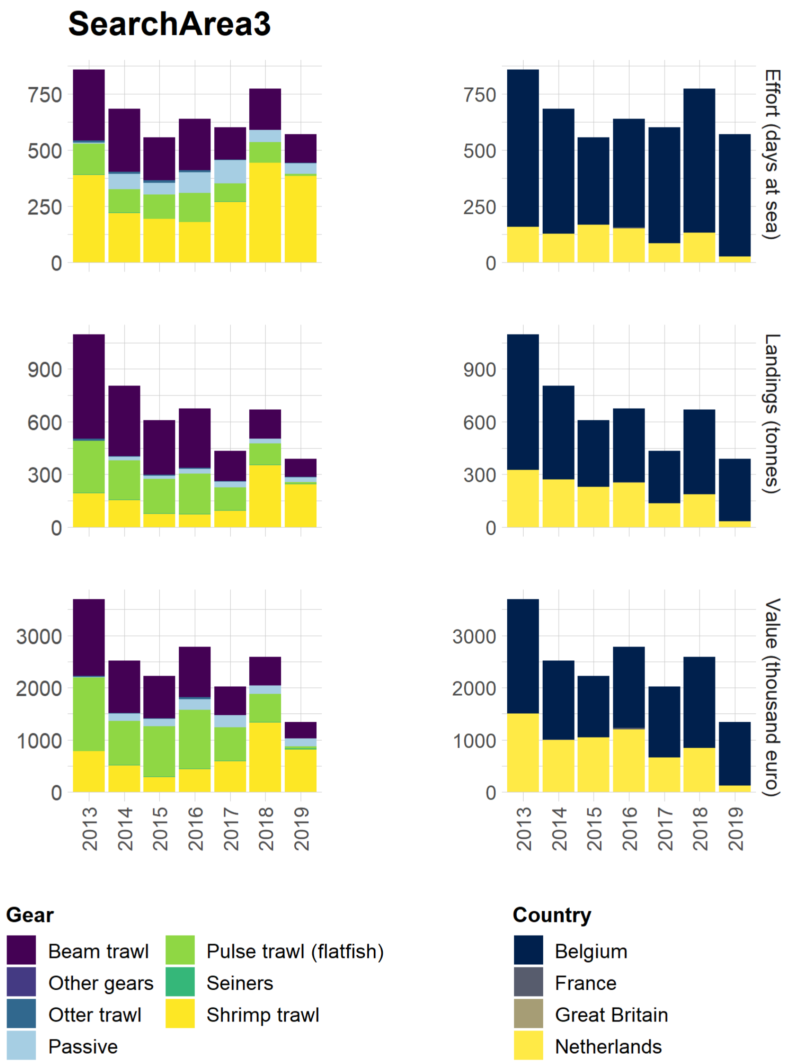


Figure 37 Overview of effort (days at sea), landed weight (tonnes) and value (thousand euro) per country (left) and per gear (right) for the period 2013-2019 in area Seach Zone 3

6.3.5. Fishing activity in Vlakte van de Raan

The area *Vlakte van de Raan* is a relatively small area within the 12NM, bordering the Dutch Natura2000 area with the same name. The size is 62.96 km².

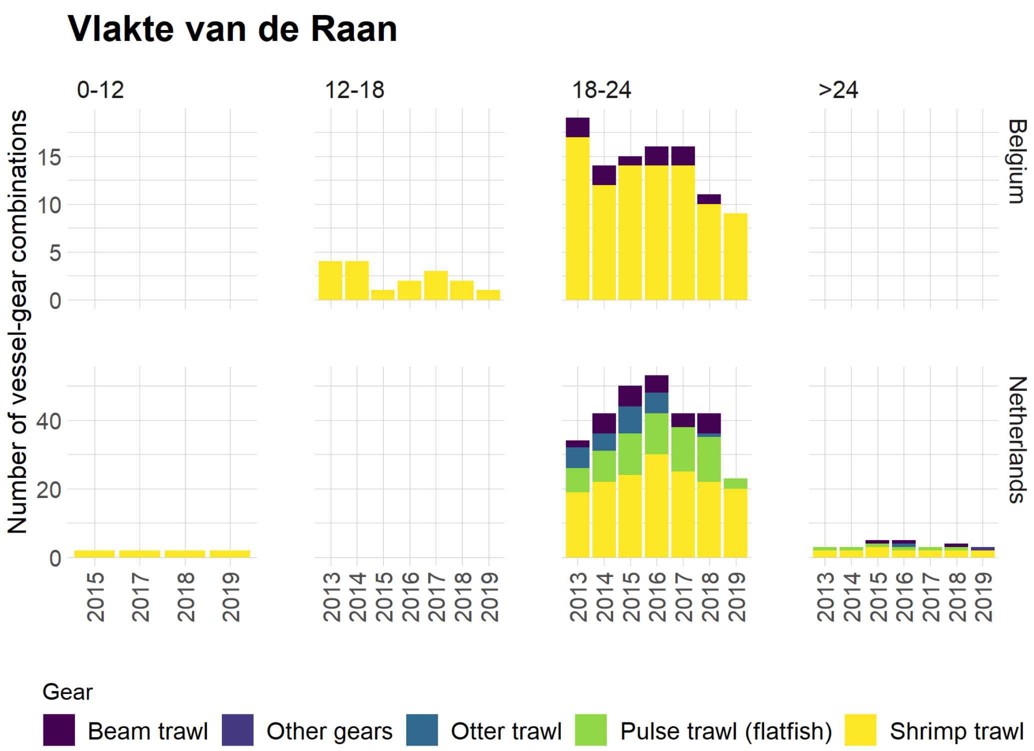


Figure 38 Number of vessel-gear combinations per vessel length class, per country and per type of fishing gear in area 'Vlakte van de Raan'

Only the Dutch and Belgian fleet had fishing activity in this area. On average, **the total** effort consisted of 97 days at sea and the share of the Dutch fleet was higher (72 days at sea or 74% of the total average effort in the area) than that of the Belgian fleet.

On average, the **amount of fish** landed from the area *Vlakte van de Raan*, amounted to 135 tonnes, representing a value of €560 thousand. The Dutch fleet accounted for 79% of landed weight and 78% of the landed value.

The fishing activities have been quite different from year to year with no clear trend, although the number of days at sea seems to be decreasing (Figure 39). Fishing activity has halved in 2019 compared to previous years.

Within this area mainly pulse trawlers (targeting flatfish) and shrimp trawlers dominated the fishing activity (Figure 17). Dutch pulse and shrimp trawlers accounted for most of the effort and landings in *Vlakte van de Raan*, while the share of the Belgian fleet comprised almost exclusively of shrimp trawlers.

*Table XXVIII. Overview of the effort (days at sea), landed weight (tonnes) and value (*1000€) per country in the period 2013-2019 in the Natura 2000 site 'Vlakte van de Raan'*

Effort (days at sea)

Country	2013	2014	2015	2016	2017	2018	2019	Mean
Belgium	39	28	21	46	21	11	11	25
Netherlands	85	85	83	81	71	70	26	72

Total	125	113	104	127	92	81	37	97

Landings (tonnes) Vlakte Van De Raan

Country	2013	2014	2015	2016	2017	2018	2019	Average
Belgium	34	38	16	58	16	25	5	27
Netherlands	109	146	109	120	79	150	37	107
Total	143	184	126	177	95	175	43	135

Value (1,000 euros)

Country	2013	2014	2015	2016	2017	2018	2019	Average
Belgium	137	125	63	349	103	89	18	126
Netherlands	434	478	452	579	383	613	96	434
Total	571	603	515	928	486	702	114	560

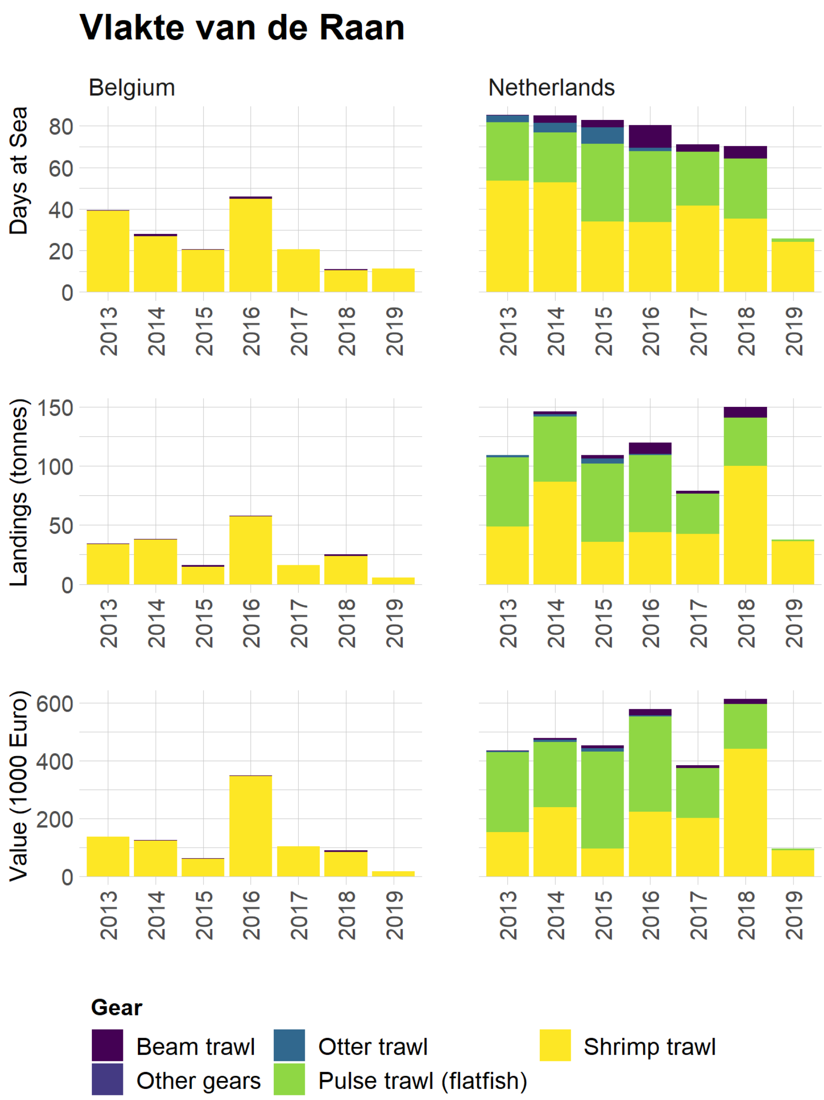


Figure 39 Overview of effort (days at sea), landed weight (tonnes) and value of landings (thousand euro) per country and per gear for the period 2013-2019 in area 'Vlakte van de Raan'.

6.3.6. Fishing activity per gear group

6.3.6.1. Shrimp trawls

The relative importance compared to activities in the BPNS of Seach Zone *3* for the shrimp fishery was variable over time but decreased from 2013 to 2016 and slightly increased afterwards. For fishing effort it was between 15% and 41% of the total, while for landings between 6% and 29% in weight and between 7% and 33% in value. This pattern can be observed for both effort and landings (**weight and value**).

The majority of the shrimp trawlers were part of the Belgian fleet. On the map (see section 3.6, Figure 46) for shrimp trawl, it is shown that the fishing activity for shrimp trawlers mainly occurred in the eastern part of the BPNS within the 12 NM (the extended area around the port of Zeebrugge).

In Figure 18, the quantitative data is presented. For the shrimp fishery, the majority of **fishing effort** occurred outside the Seach Zones. In general the shrimp fishery effort is decreasing in the rest of the BPNS, whereas this trend is not apparent in Seach Zone *3*.

In contrast to the decreasing trend for days at sea for the rest of the BPNS, the **landing** data (**weight**) has more fluctuation over time. Within Seach Zone *3*, the data was variable with a peak in 2018.

The landings in **value** were also variable over time with the lowest values in 2019 outside the Seach Zones. Within Seach Zone *3*, the value over time is variable with the lowest value in 2015.

In terms of relative importance per km^2 Seach Zone *3* was most important for **shrimp trawls,** generating an average of 1.92 € thousand.km^{-2}. It was more important than the rest of the BPNS, a much larger area, as only the coastal zones seem to be attractive for this métier (Figure 18).

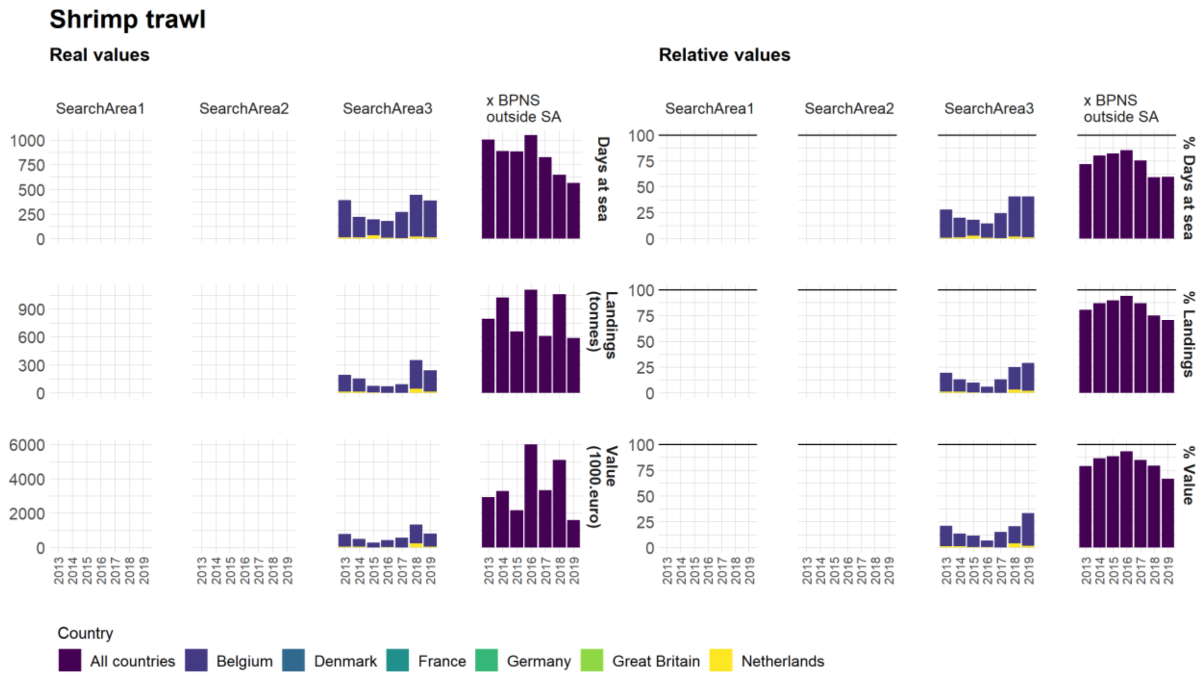


Figure 40 Relative(sum 100%) (left) and quantitative (right) importance of the 3 Seach Zones compared to the rest of the BPNS for shrimp fisheries. The data is divided per country; French data is lacking.

6.3.6.2. Passive gears

Passive fisheries occurred in all 3 Seach Zones and were mainly part of the Belgian fleet (Seach Zone *3*) and French fleet (Seach Zone *2*) and to a lesser extent the German fleet. Seach Zone *3* seems to be the most important area for vessels with passive gear. From 2014 onwards, in terms of **effort (days at sea),** Seach Zone *3* was the most important location for passive fishery: more than 50% of the days at sea were located within the area.

In Seach Zone *2*, there was also some passive fishing activity. The effort was lower than in Seach Zone *3* but remained stable over time. Both Belgian and German fishers were active in this area.

From 2016 onwards, nearly 50% of the **landings (weight)** of passive fishery was caught in Seach Zone *3*.

The map (see section 3.6, Figure 47) shows that fishers with passive gears were fishing on the entire BPNS with some focus around the sandbank 'Gootebank' and 'Oosthinder'. There are no recordings in the eastern part of the territorial waters.

Over time, passive fishery is decreasing in the BPNS. Only in 2017 there was a peak in fishing effort in Seach Zone *3* as well as in the rest of the BPNS (Figure 41).

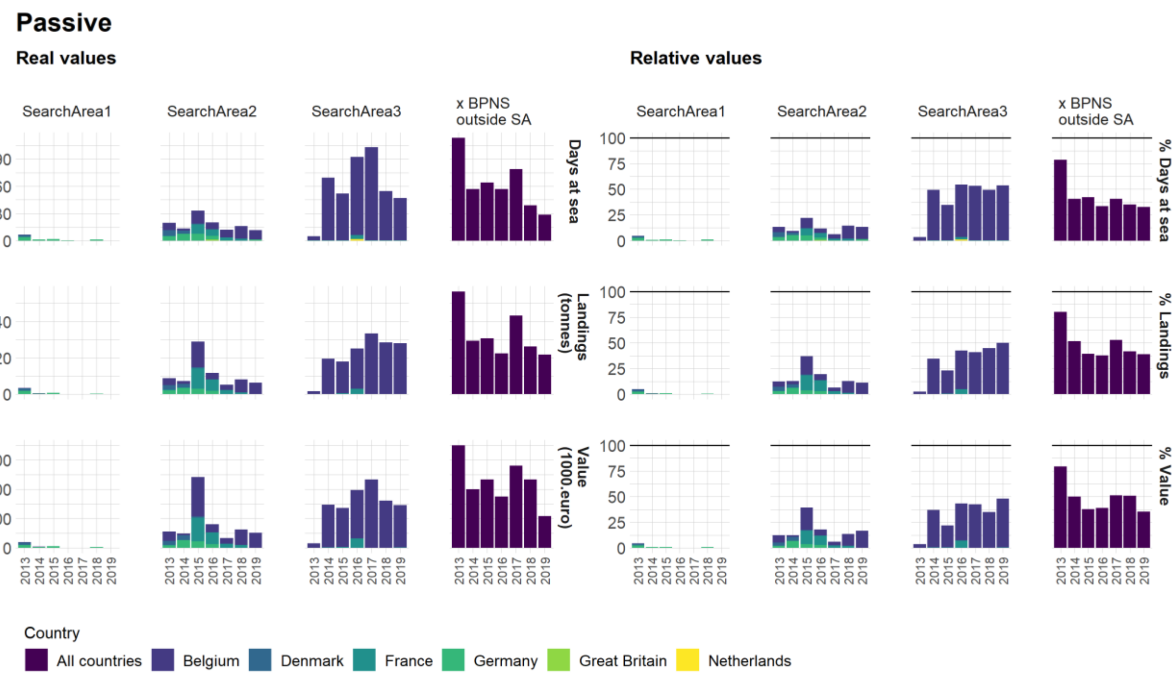


Figure 41 Quantitative (left) and relative (sum 100%) (right) importance of the 3 Seach Zones compared to the rest of the BPNS for passive fishery. The data is divided per country; French data is lacking.

6.3.6.3. Beam trawls

The majority of beam trawling occurred in Seach Zone *3* and in the rest of the BPNS. In terms of **effort**, almost 45% of the **days at sea** were recorded within Seach Zone *3* which corresponds to an average of 37% of value of landings. Seach Zone *1* and Seach Zone *2* were relatively less important. For the Dutch fleet, Seach Zone *2* was relatively more important than Seach Zone *3* for the beam trawl fishery.

Overall in the BPNS, the fishing activity of the beam trawl fishery is decreasing in time. This pattern is visible in all three Seach Zones and in the rest of the BPNS (Figure 42).

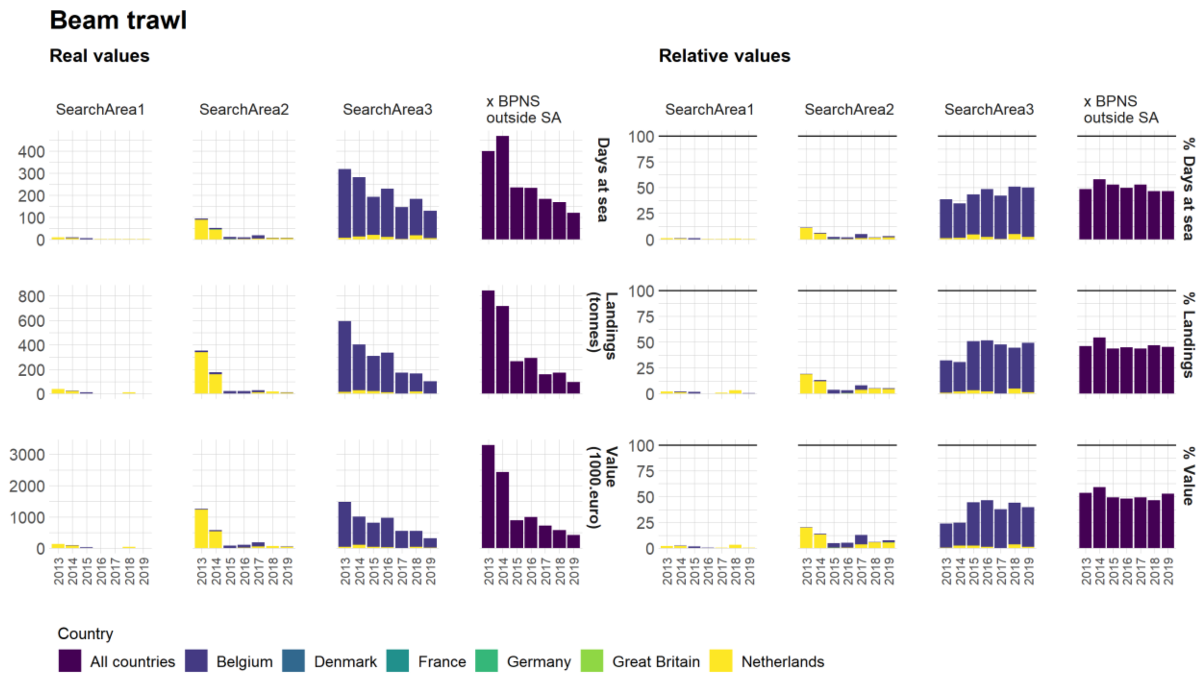


Figure 42 Quantitative (left) and relative (sum 100%) (right) importance of the 3 Seach Zones compared to the rest of the BPNS for beam trawl fishery. The data is divided per country; French data is lacking.

In terms of relative importance per km^2 Seach Zone *3* was most important for **beam trawlers**, generating an average of 2.29 € thousand.km^{-2}. In this regard, other Seach Zones were also important for beam trawlers compared to the rest of the BPNS, especially in terms of value per km^2.

Seach Zone *3* holds an important contribution to the value of landings generated by beam trawlers in the BPNS and especially important for the Belgian fleet. The importance of both Seach Zone 1 and Seach Zone 2 becomes more apparent when considering relative importance per km^2. Seach Zone 2 generated an average of 1.03 € thousand.km^{-2}. Seach Zone 1 is a much smaller area and generated a value of 1.19 €thousand.km^{-2}.

6.3.6.4. Pulse trawls

Pulse trawl fishery occurred in all the Seach Zones, but the rest of the BPNS was more important (both for **effort** and for **landings**). Seach Zone *2* gained more importance over time, while the pulse fishery in Seach Zone *3* decreased over time. The relative effort in Seach Zone *1* remained stable over time.

On the map (see section 3.6,Figure 46), it seems that pulse trawlers were active in the entire BPNS except for the 0-3nm. Only small coastal vessels are allowed in that area, so this is in line with the expectations. As a consequence, in Seach Zone *3* there is a part that had no fishing activity and another part that had a lot of pulse trawling.

In Figure 43, we can see a large decrease in both effort and landings in 2019. This can also be observed in Seach Zone *3*. The subject of pulse fishing led to an important European discussion and in August

2019, electric fishing was banned within the Belgian territorial sea. This might be an explanation with regards to the observed decrease in the area. In terms of relative importance per km² the entire BPNS seems significant for pulse trawlers.

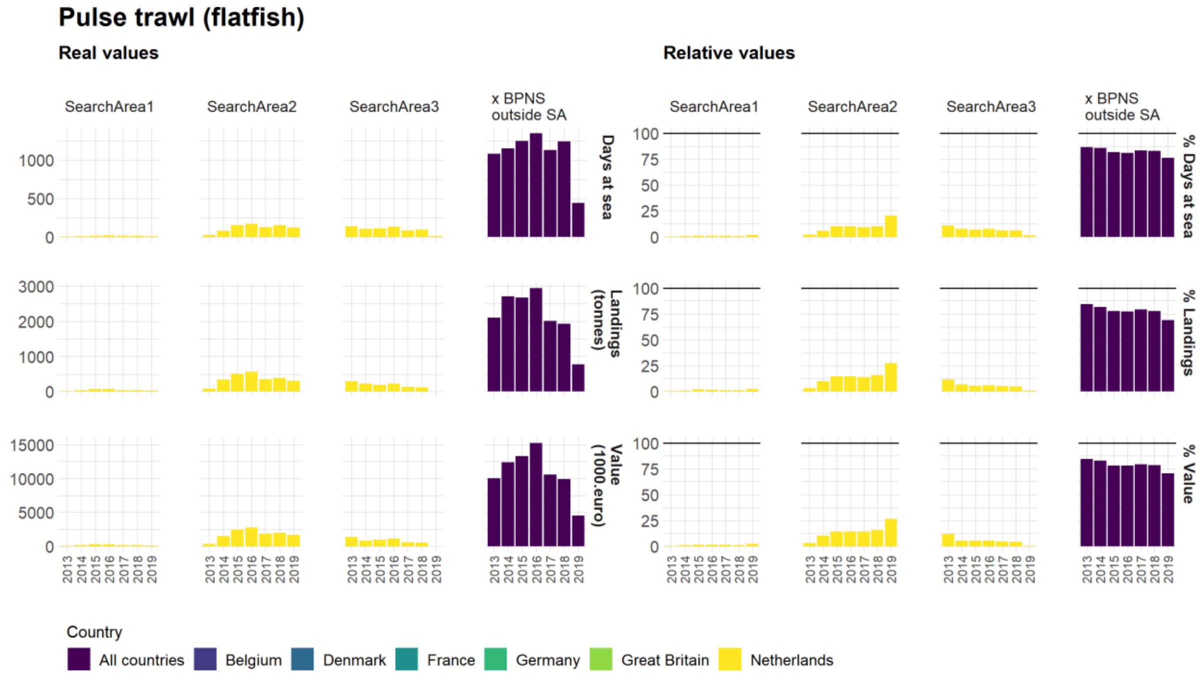


Figure 43 Quantitative (left) and relative (sum 100%) (right) importance of the 3 Seach Zones compared to the rest of the BPNS for pulse trawl fishery. The data is divided per country; French data is lacking.

6.3.6.5. Otter trawls

Otter trawls were active in all 3 Seach Zones, but mostly in Seach Zone *2.* In terms of **effort**, almost 17% of the **days at sea** were recorded within this area which corresponds to an average of 22% of the value of landings*.*

The French fleet was the most important contributor overall and specifically in Seach Zone *2* and Seach Zone *1*. The share of Seach Zone *1* seems to be increasing over time, while the share in the rest of the BPNS seems to be decreasing and so do the corresponding absolute values (Figure 44).

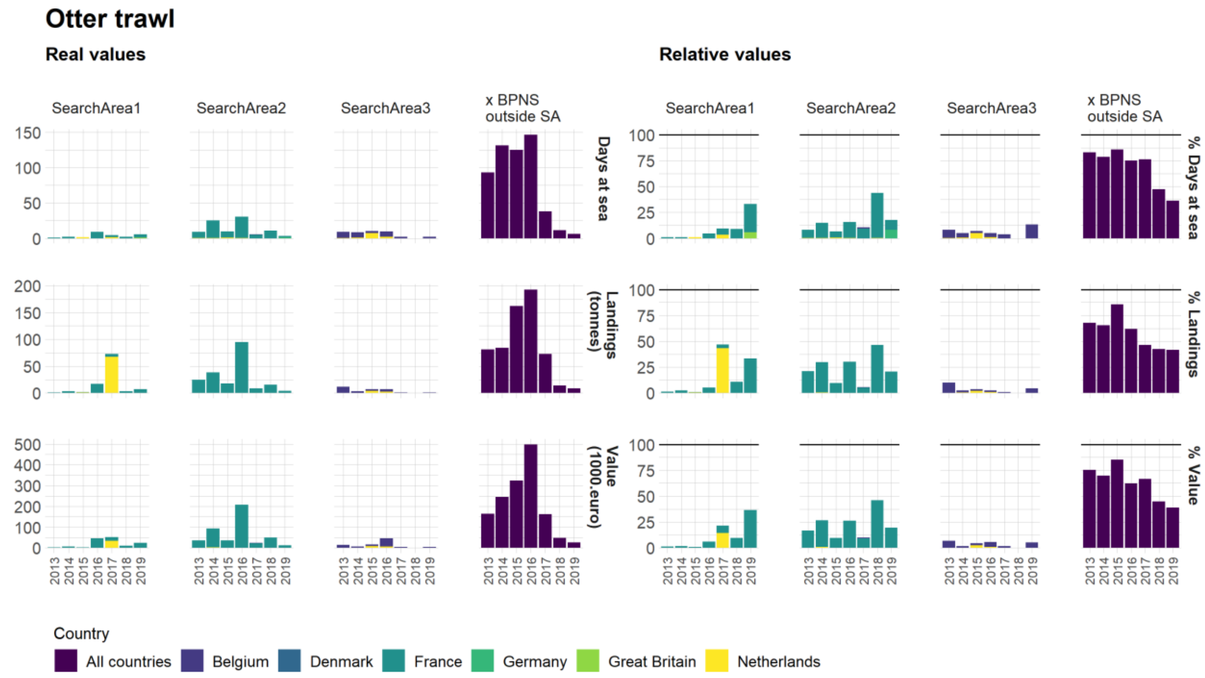


Figure 44 Quantitative (left) and relative (sum 100%) (right) importance of the 3 Seach Zones compared to the rest of the BPNS for otter trawls. The data is divided per country; French data is lacking.

In terms of relative importance per km^2 Seach Zone *1* was most important for **otter trawlers,** generating an average of 0.55 € thousand.km^{-2}. Seach Zone *2* was also important for otter trawlers compared to the rest of the BPNS, especially in terms of value per km^2. Contrarily to what is observed in Figure 44, the contribution of Seach Zone *2* becomes much smaller per km² compared with Seach Zone *1* as the former is a larger area. Belgian otter trawlers operate mainly in Seach Zone *3***,** but are not as important compared to landings per km^2 generated in the rest of the BPNS.

6.3.6.6. Seiners

Seiners were mainly active outside the Seach Zones (Figure 23). Seach Zone 1 and 2 were relatively more important compared to Seach Zone 3. Seiners consist mainly of large vessels that fish more offshore. On average, there activity was scattered over the BPNS (see section 3.6, Figure 47) with a number of hotspots around certain sandbanks: 'Gootebank' and 'Buitenratel', and in the western part of Seach Zone 1.

The seiners were mainly part of the Dutch and French fleet. The **effort** remained constant over time in Seach Zone 1 and 3. In Seach Zone 2, there was more variation and an increase in the last 2 years. This trend was even more visible for the **landings data** (both weight and value).

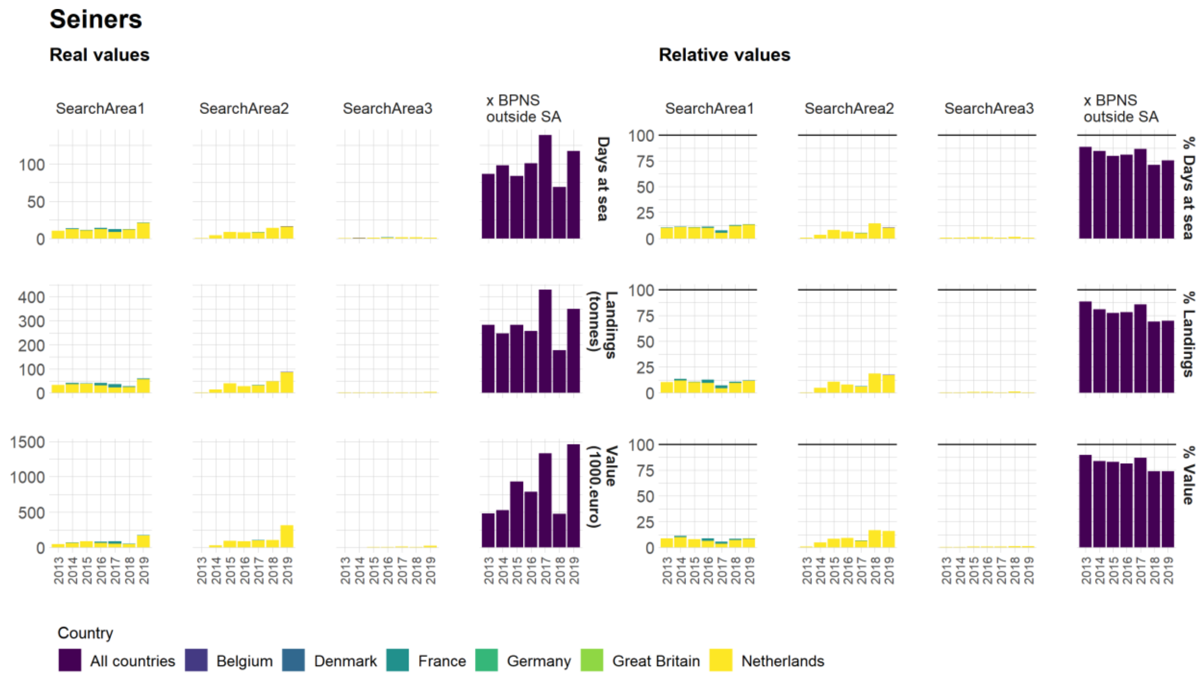


Figure 45 Quantitative (left) and relative (sum 100%) (right) importance of the 3 Seach Zones compared to the rest of the BPNS for seiners. The data is divided per country; French data is lacking.

In terms of relative importance per km^2 Seach Zone *1* was most important for **seiners,** generating an average of 2.34 € thousand.km^{-2}. Seach Zone *2* was as important as the value of landings per km^2 in the rest of the BPNS (~0.30 € thousand.km^{-2}). The contribution of Seach Zone *2* becomes much smaller per km^2 compared with Seach Zone *1* as the former is a larger area (see Figure 45).

6.3.6.7. Maps of the fishing activity per gear group

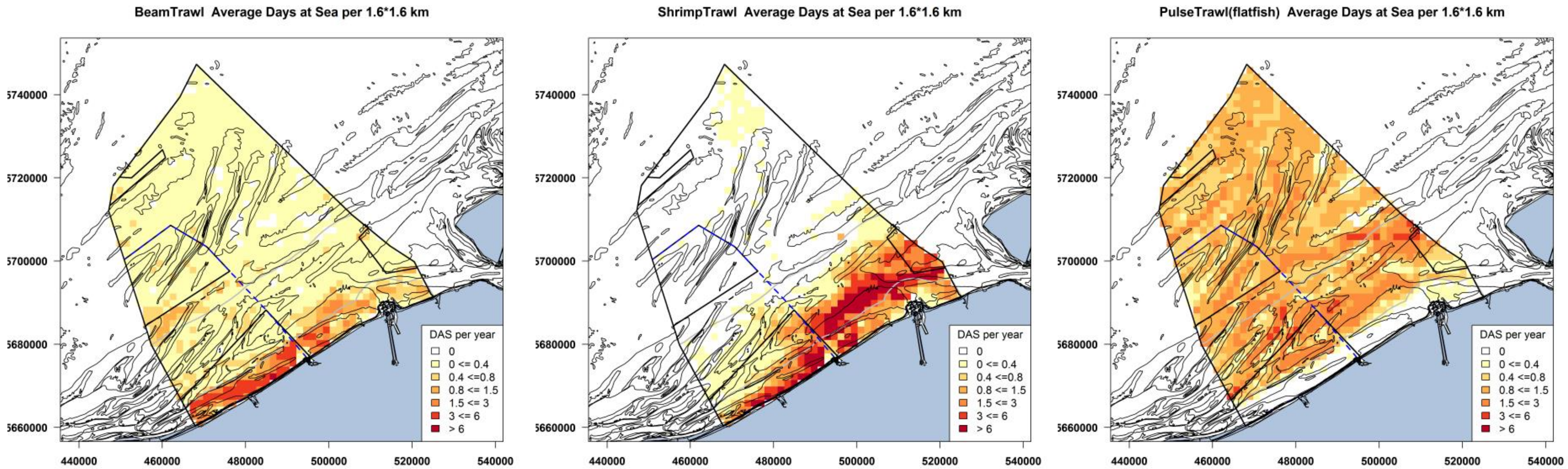


Figure 46 Average fishing intensity in number of fishing hours between 2013 and 2019 in the Belgian Part of the North Sea for all member states (excluding France) for beam trawls (left), shrimp trawls (middle) and pulse trawls (right).

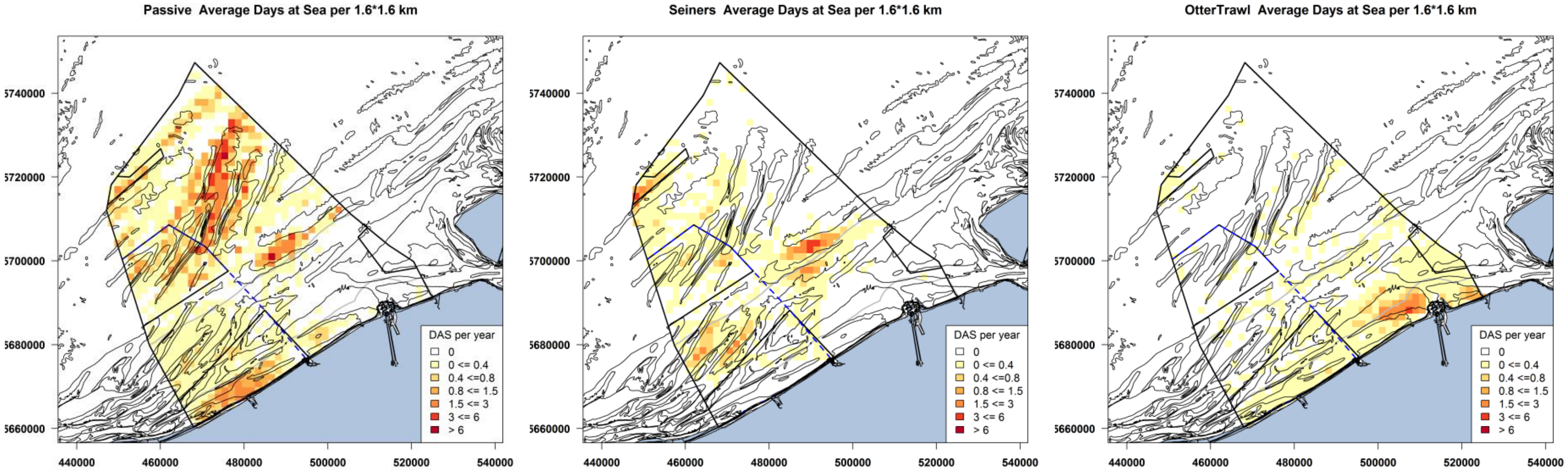


Figure 47 Average fishing intensity in DAS between 2013 and 2019 in the Belgian Part of the North Sea for all member states (excluding France) for passive gears (left), seiners (middle) and otter trawls (right)

6.3.7. Maps with swept area ratio

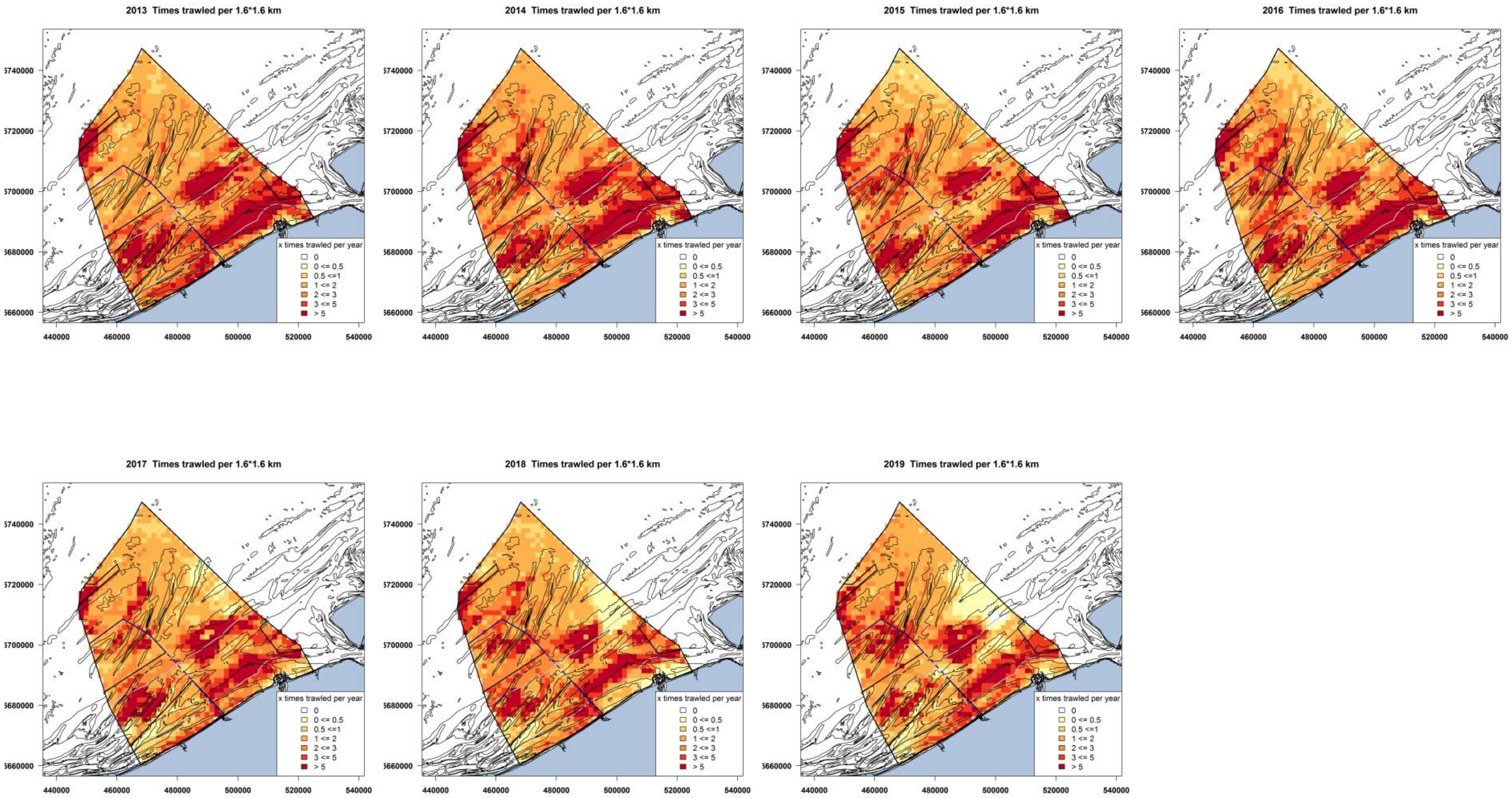


Figure 48 Swept area ratio (number of times trawled per grid cell) per year

The maps in Figure 48 indicate the number of times trawling occurred in each grid cell for each year between 2013 and 2019, and is a proxy for bottom disturbance (fishery abrasion). The intensity of trawling is calculated as the total area swept yearly in grid cells of 1600x1600 m divided by grid cell size. There are some slight fluctuations over time and as time progresses, the designated windfarm area becomes more apparent (i.e. less trawling occurs in this area). Nevertheless, the areas with most bottom disturbance are consistent over the period, as summarized in Figure 49. It gives the average number of times each grid cell was completely trawled in the considered time period. A large part of the grid cells covering the BPNS were trawled at least once. There are some hotspot areas, whereof the grid cell was on average trawled more than 5 times a year. Those areas are subjected to the highest fishery abrasion pressure. In Seach Zone *1*, the western part of the area was intensively trawled mainly by seiners. Between the sandbanks in Seach Zone *2*, there are some areas that were trawled more than 5 times, the rest was trawled between 1 and 3 times. In Seach Zone *1*, the 0-3 NM zone was more used compared to the rest of the area. In the area *Vlakte van de Raan*, all grid cells were mostly trawled between 3 to 5 times on average.

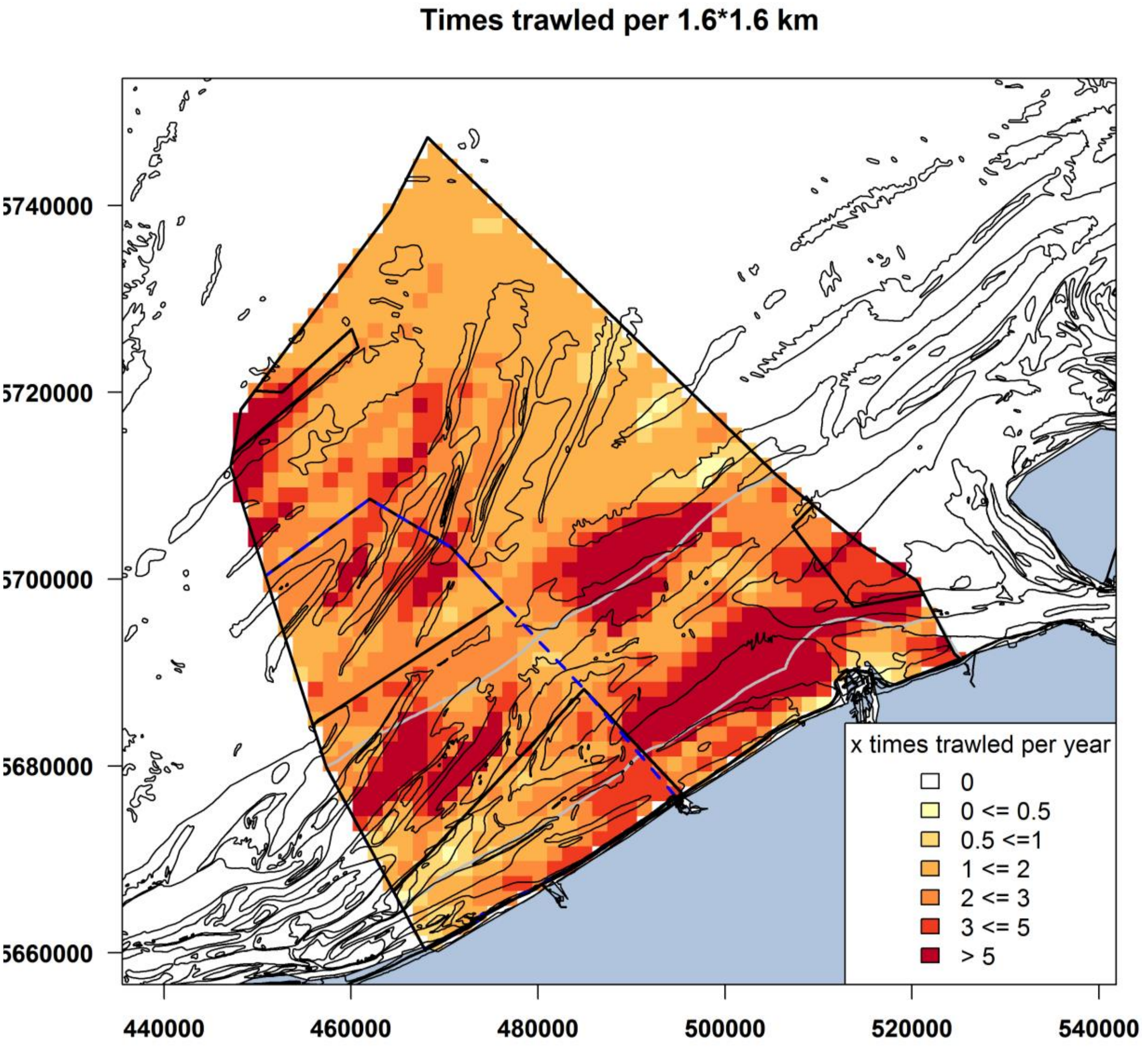


Figure 49 Average swept area ratio (number of times trawled per grid cell) between 2013 and 2019.

6.3.8. Recreational fisheries results

Recreational sea fishing in Belgium is diverse in nature. Seven different techniques can be distinguished: 1) boat angling, 2) boat trawling, 3) angling from a dam/jety, 4) angling from the beach/breakwater, 5) wading using a small shrimp net, 6) passive beach fishing and 7) horseback shrimp fishing (Verleye *et al.* 2019).

Based on the results found by Verleye *et al.* 2019, the size of the recreational sea fishing community was estimated to be around 2900 individuals in 2018, 57% of whom were boat anglers. At sea, the activities of the more than 800 vessels appeared to take place mainly within the first 3 NM of the BPNS (Figure 50).

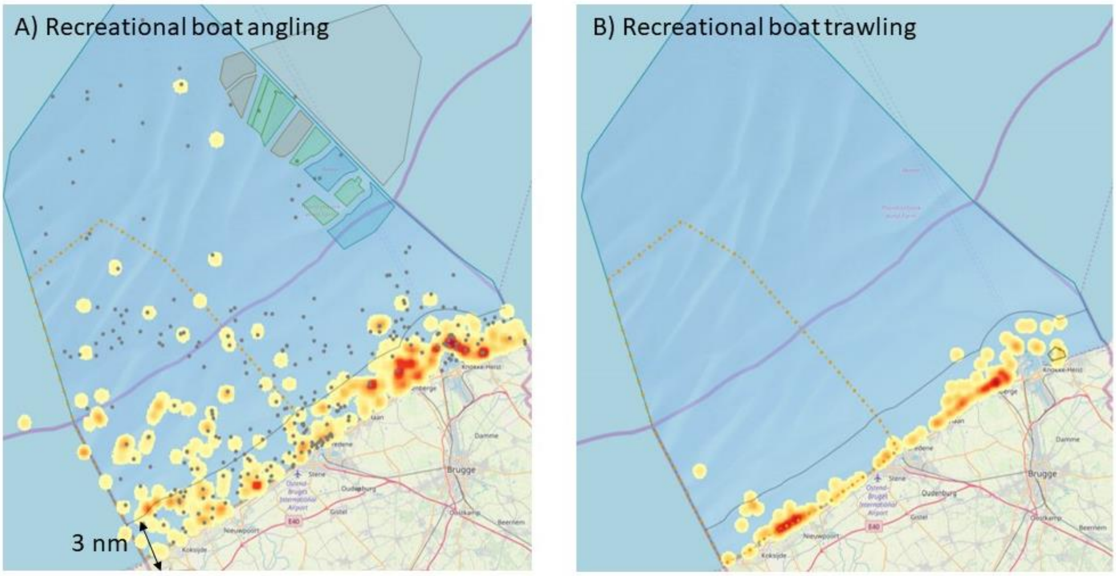


*Figure 50 Density map with fishing locations of A) recreational boat angling and B) Recreational boat trawling in the BPNS based on areal observations between November 2016 and November 2017. (*http://www.kustportaal.be/*)*

Several rules and legislation apply to recreational fishing. There is a ban on bottom-disturbing fishing in the ammunition site *Paardemarkt* and there are spatial restrictions for recreational trawling in the Natura2000 area Vlaamse Banken and (KB 20 maart 2014). Recreational fishing is permitted in the entire SAC 'Vlaamse Banken' as long as it is not bottom disturbing (f.e. angling). By way of exception, the following techniques that affect the bottom were still permitted:

- Horseback shrimp fishing
- Recreational shrimp fishery (by boat): recreational fishers that had been active for at least 3 years, could sail 10 times a year, subject to permission. This was valid for a maximum of six years (so until 2020).

No spatial restrictions with regards to trawling apply outside the Natura2000 area.

6.4. Discussion and conclusions

6.4.1. General

Overall, the pulse trawl fishery generated the most important value of landings in the BPNS (Figure 51), though this contribution has been declining in recent years as a consequence of EU regulations (Vansteenbrugge *et al.*, 2020). Shrimp trawl fishery was the second most valuable fishery, alongside the beam trawl fishery. The latter has been declining over the years, possibly related to the activities of the pulse trawl fishery. The seining fishery has become more important, whereas passive and otter trawl fisheries generated the lowest value of landings (and are characterized by smaller vessels). Thus, there is quite some variation among gear groups, member states and years in the BPNS, but also across the three Seach Zones of this study.

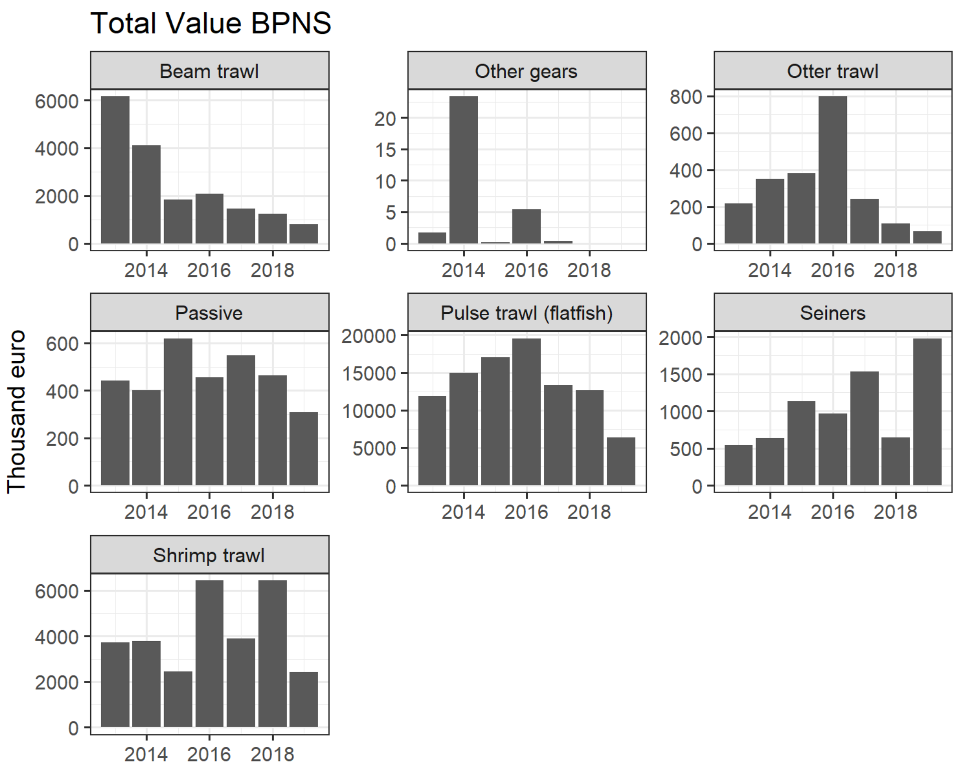


Figure 51 Map of the total value of landings in the BPNS per gear

Results for 2019 divert from other years, especially within the territorial area and especially for the area *Vlakte van de Raan* and Seach Zone 3. Since the latter largely accounts for the figures of the Natura2000 area 'Vlaamse Banken', a similar observation can be made. Therefore, 2019 does not seem to be a representative year and it remains important to consider the entire time series or work with averages to conclude on the fishery importance of certain areas. Figure 52 represents the average effort in the BPNS combining all gears.

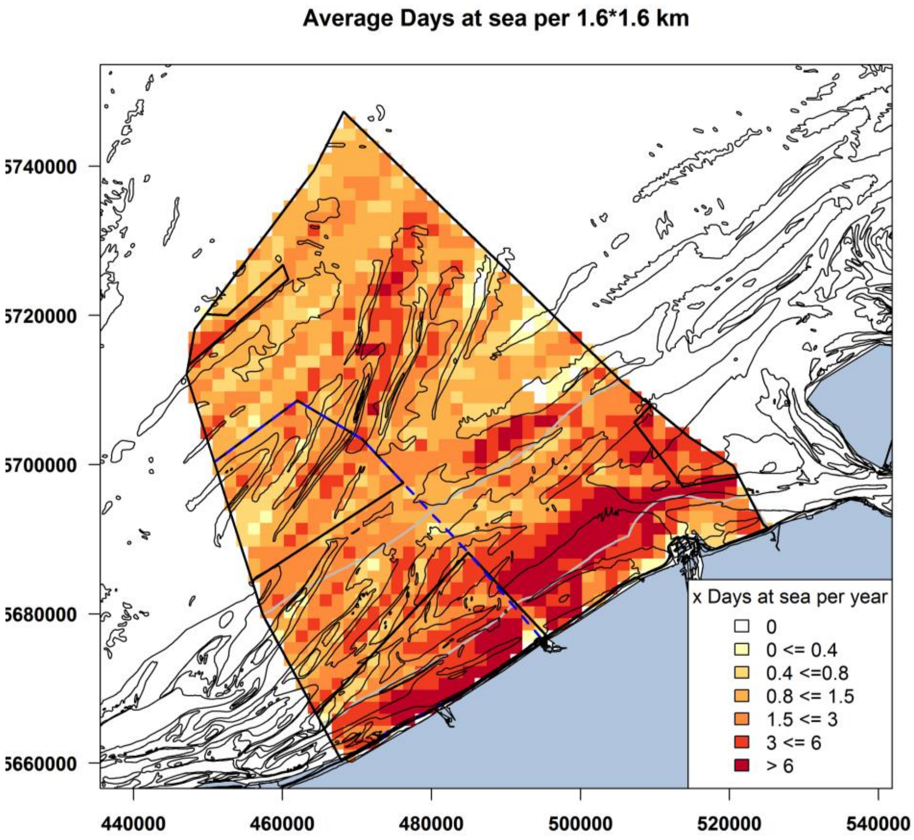


Figure 52 Combined map of the average DAS between 2013 2019 combining all gear types

The fishing activities for **pulse trawling** in the BPNS reached a peak in 2016 and have decreased since (Figure 51). This decline is observed in most areas, except in Seach Zone 1. Pulse gear allows for fishing on softer grounds and the spatial distribution of the main fisheries has shifted to the southern part of Division 4.c. A larger proportion of the sole catch is now taken in this area (ICES, 2020). This higher local exploitation of the stock lead to a higher estimate of the fishing mortality in the most Southern part of the North Sea (Vansteenbrugge *et al.*, 2020), which may explain the lower catches in most recent years. The decline in effort is also related to changes in the EU regulation for the pulse fishery (EU Regulation 2019/1241). Pulse trawl fisheries cover the whole BPNS area with higher activities within the 3-12 NM zone and along the gullies and flanks of the sandbanks. As they are mainly operated by larger vessels, they do not occur (and are not allowed to fish) within 0-3 NM of the coastline (Figure 46). From August 14th 2019 onwards, they were also excluded from the 12 NM zone. However, the future pulse activities are unclear as it was decided by Europe that electric pulse trawling should be banned. It remains uncertain whether these fishers will change to demersal beam trawling or other gears.

Beam trawl activities cover the whole BPNS area, and are targeting the same areas as the pulse fishery (within the 12 NM and gullies and flanks of the sandbanks). The fishing activities of beam trawlers has decreased over time in the BPNS, which may partly be a consequence of the increased introduction of pulse trawling (for flatfish) as these gear groups target (and perhaps compete) for the same species (Vansteenbrugge *et al.*, 2020). The Belgian beam trawl fishery mainly operates in the area, alongside the Dutch beam trawl fishery and a few British beam trawlers (very low effort and landings). Beam trawling remains an important technique for the Belgian fisheries targeting certain valuable flatfish species (e.g. common sole). The choice of species is also highly dependent on the European quota distribution system.

Next, **shrimp trawling** activities, also traditionally of importance to the Belgian and Dutch fisheries, show fluctuating figures between 2013 and 2019, but no clear trend overall. Shrimp trawlers have a more defined spatial coverage, mainly within the 12 NM zone and in the eastern part of the BPNS along the Wenduine sandbank and the *Vlakte van de Raan*. Shrimp fisheries in offshore areas take place during winter time, but to a much lesser extent (Respondek *et al.* 2014)).

Seine fishing is increasing over time in the BPNS. Seiners are dominantly part of the Dutch and to a lesser extent French fleet. Seiners are especially active between the Thornton and Goote banks, between the Oostdyck, Buiten Ratel and Kwinte banks and also in Seach Zone *1*.

Fishing using **passive gears**, though less occurring compared to other gears mentioned above, has remained stable in this time period. Only a few Danish and German vessels (less than 3) were active in the Natura 2000 areas in the BPNS and their effort was very low compared to the other fishing nations. France was also active with a passive gear fishery consisting of 10-15 small vessels (<12m), mainly in the Flemish bank area (Figure 30). The fishing activities of Belgian vessels using passive gear even increased between 2013 and 2019. The highest activity of passive gears was found between the Thornton and Goote banks and along the Noordhinder, Oosthinder and Westhinder banks.

When considering the spatial distribution map (Figure 47), **otter trawlers** had a lower activity in the BPNS and were used by most member states. They were mainly found along the Wenduine bank, the Paardenmarkt bank and in the *Vlakte van de Raan*. This representation however, excludes the French data as these could not be included in the maps. As described earlier, a large share of the otter trawlers belong to the French fleet. French otter trawling seems to be rather important in the Flemish bank area, both in Seach Zone *1* and Seach Zone *2*, and represents an important part of their otter trawl activity when considering the entire BPNS. The activity outside the Seach Zones seems to have dropped since 2016.

Overall, in terms of relative importance per km^2, the 3 Seach Zones seem to generate higher landings per km^2 (both weight and value) than in the rest of the BPNS for all of the considered métiers. Pulse trawlers are the exception. Additionally SA3 does not generate a higher landing per km^2 than in the rest of the BPNS for seiners and otter trawlers.

6.4.2. Seach Zone 1

This relatively small area is located offshore and therefore also accessible to larger vessels. The landings and value per km^2 for this area were higher compared to the two other areas. This area is of importance to the Dutch fleet, especially for pulse trawlers and seiners. Also the French fleet was present in the area, consisting of mainly otter trawlers and seiners.

For **pulse trawlers** the fishing activity remained somewhat constant over the time period. For **seiners**, the area is of relative importance and slightly increasing in the time period (see Figure 23). Also in terms of relative importance per km^2, Seach Zone *1* was the most important for seiners, generating an average of 2.34 € thousand.km^2. On average 10 seiners were active in the area over time. More specifically the western corner in Seach Zone *1* has more fishing activity on average (see map Figure 47; Note: French seiners are not included on the map but were also active in the area). In terms of relative importance per km^2 Seach Zone *1* was most important for **otter trawlers,** generating an average of 0.55 € thousand.km^2. The fishing activity of Belgian **beam trawlers** decreased since 2015, which coincides with an increase in pulse trawling in the area. There may be indications of a shift in effort allocation for these trawlers to other fishing grounds. Seach Zone *1* is of medium importance for the beam trawlers. In Seach Zone *1*, no overall trend over time can be identified.

6.4.3. Seach Zone 2

Seach Zone *2* has a lower amount of landings in weight/km² compared to Seach Zone *3*, but the average value for the landings is higher. This may be due to more valuable catches (sole fishery) in *area 2*, compared to *area 3* (brown shrimp fishery). This area was mostly important for pulse trawling and beam trawling over time. It was also relatively important for passive fisheries (mainly Belgian and German fishers) (Figure 44). As in Seach Zone 1, pulse fishing activity increased until 2016 and the share of beam trawlers decreased simultaneously. There was also a slight increase in seiners, although not large in numbers.

Seach Zone *2* was also important for **otter trawlers** compared to the rest of the BPNS, especially in terms of value per km^2. These otter trawlers are mostly part of the French fleet. In general, the fishing activity increased until 2016 and was then stable at a lower level (comparable to 2013-2014).

6.4.4. Seach Zone 3

This is the largest of the three Seach Zones and is nearest to the shore. Less member states are active within Seach Zone *3* as most are not permitted to access these fishing grounds. The area is therefore reserved to the Belgian fleet, but France and the Netherlands also have access as a consequence of historical treaties. The 1958 treaty of the Benelux Union gave Dutch fishers unlimited rights to fish all species in the Belgian 12 NM territorial zone (and vice versa). An agreement with France in 1975 gave French fishers permission to fish herring in the 3–12 NM zone (Douvere and Maes 2005). These agreements have been integrated into the CFP and can no longer be modified without addressing the European Commission (Pecceu *et al.* 2014). The 3-12 NM zone area is generally restricted to slightly larger vessels.

The 0-3 NM zone is exclusively reserved for the '*Coastal fishers'* with smaller vessels (≤ 221 kW, < 70 GT). These include vessels equipped with beam trawls, shrimp trawls, otter trawls and passive gears (Verlé *et al.*, 2020).

This legal framework and differences in vessel types operating across the area, has clear consequences on the variation in spatial importance within the area. Overall, fishing activity in Seach Zone *3* was important for beam trawlers, shrimp trawlers and pulse trawlers and vessels using passive gears (Figure 47). No pulse trawl activity was observed in the 0-3 NM zone. The amount of landings in weight per km² is higher compared to Seach Zone *2*, but the value per km² is 1.000 euro lower. For this area, many days at sea were recorded, predominantly by the Belgian fishery, but the landings and value were much lower. The Dutch pulse fishery created the highest landings and values within the area. Both member states were operating with the same amount of vessel-gear combinations within the area. The area is used differently by the member states, which probably makes it more difficult to delignate fishery measures within the area without targeting certain vessel-gear types. Additionally, the 0-3 NM area within Seach Zone *3* is also the location where the highest densities of recreational fishers can be found (both boat angling as well as boat trawling).

6.4.5. The Belgian fleet

For the Belgian fleet, Seach Zone *3* was the most important area. On average, **the effort** in the area was highest for the Belgian fleet (548 days at sea or about 82% of the total average effort in the area). The most important gear groups were the shrimp trawlers and beam trawlers. There was also some fishing activity with passive gears.

On average, the **amount of fish** landed from Seach Zone *3*, amounted to 668 tonnes, representing a **value** of €2.45 million. In terms of landings, both in value and in weight, beam trawl fishery was more important than the shrimp trawl fishery.

Overall the **value of landings** from Seach Zone *3* seems to follow a decreasing trend between 2013 and 2019. In particular, 2019 seems to have been an unfavorable year, with considerable lower landings.

Fishers are increasingly competing for space with other economic or environmental initiatives (Pecceu *et al.* 2016: www.geofish.be). For example, since 2005 fishing is prohibited in the areas designated for offshore wind farms (Degraer *et al.* 2013). Another example is the increased safety hazards fishers experienced around dredging and dumping sites due to possible sediment accumulation in the nets (Van Hoey *et al.* 2014).

6.4.6. Conclusion

As to conclude, two overview tables were compiled. The first is the relative importance per km² of the different gear groups in each Seach Zone and the rest of the BPNS; the second table is based on the grid maps in days at sea (DAS) in section 3.6 (Figure 47, Figure 48) to identify potential hotspots. In these maps, the French data is not included.

Overall, in terms of relative importance per km^2, the 3 Seach Zones seem to generate higher landings per km^2 (both weight and value) than in the rest of the BPNS for all of the considered métiers. Pulse trawlers are the exception. Additionally, Seach Zone *3* does not generate a higher landing per km^2 than in the rest of the BPNS for seiners and otter trawlers.

Seach Zone *1* is an important area for several countries and multiple gear types. Based on the relative importance per km², SA1 is the most important area for otter trawlers and seiners. For seiners especially the western part of the area is a hotspot.

Seach Zone *2* is important but without clear differences between countries or between gear types except for the French otter trawlers. These are not included in the maps.

Seach Zone *3* shows a complex pattern of spatially distributed gear types with different member state interests. Based on the relative importance per km², this area is the most important for beam trawlers, shrimp trawlers and passive gear fishery. Based on overall effort (DAS) this zone is intensively fished although landings (both in value and weight) for all gears combined were relatively low.

Table XXIX. Relative importance (per km²) of the different gears in each subarea (x BPNS outside SA is the total BPNS minus the Seach Zones)

	Search Zone 1	**Search Zone 2**	Search Zone 3	x BPNS outside SA
Beam trawl				
Effort (days at sea)/km²	0.10	0.08	**0.60**	0.09
Landings (tonnes)/km²	0.36	0.28	**0.84**	0.13
Value (thousand euro)/km²	1.19	1.03	**2.29**	0.49
Otter trawl				
Effort (days at sea)/km²	**0.10**	0.04	0.02	0.03
Landings (tonnes)/km²	**0.41**	0.09	0.01	0.03
Value (thousand euro)/km²	**0.55**	0.20	0.04	0.08
Passive				
Effort (days at sea)/km²	0.06	0.05	**0.17**	0.02
Landings (tonnes)/km²	0.03	0.03	**0.06**	0.01
Value (thousand euro)/km²	0.18	0.25	**0.42**	0.08
Pulse trawl (flatfish)				
Effort (days at sea)/km²	0.31	0.36	0.27	0.40
Landings (tonnes)/km²	1.10	1.11	0.49	0.79
Value (thousand euro)/km²	5.34	5.61	2.25	3.96
Seiners				
Effort (days at sea)/km²	**0.36**	0.03	0.003	0.04
Landings (tonnes)/km²	**1.08**	0.11	0.01	0.11
Value (thousand euro)/km²	**2.34**	0.33	0.03	0.31
Shrimp trawl				
Effort (days at sea)/km²	0	0.0001	**0.84**	0.31
Landings (tonnes)/km²	0	0.0002	**0.48**	0.30
Value (thousand euro)/km²	0	0.0005	**1.92**	1.27
All gears				
Effort (days at sea)/km²	6.38	3.98	**13.26**	6.20
Landings (tonnes)/km²	**20.81**	11.40	13.24	9.65
Value (thousand euro)/km²	**66.93**	51.99	48.64	43.38

Table XXX. Overview of the fishing effort (in days at sea) in the three Seach Zones (based on maps, excluding France). x BPNS outside SA is the total BPNS minus the Seach Zones

Gear group	Search Zone 1	Search Zone 2	Search Zone 3	x BPNS outside SA
Beam trawlers			Red between 0-3 NM, rest less intensive	Overall presence on BPNS, equal importance over the Seach Zones
Shrimp trawlers			Red between 0-3 NM, rest less intensive	Most important area in territorial waters around Zeebrugge
Pulse trawl (flatfish)				Overall, highly present, most important between 3 and 12 NM
Passive gear				Overall low activity, some important fishing locations (orange) around sandbank Oosthinder and Gootebank
Seiners	Hotspot in western part			Some important fishing locations (red) between Area 1 and Area 2 (sandbank Buiten ratel and Goote bank)
Otter trawlers				some important fishing locations in territorial waters between Ostend and Zeebrugge

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Annex 1: Test 'Vlaamse Banken' and Search Zone 1

With the Marxan analysis we also ran some tests without the search zones in order to see which areas were selected when considering the entire area 'Vlaamse Banken' together with Search Zone 1 (Figure 53).

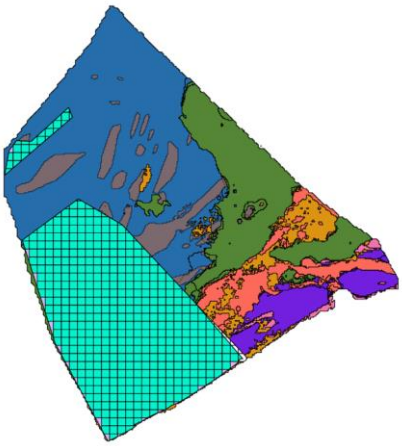


Figure 53. Total Vlaamse banken area and search zone 1.

These tests showed that the three Search Zones were well chosen and even when considering the entire Vlaamse Banken, the selected cells mainly fall within the Search Zones (Figure 54). This confirms their selection for conservation priority.

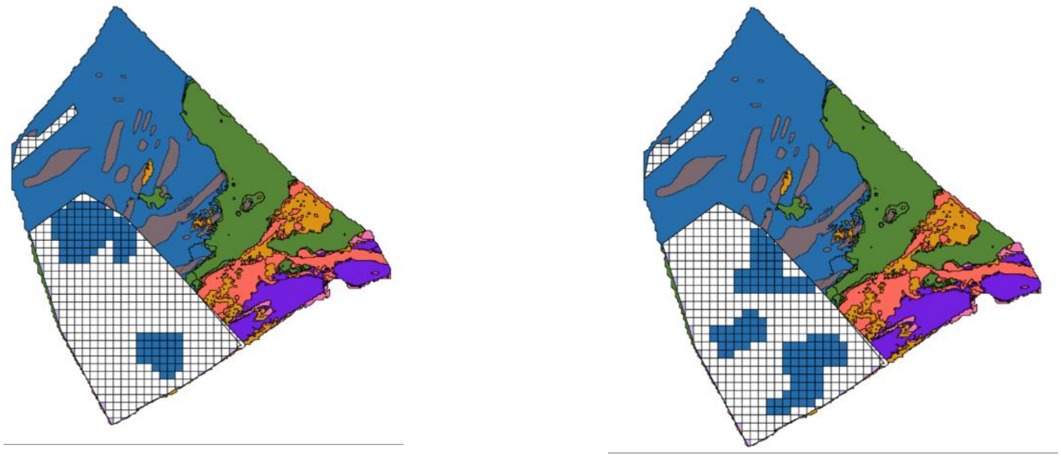


Figure 54 Right: 10% for gravel, Lanice, Abra alba & Hesionura; 2.5% for ME & NC. Left: 50% of biological value high & very high

Annex 2: MarLin text on sensitivity classificiation of the biotopes

A5.331 - Nephtys hombergii and Macoma balthica in infralittoral sandy mud
(*https://www.marlin.ac.uk/habitats/detail/173#sensitivity_review*)

Abrasion/disturbance of the surface of the substratum or seabed	Low	Medium	Medium
	Q: High A: Medium C: Medium	Q: High A: Medium C: Medium	Q: High A: Medium C: Medium

Damage to seabed surface features may occur due to human activities such as bottom towed fishing gear (trawling and dredging) and natural disturbance from storms.

Collie et al. (2000) identified that well established intertidal communities (such as this biotope) suffered the greatest impact from bottom towed fishing activities. The review concluded that there were ecologically important impacts from removal of >50% of fauna from bottom towed fishing activity (dredge and trawls) (Collie et al., 2000). However, the burrowing and tunnelling traits of the characterizing species may provide some resistance to this pressure. Kaiser et al. (2001) carried out experimental hand raking, similar to that used in inter tidal cockle fisheries. Both small and large raked plots showed changed communities in comparison to control plots, smaller plots recovered in 56 days, whilst larger plots remained in an altered state.

Collie et al. (2000) found that Nephtys hombergii displayed a negative effect on abundance as a result of fishing activities and mean response of infauna and epifauna communities to fishing activities was much more negative in mud and sand communities than other habitats. Nephtys hombergii abundance also significantly decreased in areas of the Solent, UK, where bait digging (primarily for Nereis virens) had occurred (Watson et al. 2007). Similarly, Nephtys hombergii abundance was reduced by 50% in areas where tractor towed cockle harvesting was undertaken on experimental plots in Burry inlet, south Wales, and had not recovered after 86 days (Ferns et al., 2000).

Aphelochaeta marioni, Streblospio shrubsolii and Tubificoides benedii rapidly colonise disturbed sediments, which will reduce recovery times. This was displayed by Biasi & Pacciardi (2008) in the Adriatic Sea, where polychaetes, including Aphelochaeta spp. were among the species dominating the areas disturbed by fishing activity (otter trawling).

Boat moorings were demonstrated to also impact species communities close to the mooring buoy in a case study in the Fal and Helford estuaries (south west UK). Coarser sediment was exposed close to mooring buoys, caused by suspension of fine sediments by movement of the chain (Latham et al., 2012). However, fine sand and muddy sediments displayed the least influence from disturbance from moorings, suggesting a smaller impact to this biotope than other intertidal biotopes.

Scouring around wind farm and other renewable energy device bases has been shown to reveal coarser sediment close to bases and deposition of fine material in the direction of the dominant current.

Species poor communities were revealed in coarser material and higher densities of macrobenthic organisms occurred where finer sediment was deposited (further from the base) (Coates et al., 2014).

This process created a shift in macrobenthic communities around the wind farm tower (influenced by the direction fine material had settled) (Coates et al., 2014).

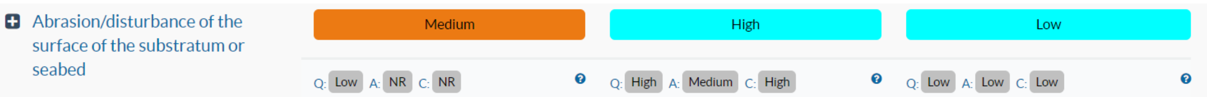
Boat moorings were demonstrated to also impact species communities close to the mooring buoy in a case study in the Fal and Helford estuaries (south west UK). Coarser sediment was exposed close to mooring buoys, caused by suspension of fine sediments by movement of the chain (Latham et al., 2012). However, fine sand and muddy sediments displayed the least influence from disturbance from moorings, suggesting a smaller impact to this biotope than other intertidal biotopes.

Sensitivity assessment. The biotope will be impacted if damage to seabed surface features is widespread, as, although, motile and opportunistic fauna, such as Streblospio shrubsolii and Tubificoides benedii may recover quickly Nephtys hombergii shows a greater negative impact (Collie et al., 2000, Ferns et al., 2000, Kaiser et al., 2001). Resistance is assessed as 'Low', Resilience is assessed as 'Medium', providing a sensitivity assessment of 'Medium'.

It is important to consider the extent and duration of the cause of abrasion. For instance, long-term change in distribution of sediment grain sizes may occur following continual trawling landings or around the base of a renewable energy device, this would alter the biotope within the footprint of the activity and sensitivity would therefore be greater.

A5.261 Abra alba & Nucula nitidosa in circalittoral muddy sand or slightly mixed sediment
Circalittoral muddy sand
https://www.marlin.ac.uk/habitats/detail/62#sensitivity_review

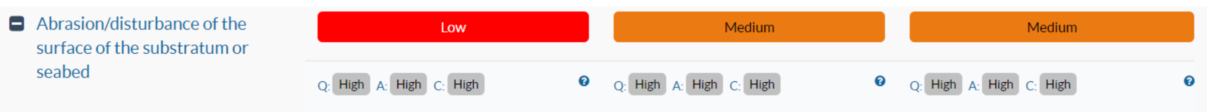
Resistence Resilience Sensitivity



Abrasion is likely to damage epifauna and flora and may damage a proportion of the characterizing species, biotope resistance is therefore assessed as 'Medium'. Resilience is assessed as 'High' as opportunistic species are likely to recruit rapidly and some damaged characterizing species may recover or recolonize. Biotope sensitivity is assessed as 'Low'.

A5.241 - *Echinocardium cordatum* and *Ensis* spp. in lower shore and shallow sublittoral slightly muddy fine sand
Part of: Infralittoral muddy sand
https://www.marlin.ac.uk/habitats/detail/124#sensitivity_review

Resistence Resilience Sensitivity



The two key species in the biotope, Echinocardium cordatum and Ensis ensis are infaunal found close to the sediment surface. This life habit provides some protection from abrasion at the surface only. Echinocardium cordatum has a fragile test that is likely to be damaged by an abrasive force, such as movement of trawling gear over the seabed. Bergman & van Santbrink (2000) suggested that Echinocardium cordatum was one of the most vulnerable species to trawling, and substantial reductions in the numbers of the species due to physical damage from scallop dredging have been observed (Eleftheriou & Robertson, 1992). Echinocardium cordatum was reported to suffer between 10 and 40% mortality due to fishing gear, depending on the type of gear and sediment after a single trawl event (Bergman & van Santbrink, 2000), with mortality possibly increasing to 90% in summer when individuals migrate to the surface of the sediment during their short reproductive season.

Bivalves such as Ensis spp., together with starfish have been reported to be relatively resistant (Bergman & van Santbrink, 2000). However, Eleftheriou & Robertson (1992) observed large numbers of Ensis ensis killed or damaged by dredging operations and Gaspar et al. (1998) reported high levels of damage in Ensis siliqua from fishing.

Upper burrow structures of species occupying the sediment may collapse by passing fishing gear, and although they may be rapidly reconstructed (Atkinson pers. com., cited in Jennings & Kaiser, 1998), the energetic costs of repeated burrow reconstruction may have long-term implications for the survivorship of individuals (Jennings & Kaiser, 1998). In the event of damage caused to species such as heart urchins, molluscs and crustaceans as a result of this pressure, damaged or undamaged animals are likely to experience increased predation pressure either at low (birds) or high tide (fish and crabs).

SS.SSa.IMuSa.EcorEns occurs in medium to fine sand and slightly muddy sand (Connor et al., 2004). Abrasion events caused by a passing fishing gear, or scour by objects on the seabed surface are likely to have marked impacts on the substratum and cause turbulent re-suspension of surface sediments. When used over fine muddy sediments, trawls are often fitted with shoes designed to prevent the boards digging too far into the sediment (M.J. Kaiser, pers. obs., cited in Jennings & Kaiser, 1998). The effects may persist for variable lengths of time depending on tidal strength and currents and may result in a loss of biological organization and reduce species richness (Hall, 1994; Bergman & van Santbrink, 2000; Reiss et al., 2009) (see change in suspended solids and smothering pressures).

Sensitivity assessment. The infaunal position provides some protection but the characterizing species of the biotope may suffer some damage as a result of surface abrasion. Resistance is therefore assessed as Low and resilience as Medium so the biotope's sensitivity is assessed as Medium.

A5.351 - *Amphiura filiformis*, *Mysella bidentata* and *Abra nitida* in circalittoral sandy mudPart of Circalittoral sandy mud

https://www.marlin.ac.uk/habitats/detail/368#sensitivity_review

	Resistence	Resilience	Sensitivity
Abrasion/disturbance of the surface of the substratum or seabed	Low	Medium	Medium
	Q: High A: High C: Medium	Q: Low A: NR C: NR	Q: Low A: NR C: NR

The characterizing species of the biotopes are infaunal and hence have some protection against surface disturbance. However, bivalves and other species require contact with the surface for respiration and feeding, so siphons and delicate feeding structures may be damaged or withdraw because of surface disturbance, resulting in loss of feeding opportunities and compromised growth.

By extending their fragile arms from the sediment to feed, characterizing species *Amphiura filiformis* become vulnerable to damage by abrasion. Brittlestars can resist considerable damage to arms and even the disk without suffering mortality and are capable of arm and even some disk regeneration (Sköld, 1998). Ramsay *et al.* (1998) suggested that *Amphiura* spp. may be less susceptible to beam trawl damage than other species like echinoids or tube dwelling amphipods and polychaetes. For example, Bergman & Hup (1992) found that beam trawling in the North Sea had no significant direct effect on small brittlestars. Holtmann *et al.* (1996) reported a decrease in the abundance of the fragile burrowing heart urchins and the brittlestar *Amphiura filiformis* in areas of the southern North Sea between 1990 and 1995. These trends suggest that fishing activity may have been the main cause of these changes. However, Bradshaw *et al.* (2002) noted that the brittlestars *Amphiura filiformis* had increased in abundance in a long-term study of the effects of scallop dredging in the Irish Sea.

Abra spp. are shallow burrowers with a fragile shell (Tebble, 1976), and have been considered amongst the list of bivalve species most vulnerable to trawling (Bergmann & Van Santbrink, 2000) who reported between <0.5% and 18% mortality of *Abra alba* due to trawling in the southern North Sea. However, the small size of *Abra* spp. relative to meshes of commercial trawls may ensure survival of at least a moderate proportion of disturbed individuals which pass through (Rees & Dare, 1993). This is likely to be the case for small infaunal bivalve *Kurtiella bidentata*. *Thyasira* spp., are small bivalves with thin fragile shells likely to be damaged and result in mortality within the population depending on the force (Jackson, 2007). Sparks-McConkey & Watling (2001) found that trawler disturbance resulted in a decline of *Thyasira flexuosa* in Penobscot Bay, Maine. *Heteromastus filiformis* occupied the top 15 cm of muddy sands and its limited mobility was considered to contribute to its vulnerability to dredging and to deposition of sediment mobilised by the dredging process by Shaffer (1983).

Rumohr & Kujawski (2000) compared qualitative historical benthos data (1902–1912) with recent data (1986) to find long-term trends in epifauna species composition in the southern North Sea that may be attributed to fishery-induced changes. In general, the frequency of occurrence of bivalve species declined, whereas scavenger and predator species (crustaceans, gastropods, and sea stars) were observed more frequently in 1986. The authors suggested that these shifts could be attributed not only to the physical fishery impact but also to the additional potential food for scavenging and predator species provided by the large amounts of discards and moribund benthos. The brittlestar *Amphiura filiformis* occurred in 1986 on only 5% of the stations while it was present in most of the historical stations. Also, virtually all bivalve species originally present had decreased drastically, including *Nucula tenuis* (also less the 5% of the sites by 1986). Despite the problems with the historical data set, the comparison presented was considered the best illustration achievable of the changes in the benthos from a near-pristine situation to the present conditions after long-term disturbance.

In a meta-analysis of the impacts of different fishing activities on the benthic biota of different habitats, muddy sands were found to be vulnerable to the impacts of fishing activities, with recovery times predicted to take years (Kaiser *et al.,* 2006). The long recovery time for muddy sands is due to the fact that these habitats are mediated by a combination of physical, chemical and biological processes (compared to sand habitats which are dominated by physical processes and recovery time takes days-months).

Furthermore, abrasion events are likely to cause turbulent re-suspension of surface sediments. When used over fine muddy sediments, trawls are often fitted with shoes designed to prevent the boards digging too far into the sediment (M.J. Kaiser, pers. obs., cited in Jennings & Kaiser, 1998). The effects may persist for variable lengths of time depending on tidal strength and currents and may result in a loss of biological organization and reduce species richness (Hall, 1994; Bergman & Van Santbrink, 2000; Reiss *et al.,* 2009) (see change in suspended solids and smothering pressures). The effects of trawling on infauna are greater in areas with low levels of natural disturbance compared to areas of high natural disturbance (e.g. Hiddink *et al.,* 2006), and its cumulative impacts can lead to profound changes in benthic community composition, with far reaching implication for marine food webs (Hinz *et al.*, 2009).

Sensitivity assessment: Although burrowing life habits may provide some protection from damage by abrasion at the surface, a proportion of the population is likely to be damaged or removed. Significant impacts in population density would be expected if such physical disturbance were repeated at regular intervals. Furthermore, the nature of the soft sediment where the biotopes occur means that objects causing abrasion, such as fishing gears (including pots and creels) are likely to penetrate the surface and cause further damage to the characterizing species. Resistance is therefore assessed as **Low** and resilience as **Medium**, so sensitivity is assessed as **Medium**.

A5.137 Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand and mixed gravelly sand

Part of: Infralittoral coarse sediment

https://www.marlin.ac.uk/habitats/detail/116#sensitivity_review

	Resistence	Resilience	Sensitivity
Abrasion/disturbance of the surface of the substratum or seabed	High	High	Not sensitive
	Q: High A: High C: High	Q: High A: High C: High	Q: High A: High C: High

The key characterizing species of this biotope (*Lanice conchilega*) has robust, flexible tubes and may retract below the surface. They are also able to rapidly rebuild or repair tubes (Nickolaidou, 2003). These characteristics reduce exposure to this pressure and enhance recovery. Rabaut *et al.* (2008) studied fisheries impacts at the species level in temperate sandy bottom areas. A controlled field manipulation experiment was designed focusing on areas with high densities of *Lanice conchilega* (i.e. *Lanice conchilega* reefs). A treatment zone was exposed to a one-off experimental trawling and the impact on, and recovery of the associated fauna was investigated for a period of 9 days post-impact. Community analysis showed a clear impact on associated species such as *Eumida sanguinea*, followed by a relatively quick recovery. The passage of a single beam trawl did not significantly alter the density of *Lanice conchilega* (Rabaut *et al.*, 2008).

The characterizing polychaetes *Magelona mirabilis, Chaetozone setosa* and *Spiophanes bombyx* are soft bodied organism which will be exposed to abrasion while feeding at the sediment surface while feeding. Abrasion would be likely to cause physical damage to these species.

Juveniles and adults of *Scoloplos armiger* stay permanently below the sediment surface, and freely move without establishing burrows. While juveniles are only found a few millimetres below the sediment surface, adults may retreat to 10 cm depth or more (Reise, 1979; Kruse *et al.,* 2004). The egg cocoons are laid on the surface and hatching time is 2-3 weeks during which these are vulnerable to surface abrasion.

Sensitivity assessment. The experiments by Rabaut *et al.* (2008) suggest that *Lanice conchilega* has 'High' resistance to abrasion, however, other associated species may be more impacted but species may be able to repair and recover from damage. Biotope resistance to a single abrasion event is assessed as 'High' based on the key characterizing species *Lanice conchilega*. There may be some damage to *Lanice conchilega* tubes and some reduction in abundances of the associated polychaete species but this unlikely to significantly alter the character of the biotope. Recovery from impacts of associated species is predicted to be 'High' and the biotope is assessed as 'Not sensitive'.

A5.233 *Nephtys cirrosa* and *Bathyporeia* spp in infralittoral sand

https://www.marlin.ac.uk/habitats/detail/154/nephtys_cirrosa_and_bathyporeia_spp_in_infralittoral_sand

	Resistence	Resilience	Sensitivity
Abrasion/disturbance of the surface of the substratum or seabed	Low	High	Low
	Q: High A: High C: High	Q: High A: Low C: High	Q: High A: Low C: High

This biotope group is present in mobile sands, the associated species are generally present in low abundances and adapted to frequent disturbance suggesting that resistance to surface abrasion would be high. The amphipod and isopod species present are agile swimmers and are characterized by their ability to withstand sediment disturbance (Elliott et al. 1998). Similarly, the polychaete N*ephtys cirrosa* is adapted to life in unstable sediments and lives within the sediment. This characteristic is likely to protect this species from surface abrasion.

Comparisons between shores with low and high levels of trampling found that the amphipod Bathyporeia pelagica is sensitive to abrasion and compaction from human trampling, other species including Pontocrates arenarius and the isopod Eurydice affinis also decreased in response to trampling but Bathyporeia pelagica appeared to be the most sensitive (Reyes-Martínez et al., 2015).

Sensitivity assessment. Resistance to a single abrasion event is assessed as 'Low' based on the evidence for trampling from Reyes-Martínez et al. (2015). Resilience is assessed as 'High', based on migration from adjacent populations and in-situ reproduction by surviving amphipods. Sensitivity is therefore assessed as 'Low'. This assessment may underestimate sensitivity to high-levels of abrasion (repeated events within a short period). The trampling evidence and the evidence for penetration from mobile gears (see below) differ in the severity (resistance) of impact. This may be due to different levels of intensity (multiple trampling/abrasion events vs single penetration/towed gear impacts) or the nature of the pressure. Abrasion from trampling also involves a level of compaction that could collapse burrows and damage species through compression. Penetration may, however, break sediments open allowing mobile species to escape or species may be pushed forwards from towed gear by a pressure wave where this is deployed subtidally (Gilkinson et al., 1998). Both risk assessments are considered applicable to single events based on the evidence and the sensitivity assessment for both pressures is the same although resistance differs.

A5.134 *Hesionura elongata & Microphthalmus similis* with other interstitial polychaetes in infralittoral mobile coarse sand
(*https://www.marlin.ac.uk/habitats/detail/379#sensitivity_review*

	Resistence	Resilience	Sensitivity
Abrasion/disturbance of the surface of the substratum or seabed	Medium	High	Low
	Q: High A: Medium C: Medium	Q: High A: Medium C: Medium	Q: High A: Medium C: Medium

The spatial scale and duration are important to consider in utilizing this assessment. For instance, spatially the whole biotope or just a smaller area may be affected. Also different sediment types and associated species communities will occur in the surface layers, at the site of aggregate extraction or scouring (where coarser sediment grain sizes prevail) and areas where finer sediment is deposited within the prevailing currents. The species characterizing this biotope are likely to colonize areas where extraction or scour has occurred and not the areas of deposition. For instance, Vanaverbeke et al. (2007) found Hesionura elongata, Polygordius appendiculatus and Microphthalmus spp. represented a more important proportion of the density in very intensively extracted dredging sites in the Belgium North Sea. Resilience is likely to be high for Hesionura elongate as the species showed the highest increase following cessation of sediment extraction in the Belgium part of the North Sea (Moulaert & Hostens, 2007).

Collie et al. (2000) suggest that bottom towed fishing gears are likely to cause a shift from communities dominated by relatively high biomass species towards dominance by high abundances of small-sized organisms, such as the characterizing species in this biotope; Hesionura elongata and Microphthalmus similis. This suggests that, even though initial resistance to physical damage from contact with fishing gears is likely to be 'Low', resilience is 'High' given the physical traits of the species and species life history.

Boat moorings were demonstrated to impact species communities close to the mooring buoy in a case study in the Fal and Helford estuaries (south west UK). Coarser sediment was exposed close to mooring buoys, caused by suspension of fine sediments by movement of the chain (Latham et al., 2012). Abrasion from anchors and anchor chains may have similar impacts on this biotope. However, the highly mobile nature of sediments in the biotope are likely to result in the sediment providing high resistance to such abrasion over small spatial scales and the biotope will only be impacted if a high density of vessels are at anchor.

Turbellarian abundance is likely to be decreased by deposition of fine material as the species live relatively shallowly in the sediment. Being mobile, individuals may be able to relocate to preferred depths. In the long-term, however, populations are likely to show a preference for sites with lower deposition of material. In the Fladen Ground area. Faubel et al. (1983) only found turbellarians below 4 cm occasionally. Huys et al. (1984) found 5 – 10 ind/10cm² in 19 stations of a shallow subtidal dumping site but on average Turbellarians accounted for only 3.6% of the total meiofauna in the samples.

Sensitivity assessment. Different sediment types and associated species communities will occur in association with aggregate extraction, scouring around renewable energy device bases and anchoring sites. <u>Where coarser sediment is exposed abundance of characterizing species will display limited</u>

impact. Where deposition of fine sediment occurs, typically further away from an obstruction such as a wind farm tower, or from deposition of aggregate or drilling waste will be likely to lead to reduction in abundance of characterizing species. Resistance to damage to seabed surface features is assessed as 'Medium'. The species community displays high recoverability and Resilience is 'High' and Sensitivity is assessed as 'Low.'

A5.152 Hesionura elongata and Protodorvillea kefersteini in offshore coarse sand

https://www.marlin.ac.uk/habitats/detail/1113/hesionura_elongata_and_protodorvillea_kefersteini_in_offshore_coarse_sand

	Resistence	Resilience	Sensitivity
Abrasion/disturbance of the surface of the substratum or seabed	Medium	High	Low
	Q: Low A: NR C: NR	Q: High A: Low C: Medium	Q: Low A: Low C: Low

Protodorvillea kefersteini is soft-bodied and therefore vulnerable to damage by physical abrasion. However, its environmental position as burrowing interstitial species should provide a high degree of protection from activities that lead to surface abrasion only. Similarly, as a small polychaete species, living infaunally and capable of burrowing rapidly, *Hesionura elongata* is also likely to withstand physical disturbance caused by bottom towed fishing gears (such as otter or beam trawls) (Vanosmael *et al.,* 1982; Bolam *et al.,* 2014). Experiments in shallow, wave disturbed areas, using a toothed, clam dredge, found that some polychaete taxa without external protection and with a carnivorous feeding mode were enhanced by fishing. *Protodorvillea kefersteini* was one of these: large increases in abundance in samples were detected post dredging and persisting over 90 days. The passage of the dredge across the sediment floor will have killed or injured some organisms that will then be exposed to potential predators/scavengers (Frid *et al.*, 2000; Veale *et al.*, 2000) providing a food source to mobile scavengers including these species.

In a coarse gravelly substratum exposed to high current velocities the crab *Cancer pagurus* was observed to dig pits, approximately 30 cm in diameter and 10 cm deep. Experiments were conducted to identify macrobenthic recolonization processes and differences in abundance between pits and unmanipulated areas.*Protodorvillia kefersteini* (McIntosh) (Polychaeta) showed a rapid increase in abundance at 21 days after disturbance (Thrush, 1986).

Gilkinson *et al.* (1998) simulated the physical interaction of otter trawl doors with the seabed in a laboratory test tank using a full-scale otter trawl door model. Between 58% and 70% of the bivalves in the scour path that were originally buried were completely or partially exposed at the test bed surface. However, only two out of a total of 42 specimens showed major damage. The pressure wave associated with the otter door pushes small bivalves out of the way without damaging them. Where species can rapidly burrow and reposition (typically within species occurring in unstable habitats) before predation mortality rates will be relatively low. These experimental observations are supported by diver observations of fauna dislodged by a hydraulic dredge used to catch *Ensis* spp. Small bivalves were found in the trawl tracks that had been dislodged, from the sediments, including the venerid bivalves *Dosinia exoleta*, *Chamelea striatula* and the hatchet shell *Lucinoma borealis*. These were usually intact (Hauton *et al.*, 2003) and could potentially reburrow. *Tellina* (formerly *Moerella pygmaea*) may, therefore, be displaced by penetration and disturbance but survive.

Sensitivity assessment. Evidence is limited but the biological assemblage present in this biotope is characterized by species that are likely to be relatively tolerant of penetration and disturbance of the sediments. Either species are robust or buried within sediments or are adapted to habitats with frequent disturbance (natural or anthropogenic) and recover quickly. Biotope resistance is assessed as ‘Medium’ as some species will be displaced and may be predated or injured and killed. Biotope resilience is assessed as ‘High’ as most species will recover rapidly. Biotope sensitivity is therefore assessed as ‘Low’.

A5.611: Sabellaria spinulosa on stable circalittoral mixed sediment

https://www.marlin.ac.uk/habitats/detail/377/sabellaria_spinulosa_on_stable_circalittoral_mixed_sediment

	Resistence	Resilience	Sensitivity
Abrasion/disturbance of the surface of the substratum or seabed	Low Q: Low A: NR C: NR	Medium Q: Medium A: High C: Medium	Medium Q: Low A: Low C: Low

Sabellaria spinulosa reef biotopes are directly exposed to physical damage that affects the surface. Gibb *et al.* (2014) found no direct evidence for impacts of the surface only for *Sabellaria spinulosa*. Studies of intertidal reefs of the congener *Sabellaria alveolata* (Cunningham *et al.*,1984) have found that the reef recovered within 23 days from the effects of trampling, (i.e. treading, walking or stamping on the reef structures) by repairing minor damage to the worm tube porches. Severe, localised damage, caused by kicking and jumping on the reef structure, resulted in large cracks between the tubes, and removal of sections (ca 15 x15 x10 cm) of the structure (Cunningham *et al.*, 1984). Subsequent wave action enlarged the holes or cracks. However, after 23 days, at one site, one side of the hole had begun to repair, and tubes had begun to extend into the eroded area.

To address concerns regarding damage from fishing activities in the Wadden Sea, Vorberg (2000) used video cameras to study the effect of shrimp fisheries on *Sabellaria alveolata* reefs. The imagery showed that the 3m beam trawl easily ran over a reef that rose to 30 to 40 cm, although the beam was occasionally caught and misshaped on the higher sections of the reef. At low tide, there were no signs of the reef being destroyed and, although the trawl had left impressions, all traces had disappeared four to five days later due to the rapid rebuilding of tubes by the worms. The daily growth rate of the worms during the restoration phase was significantly higher than undisturbed growth (undisturbed: 0.7 mm, after removal of 2 cm of surface: 4.4 mm) and indicates that as long as the reef is not completely destroyed recovery can occur rapidly.

Sabellaria spinulosa reefs are suggested to be more fragile than *Sabellaria alveolata* (B. Pearce, pers comm, cited from Gibb *et al.*, 2014) and therefore surface abrasion may lead to greater damage and lower recovery rates than observed for *Sabellaria alveolata*. *Sabellaria spinulosa* reefs are often only approximately 10cm thick, surface abrasion can, therefore, severely damage and/or remove a reef (see also evidence from penetration and disturbance of the sunbstratum, below). No direct observations of reef recovery, through repair, from abrasion were found for *Sabellaria spinulosa*.

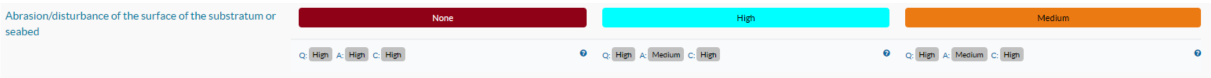
Sensitivity assessment. Based on the evidence discussed above, abrasion at the surface of *Sabellaria spinulosa* reefs is considered likely to damage the tubes and result in sub-lethal and lethal damage to the worms. Resistance is therefore assessed as ‘Low’ (loss of 25-75% of tubes and worms within the impact footprint). Resilience is therefore assessed as ‘Medium’ (within 2 years) and sensitivity is therefore assessed as ‘Medium’. This assessment is relatively precautionary and it should be noted the degree of resilience will be mediated by the character of the impact. The recovery of small areas of surficial damage in thick reefs is likely to occur through tube repair and may be relatively rapid.

A4.232: Polydora sp. Tubes on moderately exposed sublittoral soft rock

https://www.marlin.ac.uk/habitats/detail/247/polydora_sp_tubes_on_moderately_exposed_sublittoral_soft_rock

- Abrasion

Resistence Resilience Sensitivity



This biotope is characterized by epifauna occurring on hard rock substratum. The tubes of *Polydora* spp. are likely to be removed by abrasion as these project above the surface and are not physically robust. Other epifauna associated with this biotope are also likely to be damaged and/or removed by surface abrasion. Some species such as anemones and sponges may be able to rapidly repair damage while others may recolonize rapidly, e.g. barnacles.

Sensitivity assessment. The characterizing *Polydora* community in this biotope, is considered likely to be damaged and removed by abrasion. As a soft bodied species, *Polydora ciliata* is likely to be crushed and killed by an abrasive force or physical blow. Erect epifauna are directly exposed to this pressure which would displace, damage and remove individuals. Resistance to abrasion is considered **None**. However, *Polydora* is likely to be able to re-establish the lost community rapidly, so resilience of the biotope is assessed as **High** with the biotope considered to have **Medium** sensitivity to abrasion or disturbance of the surface of the seabed. The substratum is unable to recover from damage and therefore the biotope would be considered highly sensitivity to abrasion that damaged or removed the soft rock substratum.

- Extraction

Resistence Resilience Sensitivity

Removal of the substratum to 30 cm would result in the loss of Polydora sp. tubes. Resistance to the pressure is considered None, and resilience Very Low based on the loss of suitable substratum to support the community of the characterizing species of Polydora. Sensitivity has been assessed as High. Although no specific evidence is described confidence in this assessment is ‘High’, due to the incontrovertible nature of this pressure.

A4.135: Sparse sponges, Nemertesia spp., and Alcyonidium diaphanum on circalittoral mixed substrata

- Abrasion

Resistence Resilience Sensitivity

Abrasion/disturbance of the surface of the substratum or seabed	Low	Medium	Medium
	Q: High A: Medium C: Medium	Q: Medium A: Medium C: Medium	Q: Medium A: Medium C: Medium

The species characterizing this biotope occur on the rock surface and therefore have no protection from surface abrasion. High levels of abrasion from scouring by mobile sands and gravels is an important structuring factor in this biotope (Connor *et al.*, 2004) and may prevent succession. Where individuals are attached to mobile pebbles, cobbles and boulders rather than bedrock, surfaces can be displaced and turned over preventing feeding and leading to smothering.

The available evidence indicates that hydroids can be entangled and removed by abrasion. Drop down video surveys of Scottish reefs exposed to trawling showed that visual evidence of damage to bryozoans and hydroids on rock surfaces was generally limited and restricted to scrape scars on boulders (Boulcott & Howell, 2011). The study showed that damage is incremental with damage increasing with frequency of trawls rather than a blanket effect occurring on the pass of the first trawls. The results indicated that epifaunal species, including the sponge *Pachymatisma johnstoni,* were highly damaged by the experimental trawl. Please note Boulcott & Howell (2011) did not mention the abrasion caused by fully loaded collection bags on the Newhaven dredges. A fully loaded Newhaven dredge may cause higher damage to community as indicated in their study.

Re-sampling of grounds that were historically studied (from the 1930s) indicates that some species have increased in areas subject to scallop fishing (Bradshaw *et al.*, 2002). This study also found (unquantified) increase in abundance of tough stemmed hydroids including *Nemertesia* spp., its morphology may have prevented excessive damage. Bradshaw *et al.* (2002) suggested that as well as having high resistance to abrasion pressures, *Nemertesia* spp. have benthic larvae that could rapidly colonize disturbed areas with newly exposed substrata close to the adult. Hydroids may also recover rapidly as the surface covering of hydrorhizae may remain largely intact, from which new uprights are likely to grow. In addition, the resultant fragments of colonies may be able to develop into new colonies.

Hydroid colonies were still present in the heavily fished area, albeit at lower densities than in the closed area. This may largely be because the Isle of Man scallop fishery is closed from 1st June to 31st October (Andrews *et al.*, 2011), so at the time the samples were taken for the study in question, the seabed had been undredged for at least 3.5 months (Bradshaw *et al.*, 2003). The summer period is also the peak growing/breeding season for many marine species.

Freese *et al.* (1999) studied the effects of trawling on seafloor habitats and associated invertebrates in the Gulf of Alaska. They found that a transect following a single trawling event showed significantly reduced the abundance of 'vase' sponges (67% expressed damage) and 'morel' sponges (total damage could not be quantified as their brittle nature meant that these sponges were completely torn apart and scattered). The 'finger' sponges, the smallest and least damaged of the sponges assessed, were damaged (14%) by being knocked over.

Tilnant (1979) found that, following a shrimp trawl in Florida, US, over 50% of sponges, including *Neopetrosia*, *Spheciospongia*, *Spongia* and *Hippiospongia*, were torn loose from the bottom. Highest damage incidence occurred to the finger sponge *Neopetrosia longleyi.* Size did not appear to be important in determining whether a sponge was affected by the trawl. Recovery was ongoing, but not complete 11 months after the trawl, although no specific data was provided.

Freese (2001) studied deep cold-water sponges in Alaska a year after a trawl event; 46.8% of sponges exhibited damage with 32.1% having been torn loose. None of the damaged sponges displayed signs of regrowth or recovery. This was in stark contrast to early work by Freese *et al.* (1999) on warm shallow sponge communities. Impacts of trawling activity in Alaska study being much more persistent due to the slower growth/regeneration rates of deep, cold-water sponges. Given the slow growth rates and long lifespans of the rich, diverse fauna, it was considered likely to take many years for deep sponge communities to recover if adversely affected by physical damage (Freese, 2001).

Physical disturbance by fishing gear has been shown to adversely affect emergent epifaunal communities with hydroid and bryozoan matrices reported to be greatly reduced in fished areas (Jennings & Kaiser, 1998). Heavy mobile gears could also result in movement of boulders (Bullimore, 1985; Jennings & Kaiser, 1998).

Boulcott & Howell (2011) conducted experimental Newhaven scallop dredging over a circalittoral rock habitat in the sound of Jura, Scotland and recorded the damage to the resident community.

Sensitivity assessment

Given the sessile, erect nature of the sponges, hydroids and bryozoans, damage and mortality following a physical disturbance effect are likely to be significant, however some studies have brought into question the extent of damage to the faunal turf. A proportion of the biotope occurs on cobbles, pebbles and mobile substrata, which could result in increased damage in abrasion events.

The physiology of the bryozoans affords some protection in the event of abrasion events and recovery is likely to be rapid if stolons remain undamaged. Based on the potential damage to sponges, resistance is assessed as '**Low**', resilience as '**Medium**', and sensitivity is assessed as '**Medium**'.

- Extraction

	Resistence	Resilience	Sensitivity
Habitat structure changes - removal of substratum (extraction)	None Q: High A: High C: High	Medium Q: Medium A: Medium C: Medium	Medium Q: Medium A: Medium C: Medium

The species characterizing these biotopes are epifauna occurring on the cobbles and pebbles that characterize this biotope (Connor *et al.*, 2004). Removal of the substratum would remove both the habitat (boulders, cobbles and pebbles) and the characterizing, attached species.

Sensitivity assessment. Biotope resistance is assessed as '**None**' (in the extraction footprint), resilience (following habitat restoration, or where the underlying substratum remains the same) is assessed as '**Medium**'. Sensitivity is, therefore, assessed as '**Medium**'. Recovery will be prolonged (and sensitivity greater) where the entire habitat is removed and restoration (artificial or natural) to the previous state does not occur.

- Physical change (to another sediment type)

	Resistence	Resilience	Sensitivity
Physical change (to another sediment type)	None Q: High A: High C: High	Very Low Q: High A: High C: High	High Q: High A: High C: High

CR.HCR.XFa.SpNemAdi is characterized by the hard substratum provided by the pebbles and cobbles. SS.SMx.CMx.FluHydXF and SS.SSa.IFiSa.ScupHyd are dominated by hard substrata on sediment (Connor et al., 2004). A change to a mobile gravel or soft sedimentary substratum would significantly alter the character of the biotope. <u>The biotope is considered to have resistance of 'None' to this pressure based on a change to a soft sediment substratum, recovery of the biological assemblage (following habitat restoration) is considered to be 'High'. However, the pressure benchmark is considered to refer to a permanent change and recovery is therefore ‘Very low’. Sensitivity is therefore assessed as 'High'.</u>

A4.221 :Sabellaria spinulosa encrusted circalittoral rock
https://www.marlin.ac.uk/habitats/detail/348

	Resistence	Resilience	Sensitivity
Abrasion/disturbance of the surface of the substratum or seabed	Low	Medium	Medium
	Q: Low A: NR C: NR	Q: Medium A: Medium C: Medium	Q: Low A: Low C: Low

Sabellaria spinulosa reef biotopes are directly exposed to physical damage that affects the surface. The effects of abrasion coupled with penetration of sub-surface layers are described in a separate section below, this section describes abrasion of the surface only. The epifauna present on the reef could be removed and damaged by surface abrasion, however, the sensitivity assessment focuses on the effects of the reef only as this is considered the key characterizing and functional component of the biotope.

Gibb *et al.* (2014) found no direct evidence for impacts of the surface only for *Sabellaria spinulosa*. Studies of intertidal reefs of the congener *Sabellaria alveolata* (Cunningham *et al.*,1984) have found that the reef recovered within 23 days from the effects of trampling, (i.e. treading, walking or stamping on the reef structures) by repairing minor damage to the worm tube porches. Severe damage caused by kicking and jumping on the reef structure, resulted in large cracks between the tubes, and removal of sections (ca 15 x15 x10 cm) of the structure (Cunningham *et al.*, 1984). Subsequent wave action enlarged the holes or cracks. However, after 23 days, at one site, one side of the hole had begun to repair, and tubes had begun to extend into the eroded area.

To address concerns regarding damage from fishing activities in the Wadden Sea, Vorberg (2000) used video cameras to study the effect of shrimp fisheries on *Sabellaria alveolata* reefs. The imagery showed that the 3 m beam trawl easily ran over a reef that rose to 30 to 40 cm, although the beam was occasionally caught and misshaped on the higher sections of the reef. At low tide, there were no signs of the reef being destroyed and, although the trawl had left impressions, all traces had disappeared four to five days later due to the rapid rebuilding of tubes by the worms. The daily growth rate of the worms during the restoration phase was significantly higher than undisturbed growth (undisturbed: 0.7 mm, after removal of 2 cm of surface: 4.4 mm) and indicates that as long as the reef is not completely destroyed recovery can occur rapidly.

Sabellaria spinulosa reefs are suggested to be more fragile than *Sabellaria alveolata* (B. Pearce, pers comm, cited from Gibb *et al.*, 2014) and therefore surface abrasion may lead to greater damage and lower recovery rates than observed for *Sabellaria alveolata*. *Sabellaria spinulosa* reefs are often only approximately 10cm thick, surface abrasion can, therefore, severely damage and/or remove a reef (see also evidence from penetration and disturbance of the sunbstratum, below).No direct observations of reef recovery, through repair, from abrasion were found for *Sabellaria spinulosa*.

Sensitivity assessment. Based on the evidence discussed above, abrasion at the surface of *Sabellaria spinulosa* reefs is considered likely to damage the tubes and result in sub-lethal and lethal damage to the worms. Resistance is therefore assessed as 'Low' (loss of 25-75% of tubes and worms within the impact footprint). Resilience is therefore assessed as 'Medium' (within 2 years) and sensitivity is therefore assessed as 'Medium'. This assessment is relatively precautionary and it should be noted the degree of resilience will be mediated by the character of the impact. The recovery of small areas of surficial damage in thick reefs is likely to occur through tube repair and may be relatively rapid.

A4.2142: Alcyonium digitatum, Spirobranchus triqueter, algal and bryozoan crust on wave-exposed circalittoral rock

	Resistence	Resilience	Sensitivity
Abrasion/disturbance of the surface of the substratum or seabed	Medium	High	Low
	Q: High A: High C: High	Q: High A: High C: High	Q: High A: High C: High

CR.MCR.EcCr.FaAlCr.Adig, CR.MCR.EcCr.FaAlCr.Pom and CR.MCR.EcCr.FaAlCr.Sec are subtidal habitats (Connor *et al.,* 2004). Therefore, abrasion is most likely to be a result of bottom or pot fishing gear, cable laying etc. which may cause localized mobility of the substrata and mortality of the resident community. The effect would be situation dependent however if bottom fishing gear were towed over a site it may mobilize a high proportion of the rock substrata and cause **high mortality** in the resident community.

Alcyonium digitatum, Echinus esculentus, Securiflustra securifrons & *Spirobranchus triqueter* are sedentary or slow moving species that might be expected to suffer from the effects of dredging. Boulcott & Howell (2011) conducted experimental Newhaven scallop dredging over a circalittoral rock habitat in the sound of Jura, Scotland and recorded the damage to the resident community. The results indicated that the sponge *Pachymatisma johnstoni* was highly damaged by the experimental trawl. However, only 13% of photographic samples showed visible damage to *Alcyonium digitatum*. Where *Alcyonium digitatum* damage was evident it tended to be small colonies that were ripped off the rock. The authors highlight physical damage to faunal turfs (erect bryozoans and hydroids) was difficult to quantify in the study. However, the faunal turf communities did not show large signs of damage and were only damaged by the scallop dredge teeth which was often limited in extent (approximately. 2cm wide tracts). The authors indicated that species such as *Alcyonium digitatum* and faunal turf communities were not as vulnerable to damage through trawling as sedimentary fauna and whilst damage to circalittoral rock fauna did occur it was of an incremental nature, with the loss of species such as *Alcyonium digitatum* and faunal turf communities increasing with repeated trawls.

Species with fragile tests, such as *Echinus esculentus* were reported to suffer badly as a result of scallop or queen scallop dredging (Bradshaw *et al.*, 2000; Hall-Spencer & Moore, 2000). Kaiser *et al.* (2000) reported that *Echinus esculentus* were less abundant in areas subject to high trawling disturbance in the Irish Sea. Jenkins *et al.* (2001) conducted experimental scallop trawling in the North Irish sea and recorded the damage caused to several conspicuous megafauna species, both when caught as bi-catch and when left on the seabed. The authors predicted 16.4% of *Echinus esculentus* were crushed/dead, 29.3% would have >50% spine loss/minor cracks, 1.1% would have <50% spine loss and the remaining 53.3% would be in good condition. Sea urchins can rapidly regenerate spines, e.g. *Psammechinus miliaris* were found to re-grow all spines within a period of 2 months (Hobson, 1930). The trawling examples mentioned above were conducted on sedimentary habitats and thus the evidence is not directly relevant to the rock based biotopes- CR.MCR.EcCr.FaAlCr.Adig, CR.MCR.EcCr.FaAlCr.Pom & CR.MCR.EcCr.FaAlCr.Sec, however, does indicate the likely effects of abrasion on *Echinus esculentus*.

Sensitivity assessment. Resistance has been assessed '**Medium**', resilience has been assessed as '**High**'. Sensitivity has been assessed as '**Low**'

Please note Boulcott & Howell (2011) did not mention the abrasion caused by fully loaded collection bags on the new haven dredges. A fully loaded Newhaven dredge may cause higher damage to the community as indicated in their study.

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