# Impact Assessment of the Flyshoot fishery in Natura 2000 and MSFD areas of the Dutch continental shelf

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## Summary

This report commissioned by the ministry of Economic Affairs presents the results of a desk study on the state of the art knowledge about trawling impact of the sea bed and benthic ecosystems with particular reference to the flyshoot fishery, also known as Scottish seining.

- Since no empirical studies have been conducted on how the flyshoot affect sea bed and benthic organisms, the assessment is based on the inferred impact based on the dimension (swept area per hour fishing of the surface and sub-surface, weight of the gear components, towing speed) of the fishing gear relative to other bottom trawl gear.
- The footprint per hour fishing of the flyshoot (1.6 $km^2.hr^{-1}$) is relatively large as compared to other bottom trawl gears (danish seine - 1.0 $km^2.hr^{-1}$; otter trawl (0.3 – 1.2 $km^2.hr^{-1}$) or beam trawl (0.20 $km^2.hr^{-1}$).
- The sub-surface footprint of the flyshoot (0.1 $km^2.hr^{-1}$) is lower than that of the otter trawl fishery for Nephrops (0.3 $km^2.hr^{-1}$) or the beam trawl fishery for flatfish (0.2 $km^2.hr^{-1}$).
- In general, the physical impact of fishing gear scales with the mass of the gear component and the towing speed.
- The physical impact of the flyshoot, as well as the re-suspension of sediments, will be lower than that of other bottom trawl gear because of the lower towing speed.
- The impact of bottom trawling will increase with a decrease in the level of natural disturbance because habitats with a high level of natural disturbance are adapted to disturbance and relatively insensitive for bottom trawling.
- The impact of flyshoot fishing may be significant in sea bed habitats that are characterised by fragile physical or biogenic structures that take a long time to grow, such as gasseeps and biogenic habitats. The impact will be lower for more robust long-lived taxa, or taxa that live in the sea bed.
- The question whether the flyshoot fishery may have a significant impact on the sea bed and benthic ecosystem depends on the occurrence of these vulnerable structures and organisms.
- Epibenthic species presently and previously occurring in the area are listed and their vulnerability for flyshoot gear is assessed based on their vulnerability to bottom trawling in general (Wijnhoven et al., 2013) .
- Flyshoot gears are estimated to have a negligible impact on the benthic community in the Dutch coastal waters (Voordelta and Vlakte van de Raan) which are characterised by a high natural disturbance and lack of species assessed to be vulnerable to flyshoot gear.
- For the Dogger Bank and Cleaver Bank areas, the benthic community is characterised by a larger proportion of long lived and suspension feeding taxa. Among these groups, species occur that are classified as being vulnerable for the passage of flyshoot gear, such as sponges, soft corals and others. In former times, horse mussels *Modiolus modiolus* formed reefs in the northern part. (A)biotic reefs can serve as spawning areas for e.g. elasmobranchs.
- For the Central Oysterground and Frisan Front area none of the indicator species build biogenic structures that are vulnerable for the relative mild physical impact of the flyshoot. Most indicator species live in the sea bed and occur beyond the reach of the ground rope or seine ropes. In former times, the European oyster *Ostrea edulis* was an important bioengineer in these areas, forming large reefs.

# 1. Introduction

In Part I of the Dutch Marine Strategy, the Dutch government expresses the ambition to protect between 10-15% of the Dutch continental shelf from bottom disturbance (Min I&M and EL&I 2012). Accordingly a number of areas in the North Sea are designated to be closed to bottom trawl fisheries. In the stakeholder consultations the question was raised whether the flyshoot fishery (Figure 1) could be allowed to fish in some of the areas because the impact on the sea bed and benthic ecosystem was considered to be negligible.

This report presents the results of a desk study on the effect of flyshoot fisheries on the sea bed with particular reference to the areas designated by the Dutch government to be closed to bottom trawl fisheries under the Natura 2000 and MSFD legislation. A previous report focussed on the impact of the flyshoot on the Frisian Front and Central Oysterground designated areas (Rijnsdorp, 2015). Here we copy the description of the flyshoot fishery and the impact assessment methodology of Rijnsdorp et al. (2016) and extend the assessment to the impact on the designated areas on the Doggerbank, Cleaverbank and in the Dutch coastal zone.

Questions:

- What is the effect of the flyshoot fishery on sea bed habitats and benthic ecosystems in the Natura2000 and MSFD areas on the Dutch continental shelf?
- What is the probability that if the flyshoot fishery is allowed to fish in some of the Natura2000 or MSFD areas, this will result in an increase in flyshoot fishing, having a negative impact on the sea bed and benthic ecosystem?

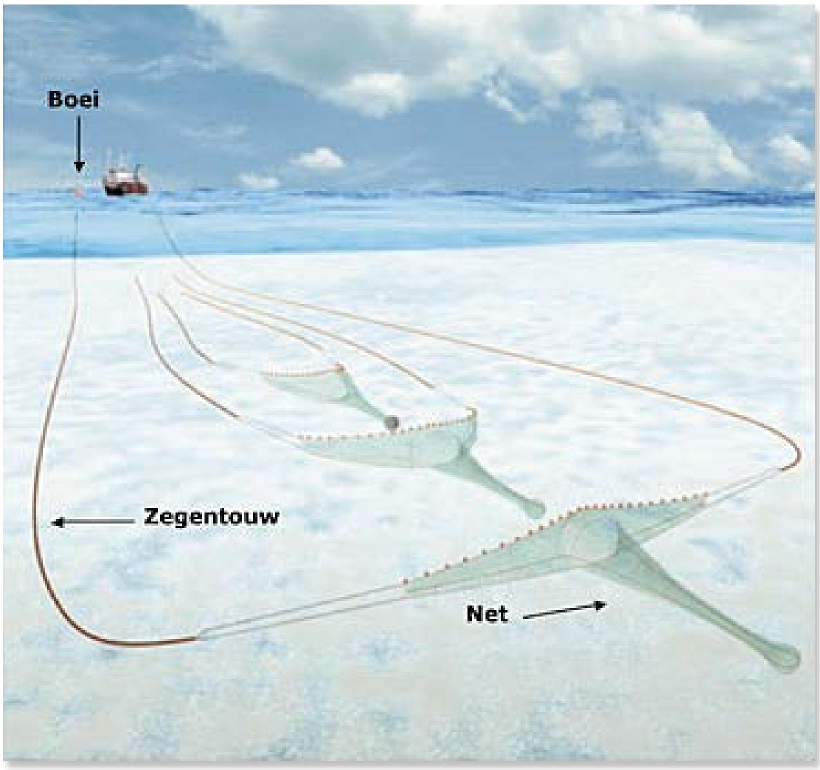


Figure 1. Flyshoot fishery (source: www.flyshootvis.nl)

# 2. Approach

In this study first an overview is given of the distribution of the flyshoot fisheries in the Dutch Part of the North Sea and their footprint. Next, we assess the impact of flyshoot fisheries on the benthic communities in different Natura 2000 areas and MSDF areas in the Dutch North Sea. To do so, first the impact of the fishing gear on the seafloor was assessed, based on the fishing gear's characteristics, as determined in the BENTHIS project (www.benthis.eu). Next the impact of flyshoot on the benthic community was assessed for a suite of species using information on their vulnerability to fishing and on their position on the seafloor. This results in a number of species that could be affected by the flyshoot gear (Chapter 4).

# 3. Distribution

Thirteen Dutch vessels deployed the Danish or Flyshoot (Scottish seine) trawl gear in the period 2010-2014. The gear code used in the effort statistics (SSC) did not distinguish between both gears. The number of fishing days increased from 170 in 201 to 193 in 2014. Figure 2 shows the annual distribution of fishing effort and revenue in the period 2010-2014.

# 4. Effects of towed gears on the sea bed and benthic ecosystem

## 4.1 BENTHIS approach

Within the European FP7 project BENTHIS (www.benthis.eu) a method is developed to determine the effects of trawling on the seabed and the seabed ecosystem (Figure 3). The method is based on a mechanistic approach comprising the characteristics of the fishing gear and the characteristics of the benthic habitat and benthic community. The gear is decomposed in components that come into contact with the seabed, and the physical impact is determined for each component. In this way, an assessment can be made of the effects of fishing gear on the seafloor in absence of targeted research on the actual impact.

The structure of the seabed is formed by different processes, each with its own characteristic time scale: (1) long-term geomorphological processes (glacial deposits and the changes during the subsequent sea level rise); (2) medium-term effects of geomorphological processes such as the formation of gas seeps and pockmarks; (3) short-term effects of (3a) local water movement (bed shear stress due to tidal movement and waves) and (3b), benthos (bioturbation, structure formation of reefs, shellfish beds). To determine the impact on the community of benthic animals, species are classified on the basis of specific traits which have an influence on their sensitivity to bottom trawling, such as the position in the seabed, the construction and the presence of a protective skin, and properties that have an influence on the recovery time as longevity. By distinguishing benthic animals according to their ecological role and longevity, an assessment can be made of the impact of bottom trawling on specific ecological functions.

The pressure of fishing on the seabed is determined by the fished area (footprint), its physical impacts and the extent to which parts of the gear penetrating the seabed. Based on a survey of fishing gear specifications used in Europe, Eigaard et al (2015) estimated the footprint for an average fishing vessel and the percentage of the fished area where gear components seabed penetrate (Figure 4).

## 4.2 Footprint

The calculation of the footprint assume that the surface area of an anchor seine is equal to the circle which is determined by the length of the seine rope ("zegentouw"). The footprint of the flyshoot is estimated to be 1.5 times the circle enclosed by the seine rope (Figure 5). It should be noted that there is little empirical data available on the flyshoot fishery. The flyshoot data reported in Eigaard et al (2015) are based on Danish data supplemented with data from Dutch fisheries that were collected in spring 2015. It is noted that the data on the earlier flyshoot report (Rijnsdorp 2015) was based on the Danish data only. Hence, the results presented in this report replace the results presented in the previous flyshoot report that were based on a previous version.

The footprint per hour fishing of the flyshoot (1.6 $km^2.hr^{-1}$) is relatively large as compared to other bottom trawl gears (danish seine - 1.0 $km^2.hr^{-1}$; otter trawl (0.3 – 1.2 $km^2.hr^{-1}$) or beam trawl (0.20 $km^2.hr^{-1}$). The sub-surface footprint of the flyshoot (0.1 $km^2.hr^{-1}$) is lower than that of the otter trawl fishery for Nephrops (0.3 $km^2.hr^{-1}$) or the beam trawl fishery for flatfish (0.2 $km^2.hr^{-1}$).

## 4.3 Physical impacts

Towed nets may affect the sea floor in various ways. The cables and ground rope that are dragged over the sea bed may homogenise the texture of the sea bottom, destroy hard structures and move stones or shells. Heavy gear components such as the otter boards or tickler chains will penetrate into the seabed and disturb the vertical structure of the sediment. Sediment may be brought into suspension by the turbulence generated in the wake of the gear. The physical impact can therefore be broadly classified into (1) penetration into the seabed; (2) collision with (hard) structures; (3) re-suspension of sediments.

The penetration of gear parts in the seabed depends on the pressure that the gear part exerts on the seabed. The penetration depth is mainly determined by the shape and mass of the gear. Fishing equipment are usually designed in such a way that they have sufficient mass to remain on the ground while not too heavy to get stuck in the sea floor. Gears which are to be pulled with a higher towing speed are heavier to compensate for the increased upward force caused by the hydrodynamic resistance.

The "impact energy" during collision with which objects on the seabed is a function of the mass of the gear component and the speed at which it is dragged over the bottom.

The re-suspension of the sediment is determined by the grain size of the sediment and the hydrodynamic resistance. This latter is a function of the surface area of the gear element and the square of the speed.

On the basis of these basic physical processes, the towing speed has an important influence on the physical impact in addition to the mass and size of the gear components. The towing speed of the flyshoot net increases from just above 0 knots at the start of the tow to 3 knots at the end of the tow. This implies that during the first part of the tow the physical impact will be much lower than that in other bottom trawl gears. Only during the latter part of the tow the physical impact of the flyshoot may become comparable with other bottom trawl gears.

## 4.4 Ecological impact

Bottom fishing causes mortality and results in a reduction of biomass and biodiversity. Long-lived species are more vulnerable because they need a longer time to recover. Robustly built animals are less susceptible than fragile species. Usually the share of long-lived species in fished areas is lower than in unfished areas.

## 4.5 Sensitivity of the seabed and the community of benthos

The sensitivity of the seabed to disturbance of towed fishing gears depends primarily upon the natural disturbance (shear stress) and the structure of the sea bed (Diesing et al., 2013). The degree of natural disturbance decreases with water depth. The grain size of the sediment is usually a good indicator of the natural disturbance. High dynamic areas are characterized by coarse sediments, low dynamic areas by fine sediments.

Van Denderen et al. (2016) analysed infaunal samples collected along a gradient in trawling intensities in eight different habitats to study how trawling intensity affected the benthic community composition and biomass. This study also provided information on the benthic community composition in the stations with minimal trawling disturbance, which can be used to estimate the composition of a number of biological traits that are related to their sensitivity for bottom trawling, such as longevity (Figure 8). Hence, the biomass distribution of the benthic taxa over the longevity can be linked to trawling intensities to estimate the ecological impact of bottom trawl fisheries (Rijnsdorp et al., 2015).

The Dutch coastal zone (area 5) is an area with a high level of natural disturbance that is characterised by a community that is composed of mainly short living animals (Figure 8). The Dogger bank (area 1), although exposed to a high natural disturbance, is characterised by a larger proportion of long-lived species, predominantly suspension feeding taxa, and taxa with a hard exoskeleton, than the community in the Dutch coastal zone. Hence, the sensitivity for bottom trawling impacts will be higher. The Frisian Front and the Central Oyster Grounds (area 4) are low dynamic areas with fine sediment and are characterized by a benthic community with a higher proportion of long-lived species.

## 5. Impact of the flyshoot in Natura 2000 and MSFD areas

Although the flyshoot gear has a relative large footprint, the impact on the benthic ecosystem will be relatively small in comparison with other bottom trawls (such as otter and beam trawls) that are heavier and towed at higher speeds, and have a higher subsurface footprint. Nevertheless, adverse effects are expected on fragile biogenic habitat (soft corals, sponge gardens, etc) and fragile benthic taxa that live on the sea bed and are attached to hard objects (stones, shells, etc), as these species may be dislodged or torn off their foundation by the passage of the rope. Examples of these species are soft corals (dead men's fingers), sea pens, reef building species such as *Sabellaria* (tube worms), *Modiolus modiolus* (horse mussels) and Bryozoa. We also expect that the recovery of these sensitive species will be hampered by flyshooting as the ropes may break down the first stages of the biogenic structures or damage or kill the recruits of fragile epibenthic species. These potentially sensitive species do not necessarily match with the typical species that have been listed for the various designated areas. For example, the species that were listed as characteristic for the Central Oysterground and Frisian Front area predominantly live in the sea bed, out of reach of the ground rope and seine rope of the flyshoot gears (Appendix 1).

To assess the potential impact of the flyshoot fishery on the benthic ecosystem, the benthic species that are potentially vulnerable for the flyshoot gear and that may occur in the Natura 2000 and MSFD areas of the Dutch Continental Shelf are reviewed.

As a starting point, we used species lists by Wijnhoven et al. (2013), who provided an overview of the lists of 'typical species' for each Natura 2000 area as well as lists of 'smart indicators' for Natura 2000 and MSFD areas. These species have been chosen because they are measured in monitoring programmes and because they have traits that allow for assessment of the quality of the habitat and changes therein under management measures to improve the habitats. In addition, we included species that are historically known to have played an important role as bioengineers and species for which the sea bed may play a role as spawning habitat. Since restoration programmes of such species are considered as options for the programme of measures for the MSFD, it is important to know if the flyshoot fisheries would prevent these species from returning to their historical habitats.

Wijnhoven et al. (2013) made a distinction between species that are sensitive/not sensitive to trawling. Since we assume that only epibenthic species will come into contact with the flyshoot, we have assessed whether these species are part of the epibenthos. In addition, we have indicated whether the species is typical to the area (Van Wijnhoven et al. 2013) and whether it is a bioengineer. Information on historically present important bioengineers, such as the flat oyster and the horse mussel was obtained from the literature (Olsen 1883, Tesch 1920, Van Moorsel 2011).

A species is considered sensitive to flyshoot in this study if:

- The species is very sensitive to trawling disturbance in general (as estimated by Wijnhoven et al. 2013) (value=1 'very sensitive' ) and if
- The species is part of the epibenthos (i.e. species is not endobenthic) (estimated by O.G Bos in this report) (value = 1) and if
- The species or its egg capsules or recruits are immobile and protrude more than 1cm above the seafloor (i.e., the species is likely to be hit by the flyshoot gear)
- In all other cases (e.g. sensitivity value = 0.5), the species is NOT considered to be sensitive to flyshoot.

The full list of assessed species is included in Appendix 1, the list of species considered to be vulnerable to flyshoot is provided in Table 1. These species are discussed in more detail below, as well as a number of species which were not included in the table. A distinction is made between bioengineers and other epibenthos. In the table, also Natura 2000 'typical species' are indicated (see Wijnhoven et al. 2013) and species that are typical to the area according to Wijnhoven et al. (2013).

Bioengineers

*Lanice conchilega*: this species can be considered to be rather resistant to the flyshoot, since this species has been able to survive in habitats that are trawled quite intensively. Experiments showed that closely associated species of *L. conchilega* reefs are impacted by beam-trawl fisheries (Rabaut et al, 2008).

*Ostrea edulis*: in former times, large European oyster reefs were present in the Dutch North Sea (Olsen, 1883). Although the adults are unlikely to be sensitive for the flyshoot, if they would be present, it is possible that spatfall may be adversely affected, hampering recovery of *Ostrea edulis* populations.

*Modiolus modiolus*: the horse mussel forms complex mussel beds and is known from the North part of the Dogger Bank. Nowadays, it has disappeared (see Van Moorsel, 2011). Although the adults are unlikely to be sensitive for the flyshoot, if they would be present, it is possible that spatfall may be adversely affected, hampering recovery of *Modiolus modiolus* populations.

Bryozoa: A species such as *Flustra foliacea* which form bush-like structure on the seafloor will be sensitive. The species is still encountered in the northern North Sea.

Bioengineers, as well as natural hard substrate, may be used as spawning habitat for e.g. elasmobranchs (sharks and rays) or herring, who attach their eggs to it. Flyshoot may dislodge attached eggs or egg capsules from the sea bed.

Other epibenthos

In Table 1, a number of epibenthic species are listed that are vulnerable because they live on the sediment or on hard substrate. These include *Alcyonidium digitatum* (dead men's finger), sponges, a gastropod (whelk) and a number of anemones. Typical species (Wijnhoven et al. 2013) are indicated with the symbol " ^ ". Crabs, bivalves and other species that are typically vulnerable to bottom fishing gear, were not considered to be vulnerable to flyshoot, either because the rope and net would probably just pass them without touching, or because their shells are not likely to be damaged by a passing rope or net.

*Table 1. List of species and functions estimated to be sensitive to flyshoot fishing (full list in Appendix 1).*

| **Area** | | **Species and habitat potentially impacted by flyshoot gear** |
|---|---|---|
| Voordelta | Bioengineers | - |
| | Epibenthos | *Buccinum undatum* (whelk/wulk) (egg capsules) |
| Vlakte van de Raan | Bioengineers | - |
| | EpibenthosEpibent | *Buccinum undatum* (whelk/wulk) (egg capsules) |
| Dutch Coastal Zone | Bioengineers | *Ostrea edulis* (European oyster/platte oester) (recruits) |
| | Epibenthos | *Buccinum undatum* (whelk/wulk) (egg capsules) |
| Dogger bank | Bioengineers | *Modiolus modiolus* (horse mussel/paardenmossel) (recruits)* |
| | | Bryozoa, e.g. *Flustra foliacea* (greater horn wrack Bladachtig hoornwier)* |
| | Epibenthos | *Alcyonidium digitatum* (dead men's finger/dodemansduim)*^ |
| | | *Buccinum undatum* (whelk/wulk) (egg capsules) |
| | | *Alcyonidium diaphanum* (sechervil/bruine zeevinger) |
| | Spawning habitat | Elasmobranchs* (sharks and rays/haaien en roggen) |
| Cleaver Bank | Bioengineer | *Sabellaria spinulosa* (tube worm/kokerworm) |
| | Characteristic (N2000 typical species) | *Lithothamnion sonderi* (alga/korstalg)^ |
| | | *Chone duneri* (sabellid worm)^ |
| | Epibenthos | *Alcyonium digitatum* (dead men's finger/dodemansduim)^ |
| | | *Buccinum undatum* (whelk/wulk) (egg capsules) |
| | | *Urticina* spec. (anemone/anemoon)^ |
| | | Porifera (sponges/sponzen) |
| | | Hydrozoa (hydroids/hydroidpoliepen) |
| | | *Cerianthus loydii* (anemone/anemoon) |
| | Spawning habitat | Elasmobranchs* (sharks and rays/haaien en roggen) |
| Oyster Grounds | Bioengineer | *Ostrea edulis** (European oyster/platte oester) |
| Frisian Front | Bioengineer | *Ostrea edulis** (European oyster/platte oester) |
| | Epibenthos | - |

*in former times abundant (Olsen, 1883), species /function will possibly profit from absence of bottom fisheries

^Characteristic to the area, according to Wijnhoven et al. (2013)

## 6. Conclusions

The assessment of the benthic impact of flyshoot fisheries is based on two aspects: (1) the knowledge on the characteristics of the fishing gear (design, size, weight, towing speed) and (2) the estimated vulnerability of the benthic fauna and habitats to the fishing gear. No specific empirical studies have been conducted to the impact of flyshoot gear on benthos.

In this study we assume that only sessile epibenthic species, or their eggs or recruits that protrude to some extent above the sediment are vulnerable to flyshoot fisheries.

Flyshoot gears are estimated to have a negligible impact on the benthic community in the Dutch coastal waters (Voordelta and Vlakte van de Raan). The community is characterised by relatively short lived species that are adapted to the high level of natural disturbance. No species are known to occur in the coastal zone that classify as particularly vulnerable for the passage of the ropes and ground rope of a flyshoot gear. *Lanice conchilega* forms reefs, but appears to recover quickly after trawling, although associated species may be affected. Only egg capsules of whelks may be vulnerable to trawling.

For the Dogger Bank and Cleaver Bank areas, the benthic community is characterised by a larger proportion of long lived and suspension feeding taxa. Among these groups, species occur that are classified as being vulnerable for the passage of flyshoot gear, such as sponges, soft corals and others. In former times, horse mussels *Modiolus modiolus* formed reefs in the northern part. (A)biotic reefs can serve as spawning areas for e.g. elasmobranchs.

For the Central Oysterground and Frisian Front area none of the indicator species build biogenic structures that are vulnerable for the relative mild physical impact of the flyshoot. Most indicator species such as mud shrimps live in the sea bed and occur beyond the reach of the ground rope or seine ropes (*Callianassa subterranea, Upogebia spp, Brissopsis lyrifera, Corystus cassivelaunus, Nephtys incisa, Thracia convexa*). The bivalves are robust with the exception of *Thracia convexa* which lives in the sea bed. In former times, the European oyster *Ostrea edulis* was an important bioengineer in these areas, forming large reefs.

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## Quality Assurance

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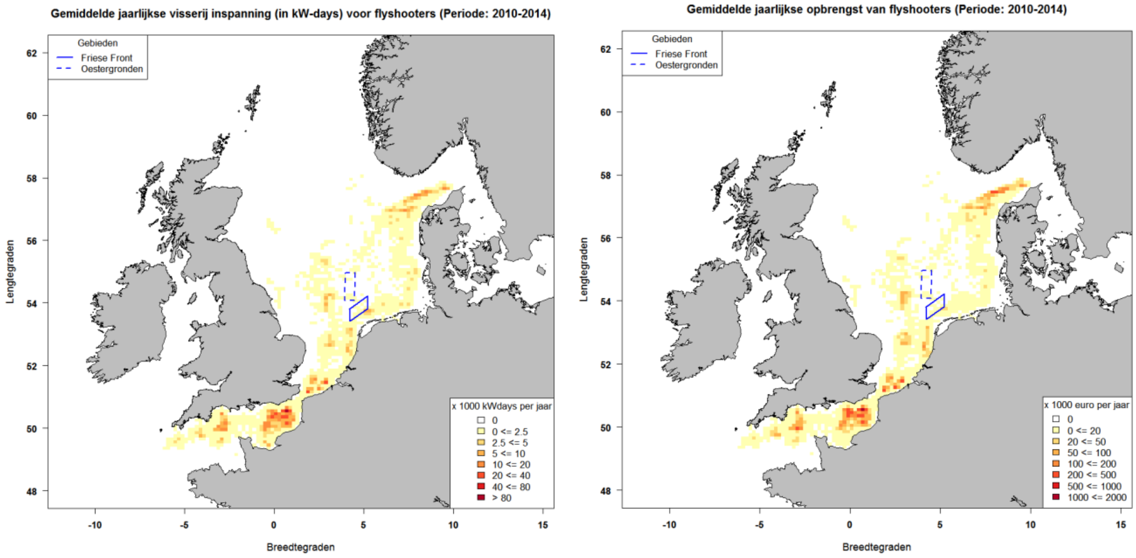



*Figure 2. Distribution of flyshoot effort (average annual kW-days) and revenue (Euro) in the period 2010-2014. The black dots represent VMS recordings. The two areas indicate the search area for the Central Oysterground (CO) and Frisian Front (FF) closed area.*

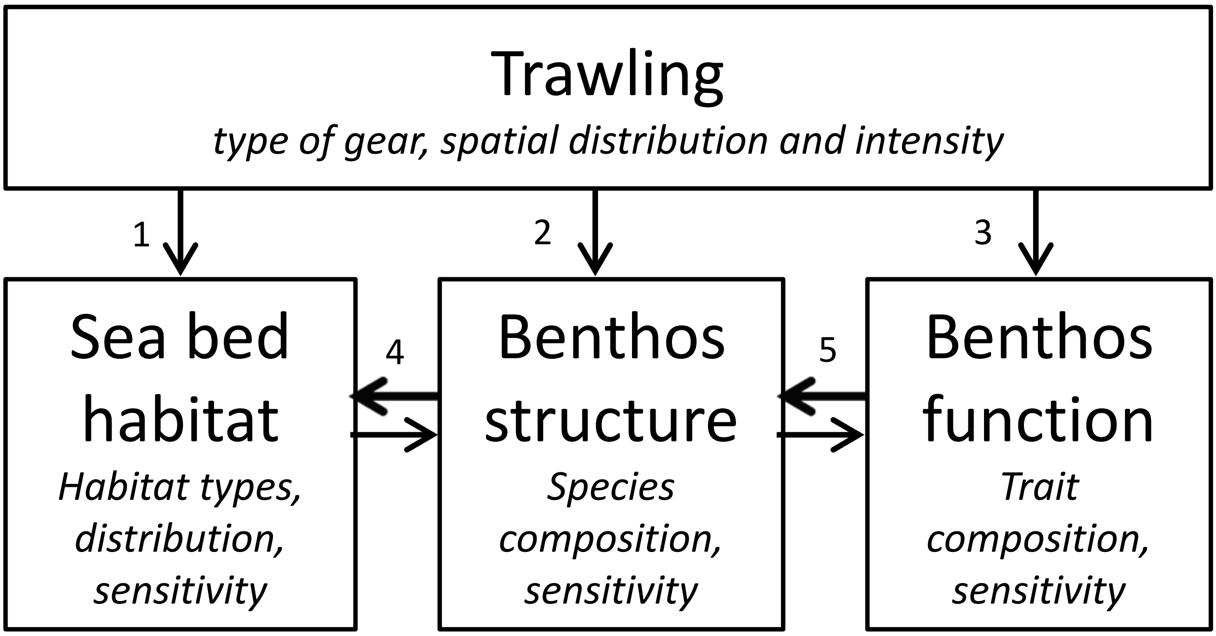



*Figure 3. Assessment framework of the impact of bottom trawl fisheries on the sea bed and benthic ecosystem. Trawling impact is determined by the type of gear, the intensity and surface area trawled. Sea bed habitats and their associated characteristic benthic community differ in their sensitivity for trawling. The functioning of the benthic ecosystem is related to the community composition of relevant functional traits that have a specific sensitivity for trawling (from Rijnsdorp et al., 2016).*

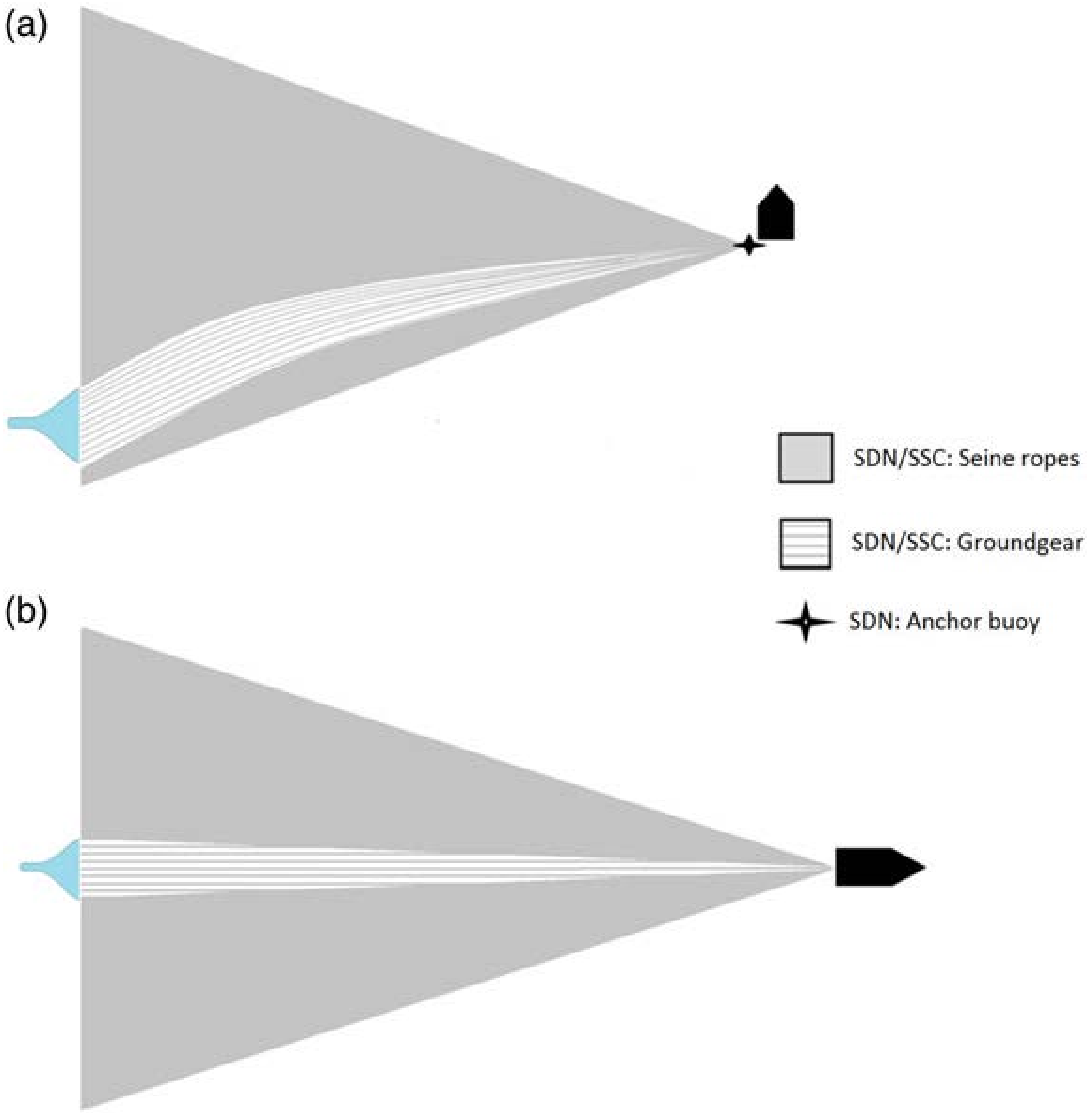



*Figure 4. Footprint of (a) Danish seine (anchor seine) and (b) Scottish seine (flyshoot). From Eigaard et al. (2015).*

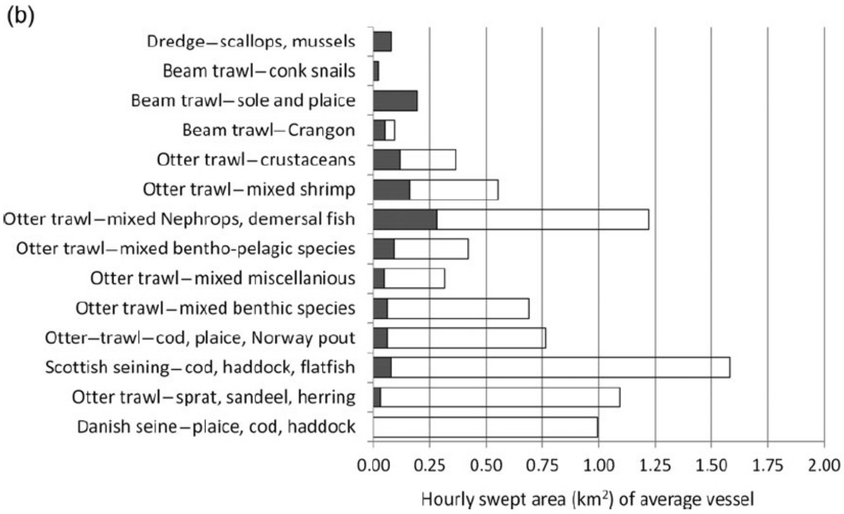



*Figure 5. Surface (white bar) and sub-surface (dark part of the bar) footprint ($km^2$ swept per hour fishing) of the different European bottom trawl fisheries. Flyshoot is labelled as Scottish seining (from Eigaard et al., 2015)*

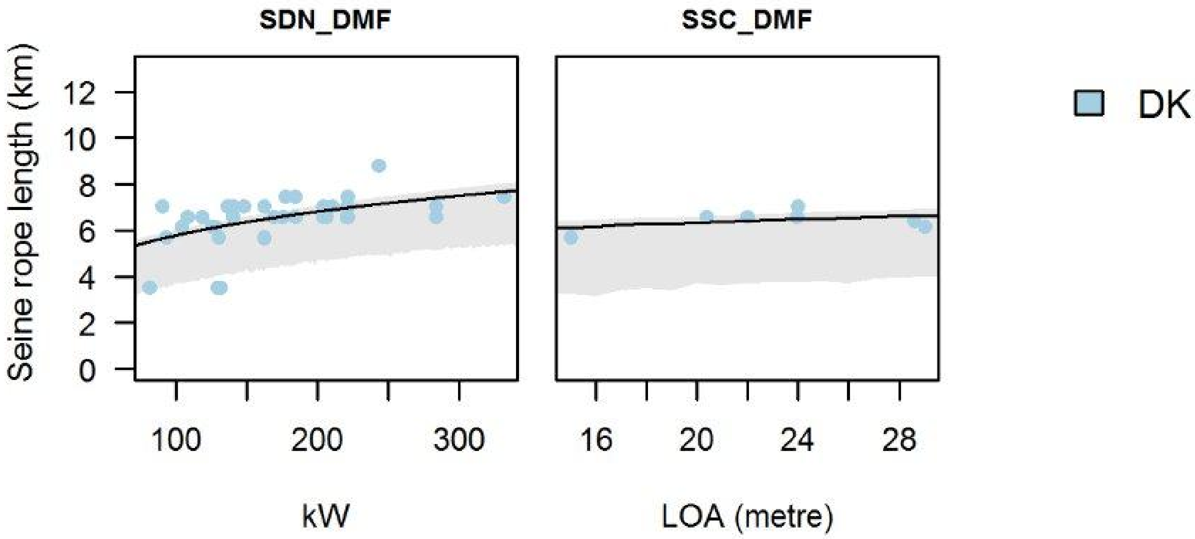



*Figure 6. The length of the seine rope in relation to the engine power and length of the vessel. Source: Eigaard et al (2015).*

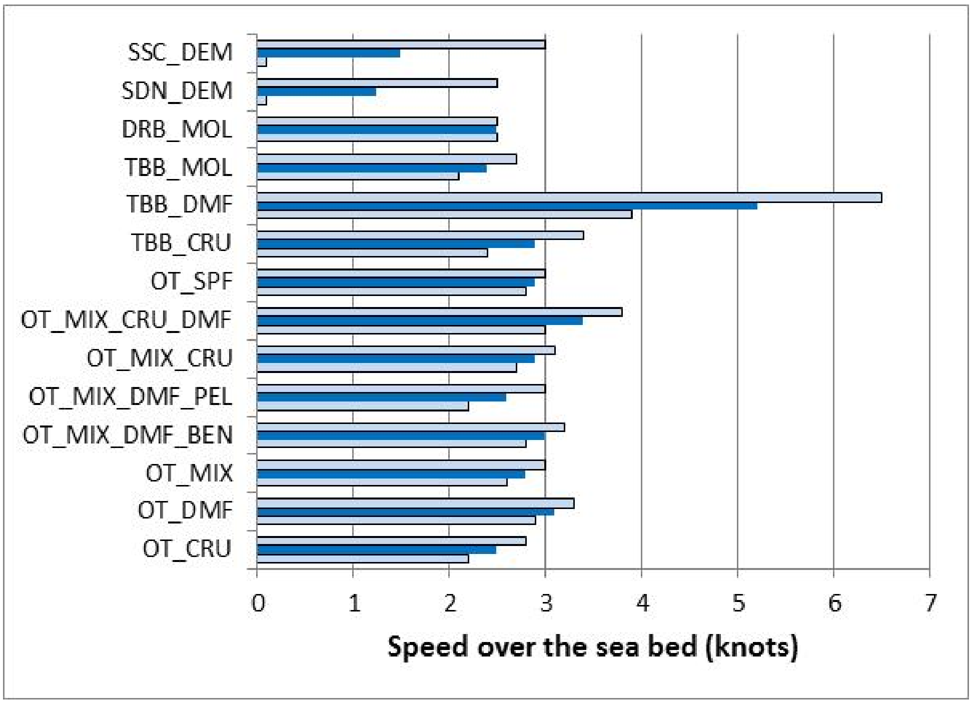
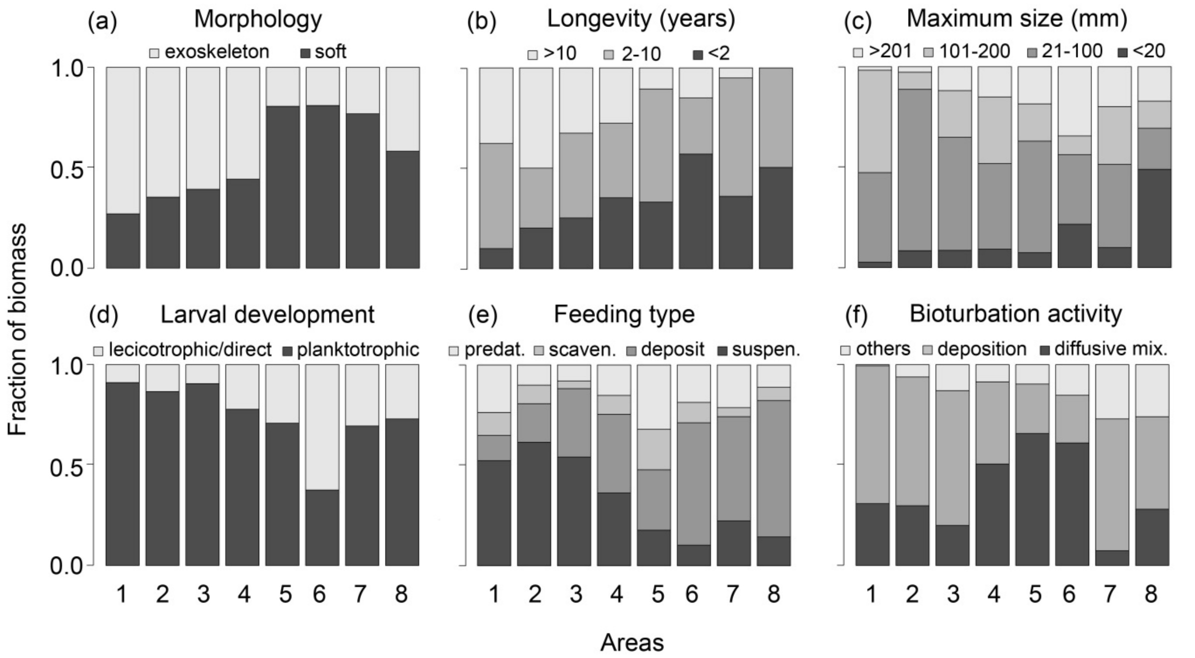



*Figure 7. The range of speeds (mean +/- SD) at which a gear is towed over the sea bed. The dark bar shows the average speed. For the Flyshoot (SSC_Dem) and Danish (SDN_Dem) seine the light bars show the speed at the start and the end of the tow (from Eigaard et al., 2015).*




1 Dogger Bank; 2 Sellafield; 3 Silver Pit; 4 Dutch FS; 5 Dutch CS; 6 Fladen Ground; 7 Long Forties; 8 Thames

*Figure 8. Differences in the community composition of the benthic community in eight study areas. The benthic community is analysed for six biological traits. The figure shows the biomass distribution over a number of biological traits such as longevity (panel b). Area 1 represents sampling locations on the Doggerbank. Area 4 represents Central Oysterground and Frisian Front area. Area 5 represents sampling locations along the Dutch coast and in the southern North Sea. Number of sampling locations and number of replicate samples: Dogger Bank 3(5); Sellafield 1(5); Silver Pit 3(4); Dutch FS 92(1); Dutch CS 9(1); Fladen Ground 2(5); Long Forties 2(2 and 5); Thames 3(4) (van Denderen et al., 2016).*

## Justification

Report C162/15

Project number: 4312810033

BAS code: BO-11-018.02-000-IMARES-7

The scientific quality of this report has been peer reviewed by the a colleague scientist and the head of the department of IMARES.

Approved: Jan Jaap Poos

Researcher

Signature:

Date: 2 December 2015

Approved: Dr. Ir. N.A. Steins

Head of Fisheries Department

Signature:

Date: 2 December 2015

## Appendix 1. Species lists and selection of species sensitive to trawling.

Table 2. List of indicator species (column 1 and 2) per Natura 2000 area from Wijnhoven et al. (2013) supplemented with species that are known to have historically occured in the areas (column 3). The remaining column if the species is characteristic to the area, if it is a bioengineer, if it is sensitive to seabed disturbance according to Wijnhoven et al. (2013), and if it is a immobile benthic species protruding > 1 cm above the seafloor, and if the species' egg capsules or recruites are sensitive to fishing. Using the rules stated in Chapter 5, the final assessment whether the species is vulnerable to flyshoot is given in the last column (1=yes, 0 = no).

| Typical species (Natura 2000) | Potential 'smart' indicator species | Bioengineers based on historical data (Olsen, 1883; Tesch 1920 (in Van Moorsel 2011)) | EXTRA info: characteristic **(van Wijnhoven)** | EXTRA info: bio-engineer (this report) | sensitivy to seabed disturbance **(van Wijnhoven)** | c) epifauna (1=yes, 0=no) **(this report)** | immobile epifauna protruding > approx 1 cm above the seafloor (1=yes, 0=no) **(this report)** | vulnerable epibenthic egg capsules or recruits **(this report)** | sensitive to flyshoot |
|---|---|---|---|---|---|---|---|---|---|
| VOORDELTA | | | | | | | | | |
| | | | | | | | | | |
| Spiophanes bombyx | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nephtys cirrosa | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ophelia borealis | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bathyporeia elegans | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Urothoe poseidonis | | | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| Euspira pulchella | | | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| Macoma balthica | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Angulus fabulus | | | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lanice conchilega | Lanice conchilega | | 0 | 1 | 0.5 | 1 | 1 | 0 | 0 |
| Echinocardium cordatum | Echinocardium cordatum | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Buccinum undatum | Buccinum undatum | | 1 | 0 | 1 | 1 | 0 | 1 | 1 |
| Spisula subtruncata | Spisula subtruncata | | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Chamelea striatula | | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Lutraria lutraria | | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Pagurus bernhardus | | 0.5 | 0 | 0 | 1 | 0 | 0 | 0 |
| | Ophiura ophiura | | 1 | 0 | 1 | 1 | 0 | 0 | 0 |
| | | | | | | | | | |
| | | | | | | | | | |
| Spiophanes bombyx | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nephtys cirrosa | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ophelia borealis | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bathyporeia elegans | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Urothoe poseidonis | | | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| Euspira pulchella | | | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| Macoma balthica | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Angulus fabulus | | | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lanice conchilega | Lanice conchilega | | 0 | 1 | 0.5 | 1 | 1 | 0 | 0 |
| Echinocardium cordatum | Echinocardium cordatum | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Buccinum undatum | Buccinum undatum | | 0 | 0 | 1 | 1 | 0 | 1 | 1 |
| Spisula | Spisula subtruncata | | 0.5 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Chamelea striatula | | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Lutraria lutraria | | 0 | 0 | 0.5 | 0 | 0 | 0 | 0 |
| | Pagurus bernhardus | | 0 | 0 | 0.5 | 1 | 0 | 0 | 0 |
| | Ophiura ophiura | | 0.5 | 0 | 1 | 1 | 0 | 0 | 0 |
| | | | | | | | | | |
| Spiophanes bombyx | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nephtys cirrosa | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ophelia borealis | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bathyporeia elegans | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Urothoe poseidonis | | | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Euspira pulchella | | | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| Macoma balthica | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Angulus fabulus | | | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lanice conchilega | Lanice conchilega | | 0 | 0 | 0.5 | 1 | 1 | 0 | 0 |
| Echinocardiumcordatum | Echinocardium | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Buccinum undatum | Buccinum undatum | | 0 | 0 | 1 | 1 | 0 | 1 | 1 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Spisula subtruncata | Spisula subtruncata | | 0.5 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Chamelea striatula | | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Lutraria lutraria | | 0 | 0 | 0.5 | 0 | 0 | 0 | 0 |
| | Pagurus bernhardus | | 0 | 0 | 0.5 | 1 | 0 | 0 | 0 |
| | Ophiura ophiura | | 0.5 | 0 | 1 | 1 | 0 | 0 | 0 |
| | Liocarcinus arcuatus | | 1 | 0 | 1 | 1 | 0 | 0 | 0 |
| | Liocarcinus marmoreus | | 1 | 0 | 1 | 1 | 0 | 0 | 0 |
| | Owenia fusiformis | | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| | Pontocrates altamarinus | | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Magelona johnstoni | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Ostrea edulis | | 1 | 1 | 1 | 1 | 1 | 1 |
| | | | | | | | | | |
| Sigalion mathildae | | | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bathyporeia elegans | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bathyporeia guilliamsoniana | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Iphinoe trispinosa | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Echinocyamus pusillus | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Euspira pulchella | | | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| Mactra stultorum | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lanice conchilega | Lanice conchilega | | 0 | 1 | 0.5 | 1 | 1 | 0 | 0 |
| Arctica islandica | Arctica islandica | | 0 | 0 | 1 | 0.5 | 0.5 | 0 | 0 |
| Acrocnida brachiata | Acrocnida brachiata | | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| Buccinum undatum | Buccinum undatum | | 0 | 0 | 1 | 1 | 0 | 1 | 1 |
| | Gari fervensis | | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Acanthocardia echinata | | 0.5 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Ensis ensis | | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Ensis siliqua | | 0.5 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Alcyonidium diaphanum | | 1 | 0 | 1 | 1 | 1 | 0 | 1 |
| | Corystes cassivelaunus | | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Astropecten irregularis | | 0.5 | 0 | 0.5 | 1 | 0 | 0 | 0 |
| | Psammechinus miliaris. | | 1 | 0 | 0.5 | 1 | 0 | 0 | 0 |
| | Spisula subtruncata & elliptica | | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Angulus fabula | | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Magelona filiformis & johnstoni | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Nephtys assimilis | | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Owenia fusiformis | | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| | Bathyporeia eleg., guil.,nana, ten. | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Perioculodus longimanus | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Siphonoecetes kroyeranus | | 0.5 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Bathyporeia nana | | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Clymenura lankesteri | | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Bryozoa (e.g. Flustra foliacea) | | 1 | 1 | 1 | 1 | 0 | 1 |
| | | Alcyonium digitatum | | 1 | 1 | 1 | 1 | 0 | 1 |
| | | Modiolus modiolus | | 1 | 1 | 1 | 1 | 1 | 1 |
| | | | | | | | | | |
| Sabellaria spinulosa | | | 1 | 0 | 1 | 1 | 1 | 0 | 1 |
| Chone duneri | | | 1 | 0 | 1 | 1 | 1 | 0 | 1 |
| Galathea intermedia | | | 1 | 0 | 1 | 1 | 0 | 0 | 0 |
| Acropagia crassa | | | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| Pododesmus patelliformis | | | 1 | 0 | 1 | 1 | 0.5 | 0 | 0 |
| Spirobranchus triqueter | Spirobranchus triqueter | | 1 | 0 | 0 | 1 | 1 | 0 | 0 |
| Lithothamnion sonderi | Lithothamnion sonderi | | 1 | 0 | 1 | 1 | 1 | 0 | 1 |
| Alcyonium digitatum | Alcyonium digitatum | | 1 | 0 | 1 | 1 | 1 | 0 | 1 |
| Buccinum undatum | Buccinum undatum | | 0 | 0 | 1 | 1 | 0 | 1 | 1 |
| Dosinia exoleta | | | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Urticina spec. | | 1 | 0 | 1 | 1 | 1 | 0 | 1 |
| | Porifera | | 0 | 0 | 1 | 1 | 1 | 0 | 1 |
| | Hydrozoa | | 0 | 0 | 1 | 1 | 1 | 0 | 1 |
| | Opisthobranchia | | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Aporrhais pespelicani | | 1 | 0 | 1 | 1 | 0 | 0 | 0 |
| | Xandarovula patula | | 1 | 0 | 1 | 1 | 0 | 0 | 0 |
| | Aequipecten opercularis | | 1 | 0 | 1 | 1 | 0 | 0 | 0 |
| | Cerianthus loydii | | 0 | 0 | 1 | 1 | 1 | 0 | 1 |
| | Aonides paucibranchiata | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Goniadella bobretzkii | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Protodorvillea kefersteini | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Urothoe marina | | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Upogebia deltaura | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Pagurus cuanensis | | 1 | 0 | 0.5 | 1 | 0 | 0 | 0 |
| | Arctica islandica | | 0 | 0 | 1 | 0.5 | 0.5 | 0 | 0 |
| | Polititapes virgineus | | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Timoclea ovata | | 0 | 0 | 1 | 0 | 0 | 0 | 0 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Echinocyamus pusillus | | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Glyphesione klatti | | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Terebellides stroemi | | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Spiophanes kroyeri | | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| | | | | | | | | | |
| | Callianassa subterranea | | 0.5 | 1 | 1 | 0 | 0 | 0 | 0 |
| | Upogebia stellata | | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| | Upogebia deltaura | | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| | Brissopsis lyrifera | | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Dosinia lupinus | | 0.5 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Chamelea striatula | | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Corbula gibba | | 1 | 0 | 0.5 | 0 | 0 | 0 | 0 |
| | Acanthocardia echinata | | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Arctica islandica | | 1 | 0 | 1 | 0.5 | 0.5 | 0 | 0 |
| | Echinocardium flavescens | | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Turritella communis | | 1 | 0 | 1 | 1 | 0 | 0 | 0 |
| | Amphiura filiformis | | 0.5 | 0 | 0.5 | 1 | 0 | 0 | 0 |
| | Thracia phaseolina | | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Thyasira flexuosa | | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Chaetopterus variopedatus | | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Aphrodite aculeata | | 1 | 0 | 0.5 | 0 | 0 | 0 | 0 |
| | Echinocardium cordatum | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Nephtys incisa | | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Cylichna cylindracea | | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| | Sthenelais limicola | | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Terebellides stroemi | | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Nucula nitidosa | | 0.5 | 0 | 1 | 0 | 0 | 0 | 0 |
| | | Ostrea edulis | | 1 | 1 | 1 | 1 | 1 | 1 |
| | | | | | | | | | |
| | Amphiura filiformis | | 0.5 | 0 | 0.5 | 1 | 0 | 0 | 0 |
| | Callianassa subterranea | | 0.5 | 1 | 1 | 0 | 0 | 0 | 0 |
| | Upogebia deltaura | | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| | Upogebia stellata | | 0.5 | 1 | 1 | 0 | 0 | 0 | 0 |
| | Thracia convexa | | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Dosinia lupinus | | 0.5 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Goneplax rhomboides | | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Ophiura albida | | 0.5 | 0 | 0.5 | 0 | 0 | 0 | 0 |
| | Corystus cassivelaunus | | 0.5 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Echinocardium cordatum | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Euspira pulchella | | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Leptosynapta inhaerens | | 0.5 | 0 | 1 | 1 | 0 | 0 | 0 |
| | Atherospio guillei | | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Ophiodromus flexuosus | | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Nephtys incisa | | 0.5 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Podarkeopsis helgolandica/capensis | | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Ostrea edulis | | 1 | 1 | 1 | 1 | 1 | 1 |