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ILVO Mededeling D/2026/07

April 2026

# NoriVis

## Precision fishery in the Belgian beam trawl industry

## Scientific Report

**ILVO**
Flanders Research Institute for Agriculture,
Fisheries and Food

www.ilvo.vlaanderen.be

**Finance**

Europees Fonds voor Maritieme Zaken, Visserij en Aquacultuur (EFMZVA)

Vlaamse overheid

Medegefinancierd door de Europese Unie

ILVO
Flanders research institute for agriculture, fisheries and food

**In cooperation with**

natural sciences .be

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Scientific Report - Period December 2024 - December 2025

ILVO MEDEDELING D/2026/07

April 2026

ISSN 1784-3197

Wettelijk Depot: D/2026/10.970/07

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# Abbreviations

| Abbreviation | Full Meaning |
|---|---|
| AL | Al-Hamdani reference |
| avg | average |
| B | Benthos |
| CPUE | Catch per unit of effort |
| D | Discards |
| DCF | Data Collection Framework |
| EEZ | Exclusive Economic Zone |
| ETP | Endangered, Threatened and Protected |
| FSSH | Fully-Sampled Scientific Hauls |
| KW | Kruskal-Wallis test |
| L | Landings |
| MCRS | Minimum Conservation Reference Size |
| MPA | Marine Protected Area |
| NDGP | National Data Gathering Program |
| NGU | Geological Survey of Norway |
| OWA | One-way Anova |
| PCA | Principal Component Analysis |
| PSSH | Partially-Sampled Scientific Hauls |
| VT | VISTools |

# Species list

| .Species FAO Code | Scientific Name | English Name |
|---|---|---|
| BIB | *Trisopterus luscus* | Pouting |
| BLL | *Scophthalmus rhombus* | Brill |
| CAA | *Anarhichas lupus* | Atlantic wolffish |
| COD | *Gadus morhua* | Atlantic cod |
| CRE | *Cancer pagurus* | Edible crab |
| DAB | *Limanda limanda* | Common dab |
| DGS | *Squalus acanthias* | Picked dogfish |
| GUG | *Eutrigla gurnardus* | Grey gurnard |
| GUU | *Chelidonichthys lucerna* | Tub gurnard |
| HAD | *Melanogrammus aeglefinus* | Haddock |
| HAL | *Hippoglossus hippoglossus* | Atlantic halibut |
| HKE | *Merluccius merluccius* | European hake |
| LEM | *Microstomus kitt* | Lemon sole |
| LIN | *Molva molva* | Ling |
| MEG | *Lepidorhombus whiffiagonis* | Megrim |
| MON | *Lophius piscatorius* | Monkfish (Anglerfish) |
| OCC | *Octopus vulgaris* | Common octopus |
| PLE | *Pleuronectes platessa* | European plaice |
| POK | *Pollachius virens* | Saithe(=Pollock) |
| POL | *Pollachius pollachius* | Pollack |
| RJC | *Raja clavata* | Thornback ray |
| RJH | *Raja brachyura* | Blonde ray |
| RJN | *Leucoraja naevus* | Cuckoo ray |
| RJR | *Amblyraja radiata* | Starry ray |
| SFV | *Sebastes viviparus* | Norway redfish |
| SME | *Osmerus eperlanus* | European smelt |
| SQF | *Loligo forbesii* | Veined squid |
| SQR | *Loligo vulgaris* | Common squid |
| SYC | *Scyliorhinus canicula* | Lesser-spotted dogfish |
| TUR | *Scophthalmus maximus* | Turbot |
| USK | *Brosme brosme* | Tusk(=Cusk) |
| WHG | *Merlangius merlangus* | Whiting |

| | | |
|---|---|---|
| **WIT** | *Glyptocephalus cynoglossus* | Witch flounder |
| **YEZ** | *Hyperoplus lanceolatus* | Great sandeel |

# Non-Technical Summary

## Project Context

The Belgian fishing industry has a long and rich history in the Norwegian Exclusive Economic Zone (EEZ). These waters, however, form a heterogeneous mosaic of both sensitive and less-sensitive marine habitats, making it hard to continue fishing activities without harming these sensitive areas. However, net modifications, new and innovative technologies and internationally acquired expertise could enable vessels to actively avoid these sensitive areas and conduct fishing activities in less-sensitive areas. This guarantees the protection of vulnerable marine habitats while the sustainability and efficiency of the fishing industry is promoted.

This scientific pilot project investigates the potential of precision fishing in the Belgian beam trawl fishing industry, with a case study in the Norwegian Exclusive Economic Zone (EEZ). The project investigates whether modern beam trawlers, equipped with innovative technologies (e.g. WASSP multibeam echosounder), can gather information on the seabed substrate and sensitivity of the present marine habitats or species. It is tested of those technologies can assist in actively avoiding sensitive areas. To this end, various decision support tools for skippers, such as the multibeam WASSP echo sounder, will be scientifically evaluated and validated. In addition, VISTools data (e.g. location and fuel consumption), and catch data will be collected and analyzed. The collected data will then be compared with existing data to evaluate the effectiveness and accuracy of precision fishing with current technologies.

The main goals are:

1. Evaluate whether **modern trawlers** equipped with **multibeam WASSP echo sounders** or **other tools,** such as the **VISTools framework,** can **detect** and **avoid sensitive areas** with high accuracy.
2. Providing practical recommendations for **improving** this **scientific** pilot project.

## Survey

For this project, a two-week survey, split over two periods of five days, was conducted in the Norwegian EEZ. For this survey, the commercial Belgian beam trawler Z.510-“Dennis” was used. This trawler is equipped with innovative techniques, such as the VISTools digital twin or the VISIM-camera, which were also used during the survey.

During the campaign, different data types were sampled: WASSP multibeam data, catch composition data, VISIM recordings and VISTools data (e.g. fuel consumption). In total, 114 hauls were completed, with nearly all accompanied by WASSP multibeam, VISIM and VISTools recordings. Complete catch composition data (commercial, non-commercial fish fraction and benthos) was obtained for 38 of these hauls, 27 additional hauls were sampled in the context of the National Data Gathering Programme (NDGP) under European Regulation No. 2017/1004 (DCF). In this report, only hauls for which complete catch data was collected were analyzed, and are referred to as “Fully-Sampled Scientific Hauls”. Remaining hauls, referred to as “Partially-Sampled Scientific Hauls”, and accompanying datasets are stored internally for further analysis.

# Data Analysis & Results

## WASSP multibeam

Analysis of the sampled WASSP data was conducted in cooperation with the Royal Belgian Institute of Natural Sciences (RBINS). Based on internally processed multibeam data (i.e., flattened backscatter expressed as grayscale values), several acoustic groups could be identified. These groups could then be partly linked to different seabed substrate types using the available sediment maps of the study area derived from EMODnet Based on zonal statistical analysis, it could be concluded that the acoustic group with values ≤ 60 occurs more frequently in areas where coarse substrates are present. Additionally, acoustic groups with values 60-110 and > 110, corresponded to areas where more (muddy) sandy areas seem to dominate. In addition, a Principal Component Analysis (PCA) revealed that hauls classified with OSPAR Score 4 and situated in station S1 are more associated with acoustic group 60-110, while hauls labeled as low-sensitive (OSPAR score 2) are more associated with acoustic group >110.

These preliminary results indicate that the WASSP multibeam shows potential to differentiate between different substrates (sand versus sand with rock and boulders), but that some remarks need to be considered.

First, this study used internally processed backscatter data, which limited certainty in assigning substrate types; raw acoustic decibel data, accessible via the WASSP "Survey License," would improve classification. Second, the shallow penetration depth of the acoustic wave (~a few centimeters at 300 kHz) and the presence of overlying sediments or suspended particles—caused by natural processes or anthropogenic activities such as beam trawling—can obscure the underlying substrate, potentially leading to misclassification of sensitive areas as less-sensitive. Finally, the EMODnet Geology seabed substrate map, used for validation, has a low resolution (1:1,000,000) making it insufficient for comparison with high-resolution backscatter data (2.5 m). Additionally, these low-resolution substrate or sensitivity maps also introduce an additional uncertainty when interpreting results.

Furthermore, the WASSP multibeam echosounder does give differentiation in seabed substrate types, but it does not provide additional information on the grade of sensitivity of a certain area or substrate type. To do so, the WASSP multibeam should always be used in combination with other techniques, such as the presence of certain indicator species in the catch data.

## Catch Composition

Catch composition of several hauls was analyzed, revealing several trends. In or near the vicinity of highly-sensitive areas, a higher abundance of commercial-sized cod (*Gadus morhua*), monkfish (*Lophius piscatorius*) and Atlantic wolfish (*Anarhichas lupus*), was noted, while plaice (*Pleuronectes platessa*) exhibited lower abundances compared to lower-sensitive areas. In addition, it was also found that commercial-sized Atlantic wolffish cod and monkfish exhibited significantly higher abundances in areas with harder seabed substrates (coarser). A similar pattern was observed for the non-commercial fish fraction. Monkfish exhibited a significantly higher abundance in high-sensitive areas, whilst plaice and common dab (DAB) recorded significantly lower abundances. In addition, an increased abundance of the non-commercial Norway redfish (*Norvegicus viviparus*) in highly-sensitive regions was noticed. Since the latter is also classified as Endangered, Threatened and Protected (ETP) by ICES, the authors believe that this species could act as an indicator species for highly-sensitive areas.

Regarding the benthic community, sea anemones (*Actinaria*), dead man's fingers (*Alcyonium digitatum*) and sponges (*Halicondria*) recorded the highest abundance in areas with a coarse substrate type. Sea anemones and sponges were also predominantly present in OSPAR score 4 areas, meaning that they could potentially also be considered as indicator species for these highly-sensitive regions. Dead man's fingers on the other hand were only recorded in low to medium sensitive areas (OSPAR score 2 & 3) and were absent in highly-sensitive regions (OSPAR 4). This is a rather surprising result since this species is usually associated with more sensitive regions (Danish Environmental Protection Agency, 2021).

A cluster analysis revealed that a distinction could be made between softer substrates (Sand) and more coarser substrates based on the composition of the commercial-sized species (i.e. landings). In addition, some acoustic groups derived from the WASSP analysis could also be associated with some discard cluster groups.

Next to the cluster analysis, a Principal Component Analysis (PCA) of the three categories demonstrated that hauls which were located in highly-sensitive areas were characterized by an increased presence of Norway redfish and a reduced discard plaice fraction, which was also described earlier.

This report demonstrated that some non-commercial and benthic species could act as an indicator species for highly-sensitive areas. Today however, these non-commercial and benthic species are not recorded by fishers since they are discarded, making it not possible to monitor them. Intelligent camera's, such as the VISIM camera of ILVO, or registering it's presence by the vessels crew could offer a solution.

## VISTools

During the NoriVis survey, additional data from the VISTools (VT) framework was collected. VISTools monitors and records various vessel parameters, including engine, catch, and fuel data. In this project, a subset of parameters—fuel consumption (L $h^{-1}$), speed (knots), and net traction (kg)—was analyzed to evaluate their relevance to precision fisheries.

Significant higher speed, fuel consumption and traction was observed for hauls conducted in sandier areas compared to coarser substrates. This could be explained by the equipment used during the survey (i.e. chain mats), which sink in softer substrates such as sand. To prevent this, a fishing vessel will sail faster, which is translated to increased fuel consumption and traction. Additionally, highly-sensitive areas recorded higher fuel consumption, speed and traction compared to lower sensitive regions. This could be explained by a possible mismatch in classification due to the low-resolution substrate maps and associated models. For example, haul NOR2_S_27 is classified as "Sand", but is predominantly present in highly-sensitive areas. High-resolution habitat mapping could be a solution to this problem.

The assessment indicates that data from the VISTools framework could offer a useful insight into the type of substrate a fishing vessel has been operating in. However, it should be noted that the observed parameters, such as fuel consumption, are influenced by the skippers behavior. Based on for example, live-images of the WASSP multibeam, they adjust their speed in order to not lose their gear. Therefore, VISTools does not provide independent data which can be used for real-time monitoring (yet), but, when used in combination with tools such as the WASSP multibeam, it could provide an added value for precision fishery. Further analyses will explore the potential integration of WASSP data into the VISTools framework.

## VISIM

The in-house developed intelligent VISIM camera was also deployed during this project. The VISIM camera and -models are still under development, and no analytical results have been obtained yet. However, in the future, these camera's will be deployed for the remote detection and identification of certain fish species, enabling the possibility of a remote alert when species linked to sensitive grounds, such as Norway redfish, are present in the catch. Together with appropriate positioning info, such as VISTools, a more real-time assessment could be made, providing the skipper with information on the presence of substrate type and its related sensitivity.

## Recommendations & Lessons learned

Since this project was a pilot study, several recommendations could be made for future research, as well as various lessons learned. The most important ones are listed below:

- There is a need for a **uniform, complete and detailed characterization of sensitive habitats.** The mapping of these habitats could be facilitated by using data directly from the fishery fleet such as catch composition in combination with WASSP images. This characterization could be further carried out by an international oriented working group, consisting both of Norwegian and foreign scientists.
- There is a need for a complete and clear **protocol for fishing vessels** in case signs are present that fishing activities took place in a sensitive area. (e.g. guidelines on how vessels should be relocated, or fishing equipment should be adapted).
- The current analysis showed that the WASSP multibeam displayed potential to distinguish between different substrates. Therefore, the **integration** of this data source in **data platforms**, such as VISTools, should be considered in future analysis.
- **Habitat maps** which were extracted from EMODnet demonstrated a **low spatial resolution** resulting in some **uncertainty on the present substrate type** or **sensitivity level**. Detailed mapping with e.g. side scan sonar of WASSP multibeam with Survey License, could offer a solution.
- Backscatter values expressed in gray-scale values make it difficult to assign a substrate type to the acoustic groups. It is better to use acoustic decibels, which provide an indication for the classification. Therefore, it is advised to install a **WASSP Survey License**, which enables the recording and processing of this raw acoustic backscatter data and translate it in substrate maps.
- Future projects should include the **impact of rising sediments** originating from e.g. fishing activities on the WASSP readings.
- **Presence of certain (ETP-)species** (i.e. Norway redfish) could indicate that fishing activities took place in sensitive areas. However, nowadays this is **not automatically recorded**, as they are discarded (non-commercial fraction). An intelligent camera, such as VISIM , could offer a solution by identifying all present species in the catch (fish and benthos). During the NoriVis project, the in-house developed VISIM camera (ILVO-VISIM) was deployed, but no analytical results were obtained yet. Another feasible solution would be the real-time monitoring of certain species by the vessel crew itself.
- During the project, no **length measurements** were collected during the Fully-Sampled Scientific Hauls, excluding this parameter from the analysis. However, it would be interesting for future projects to also investigate this parameter to evaluate if certain length classes could be associated with certain substrates or sensitivities.
- The NoriVis survey was characterized by a rather **non-uniform sampling**, meaning that certain areas or habitats were more sampled than others. This makes it harder to compare these areas and habitats with each other. In future projects, a more equal sampling design could be strived for.

- In addition to the previous recommendation, future projects should focus on **more homogeneous composition of the hauls**. Hauls conducted in this report were often a combination of several substrates or sensitivity levels, making it harder to provide non-biased results for a certain substrate type or sensitivity level. Future projects should therefore ensure that hauls should mainly be conducted in the same substrate type or at the same sensitivity level.
- More samples were taken during daytime than at nighttime. To get an estimation of the effect of the presence of light during the sampling, future projects should include a **comparison** of hauls between **day- and nighttime.**
- Some hauls were conducted outside the allocated research area. In future research, more attention should be paid to the determination of the position of the various tracks, and **expertise of the participating country** should **be consulted**. Having the engagement of the participating country (Norway in this study), could deliver optimal results for both countries and improve the sampling procedure.
- In addition to the conducted measurements which are described in this report, **samples of the seafloor (grab samples)** could also be included in future projects. These samples give a direct indication of the present substrate and provide extra verification of the WASSP data.
- Next to assessing the effects of suspended particles on the acoustic signal, the effect of the **sediment plume** caused by **bottom trawling** should be further investigated.
- Future projects should also explore the use of **alternative fishing gear**, such as **tickler beam trawling** in combination with sumwing. During this survey, a heavy chain-mat was used with a traditional beam, which is less suitable for fishing in softer substrates (i.e. sand). Tickler chains combined with a sumwing are commonly used on softer substrates and coarser areas are naturally avoided, meaning that impact on these areas would also be reduced.

# Conclusion

The NoriVis project served as a scientific pilot study to explore techniques for improving the real-time characterization of the seafloor and its associated sensitivity, with the aim of supporting precision fisheries and guiding future research. The study demonstrated that the WASSP multibeam echosounder shows promise in differentiating seabed substrate types, though results remain explorative and require cautious interpretation. While substrate types can be distinguished, assessing habitat sensitivity requires combining WASSP data with other sources, such as catch composition. However, current technical and biological knowledge is not yet mature enough to have a real-time application such as the avoidance of sensitive marine habitats. Further research is thus required to optimize the different tools and data gathering procedures. Additionally, clear definitions of habitat sensitivity and  species, produced by Norwegian and/or international scientists, are needed to improve practical application. Nonetheless, the study provides valuable insights, recommendations, and a foundation for future work in selective and environmentally responsible fisheries.

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# Introduction

# 1. Seabed Disturbance

## 1.1. Quantifying impact

The majority of the Belgian fishing fleet consists of beam trawling vessels, specialized in catching flatfish such as plaice or sole (Scherrens, 2024). This fishing technique involves a vessel dragging a funnel shaped net across the seafloor at approximately 4-6 knots. During the towing, the seafloor is disturbed due to the interaction between the components of the net and the seafloor, impacting marine fauna and flora (Ghorai et al., 2025). This footprint impact for varying fishing techniques is mostly estimated by vessel monitoring data and gear specification (Eigaard et al., 2017), however, due to varying fishing techniques and marine habitats, hard to estimate.

In general, the impact of fishing activities on the seafloor is estimated by two components: 1) the footprint of the involved vessel on the seafloor and 2) the bottom sensitivity of a certain area. Together, they are combined to an unambiguous indicator (Depestele & Van Hoey et al., 2022).

Nowadays, several indicators are used to assess seabed disturbance, all with their own history, specifications and objectives. On the one hand, a qualitative approach, based on several sensitivity categories, could be implemented, such as the MarLIN of OSPAR BH3 indicators. Other indicators, such as the Relative Benthic State or RBS indicator, use a quantitative approach based on the lifespan of bottom fauna.

Two of these indicators -OSPAR BH3 and RBS- are applied on a broad scale. They share the same principles, i.e. quantifying the bottom impact based on the vessel footprint and bottom sensitivity, but differ in method of quantification. Both methods are valid and have been found to be sufficiently effective, but the relationship between the two still needs to be determined. For instance, different risk-impact assessments are produced with these indicators for the same area. Since these assessments form the basis for the management of human activities at sea, and more specifically, fishing activities, it is important to continue investing in follow-up and research into the assessment methodologies (Depestele & Van Hoey et al., 2022).

## 1.2. Reducing seabed disturbance

Depestele & Van Hoey et al. (2022) suggest three possible principles to reduce the impact of fisheries on the seabed. First, acute disturbance of the seafloor should be avoided as much as possible. This can be realized by technical adaptations to the equipment used, which for example could minimize seafloor penetration. Second, fishing should take place in areas where fishing occurs regularly. Areas where fishing disturbs the sea floor for the first time experience a higher mortality rate than areas where seabed disturbance occurs frequently. Third and last, fishing should focus on resistant and fast recovering areas. Areas with a low recovering rate should be avoided as much as possible.

Adaptations to fishing equipment and a well-considered choice of fishing grounds do contribute to a reduced impact of fisheries on the seafloor and the community that lives there. The latter is not an easy choice, but the effect is significant. Therefore, it is important to correctly quantify sensitive areas, as well as using the correct tools to identify them (e.g. relation to catch composition).

Scientific research has demonstrated that the seafloor impact of towed demersal fishing gears varies strongly depending on the physical characteristics of the fishing grounds ( (Eigaard et al., 2017; Rijnsdorp et al., 2016)

On hard substrates such as reefs, stones and biogenic structures, many organisms are physically attached to the seabed. When demersal gears pass over such grounds, they scrape the substrate, detaching and damaging sessile fauna and causing substantial habitat degradation (Kaiser et al., 2006). This reduces local abundance and alters species composition, particularly in habitats with slow-growing epifauna such as sponges, bryozoans, and coralline algae.

In contrast, in soft, muddy sediments—particularly in deeper areas such as *Nephrops* grounds—trawling may partly destroy the habitat structures built by benthic organisms. Tube-building polychaetes and burrowing crustaceans are especially affected, as trawl doors and ground gear can infill or collapse their burrows and tubes (Tuck et al., 2017; Hiddink et al., 2011; ICES 2022a). This mechanical disturbance can alter sediment properties and community structure, resulting in slower recovery and shifts towards opportunistic species (Depestele et al., 2019).

Certain habitats, however, are more resilient. Dynamic, shallow fishing grounds with sandy sediments naturally experience frequent physical disturbance by waves and currents. The communities living there tend to consist of short-lived species adapted to frequent perturbation, so trawling does not increase mortality or alter species composition in the same way as for sensitive habitats (Eigaard et al., 2017; Hiddink et al., 2006).

To minimize seafloor disturbance and associated ecological effects, careful selection of fishing grounds is essential (Eigaard et al., 2017). This is relatively straightforward on extensive sandy flats where sediment composition is uniform over large areas. It becomes more difficult in heterogeneous environments where reefs, stones and sandy areas are closely interspersed (Rijnsdorp, Hiddink, et al., 2020).

### 1.2.1. Monitoring and technological support

The main challenge is to detect and discriminate sandy areas from stony or biogenic grounds, especially when they are closely intertwined. Sediment maps and nautical charts such as EUSeaMap provide valuable guidance (EMODnet, 2022), but real-time seabed verification remains essential to avoid accidental damage.

The Belgian beam-trawl fleet, supported by ILVO, is currently investigating several methods to achieve this. Multibeam echosounder systems such as WASSP are used to detect changes in seabed hardness and texture, while continuous analysis of catch composition helps verify sediment type. Together, these technologies enable fishers to target less sensitive sandy areas and avoid vulnerable habitats, thus contributing to more sustainable demersal fishing practices (Depestele et al., 2019; Rijnsdorp, Depestele, et al., 2020)

## 1.3. Precision Fishery

At the Flanders Research Institute for Agriculture, Fisheries and Food (ILVO), precision fishery means the development and application of innovative techniques and high-tech solutions for fisheries. These should allow for more and better data collection, more selective fishing with less environmental impact, more efficient operation and management of vessels and fishing activities, and better valorization.

Focusing on seabed disturbance, precision fishery means the development of new- and assessment of existing tools which could be applied for the characterization, detection and avoidance of (highly) sensitive areas.

Within ILVO, several projects are already running which contribute to this project. It developed for instance the digital twin VISTools (see §6.2) and is also testing an AI-driven camera to map catch composition (see §6.5). Additionally, the NoriVis project evaluates if the WASSP multibeam could also contribute to the concept of precision fishery.

More info on running ILVO-projects related to precision fisheries can be found through: https://ilvo.vlaanderen.be/en/dossiers/precision-fishing

# 2. NoriVis

## 2.1. Project context

The fishing industry has been under pressure for decades due to high fuel costs, catch restrictions or the closure of fishing grounds because of the construction of offshore wind farms or the creation of Marine Protected Areas (MPA's). Currently, large areas are assigned as MPA, wherein nature conservation measures (e.g. closures) are taken to reduce bottom disturbance activities, focusing on mobile bottom trawl fishery. As such, (Belgian) beam trawl vessels are increasingly limited in their operations. In addition, the available fishing grounds are increasingly regulated by numerous (European) directives. Norway, for example, decided in 2022 to close its Exclusive Economic Zone (EEZ) to (Belgian) beam trawl fishing. In this way, it aims to protect sensitive areas such as rocky reefs and gravel beds. However, this beam trawl ban also closes off sandy areas that are considered less sensitive.

The Belgian fishing industry wants to continue fishing activities in less-sensitive areas (even within MPAs), while focusing on avoiding sensitive and ecologically important areas (within and outside MPAs). Modifications to fishing gear, innovative technology, and years of know-how should ensure that vessels are able to avoid vulnerable areas with a high degree of accuracy, and that only less-sensitive areas are being fished. This guarantees the protection of vulnerable marine habitats and promotes the sustainability and efficiency of the fishing industry. In this way, the protection of the marine ecosystem is not only managed by policy rules (e.g. closures), but also from the fishing industry side. This is a good principle, but we are not yet there to practically implement and guide the sector in this.

Therefore, this pilot study investigates and evaluates the potential for precision fishing in Belgian beam trawl industry, applied to the Norwegian exclusive economic zone (EEZ). The project aims to determine whether modern beam trawlers equipped with innovative technologies—such as the WASSP multibeam echosounder—can effectively avoid sensitive areas and selectively target areas classified as less-sensitive. To evaluate these tools, available information (e.g. substrate and sensitivity maps) will be used for comparison and evaluate the effectiveness and accuracy of the proposed tools.

## 2.2. Project Goals

The NoriVis project has two major goals, which are listed below:

1. Evaluate whether **modern trawlers** equipped with **multibeam WASSP echo sounders** or **other tools** can **detect** and **avoid sensitive areas** with high accuracy.
2. Providing **practical recommendations** for improving this pilot and future scientific projects.

# Material & Methods

# 3. Terminology: Backscatter

In this report, the term “Backscatter” will be mentioned. This section provides a brief explanation of what this concept is all about.

Backscatter is the reflection of a signal—such as sound waves or light—back toward its source, in this case a multibeam sonar. Backscatter plays a crucial role in hydrography and marine science since different substrate types reflect a different intensity of the signal. For instance, hard substrates, such as rock, absorb fewer acoustic waves than softer substrates, such as sand, resulting in a higher backscattered signal. In this way, based on the signal received (i.e. backscatter), an estimation could be made of which  type of substrate is present (US Department of Commerce, 2024).

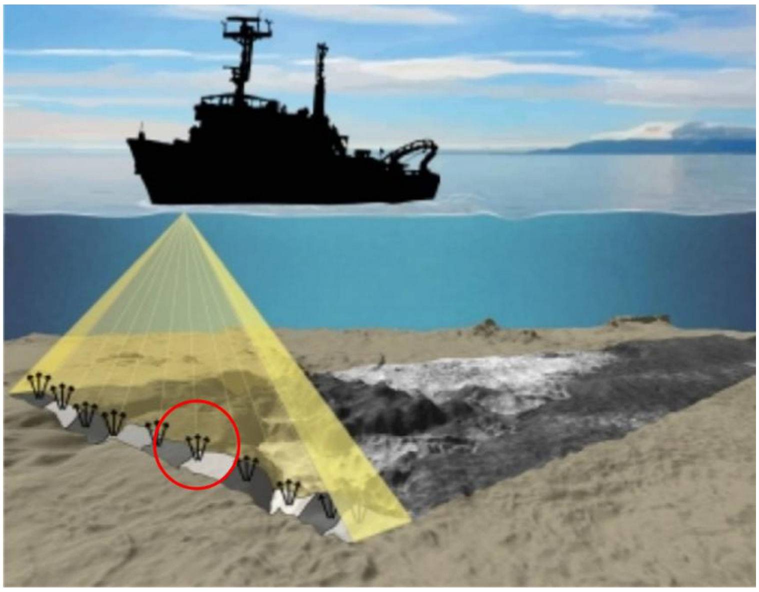


*Figure 3-1 Visualization of “backscatter” (red circle) originating from a multibeam sonar. Figure taken from Applied Oceans Research Group (AORG) (n.d.)*

# 4. Survey Design

## 4.1. Study Area

For the NoriVis survey, certain designated test areas were determined in the Norwegian waters, as described by the project dipclear which was added to the annex of this report (*ANNEX C: Documentation*). These areas are shown in **Figure 4-1** and are labeled B1, B2 and B3 (boxes) and S1 and S2 (lines), respectively. Coordinates of these boxes and lines are added to Annex A (**Table A- 1**)

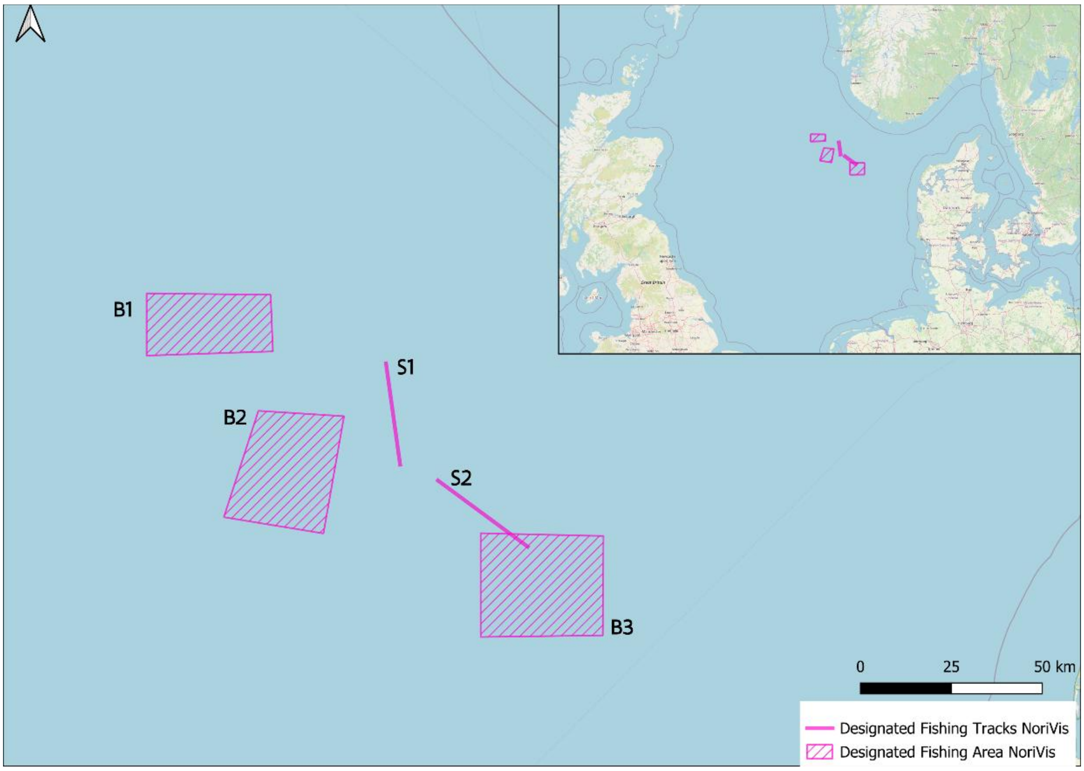


***Figure 4-1*** *Predetermined fishing areas of the NoriVis project.*

Over the survey period, a total of 114 hauls were conducted over two five-day survey periods, referred to as NOR1 and NOR2. For almost all of them, WASSP-data was obtained. For 38 of the total hauls fished, supplementary catch composition data of fish (commercial and non-commercial fraction) and benthos was collected. Additionally, 28 hauls were also sampled with the methodology and procedures as described under the National Data Gathering Program (NDGP- Work Plans - Data Collection Framework - DCF - European Commission). This diverse working method allows comparison with already existing methods and obligations, albeit in future research.

As the project is limited in time, room aboard the survey vessel and personnel, it is not possible to process all the data collected. Therefore, it is decided that only hauls for which complete catch composition, VISTools and WASSP data was collected will be included in the analysis, and that these hauls will be referred to as **"Fully-Sampled Scientific hauls" (FSSHs).**

Other hauls -referred to as "**Partially-Sampled Scientific Hauls" (PSSHs)-** miss one or more types of datasets (e.g. catch composition data) and will be stored for future research and analysis.

*__Table 4-1__ Summary of the collected data series of the Fully-Sampled Scientific Hauls (NOR_S_) and Partially-Sampled Scientific Hauls (NOR_C_). Fully-Sampled scientific hauls are highlighted in green. For each haul, shoot and haul time is given. The presented date corresponds with the shoot date. The different data series are: WASSP multibeam data (WASSP), catch composition data (Catch), VISTools data (VISTools) and VISIM data (VISIM). An "X" marks if one of the latter data series was sampled during the specific hauls. An "X*" marks a partially sampled data series.*

| Haul nr. | Date | Shoot time | Haul time | Haul ID | Data type | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | WASSP | Catch | VISTools | VISIM | NDGP |
| 1 | 3/04/2025 | 23h50 | 1h15 | NOR1_C_1 | X | | X | X | |
| 2 | 4/04/2025 | 01h30 | 03h45 | NOR1_C_2 | X | | X | X | |
| 3 | 4/04/2025 | 03h55 | 06h15 | NOR1_C_3 | X | | X | X | |
| 4 | 4/04/2025 | 06h25 | 08h45 | NOR1_C_4 | X | | X | X | |
| 5 | 4/04/2025 | 08h55 | 10h05 | NOR1_S_1 | X | X | X | X | |
| 6 | 4/04/2025 | 10h10 | 12h30 | NOR1_C_5 | X | | X | X | X |
| 7 | 4/04/2025 | 12h40 | 15h00 | NOR1_C_6 | X | | X | X | |
| 8 | 4/04/2025 | 15h30 | 16h30 | NOR1_S_2 | X | X | X | X | |
| 9 | 4/04/2025 | 16h45 | 19h00 | NOR1_C_7 | X | | X | X | X |
| 10 | 4/04/2025 | 19h10 | 21h30 | NOR1_C_8 | X | | X | X | |
| 11 | 4/04/2025 | 21h45 | 22h45 | NOR1_S_3 | X | X | X | X | |
| 12 | 4/04/2025 | 22h55 | 01h15 | NOR1_C_9 | X | | X | X | X |
| 13 | 5/04/2025 | 01h20 | 03h45 | NOR1_C_10 | X | | X | X | |
| 14 | 5/04/2025 | 03h55 | 05h00 | NOR1_S_4 | X | X | X | X | |
| 15 | 5/04/2025 | 05h15 | 07h30 | NOR1_C_11 | X | | X | X | X |
| 16 | 5/04/2025 | 07h10 | 10h00 | NOR1_C_12 | X | | X | X | |
| 17 | 5/04/2025 | 10h40 | 11h40 | NOR1_S_5 | X | X | X | X | |
| 18 | 5/04/2025 | 12h00 | 14h30 | NOR1_C_13 | X | | X | X | |
| 19 | 5/04/2025 | 14h40 | 15h45 | NOR1_S_6 | X | X | X | X | |
| 20 | 5/04/2025 | 16h15 | 18h30 | NOR1_C_14 | X | | X | X | X |
| 21 | 5/04/2025 | 18h40 | 21h00 | NOR1_C_15 | X | | X | X | |
| 22 | 5/04/2025 | 21h10 | 22h15 | NOR1_S_7 | X | X | X | X | |
| 23 | 5/04/2025 | 22h25 | 0h45 | NOR1_C_16 | X | | X | X | X |
| 24 | 6/04/2025 | 01h00 | 03h15 | NOR1_C_17 | X | | X | X | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **25** | 6/04/2025 | 03h30 | 05h45 | NOR1_C_18 | X | | X | X | |
| **26** | 6/04/2025 | 05h55 | 07h00 | NOR1_S_8 | X | X | X | X | |
| **27** | 6/04/2025 | 07h15 | 09h30 | NOR1_C_19 | X | | X | X | |
| **28** | 6/04/2025 | 09h40 | 12h00 | NOR1_C_20 | X | | X | X | X |
| **29** | 6/04/2025 | 12h10 | 13h15 | NOR1_S_9 | X | X | X | X | |
| **30** | 6/04/2025 | 13h30 | 15h45 | NOR1_C_21 | X | | X | X | |
| **31** | 6/04/2025 | 16h00 | 18h00 | NOR1_C_22 | X | | X | X | |
| **32** | 6/04/2025 | 18h45 | 21h00 | NOR1_C_23 | X* | | X | X | |
| **33** | 6/04/2025 | 23h00 | 01h15 | NOR1_C_24 | | | X | X | |
| **34** | 7/04/2025 | 01h20 | 03h45 | NOR1_C_25 | | | X | X | |
| **35** | 7/04/2025 | 03h55 | 06h15 | NOR1_C_26 | | | X | X | X |
| **36** | 7/04/2025 | 06h20 | 08h45 | NOR1_C_27 | X | | X | X | |
| **37** | 7/04/2025 | 09h30 | 10h30 | NOR1_S_10 | X | X | X | X | |
| **38** | 7/04/2025 | 10h45 | 13h00 | NOR1_C_28 | X | | X | X | X |
| **39** | 7/04/2025 | 13h15 | 15h30 | NOR1_C_29 | X | | X | X | |
| **40** | 7/04/2025 | 15h40 | 16h45 | NOR1_S_11 | X | X | X | X | |
| **41** | 7/04/2025 | 17h00 | 19h15 | NOR1_C_30 | X | | X | X | |
| **42** | 7/04/2025 | 20h00 | 22h15 | NOR1_C_31 | X | | X | X | X |
| **43** | 7/04/2025 | 22h45 | 23h45 | NOR1_S_12 | X | X | X | X | |
| **44** | 8/04/2025 | 00h00 | 02h15 | NOR1_C_31 | X | | X | X | |
| **45** | 8/04/2025 | 02h30 | 04h45 | NOR1_C_32 | X | | X | X | |
| **46** | 8/04/2025 | 05h00 | 07h15 | NOR1_C_33 | X* | | X | X | |
| **47** | 8/04/2025 | 07h30 | 08h30 | NOR1_S_13 | | X | X | X | |
| **48** | 8/04/2025 | 08h45 | 11h00 | NOR1_C_34 | X | | X | X | |
| **49** | 8/04/2025 | 12h10 | 13h10 | NOR1_S_14 | X | X | X | X | |
| **50** | 8/04/2025 | 13h15 | 15h30 | NOR1_C_35 | X | | X | X | X |
| **51** | 8/04/2025 | 15h40 | 16h45 | NOR1_S_15 | X | X | X | X | |
| **52** | 8/04/2025 | 16h50 | 19h20 | NOR1_C_36 | X | | X | X | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **53** | 8/04/2025 | 19h30 | 20h30 | NOR1_S_16 | X | X | X | X | |
| **54** | 8/04/2025 | 20h40 | 23h15 | NOR1_C_37 | X | | X | X | X |
| **55** | 8/04/2025 | 23h30 | 01h30 | NOR1_C_38 | X* | | X | X | |
| **56** | 10/04/2025 | 00h45 | 03h00 | NOR2_C_39 | | | X | X | X |
| **57** | 10/04/2025 | 03h15 | 05h30 | NOR2_C_40 | | | X | X | |
| **58** | 10/04/2025 | 05h45 | 08h00 | NOR2_C_41 | | | X | X | |
| **59** | 10/04/2025 | 08h15 | 09h20 | NOR2_S_17 | X | X | X | X | |
| **60** | 10/04/2025 | 09h30 | 12h00 | NOR2_C_42 | X | | X | X | X |
| **61** | 10/04/2025 | 12h15 | 15h00 | NOR2_C_43 | X | | X | X | |
| **62** | 10/04/2025 | 15h35 | 16h35 | NOR2_S_18 | X | X | X | X | |
| **63** | 10/04/2025 | 16h50 | 19h00 | NOR2_C_44 | X | | X | X | X |
| **64** | 10/04/2025 | 19h15 | 21h30 | NOR2_C_45 | X | | X | X | |
| **65** | 10/04/2025 | 21h45 | 22h45 | NOR2_S_19 | X | X | X | X | |
| **66** | 10/04/2025 | 23h00 | 01h15 | NOR2_C_46 | | | X | X | |
| **67** | 11/04/2025 | 01h30 | 03h45 | NOR2_C_47 | X* | | X | X | |
| **68** | 11/04/2025 | 04h20 | 05h20 | NOR2_S_20 | | X | X | X | |
| **69** | 11/04/2025 | 05h30 | 07h50 | NOR2_C_48 | X | | X | X | |
| **70** | 11/04/2025 | 08h00 | 09h00 | NOR2_S_21 | X | X | X | X | |
| **71** | 11/04/2025 | 09h15 | 11h40 | NOR2_C_49 | X | | X | X | X |
| **72** | 11/04/2025 | 12h00 | 13h00 | NOR2_S_22 | X | X | X | X | |
| **73** | 11/04/2025 | 13h15 | 15h30 | NOR2_C_50 | X | | X | X | X |
| **74** | 11/04/2025 | 15h45 | 16h45 | NOR2_S_23 | X | X | X | X | |
| **75** | 11/04/2025 | 17h00 | 19h15 | NOR2_C_51 | X | | X | X | |
| **76** | 11/04/2025 | 19h45 | 22h00 | NOR2_C_52 | X | | X | X | X |
| **77** | 11/04/2025 | 22h15 | 23h15 | NOR2_S_24 | X | X | X | X | |
| **78** | 11/04/2025 | 23h30 | 01h45 | NOR2_C_53 | X | | X | X | |
| **79** | 12/04/2025 | 02h05 | 04h15 | NOR2_C_54 | X | | X | X | |
| **80** | 12/04/2025 | 04h30 | 06h45 | NOR2_C_55 | X | | X | X | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **81** | 12/04/2025 | 07h00 | 08h00 | NOR2_S_25 | X | X | X | X | |
| **82** | 12/04/2025 | 08h15 | 10h30 | NOR2_C_56 | X | | X | X | X |
| **83** | 12/04/2025 | 10h45 | 11h45 | NOR2_S_26 | X | X | X | X | |
| **84** | 12/04/2025 | 12h00 | 13h00 | NOR2_S_27 | X | X | X | X | |
| **85** | 12/04/2025 | 13h10 | 15h30 | NOR2_C_57 | X | | X | X | X |
| **86** | 12/04/2025 | 15h45 | 16h45 | NOR2_S_28 | X | X | X | X | |
| **87** | 12/04/2025 | 17h00 | 19h45 | NOR2_C_58 | X | | X | X | |
| **88** | 12/04/2025 | 19h00 | 21h15 | NOR2_C_59 | X | | X | X | X |
| **89** | 12/04/2025 | 21h30 | 22h30 | NOR2_S_29 | X | X | X | X | |
| **90** | 12/04/2025 | 22h45 | 01h00 | NOR2_C_60 | X* | | X | X | |
| **91** | 13/04/2025 | 01h15 | 03h30 | NOR2_C_61 | | | X | X | |
| **92** | 13/04/2025 | 03h40 | 06h00 | NOR2_C_62 | | | X | X | X |
| **93** | 13/04/2025 | 06h20 | 07h20 | NOR2_S_30 | X | X | X | X | |
| **94** | 13/04/2025 | 07h30 | 09h50 | NOR2_C_63 | X | | X | X | |
| **95** | 13/04/2025 | 10h00 | 11h10 | NOR2_S_31 | X | X | X | X | |
| **96** | 13/04/2025 | 11h25 | 12h30 | NOR2_S_32 | X | X | X | X | |
| **97** | 13/04/2025 | 12h45 | 15h00 | NOR2_C_64 | X | | X | X | X |
| **98** | 13/04/2025 | 15h15 | 17h30 | NOR2_C_65 | X | | X | X | |
| **99** | 13/04/2025 | 18h00 | 19h00 | NOR2_S_33 | X | X | X | X | |
| **100** | 13/04/2025 | 19h15 | 21h30 | NOR2_C_66 | X | | X | X | X |
| **101** | 13/04/2025 | 21h45 | 22h45 | NOR2_S_34 | X | X | X | X | |
| **102** | 13/04/2025 | 23h00 | 01h15 | NOR2_C_67 | X | | X | X | |
| **103** | 14/04/2025 | 01h30 | 03h45 | NOR2_C_68 | X | | X | X | |
| **104** | 14/04/2025 | 04h00 | 06h15 | NOR2_C_69 | X | | X | X | |
| **105** | 14/04/2025 | 06h30 | 07h30 | NOR2_S_35 | X | X | X | X | |
| **106** | 14/04/2025 | 07h40 | 10h00 | NOR2_C_70 | X | | X | X | |
| **107** | 14/04/2025 | 10h15 | 11h15 | NOR2_S_36 | X | X | X | X | |
| **108** | 14/04/2025 | 11h25 | 12h30 | NOR2_S_37 | X | X | X | X | |

|  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|
| **109** | 14/04/2025 | 12h45 | 15h00 | NOR2_C_71 | X |  | X | X | X |
| **110** | 14/04/2025 | 16h10 | 17h10 | NOR2_S_38 | X | X | X | X |  |
| **111** | 14/04/2025 | 17h30 | 19h45 | NOR2_C_72 | X |  | X | X | X |
| **112** | 14/04/2025 | 20h00 | 22h20 | NOR2_C_73 | X |  | X | X |  |
| **113** | 14/04/2025 | 22h30 | 01h00 | NOR2_C_74 | X |  | X | X | X |
| **114** | 14/04/2025 | 01h15 | 03h30 | NOR2_C_75 | X |  | X | X |  |

### 4.1.1. Fully-Sampled Scientific Hauls

The “**Fully-Sampled Scientific Hauls**” were labeled as ‘NOR1/2_S_number and highlighted in green in **Table 4-1**. The location of the different hauls are visualized in **Figure 4-2**, with an additional breakdown of the different scientific hauls per designated survey area provided in **Figure 4-3**, **Figure 4-4**, **Figure 4-5**, **Figure 4-6** and **Figure 4-7**. Due to the exploratory character of the project and the change in timing, a miscommunication occurred, which caused sampling to take place outside the allocated scientific areas. Additionally, since *Fully-Sampled Scientific* and *Partially-Sampled Scientific Hauls* were conducted directly after each other, it was sometimes hard to maneuver the different hauls inside the allocated research areas. Moreover, due to the low resolutions of the maps used (see §5), and the type of pilot study conducted (i.e. chartering a commercial fishing vessel), some of the fishing track deviated from the allocated research area.

Exact coordinates of begin (shoot) and end (haul) points of each haul are summarized in **Table A- 2**.

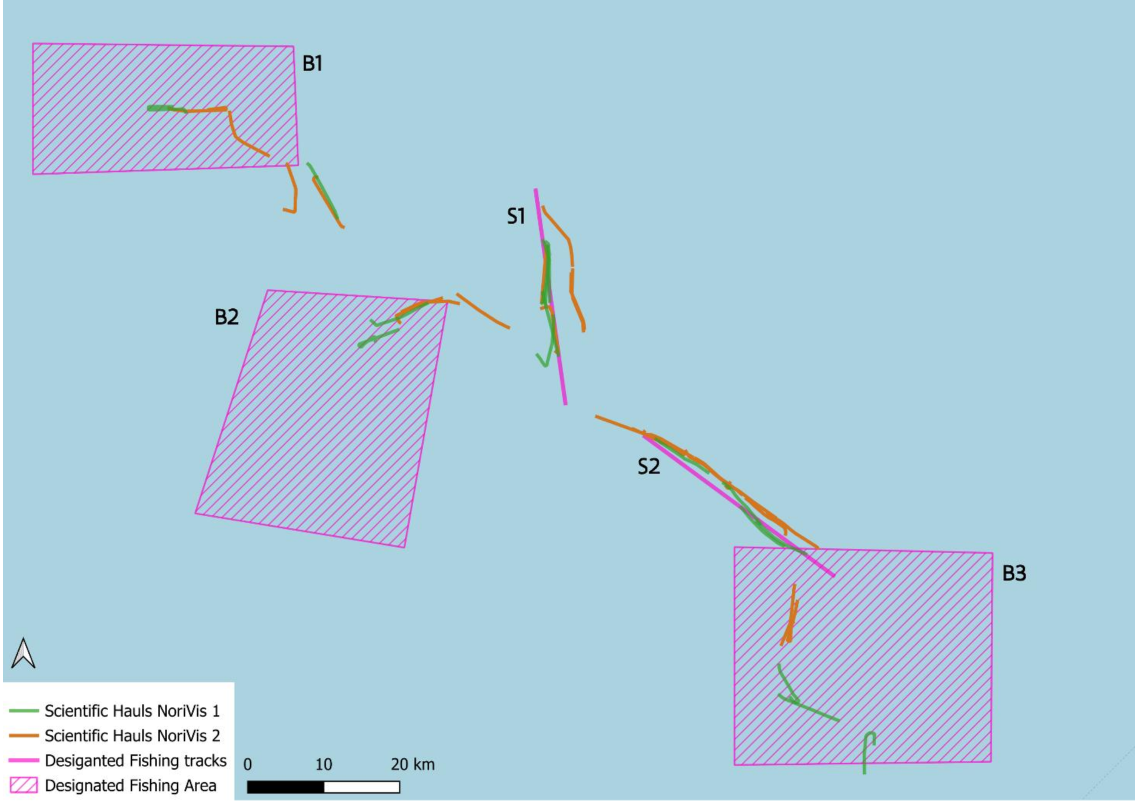


*Figure 4-2 All Fully-Sampled Scientific hauls which were conducted during the NoriVis survey.*

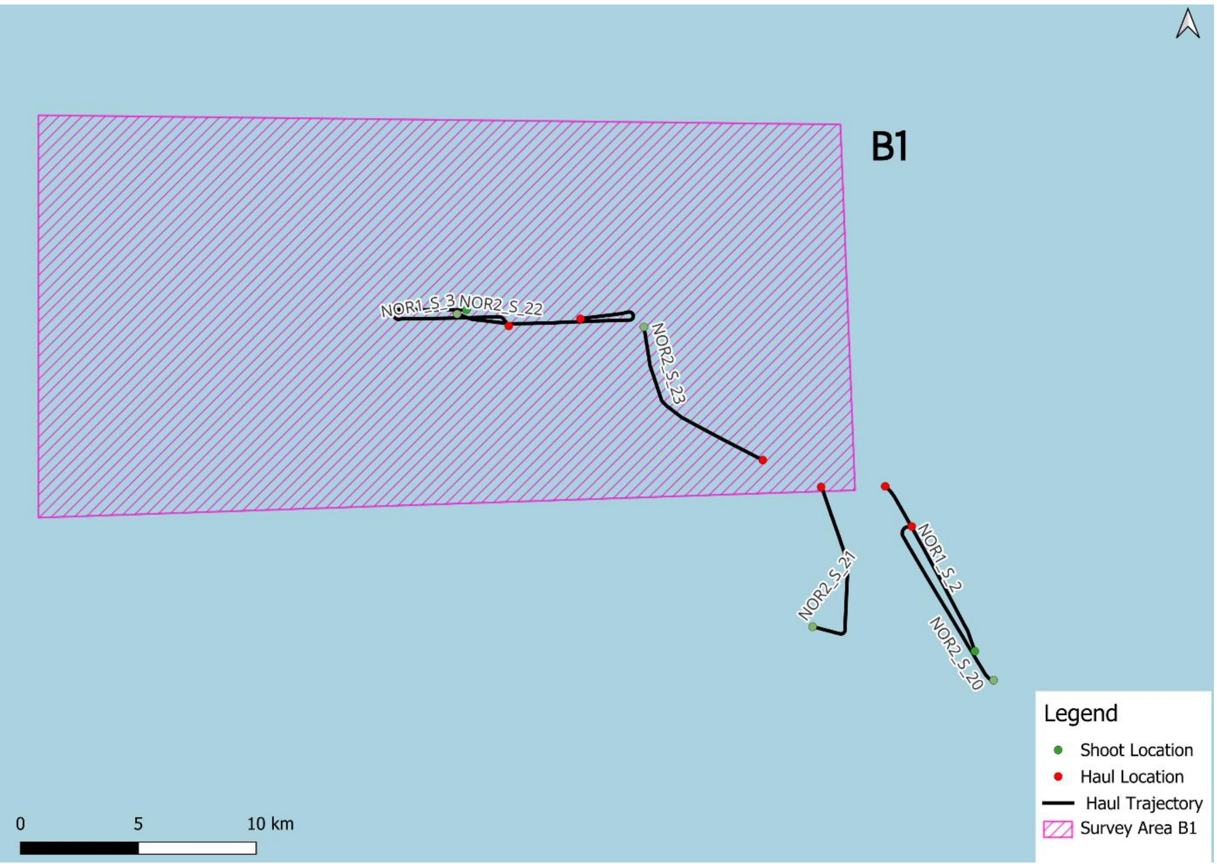


*Figure 4-3* Fully-Sampled Scientific hauls conducted in or in the surroundings of survey area *B1.*

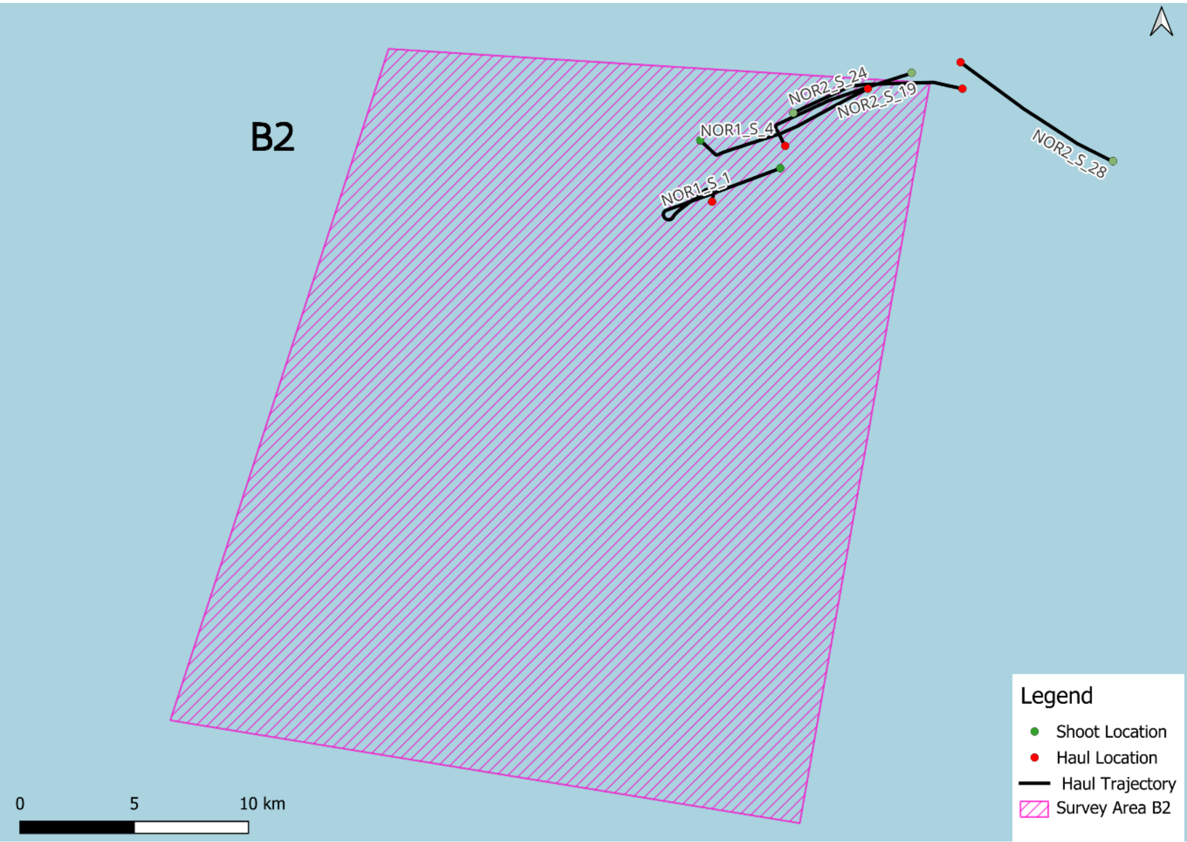


*Figure 4-4* Fully-Sampled Scientific hauls conducted in or in the surroundings of survey area *B2.*

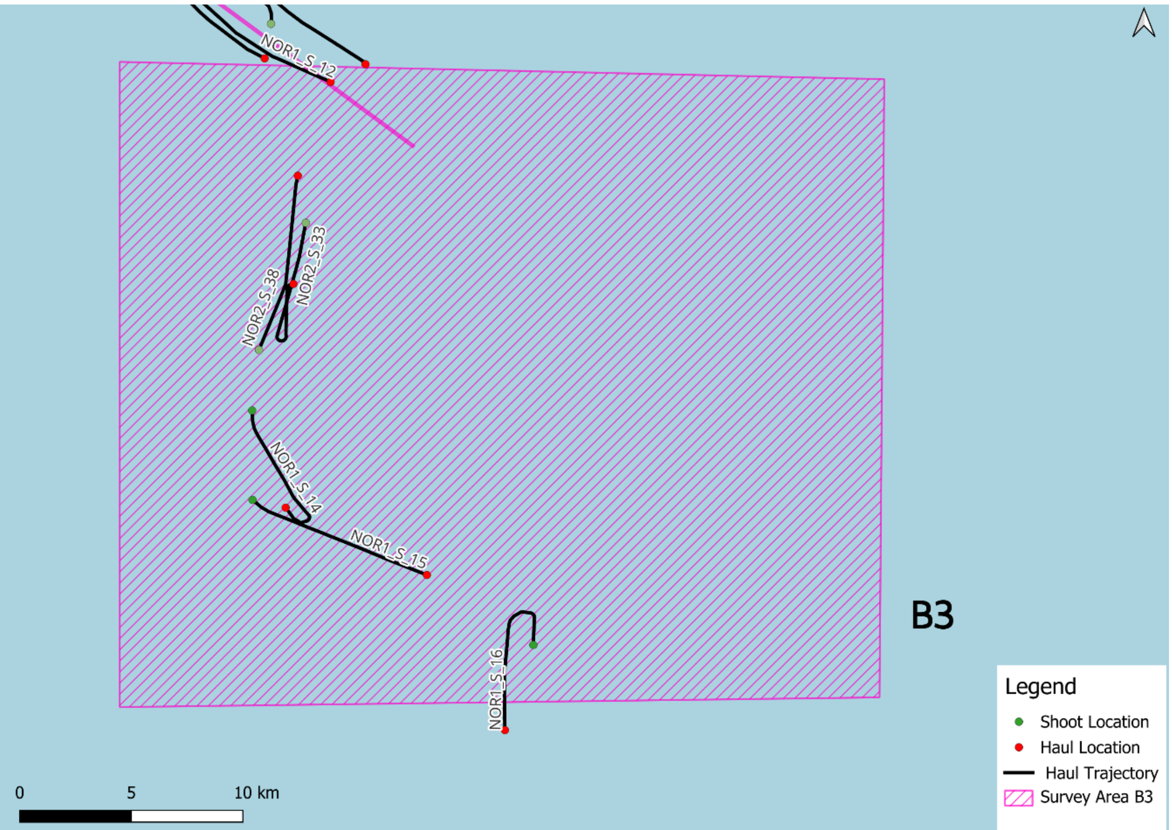


*Figure 4-5 Fully-Sampled Scientific hauls conducted in or in the surroundings of survey area **B3**.*

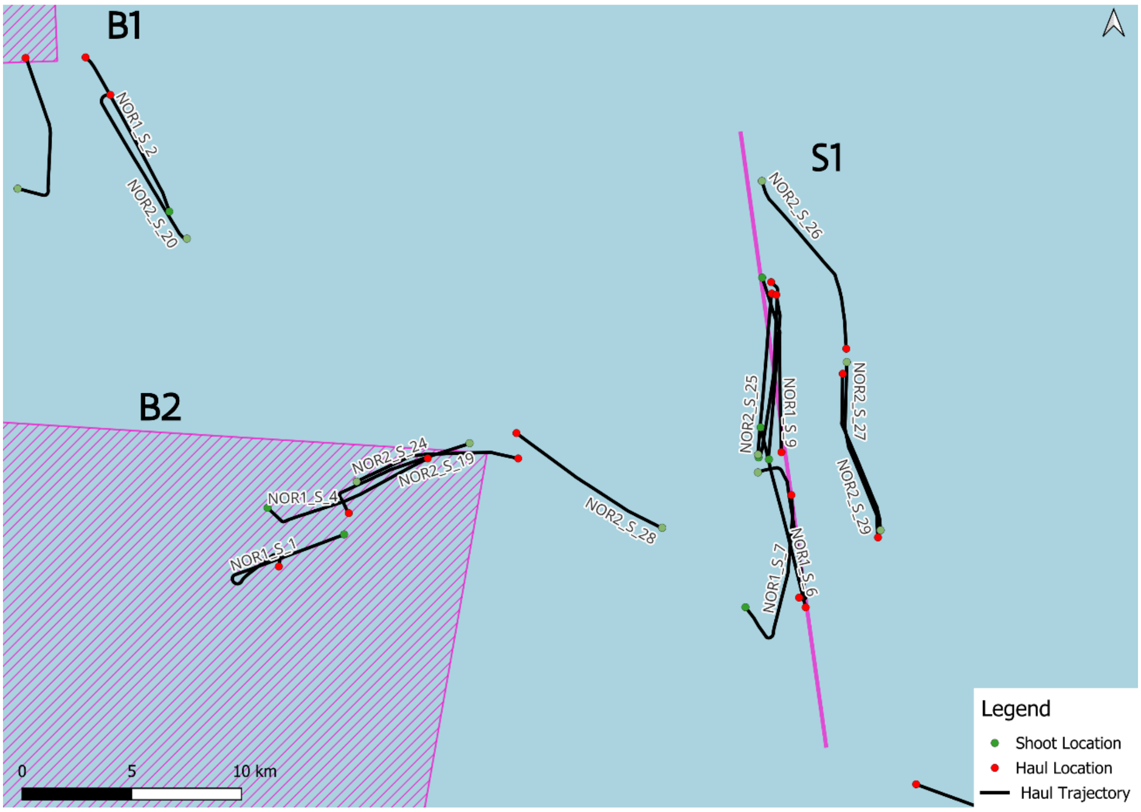


*Figure 4-6 Fully-Sampled Scientific hauls conducted in or in the surroundings of survey areas **S1**, **B1** and **B2**.*

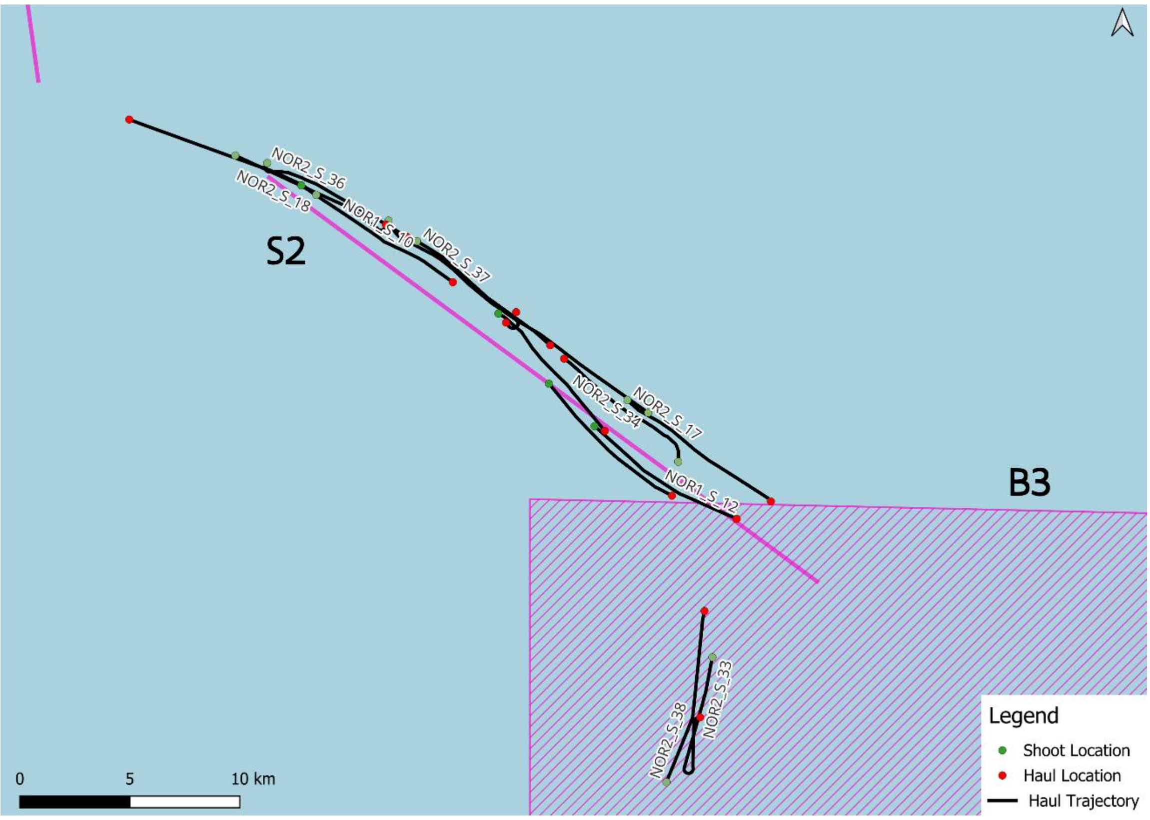


*Figure 4-7Fully-Sampled Scientific hauls conducted in or in the surroundings of survey areas S2 and B3.*

### 4.1.2. Partially-Sampled Scientific hauls

The "**Partially-Sampled Hauls**" served to collect additional WASSP, VISIM, VISTools or NDGP data which could be used in subsequent projects or analyses and were not included in the results in this report Additionally, the catch from these hauls was allowed to be landed and sold in the auction, as a (partly) revenue for the participating vessel to cover fuel and other expenses. Partially-Sampled Scientific hauls are labelled as NOR1/2_C_number.

Locations of these hauls are visualized in **Figure 4-8**.

*Figure 4-8All Partially-Sampled Scientific hauls conducted during the NoriVis survey. Hauls conducted in the first part of the survey (NoriVis 1) are brown-colored, hauls conducted in the second part of the survey are indicated in green.*

## 4.2. Survey Vessel

All hauls were conducted with the Belgian beam trawler “Z.510-Dennis” (38mx9m) (**Figure 4-9**). Technical specifications of the equipment used aboard this vessel and during the project are listed in **Table 4-2.**

*Figure 4-9 The Belgian beam trawler Z.510-Dennis. Picture taken from Marine Traffic & De Corte (2024).*

*Table 4-2 Net specifications Z.510-Dennis used during the survey.*

| Component | Value | Unit |
|---|---|---|
| Beam length | 11 | m |
| Mesh size escape panel | 360 | mm |
| Mesh size cod-end | 120 | mm |
| Mesh size net | 150 | mm |

# 5. Literature

Data and concepts which were taken from literature and used in this report will be summarized in this section.

## 5.1. Present Substrate Data

For this report, substrate data was taken from EMODnet and visualized in **Figure 5-1** (EMODnet, 2022). Different substrates are distinguished based on Folk's sediment triangle, with a hierarchy of 5 substrate classes. In this project, a 1:1M scale is used, with a cartographic unit about 4 km$^2$.

Different substrate classes, and accompanying substrate ID's between brackets, are:

- Mud – Muddy Sand (1)
- Sand (2)
- Coarse substrate (3)
- Mixed Substrate (4)
- Rock & Boulders (5)

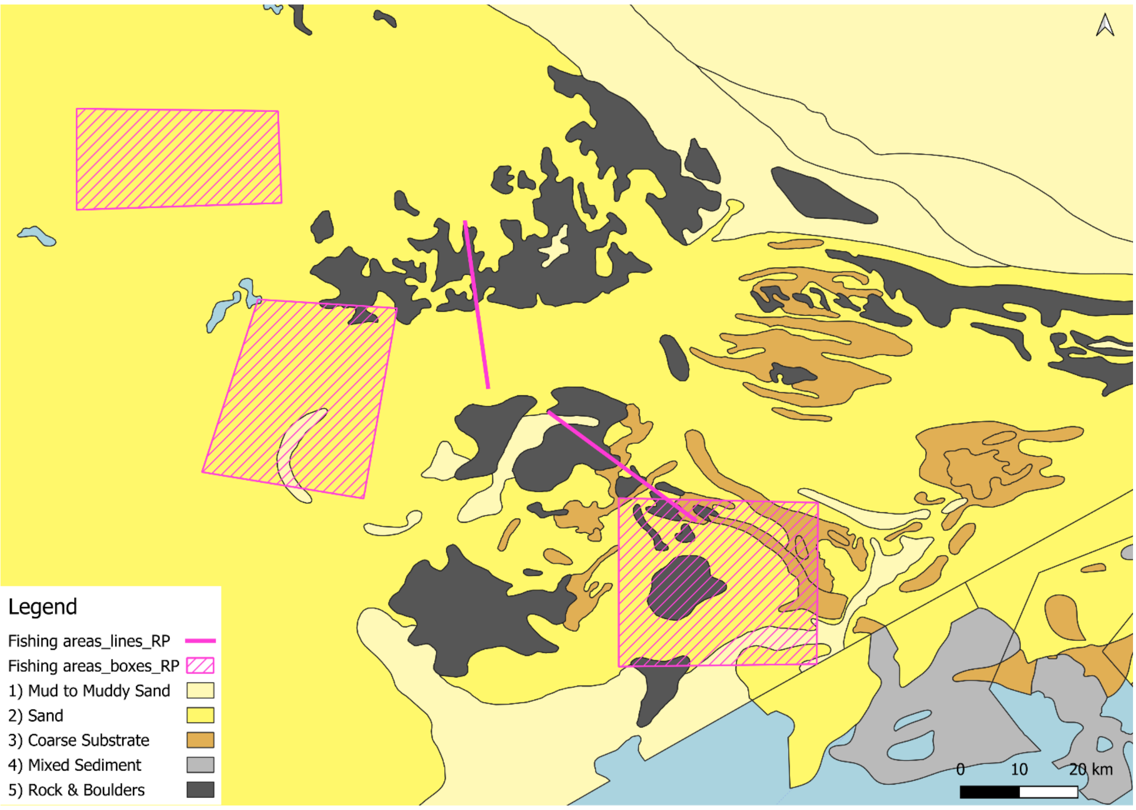


*Figure 5-1 Sea substrates are present in or in the vicinity of the survey area, which is indicated in pink. Different substrates are 1) Mud to Muddy Sand 2) Sand 3) Coarse sediment 4) Mixed Sediment 5) Rock and Boulders. Substrate map derived from EMODnet (2022)*

## 5.2. OSPAR Sensitivity Score

To illustrate the bottom sensitivity of the survey area, the OSPAR BH3 assessment is plotted in **Figure 5-2**. This assessment allocates a score to a certain area, based on the resistance and resilience of the fauna of the seabed of the area towards stressors e.g. fishing activities. The assessment protocol consists of four steps, which are described in detail by Matear et al. (2023).

The following OSPAR sensitivity categories are distinguished:

- 0: None
- 1: Very Low
- 2: Low
- 3: Medium
- 4: High
- 5: Very High

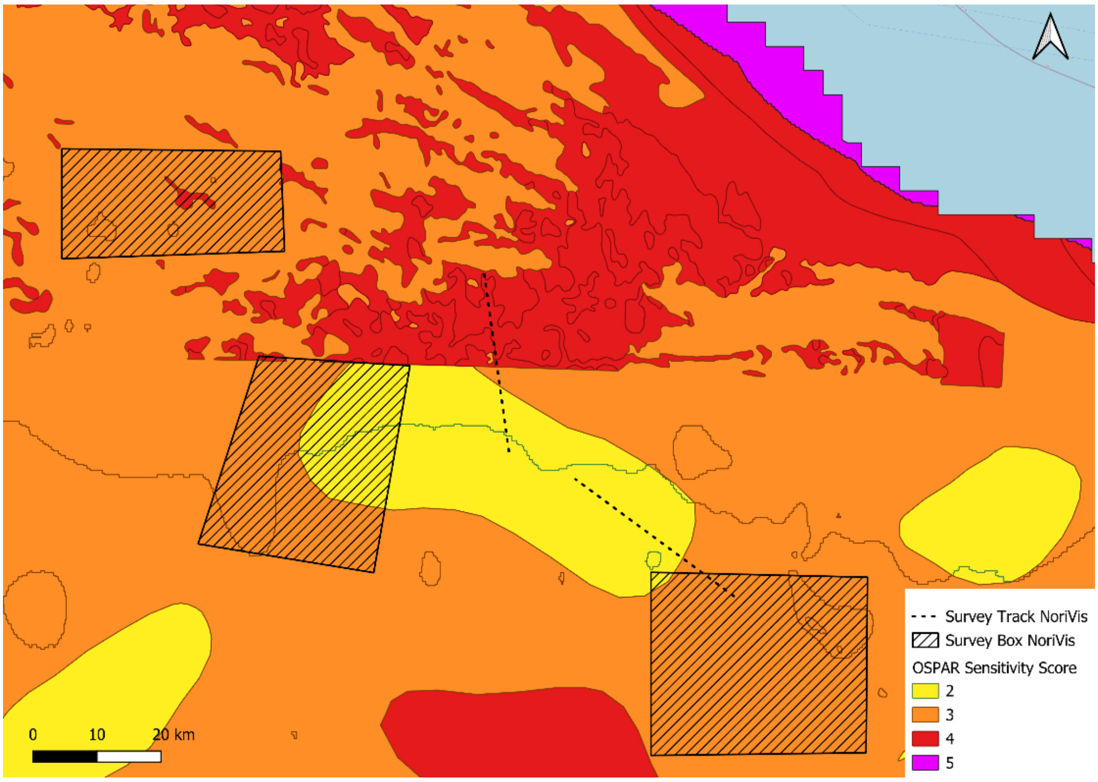


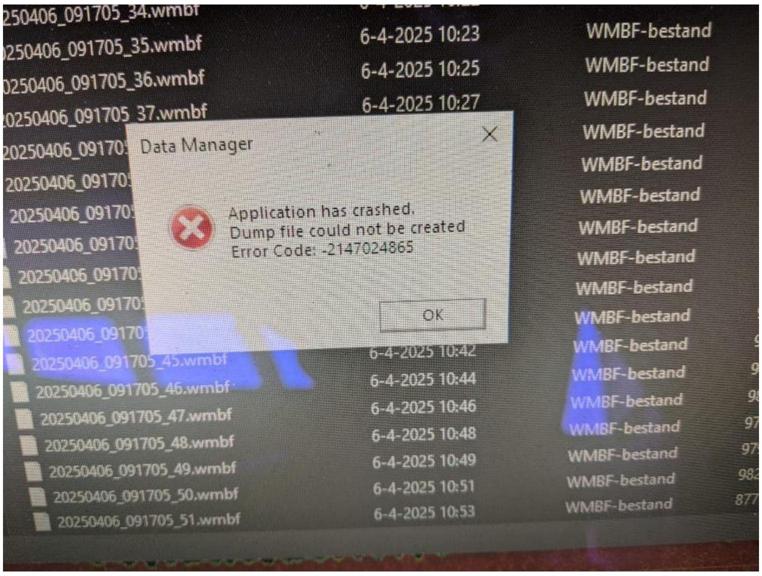
*Figure 5-2 OSPAR sensitivity score of the allocated survey areas of the NoriVis project. Figure based on* Matear et al. (2023).

# 6. Data Collection

## 6.1. WASSP Multibeam Echosounder

Multibeam echosounder (MBES) data were collected during dedicated sea trials in the study area, using a WASSP F3i system mounted on a commercial fishing vessel. The sonar array was equipped with a WMB-160 kHz transducer, which operated in wideband mode (136–184 kHz) and provided coverage of 224 beams across a 120° swath. Signal transmission and reception were managed by a DRX transceiver, while vessel navigation and orientation were constrained using a Hemisphere satellite compass for accurate positioning and heading. Vessel motion (heave, pitch, and roll) was continuously monitored with an IMU-038 sensor, enabling real-time motion compensation during acquisition. Together, these components ensured accurate beam steering, stable signal quality, and precise georeferencing of sonar pings throughout the survey.

During the survey, WASSP multibeam data was collected for the 38 Fully-Sampled Scientific Hauls (see § 4.1.1), but during two of these hauls, a system crash occurred which prohibited data recording (**Figure 6-1**). Despite contacting several companies, no clear cause of these crashes was identified.



```
Application has crashed.
Dump file could not be created
Error Code: -2147024865
```

*Figure 6-1 Screenshot of the WASSP CDX just after a crash occurred. Picture taken on 06/04/2025.*

The used WASSP CDX was operated under a WASSP Backscatter license, enabling the recording of motion-compensated bathymetry and flattened backscatter in the proprietary .wmbf format. However, the WASSP Survey license, which provides access to unprocessed backscatter, raw motion sensor data, and unflattened angular response curves, was not available for this project, limiting the interpretation and complete appreciation of the total backscattered acoustic signal. Instead, so-called “grey values” were used for analysis and discriminating substrate types (see §7.1.1).

## 6.2. VISTools Data

VISTools is the North Sea Fisheries Pilot of Iliad, designed to support the Belgian fleet with advanced decision-making tools. By leveraging real-time data collection and predictive models, VISTools enhances operational efficiency. The pilot includes three key tools: Analytics, Fishing Suitability, and Vessel Routing—the latter currently under development.

VISTools provides vessel owners with real-time insights into fishing operations while their vessels are at sea. Data can be viewed at multiple levels—aggregated for an entire trip or broken down by specific hauls and days. To achieve this, sensors are installed on vessels to capture key operational data. These include (a) scale that weighs catches per species, (b) engine sensor that records fuel consumption, (c) sensor attached to the net which measures rope length and traction force, and (d) GPS tracking that logs vessel location and movements. These different dataflows are subsequently concentrated in the so-called “concentrator”, after which it is sent to the ILVO database (**Figure 6-2**). Detailed information on the VISTools framework can be found on https://ocean-twin.eu/marketplace/lab/vistools or via Lancelot Blondeel (lancelot.blondeel@ilvo.vlaanderen.be)

During the NoriVis survey, VISTools (VT) data was automatically collected. Especially parameters regarding GPS-location and fuel consumption are analyzed within this report.

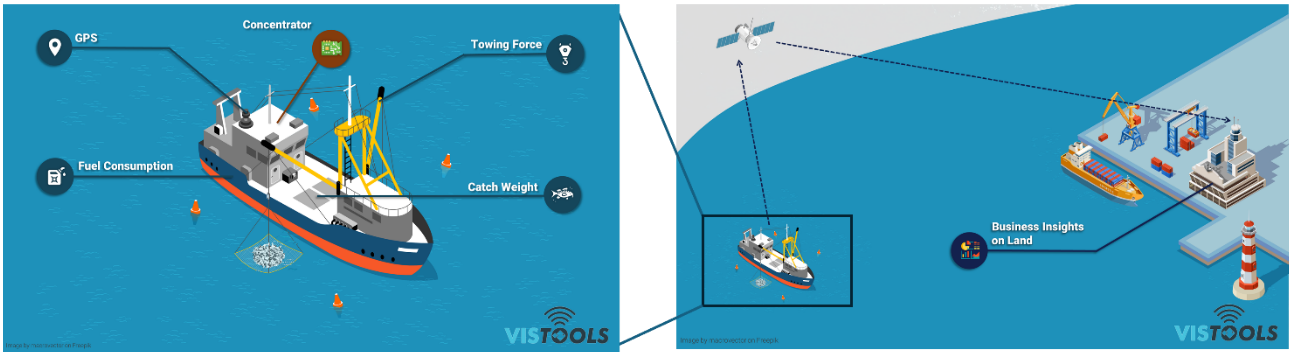


*Figure 6-2 Working of VISTools. Left: Types of data collected by the VISTools concentrator. These include catch weight, fuel consumption, GPS and Towing force. Right: General data flow of the collected data. Data is centralized in the onboard concentrator, after which it is sent through satellite connection to the ILVO database where it is processed and analyzed. Figures taken from Iliad (2025).*

## 6.3. Catch Data

As described in §4.1.1, additional catch data was collected for all Fully-Sampled Scientific Hauls. In total, three distinct groups were identified: landings, discards and benthos. Benthic organisms from trawl samples are classified as the assemblage of organisms that live on the seafloor, such as crabs, anemones or sponges (The Editors of Encyclopaedia Britannica, n.d.). Fish are divided into two different groups: discards and landings. The latter category includes commercial fish species which comply with the regulations of the European Union Minimum Conservation Reference Sizes (MCRS). These regulations, and more specifically commercial sizes, depend on the region and fished species, and differ between Norway and the EU (**Table 6-1**). Since collected fish was landed in Thyborøn, Denmark, European sizes were used to make a distinction between discards and landings in this report. Consequently, undersized fish and non-commercial species are allocated to the category "discards".

*Table 6-1 Landing sizes defined by the Norwegian and European legislations.*

| Fish species | Landing size Norway (cm) | Landing size EU (cm) |
|---|---|---|
| COD | 40 | 35 |
| HAD | 32 | 30 |
| PLE | 29 | 27 |
| POK | 40 | 30 |
| WHG | 32 | 27 |
| BLL | 30 | 30 |
| DAB | 23 | 23 |
| LEM | 25 | 25 |
| TUR | 30 | 30 |
| HAL | 84 | - |
| WIT | 28 | 28 |
| MON | 60 | - |

## 6.4. NDGP-Data

In addition to sampling hauls for catch data used in the NoriVis project, 27 hauls were also sampled as part of the National Data Gathering Program. These samples include length and mass measurements of both landings and discards and are primarily used for stock assessments.

Detailed information about the NDGP program can be obtained via Els Torreele (els.torreele@ilvo.vlaanderen.be). Analyzing this type of data falls out of the scope of this project and will therefore not be included in this report.

## 6.5. VISIM-camera

During the NoriVis survey, a VISIM camera was installed on the survey vessel (**Figure 6-3**). The VISIM III project aims to develop an advanced measurement system for automatic species recognition and length measurements of fish onboard by an intelligent camera system.

During the Norivis survey, images of the catches of all hauls were taken to serve as training material for the already existing models. In total, two types of models are already developed by ILVO. The first one localizes the conveyor belt on the received images, which is important for minimizing the region to be processed. The second model detects activity and is used to sort the incoming data, to log activity and to manage the recording period. Next to this, the collected data will be labeled and used to train future models, especially for species recognition.

Next to its role as training data, the collected data will also be used as test data for models which were developed with data from another vessel. This allows one to estimate whether models trained on one vessel could be used on another.

More information on the VISIM III project can be found via VISIM III-ILVO or by contacting Sander Delacauw (sander.delacauw@ilvo.vlaanderen.be).

*Figure 6-3 VISIM camera installed on the survey vessel during the NoriVis survey (red).*

# 7. Data processing

## 7.1. WASSP Backscatter Data

The data collected by the WASSP multibeam echosounder was processed and analyzed in cooperation with the Royal Belgian Institute of Natural Sciences (RBINS). This report summarizes the most important steps and findings, and the detailed analysis process is described by Kint et al. (2025).

### 7.1.1. Grey-values

After data collection, WASSP data files were converted to the Generic Sensor Format (GSF) using the BeamworX AutoClean tool (https://www.beamworx.com/). GSF is a standardized binary format designed for multibeam echosounder data, storing depth soundings, backscatter intensity, beam geometry, and associated navigation and sensor metadata. The format was developed to enhance interoperability between sonar systems and processing software, enabling efficient management and analysis of high-resolution seafloor mapping datasets.

Multibeam GSF files were processed on a 2.5 m x 2.5 m grid. Features were exported in AutoClean as GeoTIFF for visualization in GIS software and compiled as flat data frames where each row represented a grid cell and each column corresponded to a derived feature (depth and flat backscatter). Flat backscatter values are exported as grey values, ranging from 0 (black) to 255 (white) in value, from low backscatter to high backscatter. Based on the frequency of occurrence of the different grey-values, different acoustic groups could be identified. A histogram which displays the occurrence of all pixel values is added to *Annex A* (**Figure A- 1**).

### 7.1.2. Acoustic groups

Three distinct acoustic groups were distinguished from the acquired backscatter data. These groups are:

- Acoustic Group 1: pixel value < 60
- Acoustic Group 2: 60 < pixel value < 110
- Acoustic Group 3 : pixel value > 110

Next, for each of the types of seabed substrate encountered during the survey (see **Figure 7-1**), and each of the 38 trawl tracks, the ratios per acoustic group were derived and zonal statistics were calculated (**Table 10-1** and **Table 10-2**, respectively).

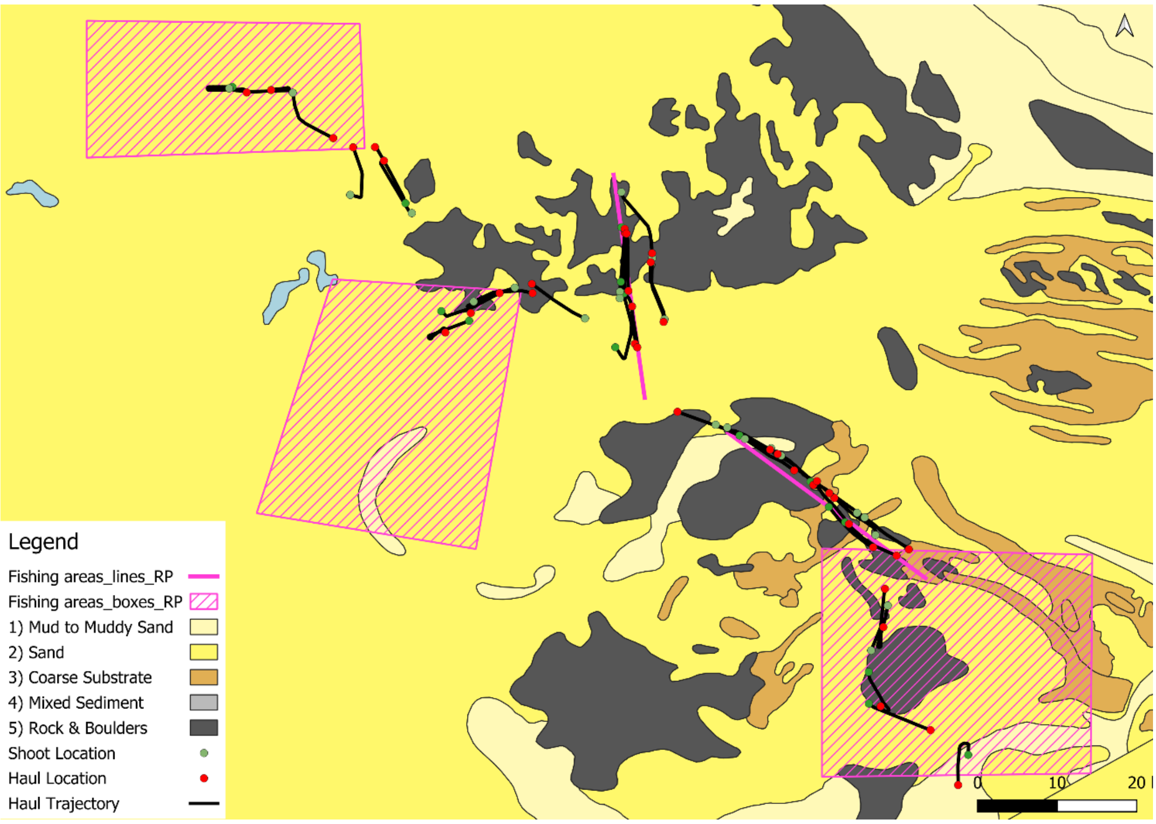


*Figure 7-1 Illustration of the different fully-Sampled Scientific Hauls and the encountered substrate types. Substrate map derived from EMODnet (2022).*

## 7.2. VISTools

For this project, a selection of VISTools parameters was made based on importance and relevance to this project. Selected parameters are:

- Fuel Consumption (L $h^{-1}$)
- Speed (knots)
- Traction Left / Right (kg)

Subsequently, each of these parameters was assessed for significant differences across the above-described factors “Sampled Station”, “OSPAR score” and “Dominant Substrate Type”.

# 8. Haul Labelling

Based on §5, §6 and §7, Fully-Sampled scientific hauls were labeled according to the factors: the Sampled Station, OSPAR score or Dominant Substrate type (

**Table 8-2**). Labeling of the different hauls is length-based, meaning that each haul is assigned to the factor level in which the greatest proportion of its length occurs. For example, if a haul is 80% located in level A, 5% in level B and 5% in level C, the haul will be allocated to level A.

The levels of the different factors which will be used in this report are summarized in **Table 8-1**.

*Table 8-1 Factors and labels used during the NoriVis report. The factor "dominant substrate type" is based on the classifications used in the map presented in §5.1 and the substrate map derived from EMODnet.*

| Factor | Level | Meaning |
|---|---|---|
| **Sampled Station** | B1 | Box 1 |
| | B2 | Box 2 |
| | B3 | Box 3 |
| | S1 | Line 1 |
| | S2 | Line 2 |
| | OUT | Outside a designated survey area |
| **OSPAR score** | 2 | Low-sensitive |
| | 3 | Medium-sensitive |
| | 4 | High-sensitive |
| **Dominant Substrate Type (EMODnet)** | 1 | Mud to Muddy Sand |
| | 2 | Sand |
| | 3 | Coarse Sediment |
| | 4 | Mixed Sediment |
| | 5 | Rock and Boulders |

*Table 8-2 Labels of all Fully-Sampled Scientific hauls based on data derived from literature.*

| Haul | Sampled Station | OSPAR Score | Dominant Substrate Type (EMODnet) |
|---|---|---|---|
| **NOR1_S_1** | B2 | 2 | 2 |
| **NOR1_S_2** | OUT | 4 | 2 |
| **NOR1_S_3** | B1 | 4 | 2 |

|  |  |  |  |
|---|---|---|---|
| NOR1_S_4 | B2 | 2 | 5 |
| NOR1_S_5 | S1 | 4 | 5 |
| NOR1_S_6 | S1 | 2 | 2 |
| NOR1_S_7 | S1 | 2 | 2 |
| NOR1_S_8 | S1 | 4 | 5 |
| NOR1_S_9 | S1 | 4 | 5 |
| NOR1_S_10 | S2 | 2 | 5 |
| NOR1_S_11 | S2 | 2 | 3 |
| NOR1_S_12 | S2 | 3 | 5 |
| NOR1_S_13 | S2 | 2 | 5 |
| NOR1_S_14 | B3 | 3 | 5 |
| NOR1_S_15 | B3 | 3 | 2 |
| NOR1_S_16 | B3 | 3 | 1 |
| NOR2_S_17 | S2 | 3 | 5 |
| NOR2_S_18 | S2 | 2 | 5 |
| NOR2_S_19 | B2 | 2 | 2 |
| NOR2_S_20 | OUT | 4 | 2 |
| NOR2_S_21 | OUT | 3 | 2 |
| NOR2_S_22 | B1 | 4 | 2 |
| NOR2_S_23 | B1 | 3 | 2 |
| NOR2_S_24 | B2 | 2 | 2 |
| NOR2_S_25 | S1 | 4 | 5 |
| NOR2_S_26 | S1 | 4 | 2 |
| NOR2_S_27 | S1 | 4 | 2 |
| NOR2_S_28 | OUT | 2 | 2 |
| NOR2_S_29 | S1 | 4 | 2 |
| NOR2_S_30 | S1 | 2 | 2 |
| NOR2_S_31 | S2 | 2 | 1 |
| NOR2_S_32 | S2 | 2 | 5 |
| NOR2_S_33 | B3 | 3 | 2 |

| | | | |
|---|---|---|---|
| NOR2_S_34 | S2 | 2 | 5 |
| NOR2_S_35 | S2 | 2 | 2 |
| NOR2_S_36 | S2 | 2 | 5 |
| NOR2_S_37 | S2 | 2 | 5 |
| NOR2_S_38 | B3 | 3 | 2 |

# 9. Artificial Intelligence Usage

During the construction of this report, Artificial Intelligence (AI) was solely used to rewrite certain paragraphs. It was not used to generate new information or to perform any analyses.

# Results

## 10. Backscatter Analysis

In this section, results of the analysis of collected WASSP data, expressed as grey-values, are summarized. Fully-Sampled Scientific Hauls for which no WASSP data is available due to the unexpected WASSP crashes (see §6.1), such as NOR2_S_20, were excluded from this analysis.

### 10.1. General results

Along the trajectories surveyed, acoustic groups with shades of gray 60-110 and > 110 occur equally often (±48% and ±46% respectively) , while pixel values ≤ 60 are limited (±6%) (**Table 10-1**).

*Table 10-1 Proportions of the three acoustic groups (in %) and zonal statistics (in grey values) within the NoriVis survey.*

| | In percentages (%) | | | In grey values | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | ≤ 60 | 60-110 | > 110 | Mean | Median | StDev | Min | Max | Range |
| NoriVis Survey | 6.03 | 48.41 | 45.56 | 106 | 105 | 31 | 0 | 254 | 254 |

There is no clear distinction between acoustic groups 60-110 and > 110 for muddy sand (± 47 % and ± 42 %) and sand (± 46 % and ± 52 %), while pixel values 60-110 occur more frequently than values > 110 for the coarse substrate (± 53 % and ± 36 %) (**Table 10-2**). This makes it difficult to match values on a gray scale to specific types of pre-mapped seabed substrates. Values ≤ 60 are again limited for sand (± 2 %) but occur in muddy sand and the coarse substrate (both ± 11 %). The median of the gray-scale values decreases from sand (112) to muddy sand (95), and to the coarse substrate (88).

*Table 10-2 Proportions of the three acoustic groups (in %) and zonal statistics (in grey values) per Scientific Haul.*

| | Percentages (%) | | | Grey values | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | ≤ 60 | 60-110 | > 110 | Mean | Median | StDev | Min | Max | Range |
| Mud and sand with gravel, cobbles and boulders | 11.33 | 52.97 | 35.69 | 98 | 88 | 34 | 0 | 254 | 254 |
| Muddy Sand | 11.15 | 47.20 | 41.65 | 102 | 95 | 35 | 0 | 233 | 233 |
| Sand | 2.22 | 46.05 | 51.73 | 110 | 112 | 27 | 0 | 254 | 254 |

### 10.2. Haul specific classifications

Hauls NOR1_S_2, NOR1_S_3, NOR2_S_20, NOR2_S_21, NOR2_S_22 and NOR2_S_23 are located in a sandy area (brown) (**Figure 10-1**). Haul NOR1_S_20 can be ignored, as no backscatter data were collected on this transect due to a system crash during data collection (see §6.1 ). Hauls NOR1_S_2 and NOR1_S_3 contain two acoustic groups with values 60-110 (± 41 % and ± 56 %) and > 110 (± 55 % and ± 44 %). The acoustic group with values > 110 is dominant for tracks NOR2_S_21, NOR2_S_22 and NOR2_S_23 (± 69 %, ± 67 % and ± 97 %). Only haul NOR1_S_2 shows the presence of acoustic group with values ≤ 60 (± 4 %), while this is negligible for all other tracks. The median ranges from 108 to 136. Here: Acoustic groups with values 60-110 and > 110 with median between 108 and 136 correspond to sand, while the acoustic group with values ≤ 60 is detected near a small coarse substrate patch; i.e. mud and sand with gravel, cobbles and boulders (blue).

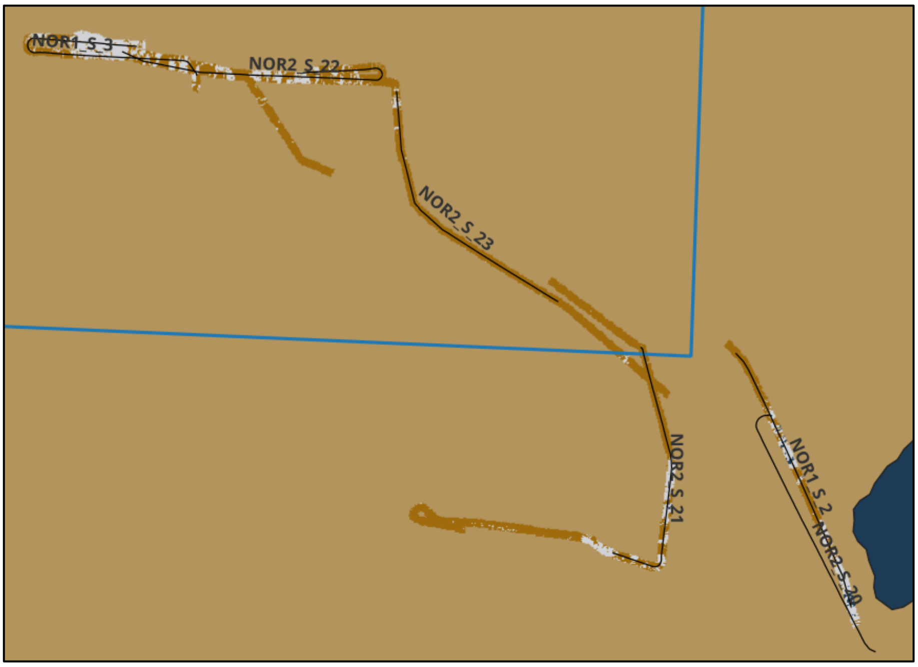


*Figure 10-1 Fully-Sampled Scientific hauls NOR1_S_2, NOR1_S_3, NOR2_S_20, NOR2_S_21, NOR2_S_22 and NOR2_S_23 are located in a sandy area (brown).*

Fully-Sampled Scientific hauls NOR1_S_1, NOR1_S_4-9, NOR2_S_19 and NOR2_S_24-30 are located in a sandy area (brown) mixed with patches of coarse substrate (blue) (**Figure 10-2**). The acoustic group with values 60-110 is common among all hauls (± 59 % to ± 93 %), with the exception of haul NOR1_S_6 and NOR2_S_25 ( ± 43 % and ± 53 %). The median ranges from 83 to 107, excluding track 6 (114). Hauls NOR1_S_4, NOR1_S_7, NOR2_S_19 and NOR2_S_27 contain more than 3 % of the acoustic group with values ≤ 60, resulting in a lower median (83), excluding haul NOR2_S_27 (102). Acoustic groups with values 60-110 and median between 83 and 107 correspond to sand with a coarse substrate. The more frequently the acoustic group with values ≤ 60 occurs, the coarser substrate and the lower the median.

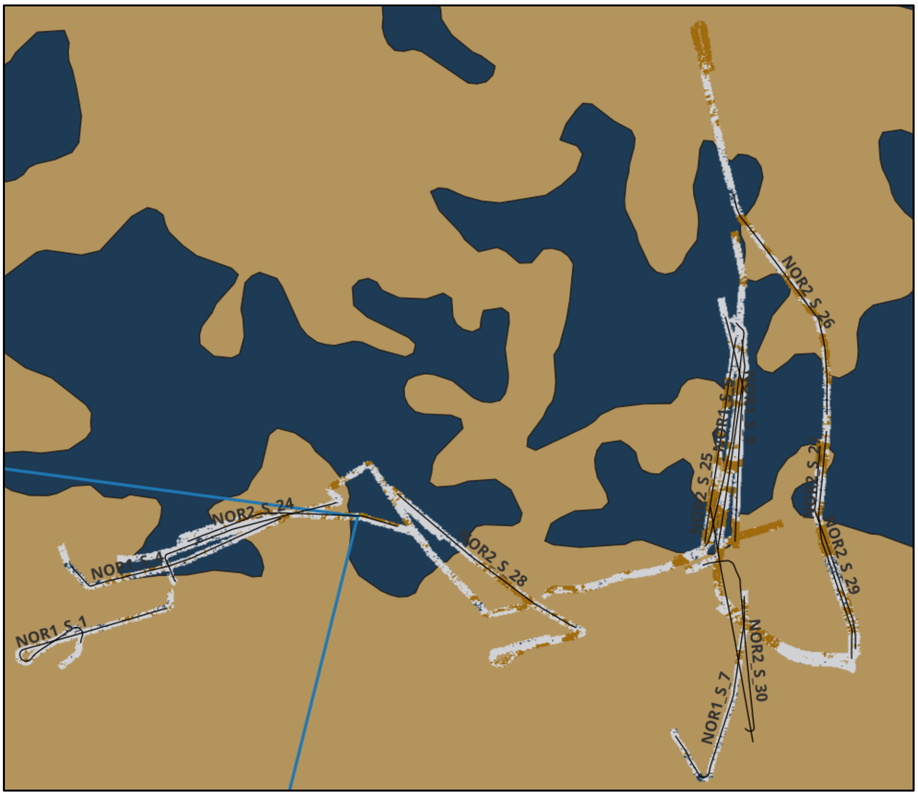


*Figure 10-2 Fully-Sampled Scientific hauls 1, 4-9, 19 and 24-30 are located in a sandy area (brown) mixed with patches of coarse substrate (blue).*

Fully-Sampled Scientific hauls NOR1_S_10-13, NOR2_S_17-18, NOR2_S_31-32 and NOR2_S_34-37 are located in a sand (brown) to muddy sand (grey) area with a large patch of coarse substrate (blue) (**Figure 10-3**). NOR1_S_13 can be ignored, as no backscatter data were collected on this transect. NOR1_S_10-12, NOR2_S_31-32 and NOR2_S_36-37 contain more than 5 % of the acoustic group with values ≤ 60. However, the median varies between 67 and 134 and depends on the ratios between the three acoustic groups. NOR2_S_18 and NOR2_S_34-35 correspond to a sandy area with a dominant acoustic group with values > 110 (± 79 % to ± 85 %) and a median between 129 and 149. NOR2_S_17 contains both acoustic groups with values 60-110 (± 44 %) and > 110 (± 52 %). Due to the high proportions of the acoustic group with values ≤ 60, this can be linked to the presence of coarse substrate. The acoustic groups with values 60-110 and > 110, which correspond to a (muddy) sandy area, are still predominant.

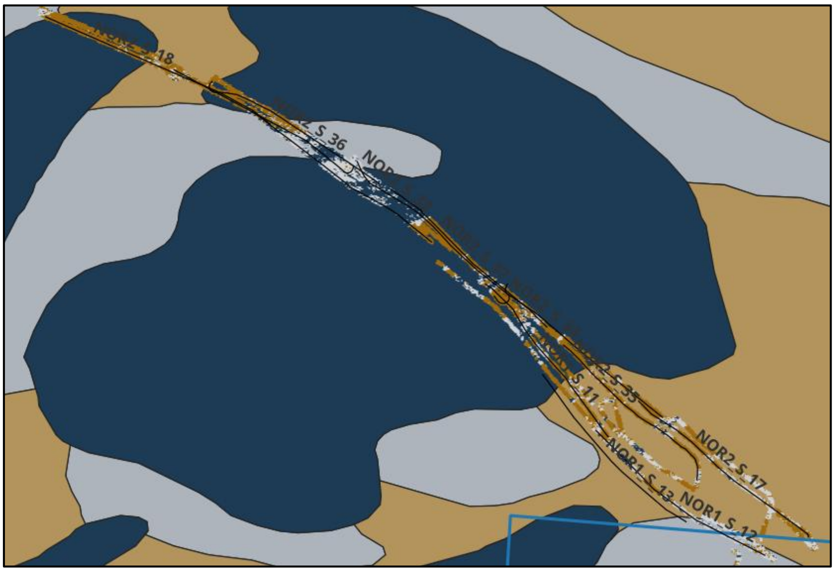


*Figure 10-3 Fully-Sampled Scientific hauls 10-13, 17-18, 31-32 and 34-37 are located in a sand (brown) to muddy sand (grey) area with a large patch of coarse substrate (blue).*

NOR1_S_14-16, NOR2_S_33 and NOR2_S_38 are located in a sand (brown) to muddy sand (grey) area with a small patch of coarse substrate (blue) (**Figure 10-4**). NOR1_S_14 within the coarse substrate patch contains ± 26 % of the acoustic group with values ≤ 60 and has a median of 80. Along the other tracks NOR1_S_15-16, NOR2_S_33 and NOR2_S_38, located in the sand to muddy sand area, the acoustic group with values > 110 dominates (± 62 % to ± 86 %) and the acoustic group with values ≤ 60 is less than 5 %, resulting in a median between 118 and 135. Acoustic group with values ≤ 60 corresponds to a coarse substrate, while acoustic group with values > 110 is associated with a sand to muddy sand area.

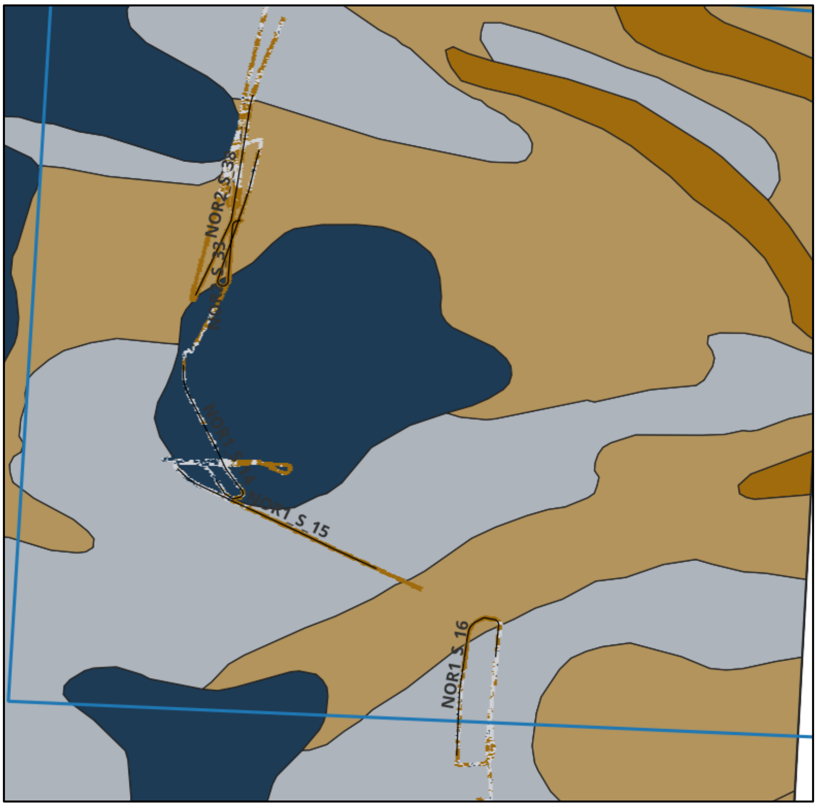


*Figure 10-4 Fully-Sampled Scientific hauls 14-16, 33 and 38 are located in a sand (brown) to muddy sand (grey) area with a small patch of coarse substrate (blue).*

The above hauls statistics are summarized in *Annex A: Material & Methods* (**Table A- 3**).

Based on the above assumptions and expert opinion of RBINS, an initial categorization of substrate linked to the received backscatter signal, expressed in grey values, is made:

- Acoustic group 1 (≤ 60): Coarse substrate (gravel, cobbles, boulders)
- Acoustic group 2 (60-110): (muddy) Sand with some coarse substrate (gravel, cobbles, boulders)
- Acoustic group 3 (> 110): Sand

In further results, **acoustic group 1** will be referred to as **Group A**, , **acoustic group 2** as **Group B** and **acoustic group 3** as **Group C.**

# 11. VISTools

This section focusses on the influence of Sampled Station, OSPAR Score and Dominant Substrate type on the selected VISTools parameters ( see §7.2).

## 11.1. Sampled Station

Mean fuel consumption is highest in stations B1, B2 and OUT, whereas stations B3 and S2 record the lowest values (**Figure 10-1**). For these stations, traction on the left and right side is, respectively, the highest and lowest. A similar trend can be observed for the mean speed, although stations B2 and B3 display opposing values compared to e.g. mean fuel consumption: station B2 is characterized by a relatively low mean speed, while B3 records a relatively high mean speed.

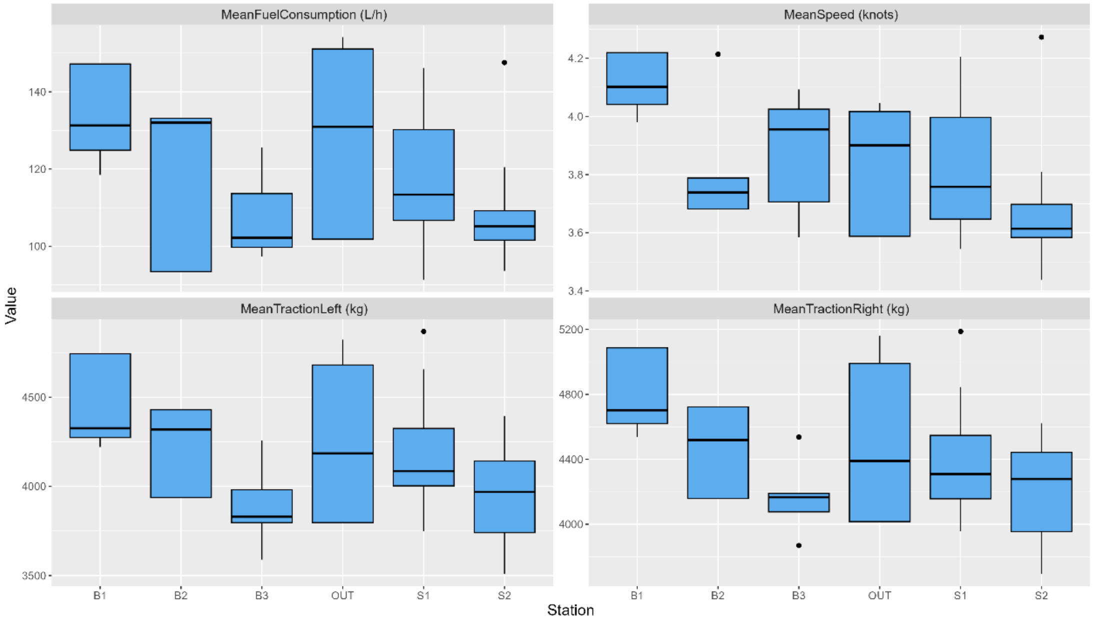


*Figure 11-1 Boxplots representing the mean fuel consumption (L h$^{-1}$, top left), mean speed (knots, top right), mean traction on the left side of the vessel (kg, bottom left) and mean traction of the right side of the vessel (kg, bottom right) categorized per sampled station (x-axis). Different stations are: B1 (n = 3); B2 (n = 4); B3 (n = 5); S1 (n = 10); S2 (n = 12); OUT (n = 4).*

## 11.2. OSPAR Score

Regarding the *OSPAR Score,* a general upward trend is observed across all vessel parameters (**Figure 11-2**). OSPAR score 2 consistently records the lowest values, whereas OSPAR score 4 corresponds to the highest. Differences between the different levels of the OSPAR score are significant for all parameters ($p<0.05$), except for MeanTractionRight. For this parameter, a non-significant difference was found between OSPAR score 2 and 3 ($p>0.05$).

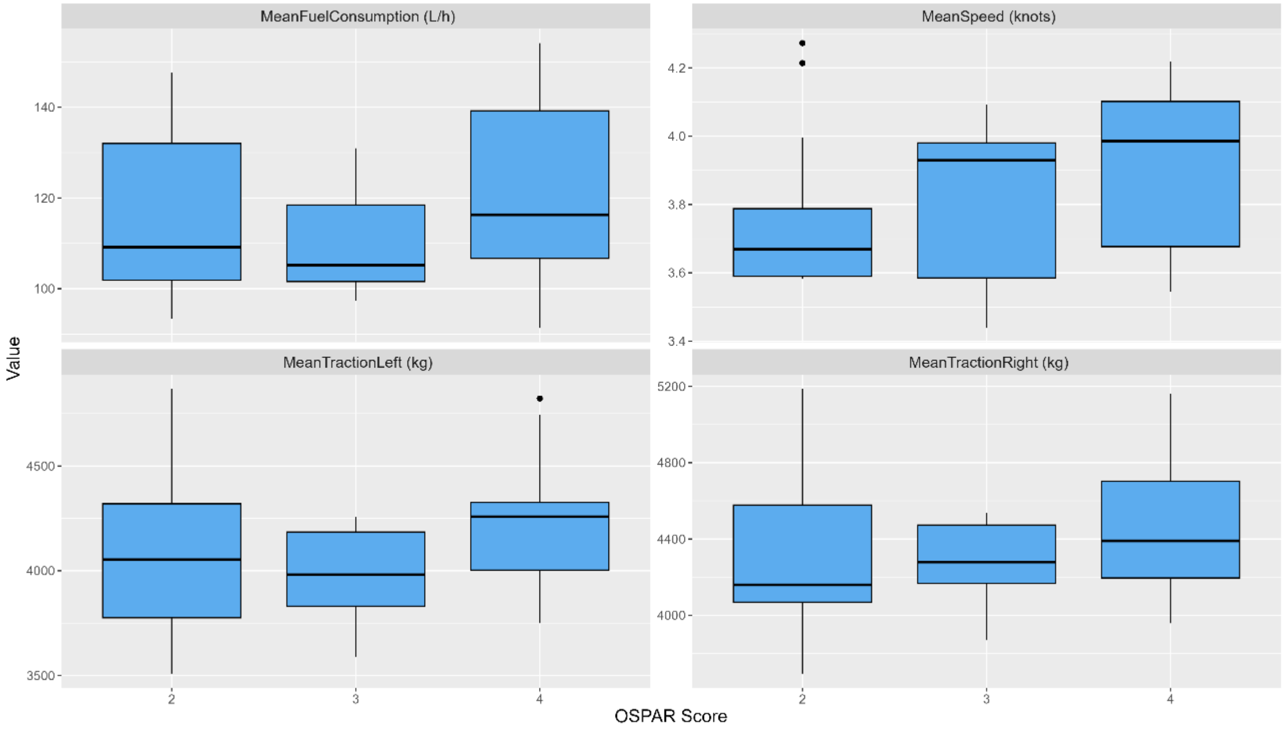


*Figure 11-2 Boxplots representing the mean fuel consumption (L $h^{-1}$, top right), mean speed (knots, top right), mean traction on the left side of the vessel (kg, bottom left) and mean traction of the right side of the vessel (kg, bottom right) categorized OSPAR sensitivity score (x-axis). Levels of OSPAR score are 2 (n = 18); 3 (n = 9); 4 (n = 11).*

## 11.3. Dominant Substrate Type

Because of the low number of hauls conducted on Substrate types 1 (Mud-Muddy Sand; n = 2, 3 (Coarse sediment; n = 1) and 4 (Mixed Sediment; n = 0); these substrate types can be neglected for any comparison.

Kruskal-Wallis tests, in combination with post-hoc Dunn's tests, revealed that among all parameters, substrate type 2 (Sand) significantly differs ($p<0.05$) from substrate type 5 (Boulder + Rock) (**Figure 11-3**).

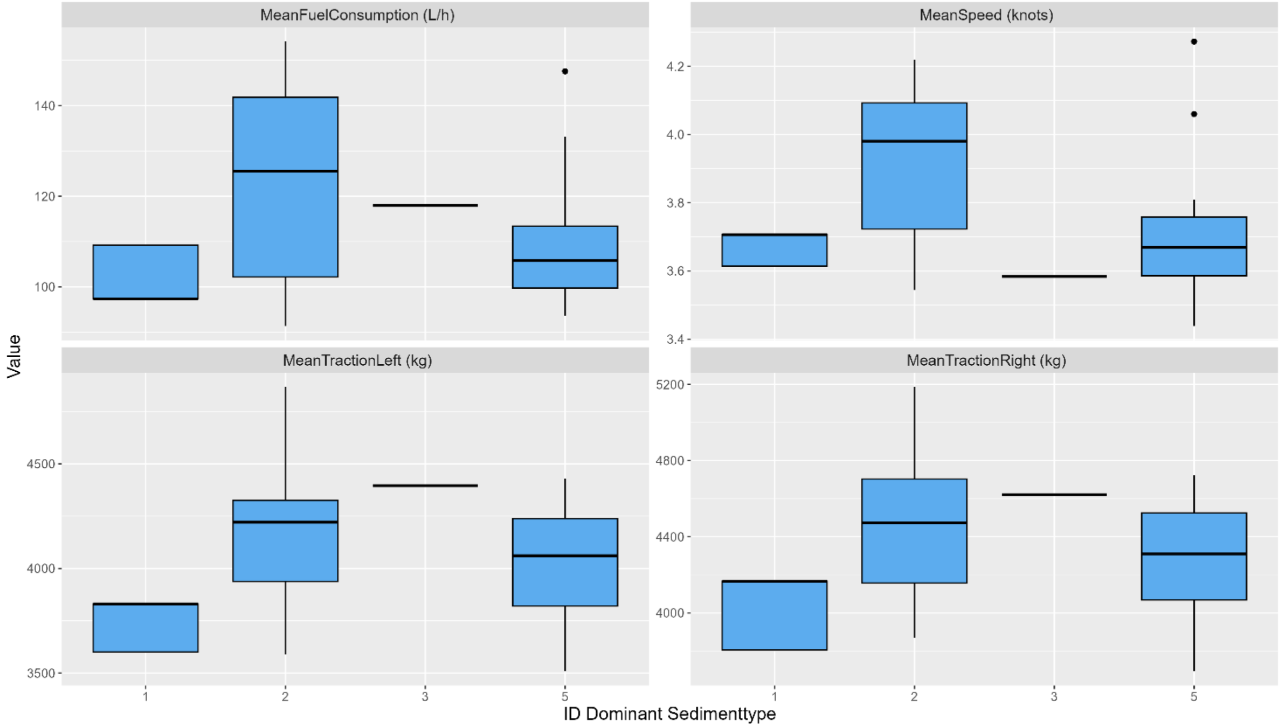


*Figure 11-3 Boxplots representing the mean fuel consumption (L $h^{-1}$, top right), mean speed (knots, top right), mean traction on the left side of the vessel (kg, bottom left) and mean traction of the right side of the vessel (kg, bottom right) categorized per dominant sediment ID (x-axis). Substrate types are (1) Mud-Muddy Sand (n = 2); (2) Sand (n = 20); (3) Coarse substrate (n = 1); (4) Mixed Sediments (n = 0); (5) Rock + Boulder (n = 15).*

# 12. Catch Composition

## 12.1. Species Diversity

### 12.1.1. Landings & Discards

To observe the diversity of species during the NoriVis project, boxplots of the log-transformed ($\log_{10}$) CPUE (kg $km^{-2}$) were made (**Figure 12-1**). These boxplots demonstrate a high variance in the CPUE of plaice, monkfish and cod. Plaice (PLE) recorded the highest mean CPUE (127.44 kg $km^{-2}$), followed by cod (COD; 63.34 kg $km^{-2}$) and Atlantic wolffish (CAA; 57.31 kg $km^{-2}$). Atlantic halibut (HAL) shows a very high CPUE (339.82 kg $km^{-2}$) but will be considered as an outlier since only one individual was caught during the survey.

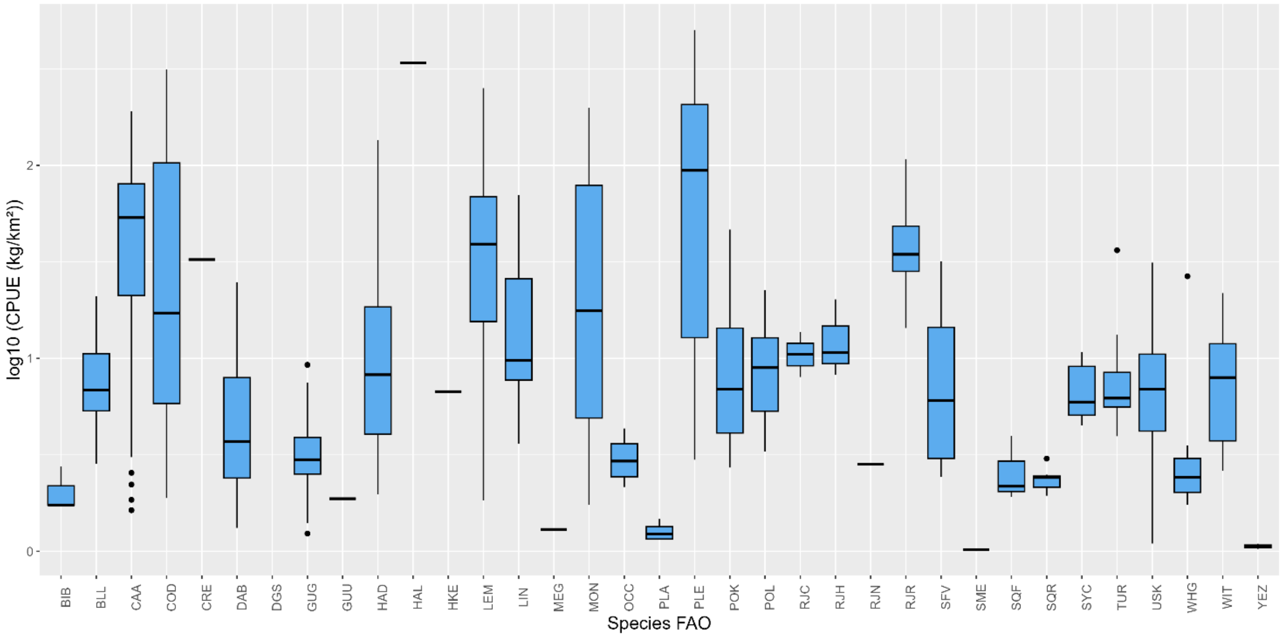


***Figure 12-1*** *Boxplots of CPUE (kg km$^{-2}$) of the different fish species caught during the NoriVis project (n = 38). The CPUE is log$_{10}$-transformed, and pseudo count (all data + 1) is applied to take the logarithm of zero-values (log$_{10}$(1) = 0).*

**Figure 12-2** shows the same boxplots as discussed above, but with an additional distinction between discards and landings. Several differences can already be observed. For example, starry ray (RJR) exhibits one of the highest CPUE's in the discard category, while it is not represented in the landing category. A similar pattern is observed for Norway Redfish (SFV). Furthermore, it can also be observed that the variance of plaice (PLE) is lower in the landing category compared to the discard category. On the contrary, the CPUE of cod (COD) shows a higher variance in the landing category compared to the discard category.

Because of these differences, a clear distinction between landings and discards will be made in all subsequent analysis.

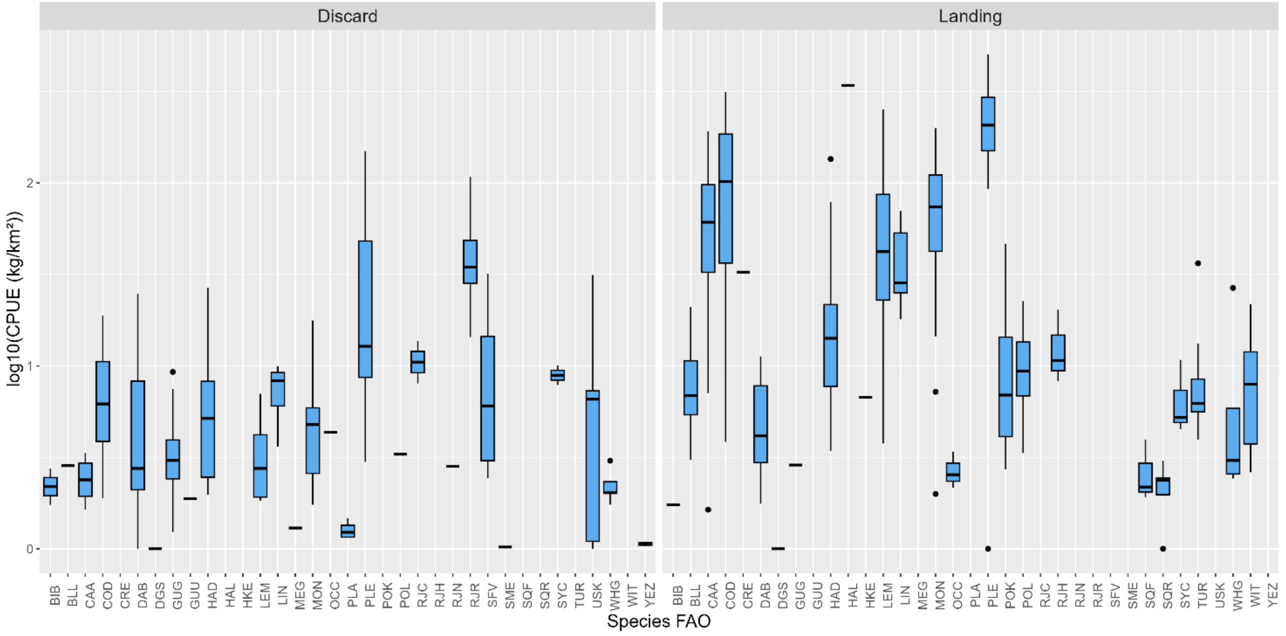


*Figure 12-2 Boxplots representing the log10-transformed CPUE (kg km$^{-2}$) of all fish species sampled during the NoriVis survey. A distinction is made between landing- and discard sized species. Pseudo-count (all data+1) was applied to account for zero values ($\log_{10}(1) = 0$).*

Given the total number of species present (n = 35), a selection will be made to reduce the set of species included in further exploratory graphs. This selection will be based on a certain rank, which will be calculated by the following formula:

*Equation 1: Calculating ranks for all the sampled fish species.*

$$R_i = n * CPUE$$

With:

- $R_i$ = rank of a species
- n = number of hauls in which the species is present
- CPUE = average CPUE (kg km$^{-2}$) over the entire NoriVis survey

The ten species with the highest rank are summarized in **Table 12-1**.

*Table 12-1 Selection of fish species which will be retained in further exploratory graphs. Species not mentioned in this table will be referred to as "Other".*

| | **Discards** | **Landings** |
|---|---|---|
| 1 | Plaice (PLE) | Plaice (PLE) |
| 2 | Cod (COD) | Cod (COD) |
| 3 | Starry Ray (RJR) | Atlantic wolffish (CAA) |
| 4 | Monkfish (MON) | Lemon sole (LEM) |
| 5 | Haddock (HAD) | Monkfish (MON) |

| | | |
|---|---|---|
| **6** | Atlantic wolffish (CAA) | Haddock (HAD) |
| **7** | Lemon Sole (LEM) | Brill (BLL) |
| **8** | Norwegian Redfish (SFV) | Witch flounder (WIT) |
| **9** | Ling (LIN) | Common dab (DAB) |
| **10** | Common dab (DAB) | Ling (LIN) |

Atlantic Halibut (HAL) was originally included in the landing selection due to its high CPUE (339.82 kg km$^{-2}$). However, as this was only one individual, it is considered as an outlier and is excluded from the selection.

### 12.1.2. Benthos

To illustrate the diversity within the benthos species, **Figure 12-3** was created, showing the log$_{10}$-transformed CPUE for the 64 species found. On this graph, *Alcyonium digitatum* has the highest log-transformed CPUE value (2.142), followed by *Actiniaria* (1.228) and *Asterias rubens* (1.101). These values correspond with a CPUE of 137.74 kg km$^{-2}$, 15.90 kg km$^{-2}$ and 11.63 kg km$^{-2}$, respectively.

*Alcyonium digitatum, Actiniaria* and *Asterias rubens* also record the highest mean CPUE, with values of 236.95 kg km$^{-2}$, 51.15 kg km$^{-2}$ and 11.97 kg km$^{-2}$, respectively.

The most present species during the NoriVis survey were *Asterias rubens* (38 hauls), *Lithodes maja* (38 hauls) and *Stichastrella rosea* (37 hauls).

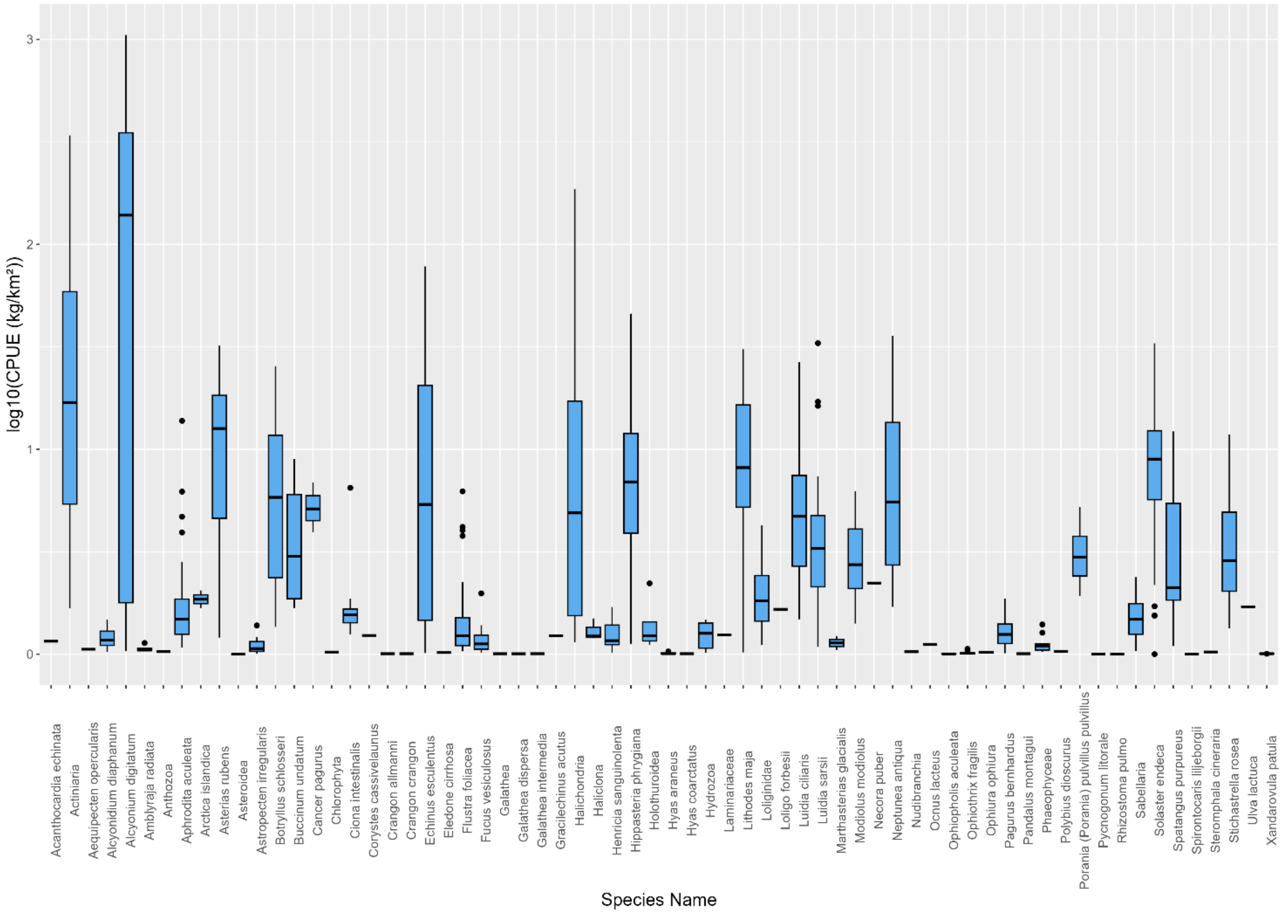


*Figure 12-3 Boxplots representing the log10-transformed CPUE (kg km$^{-2}$) of all benthic species sampled during the NoriVis survey. Pseudo-count (all data+1) was applied to account for zero values (log10 (1) = 0).*

In correspondence with the analyses for discards and landings, a selection of benthic species is made to reduce the set of variables which will be used in further exploratory graphs. This analysis is based on **Equation 1**, which is explained in §12.1.1.

Species that will be retained for analysis are summarized in **Table 12-2**.

*Table 12-2 Retained benthic species. Species not mentioned in this table will be referred to as "Other".*

**Benthos**

| Rank | Scientific | English |
|---|---|---|
| 1 | *Asterias rubens* | Common starfish |
| 2 | *Lithodes maja* | Northern stone crab, Norway king crab |
| 3 | *Alcyonium digitatum* | Dead man's fingers |
| 4 | *Solaster endeca* | Purple sun star, northern sunstar |
| 5 | *Actiniaria* | Sea anemones |

| | | |
|---|---|---|
| 6 | *Echinus esculentus* | Edible sea urchin |
| 7 | *Neptunea antiqua* | Red whelk |
| 8 | *Luidia ciliaris* | Seven-armed starfish |
| 9 | *Hippasteria phrygiana* | Cushion star |
| 10 | *Halichondria* | Sponges |

## 12.2. Spatial Distribution

### 12.2.1. Landings

**Figure 12-4** demonstrates the spatial distribution of the selected landings. On these figures, the CPUE of each species is plotted for each haul, with larger and redder circles representing larger CPUE's. Point coordinates on the figure correspond with the haul location of each haul.

Across most species, the largest CPUE's are located around S1, S2 and B3. Only for brill (BLL) and Atlantic wolffish (CAA), high CPUE's are also located in B1 and B2.

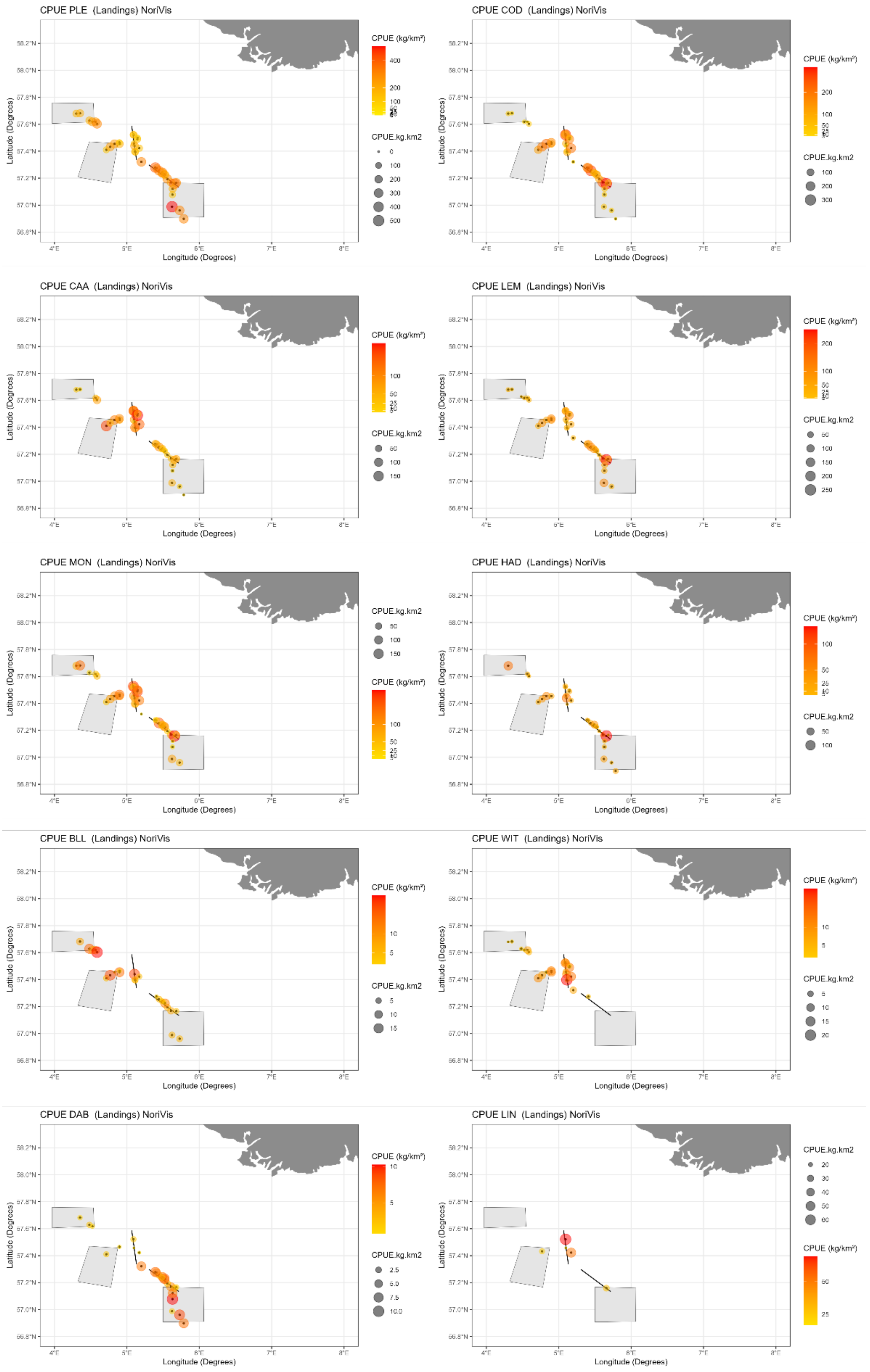


*Figure 12-4* *CPUE (kg/km$^2$) of the selected fish species (landings) sampled during the NoriVis campaign. The color and size of the circles indicate the size of the CPUE: the larger and redder the circle, the larger the CPUE. Color and size scales for each graph are provided on the right side. Point-coordinates used in the figure correspond to the haul location of each scientific haul.*

### 12.2.2. Discards

A rather similar pattern is visible in **Figure 12-5**, which maps the spatial distribution of discards. Higher CPUE values are again associated with S1, S2 and B3. Specifically, plaice (PLE), haddock (HAD) and common dab (DAB) record highest CPUE's in B3, while cod (COD), starry ray (RJR) and haddock (HAD) exhibit high CPUE's in S2.

Compared to **Figure 12-4**, discards exhibit a more distributed pattern, with several species, such as cod, recording high CPUE's in B1 and B2. However, lemon sole (LEM) and, in particular, Norway redfish (SFV), seem to deviate from this pattern. Lemon sole only seems to be caught in or around B3, while Norway redfish -an ETP-species- predominantly occurs around S1. The upper part of this station is classified as OSPAR score 4, which indicates that this area is highly sensitive (**Figure 5-2**). The increased presence of SFV in this region may therefore correspond to this OSPAR sensitivity classification.

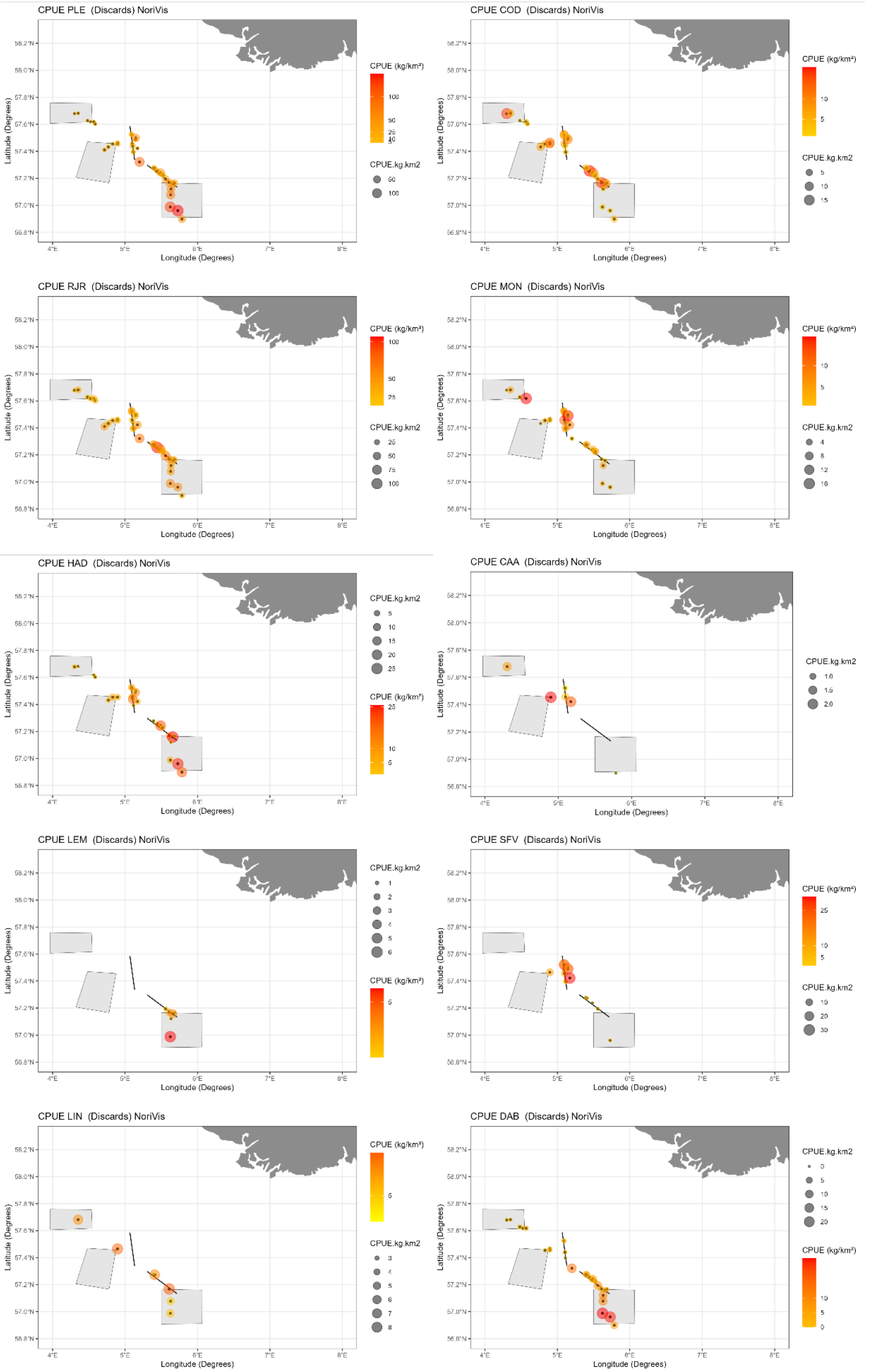


***Figure 12-5*** *CPUE (kg/km²) of the selected fish species (discards) sampled during the NoriVis campaign. The color and size of the circles indicate the size of the CPUE: the larger and redder the circle, the larger the CPUE. Color and size scales for each graph are provided on the right side. Point-coordinates used in the figure correspond to the haul location of each scientific haul.*

## 12.3. Factor-Species Relation

This section visualizes the standardized catch composition of landings, discards and benthos, expressed as kg km$^{-2}$, per OSPAR score and Dominant Substrate Type. Sections §12.3.1 and §12.3.2 summarize the most striking trends of the catch composition on a general scale, whilst *Annex B: Results* contains the catch composition of each individual haul.

### 12.3.1. OSPAR Sensitivity Score

#### *12.3.1.1. Landings & Discards*

On **Figure 12-6**, Norway redfish (SFV) is predominantly present in areas labeled with the highest OSPAR score (4). Hauls labeled with a lower OSPAR score but located near or partially in a highly sensitive area, such as NOR1_S_6 or NOR2_S28, do also contain a relatively large share of SFV compared to other hauls (**Figure B- 4**). Additionally, the plaice fraction seems to be the lowest in areas labeled as highly sensitive.

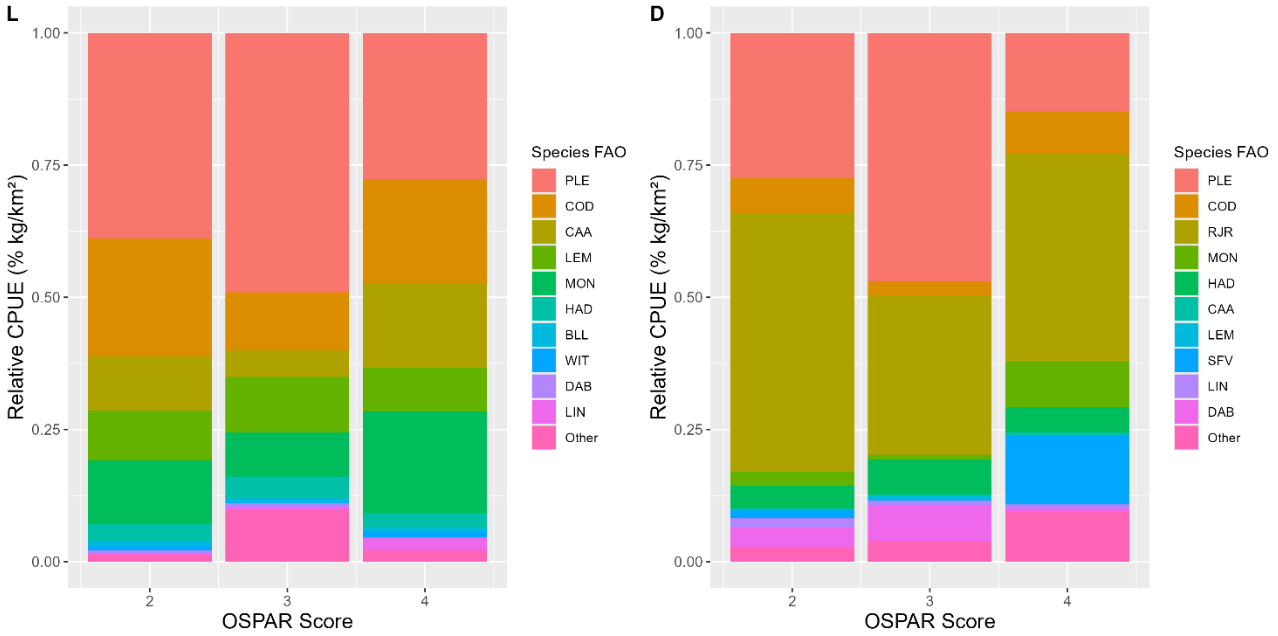


*Figure 12-6 General catch composition of [L] landings and [D] discards, expressed as kg km$^{-2}$, across the different OSPAR Scores. OSPAR Scores are: 2 (n = 18); 3 (n = 9); 4 (n = 11).*

#### *12.3.1.2. Benthos*

Dead man's fingers (*Alcyonium digitatum*) does not seem to be present in areas labeled with the highest OSPAR score (4) (**Figure 12-7**). On the other hand, *Halichondria* and *Echinus esculentus* seem the dominant benthic taxa in areas labelled as OSPAR score 4.

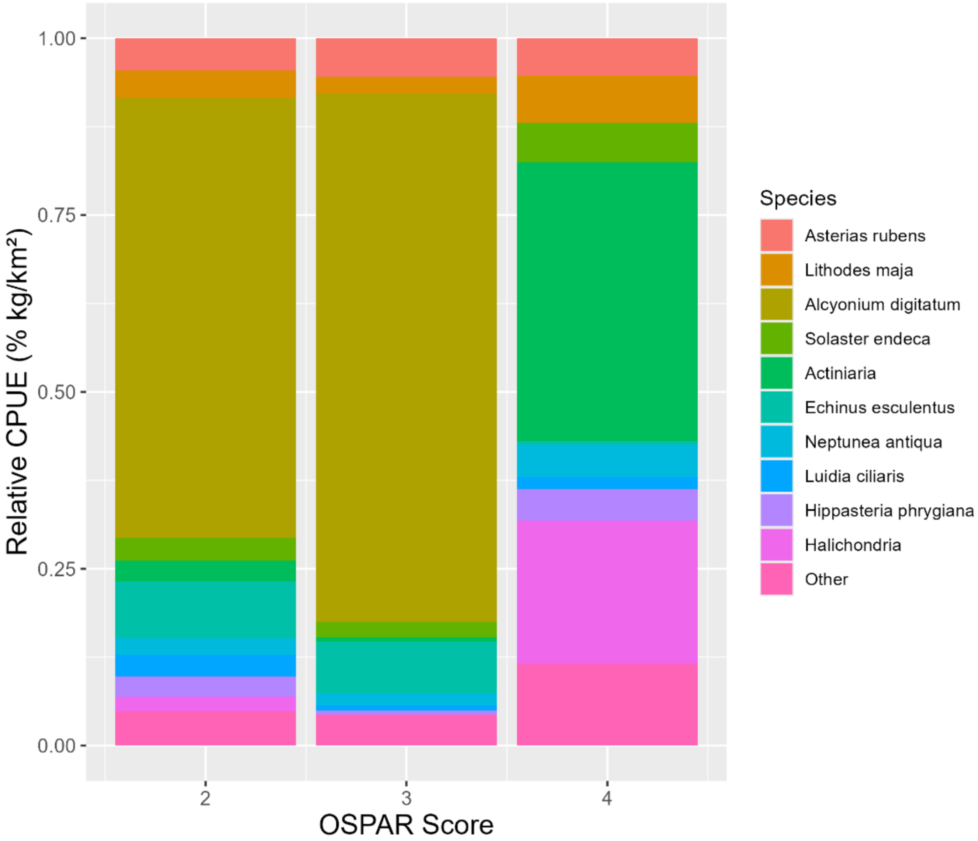


*Figure 12-7 General catch composition of benthic species, expressed as kg km$^{-2}$ , across the different OSPAR Scores. OSPAR Scores are: 2 (n = 18); 3 (n = 9); 4 (n = 11).*

## 12.3.2. Dominant Substrate Type

### *12.3.2.1. Landings & Discards*

**Figure 12-8** summarizes the general catch composition across the different sampled substrate types, both for landings (L) and discards (D). Plaice is dominating in all substrate types. An additional breakdown for the two most dominant substrate types (Sand and Rock + Boulders) is provided by **Figure B- 5**.

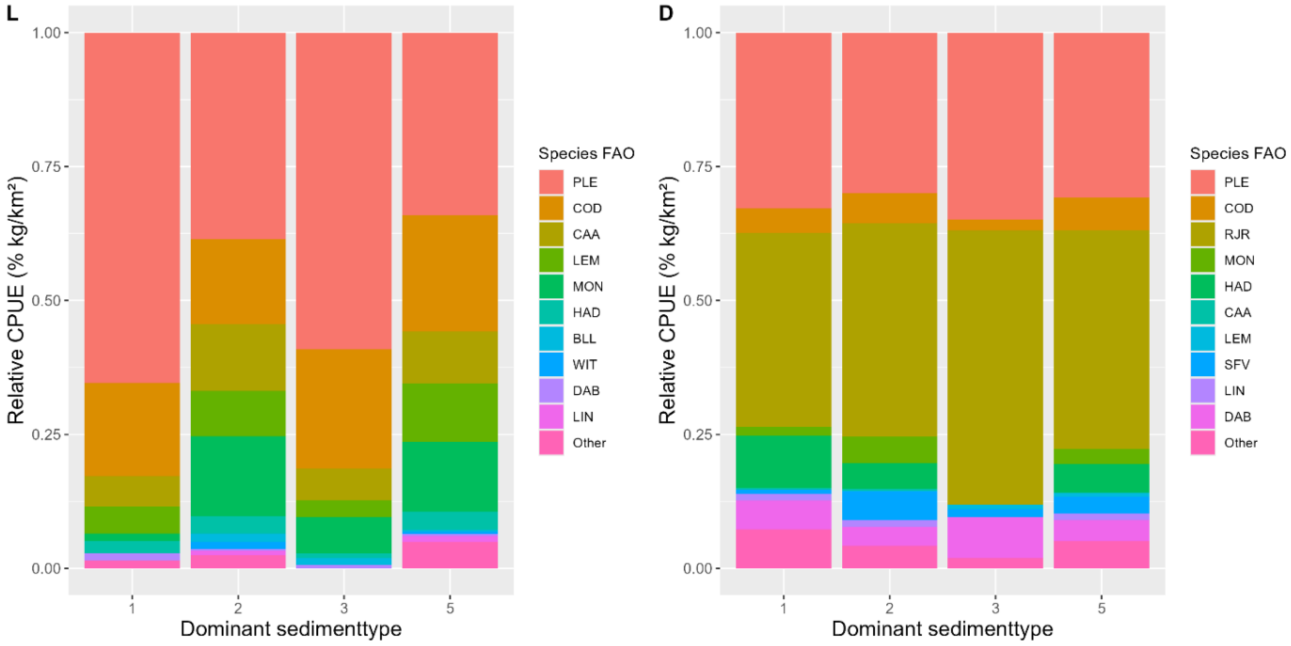


*Figure 12-8 General catch composition of [L] landings and [D] discards, expressed as kg km$^{-2}$, across different substrate types. Substrate types are: (1) Mud-Muddy Sand (n = 2); (2) Sand (n = 20); (3) Coarse substrate (n = 1); (4) Mixed Sediments (n = 0); (5) Rock + Boulders (n = 15).*

### *12.3.2.2. Benthos*

*Alcyonium digitatum* dominates in substrate type 1 and 5, and absent in type 3, where *Echinus esculentus* dominates. Sediment type 2 seems to show a more equal dominance of several benthos species, compared to the other substrates (**Figure 12-9**).

An additional breakdown for the two most dominant substrate types (Sand and Rock + Boulders) is provided by **Figure B- 6**.

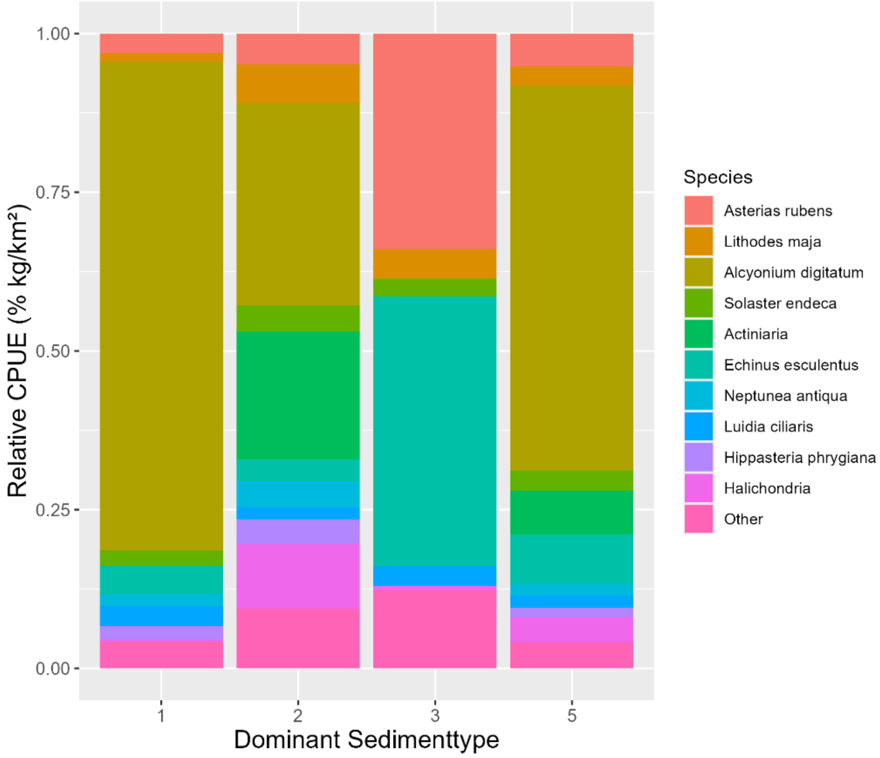


*Figure 12-9 General catch composition of benthos, expressed as kg km$^{-2}$ , across different substrate types. Substrate types are: (1) Mud-Muddy Sand (n = 2); (2) Sand (n = 20); (3) Coarse substrate (n = 1); (4) Mixed Sediments (n = 0); (5) Rock + Boulders (n = 15).*

## 12.4. ETP-Species

During the NoriVis survey, five species were classified as Endangered, Threatened and Protected (ETP). Guidelines for this classification are provided by the International Council for the Exploration of the Sea (ICES) (2024). The following species were classified as ETP:

- *Anarhichas lupus* (Atlantic wolffish)
- *Cyclopterus lumpus* (Lumpfish)
- *Hippoglossus hippoglossus* (Atlantic halibut)
- *Sebastes viviparus* (Norway redfish)
- *Zeus faber* (John Dory)

Three of these species, *Anarhichas lupus* (CAA), *Hippoglossus hippoglossus* (HAL) and *Sebastes vivparus* (SFV), were caught during Fully-Sampled Scientific hauls and therefore present in the data analysis. Abundances of these species are summarized in **Figure 12-10**.

*Cyclopterus lumpus* and *Zeus faber* were only caught in the supplementary hauls and are therefore not included in the data analysis.

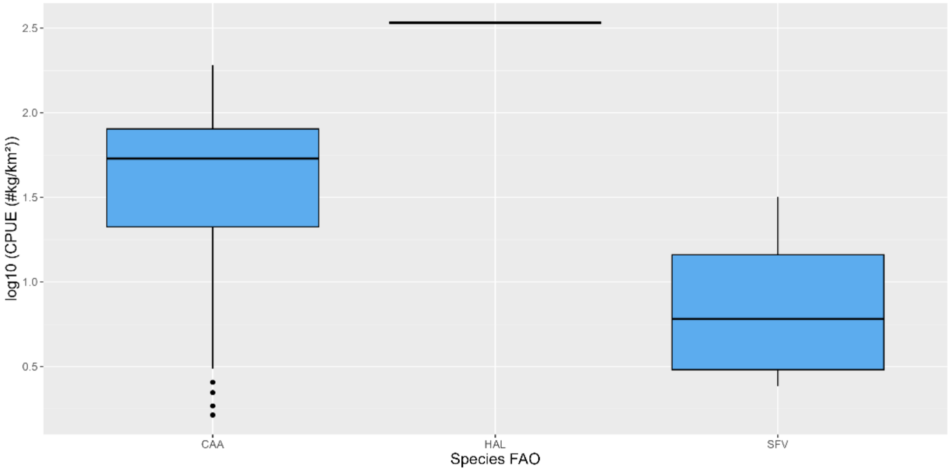


***Figure 12-10*** *log10- transformed CPUE (kg km$^{-2}$) of the recorded ETP-species over the entire survey. +Pseudo-count (all data+1) was performed to account for zero-values (log10(1) = 0).*

If the CPUE (kg km$^{-2}$) of the different ETP-species are plotted for the different levels of *OSPAR Score*, it can be seen that for Norway Redfish (SFV), a significant higher abundance was recorded in OSPAR 4 compared to OSPAR 2 and 3 ($p<0.01$) (**Figure 12-11**). On the contrary, the distribution of Atlantic wolffish (CAA) seems to be distributed evenly across the different levels, which is also confirmed by a one-way Anova test ($p>0.05$). The same also applies for the levels of *Dominant Substrate type*.: no clear distinction in those species occurrence can be made across the different substrate types.

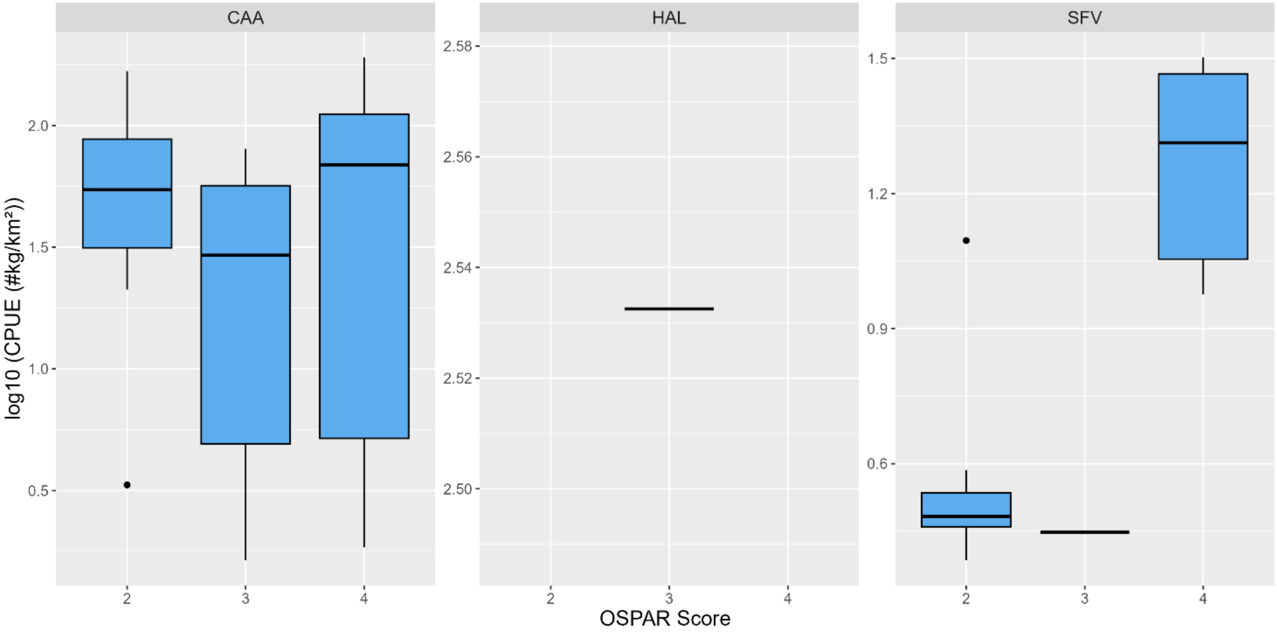


***Figure 12-11*** *log10- transformed CPUE (kg km$^{-2}$) of the recorded ETP-species per OSPAR score. Levels of OSPAR score are 2 (n = 18); 3 (n = 9); 4 (n = 11). Pseudo-count (all data+1) was performed to account for zero-values (log10(1) = 0).*

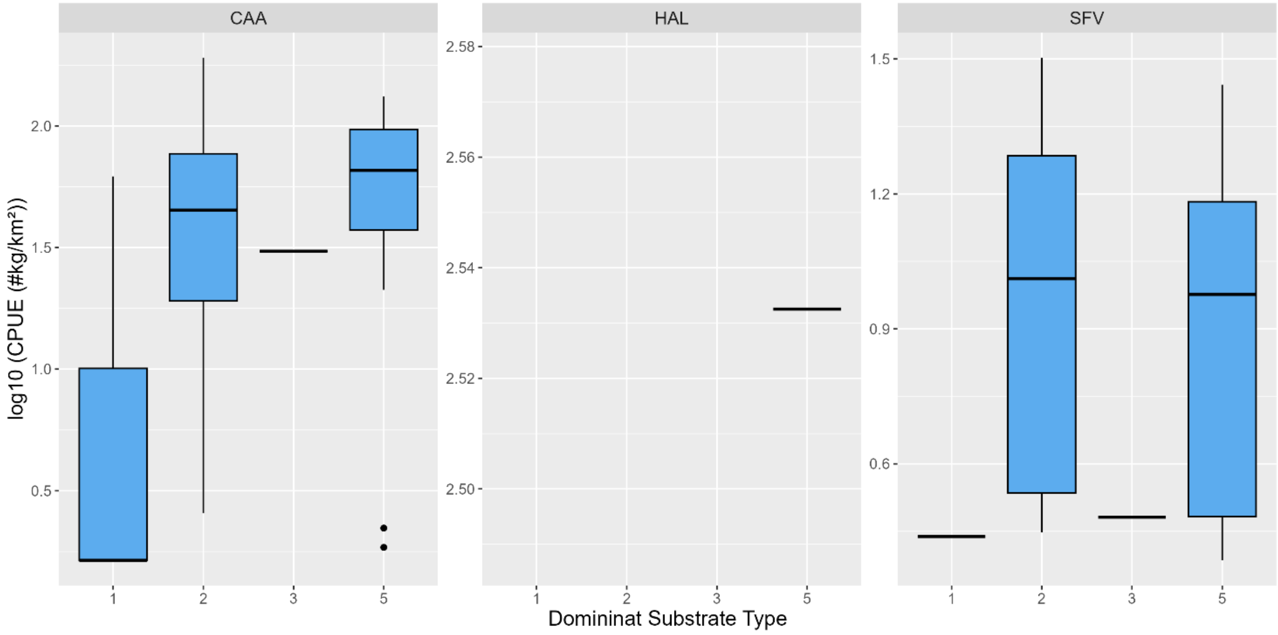


*Figure 12-12 CPUE (kg km$^{-2}$) of the recorded ETP-species per Dominant Substrate type. Substrate types are (1) Mud-Muddy Sand (n = 2); (2) Sand (n = 20); (3) Coarse substrate (n = 1); (4) Mixed Sediments (n = 0); (5) Rock + Boulders (n = 15). Pseudo-count (all data+1) was performed to account for zero-values (log10(1) = 0).*

## 12.5. Cluster Analysis

A Hierarchical Cluster Analysis is performed to investigate potential clustering of hauls based on species composition (landings, discards, benthos) in accordance with location (Sampled Station), sensitivity (OSPAR Score) or substrate (Dominant Substrate Type). First, the different clusters are defined (§12.5.1), which represents samples that are more related to each other. Next, the correspondence with the different factors, such as OSPAR score, is calculated (§12.5.2). Finally, species composition of each cluster is also visualized.

### 12.5.1. Clustering groups

#### *12.5.1.1. Landings & Discards*

The landings tend to cluster into two main clusters on a high dissimilarity level (0.8) (**Figure 12-13**).However, on a lower level of e.g. 0.55, there are three main clusters visible. The value of 0.55 ( **Figure 12-13**, red line) is arbitrarily chosen to divide the Fully-Sampled Scientific hauls into different clusters, which are visualized in **Figure 12-14**.

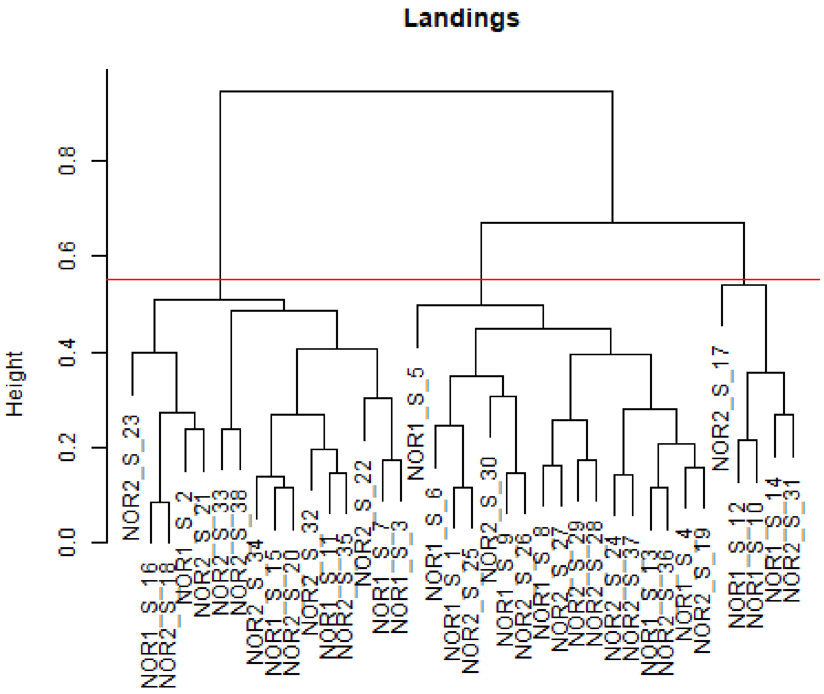


*Figure 12-13 Cluster analysis of the CPUE of the landings. The arbitrary level of 0.55 is highlighted with a red line.*

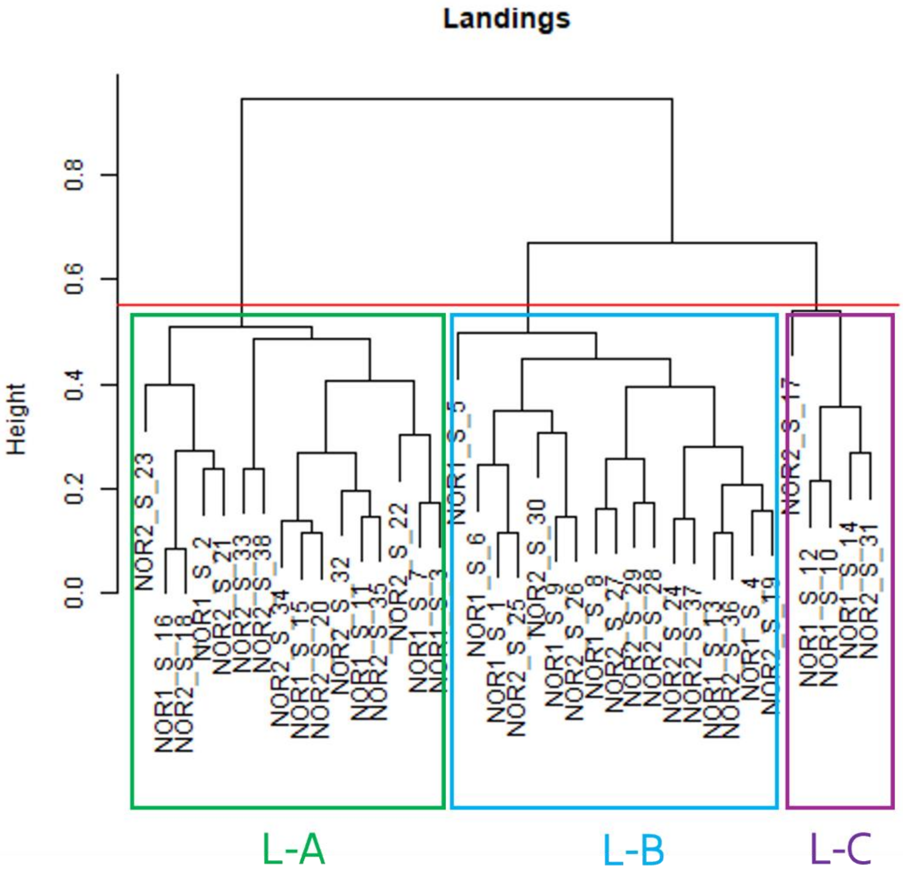


*Figure 12-14 Cluster analysis of the scientific haul of NoriVis. The cut-off value of 0.55 is highlighted with red. The arbitrarily chosen clusters are highlighted by the colored rectangles.*

Concerning the discards, there is already a breakup in different groups on a high level (0.8), with five distinct groups on level 0.55 (**Figure 12-15**, red line). This value will again be chosen as an arbitrary cut-off to divide the hauls into different groups, which are highlighted in **Figure 12-16**.

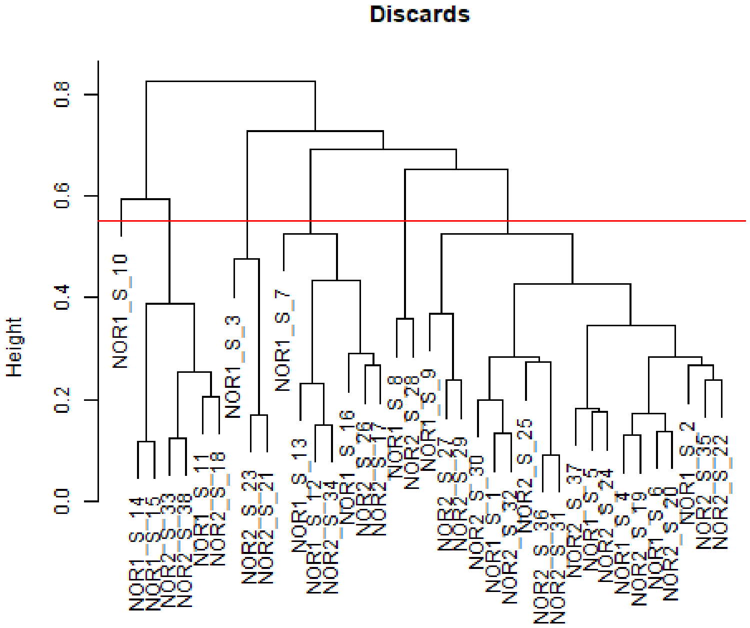


*Figure 12-15 Cluster analysis of the CPUE of the discards. The cut-off value of 0.55 is highlighted with red.*

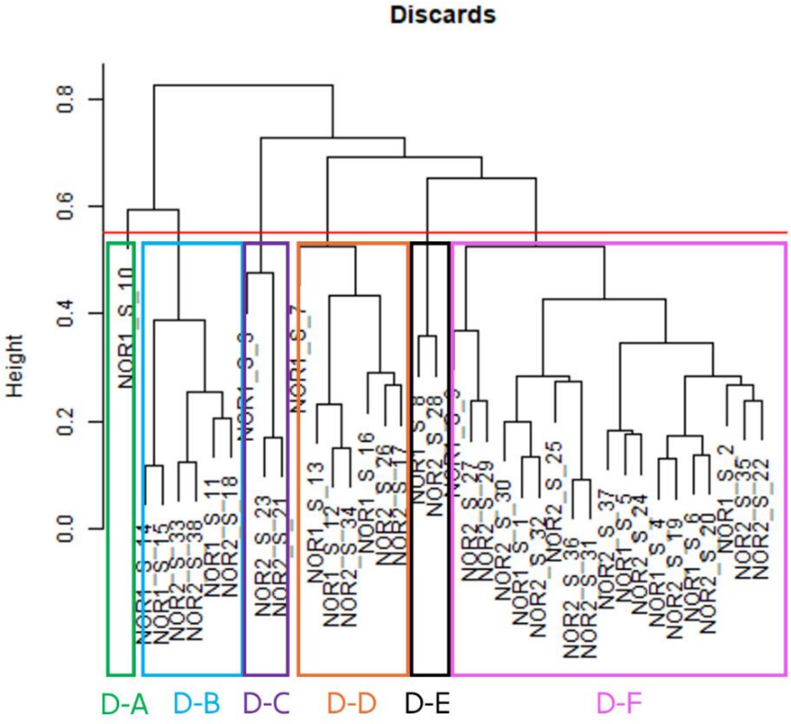


*Figure 12-16 Cluster analysis of the CPUE of the discards. The cut-off value of 0.55 is highlighted with red. The arbitrarily chosen clusters are highlighted by the colored rectangles.*

### *12.5.1.2. Benthos*

Within the benthos category, there are already six distinct groups on a high dissimilarity level (0.8) (**Figure 12-17**). Contrary to landings and discards, the cut-off value for benthos is chosen to be 0.775, because for lower values, too many clusters would be formed, and results would be less distinct. It also indicated that for benthos there is a higher dissimilarity between the different sample clusters, meaning more distinct differences in benthic species composition. Clusters are illustrated in **Figure 12-18**.

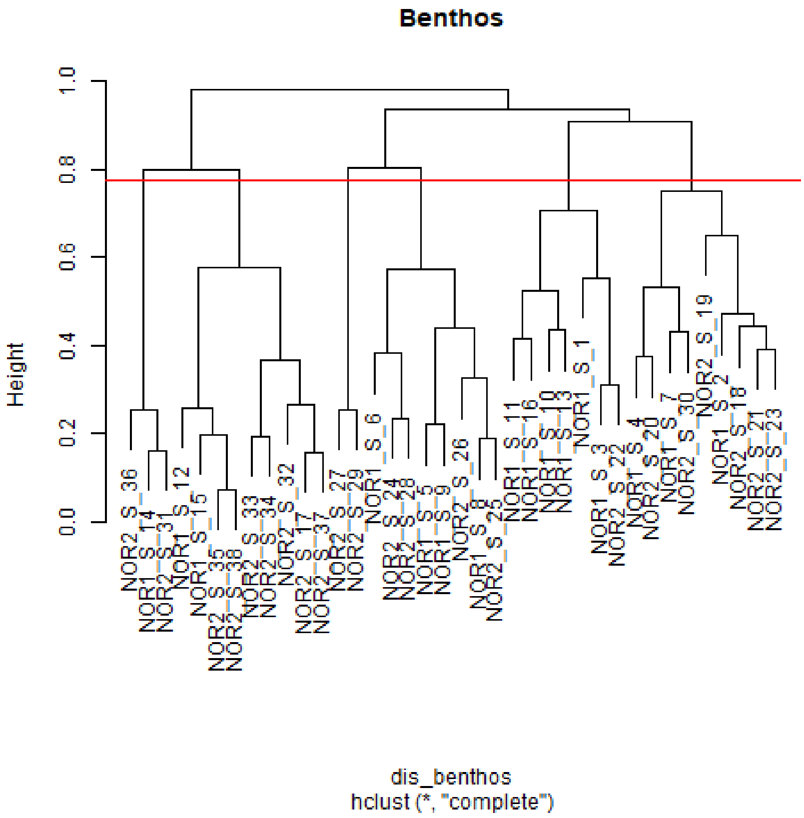


***Figure 12-17*** *Cluster analysis of the CPUE of the benthos. The cut-off value of 0.775 is highlighted with red.*

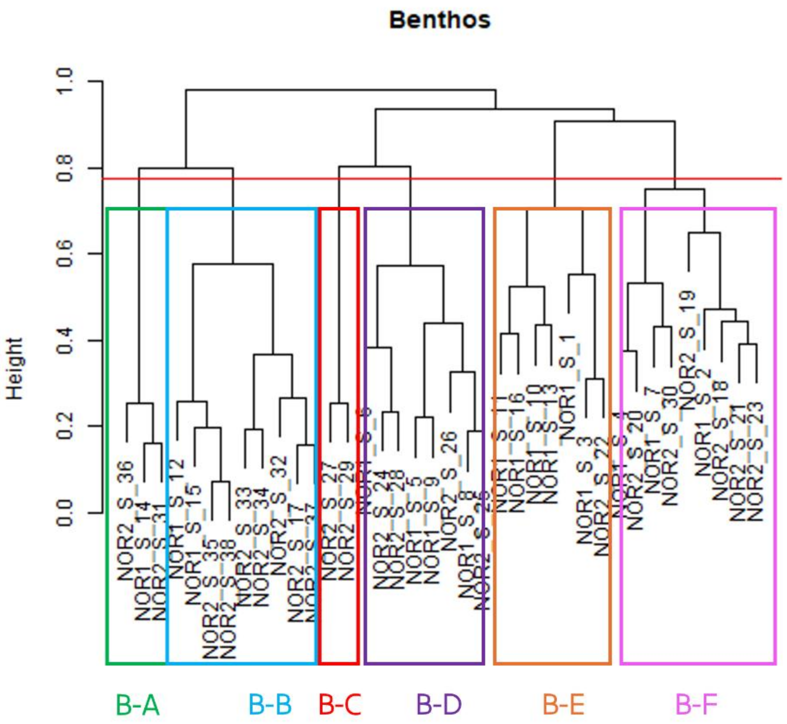


*Figure 12-18 Cluster analysis of the CPUE of the benthos. The cut-off value of 0.775 is highlighted with red. The arbitrarily chosen clusters are highlighted by the colored rectangles.*

## 12.5.2. Cluster-Factor relation

### *12.5.2.1. Landings & Discards*

For each defined landing (L-) and discard (D-) cluster, the percentage of the different levels of the factors *Sampled Station*, *OSPAR Score* and *Dominant Substrate Type* are calculated (**Table 12-3**). These percentages represent the level of presence of each factor in each cluster.

For the landing clusters (L-), only L-C seems to be dominated by a certain station, namely S2. L-B also shows a slight domination by station S1, but rather on a smaller scale. In cluster L-A, station presence is spread across all station areas. Regarding the *OSPAR score*, there is no clear distinction between the different levels in all three clusters. For *Dominant Substrate Type* however, a clear dominance is observed in both clusters L-A and L-C. In cluster L-A, substrate type 2 (Sand) is prominently present (62.5%), while in cluster L-C, substrate type 5 (Rock+Boulders) is the dominant level (80%). In cluster L-B, the distribution is spread more evenly.

Regarding the discard clusters (D-), the most pronounced distinction between stations can be observed in cluster D-D, where station S2 is the most dominant one. Additionally, a distinction can be seen in clusters D-B and D-C, where stations B3 and B1 pop out, respectively. In cluster D-A, there is a 100% presence for station S2, but since the sample size is equal to one, this can be neglected.

The discard clusters show a similar pattern for the *OSPAR Score*. OSPAR score 3 is dominant in both Cluster D-B and D-C, although it is not very pronounced. In contrast to the *Sampled Station* factor, no clear distinction is observed for cluster D-D in relation to the OSPAR score. As before, the result for cluster D-A can be neglected.

For the *Dominant Substrate Factor*, some clear distinctions can be observed. Cluster D-C and D-F are predominantly associated with substrate type 2 (sand), with a presence of 100% and 63.16%, respectively.

Cluster D-D in turn is characterized by a high presence of substrate type 5 (rock+boulders). The remaining clusters do not show any pronounced substrate characterization.

Lastley, cluster D-F is characterized by a large share of acoustic group B (52.63%), while acoustic group C is most dominant in cluster D-B (83.33%) and D-C ( 66.67%).

*Table 12-3 Presence of the different levels of "Sampled Station", "OSPAR Score" and "Dominant Substrate Type" in the different landing (L-) and discard (D-) clusters, which are defined and visualized in* ***Figure 12-14*** *and* ***Figure 12-16****. Presence is expressed as percentage. Sample sizes of the different clusters are given in the graph header (n = ...). Substrate IDs are: 1) Mud to Muddy Sand; (2) Sand; (3) Coarse Sediments; (4) Mixed Sediments; (5) Rock + Boulders.*

| | L-A (n = 16) | L-B (n = 17) | L-C (n = 5) | D-A (n = 1) | D-B (n = 6) | D-C (n = 3) | D-D (n = 7) | D-E (n = 2) | D-F (n =19) |
|---|---|---|---|---|---|---|---|---|---|
| *Sampled Station* | | | | | | | | | |
| B1 | 18.75% | 0.00% | 0.00% | 0.00% | 0.00% | **66.67%** | 0.00% | 0.00% | 5.26% |
| B2 | 0.00% | 23.53% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 21.05% |
| B3 | 25.00% | 0.00% | 20.00% | 0.00% | **66.67%** | 0.00% | 14.29% | 0.00% | 0.00% |
| S1 | 6.25% | **52.94%** | 0.00% | 0.00% | 0.00% | 0.00% | 28.57% | 50.00% | **36.84%** |
| S2 | **31.25%** | 17.65% | **80.00%** | **100.00 %** | 33.33% | 0.00% | **57.14%** | 0.00% | 26.32% |
| OUT | 18.75% | 5.88% | 0.00% | 0.00% | 0.00% | 33.33% | 0.00% | 50.00% | 10.53% |
| *OSPAR Score* | | | | | | | | | |
| OSPAR Score 2 | 37.50% | **58.82%** | 40.00% | **100.00 %** | 33.33% | 0.00% | **42.86%** | 50.00% | **57.89%** |
| OSPAR Score 3 | 37.50% | 0.00% | **60.00%** | 0.00% | **66.67%** | **66.67%** | **42.86%** | 0.00% | 0.00% |
| OSPAR Score 4 | 25.00% | **41.18%** | 0.00% | 0.00% | 0.00% | 33.33% | 14.29% | **50.00%** | 42.11% |
| *Dominant Substrate Type* | | | | | | | | | |
| 1 | 6.25% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 14.29% | 0.00% | 0.00% |
| 2 | **68.75%** | 52.94% | 20.00% | 0.00% | **50.00%** | **100.00 %** | 28.57% | **50.00%** | **63.16%** |
| 3 | 6.25% | 0.00% | 0.00% | 0.00% | 16.67% | 0.00% | 0.00% | 0.00% | 0.00% |
| 5 | 18.75% | **47.06%** | **80.00%** | **100.00 %** | 33.33% | 0.00% | **57.14%** | **50.00%** | 36.84% |
| *WASSP grey-value* | | | | | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| A (<60) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| B (60-110) | 12.50% | **76.47%** | **60.00%** | **100.00 %** | 16.67% | 33.33% | **42.86%** | **100.00 %** | **52.63%** |
| C (>110) | **81.25%** | 17.65% | 40.00% | 0.00% | **83.33%** | **66.67%** | **42.86%** | 0.00% | 42.11% |
| UNK | 6.25% | 5.88% | 0.00% | 0.00% | 0.00% | 0.00% | 14.29% | 0.00% | 5.26% |

The species composition of each cluster is visualized by **Figure 12-19** (landings) and **Figure 12-20** (discards).

Plaice (PLE) is the most present species in both clusters L-A (58.39%) and L-C (38.78%). In cluster L-A, monkfish (MON) follows as second most present species, with a relative abundance of 10.54%, while in cluster L-C cod (COD) is second most present (18.11%). The latter records the highest abundance in cluster L-B (25.28%), nearly followed by plaice (24.89%).

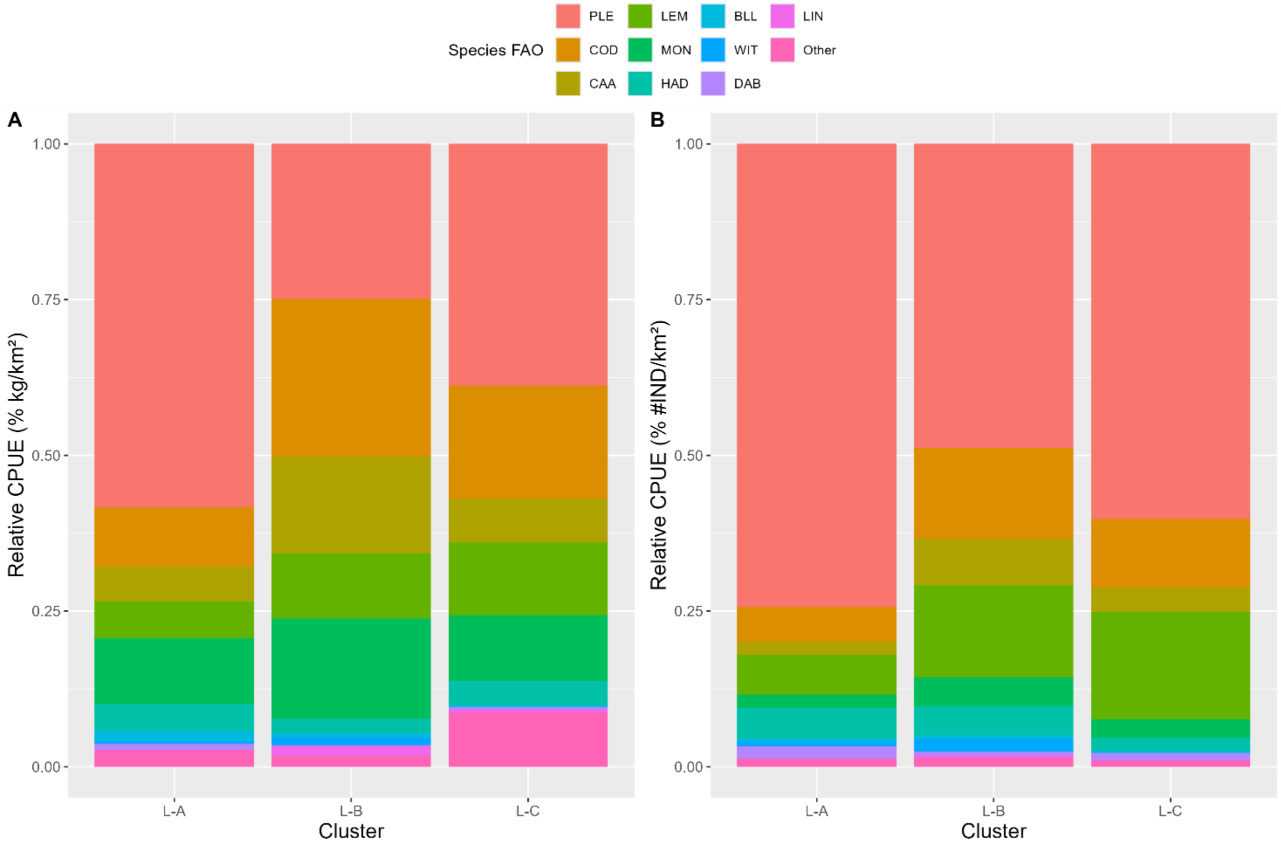


*__Figure 12-19__ Catch composition of different landing clusters as presented by __Figure 12-12__. CPUE is expressed as relative [A] abundance (kg km$^{-2}$) and [B] density (#IND km$^{-2}$);*

Regarding the discard clusters, it can be noticed that Norway redfish (SFV) is dominant in cluster D-E, with a relative abundance of 22.06%, followed by starry ray (RJR), which has a relative abundance of 21.45%. Norway redfish is also present in cluster D-F, albeit with a lower percentage (7.06%). In this cluster, starry rays are the most occurring species, with a relative abundance of 52.38%. The same applies for clusters D-A (68.23%) and D-C (57.81%), where starry ray record the highest relative abundance, followed by plaice (13.5%) and cod (15.69%), respectively. Subsequently, cluster D-B exhibits a large fraction of plaice (51.43%) in combination with starry ray (31.52%). Finally, cluster D-D, in previous analysis linked to gravel and boulders, exhibits a similar pattern, with a relative abundance of plaice of 39.23%, starry ray of 30.44% and less the Norway redfish (**Figure 12-20**).

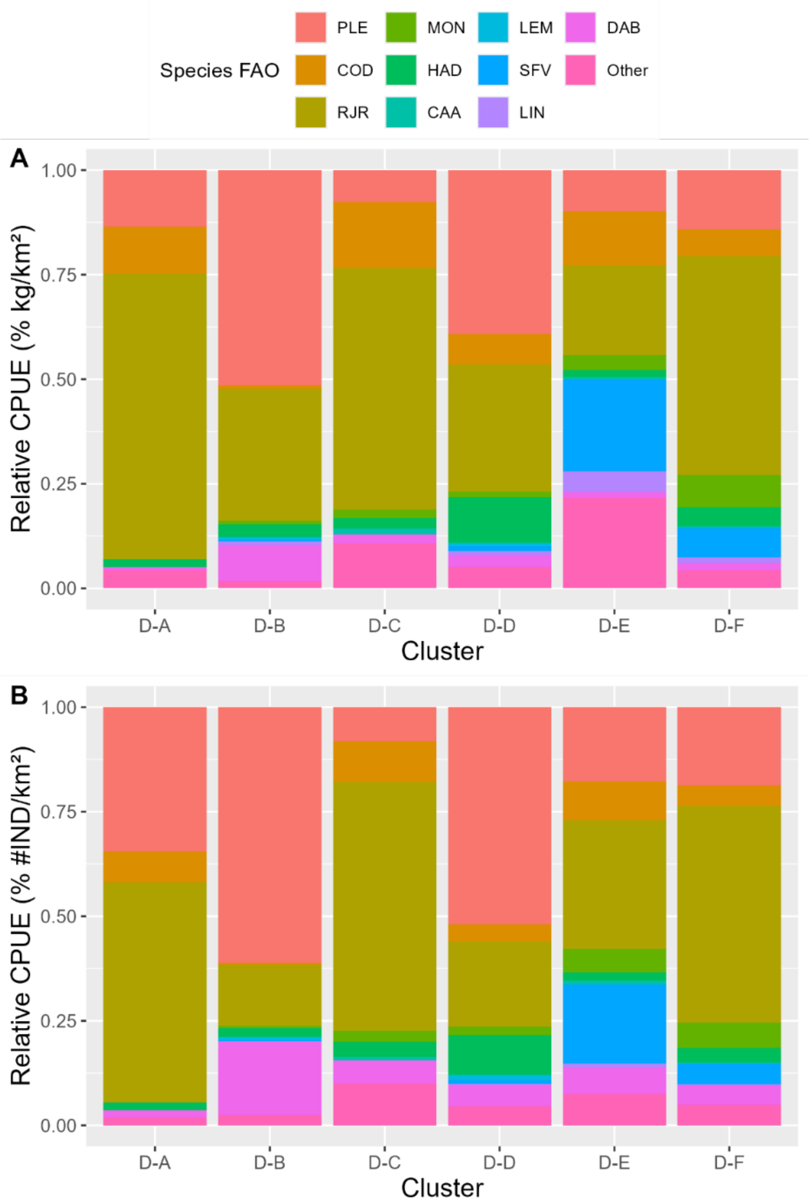


*Figure 12-20 Catch composition of different discard clusters as presented by Figure 12-16. CPUE is expressed as relative [A] abundance (kg km$^{-2}$) and [B] density (#IND km$^{-2}$)*

### *12.5.2.2. Benthos*

**Table 12-4** summarizes the ratios of the different levels of *Sampled Station*, *OSPAR Score* and *Dominant Substrate Type* across the different benthic clusters (B-) presented in §12.5.1.2

In Cluster B-A and B-B, station S2 is mainly present, with a relative presence of 66.67% in both clusters. Cluster B-E is also dominated by hauls conducted in S2, albeit to less extent than B-A and B-B. Additionally, cluster B-D is mainly characterized by station S1 (75.00%), while other clusters do not exhibit any pronounced dominant station.

Regarding the *OSPAR Score*, cluster B-D seems to be characterized by OSPAR score 4, with a presence of 62.5%. Furthermore, clusters B-E and B-F show a less pronounced dominance of OSPAR score 2 (57.14% and 55.56%, respectively). Cluster B-A also seems to be dominated by OSPAR score 2 but given the small sample size (n = 3) , this result should be interpreted with care. Finally, cluster B-B seems to be a combination of OSPAR Score 2 and 3.

Cluster B-F is characterized by a high presence of substrate class 2 (Sand), with a presence of 77.78. Only one cluster (B-A) is slightly dominated by substrate class 5, other cluster groups are a balanced combination of substrate classes 2 and 5.

Finally, cluster B-B is dominated by acoustic group C (>110), with a presence of 88.89%. Additionally, the dominance of acoustic group B (60-110) is noticed for cluster B-D and B-C, with a presence of respectively 87.5% and 100%. No occurrence of group A (<60%) are noted.

*Table 12-4 Presence of the different levels of "Sampled Station", "OSPAR Score" and "Dominant Substrate Type" in the different benthos (B-) clusters, which are defined and visualized in* ***Figure 12-18****. Presence is expressed as percentage. Sample sizes of the different clusters are given in the graph header (n = ...). Substrate IDs are: 1) Mud to Muddy Sand; (2) Sand; (3) Coarse Sediments; (4) Mixed Sediments; (5) Rock + Boulders.*

| | B-A (n = 3) | B-B (n = 9) | B-C (n = 2) | B-D (n = 8) | B-E (n = 7) | B-F (n=9) |
|---|---|---|---|---|---|---|
| *Sampled Station* | | | | | | |
| B1 | 0.00% | 0.00% | 0.00% | 0.00% | 28.57% | 11.11% |
| B2 | 0.00% | 0.00% | 0.00% | 12.50% | 14.29% | 22.22% |
| B3 | 33.33% | 33.33% | 0.00% | 0.00% | 14.29% | 0.00% |
| S1 | 0.00% | 0.00% | 100.00% | 75.00% | 0.00% | 22.22% |
| S2 | 66.67% | 66.67% | 0.00% | 0.00% | 42.86% | 11.11% |
| OUT | 0.00% | 0.00% | 0.00% | 12.50% | 0.00% | 33.33% |
| *OSPAR Score* | | | | | | |
| 2 | 66.67% | 44.44% | 0.00% | 37.50% | 57.14% | 55.56% |
| 3 | 33.33% | 55.56% | 0.00% | 0.00% | 14.29% | 22.22% |
| 4 | 0.00% | 0.00% | 100.00% | 62.50% | 28.57% | 22.22% |
| Dominant Substrate Type (ID) | | | | | | |
| 1 | 33.33% | 0.00% | 0.00% | 0.00% | 14.29% | 0.00% |
| 2 | 0.00% | 44.44% | 100.00% | 50.00% | 42.86% | 77.78% |
| 3 | 0.00% | 0.00% | 0.00% | 0.00% | 14.29% | 0.00% |
| 5 | 66.67% | 55.56% | 0.00% | 50.00% | 28.57% | 22.22% |
| *WASSP grey-value* | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **A (<60)** | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| **B (60-110)** | 33.33% | 11.11% | 100.00% | 87.50% | 42.86% | 44.44% |
| **C (>110)** | 66.67% | 88.89% | 0.00% | 12.50% | 42.86% | 44.44% |
| **UNK** | 0.00% | 0.00% | 0.00% | 0.00% | 14.29% | 11.11% |

In addition to **Table 12-4**, **Figure 12-21** demonstrates the general catch composition of the benthic species for all benthic clusters. Large shares of dead man's fingers (*Alcyonium digitatum*) characterize clusters B-A (85.96%) and B-B (76.53%), whilst it is not recorded in other clusters. Cluster B-C is characterized by a dominance of sea anemones (*Actinaria*, 50.22%) and sponges (*Halichondria*, 28.24%). B-D follows a similar pattern, with sea anemones (35.77%) and sponges (15.61%) the most present groups, albeit in smaller fractions. Cluster B-E exhibits a more balanced catch composition, with edible sea urchin (*Echinus esculentus*, 22.66%) and common sea star (*Asterias rubens;* 20.44%*)* as most present species. Finally, in cluster B-F, Norway king crab (*Lithodes maja;* 17.26%) and red whelk (*Neptunea antiqua*, 15.7%) represent the largest fractions.

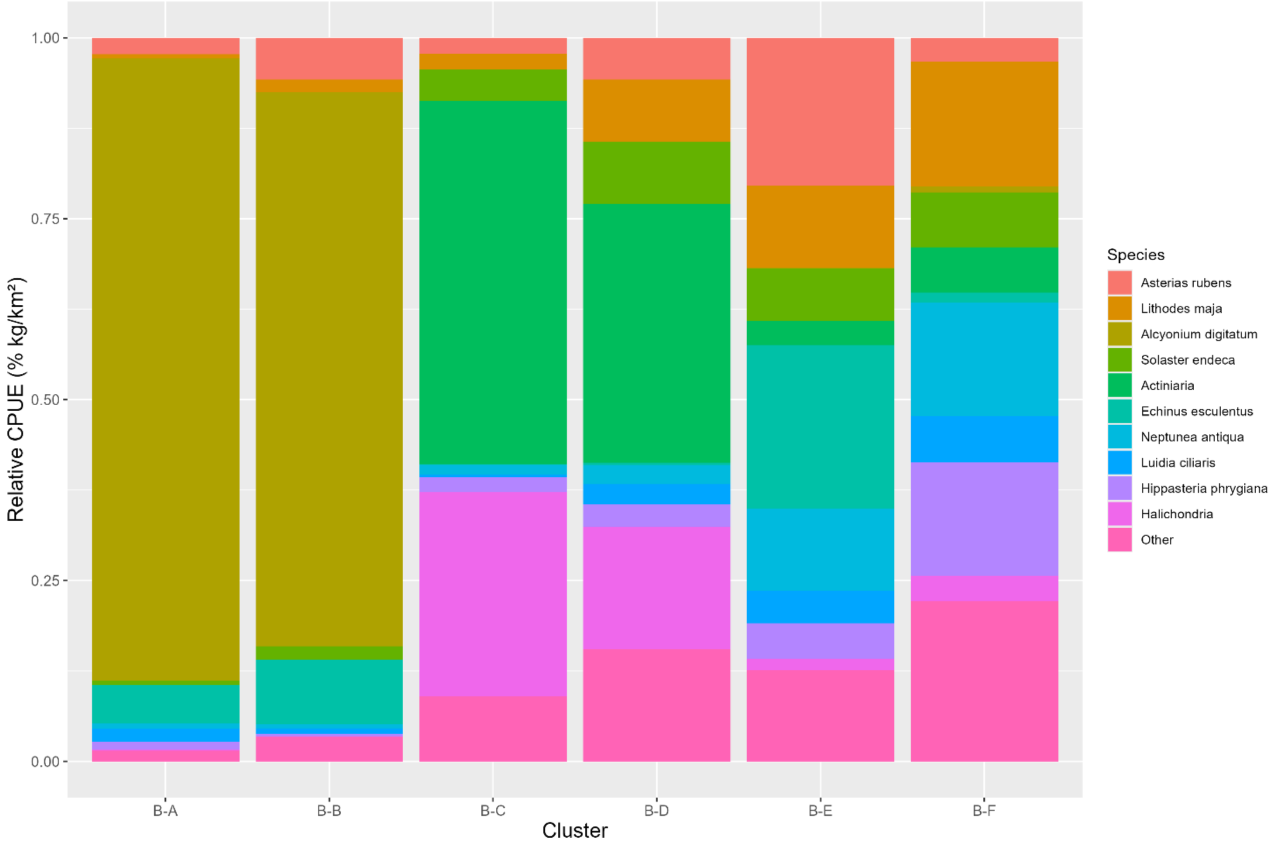


*Figure 12-21 General catch composition, expressed as relative CPUE (kg km$^{-2}$), of the different benthic clusters. Cluster sizes are n = 3 (B-A); n = 9 (B-B); n = 2 (B-C); n = 8 (B-D), n = 7 (B-E); n = 9 (B-F).*

## 12.6. Principal Component Analysis

In addition to the hierarchical cluster analysis provided in §12.5, a Principal Component Analysis (PCA) is performed to link the influence of the different species to the individual Fully-Sampled Scientific hauls.

### 12.6.1. Landings

**Figure 12-22** displays the relation of the different Fully-Sampled Scientific hauls to the different present landing species. At first sight, the stations (except Nor1_S_12, outlier), no clear clustering of the different hauls can be observed.

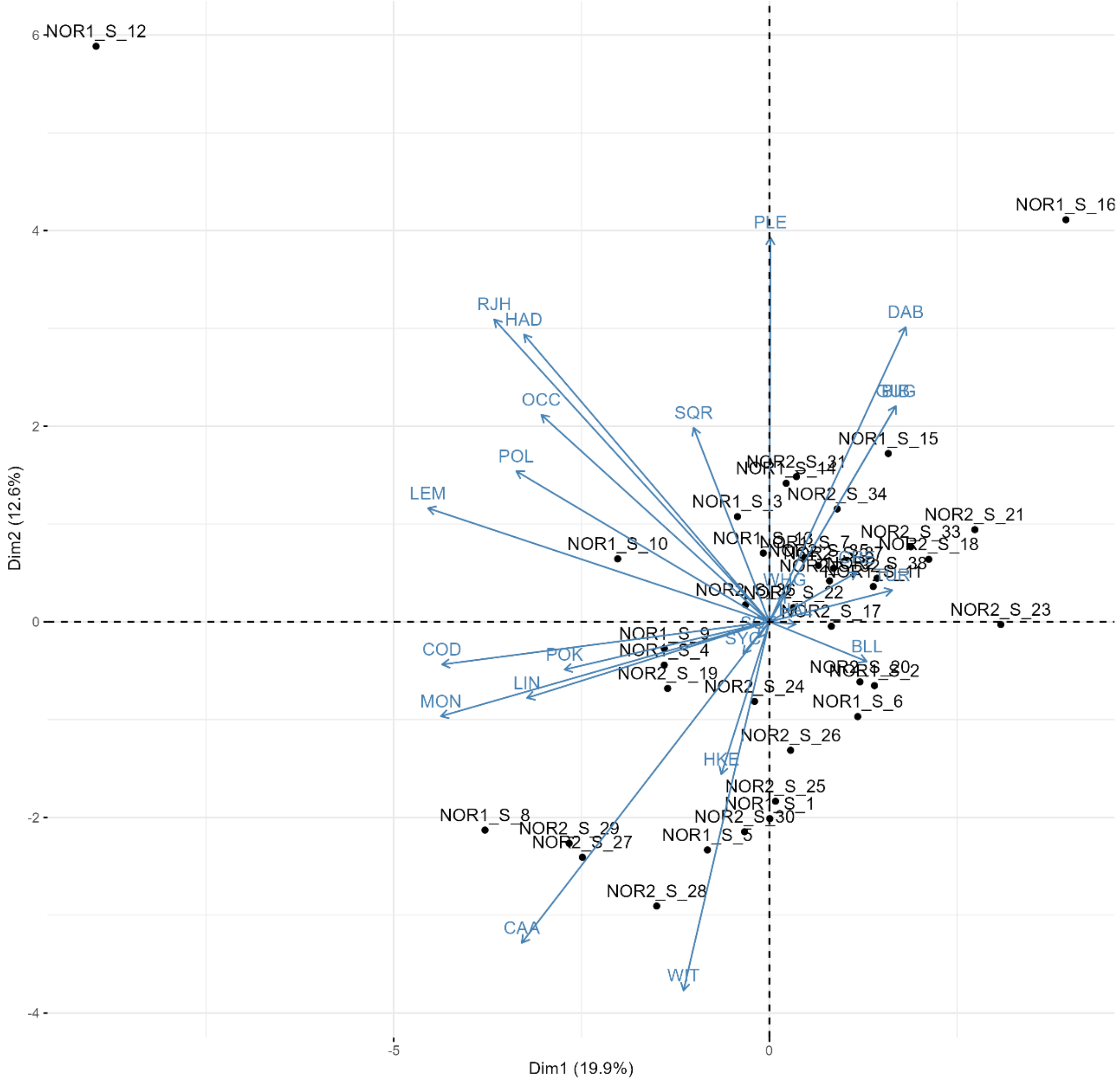


*Figure 12-22 PCA plot of the different fish species labeled as "landings".*

**Figure B- 7**, **Figure B- 8** and **Figure B- 9** show the same PCA plot, but with an additional classification based on the factors Sampled Station, OSPAR score, Dominant Substrate type and WASSP recording. Again, no clear clustering could be observed. There is however a trace of clustering for the factor S*ampled Station.* Hauls conducted in stations S2 and B3 tend to cluster together, which could be explained by the partial overlap between these stations. Hauls sampled in S1 also show a tendency to cluster together, although some hauls, like *NOR1_S_7*, are located far from this cluster. No additional, significant clustering is observed when considering OSPAR score, Dominant substate type or WASSP grey-values.

In general, besides some slight clustering by the factor "*Sampled Station*", no obvious clustering can be observed in the landings.

### 12.6.2. Discards

**Figure 12-23** illustrates the results of the PCA of the discards. In contrast to **Figure 12-22**, this figure shows three prominent clusters, which are encircled with red on the figure.

One cluster, located in the top left corner of the figure, is characterized by the presence of the two ETP-species, SFV and to a lesser extent, CAA. Hauls that are situated in this cluster, are mainly located around the upper part of S1, which is associated with OSPAR score 4.

Hauls located in the cluster on the top right of the figure are characterized by relatively high CPUE's of plaice (PLE), haddock (HAD), lemon sole (LEM) and common dab (DAB), and are also located around stations B3 and S2. This could already be observed in on **Figure 12-5**, which represents the relative abundance and density of the different discards species across the different sampled stations. The large SFV fraction is clearly visible for station S1 compared to other stations. Additionally, Station B3 records a higher plaice (PLE) and discard dab (DAB), but a smaller starry ray (RJR) fraction.

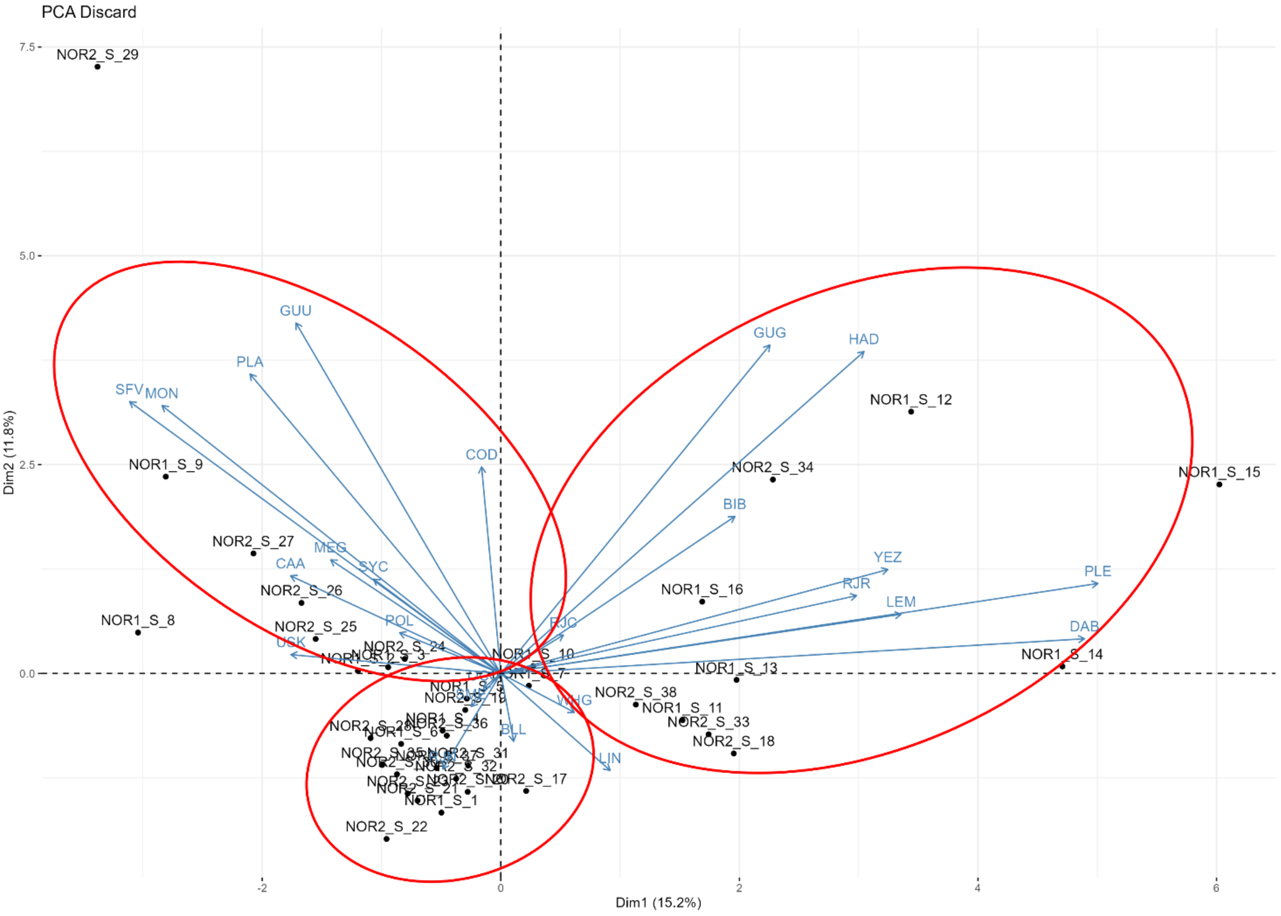


*Figure 12-23 PCA plot of the different fish species labeled as "discards". Potential clusters are indicated with red circles.*

Like the landings, an additional breakdown of this PCA is provided in ANNEX B, based on the different factors. (**Figure B- 10**, **Figure B- 11** and **Figure B- 12**)

**Figure B- 10** shows the results of the PCA with an additional breakdown based on the factors *Sampled Station* and *OSPAR score*. This figure shows a clear clustering of the hauls taken in S1 (blue) with an OSPAR score 4 (rectangle), which were also characterized by the increased Norway redfish (SFV) fraction. Additionally, a reduced plaice (PLE) fraction compared to the other levels is also observed of OSPAR score 4 (**Figure 12-6**). Furthermore, hauls from B3 (green) and S2 (pink) also seem to congregate. This makes sense however, since these two locations are located near to each other.

**Figure B- 11** also demonstrates that hauls classified with OSPAR Score 4 and situated in S1 are associated with acoustic group B (60-110). Additionally, hauls labeled as low-sensitive (OSPAR score 2) tend to cluster in the middle and also belong more or less to acoustic group C (>110).

When the PCA plot is visualized with a focus on *Dominant substrate Type*, as shown by **Figure B- 12**, it can be seen that hauls which all clustered as highly sensitive (OSPAR score 4) around station S1, have a mixed dominance of Sand (2) and Rock+ Boulders (5). They, however, all belong to the same acoustic group (B).

### 12.6.3. Benthos

**Figure 12-24** provides the biplot of the PCA of the benthic species. Just as in the previous section, three different clusters could be observed. However, since the majority of the hauls cluster in one group, and because of the large number of benthic species, the characterization of the clusters is less obvious.

Similar to the previous sections, an additional breakdown of the different factors is provided. **Figure B- 13** visualizes factors “Sampled Station” (color) and OSPAR score (shape). Hauls conducted in area S1 (blue) and which as classified with an OSPAR score 4 (rectangle) tend to cluster again together, just as in **Figure B- 15Figure B- 10**. On the contrary, no clear distinction between OSPAR score 2 and 3 can be observed. Regarding the sampled station, a cluster of hauls sampled in S1 (blue) and another of hauls conducted in both S2 (pink) and B3 (green). These trends were also observed in the previous section.

**Figure B- 14** illustrates the classification according to the EMODnet substrate mapping and based on WASPP images. Acoustic group B, associated with coarser substrates, tend to cluster to the left. Remarkable is that this “cluster” contains both hauls classified as Sand (type 2) and Rock+ Boulders (type 5). This will further be discussed in §14.3.1.

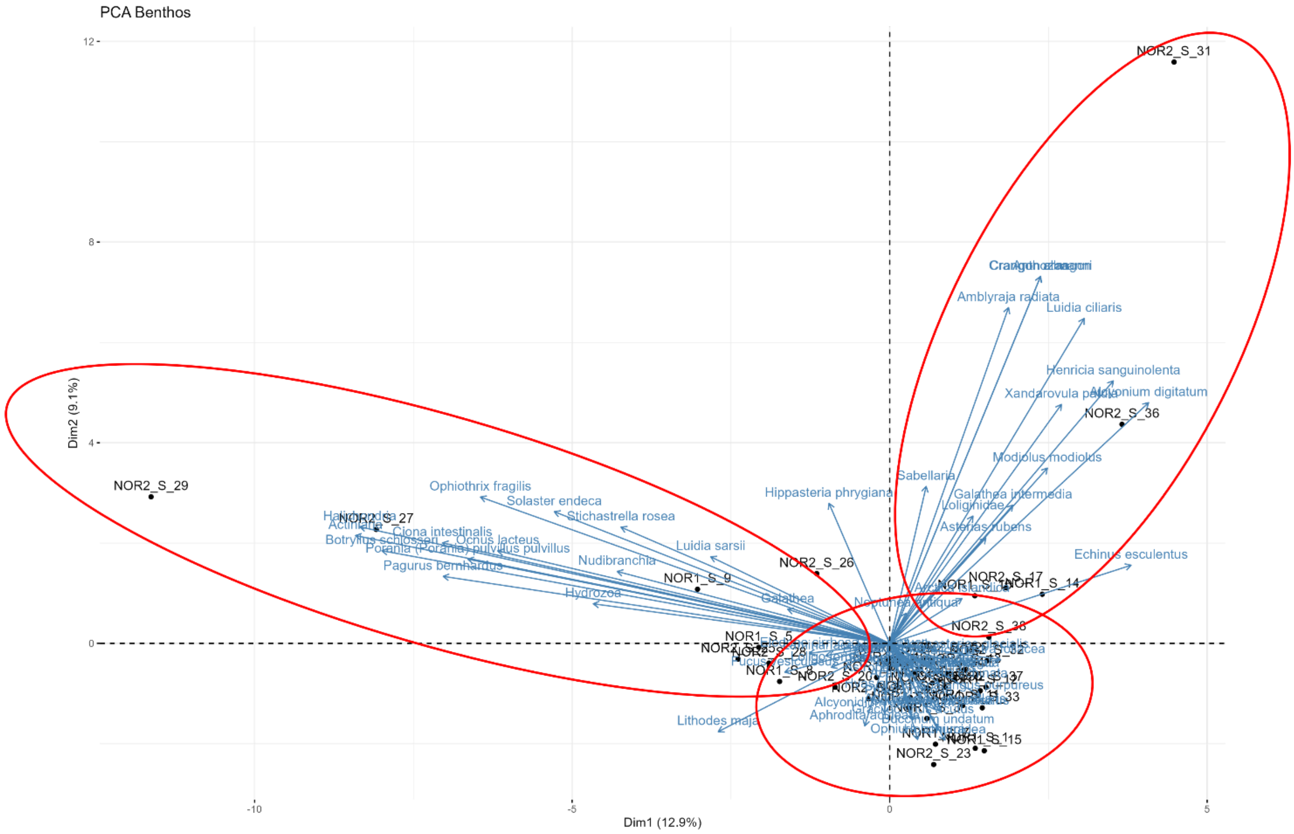


*Figure 12-24 PCA plot of the different benthic species. Potential clusters are indicated with red circles.*

# 13. VISIM-Camera

As stated in §6.5, VISIM-data will be mostly used to train existing and future models. Results from this training and testing phase will not be available within the project time. However, this section provides an example of how the model training is performed.

**Figure 13-1** shows an image taken by the VISIM camera aboard the survey vessel during the sorting of the catch. On the picture, a plaice and start ray can be seen, as well as some benthic species.

After applying the existing models to the image, **Figure 13-2** was produced. On this picture, the plaice and starry ray were detected as “Fish”, with the confidence of the prediction also visualized. The search area was also minimalized, as the picture is completely focused on the conveyor belt.

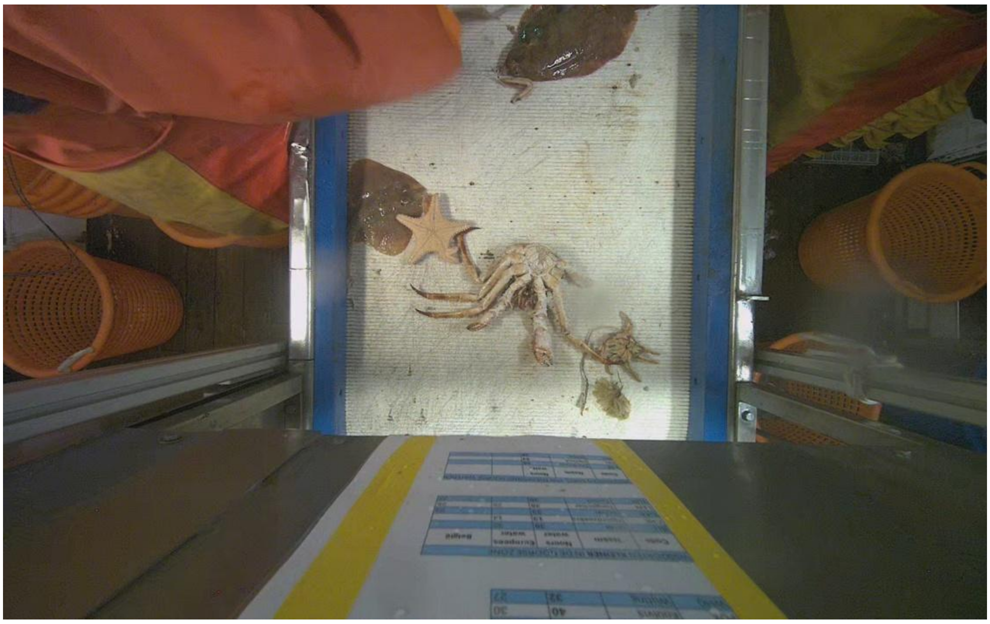


*__Figure 13-1__ Picture taken by the VISIM camera aboard the survey vessel Z.510-Dennis. Picture taken during the sorting of the catch.*

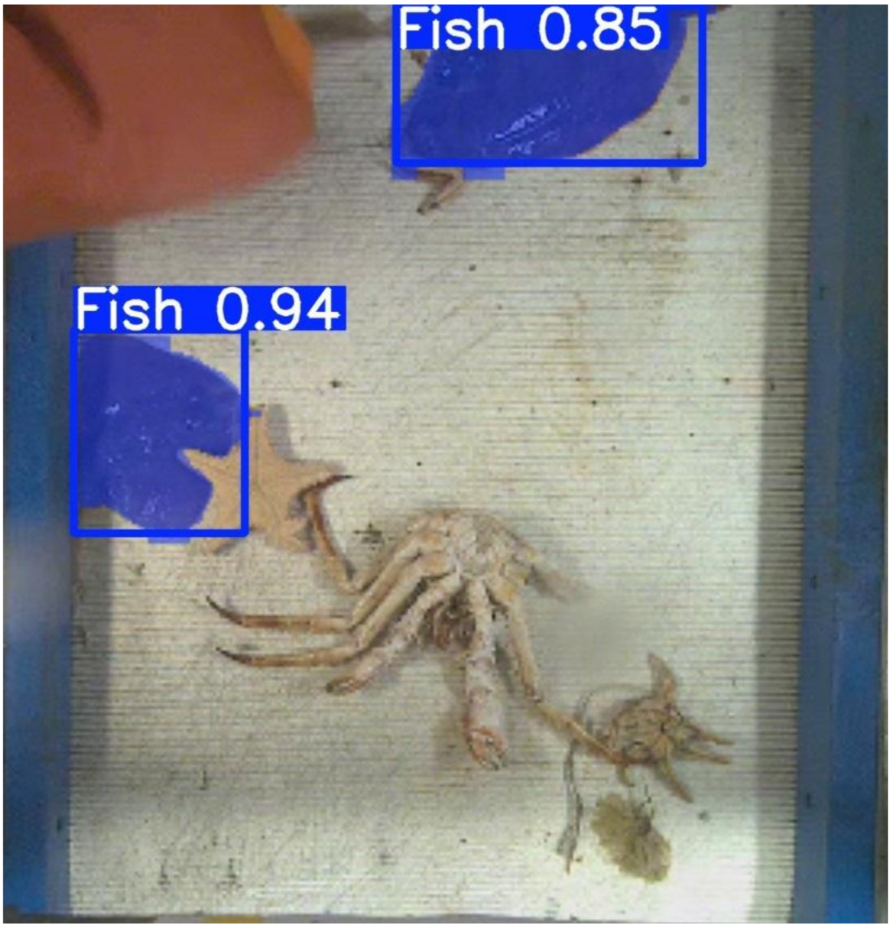


*__Figure 13-2__ Processed image of __Figure 13-1__. The search area is minimized, and fish species are detected. The number next to "Fish" represents the confidence of the prediction (maximum of 1).*

# Discussion

# 14. Evaluation of Precision Fishery Techniques

The main goal of this study is to evaluate current innovative techniques and their capability to contribute to precision fishery. The vessel that participated in this study, the Belgian beam trawler Z.510-Dennis, was equipped with a **WASSP multibeam sensor,** which provides information on the present sea floor substrate. In addition, the vessel is equipped with the automatic data collection platform **VISTools,** which integrates real time onboard data with additional sensor- (e.g. water temperature) and economic data (e.g. fuel prices) of the vessel. In addition to these technologies, data on the **catch composition** (fish and benthos) was also collected by two ILVO-scientists onboard and a **VISIM-camera**. This section provides a first evaluation of the different data sources presented and their potential to precision fishery.

## 14.1. WASSP Multibeam Echosounder

### 14.1.1. Substrate Type versus Sensitivity

Based on the provided WASSP analysis and evaluation of RBINS and ILVO, it can be concluded that the WASSP multibeam demonstrates potential for distinguishing between different substrate types. The collected backscatter data in this project was already internally processed and expressed as grey values, meaning that raw values were unavailable. By comparing these grey-values with literature data, an attempt was made to link the different acoustic groups to a certain substrate type, resulting in the initial classification presented in §10. This classification suggests that if a WASSP signal of an unknown area is in the range of one of the three acoustic groups, a certain substrate type could be present. However, as stated before, this is rather an assumption since this classification is based on already processed data (i.e. flat backscatter) and low-resolution substate maps. Shortcomings of this method will be discussed in §15.2.1.

Furthermore, the presented estimations provide information about the substrate present in a certain area, but do not provide any additional information on the sensitivity. For instance, according to literature, hard substrates are present in areas labelled as low-, medium- or highly sensitive (see **Figure 5-1** and **Figure 5-2**.). The WASSP multibeam could thus differentiate these harder areas from softer substrates but could not provide additional information on the type of sensitivity of the detected harder area. Therefore, it can be concluded that the WASSP multibeam, in its configuration used on the survey vessel, cannot be used on its own when practicing precision fishery, and more specifically, avoiding sensitive marine habitats. It should always be used in combination with other, complementary data sources, such as the monitoring of ETP-species in the catch. Together, the combination of these data sources could provide a more correct estimation of the seabed sensitivity.

It should be noted that these findings are based solely on the specific data series utilized within the scope of this project (i.e. flat backscatter and grey-values). Future projects should further investigate the possibilities of a WASSP multibeam when a "Survey license" is installed on the CDX (see also §15.2.1). This license provides access to and enables the processing of raw WASSP data, allowing researchers to generate a more detailed seabed profile. However, as this license was originally developed for survey operations, it is not commonly installed on commercial fishing vessels, meaning that these vessels do not record such high-resolution data. To enable the development of detailed seabed profiles, it is strongly recommended that such a license is installed on commercial vessels.

In addition, a detailed profile of sensitive marine habitats –based on raw WASSP data or the occurrence of key species– should be developed through collaboration between Norwegian and international scientists and policymakers. Such a profile would enable more accurate delineation of these areas, thereby facilitating their detection, monitoring, and management.

### 14.1.2. Remarks & Recommendations

As described in the results and the above section, the WASSP multibeam echosounder shows potential to differentiate between different substrate types, but some remarks need to be made when interpreting the presented results.

First, as discussed in the previous section, the presented seabed substrate classification is based on processed WASSP data (i.e. flattened backscatter) and low-resolution substrate maps obtained from EMODnet. Due to their coarse spatial resolution, these maps are difficult to directly compare with WASSP multibeam data, which provides a much higher resolution (2.5 × 2.5 m) compared to the EMODnet maps (2000 × 2000 m) (**Figure 14-1**). This discrepancy also complicates the correct labeling of hauls, as haul classification is length-based. Consequently, catch compositions may be incorrectly associated with certain substrate types due to inaccurate labeling. Instead of internally processed multibeam data, it is better to use raw WASSP data, expressed in decibels, which provide a better indication for the present substrate. Hard substrates namely reflect more sound, while loose sediment absorbs more acoustic waves, resulting in a lower backscatter intensity. To access this raw data, the WASSP "Survey-License" needs to be installed on the used CDX. Future projects should explore the possibilities and should take this into account.

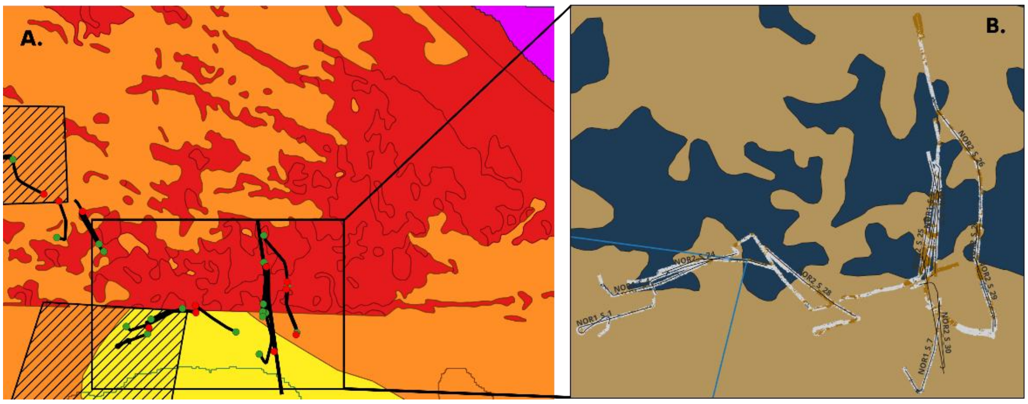


*__Figure 14-1__ Examples of low-resolution data. [A] Snippet of __Figure 5-2__, exhibiting t*

Second, because the acoustic groups in this report are based on a grey-scale, and thus not calibrated over a reference area, collected data cannot be compared to other studies or surveys in different areas. To do so, calibration is needed on a reference area such as the Kwinte Bank in the Belgian part of the North Sea. More information can be accessed through: https://www.agentschapmdk.be/en/acoustic-reference-area-kwinte

Third, the penetration depth of the used acoustic wave is estimated to be around a few centimeters at 300 kHz in soft sediments (Huff, 2008; Lurton & Lamarch, 2015). As such, a layer of sediment (mud or fine sand) on top of a coarse substrate can mask the original or former seabed substrate. This could lead to misinterpretations, e.g. classifying highly-sensitive areas as less-sensitive.

Additionally, some acoustic uncertainty arises because of suspended sediment above the seabed, as this affects the scattering and reflection of sound waves. This suspended sediment may originate from natural processes, such as currents, or could also be the result of anthropogenic activities, such as dredging or fishing. Beam trawling causes seafloor substrates to resuspend into the water column, resulting in a sediment plume which then settles down in the same or neighboring areas. This is an important remark to make in the context of precision fishery. When fishing in an area which forms a combination of less- and high-sensitive areas, sediment plumes originating from less-sensitive areas may disperse and settle down in higher-sensitive areas, masking it as a less-sensitive region. However, the size of the effect of this sediment plume is still uncertain.

Fourth, during the collection of WASSP data, the WASSP Data Manager experienced some unexpected crashes, which caused some small-scale data losses. After consulting several instances, no clear cause was found. The issue may have been caused by limited onboard computer resources, network instability, or conflicts with other running software. Future projects or the application on commercial vessels need to ensure that the used PC meets or exceeds WASSP's hardware specifications. Regular system monitoring and pre-survey stress testing could also help monitor and prevent data loss due to software instability.

Fifth, the EMODnet Geology seabed substrate map which was used to validate the backscatter results used a 1 million scale, with the smallest unit 4 km$^2$. This is insufficient to expect a 1-to-1 relationship with the backscatter data with a resolution of 2.5 m x 2.5m. More detailed sediment maps would be necessary to compare both types of data. This could be achieved with more precise techniques, such as a WASSP multibeam echosounder equipped with a Survey license or a side scan sonar.

Lastly, the current analysis showed that the WASSP multibeam displayed potential to distinguish between different substrates. Therefore, it can be advised that the potential integration in data platforms, such as VISTools, should be considered in future analysis or research.

## 14.2. VISTools

### 14.2.1. Current parameters

With a few exceptions, significant differences were found for all parameters across all levels of observed factors. Higher fuel consumption and speed was observed for more sandy regions, and lower fuel consumption was registered for harder or more stony regions . This could be explained by the type of equipment used. During the survey, a chain mat was used to collect the catch samples, adding a substantial weight to the net that needed to be dragged across the seafloor. In more sandier substrates, the net is more likely to sink into the substrate, increasing the drag and potentially posing a risk of capsizing of the ship. To prevent this, the skipper usually increases speed to minimize the risk of the sinking of the net. Additionally, since sandier substrates create more drag on the net, higher fuel consumption could be associated with more sandy areas.

### 14.2.2. Remarks & Recommendations

Based on the results of the assessment in this project, it can be stated that the VISTools framework -in its current form- provides a useful tool to assess the fished substrate type. However, it is not suitable for real-time monitoring applications, such as assessing habitat sensitivity or seabed substrate. The parameters assessed, such as fuel consumption, are (partially) controlled by the skipper itself, who adjusts them based on the received WASSP images. For instance, if the WASSP indicates softer substrates, the skipper will increase its speed to not lose his gear, resulting in higher fuel consumption.

However, since the WASSP multibeam demonstrates potential for differentiating between substrate types, the combined use of WASSP and VISTools to support precision fisheries represents an added value. Further analyses will investigate the potential integration of WASSP data into the VISTools framework.

## 14.3. Catch Composition

### 14.3.1. General trends

#### *14.3.1.1. Sensitivity*

According to the PCA plots presented in §12.6.1, hauls (partially) located near the vicinity of highly sensitive area would exhibit a higher abundance of cod (COD), monkfish (MON) and Atlantic wolffish (CAA). On the other hand, a reduced plaice (PLE) and common dab (DAB) abundance is expected (**Figure 12-22**, **Figure B- 7** and **Figure B- 9**). These assumptions are, however, not confirmed by a one-way Anova (OWA) test based on the collected dataset. The authors believe that is rather due to the reduced sample size in each specific region than the lack of correlation.

Looking at the PCA plot of the discards, a more or less similar pattern could be observed: Atlantic wolffish, monkfish and cod seem to have a positive correlation with highly sensitive areas, while plaice and common dab seem to have a negative relation. Statistical testing revealed that the abundance of cod and Atlantic wolffish did not differ significantly between the different OSPAR scores, but for plaice (OWA, $p<0.05$), monkfish (OWA, $p<0.05$), and common dab (KW, $p<0.05$) significant differences were found. For monkfish, a post-hoc Tukey's test revealed that abundances recorded in highly sensitive areas are significantly higher than in areas labeled as low- to medium sensitive ($p<0.05$). Based on a post-hoc Dunn's test, abundance of common dab is significantly lower in highly sensitive areas than in medium sensitive areas ($p<0.05$). Abundances in low-sensitive areas did not differ significantly with the abundance in highly sensitive areas ($p>.05$). For plaice, Tukey's test revealed significant differences between OSPAR score 2 and 3 ($p<0.05$) and 3 and 4 ($p<0.01$), but not between 2 and 4 ($p>0.05$). This can also be seen on **Figure 12-6**, where the plaice fraction present in OSPAR score 3 seems to be larger than the fractions associated with score 2 and 4. One possible explanation for the lack of significant difference between OSPAR score 2 and 4 could be found in the fact that several hauls classified, as low-sensitive, are partially located in or near a highly sensitive area. For instance, haul NOR2_S_28 is mostly located in a low-sensitive area, but as illustrated on **Figure B- 4**, a small fraction of plaice is present.

In addition to the reduced plaice and dab abundance and the increased monkfish abundance, a correlation between the bottom sensitivity and Norway redfish (SFV) was observed. This will be further discussed in §14.3.2

Regarding the benthic community, dead man's finger (*Alcyonium digitatum)* was expected to be an indicator species since this species is typically associated with sensitive marine habitats, such as boulders or rocky seabed (Al-Hamdani et al., 2019). But, according to **Figure 12-7**, no dead man's fingers were recorded in hauls labeled with an OSPAR score 4. Instead, sea anemones (*Actinaria*) and sponges (*Halicondria*) were the most frequently occurring benthic species, as for instance demonstrated with **Figure 12-21**, cluster B-D. In addition, the PCA plot (**Figure 12-24**) demonstrated that these two species were positively associated with hauls located in highly sensitive areas. On the other hand, dead man's finger was the most dominant species in low to medium sensitive areas, meaning that this species cannot be considered as an indicator for sensitive marine habitats in this specific survey area.

#### *14.3.1.2. Substrate type*

It could be concluded that hauls associated with harder substrates, such as NOR1_S_8, would have an increased abundance of commercial-sized Atlantic wolffish and, in lesser extent, cod and monkfish. On the contrary, lower abundances of plaice and common dab would be expected, since these species tend to be increased when fishing in softer regions.

A one-way Anova, followed by a Tuskey test, revealed that Atlantic wolffish exhibits a higher abundance in areas which belong to acoustic group B, the group associated with harder substrate types. This is also confirmed by literature, such as Atlantic Wolffish Biological Review Team (2009). Additionally, when the grey-value classification based on WASSP data was used, significant differences between group B and C were found for commercial sized (i.e. landings) cod ($p<0.05$), monkfish ($p<0.01$) and dab ($p<0.05$).

However, when the classification based on the EMODnet substrate map was used, there was only a significant difference between substrate type 2 (Sand) and 5 (Rock+Boulders) for cod. The other species mentioned did not record any significant difference.

The PCA plot of the discards (**Figure 12-23** and **Figure B- 12**) exhibits a similar pattern, although this was not confirmed by statistical tests. Just as for the landings, only a significant difference was found for cod ($p<0.01$) and Norway redfish ($p<0.01$). Again, the authors believe that this could be related to the small sample size ($n = 38$) across the different substrate types and the method of classification. This will further be discussed in §15.

Contrary to the findings in §14.3.1.1, dead man's fingers seem to be present on the same substrate type (Rock+Boulders) as sea anemones and sponges, as demonstrated by the results of the cluster analysis in §12.5. This finding is also supported by literature which link these dead man's fingers to more coarse substrates (Al-Hamdani et al., 2019; Danish Environmental Protection Agency, 2021). Therefore, the result presented in **Table 12-4** concerning the grey-values is rather surprising: one would expect that cluster B-A and B-B would contain a higher percentage of acoustic group B, since this is related to harder substrates. Instead, acoustic group C, which is associated with the softer substrates, is dominantly present. This example illustrates that there is still some uncertainty about the correctness of the two data sources, and that this report is rather explorative.

### 14.3.2. ETP-species

#### *14.3.2.1. Sensitivity*

Based on the results presented in this report, it can be concluded that Norway redfish (SFV) is an indicator of highly sensitive marine habitats. This fish species, which was treated as a discard species, was predominantly present in hauls which were located in or near highly sensitive areas, as demonstrated by the various stack-, bubble-, cluster- and PCA-plots.

However, since Belgian fishers do not target this species, it is not recorded in logbooks or data gathering platforms such as VISTools. Therefore, without any monitoring method, it does not provide any information on the sensitivity. Intelligent cameras, such as the VISIM camera could provide a solution for this: images of the catch could be taken to monitor the presence of ETP-species, such as for example Norway redfish. Unfortunately, the VISIM camera is still under development and not applicable in real-life applications (see §14.4). Additionally, cameras are a sensitive subject within the fishing industry. To facilitate good cooperation between government, fishers and scientists, clear arrangements should be made which define the use and purpose of these images.

#### *14.3.2.2. Substrate*

While the presence of Norway redfish seems to be an indicator for highly sensitive areas, it does not seem to correlate with a certain substrate type. For instance, as can be seen on **Figure B- 11** and **Figure B- 12**, hauls associated with an increased Norway redfish presence, are either as Sand or as Rock+Boulders. One possible explanation could be found in the way these labels were allocated, which was done by measuring the distance the haul is located in both sandy as rocky areas, after which the substrate with the longest stretch of the haul was allocated to the entire haul. This means that, if a haul is 60% located in sandy areas and 40% in rocky areas, the hauls is classified as sandy.

Additionally, **Figure B- 4** demonstrates the importance of a buffer region between the fishing grounds and highly sensitive area. On this figure, hauls which are partially located in highly sensitive areas, , or in the vicinity of them, also contain sensitive species such as Norway redfish. Therefore, it should be advised that buffer zones should be installed between around highly sensitive areas and fishing grounds to minimize the risk of disturbing the sensitive areas.

### 14.3.3. Buffer zones

For some hauls, it was noted that the catch composition did not follow the general catch composition associated with a certain OSPAR Score or substrate type. For example, haul NOR2_S_28 is labeled as low-sensitive since this haul is mainly located in a low-sensitive area. However, when looking at the catch composition of the discards (**Figure B- 4**), a relatively high Norway redfish and a reduced plaice abundance could be observed, trends that were earlier associated with hauls conducted in highly sensitive areas. Another example is illustrated by haul NOR1_S_15, which has been labeled with substrate type no.2 (Sand). According to **Figure B- 6** however, a large share of dead man's fingers was present, which was earlier associated with more coarser substrates. As visualized in **Figure 14-2**, the haul was conducted just next to a coarser area, which could explain this increased dead man's fingers fraction. Because this substrate map is an estimation of the present substrate, it could thus have happened that haul NOR1_S_15 was conducted through the coarse area instead of along it.

This example emphasis the importance of the creation of buffer zones between fishing grounds and (highly) sensitive areas. These buffer zones could account for the uncertainty of mapping these areas or human errors. Especially in terms of precision fishery, where fishing grounds and sensitive areas are intertwined with each other, these buffer zones play a crucial role.

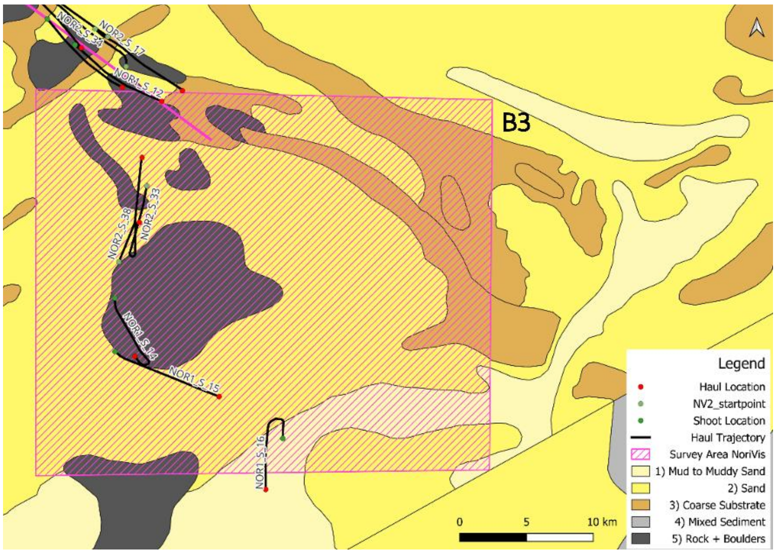


***Figure 14-2*** *Survey area B3 and associated Fully-Sampled Scientific hauls. The sediment map derived from EMODnet is used as background.*

## 14.3.4. Evaluation as tool for precision fishery

As discussed in previous sections, the presence of some (ETP) species, such as Norway redfish or see anemones, could indicate that fishing activities took place in sensitive areas. However, since Belgian fishers do not target these species, it is not recorded in logbooks or data gathering platforms such as VISTools. Therefore, without any monitoring method, it does not provide any information on the sensitivity of the fished area (yet). Intelligent cameras, such as the VISIM camera could provide a solution for this: images of the catch could be taken to monitor the presence of ETP-species, such as Norway redfish. At this moment, the VISIM camera is still under development and not applicable in real-life applications (see §14.4). Additionally, cameras are a sensitive subject within the fishing industry. To facilitate good cooperation between governance, fishers and scientists, clear arrangements should be made which define the use and purpose of these images.

In general, some trends could be observed regarding the catch composition of landings, discards and benthos. But since several hauls are in two or more areas with a different OSPAR score or substrate type, it is hard to link a specific species to a certain sensitivity level or substrate type with high confidence. As example, hauls conducted in S1, such as NOR2_S_26 or NOR2_S29 were labeled as "Sand", because a major part of the hauls is located in a sandy area. Catch composition and WASSP data suggested that these hauls could be associated with a coarse substrate.

It is thus hard to link one specific species to a certain sensitivity level or substrate type. The catch composition could always be influenced by neighboring areas or areas which were not mapped correctly. Therefore, it should be advised that information on the catch composition should be used in combination with, for example, WASSP images. In this way, a completer and more correct picture could be sketched of the fished area. This report provides however a first estimation of how sensitive areas could be detected based on the catch composition.

Additionally, during the project, no length measurements were collected during the Fully-Sampled Scientific hauls, due to limited time and working space abord the survey vessel. This parameter could however provide valuable information on, for instance, the link between undersized fish and bottom sensitivity. Therefore, this parameter should also be included in further analysis.

## 14.4. VISIM-Camera

As stated in §6.5 and illustrated in §13, the VISIM-camera and models are still in development, and no significant results were obtained yet. However, for future conservation strategies and the enrollment of precision fishery, this type of camera could provide valuable information on e.g. the presence of ETP-species and consequently the sensitivity of the seabed.

## 14.5. Used Literature

To characterize the bottom sensitivity and seabed substate, data from literature (i.e. OSPAR BH3 indicator and EMODnet substrate maps) were used. Just as the tools discussed in this report, these two data sources have certain shortcomings, which will be discussed in this section.

### 14.5.1. Map Resolution

First, the resolution of both data sources is rather low. The seabed substrate map has, for example, a unit of 4 $km^2$. This makes it hard to compare high resolution data with, such as the collected WASSP data. Additionally, it creates uncertainty. The OSPAR Score, for instance, shows a rather arbitrary transition between the different sensitivity classes, as illustrated by **Figure 5-2**. This makes it hard to make reliable assessments of, for example, catch composition or substrate.

Therefore, future research should focus on the characterization of these sensitive areas in a complete and detailed way. This would also facilitate the creation of the buffer zones which were discussed in §14.3.3. Furthermore, the WASSP multibeam could assist to improve and update current substrate maps.

### 14.5.2. Variety of data sources

As already shortly discussed in the introduction, several indicators exist to assess sensitivity. Since some of these indicators have a different outcome for the same area, it is hard to make correct estimations on catch composition or seabed substrate of the highly sensitive areas. As stated before, a uniform and detailed characterization of the sensitive areas by e.g. Norwegian or foreign governments and scientists would facilitate the development and implementation of precision fishery in this region.

# 15. Recommendations/Lesson learned

This section summarizes all lessons learned and recommendations from this project

## 15.1. General

- There is a need for a **uniform, complete and detailed characterization of sensitive regions**. Due to the variety of sensitivity indicators and the low resolution, there is now some uncertainty about which areas are to be considered sensitive and which not. The characterization of these sensitive regions through collaboration between for example Norwegian and international scientists would facilitate research and development in the field of precision fishery.
- **Data extracted from literature exhibited a low resolution**, resulting in some uncertainty on the present substrate type or sensitivity level. Additionally, this makes it hard to compare with higher resolution data such as the collected WASSP images. Detailed mapping with e.g. side scan sonar of WASSP multibeam with Survey License, could offer a solution.

- There is a need for a complete and clear **protocol for fishing vessels** in case signs are present that fishing activities took place in a sensitive area. This could, for example, include guidelines on how vessels should be relocated, or fishing equipment should be adapted.
- Future projects should also explore the use of **alternative fishing gear**, such as **tickler beam trawling** in combination with sumwing. During this survey, a heavy chain-mat was used with a traditional beam, which is less suitable for fishing in softer substrates (i.e. sand). Tickler chains combined with a sumwing are commonly used on softer substrates and coarser areas are naturally avoided, meaning that impact on these areas would also be reduced.

## 15.2. Innovative tools

### 15.2.1. WASSP multibeam

- Backscatter values expressed in gray-scale values make it difficult to assign a substrate type to the acoustic groups. It is better to use acoustic decibels, which provide an indication for the classification. Therefore, it is advised to install a **WASSP Survey License**, which enables the recording and processing of raw backscatter data.
- The acoustic groups referenced in this report were determined based on gray-scale values and are therefore not directly comparable with results from other studies or surveys conducted in different areas or time periods. To enable such comparisons, **raw acoustic backscatter** data expressed in decibels should be used and **calibrated against a reference area**. A suitable reference area for this purpose could be the Kwinte Bank reference site (KWGS) in the Belgian part of the North Sea.
- During the collection of WASSP data, **the WASSP Data Manager** experienced some unexpected **crashes,** which caused some small-scale data losses. After consulting several instances, no clear cause was found. The issue may have been related to limited onboard computer resources, network instability, or conflicts with other running software. Future projects or future applications on commercial vessels should ensure that the used PC meets or exceeds WASSP's hardware specifications. Regular system monitoring and pre-survey stress testing could also help monitor and prevent data loss due to software instability.
- The current analysis showed that the WASSP multibeam displayed potential to distinguish between different substrates. Therefore, the **integration** of this data source in **data platforms**, such as VISTools, should be considered in future analysis.
- Future projects should include the **impact of rising sediments** originating from e.g. fishing activities on the WASSP readings.
- Next to assessing the effects of suspended particles on the acoustic signal, the effect of the **sediment plume** caused by **bottom trawling** should be further investigated.

### 15.2.2. Catch Composition

- As discussed in §14.3.2, presence of certain ETP-species could indicate that fishing activities took place in sensitive areas. However, some of these species are discarded and therefore not recorded. A potential solution would be an **intelligent camera** which could identify all present species in the catch (fish and benthos). During the NoriVis, tests were done with the in-house developed **VISIM camera**, but no significant results were obtained yet (link to VISIM project: ILVO-VISIM). This camera should be included in further research to correctly assess the presence of benthic or discard species.

- During the project, no **length measurements** were collected during the scientific hauls, excluding this parameter from the analysis. However, it would be interesting for future projects to also look into this parameter for potential substrate characterization.

### 15.3. Survey

- The NoriVis survey was characterized by a rather **non-uniform sampling**, meaning that certain areas were more sampled than others. This makes it hard to compare these areas with others. In future projects, all different regions should be sampled equally. Additionally, more samples were taken during daytime than at nighttime. To get an estimation of the effect of the presence of light during the sampling, future projects should be incorporated **comparin**g hauls between **day- and nighttime.**
- As discussed in §4.1, some hauls were conducted outside the allocated research area. In future research, more attention should be paid to the determination of the position of the various tracks, and **expertise of the participating country** should **be consulted**. In this way, both countries could obtain the most optimal result.
- In addition to the conducted measurements which are described in this report, **samples of the seafloor (grab samples)** should also be included in future projects. These samples give a direct indication of the present substrate and provide extra verification.
- In addition to the previous recommendation, future projects should focus on **more homogeneous composition of the hauls**. Hauls conducted in this report were often a combination of several substrates or sensitivity levels, making it harder to provide non-biased results for a certain substrate type or sensitivity level. Future projects should therefore ensure that hauls should mainly be conducted in the same substrate type or in the same sensitivity level.

## 16. Project Evaluation Fishers

During the survey and analysis of this project, the involved fishers were asked on their opinion on the survey design and results. This section summarizes their main thoughts and conclusions.

The fishers confirmed the widespread occurrence of dead man's fingers in low and medium sensitive areas. They indicated that, in recent years, the population of this species has increased rapidly, with individuals now appearing more frequently and expanding into softer substrate areas. Based on these observations, they concluded that dead man's fingers can no longer be considered a reliable indicator species for sensitive habitats.

Furthermore, the fishers questioned the accuracy of the substrate maps, noting discrepancies with their own experience in the surveyed area. They indicated that substrate classifications in areas B1 and B3 are generally accurate, but that other areas contain different substrate types than those shown on the map (**Figure 16-1**). For example, area B2 is classified as "sandy" by EMODnet, whereas the fishers described it as predominantly mixed substrate. Similarly, areas S1 and S2 were considered by the fishers to be "mixed," with a tendency towards sand, which contrasts with their current classification on the substrate map. These observations further emphasize that existing substrate maps should be critically evaluated and, where possible, updated using higher-resolution data. Additionally, they stated that the survey design (i.e. limited survey area, haul duration and mesh size) did not allow a representative sampling. They did recommend other sampling areas, but, due to restrictions, these areas could not be entered.

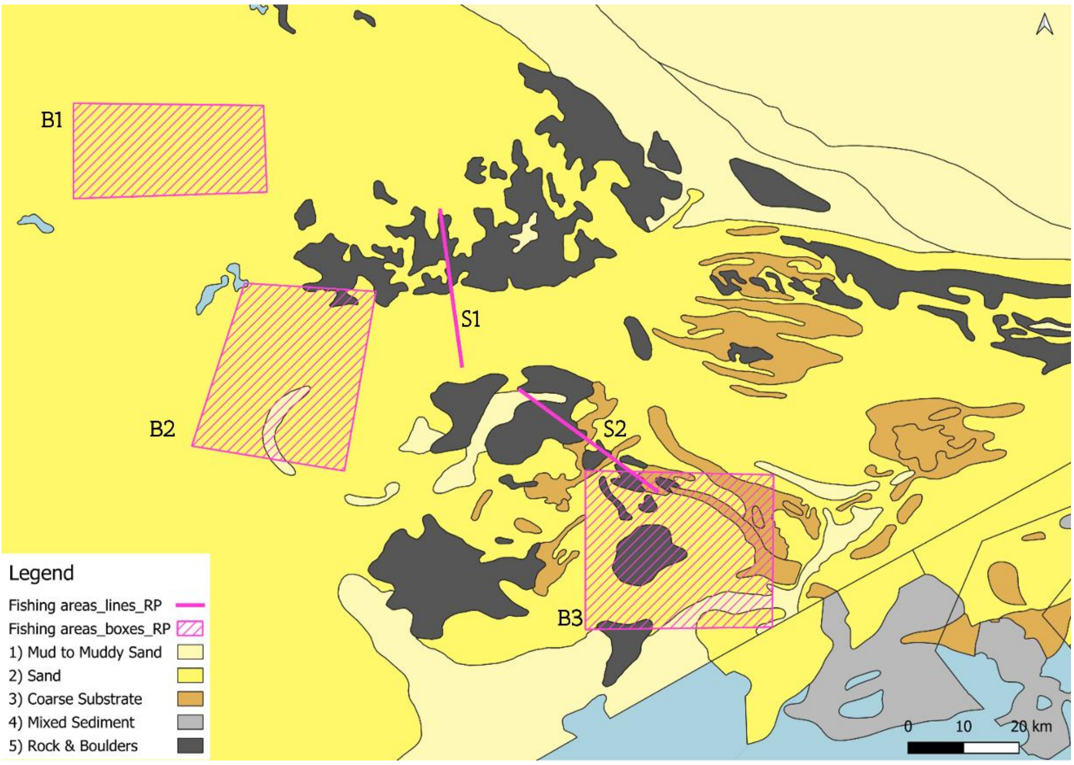


***Figure 16-1*** *Illustration of the different fully-Sampled Scientific Hauls and the encountered substrate types. Substrate map derived from EMODnet (2022).*

# 17. Conclusion

In conclusion, the NoriVis project acted as a pilot study to explore and evaluate different techniques within the context of precision fishery, and to advise on future research. With the presented techniques, ILVO wants to enhance real-time data collection aboard of commercial fishing vessels, improve resource valorization and contribute to a more selective fishing industry with a reduced environmental impact.

Despite the use of processed grey-values, the WASSP multibeam echosounder displayed promising results during this study. Based on the collected data, literature and some assumptions, different acoustic groups could be identified and linked to a certain substrate type. These findings remain, however, exploratory results and need to be interpreted with caution. A detailed seabed profile derived from acoustic decibel measurements would enable more precise and comprehensive habitat characterization. Capabilities of a WASSP multibeam, equipped with a Survey License, should therefore be explored in future projects.

Additionally, it is important to understand the difference between the present seabed substrate and the habitat sensitivity, as illustrated in this report. The WASSP multibeam only differentiates between substrate types but can't provide any additional information on the habitat sensitivity. For example, some areas within the survey area, which are characterized by a softer seabed substrate, received a higher sensitivity score than others with a harder substrate. Furthermore, since multiple sensitivity indicators are used globally, different sensitivity scores could be present for the same area, making it hard to assess the effective bottom sensitivity.

Therefore, it is essential to combine the WASSP echosounder with other data sources, such as VISTools or catch composition, to assess habitat sensitivity. As demonstrated in this report, certain areas inside the survey area exhibited a significant higher presence of Endangered, Threatened and Protected (ETP) species, indicating these specific species could potentially serve as indicators of the studied sensitive habitats. Furthermore, establishing a clear and operational definition of habitat sensitivity—developed through collaboration between Norwegian and Belgian scientists and policymakers, and expressed, for example, via specific WASSP imagery characteristics or the presence of key species—would further improve the interpretation and practical application of the described techniques.

While the WASSP multibeam echosounder and other tools showed promising results to differentiate between different marine habitats, it is important to emphasize that current technical and biological knowledge are still too insufficient to apply them to real-time applications, such as actively avoiding sensitive marine habitats. Future research (projects) will be needed to determine the effectiveness of these tools and how the sampling and processing procedure can be further optimized. Nevertheless, this report contains exploratory results, recommendations and lessons learned that can serve as a foundation for future research.

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# Annex A: Material & Methods

## Survey area

*Table A- 1 Coordinates of the designated survey areas in the Norwegian EEZ, as defined by the diplomatic clearance.*

| | LATITUDE | LONGITUDE |
|---|---|---|
| B1 | 57° 10’ 0.5484” N | 5° 30’ 6.282” E |
| | 56° 54’ 27.4536” N | 5° 30’ 6.282” E |
| | 56° 54’ 41.5188” N | 6° 3’ 44.0856” E |
| | 57° 9’ 35.5428” N | 6° 3’ 56.5884” E |
| B2 | 57° 28’ 12.5508” N | 4° 28’ 52.2408” E |
| | 57° 27’ 24.6168” N | 4° 52’ 27.7752” E |
| | 57° 9’ 58.464” N | 4° 46’ 47.5716” E |
| | 57° 12’ 24.3432” N | 4° 19’ 21.234” E |
| B3 | 57° 45’ 32.4504” N | 3° 58’ 4.2816” E |
| | 57° 36’ 22.2804” N | 3° 58’ 4.2816” E |
| | 57° 36’ 59.7924” N | 4° 32’ 52.4184” E |
| | 57° 45’ 19.9476” N | 4° 32’ 14.91” E |
| S1 | 57” 08’N | 05” 43’E |
| | 57” 18’N | 05” 18’E |
| S2 | 57” 20’N | 05” 08’E |
| | 57” 35’N | 05” 04’E |

*Table A- 2 Coordinates of start- (shoot) and end-(haul) point of all Fully-Sampled scientific hauls, as presented on* ***Figure 4-2****..*

| Haul ID | Latitude Shoot (°N) | Longitude Shoot (°E) | Latitude Haul (°N) | Longitude Haul (°E) |
|---|---|---|---|---|
| NOR1_S_1 | 57.4235 | 4.76574 | 57.41037 | 4.716187 |
| NOR1_S_2 | 57.555321 | 4.63297 | 57.618107 | 4.569314 |
| NOR1_S_3 | 57.685242 | 4.271877 | 57.679066 | 4.30187 |
| NOR1_S_4 | 57.434357 | 4.707585 | 57.454578 | 4.829335 |
| NOR1_S_5 | 57.454964 | 5.0807 | 57.526562 | 5.090235 |
| NOR1_S_6 | 57.467281 | 5.08222 | 57.393661 | 5.116468 |
| NOR1_S_7 | 57.393738 | 5.070724 | 57.439598 | 5.105632 |

| | | | | |
|---|---|---|---|---|
| **NOR1_S_8** | 57.454201 | 5.088573 | 57.521374 | 5.09418 |
| **NOR1_S_9** | 57.528393 | 5.083436 | 57.457115 | 5.098023 |
| **NOR1_S_10** | 57.294449 | 5.329834 | 57.255123 | 5.443809 |
| **NOR1_S_11** | 57.242386 | 5.478052 | 57.194618 | 5.558142 |
| **NOR1_S_12** | 57.196545 | 5.550357 | 57.158798 | 5.657355 |
| **NOR1_S_13** | 57.21386 | 5.516062 | 57.168209 | 5.608642 |
| **NOR1_S_14** | 57.026997 | 5.599413 | 56.987938 | 5.624128 |
| **NOR1_S_15** | 56.991055 | 5.5997 | 56.960857 | 5.728323 |
| **NOR1_S_16** | 56.932686 | 5.806893 | 56.898357 | 5.785872 |
| **NOR2_S_17** | 57.20717 | 5.575055 | 57.16588 | 5.68305 |
| **NOR2_S_18** | 57.29062 | 5.341068 | 57.32119 | 5.200427 |
| **NOR2_S_19** | 57.4608 | 4.861143 | 57.43221 | 4.76932 |
| **NOR2_S_20** | 57.54429 | 4.646268 | 57.60285 | 4.588157 |
| **NOR2_S_21** | 57.56466 | 4.517728 | 57.61786 | 4.523743 |
| **NOR2_S_22** | 57.68363 | 4.265238 | 57.68177 | 4.352773 |
| **NOR2_S_23** | 57.67871 | 4.397915 | 57.62809 | 4.482358 |
| **NOR2_S_24** | 57.44509 | 4.775263 | 57.45456 | 4.898042 |
| **NOR2_S_25** | 57.45618 | 5.080227 | 57.52189 | 5.090734 |
| **NOR2_S_26** | 57.56778 | 5.083217 | 57.49938 | 5.14736 |
| **NOR2_S_27** | 57.49394 | 5.147695 | 57.42227 | 5.171417 |
| **NOR2_S_28** | 57.42624 | 5.007455 | 57.46493 | 4.896722 |
| **NOR2_S_29** | 57.42523 | 5.17336 | 57.48917 | 5.144639 |
| **NOR2_S_30** | 57.44885 | 5.08021 | 57.39765 | 5.111513 |
| **NOR2_S_31** | 57.30658 | 5.280167 | 57.27852 | 5.393498 |
| **NOR2_S_32** | 57.28014 | 5.395407 | 57.23867 | 5.483777 |
| **NOR2_S_33** | 57.10231 | 5.639053 | 57.07782 | 5.629845 |
| **NOR2_S_34** | 57.202 | 5.590815 | 57.24294 | 5.491438 |
| **NOR2_S_35** | 57.18206 | 5.613325 | 57.22402 | 5.527505 |
| **NOR2_S_36** | 57.30351 | 5.30417 | 57.27349 | 5.40944 |
| **NOR2_S_37** | 57.27178 | 5.416792 | 57.22947 | 5.517068 |
| **NOR2_S_38** | 57.05134 | 5.60448 | 57.12122 | 5.633113 |

## WASSP Multibeam EchoSounder

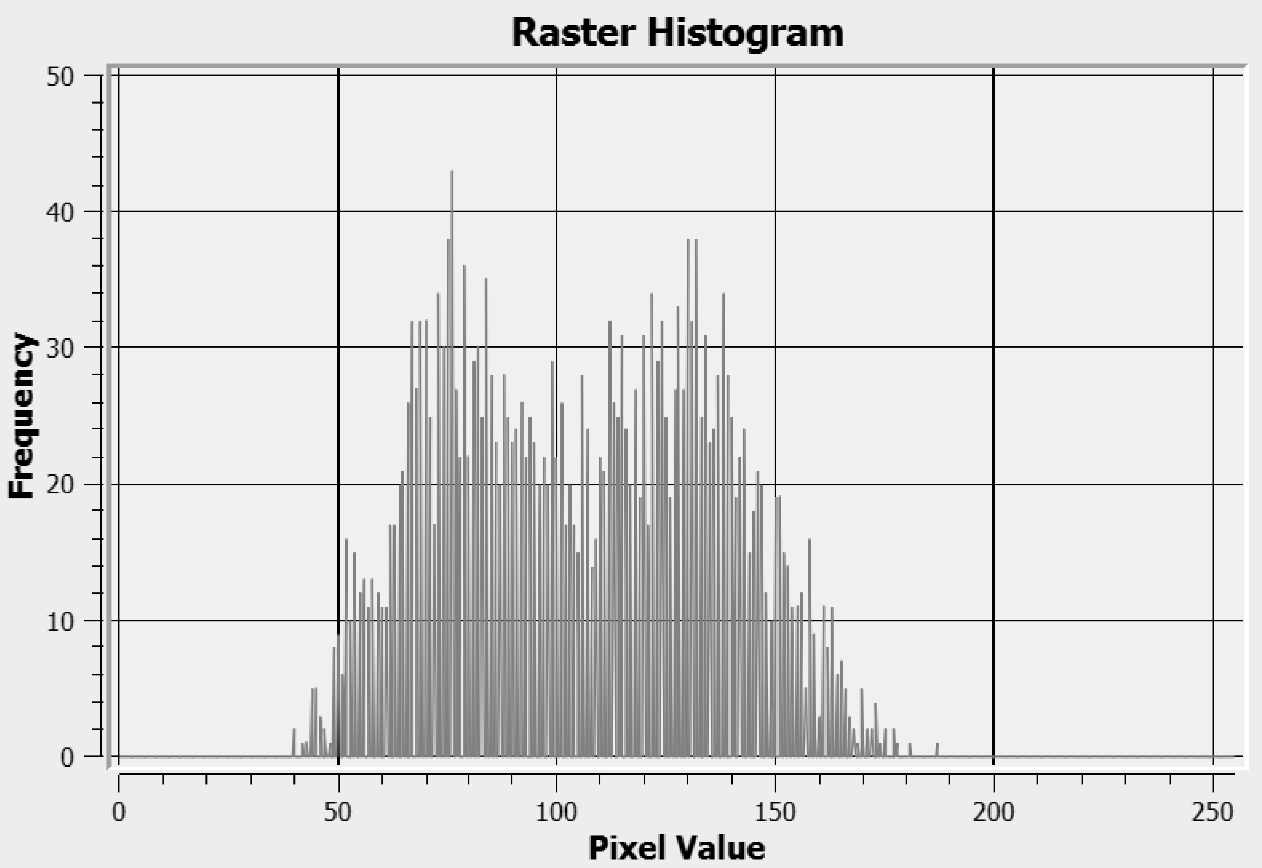

*Figure A- 1 Raster histogram which displays the occurrence, expressed as frequency (y-axis) of the different pixel values (x-axis). These values represent the intensity of the received backscatter signal from the WASSP Multibeam EchoSounder.*

*Table A- 3 Proportions of the three acoustic groups (in %) and zonal statistics (in grey values) per* ***Scientific Haul.***

| | In percentages (%) | | | In grey values | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | ≤ 60 | 60-110 | > 110 | Mean | Median | StDev | Min | Max | Range |
| NOR1_S_1 | 1.29 | 92.62 | 6.09 | 87 | 86 | 14 | 32 | 161 | 129 |
| NOR1_S_2 | 4.25 | 40.99 | 54.76 | 109 | 113 | 24 | 21 | 191 | 170 |
| NOR1_S_3 | 0.01 | 55.55 | 44.44 | 110 | 108 | 13 | 48 | 206 | 158 |
| NOR1_S_4 | 4.20 | 86.14 | 9.66 | 86 | 83 | 17 | 0 | 166 | 166 |
| NOR1_S_5 | 0.26 | 64.73 | 35.01 | 101 | 99 | 21 | 38 | 200 | 162 |
| NOR1_S_6 | 0.44 | 42.78 | 56.78 | 110 | 114 | 20 | 40 | 178 | 138 |
| NOR1_S_7 | 5.52 | 81.47 | 13.01 | 86 | 83 | 19 | 26 | 170 | 144 |
| NOR1_S_8 | 0.50 | 71.62 | 27.88 | 98 | 94 | 20 | 24 | 184 | 160 |
| NOR1_S_9 | 1.07 | 76.62 | 22.31 | 93 | 88 | 20 | 37 | 171 | 134 |
| NOR1_S_10 | 35.52 | 45.43 | 19.05 | 82 | 67 | 37 | 26 | 196 | 170 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **NOR1_S_11** | 8.21 | 26.82 | 64.96 | 122 | 134 | 38 | 34 | 216 | 182 |
| **NOR1_S_12** | 10.15 | 67.36 | 22.49 | 91 | 83 | 29 | 25 | 202 | 177 |
| **NOR1_S_13** | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **NOR1_S_14** | 26.02 | 57.47 | 16.51 | 80 | 71 | 29 | 25 | 174 | 149 |
| **NOR1_S_15** | 4.34 | 25.76 | 69.89 | 123 | 140 | 34 | 25 | 182 | 157 |
| **NOR1_S_16** | 1.49 | 36.17 | 62.35 | 118 | 129 | 28 | 31 | 186 | 155 |
| **NOR2_S_17** | 4.01 | 43.88 | 52.11 | 113 | 114 | 34 | 30 | 208 | 178 |
| **NOR2_S_18** | 2.34 | 12.24 | 85.42 | 126 | 129 | 21 | 39 | 239 | 200 |
| **NOR2_S_19** | 3.63 | 87.53 | 8.84 | 85 | 83 | 17 | 15 | 175 | 160 |
| **NOR2_S_20** | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **NOR2_S_21** | 0.13 | 30.44 | 69.43 | 120 | 123 | 20 | 44 | 215 | 171 |
| **NOR2_S_22** | 0.00 | 33.32 | 66.67 | 118 | 118 | 15 | 51 | 223 | 172 |
| **NOR2_S_23** | 0.00 | 3.23 | 96.77 | 135 | 136 | 10 | 58 | 200 | 142 |
| **NOR2_S_24** | 1.44 | 71.97 | 26.59 | 97 | 99 | 18 | 33 | 167 | 134 |
| **NOR2_S_25** | 1.28 | 52.76 | 45.96 | 103 | 107 | 22 | 27 | 198 | 171 |
| **NOR2_S_26** | 2.26 | 58.55 | 39.19 | 102 | 105 | 20 | 28 | 246 | 218 |
| **NOR2_S_27** | 3.22 | 59.19 | 37.59 | 99 | 102 | 23 | 33 | 174 | 141 |
| **NOR2_S_28** | 0.86 | 69.75 | 29.38 | 95 | 92 | 20 | 21 | 178 | 157 |
| **NOR2_S_29** | 2.87 | 60.40 | 36.74 | 99 | 101 | 23 | 29 | 165 | 136 |
| **NOR2_S_30** | 0.87 | 61.10 | 38.02 | 103 | 103 | 19 | 41 | 165 | 124 |
| **NOR2_S_31** | 16.22 | 35.69 | 48.09 | 103 | 106 | 37 | 0 | 239 | 239 |
| **NOR2_S_32** | 27.78 | 23.90 | 48.32 | 107 | 98 | 48 | 0 | 237 | 237 |
| **NOR2_S_33** | 0.80 | 13.25 | 85.95 | 135 | 142 | 25 | 40 | 246 | 206 |
| **NOR2_S_34** | 0.49 | 14.19 | 85.33 | 140 | 149 | 26 | 42 | 237 | 195 |
| **NOR2_S_35** | 2.44 | 19.06 | 78.51 | 134 | 144 | 31 | 36 | 216 | 180 |
| **NOR2_S_36** | 16.90 | 32.43 | 50.67 | 106 | 113 | 40 | 31 | 196 | 165 |
| **NOR2_S_37** | 25.97 | 14.51 | 59.52 | 115 | 134 | 46 | 25 | 206 | 181 |
| **NOR2_S_38** | 0.14 | 24.11 | 75.75 | 130 | 139 | 29 | 46 | 199 | 153 |

# Annex B: Results

## Catch composition: Stack Plots

### Landing & Discards

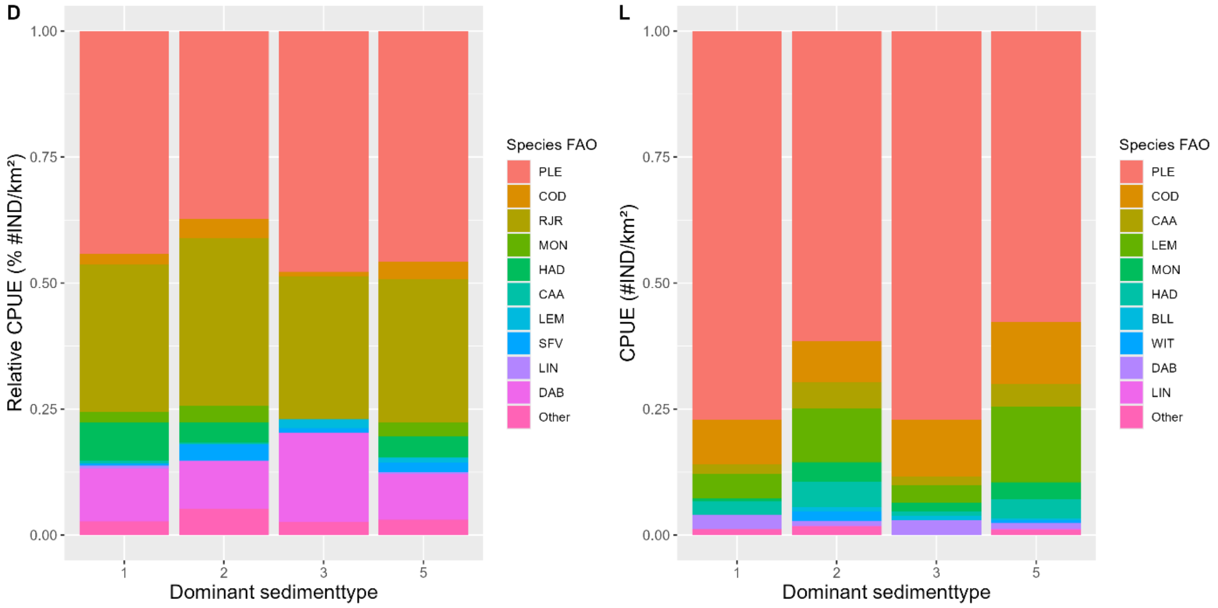

*Figure B- 1 General catch composition of [L] landings and [D] discards, expressed as #IND km$^{-2}$ , across different substrate types. Substrate types are: (1) Mud-Muddy Sand (n = 2); (2) Sand (n = 20); (3) Coarse substrate (n = 1); (4) Mixed Sediments (n = 0); (5) Rock + Boulders (n = 15).*

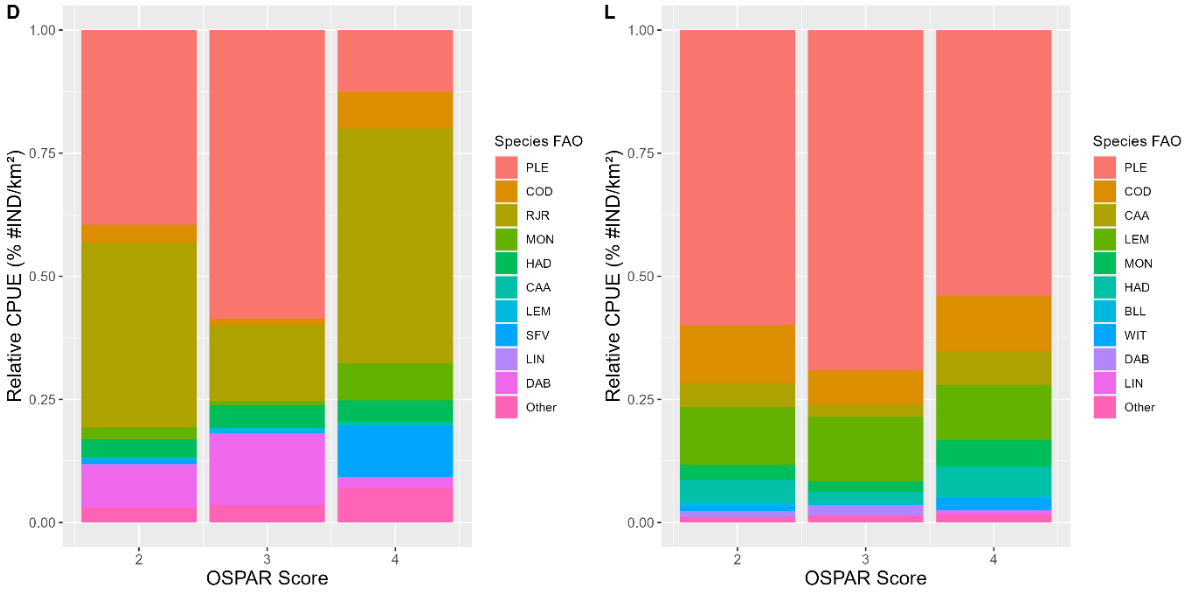

*Figure B- 2 Relative CPUE (% #IND km$^{-2}$)(y-axis) of the selected [D] discard and [L] landing species across the different levels of the factor "OSPAR Score" (x-axis). Levels are: 2 (n = 18); 3 (n = 9); 4 (n = 11).*

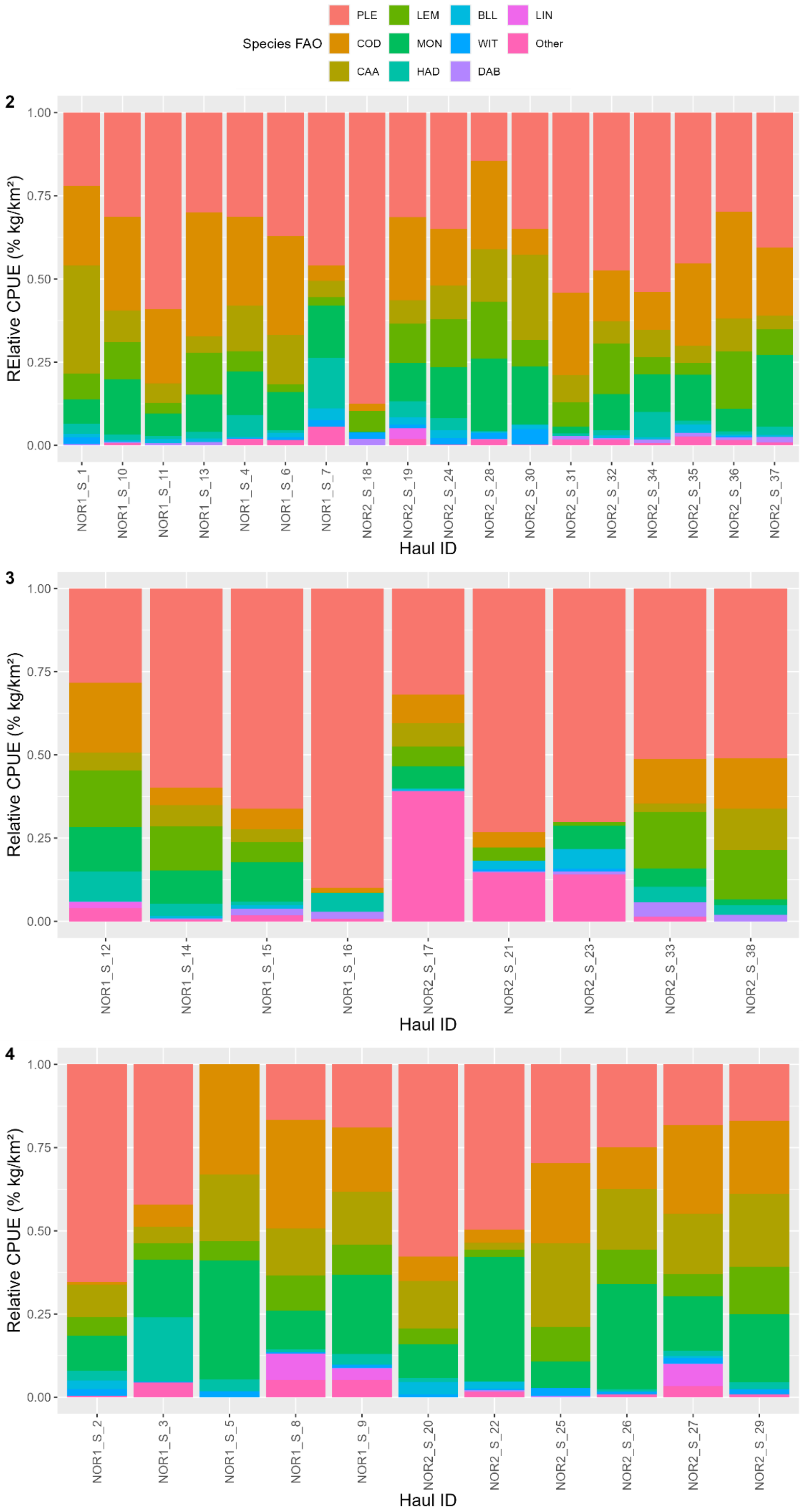

*Figure B- 3 Catch composition of the landings of the individual hauls, ordered by OSPAR score (2, 3 & 4).*

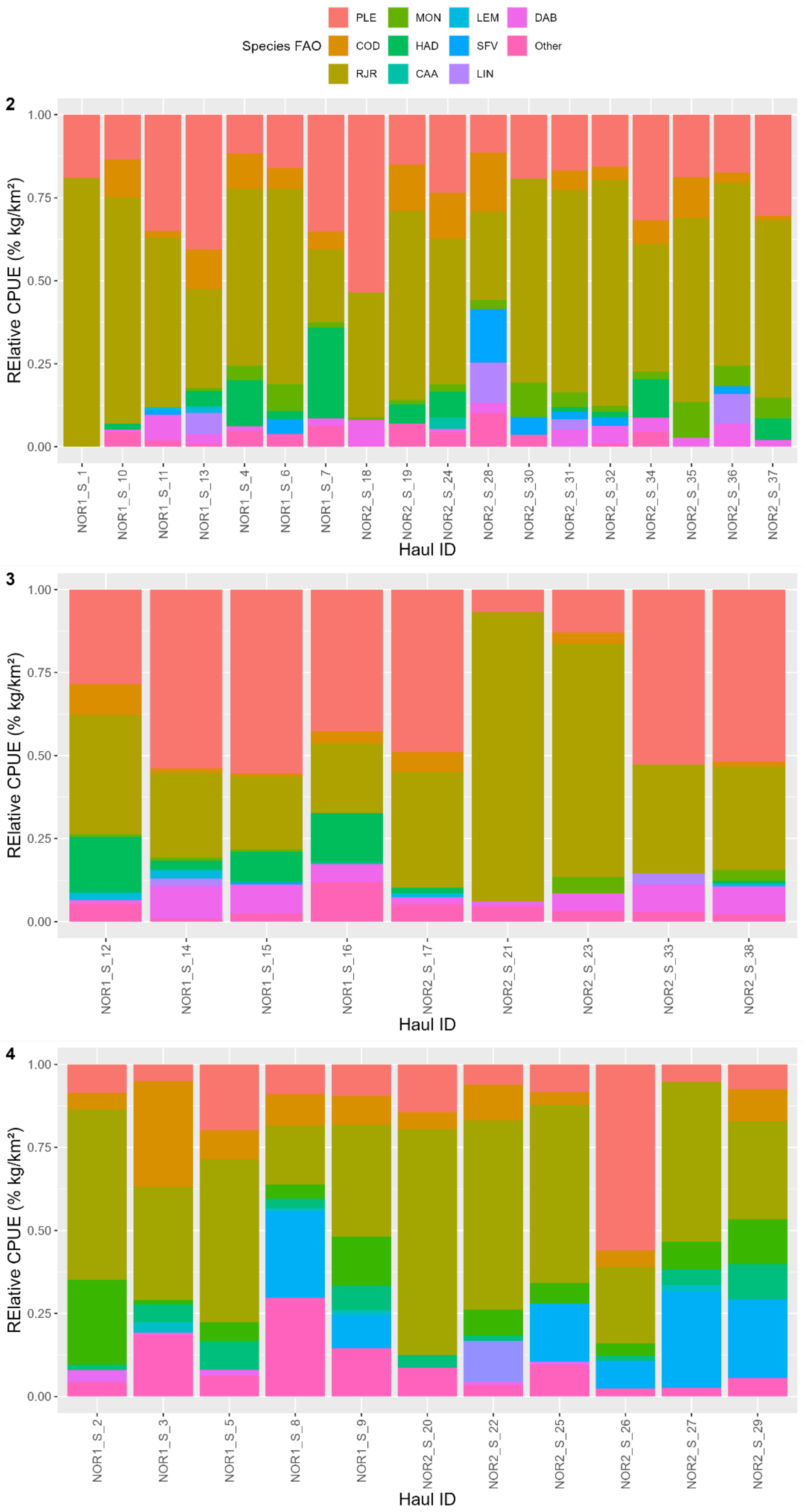

*Figure B- 4 Catch composition of the discards of the individual hauls, ordered by OSPAR score (2, 3 & 4).*

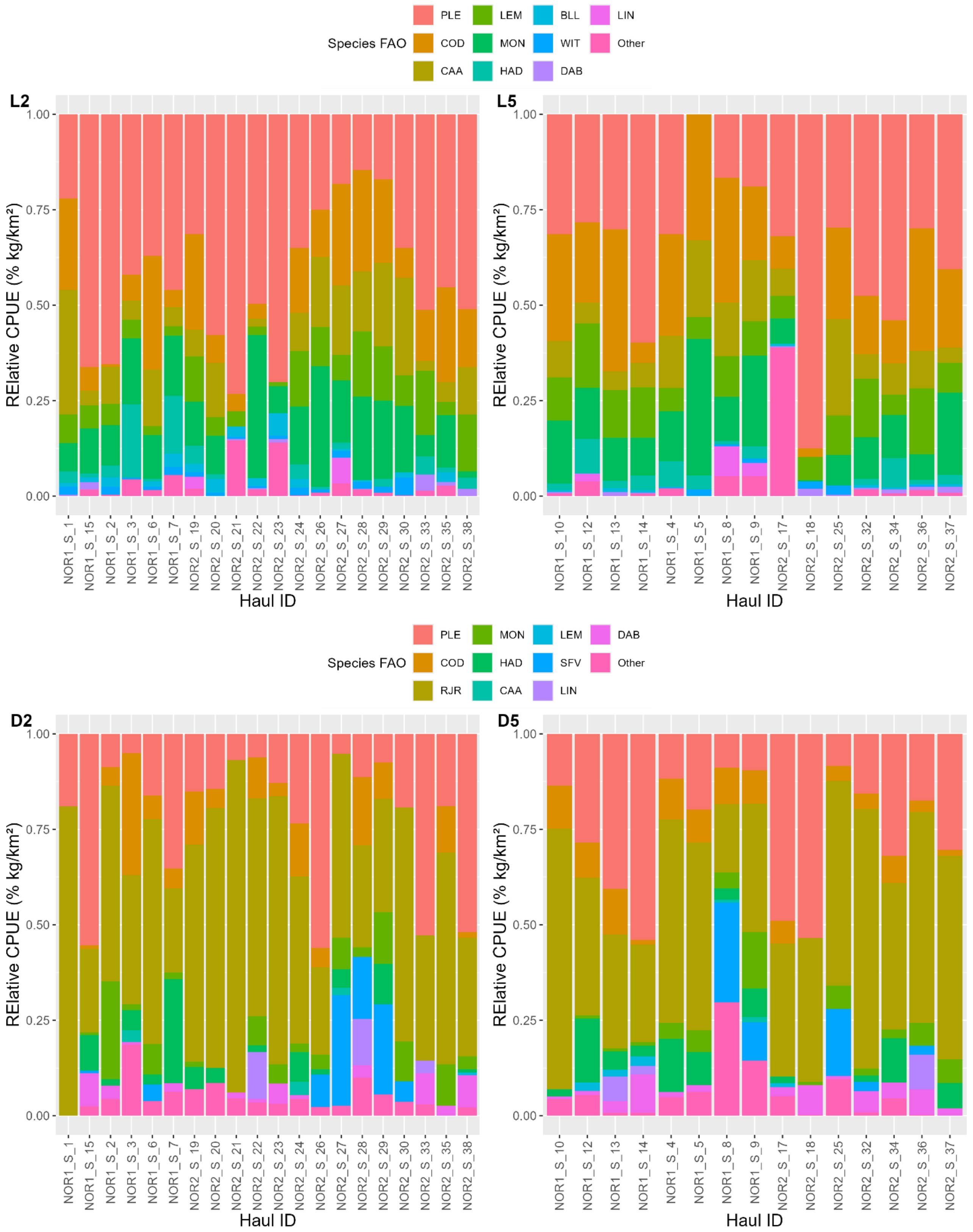

*__Figure B- 5__ Catch composition of the different hauls labeled as "Sand" (2) or "Rock + Boulders" (5). An additional breakdown is made between landings (L) and discards (D). Consequently, figure L2 represents the catch composition of the landings of all hauls which have "Sand" as most dominant occurring substrate type.*

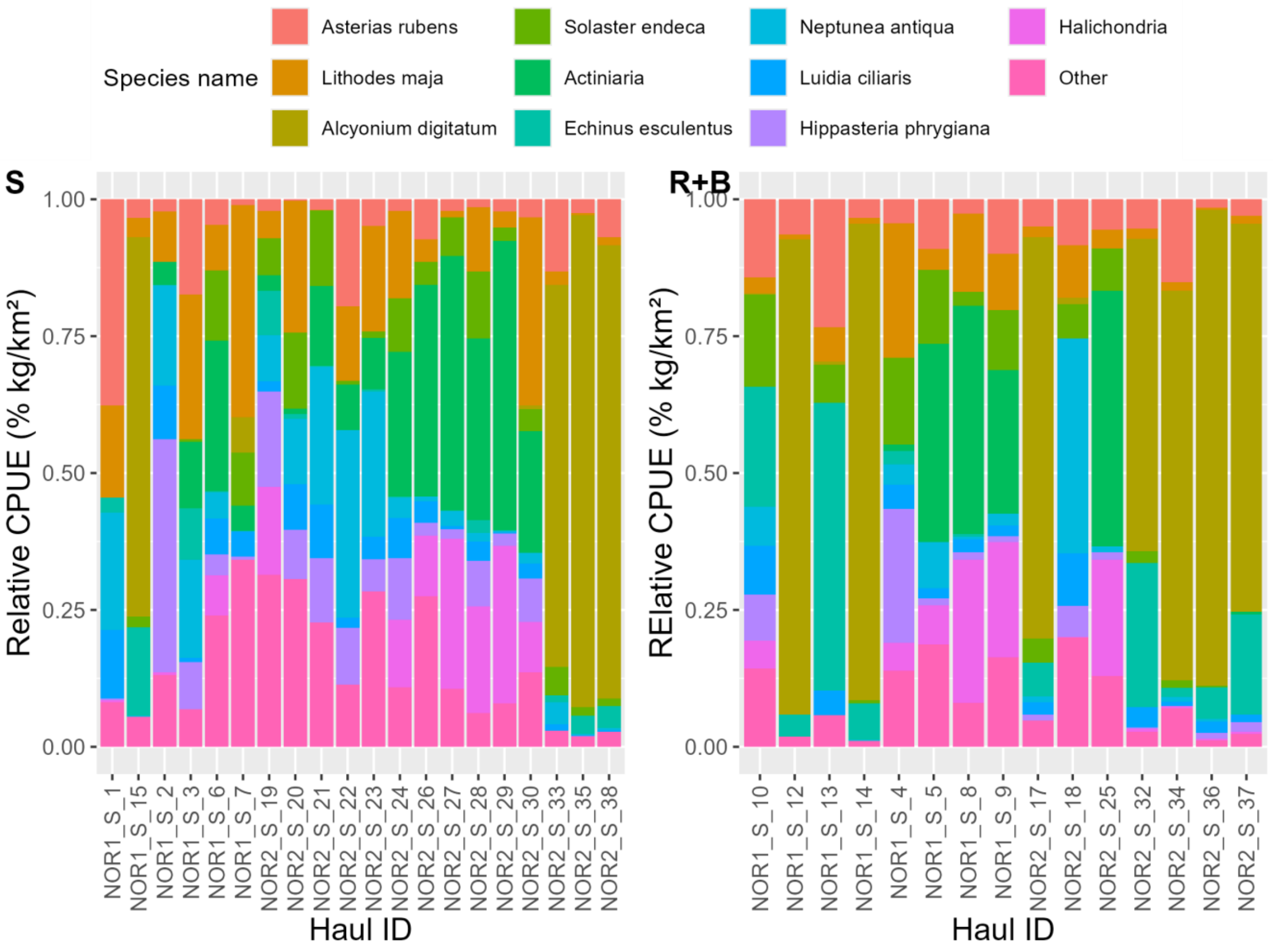

*Figure B- 6 Catch composition of benthos of the different hauls labeled as "Sand" (S) or "Rock + Boulders" (R&B).*

# PCA-Plots

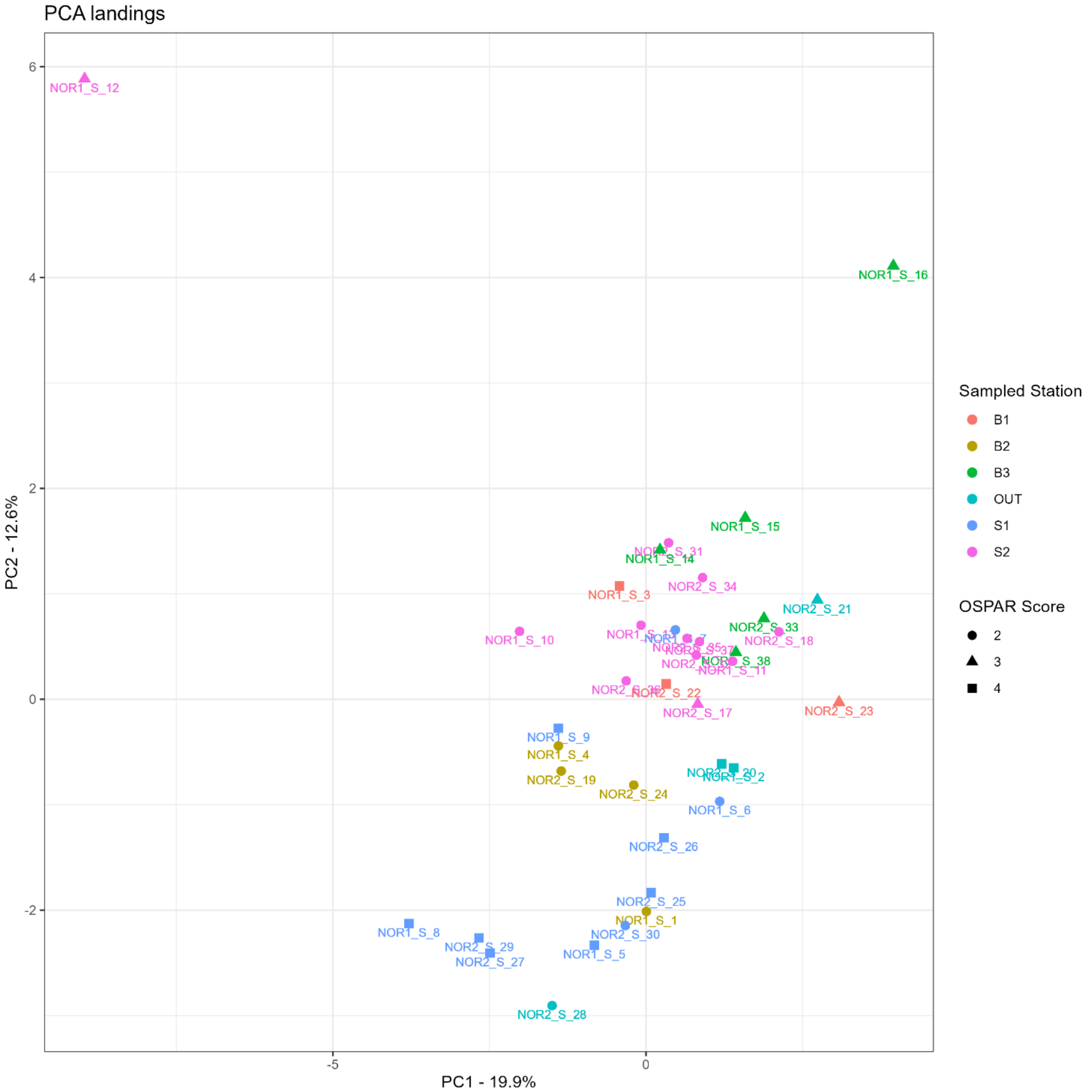

*Figure B- 7 PCA plot of landings. A distinction is made based on Sampled Station (color) and OSPAR sensitivity score (shape). Levels of Sampled Station are: B1 (n = 3); B2 (n = 4); B3 (n = 5); S1 (n = 10); S2 (n = 12); OUT (n = 4). Levels of OSPAR score are: 2 (n = 18); 3 (n = 9); 4 (n = 11).*

*Figure B- 8 PCA plot of landings. A distinction is made based on Dominant Substrate Type (color) and WASSP classification (shape). Levels of Dominant Substrate Type are: Levels of OSPAR score are: 2 (n = 18); 3 (n = 9); 4 (n = 11). Grey Value groups are [A]<60; [B] 60-110 [C] >110, UNKOWN hauls are labeled with UNK.*

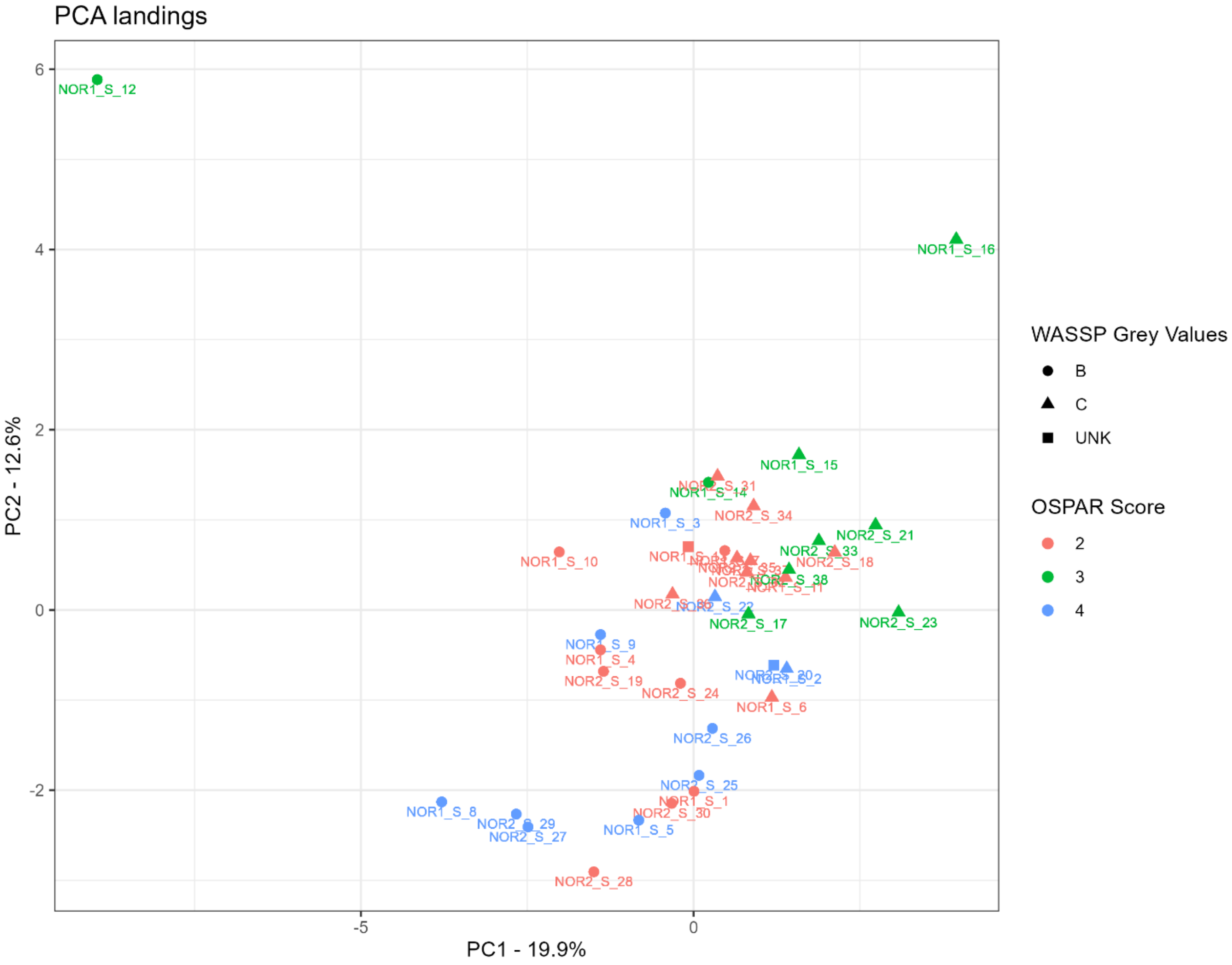

*Figure B- 9* PCA plot of landings. A distinction is made based on OSPAR Score (color) and WASSP classification (shape). Levels of Dominant Substrate Type are: (1) Mud-Muddy Sand (n = 2); (2) Sand (n = 20); (3) Coarse substrate (n = 1); (4) Mixed Sediments (n = 0); (5) Rock + Boulders (n = 15). Grey Value groups are [A]<60; [B] 60-110 [C] >110, UNKOWN hauls are labeled with UNK.

*Figure B- 10 PCA plot of discards. A distinction is made based on Sampled Station (color) and OSPAR sensitivity score (shape). Levels of Sampled Station are: B1 (n = 3); B2 (n = 4); B3 (n = 5); S1 (n = 10); S2 (n = 12); OUT (n = 4). Levels of OSPAR score are: 2 (n = 18); 3 (n = 9); 4 (n = 11).*

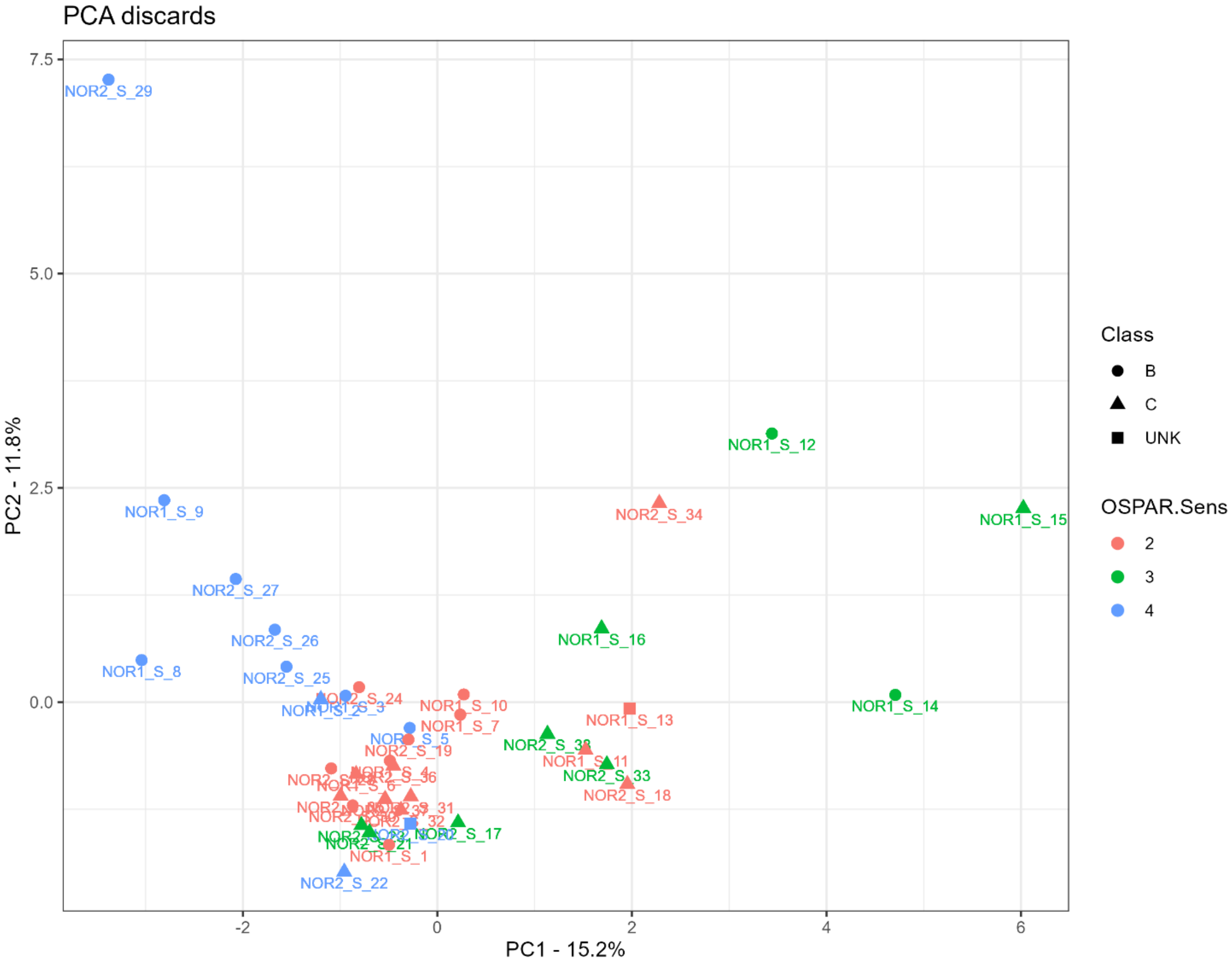

*Figure B- 11* *PCA plot of discards. A distinction is made based on OSPAR Score (color) and WASSP classification (shape). Levels of Dominant Substrate Type are: (1) Mud-Muddy Sand (n = 2); (2) Sand (n = 20); (3) Coarse substrate (n = 1); (4) Mixed Sediments (n = 0); (5) Rock + Boulders (n = 15). Grey Value groups are [A]<60; [B] 60-110 [C] >110, UNKOWN hauls are labeled with UNK.*

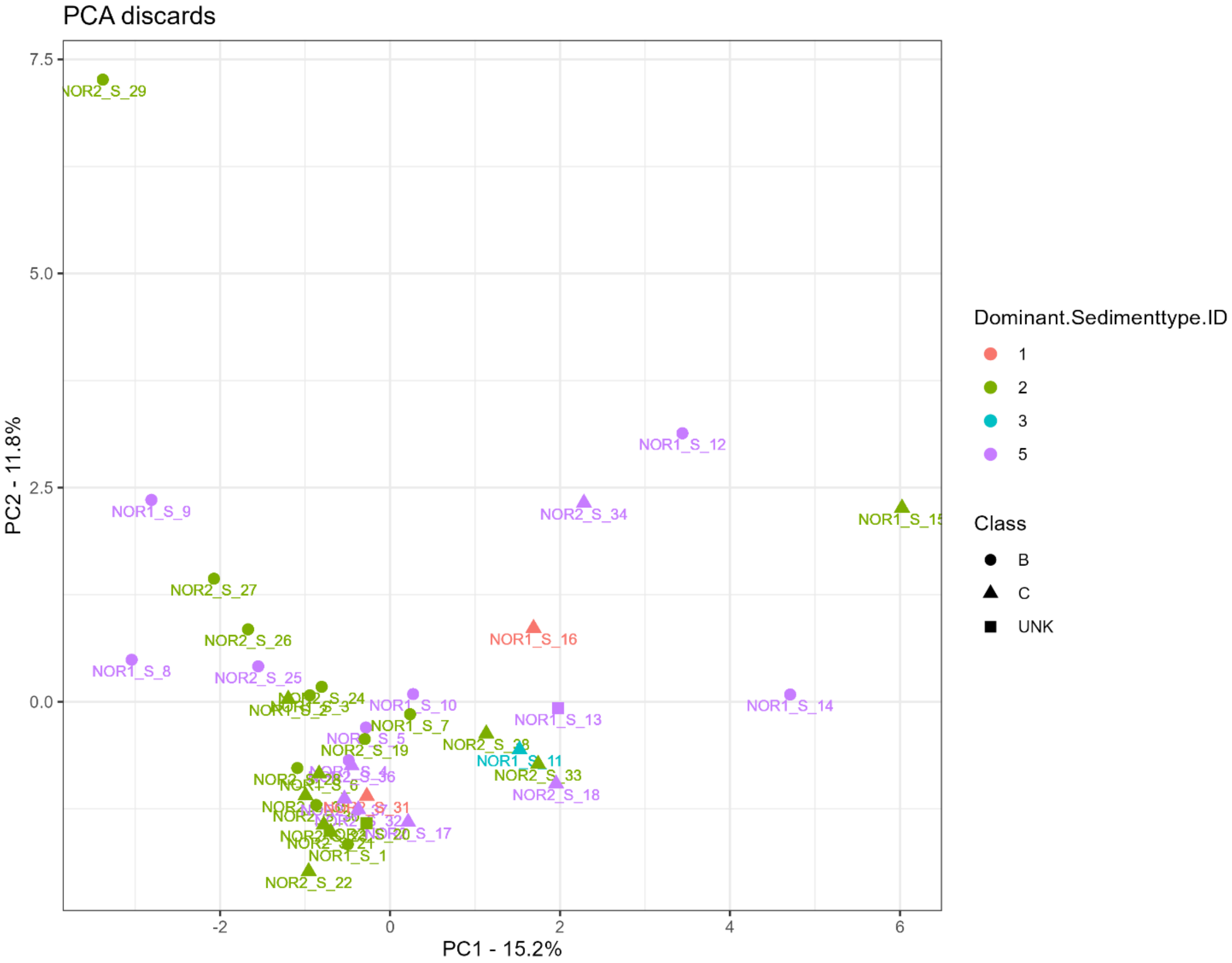

*Figure B- 12* *PCA plot of discards. A distinction is made based on Dominant Substrate Type (color) and WASSP classification (shape). Levels of Dominant Substrate Type are: Levels of OSPAR score are: 2 (n = 18); 3 (n = 9); 4 (n = 11). Grey Value groups are [A]<60; [B] 60-110 [C] >110, UNKOWN hauls are labeled with UNK.*

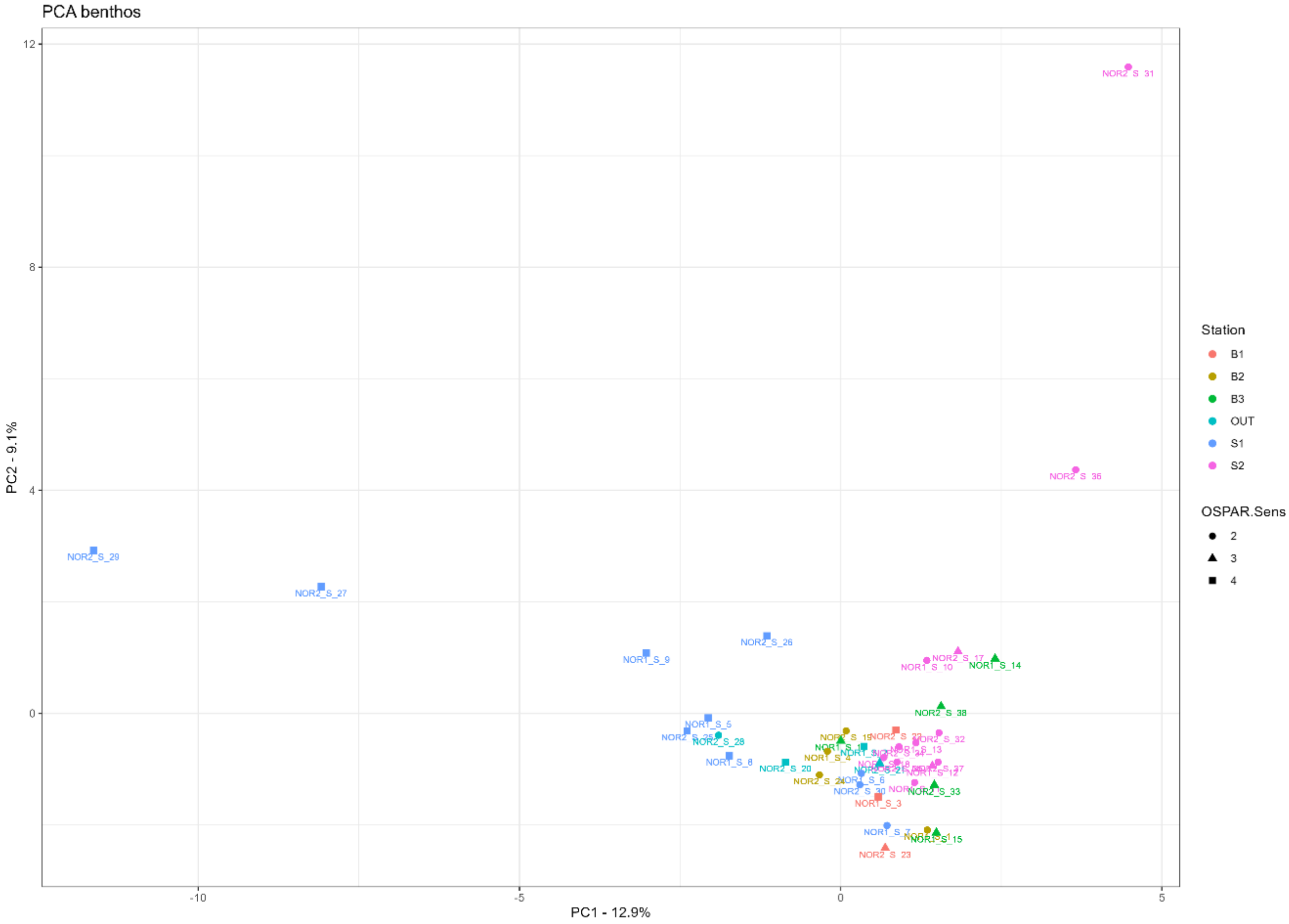

*Figure B- 13* PCA plot of benthos A distinction is made based on Sampled Station (color) and OSPAR sensitivity score (shape). Levels of Sampled Station are: B1 (n = 3); B2 (n = 4); B3 (n = 5); S1 (n = 10); S2 (n = 12); OUT (n = 4). Levels of OSPAR score are: 2 (n = 18); 3 (n = 9); 4 (n = 11).

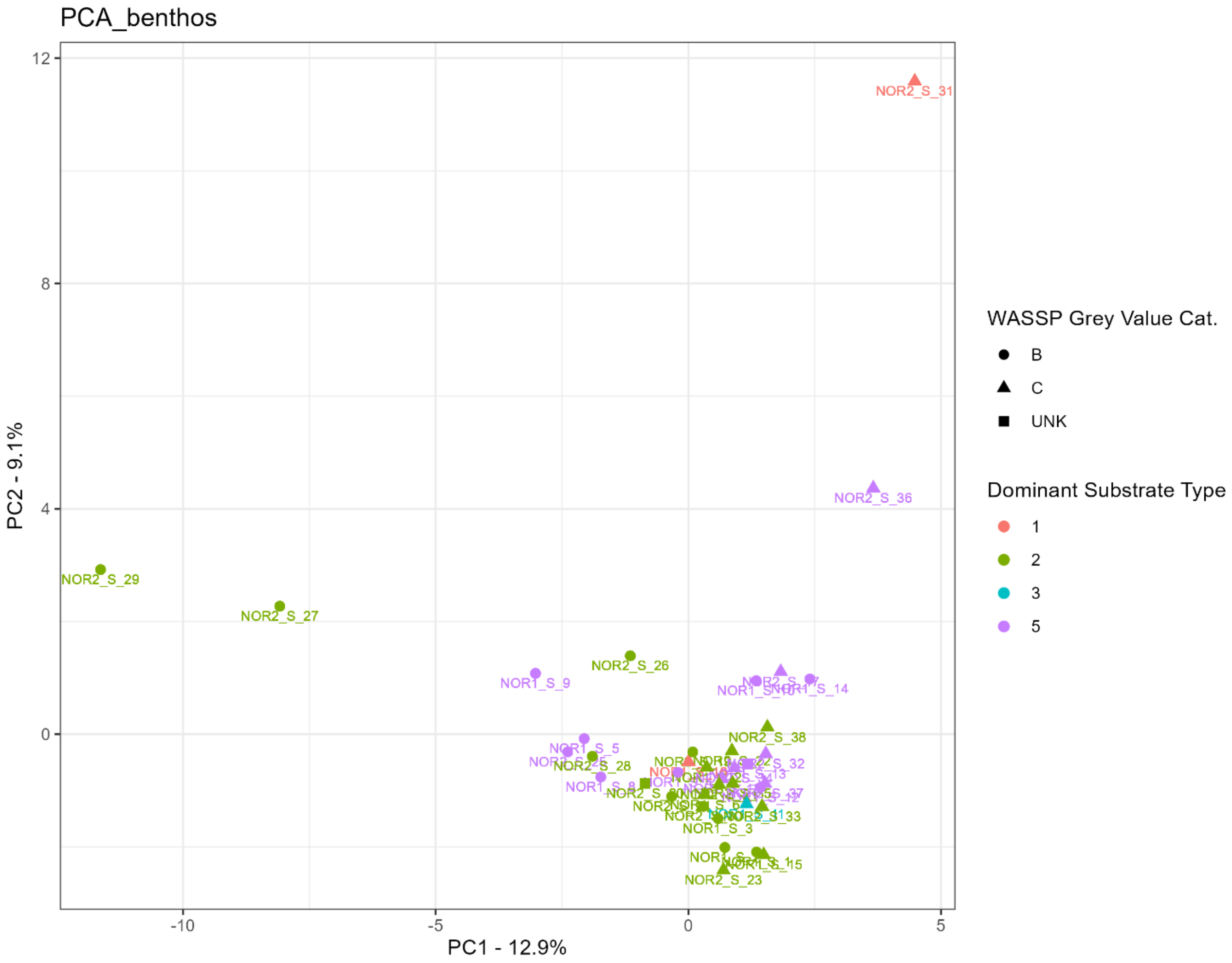

*Figure B- 14* PCA plot of benthos. A distinction is made based on Dominant Substrate Type (color) and WASSP classification (shape). Levels of Dominant Substrate Type are: Levels of OSPAR score are: 2 (n = 18); 3 (n = 9); 4 (n = 11). Grey Value groups are [A]<60; [B] 60-110 [C] >110, UNKOWN hauls are labeled with UNK.

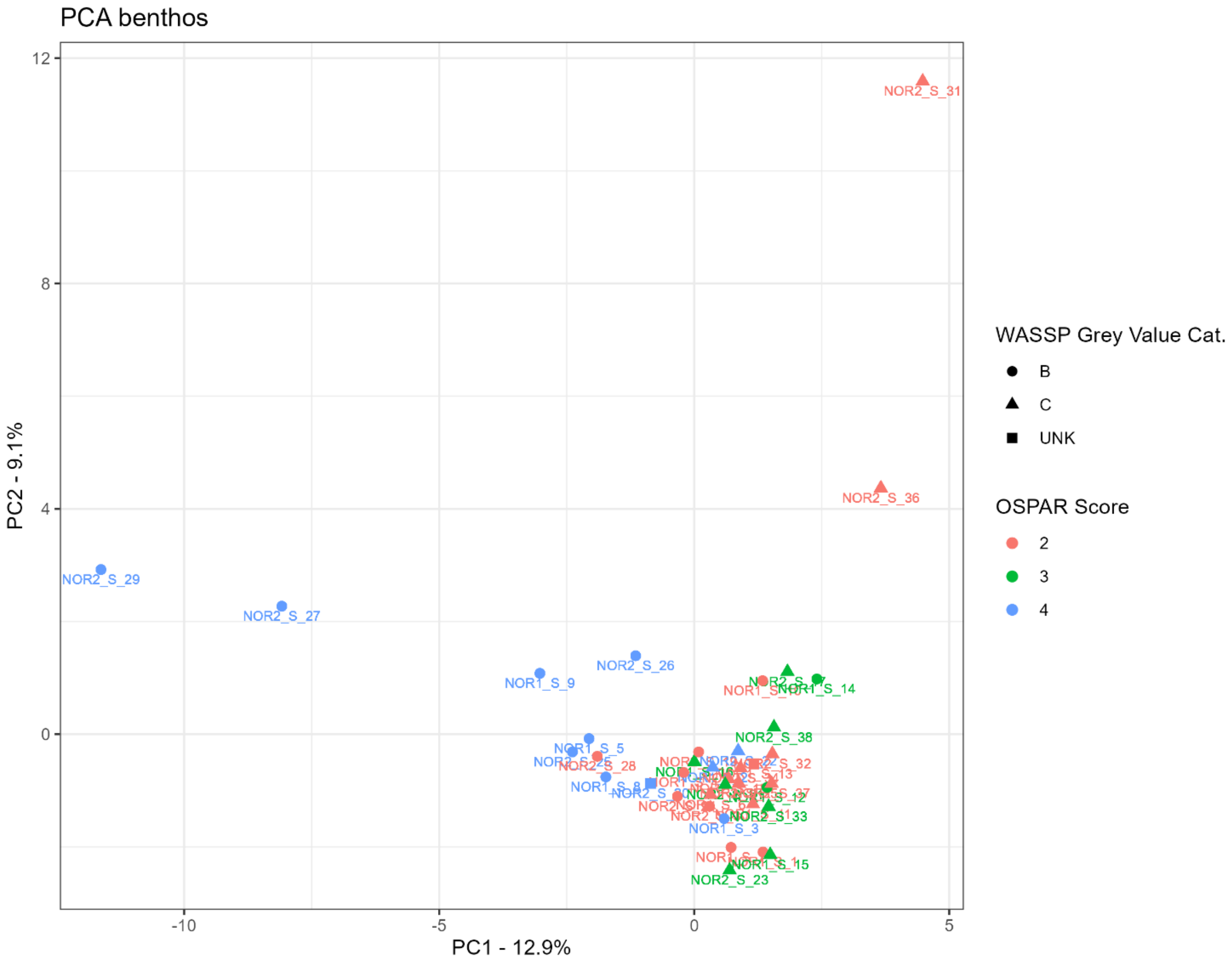

*Figure B- 15* *PCA plot of benthos. A distinction is made based on OSPAR Score (color) and WASSP classification (shape). Levels of Dominant Substrate Type are: (1) Mud-Muddy Sand (n = 2); (2) Sand (n = 20); (3) Coarse substrate (n = 1); (4) Mixed Sediments (n = 0); (5) Rock + Boulders (n = 15). Grey Value groups are [A]<60; [B] 60-110 [C] >110, UNKOWN hauls are labeled with UNK.*

# ANNEX C: Documentation

## Dipclear

### NOTIFICATION OF PROPOSED RESEARCH CRUISE

PART A: GENERAL

1. NAME OF RESEARCH SHIP : CRUISE NO.

**Z.510 Dennis**

2. DATES OF CRUISE From To

**October 2024**

3. OPERATING AUTHORITY:

**Agentschap Landbouw en Zeevisserij Brussel**
**Koning Albert II-laan 15, bus 360**
**1210 Brussel**
**Belgium**

TELEPHONE:

**+32 02 214 48 48**

TELEFAX: /

TELEX:/

4. OWNER : **Chris De Waegenaere**

5. PARTICULARS OF SHIP:

Name: **Z.510 Dennis**

Nationality: **Belgian**

Overall length: **38 m**

Maximum draught: **5.6m**

Net tonnage: **116**

Propulsion e.g. diesel/steam: **Diesel**

Call sign: **OPUF**

Registration port and number (if registered fishing vessel): **Z.510**

6. CREW

Name of master: **Chris De Waegenaere**

Number of crew: **7**

7. SCIENTIFIC PERSONNEL

Name and address of scientist in charge:

**Research institute in charge of project:**

**Flanders Research Institute for Agriculture Fisheries and Food (ILVO Belgium)**

**Scientists in charge of project:**

**Laura Lemey:**

**laura.lemey@ilvo.vlaanderen.be**
**Ellen Pecceu:**
**ellen.pecceu@ilvo.vlaanderen.be**

**Scientists/observer on board:**

**Benedict Deputter or**

**Coenraad Deputter**

**Tel/telex/fax no.: +32492497512 (Laura Lemey)**

**No. of scientists: 1 on board**

8. GEOGRAPHICAL AREA IN WHICH SHIP WILL OPERATE (with reference to latitude and longitude)

| | **LATITUDE** | **LONGITUDE** |
|---|---|---|
| **Box 1** | 57° 10' 0.5484" N | 5° 30' 6.282" E |
| | 56° 54' 27.4536" N | 5° 30' 6.282" E |
| | 56° 54' 41.5188" N | 6° 3' 44.0856" E |
| | 57° 9' 35.5428" N | 6° 3' 56.5884" E |
| | | |
| **Box 2** | 57° 28' 12.5508" N | 4° 28' 52.2408" E |
| | 57° 27' 24.6168" N | 4° 52' 27.7752" E |
| | 57° 9' 58.464" N | 4° 46' 47.5716" E |
| | 57° 12' 24.3432" N | 4° 19' 21.234" E |
| | | |
| **Box 3** | 57° 45' 32.4504" N | 3° 58' 4.2816" E |
| | 57° 36' 22.2804" N | 3° 58' 4.2816" E |

| | | |
|---|---|---|
| | 57° 36' 59.7924" N | 4° 32' 52.4184" E |
| | 57° 45' 19.9476" N | 4° 32' 14.91" E |
| | | |
| **Line 1** | 57’’ 08’N | 05’’ 43’E |
| | 57’’ 18’N | 05’’ 18’E |

| | | |
|---|---|---|
| **Line 2** | 57’’ 20’N | 05’’ 08’E |
| | 57’’ 35’N | 05’’ 04’E |

9. BRIEF DESCRIPTION OF PURPOSE OF CRUISE

**EU beam trawlers, in particular Belgian trawlers, have traditionally fished in Norwegian waters and have experience with the diverse sediment types and fishing grounds. The modern beam trawler is equipped with innovative technologies such as the WASSP multibeam, VISTools sensor and machine vision camera making it possible to collect more data on the fisheries, fish more sustainably and avoid sensitive habitat types. The Norwegian waters are a suitable area for testing precision fisheries due to the diverse habitat types and the presence of sensitive areas, which provide a robust environment for assessing the effectiveness and sustainability of these innovative fishing techniques in these well known areas. This pilot study aims to explore the potential of precision fisheries in the Norwegian Exclusive Economic Zone with this modern equipped beam trawler, and promotes a more widespread use of these fishing techniques.**

**Norwegian waters are well-mapped and studied, providing a rich background of data against which new data can be compared. This comprehensive baseline enhances the ability to assess the impact and success of the precision fishing techniques. Norwegian waters offer a unique combination of diverse habitats, sensitive areas, historical collaboration, and stringent environmental standards, making them an ideal location for testing and showcasing the benefits of precision fishing technologies.**

10. DATES AND NAMES OF INTENDED PORTS OF CALL

**Trip planned in October 2024, landing port in Thyboron, Denmark or Zeebrugge, Belgium.**

11. ANY SPECIAL REQUIREMENTS AT PORTS OF CALL

**N.A**

# NOTIFICATION OF PROPOSED RESEARCH CRUISE

## PART B: DETAILS

1. NAME OF RESEARCH SHIP CRUISE NO.

**Z.510 Dennis**

2. DATES OF CRUISE From To

**October 2024**

**3. a) PURPOSE OF RESEARCH**

**The EU fleet, in particular the Belgian fleet, has a long-standing tradition of beam trawl fishing in Norwegian waters, taking advantage of the historical fishing rights established through international agreements. During the period from 2001 to 2010, the Belgian fleet predominantly caught species such as plaice, cod, anglerfish, haddock, lemon sole, Atlantic wolffish, and saithe. These consistent activities underscore the Belgian fleet's sustained utilization of its historical fishing rights in the region. In recent years, Belgian beam trawl fishing has been adapted and modified to incorporate precision fishing techniques and more sustainable practices, utilizing advanced technologies to minimize environmental impact and protect sensitive marine habitats.**

**The pilot project shall aim at showing that the modern beam trawl can avoid fishing in sensitive areas by testing if the vessels are able to follow sediment maps to a very precise level. The Belgian fleet is currently consisting of 59 fishing vessels, mainly consisting of beam trawlers. The fishery is a mixed demersal fishery, mainly targeting sole and plaice, but typically catching over 30 species per fish trip, of which mainly flatfish. The Belgian fishery sector cooperates closely with the Flanders Research Institute for Agriculture Fisheries and Food (ILVO Belgium) to increase selectivity, energy efficiency etc, via VISTools, a data collection platform that makes precision fishery possible. Although primarily targeting sole and plaice, the fleet equipped for flatfish fishing exerts a distributed fishing pressure on various components of the demersal ecosystem, partly due to the broad distribution of the different fishing grounds. Compared to other fishing techniques, beam trawl fishing can exert much less pressure on specific fish aggregations and their seasonal patterns. This is largely due to the Belgian quota system, which allocates fishing quotas as a mixed package, rather than allowing individual transactions between fishermen. This system ensures that fishing pressure is distributed more evenly across various fish species and areas, avoiding intense targeting of specific fish species. Consequently, this approach supports the sustainable management of beam trawl fisheries. The negative consequences of seabed disturbance caused by beam trawling have been greatly reduced in recent years by changes to the gear (lighter chain, roller skids, sumwing, etc.) depending on the locations fished.**

**This precision fishing project will be carried out with a modern equipped beam trawler (specifications of the gear are listed in next paragraph).**

**Over the years a lot of changes have been introduced in the beam trawl fleet. Since the 2000s several selective devices such as a large mesh top panel, large mesh extension and flip-up rope are present with the aim of reducing bycatch. Roller shoes have also been introduced, minimizing the impact of the trawl gear on the seabed. In Belgium, eight new vessels have been built, each with a strong emphasis on energy efficiency. Since 2023 a total of 38 vessels are equipped with the VISTools sensor. This automatic data collection platform provides real- time data and visualisation on fishing location, catch weights, fuel consumption and information on fishing activities such as the towing force and depth. The development of this digital system based on data- sharing agreements is a win-win for the fishing sector, science, policy and the environment. The skipper can navigate more efficiently, reducing fuel consumption, and will soon have insights into the locations of sensitive fishing grounds. For the scientist, the detailed series of current catch data can alter the estimation system of fish populations, which forms the basis for the annual allocation of fish quotas.**

**Precision fisheries is an advanced approach to managing and optimizing fishery operations by leveraging technology, data analytics, and scientific research. It aims to enhance the sustainability, efficiency, and productivity of fishing activities. Key aspects of precision fisheries include:**

1. Data Collection and Monitoring**: Utilizing modern technologies such as satellite imagery, GPS, sonar, and underwater drones to collect detailed information about fish populations, their habitats, and environmental conditions.**
2. Data Analysis and Modelling**: Applying statistical and computational tools to analyse collected data. This helps in predicting fish movements, understanding ecosystem dynamics, and assessing the impact of fishing practices on fish stocks and habitats.**
3. Sustainable Practices**: Implementing fishing techniques and strategies that minimize environmental impact and avoid overfishing. This includes setting quotas, using selective fishing gear, and adopting eco-friendly practices.**
4. Real-Time Decision Making**: Using real-time data to make informed decisions about where, when, and how to fish. This reduces bycatch, improves yield, and ensures that fishing activities are conducted in a sustainable manner.**
5. Regulatory Compliance**: Ensuring that fishing operations comply with local, national, and international regulations and standards. Precision fisheries can provide the data needed for accurate reporting and monitoring of compliance.**
6. Economic Efficiency**: Enhancing the economic viability of fisheries by optimizing resource use, reducing waste, and increasing the market value of catches through better quality control and traceability.**

**In summary, precision fisheries integrate cutting-edge technology and data-driven approaches to improve the management and sustainability of fishing activities, benefiting both the environment and the fishing industry. The aim of this pilot project is to demonstrate that, by using a variety of innovative solutions in beam trawl fisheries, precision fisheries could be a solution to fish in such a way that sensitive areas are avoided, and the disturbance therein is minimised. Using automation and artificial intelligence (AI), advanced analytics techniques can do complex data/text mining, pattern matching, forecasting, and analysis, all of which produce deeper, more nuanced insights and predictions. Additionally, the project aims at analysing the viability of precision fishing methods.**

**Since there is an increasing societal push for more sustainable fishing, a pilot project which aims at improving and developing the possibility to avoid sensitive areas would be beneficial for all parties and countries involved. Fishing gear, such as trawls and nets, can cause significant damage to the seafloor and other habitats when used intensively in a small area. Spreading out fishing activities minimizes the cumulative physical impact on these habitats, preserving essential structures like**

**coral reefs, seagrass beds, and sponge gardens. Intense fishing in specific areas can lead to localized depletion, where certain species become rare or absent in those regions. This can disrupt local ecosystems and affect other species that depend on them. Wider distribution of fishing efforts prevents such localized depletions. Overall, spreading fishing areas widely helps to mitigate the negative impacts of fishing on marine ecosystems, ensuring that fish populations and their habitats remain healthy and productive. This approach supports both ecological sustainability and the long-term viability of the fishing industry. Hence, including the Norwegian waters where Belgian fishers have traditionally fished and have experience, is a logical step towards promoting a more widespread use of these fishing techniques. Although the beam trawl has high impact on vulnerable areas, such as reefs and mud, it has low impact on the dynamic sandy seabed[1]. As the marine space is to be shared with an increasing number of different players (e.g. renewable energy), it is important that traditional fishing grounds remain accessible to the fishing fleets while avoiding the most sensitive areas.**

**Apart from the fact that spreading the fishery activities in low impact areas leads to more sustainably responsible fishing, the project will also lead to more knowledge acquisition of the areas suggested in this document below. Additionally, the project aims to demonstrate that the beam trawl ban as it is currently designed to safeguard the Norwegian seabed, is gaining nothing by excluding modern beam trawl vessels, as they are equipped with innovative technologies which enables them to map the seabed and avoid the sensitive areas. The method is already used in large parts of the traditional fishing grounds by the Belgian beam trawl fishery. The aim is to promote this sustainable form of fishing across all traditional fishing grounds. Additionally, this approach could serve as an example to encourage other fisheries globally to adopt precision fishing techniques.**

**The research in Norwegian waters can only be carried out based on an exploratory fishery authorisation, pursuant to the Agreed Record of Fisheries Consultations between the European Union and Norway for 2024, dated December 8, 2023, where the Norwegian Delegation notified the EU delegation of the possibility to submit a request for authorisation for an exploratory fishery, testing fishing gear technology in Norwegian waters[2].**

**The research will be carried out by the fishing vessel Z.510 beam trawler, which has experience in scientific data collection under the Data Collection Framework (EC 2017/1004). In section G of this dipclear, a map is provided of the research fishing areas. These areas have been carefully chosen taking into account the known fishing areas by the master and the scientific sediment maps, with the aim of avoiding high sensitive areas.**

**The vessel is equipped with a WASSP multibeam sensor capable of mapping seafloor substrate types by analysing backscatter, which reflects seafloor hardness. This real-time backscatter visualization enables the skipper to identify sandy, and thus less vulnerable areas for targeting flatfish.**

**In addition to the WASSP multibeam sensor, the vessel is equipped with an automatic data collection platform (VISTools[3]) which integrates and visualizes real-time onboard data such as location, catch weights, fuel consumption and information on fishing activities i.e. towing force and depth. Apart from that, fishing prices and fuel prices are also available in the platform. The WASSP**

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[1] van Denderen PD, Bolam SG, Hiddink JG, Jennings S, Kenny A, Rijnsdorp AD, van Kooten T (2015) Similar effects of bottom trawling and natural disturbance on composition and function of benthic communities across habitats. Mar Ecol Prog Ser 541:31-43. https://doi.org/10.3354/meps11550

[2] https://oceans-and-fisheries.ec.europa.eu/fisheries/international-agreements/northern-agreements_en#norway

[3] Precisievisserij - ILVO Vlaanderen (VisTools)

**and VISTools data will be analysed and compared with available sediment and sensitivity maps to assess the precision and effectiveness of the fish tracks in targeting less vulnerable areas.**

**The Belgian VISIM II[4] project will integrate state-of-the-art electronic monitoring methods focusing on advanced camera technologies and deep learning techniques. The fishing vessel shall be equipped with a camera positioned above the conveyor belt to collect images of the entire catch to identify the catch composition. This data will be correlated with the species composition of the expected sediment type, allowing the comparison of the fishing carried out in the intended substrate and to cross-reference the catch composition with existing sediment maps, to ensure accurate substrate targeting during fishing operations. ETP species will be monitored by the camera system, which could allow an almost permanent inventarization of ETP caught.**

**The fishing vessel shall have a scientific observer from the Flanders Research Institute for Agriculture, Fisheries and Food (ILVO) on board during the research fishing trip, collecting weight information for commercial species. Additionally, the observer will collect a subsample of the total catch (fish, commercial invertebrates and epibenthos) during some hauls for comprehensive analysis onshore after the trip. During all hauls, the total numbers of ETP (Endangered, Threatened and Protected) species will also be monitored by the observer or camera.**

**The research will assess if beam trawl vessels equipped with the latest available innovative technology are capable to exercise precision fishery in the areas where natural disturbance of the seabed occurs, i.e. in dynamic sandy areas. The project will control that fishing only takes place in non-sensitive areas.**

**During the research trip, a Norwegian observer can be allowed on board, if so requested by the Norwegian authorities. The research results will be included in a report detailing sediment maps. A copy of the report will be sent to the Norwegian authorities and to the European Commission.**

**The aim for Norway in granting access for this research project is multifaceted. Firstly, it serves as proof that precision fishing techniques can be effective, demonstrating the potential for sustainable fishing practices that minimize bycatch and environmental impact. Allowing fishing activities in areas where it is typically prohibited provides a significant incentive for fishermen to invest in advanced precision fishing technologies. This collaboration not only promotes responsible fishing but also offers Norway the opportunity to enhance its marine research capabilities. Through this project, Norway could obtain more detailed sediment maps, contributing to a better understanding of the marine environment and supporting future conservation efforts.**

b) GENERAL OPERATIONAL METHODS (including full description of any fish gear, trawl type, mesh size, etc.)

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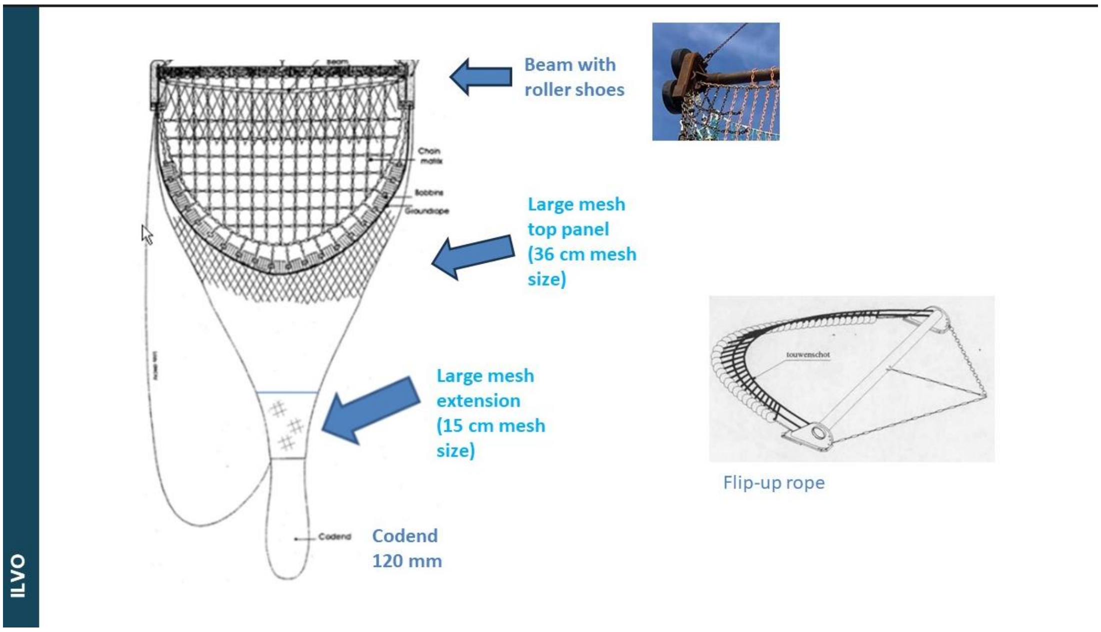
[4] Applicability of self-sampling for biological data collection within the Belgian fisheries sector to improve stock assessments for commercial fish species — ILVO

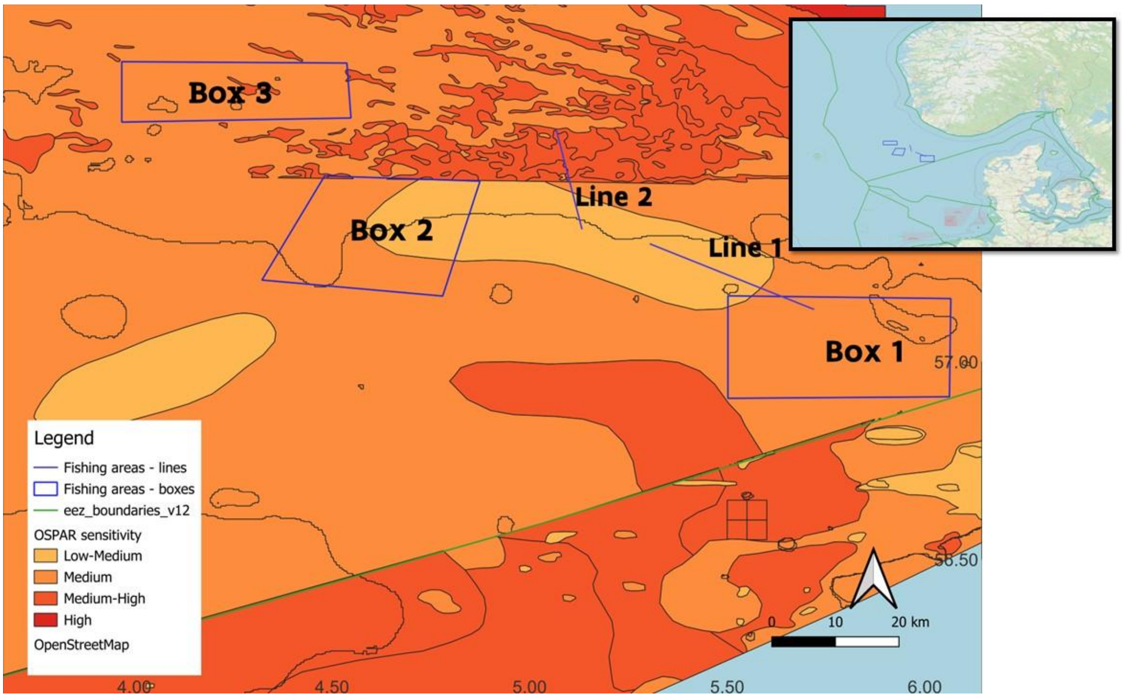
The fising vessel shall use the following gear and equipment:

- **Gear type: TBB_DEF>=120 mm**
- **Beam trawl**
- **Mesh size: minimum 120mm**
- **Beams: 2x 11m20**
- **Roller shoes**
- **Flip up rope**



G ATTACH CHART showing (on an appropriate scale) the geographical area of intended work, positions of intended stations, tracks of survey lines, positions of moored/seabed equipment, areas to be fished

This figure shows the research area for this study and more precisely shows 3 boxes which represent experimental fishing areas and two lines which represent experimental fish tracks. These areas and tracks are within low to medium sensitivity areas and are also grounds which have been fished before by Belgian fishers. During the fishing trip, the skipper will navigate through these different designated areas and will fish on these fish tracks while trying to avoid sensitive areas.



| | **LATITUDE** | **LONGITUDE** |
|---|---|---|
| **Box 1** | 57° 10' 0.5484" N | 5° 30' 6.282" E |
| | 56° 54' 27.4536" N | 5° 30' 6.282" E |
| | 56° 54' 41.5188" N | 6° 3' 44.0856" E |
| | 57° 9' 35.5428" N | 6° 3' 56.5884" E |
| | | |
| **Box 2** | 57° 28' 12.5508" N | 4° 28' 52.2408" E |
| | 57° 27' 24.6168" N | 4° 52' 27.7752" E |
| | 57° 9' 58.464" N | 4° 46' 47.5716" E |
| | 57° 12' 24.3432" N | 4° 19' 21.234" E |
| | | |
| **Box 3** | 57° 45' 32.4504" N | 3° 58' 4.2816" E |
| | 57° 36' 22.2804" N | 3° 58' 4.2816" E |
| | 57° 36' 59.7924" N | 4° 32' 52.4184" E |
| | 57° 45' 19.9476" N | 4° 32' 14.91" E |
| | | |
| **Line 1** | 57’’ 08’N | 05’’ 43’E |

| | |
|---|---|
| 57’’ 18’N | 05’’ 18’E |

**Line 2**

| | |
|---|---|
| 57’’ 20’N | 05’’ 08’E |
| 57’’ 35’N | 05’’ 04’E |

**This section shall be updated and notified to the operator and the European Commission for transmission to the Norwegian authorities, if additional sediment and sensitivity maps are used to identify sensitive areas before the begining of the fishing trip.**

a) TYPES OF SAMPLES REQUIRED (e.g., geological/water/plankton/fish/radionuclide)

5.

**Fish, commercial invertebrates and epibenthos.**

b) METHODS OF OBTAINING SAMPLES (e.g., dredging/coring/drilling/fishing, etc. When using fishing gear, indicate fish stocks being worked, quantity of each species required, and quantity of fish to be retained on board).

**Fish, commercial invertebrates and epibenthos samples will be obtained by fishing with a commercial beam trawler, gear specifications see above.**

**Fish stocks and allowed quantity:**

| **Species** | **Stock** | **Quota in Norwegian waters allocated to Z.510 in tonnes** |
|---|---|---|
| **Haddock** | **HAD/2A4C** | **4** |
| **Hake** | **HKE/04-N** | **2,5** |
| **Ling** | **LIN/04-N** | **0,6** |
| **Monkfish** | **ANF/04-N** | **2,8** |
| **Cod** | **COD/2A3AX4** | **0,6/ fishing day** |
| **Plaice** | **PLE/2A3AX4** | **0,2/kW (0,2 * 1200)** |
| **Saithe** | **POK/2C3A4** | **0,5** |
| **Whiting** | **WHG/2AC4** | **1** |

| | | |
|---|---|---|
| **Herring** | **HER/4CXB7D** | **0,4** |
| **Other** | **OTH/04-N** | **8** |

**Apart from the commercial species, a subsample of the total catch (fish, epibenthos and commercial invertebrates) will be collected during certain hauls.**

6. DETAILS OF MOORED EQUIPMENT

**N.A.**

| Dates | Recovery | Description | Depth | Latitude | Longitude |
|---|---|---|---|---|---|
| Laying | | | | | |

7. ANY HAZARDOUS MATERIALS (chemicals/explosives/gases/radioactives, etc.)

(Use separate sheet if necessary)

**N.A.**

a) Type and trade name

b) Chemical content (and formula)

c) IMO IMDG code (reference and UN no.)

d) Quantity and method of storage on board

e) If explosives give dates of detonation

- Method of detonation
- Position of detonation
- Position of detonation
- Frequency of detonation
- Depth of detonation
- Size of explosive charge in kg.

8. DETAIL AND REFERENCE OF

a) Any relevant previous/future cruises

**The master shall have at least 10 years of experience with fishing in Norwegian waters and 3 years of experience in the use of WASSP.**

**Scientific observer shall have at least 10 years of experience onboard of commercial vessels. As part of the DCF Council Regulation (EC No 2017/1004, 2021/1167, 2021/1168 & 2022/39), ILVO collects on a yearly scientific data onboard of commercial vessels including a trip in Norwegian waters in May 2022 with the Z.48.**

b) Any previously published research data relating to the proposed cruise

**N.A.**

9. NAMES AND ADDRESSES OF SCIENTISTS OF THE COASTAL STATE(S) IN WHOSE WATERS THE PROPOSED CRUISE TAKES PLACE WITH WHOM PREVIOUS CONTACT HAS BEEN MADE

**N.A**.

10. STATE

a) Whether visits to the ship in port by scientists of the coastal state concerned will be acceptable
**The master shall accept port visits by scientist of the coastal State.**

b) Participation of an observer from the coastal state for any part of the cruise together with the dates and the ports for embarkation and disembarkation
**An ILVO scientific observer will be on board monitoring the trip. Although a scientific observer will be on board to monitor the trip, a Norwegian observer is also welcome.**

c) When research data from the intended cruise are likely to be made available to the coastal state and by what means

**As soon as the report is available, it will be communicated via email to the relevant points of contact within the Norwegian authorities.**

## PART C. SCIENTIFIC EQUIPMENT

Complete the following table
using a separate page for
each coastal state

Coastal state

Port of call: **Thyboron (DK) or Zeebrugge, Belgium**

Dates: October 2024

Indicate "YES" or "NO"

| | | | | DISTANCE FROM COAST | | |
|---|---|---|---|---|---|---|
| List scientific work by function e.g. | Water column including sediment sampling of the seabed | Fisheries research within fishing limits | Research concerning the natural resources of the continental shelf or its physical characteristics | Within 4 nm | Between 4-12 nm | Between 12-200 nm |
| Magnetometry | No<br>No | No | No | No | No | No |
| Gravity | No<br>No | No | No | No | No | No |
| Diving | No | No | No | No | No | No |
| Seismics | No | No | No | No | No | No |

| | | | | | | |
|---|---|---|---|---|---|---|
| Seabed sampling | No | No | No | No | No | No |
| Bathymetry | No | Yes | No | No | No | Yes |
| Trawling | No | Yes | No | No | No | Yes |
| Echo sounding | ? | Yes | No | No | No | Yes |
| Water sampling | No | No | No | No | No | No |
| U/W TV | ? | ? | ? | ? | ? | ? |
| Moored instr. | | No | No | No | No | No |
| Towed instr. | | ? | ? | ? | ? | ? |

A copy of these conditions to carry out the research shall be carried on board at all times and presented to the control authorities upon request.

Any changes on the research plan and conditions to carry out the research shall also be carried on board.

The research activity can only be carried out in accordance with the conditions laid down in this authorisation and any changes thereof, and once the fishing vessel has obtained an authorisation by the flag and coastal State authorities.

______________________________________________

Dated__________________________________ (On behalf of the Principal Scientist)

NB IF ANY DETAILS ARE MATERIALLY CHANGED REGARDING DATES/AREA OF OPERATION AFTER THIS FORM HAS BEEN SUBMITTED, THE COASTAL STATE AUTHORITIES MUST BE NOTIFIED IMMEDIATELY

ILVO

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