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PreciVis

**Precision fishery in the Belgian beam trawl industry
Scientific Report**

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Abbreviations

Abbreviations	Full meaning
AL	Al-Hamdani reference
B	Benthos
CPUE	Catch Per Unit Effort
D	Discards
DCF	Data Collection Framework
EEZ	Exclusive Economic Zone
FSSH	Fully-Sampled Scientific Hauls
L	Landings
MCRS	Minimum Conservation Reference Size
MPA	Marine Protected Area
NDGP	National Data Gathering Programme
OB	OceanBox B.V.
PCA	Principle Component Analysis
PSSH	Partially-Sampled Scientific Hauls

Species List

FAO Code	Scientific Name	English common name	Dutch common name
BIB	<i>Trisopterus luscus</i>	Pouting	Steenbolk
BLL	<i>Scophthalmus rhombus</i>	Brill	Griet
CAA	<i>Anarhichas lupus</i>	Atlantic wolffish	Zeewolf
COD	<i>Gadus morhua</i>	Atlantic cod	Kabeljauw
DAB	<i>Limanda limanda</i>	Common dab	Schar
GUG	<i>Eutrigla gurnardus</i>	Grey gurnard	Grauwe poon
HAD	<i>Melanogrammus aeglefinus</i>	Haddock	Schelvis
LBE	<i>Homarus gammarus</i>	European lobster	Zeekreeft
LEM	<i>Microstomus kitt</i>	Lemon sole	Tongschar
LIN	<i>Molva molva</i>	Ling	Leng
LUM	<i>Cyclopterus lumpus</i>	Lumpfish(=Lumpsucker)	Snotolf
MON	<i>Lophius piscatorius</i>	Monkfish (Anglerfish)	Zeeduivel
MSF	<i>Arnoglossus laterna</i>	Mediterranean scaldfish	Schurftvis
MXV	<i>Myoxocephalus scorpius</i>	Shorthorn sculpin	Gewone zeedonderpad
OCC	<i>Octopus vulgaris</i>	Common octopus	Gewone octopus
PLA	<i>Hippoglossoides platessoides</i>	American plaice	Lange schar
PLE	<i>Pleuronectes platessa</i>	European plaice	Schol
POL	<i>Pollachius pollachius</i>	Pollack	Pollak
RJC	<i>Raja clavata</i>	Thornback ray	Stekelrog
RJR	<i>Amblyraja radiata</i>	Starry ray	Sterrog
SOL	<i>Solea solea</i>	Common sole	Tong
SQR	<i>Loligo vulgaris</i>	Common squid	Gewone Pijlinktvis
SYC	<i>Scyliorhinus canicula</i>	Lesser-spotted dogfish	Hondshaai

TUR

*Scophthalmus
maximus*

Turbot

Tarbot

WEG

Trachinus draco

Greater weever

Grote pieterman

YEZ

Hyperoplus lanceolatus

Great sandeel

Smelt

ZGP

Zeugopterus punctatus

Topknot

Gevlekte griet

Non-Technical Summary

Project Context

The Belgian fishing industry has a long and rich history in the Danish Exclusive Economic Zone (EEZ). These waters form a heterogeneous mosaic of both less-sensitive and sensitive marine habitats, making it hard to continue fishing activities without harming the latter. In recent years, new and innovative technologies, gear modifications and internationally acquired expertise have evolved, and 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 Danish 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 if 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. **Evaluate** whether sensitive areas could be characterized by certain key-species.
3. Providing **practical recommendations** for future projects and applications.
4. Develop a concept for the integration of the WASSP multibeam into the VISTools Framework

Survey

For the PreciVis project, a five-day survey, was conducted in the Danish EEZ, and in particular in the Natura-2000 area Gule Rev. This area was chosen for multiple reasons.

First, Gule Rev consists of a mixture of sensitive and non-sensitive areas, which makes it ideal to evaluate the capability and accuracy of the WASSP multibeam in distinguishing different seafloor substrates. Additionally, studying the catch composition across the different substrates allows for the identification of key species in both sensitive and non-sensitive regions. In this way, both sensitive and non-sensitive areas will be characterized by WASSP- and catch composition data.

Secondly, the area has been previously studied in detail. In 2015, Ziad Al-Hamdani (Geological Survey of Denmark and Greenland) and his team conducted an extensive study of the area, mapping the present substrate types of Gule Rev (Al-Hamdani et al., 2015). This study provides valuable information for comparing our newly collected data. Since the surrounding area of Gule Rev is mapped in less detail, the availability of detailed information on the seafloor substrate within Gule Rev makes it a suitable study area. Furthermore, since no recent studies are available, this project could provide some valuable insights in the area for ILVO and Danish marine research.

Thirdly, Gule Rev is an economically important area for Belgian fishers (Geofish, 2025). The Belgian fishing industry has a rich history in this area, resulting in extensive knowledge about the area and effective

fishing practices. Both the skipper of the chartered fishing vessel and the seagoing observer of ILVO have many years of experience fishing in Gule Rev and the surrounding waters. Finally, if we want to avoid sensitive areas such as the rocky reefs present in Gule Rev, we need to be able to characterize them in a precise way.

For this survey, the commercial Belgian beam trawler Z.510-“Dennis” was chartered. The vessel is equipped with innovative technologies, such as the VISTools digital twin or the VISIM-camera system, which were used and tested during this project. With these technologies, different data types were sampled, such as WASSP multibeam data, catch composition data, VISIM recordings, underwater footage and VISTools data (e.g. fuel consumption). In total, 54 hauls were completed, with nearly all accompanied by WASSP multibeam, VISIM and VISTools recordings. Complete catch composition data (commercial, non-commercial fraction and benthos) was obtained for 15 of these hauls, 16 additional hauls were sampled in the context of the National Data Gathering Program (NDGP) under the Data Collection Framework (DCF – 2017/1004). Additional underwater video footage was collected for four of these hauls. In this report, only hauls for which complete catch data was collected and analyzed 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 Dutch company OceanBox B.V. (Contact: m.s.ybeam@oceanbox.eu). Based on the collected backscatter data and using a machine learning approach, an AI model (XG Boost) was built to recognize different substrate- and habitat types present inside or in the vicinity of the survey area. Training data were derived from the detailed substrate maps of Al-Hamdani et al. (2015), enabling the model to predict the substrate present in a given area. The model reached a 64% precision level when using training data, while a precision level of 74% was reached for the testing dataset. The model struggled the most with the detection and classification of the “mixed” substrate type -57% accuracy for training data, 62% for testing data-, since the latter is an overlap between either “sand” and “stony” substrates. Consequently, the introduction of this substrate type increases complexity and complicates correct classifications.

In addition to the ML-model, OceanBox B.V. created a post-processing tool which translates the model’s output (i.e. substrate classification) into a meaningful habitat designation. In total, three habitat classifications were identified:

- *Reef*: Areas with high stone coverage, representing sensitive habitats that should be avoided.
- *Reef Candidate*: Areas with characteristics suggesting possible reef presence, warranting caution.
- *Non-Reef*: Areas without reef characteristics, potentially suitable for fishing activities.

With this post-processing tool, the model shows promise in detecting and classifying reef structures, achieving 80% accuracy on training data and 70% on test data. However, these results remain exploratory and are still too insufficient for real-time monitoring, where higher accuracy levels are expected. Additionally, it was also noted that certain novel areas located outside Gule Rev were classified as “reef” despite the absence of reef-structures in these areas.

These results highlight the exploratory character of this project, and that several challenges still prevent real-time application. First, multibeam data used to construct the ML-model originates from a survey

conducted by the Geological Survey of Denmark and Greenland (GEUS) institute in 2015 (Al-Hamdani et al., 2015). Since this dataset is already a decade old, changes to the seafloor could have occurred in the meantime, meaning that this dataset could be less reliable. In addition, training data was also limited to Gule Rev, resulting in a dataset that was both numerically and spatially restricted. Consequently, the model struggled to correctly classify novel regions. Furthermore, substrate maps for neighboring areas exhibited a low resolution, making them unsuitable for model training. Finally, the multi-layer definition of “rocky reefs” (H1170), as presented by Danish authorities (Danish Environmental Protection Agency, 2021) also introduced an additional complexity to the classification process.

To further develop the model, there is a need for a more extensive training dataset which includes sufficiently spatially dispersed, homogenous and detailed datapoints. These could be acquired through the WASSP’ Survey License, which was not installed on the WASSP system of the survey vessel. This license gives access to the “raw”, unprocessed multibeam data, which can be used for detailed substrate mapping and improved habitat classification.

In conclusion, the WASSP multibeam and the constructed model exhibited promising results but are limited in their real-time application by the lack of sufficient and reliable training datasets. To acquire these, testing should be conducted with the WASSP’ Survey License, which provides access to unfiltered and unprocessed multibeam data. Additionally, international knowledge should be bundled to optimize sampling campaigns and analysis.

VISTools

During the PreciVis 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, a distinct characterization of the different substrate types could be made based on the traction values registered during each haul.

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 to not lose their gear. However, since these parameters give an indication of the substrate fished, the VISTools framework could act as an additional validation method for the observed WASSP multibeam recordings.

Catch Composition

Throughout the study, several analyses were conducted to identify species associated with specific substrate or habitat types. However, the limited sample size ($n = 15$), uneven spatial distribution, and heterogeneity of sampled areas made it challenging to identify clear indicator species. Due to the latter, the results presented should also be interpreted with caution, since they could be statistically biased.

Several significant correlations were found between present substrate and the abundance of landings (i.e. commercial-sized fish) and discards (i.e. under-sized or non-target fish). For example, Commercial-sized cod (*Gadus morhua*) exhibited a significant positive correlation with the presence of harder (i.e.

stone) substrates. In contrast, discard plaice (*Pleuronectes platessa*) displayed a significant positive correlation with softer (i.e. sand) substrates. Regarding the benthos community, significant correlations were found for edible sea crab (*Cancer pagurus*), seven-armed starfish (*Luidia ciliaris*) and common-starfish (*Asterias rubens*). Additionally, two fish species displayed a significant correlation between the species abundance and the present habitat type. Commercial-sized cod demonstrated a positive correlation with the presence of the reef habitat, while under-sized plaice was found positively correlated with the non-reef habitat type.

Remarkably, no significant correlations were found between any present benthic species and the present habitat type. According to literature, dead man's fingers (*Alcyonium digitatum*) typically forms an indicator of hard substrates (Danish Environmental Protection Agency, 2016, 2021). However, during this study, this species was present in all hauls, including those dominated by sandy areas. This is a rather surprising result since this species grows on hard surfaces and is usually associated with more sensitive habitat types, such as rocky reefs (H1170). This indicates that the presence of dead man's fingers is not necessarily an indication of sensitivity, but that it's fraction should be compared to the rest of the catch. As discussed in the beginning of this section, the authors believe that the absence of direct correlations between abundance of certain benthic species and habitat types is rather due to a limited sampling.

In addition, catch composition sometimes varies considerably between hauls with the same substrate classification. For example, hauls DK_S_13 and DK_S_15 are both characterized by the dominant presence of "stony" substrates, and, additionally, are located near the borders of Gule Rev where reefs are present. In addition, haul DK_S_14 was located outside the Gule Rev region in an area classified as "sand". After comparing the catch composition of the three hauls, notable differences were observed in the discard and benthos category. For example, hauls DL_S_13 is characterized by a large discard plaice fraction, which was earlier already associated with softer substrates. Additionally, haul DK_S_14 exhibited a larger cod fraction than both DK_S_14 and DK_S_15. Regarding the benthos category, haul DK_S_15 was characterized by the largest dead man's fingers fraction, followed by DK_S_14. Haul DK_S_13 recorded the lowest fraction of the latter species.

Although some trends could be observed regarding the catch composition of landings, discards and benthos, identifying reliable indicator species for specific substrate or habitat types remains challenging. Many hauls were conducted across areas characterized by a mixture of different substrates and habitats, making it difficult to associate species with a single habitat type. In addition, the limited sample size ($n = 15$) restricted the statistical robustness of the results. Furthermore, low-resolution substrate data (e.g. EMODnet) complicated accurate haul labeling, and consequently hindered catch composition analysis. As a result, while this study provided some indications, specific key-species could not be identified on a high confidence level. More extensive sampling, including more homogenous and spatially spread samples, combined with high-resolution substrate maps would offer more insight into the species-habitat relationship.

VISIM

The in-house developed intelligent VISIM camera was also deployed during this project. The camera and accompanying 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 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. More information on the VISIM-camera can be obtained via Sander Delacauw (sander.delacauw@ilvo.vlaanderen.be)

Underwater Footage

During the survey, experimental deployments of an underwater camera were carried out. The system was deployed in four hauls, successfully collecting underwater footage for all of them. Initial expectations were modest due to an anticipated poor visibility and small camera. But image quality turned out to be high, with clear and detailed images obtained for all sampled hauls. A distinguishment between soft and harder substrate could be observed on these recordings, which is also described in this report. In addition, the collected images were compared with the substrate map published by Al-Hamdani et al. (2015). Based on visual assessment, underwater footage appeared to be consistent with the used substrate map, although a quantitative comparison remained challenging due to the absence of detailed image labeling (e.g., coordinates), and the limited spatial coverage of the camera, which captured only a few square meters of seabed. Additionally, low water temperatures substantially reduced the camera's battery life to approximately 45 minutes, thereby constraining data collection.

Despite these constraints, this method demonstrates potential to act as a validation tool for WASSP. Therefore, future projects should further investigate the potential of this technique.

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 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 Denmark and international scientists would facilitate research and development in the field of precision fishery.
- **Substrate data** extracted from **EMODnet** exhibited a **low resolution**, resulting in some uncertainty on the present substrate type. Additionally, this makes it hard to compare with higher resolution data such as the collected WASSP images or results obtained through Al-Hamdani et al. (2015). Detailed mapping with e.g. side scan sonar or WASSP multibeam with Survey License, could offer a solution.
- A comprehensive **and clear response protocol** should be established for cases where evidence indicates 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.
- Only the **“WASSP Backscatter license”** was installed on the WASSP module. As a result, raw-backscatter and -bathymetry data was already pre-processed by the WASSP module itself, which lead to undocumented corrections and an inhibition of external post-processing. To avoid this, the **“WASSP Survey-license”** should be installed in addition to the backscatter license on the used module. This license enables access to raw, unprocessed backscatter data, which can be used for a more detailed acoustic analysis.

- Training data of the developed model originated from a survey which was carried out in 2015, meaning that these **training labels may be outdated**. This potentially increases the risk of false results, and therefore, future projects should also focus on the **collection of updated, observation-based training data** to ensure model predictions remain valid and ecologically relevant.
- Future projects should include the **impact of rising sediments** originating from e.g. fishing activities on the WASSP readings, which was also described by Kint et al. (2025). **Acoustic uncertainty** could arise due to suspended sediment above the seabed, as this affects the scattering and reflection of sound waves. Underwater footage, collected during the PreciVis project, demonstrated that the equipment used (i.e. chain mat) caused occasional sediment rises. Therefore, this should be considered in future research. Additionally, this suspended sediment could also cover harder substrates such as rocky reefs and therefore **mask the original seabed substrate**.
- The **WASSP Data Manager** experienced some **unexpected crashes**, which caused some **small-scale data losses**. The issue may have been caused by limited onboard computer resources, network instability, or conflicts with other running software, but no uniform solution was found. Future projects or applications 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.
- Discard or benthic catch composition could, in combination with other technologies, imply certain substrate or habitat types. However, 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 PreciVis, tests were done with the in-house developed **VISIM camera**, but no significant results were obtained yet (more info on: [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 investigate this parameter for potential substrate or habitat characterization.
- The limited sample size increased uncertainty in presented results, highlighting the importance of collecting a sufficient number of samples to improve robustness.
- The camera (i.e. GoPro) used during the PreciVis survey provided only a **limited view** of both the net and the seafloor, potentially overlooking relevant occurrences or activities. In addition, low water temperatures significantly reduced battery life, leading to limited recording time and potential data loss. To enhance its effectiveness as a monitoring and control tool, future projects should therefore consider a **camera setup** with a wider field of view and sufficient battery capacity to ensure continuous data collection.
- The PreciVis survey was characterized by a rather **non-uniform sampling**, meaning that certain areas were more sampled than others. This makes it hard to compare certain 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 include **comparing hauls between day- and nighttime**.
- 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 habitat types**, 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

- Future research should prioritize the accurate positioning of the survey tracks and involve the **expertise of the participating country**. Such collaborative approach would not only improve the quality of the results but also strengthen cooperation and mutual understanding between the countries involved.
- 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 investigate this parameter for potential substrate characterization.
- 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.

Conclusion

The PreciVis project served as a scientific pilot study to explore innovative techniques for improving real-time characterization of the seafloor and its related sensitivity, and guide future research. This study demonstrated that discussed technologies show promise to contribute to precision fishery, but that results remain explorative and require cautious interpretation. Consequently, real-time application of, for example, the WASSP multibeam, is not yet feasible and requires additional (international) research and knowledge development.

Nevertheless, this study provided a baseline for future research: a machine-learning model was developed to detect different substrate- and habitat types present in the survey area, which demonstrated adequate accuracy. Additionally, catch composition analysis provided indications of certain indicator species, but, due to limited sampling, no statistically robust conclusions could be obtained. Furthermore, the VISTools framework and underwater camera deployments proved to be valuable validation tools which can support future research efforts. The combined use of these techniques offers the most comprehensive assessment of seabed and habitat characteristics, which is desired in the context of precision fishery, as it can support more selective fishing with less environmental impact. In addition to the results and conclusions provided, several lessons learned and recommendations were also listed in order to assist future research. These emphasize the need for improved sampling strategies, including larger and homogenous sample sizes, more spatially distributed sampling, and strengthened international collaboration among scientists.

Overall, the study provides valuable insights, recommendations, and a foundation for future research 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 into an unambiguous indicator (Depestele et al., 2022).

1.2. Reducing seabed disturbance

Depestele 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. 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.

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 et al., 2020)

1.3. 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.

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. The PreciVis project wants to investigate if the combination of these technologies could enable fishers to target less sensitive sandy areas and avoid vulnerable habitats, thus contributing to more sustainable demersal fishing practices.

1.4. 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 concept. For example, the VISTools project developed the digital twin “VISTools” (see §5.2) and the VISIM III project is testing an AI-driven camera to facilitate the collection of catch composition data (see §5.5). Additionally, the PreciVis 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. PreciVis

2.1. Project context

2.1.1. General

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 with the aim to protect sensitive areas such as rocky reefs and gravel beds (McBride, 2022). In addition, Denmark plans to close its designated Natura-2000 areas to protect these marine habitats from fishing activities. This beam trawl ban, however, also closes off sandy areas that are considered less sensitive to trawling. Additionally, the closure of these areas also increases the fishing pressure and environmental impact on adjacent areas. The Belgian fishing industry wants to continue fishing activities in less-sensitive areas, 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 approach could ensure the protection of vulnerable marine habitats, while promoting the sustainability and efficiency of the fishing industry. As such, the protection of the marine ecosystem is not only managed by policy rules (e.g. closures), but also from the side of the fishing industry. 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, with a test case in Danish waters. 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 low-sensitive. To evaluate these tools, available information (e.g. substrate maps) will be used for comparison and evaluating the effectiveness and accuracy of the proposed tools.

2.1.2. Choice of Study Area: Gule Rev

Several factors led to the selection of Gule Rev area as study area of the PreciVis project.

First, Gule Rev consists of a mixture of sensitive and non-sensitive areas, which makes it ideal to evaluate the capability and accuracy of the WASSP multibeam in distinguishing different seafloor substrates. Additionally, studying the catch composition across the different substrates allows for the identification of key species in both sensitive and non-sensitive regions. In this way, both sensitive and non-sensitive areas will be characterized by WASSP- and catch composition data.

Secondly, the area has been previously studied in detail. In 2015, Ziad Al-Hamdani (Geological Survey of Denmark and Greenland) and his team conducted an extensive study of the area, mapping the present substrate types of Gule Rev (Al-Hamdani et al., 2015). This study provides valuable information for comparing our newly collected data. Since the surrounding area of Gule Rev is mapped in less detail, the availability of detailed information on the seafloor substrate within Gule Rev makes it a suitable study area. Furthermore, since no recent studies are available, this project could provide some valuable insights in the area for ILVO and Danish marine research.

Thirdly, Gule Rev is an economically important area for Belgian fishers, as demonstrated by **Figure 2-1** and **Figure 2-2**. The Belgian fishing industry has a rich history in this area, resulting in extensive knowledge about the area and effective fishing practices. Both the skipper of the chartered fishing vessel and the seagoing observer of ILVO have many years of experience fishing in Gule Rev and the surrounding waters.

Finally, if we want to avoid sensitive areas such as the rocky reefs present in Gule Rev, we need to be able to characterize them in a precise way.

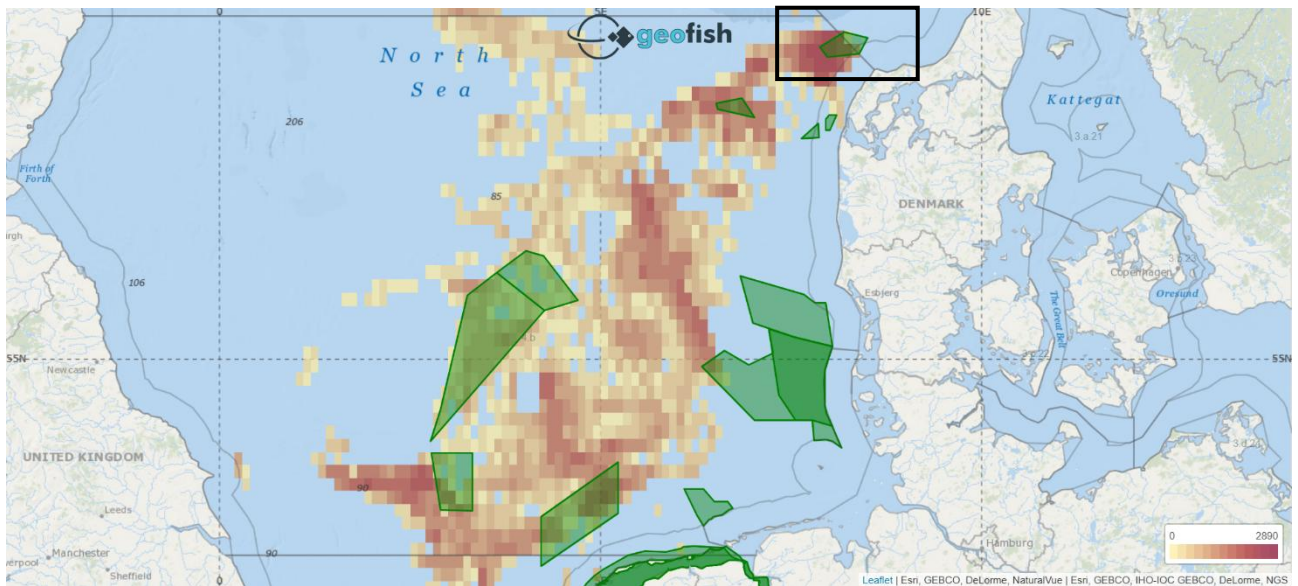


Figure 2-1 Overview of fishing hours of Belgian fishers in the Danish North Sea during 2023. Light yellow indicates a low amount of fishing hours, dark red indicates a high amount of fishing hours. Gule Rev is highlighted with a black box. Map taken from Geofish (2025).

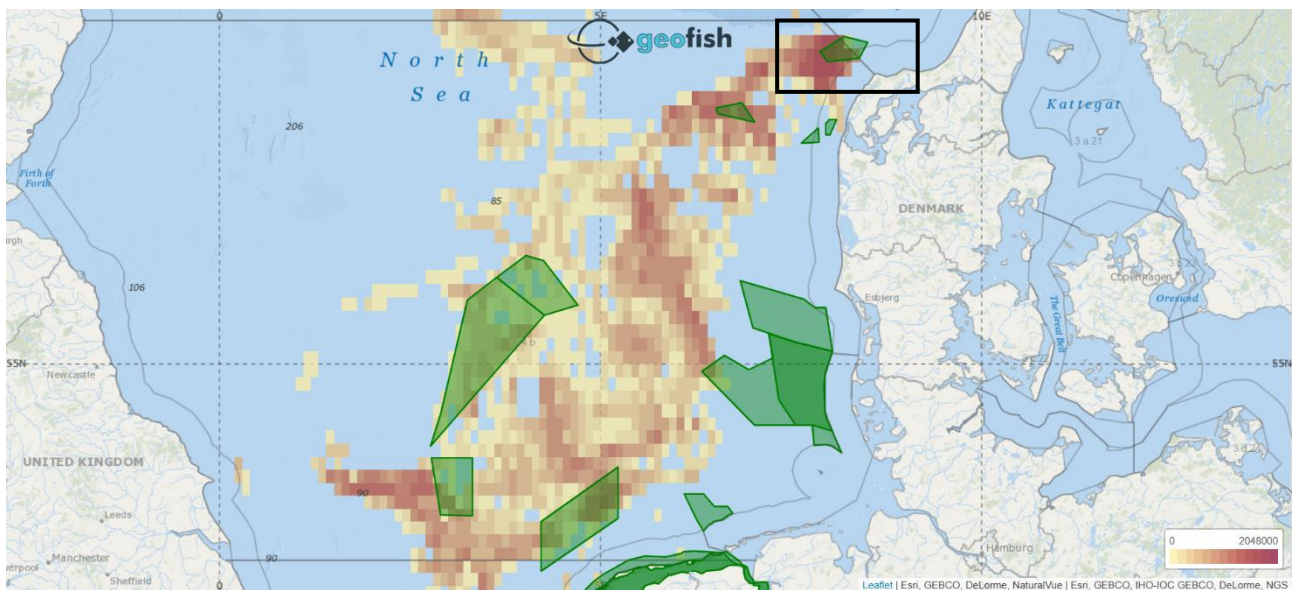


Figure 2-2 Overview of annual revenue of Belgian fishers in the Danish North Sea during 2023 in euros (€). Light yellow indicates a low annual revenue; dark red indicates high annual revenue. Gule Rev is highlighted with a black box. Map taken from Geofish (2025).

2.2. Project Goals

The **main goal** of this pilot study is to **explore the potential of precision fishery in the Belgian beam trawl industry**. Within the project, four major goals are defined:

- I. **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**.
- II. **Evaluate** whether sensitive areas could be characterized by certain key-species.
- III. Providing **practical recommendations** for future projects and applications.
- IV. Develop a concept for the integration of the WASSP multibeam into the VISTools Framework.

To achieve this, the following activities are included in the project:

- Compare WASSP substrate data with available substrate data from other studies or open-source platforms (e.g. EMODnet).
- Catch composition analysis (e.g. identification of key-species).
- Evaluation of operational parameters related to fishing activities, such as traction or fuel consumption.
- Analysis of underwater footage.
- Design architecture for a decision support tool based on WASSP/VISTools and camera data for skippers and shipowners, on the condition that results of WASSP and catch analysis allow this.

Material & Methods

3. Literature

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

3.1. 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 rocks, 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).

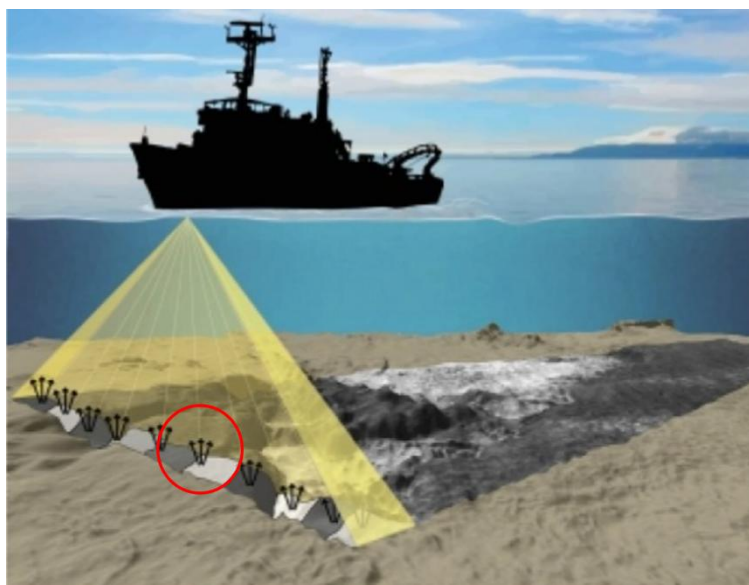


Figure 3-1 Visualization of “backscatter” (red circle) originating from a multibeam sonar. Figure taken from Applied Oceans Research Group (AORG) (n.d.).

3.2. Substrate Data

3.2.1. Substrate Inside Gule Rev

Seabed substrate data of Gule Rev was obtained through Al-Hamdani et al. (2015). This report conducted an intensive mapping of the present substrate at Gule Rev and other Danish Natura-2000 areas, which resulted in the following substrate classes:

- Substrate Type 2: Sand, gravel and pebbles with (<10%) stones >10 cm
- Substrate Type 3: Sand, gravel and pebbles with (10%-25%) stones >10 cm
- Substrate Type 4: Stones > 10 cm covering >25%

These substrate classes are also used throughout this report and will be referred to as “Sand Dominated” (Substrate type 2), “Mixed” (Substrate Type 3) and “Stone Dominated” (Substrate Type 4). These are also visualized in **Figure 3-2**.

In addition to these substrate classes, Al-Hamdani et al. (2015) identified regions which can be classified as “Stony reefs” (H1170). These reefs are defined based on the definitions of Habitat 1170 under the EU Habitats Directive and meet the following criteria (Al-Hamdani et al., 2015, 2019; Miljø -og Fødevareministeriet, 2021):

- Area > 100 m²
- Areas classified as “Stone dominated” (>25% stones > 10 cm)
- Adjacent areas to “Stone Dominated” areas classified as “Mix Sand-Stone” (10-25% stones > 10 cm)

Additionally, this habitat type is described by the Danish Environmental Protection Agency as hard compact substrates on a firm or soft bottom, which rise from the seabed in deep or shallow water, so that the reef is topographically distinct by separating and rising from the surrounding seabed. The hard substrate of the reef can be either of biological origin - e.g. living or dead mussel shells - or geological origin - e.g. stone, chalk or other hard material (Danish Environmental Protection Agency, 2021).

Stony reefs are visualized by a dashed pattern in **Figure 3-2**.

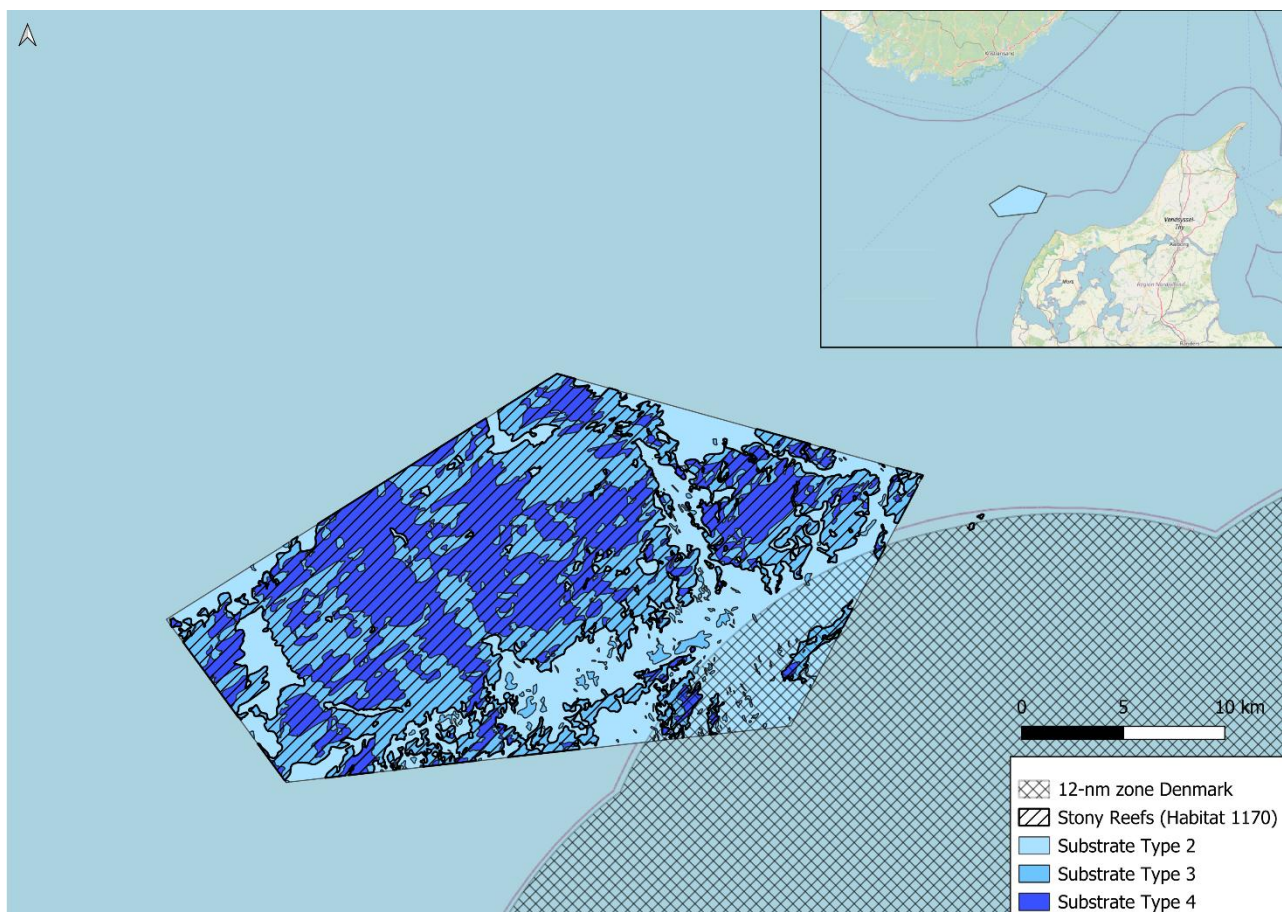


Figure 3-2 Different substrates present in the Gule Rev area. Stone dominated areas (substrate type 4) are indicated in dark blue, mixed areas (substrate type 3) are highlighted in blue and sand dominated (substrate type 2) areas are highlighted in light blue. Rocky reefs (H1170) are indicated with the dashed lines inside Gule Rev. The 12-nautical mile (nm) zone, which is prohibited for Belgian fishers is indicated with the rectangular pattern. Figure based on the results of Al-Hamdani et al. (2015).

3.2.2. Substrate Outside Gule Rev

Since the mapping of Al-Hamdani et al. (2015) is limited to the Gule Rev area, substrate data from EMODnet Map Viewer will be used to identify substrate types in the surrounding area (EMODnet, 2022) (Figure 3-3). According to this dataset, only two types of substrates are present in the vicinity of the study area.

- Sand
- Mixed Sediment

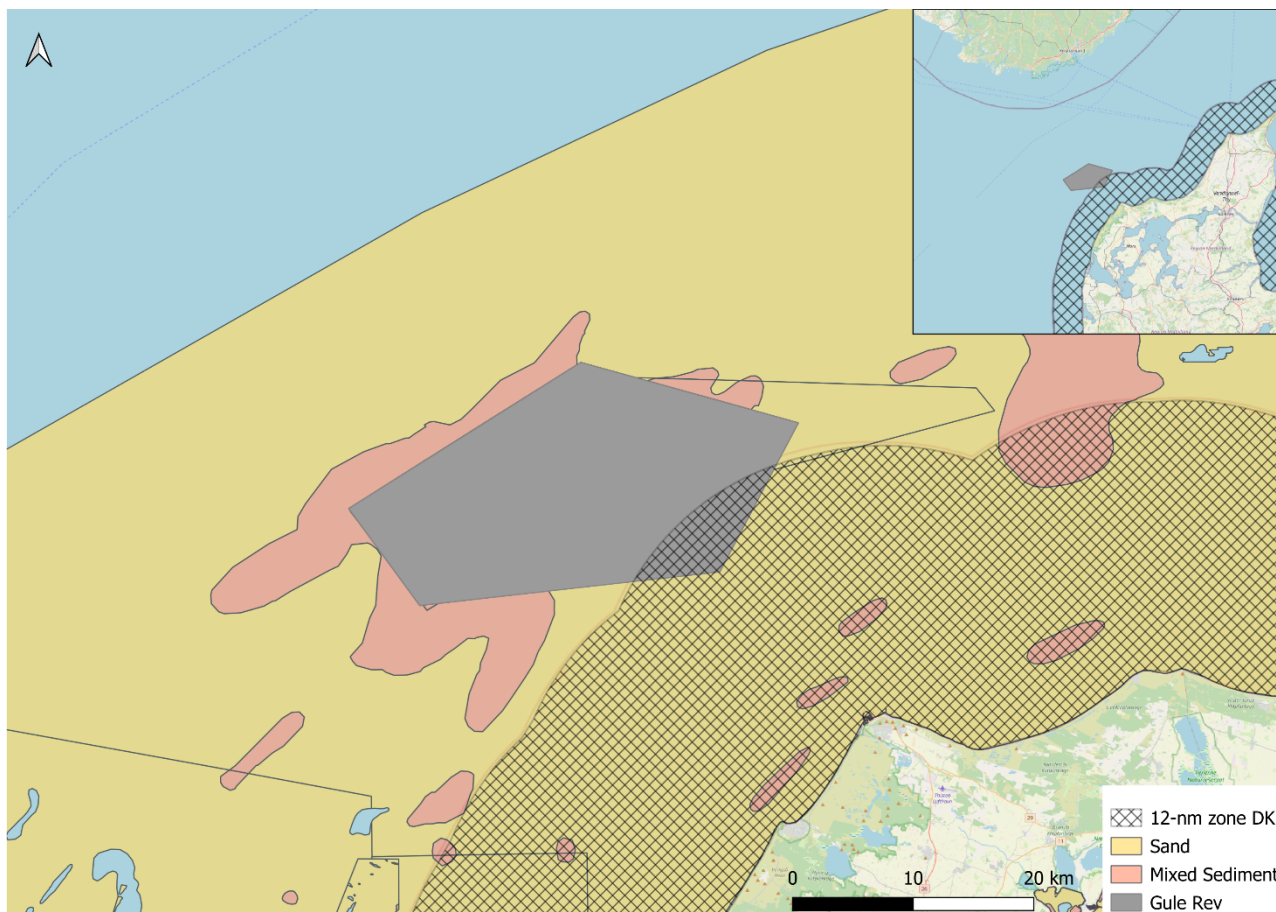


Figure 3-3 Substrates present outside the Gule Rev area, as determined by EMODnet (2022). Sandy areas are indicated in yellow, whereas mixed sediments are highlighted in pink-orange. The 12-nautical mile (nm) zone, which is prohibited for Belgian fishers is indicated with the rectangular pattern.

4. Survey Design

4.1. Survey Area

For the PreciVis project, a designated survey area in the Natura-2000 area Gule Rev was determined by the Danish Environmental Protection Agency. This area is visualized in **Figure 4-1** (red shape), and coordinates of the specific region are listed in the Joint Recommendation, which was added to Annex A: Material & Methods.

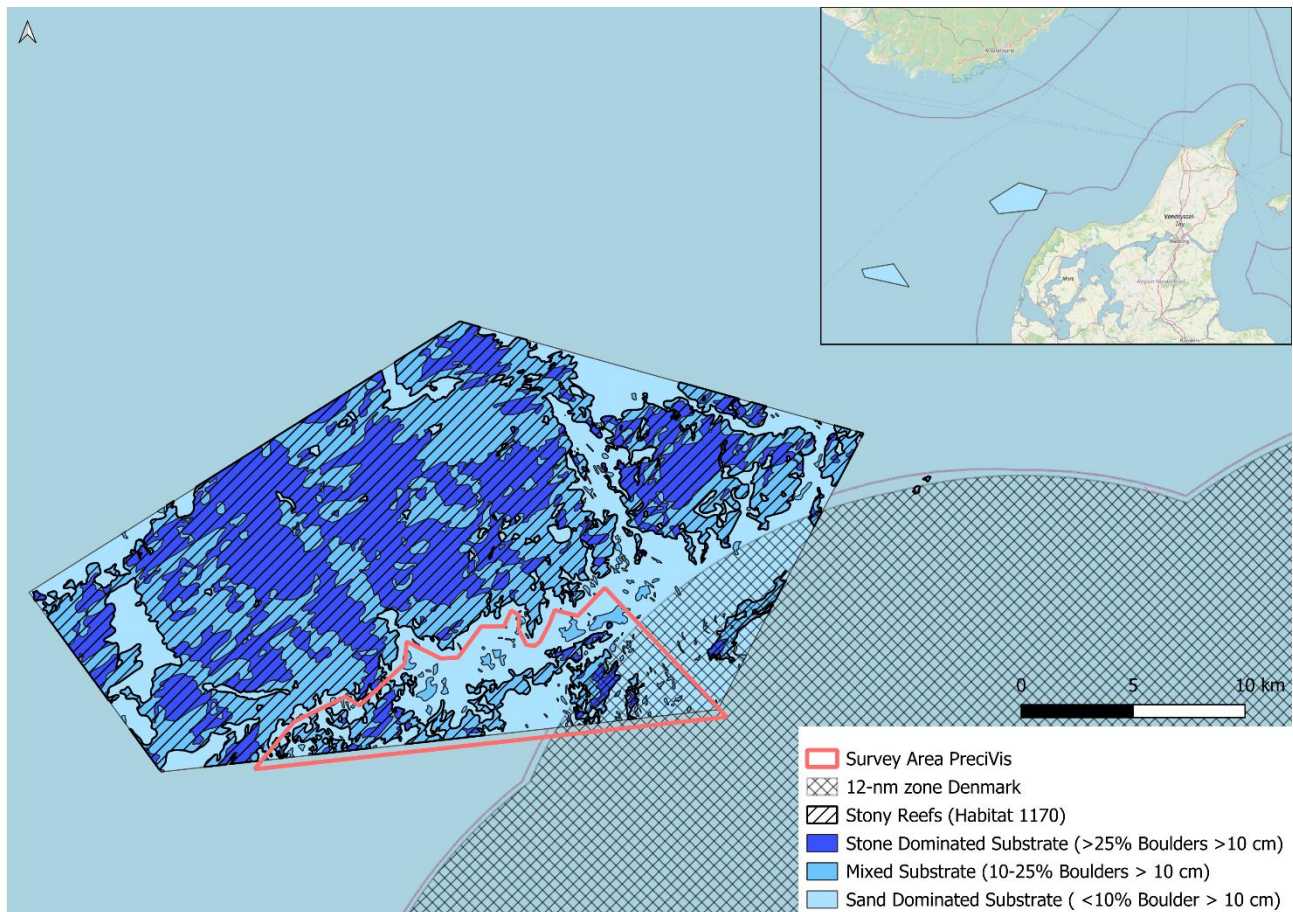


Figure 4-1 Detailed representation of the Natura-2000 area Gule Rev and the predetermined survey area (red) of the PreciVis project. Different substrate types are indicated with different shades of blue. Dark blue = rock dominated (>25% stones >10cm); blue = sand-rock (10-25% stones >10cm); light blue = sand dominated (<10% stones >10 cm). The dashed area represents the Stony Reef habitat (H1170) as identified by The Danish Environmental Protection Agency (Danish Environmental Protection Agency, 2021).

Over the survey period, a total of 54 hauls were conducted over a five-day survey period (16/04/2025-21/04/2025). For almost all of them, WASSP-, VISIM- and VISTools-data was obtained. For 15 of the total hauls fished, supplementary catch composition data of fish (commercial and non-commercial fraction) and benthos was collected. Additionally, 16 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](#)). Finally, underwater footage was collected for four sampled hauls. This diverse working method allows comparison with already existing methods and obligations, albeit in future research.

As the project was limited in time, room aboard the survey vessel and personnel, it was 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.

An overview of available datasets for each conducted haul will be provided in **Table 4-1**

Table 4-1 Summary of the collected data series of the Fully-Sampled Scientific Hauls (DK_S_) and Partially-Sampled Scientific Hauls (DK_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), VISIM data (VISIM) and underwater footage (UWF). 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)	Shoot time (UTC+2)	Haul time (UTC+2)	Haul ID	Data Type					
					WASSP	Catch	VISTools	VISIM	NDGP	UWF
1	15/04/2025	23h10	01h40	DK_C_1	X		X	X	X	
2	16/04/2025	01h55	4h20	DK_C_2	X		X	X		
3	16/04/2025	04h30	7h20	DK_C_3	X		X	X	X	
4	16/04/2025	08h10	08h45	DK_S_1	X	X	X	X		
5	16/04/2025	09h00	09h50	DK_S_2	X	X	X	X		
6	16/04/2025	10h00	10h40	DK_S_3	X	X	X	X		X
7	16/04/2025	10h40	11h15	DK_S_4	X	X	X	X		
8	16/04/2025	11h20	12h10	DK_S_5	X	X	X	X		
9	16/04/2025	12h15	13h00	DK_S_6	X*	X*	X	X		
10	16/04/2025	13h05	14h00	DK_S_7	X	X	X	X		
11	16/04/2025	14h10	14h40	DK_S_8	X	X	X	X		X
12	16/04/2025	14h50	15h50	DK_S_9	X	X	X	X		
13	16/04/2025	16h00	16h40	DK_S_10	X	X	X	X		
14	16/04/2025	16h50	17h20	DK_S_11	X	X	X	X		
15	16/04/2025	17h30	18h10	DK_S_12	X	X	X	X		
16	16/04/2025	19h25	21h55	DK_C_4	X		X	X		
17	16/04/2025	22h10	00h35	DK_C_5	X		X	X		
18	17/04/2025	00h50	03h20	DK_C_6	X*		X	X		
19	17/04/2025	03h30	06h00	DK_C_7			X	X	X	
20	17/04/2025	06h10	08h40	DK_C_8	X*		X	X		
21	17/04/2025	08h50	11h20	DK_C_9	X		X	X	X	
22	17/04/2025	11h30	14h00	DK_C_10	X		X	X		

23	17/04/2025	14h15	15h30	DK_S_13	X	X	X	X	X
24	17/04/2025	15h45	18h15	DK_C_11	X		X	X	X
25	17/04/2025	18h30	21h00	DK_C_12	X		X	X	
26	17/04/2025	21h10	23h45	DK_C_13	X*		X	X	X
27	17/04/2025	23h55	02h30	DK_C_14	X*		X	X	
28	18/04/2025	02h45	05h15	DK_C_15	X		X	X	X
29	18/04/2025	05h30	08h00	DK_C_16	X		X	X	
30	18/04/2025	08h25	10h50	DK_S_14	X	X	X	X	X
31	18/04/2025	11h50	12h40	DK_S_15	X	X	X	X	X
32	18/04/2025	13h20	16h00	DK_C_17	X		X	X	
33	18/04/2025	16h15	18h40	DK_C_18	X		X	X	
34	18/04/2025	18h50	19h10	DK_C_19	X		X	X	X
35	18/04/2025	20h50	23h20	DK_C_20	X		X	X	
36	18/04/2025	23h30	02h00	DK_C_21	X		X	X	
37	19/04/2025	02h10	04h10	DK_C_22	X		X	X	X
38	19/04/2025	4h50	7h20	DK_C_23	X		X	X	
39	19/04/2025	07h40	10h10	DK_C_24	X		X	X	X
40	19/04/2025	10h20	12h50	DK_C_25	X		X	X	
41	19/04/2025	13h20	15h50	DK_C_26	X		X	X	X
42	19/04/2025	16h20	17h00	DK_C_27	X		X	X	
43	20/04/2025	02h00	04h20	DK_C_28			X	X	
44	20/04/2025	04h30	07h00	DK_C_29			X	X	X
45	20/04/2025	07h10	09h40	DK_C_30			X	X	
46	20/04/2025	10h20	12h50	DK_C_31			X	X	X

47	20/04/2025	13h00	15h30	DK_C_32	X	X	
48	20/04/2025	16h00	18h30	DK_C_33	X	X	X
49	20/04/2025	18h40	21h10	DK_C_34	X	X	
50	20/04/2025	21h30	00h10	DK_C_35	X	X	X
51	21/04/2025	00h20	02h50	DK_C_36	X	X	
52	21/04/2025	03h00	03h30	DK_C_37	X	X	X
53	21/04/2025	05h50	08h20	DK_C_38	X	X	
54	21/04/2025	08h30	11h10	DK_C_39	X	X	

4.1.1. Fully-Sampled Scientific Hauls

The “Fully-Sampled Scientific hauls” (FSSHs) were labeled as “DK_S_number”, highlighted in green in **Table 4-1** and visualized by **Figure 4-2**. Exact coordinates of begin (shoot) and end (haul) points of each haul are summarized in **Table A- 1**. Corresponding stations are summarized in **Table 4-2**.

Inside the predetermined survey area, 12 samples were taken. These hauls did not occur on reef- or stone dominated areas to preserve the local ecosystem. Additionally, no hauls were carried out inside the 12 nautical mile zone of Denmark or the Skagerrak area. Hauls conducted in mixed region did not last more than 30 minutes. Three FSSHs -DK_S_13, DK_S_14 and DK_S_15- were conducted outside of Gule Rev. Important to note is that hauls located near the border of the Gule Rev area were assigned the same substrate and habitat labels as if they were inside the mapped zone. This assumption was necessary due to data limitations, but it may have introduced classification errors where substrate conditions differed across boundaries.

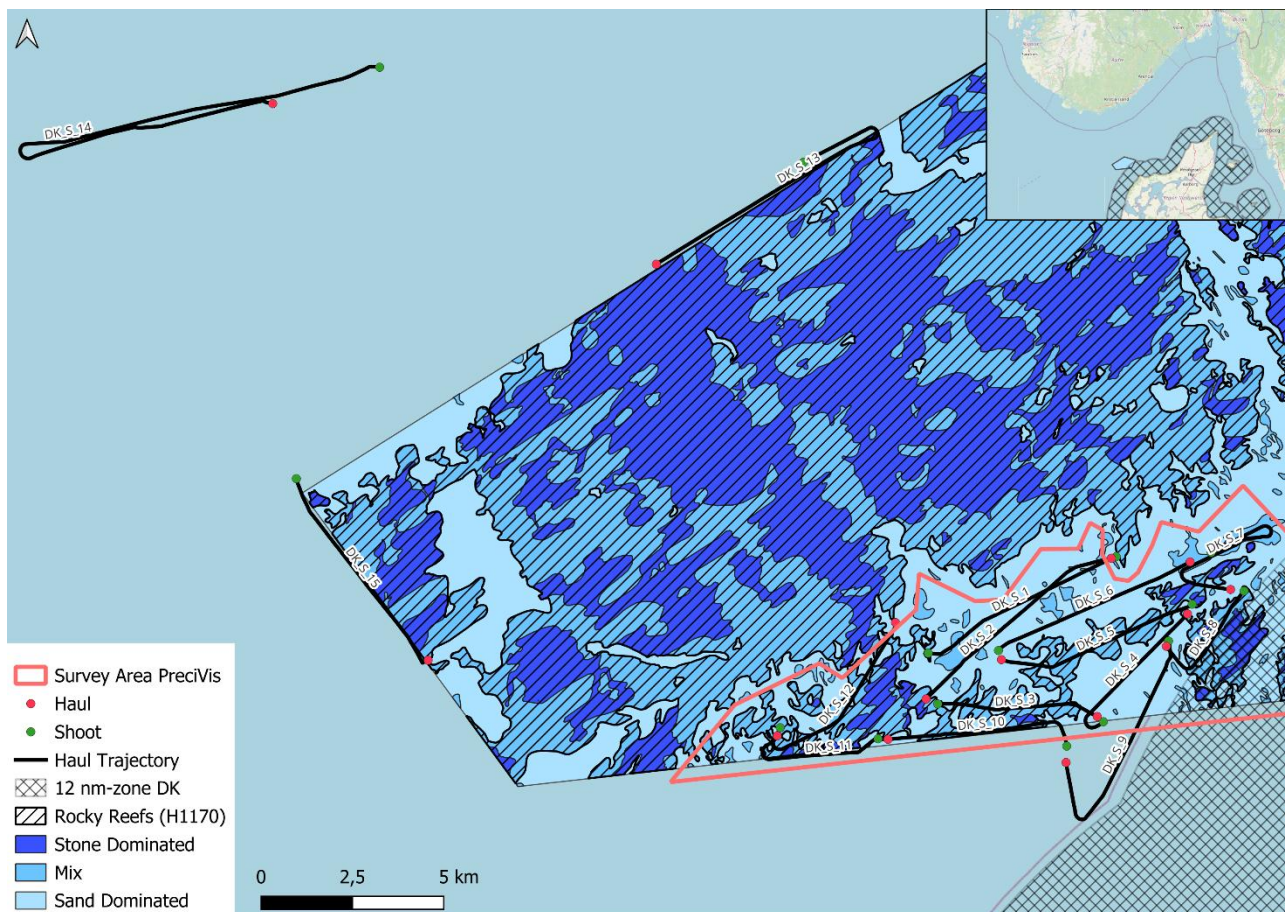


Figure 4-2 All Fully-Sampled Scientific hauls (FSSHs) which were conducted during the PreciVis survey. The allocated survey area inside the Gule Rev area is highlighted in red. Shoot and haul locations are indicated by red and green dots, respectively, haul trajectories are illustrated in black. The Danish 12-nm zone is highlighted by the black lattice pattern; the rocky reef habitat is highlighted by a dashed pattern. Different substrate types, as described in §3.2.1, are also visualized in the figure.

Table 4-2 Conducted hauls and corresponding stations.

Haul Sampled	Corresponding Station
DK_S_1	6
DK_S_2	25
DK_S_3	5.4
DK_S_4	27
DK_S_5	5.3
DK_S_6	7
DK_S_7	7.2
DK_S_8	28
DK_S_9	23
DK_S_10	24.2

DK_S_11	24.3
DK_S_12	22.3
DK_S_13	20
DK_S_14	13
DK_S_15	19.1

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.

4.2. Survey vessel

All hauls were conducted with the Belgian beam trawler “Z.510-Dennis” (38m x 9m) (**Figure 4-3**). The equipment consisted of a 11-meter beam equipped with side wheels, chain mats (**Figure 4-4**) and a modified net consistent with Flemish and international regulations, as listed by the European Parliament & Council (2019) (e.g. 120 mm mesh size). Technical specifications of the net used during the project are listed in

Table 4-3.



Figure 4-3 The Belgian beam trawler Z.510-Dennis. Picture taken from Marine Traffic & De Corte (2024).



Figure 4-4 Beam and chain mat used during the PreciVis survey. Picture taken during the survey (16/04/2025).

Table 4-3 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. Data Collection

During the PreciVis project, different data series were collected and analyzed. This section provides an overview of the different data series and how they were collected.

5.1. 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 all 15 FFSHs (see § 4.1.1), but during haul DK_S_6, a system crash occurred which prohibited data recording (**Figure 5-1**). Despite contacting several companies, no clear cause of these crashes was identified.

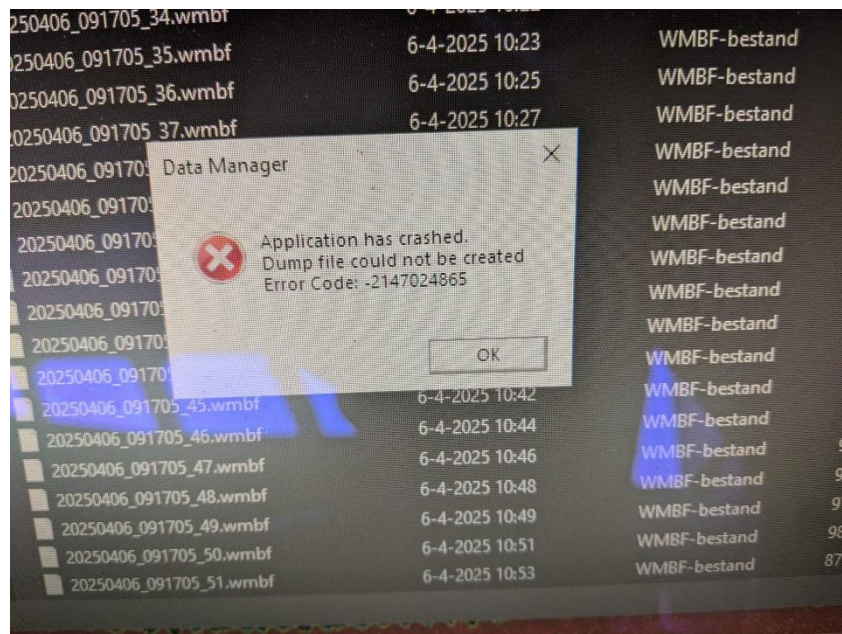


Figure 5-1 Screenshot of the WASSP CDX just after a crash occurred.

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.

5.2. 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 5-2). 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 PreciVis survey, VISTools (VT) data was automatically collected. Especially parameters regarding GPS-location and fuel consumption are analyzed within this report.

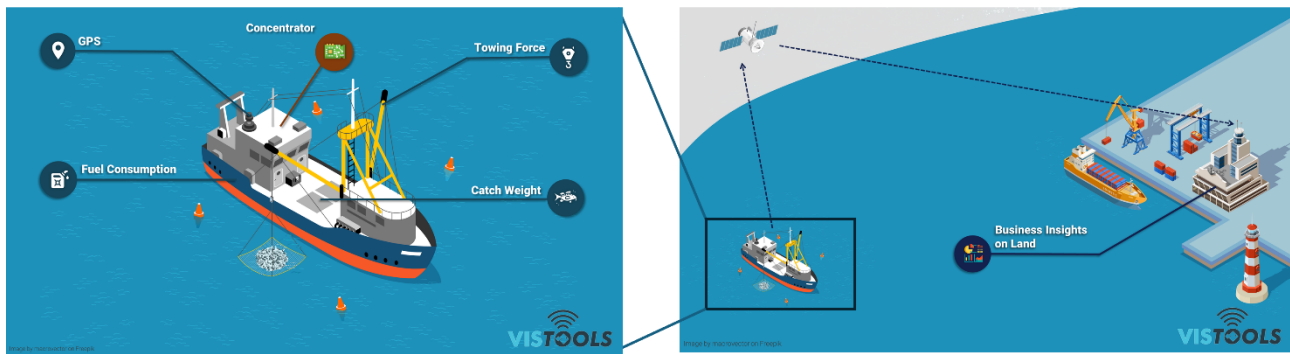


Figure 5-2 Functioning of VISTools. Left: Types of data collected by the VISTools concentrator. These include catch weight, fuel consumption, GPS and Towing force. Right: General data flow of the collected data. Data is centralized in the onboard concentrator, after which it is sent through satellite connection to the ILVO database where it is processed and analyzed. Figures taken from Iliad (2025).

5.3. Catch data

Additional catch data was collected for all hauls, with an exception for DK_S_7. For this haul, no benthos data was collected. 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 minimum sizes, depend on the region and fished species. Since collected fish was landed in Thyborøn, Denmark, European sizes were used to make a distinction between discards and landings in this report. The used minimum sizes are listed in Table 6-1). Consequently, undersized fish and non-commercial species are allocated to the category “discards”.

Table 5-1 Landing sizes defined by the European legislations .

Fish species	Landing size EU (cm)
COD	35
HAD	30
PLE	27
POK	30
WHG	27
BLL	30
DAB	23
LEM	25
TUR	30
HAL	-
WIT	28

5.4. NDGP data

In addition to the sampled hauls for the PreciVis project, 16 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 Laura Lemey (). Analyzing this type of data falls out of the scope of this project and will therefore not be included in this report.

5.5. VISIM-Camera

During the PreciVis survey, a VISIM camera was installed on the survey vessel (**Figure 5-3**). 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 PreciVis 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 5-3 VISIM camera installed on the survey vessel (Z.510-Dennis) during the PreciVis survey (red).

5.6. Underwater footage

During FSSHs DK_S_3, DK_S_8, DK_S_13, DK_S_15, a GoPro-camera (**Figure 5-4-B**) was attached to the headline of the net of the beam trawler (**Figure 5-4-A**) to collect under water footage (e.g. **Figure 5-5**). More information on the used setup could be obtained by contacting Jasper Van Vlasselaer (jasper.vanvlasselaer@ilvo.vlaanderen.be) or Mattias Van Opstal (mattias.vanopstal@ilvo.vlaanderen.be).

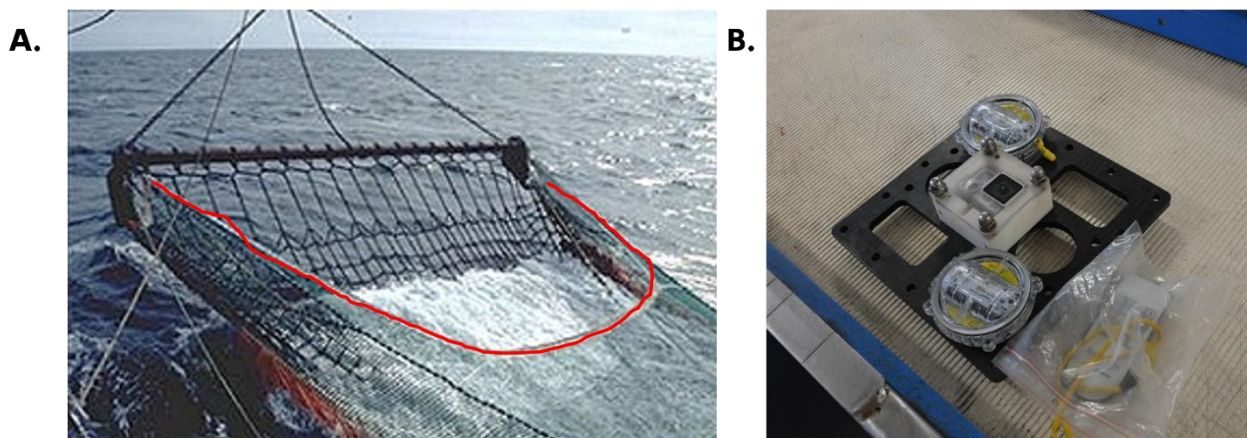


Figure 5-4 [A] Picture of a beam trawler net equipped with chain mat, the headline of the net is indicated in red. Picture taken from VLIZ(n.d.) [B] Setup which was used during the PreciVis-survey to collect underwater footage. A GoPro-camera is installed in a protective case in the middle of the frame, with two supporting lights attached to the side.

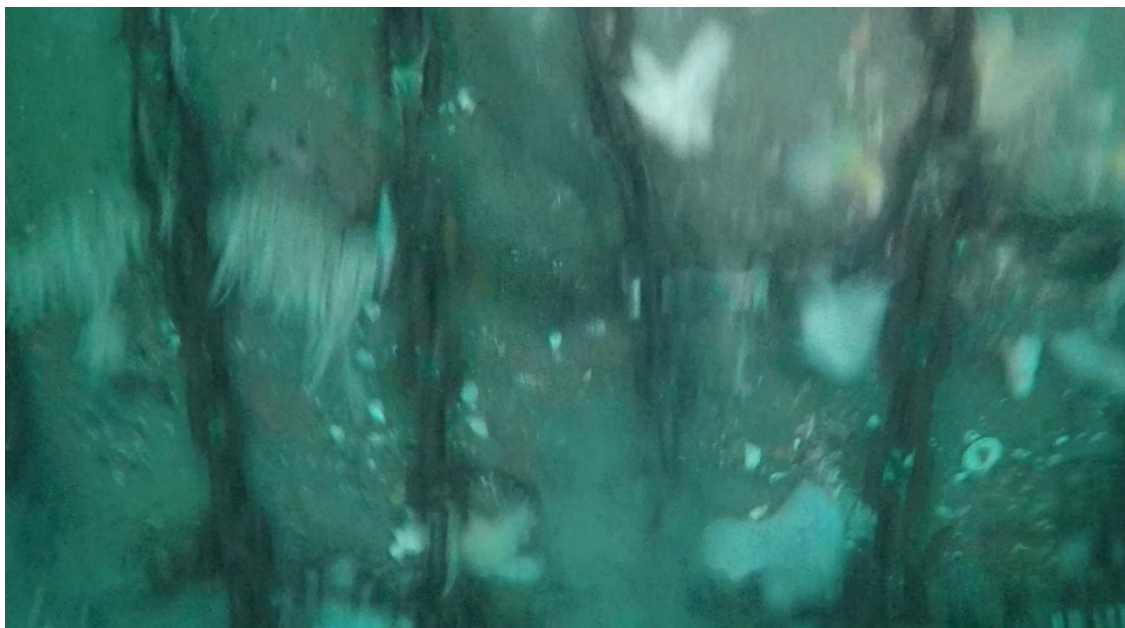


Figure 5-5 Example of underwater footage shot during the PreciVis survey.

6. Data processing

6.1. WASSP Multibeam Echosounder

WASSP data conversion and analysis was conducted in cooperation with the Dutch company OceanBox B.V., with Mark Ybema (m.s.ybema@oceanbox.eu) as lead consultant and Roland Proud (roland.proud@cuparanalytics.com) as data analyst. A summary of the workflow is provided in this section and is based on the OceanBox report (OceanBox B.V., 2025).

6.1.1. Data conversion + transfer

WASSP-recordings were extracted as .wbmf files from the survey vessel. These files were then converted to .gsf files with the AutoClean application of Beamworx (v.2025_1_1_2). After conversion, converted .gsf-files were transferred to OceanBox B.V.

6.1.2. Analysis process

6.1.2.1. Data preparation

After the data transfer, .gsf files were processed into standardized 10x10 meter grid cells. Detailed information that describes the seafloor characteristics, such as roughness or hardness, were also extracted from these raw data files.

6.1.2.2. Model development

After preparing the data, an AI-model (XGBoost) was created and trained to recognize patterns in acoustic data that correspond to different seafloor substrate types. Training data was provided by Al-Hamdani et al. (2015), identifying three types of substrates (see also §3.2.1):

- Sand (<10% stones > 10 cm)
- Mix sand-stone (10%-25% stones > 10 cm)
- Stone (>25% stones > 10 cm)

The model was trained to classify each grid cell as a “sand”, “mix” or “stone” based on the provided acoustic signals from the .wbmf files.

After this classification, an additional spatial post-processing system was developed to provide a more ecological meaningful categorization. This translates the model predictions into predefined marine habitat designations. In total, three habitat categories were constructed:

- Reefs: areas with high stone coverage, representing sensitive habitats that should be avoided. Characteristics of this habitat type are provided in §3.2.1.
- Reef candidates: areas with reef characteristics but too little data available to make a clear distinguishment. Caution is needed when fishing in these areas.
- Non-reef: areas with no reef characteristics

6.1.2.3. Model selection

To ensure reliability, 216 different model configurations were tested with varying sensitivity levels. Finally, the so-called “low-error” model was selected as best performing model. This model struck an optimal balance between being too cautious (which would unnecessarily restrict fishing areas) and too permissive (which might fail to protect sensitive habitats).

6.2. VISTools Data

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)

7. 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

8. Backscatter analysis

In this project, recorded WASSP data was analyzed by OceanBox B.V. This section provides a summary of their results, a more detailed report is provided by OceanBox B.V. (2025).

8.1. Substrate Classification

8.1.1. General results

Overall, the produced model reached an accuracy level of 64% for the validation dataset and 74% of the testing dataset (**Table 8-1**). Within the validation dataset, the model reached highest accuracy levels for the sand substrate type (72%), but struggled to detect the mixed category, with only an accuracy level of 57%. Similar trends could be observed in the testing dataset. The sand category was detected with an accuracy of 81%, whilst the mixed substrate reached only 62% (**Table 8-1**).

Table 8-1 Accuracy levels of the constructed model on detecting the different substrate types present within Gule Rev.

Datatype	Substrate	Accuracy level
Validation (training)	Overall	0.64
Validation (training)	Sand	0.72
Validation (training)	Stone	0.64
Validation (training)	Mix	0.57
Test	Overall	0.74
Test	Sand	0.81
Test	Stone	0.76
Test	Mix	0.62

To allocate a certain substrate type to each conducted haul, 10x10m cells were created. For each of these cells, a “substrate probability” was assigned, indicating how likely a certain substrate is present in this cell. For example, cell x could have a 0.5 probability for *Stone*, 0.3 for *Mix* and 0.2 for *Sand*. The highest probability of these will eventually be allocated to the cell itself. Cell x would thus be classified as *Stone* with a probability of 0.5. Prediction confidence of the maximum substrate probability by the model is illustrated by **Figure 8-1**. Higher values, and thus brighter colors, indicate a higher confidence of the defined probabilities. Lower values and darker colors correspond to a lower confidence, possibly caused by e.g. mixed acoustic signals or overlapping substrate types. Generally, prediction confidence ranges from 0.35 to 0.6, with highest values for areas classified as either clear *Sand* or *Stone*, as earlier demonstrated by **Table 8-1**. Lower prediction confidence values occur in the transition zone of two substrate and areas which are classified as *Mixed*.

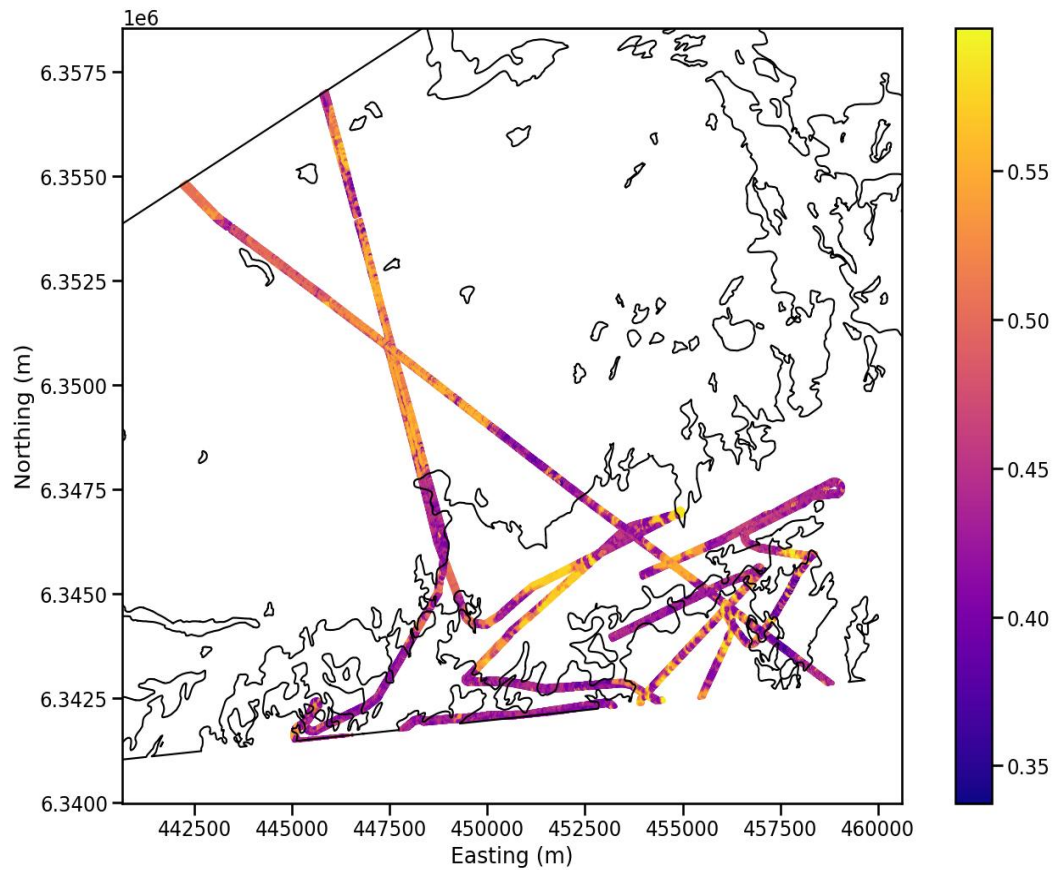


Figure 8-1 Prediction confidence of the habitat classification of the model used. Prediction confidence is based on the maximum predicted habitat category. Brighter colors indicate a higher confidence level; darker colors indicate lower confidence levels. Figure taken from OceanBox B.V. (2025).

Figure 8-2 exhibits the predicted probability of the substrate class *Stone*, which is used to define reef structures. Just like in **Figure 8-1**, some clear spatial patterns can be noticed. Areas in the north of Gule Rev tend to have higher values, while areas in the south, which are labeled in literature as *Mixed* or *Sand*, exhibit a lower *Stone* probability.

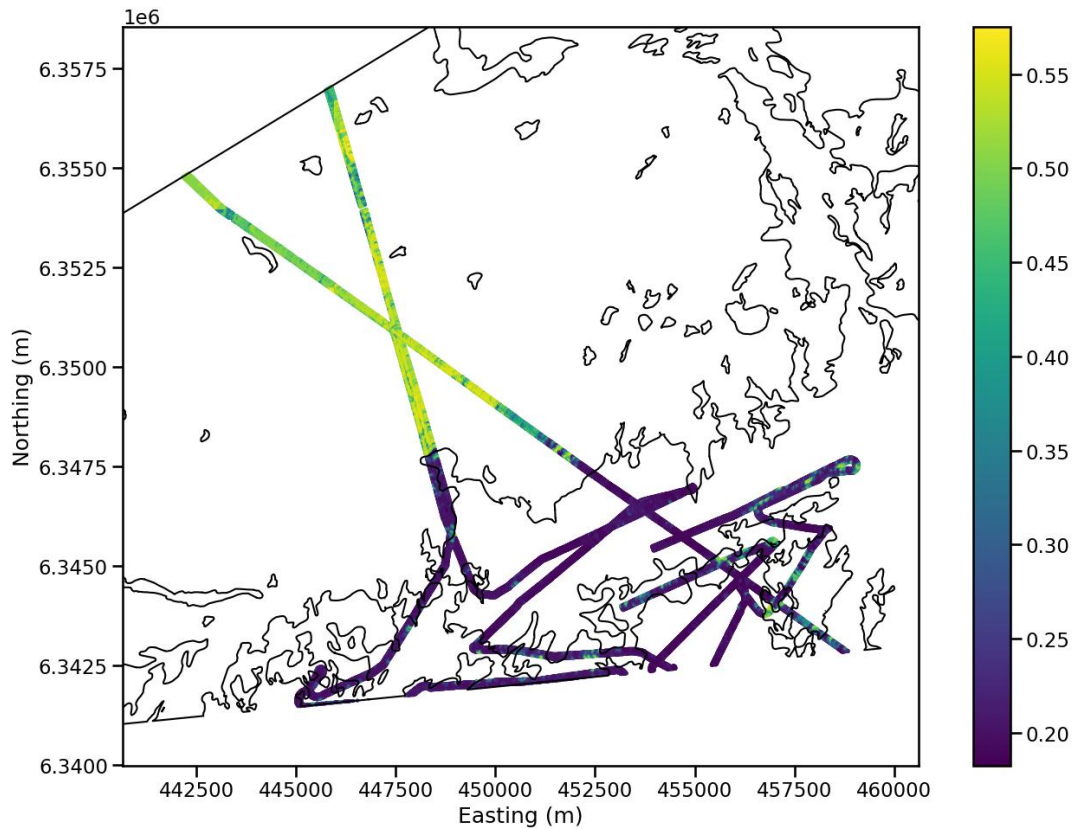


Figure 8-2 Predicted probability of the “Stone” category across the different FSSHs. Brighter areas indicate areas classified with a higher “Stone” probability, while darker areas illustrate a lower Stone probability. Figure taken from OceanBox B.V. (2025).

8.1.2. Haul labelling

The relative fraction of each substrate type was calculated for each sampled haul and visualized in **Figure 8-3**. **Figure 8-3-A** illustrates the substrate classification based on the existing substrate maps of Al-Hamdani et al. (2015). This figure uses the “sampled station” on the x-axis instead of the haul ID’s. Sampled stations and corresponding haul ID’s can be found in **Table 4-2** (§4.1.1)

Some of the hauls are classified as “unlabeled” because they were located outside the Gule Rev area, and hence, no existing data was available for these hauls. Further in this report, these missing classifications are supplemented with data extracted from EMODnet (2022), as presented in §3.2.2. The classification based on the sampled WASSP data is provided in **Figure 8-3-B**, which exhibits the substrate classification for each scientific haul (n = 15), except for haul DK_S_14. For the latter, no substrate and habitat proportions are available due to an unexpected issue. Therefore, haul DK_S_14 was manually categorized -based on backscatter results- and labeled as “Sand”. Other hauls classified by the model as *Sand* dominated are DK_S_1 (ID = 6.0), DK_S_2 (ID = 25.0), DK_S_4 (ID = 27.0), DK_S_6 (ID = 7.0), DK_S_8 (ID = 28.0), DK_S_9 (ID = 23.0) and DK_S_12 (ID = 22.3). Hauls classified as *Mixed* are DK_S_3 (ID = 5.4), DK_S_5 (ID = 5.3), DK_S_7 (ID = 7.2), DK_S_10 (ID = 24.2), DK_S_11 (ID = 24.3) and DK_S_15 (ID = 19.1). DK_S_13 (ID = 20.0) and DK_S_15 (ID = 19.1) are classified as *Stone* dominated.

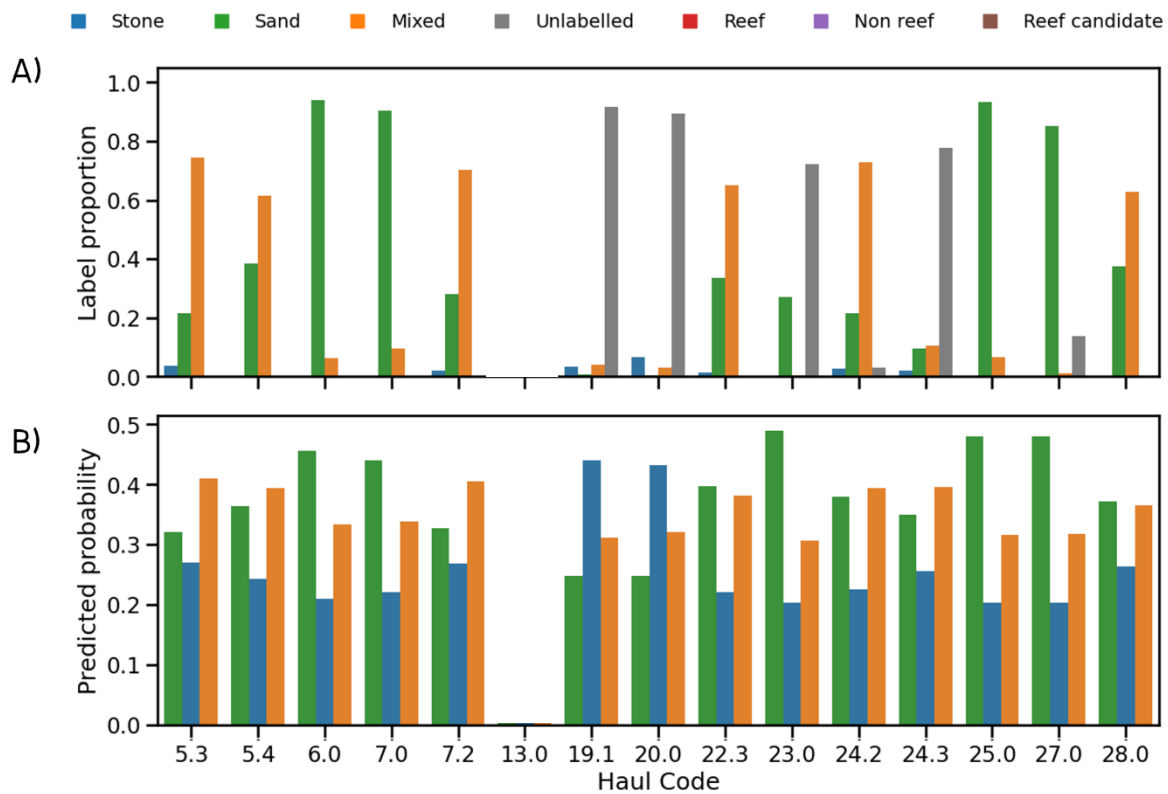


Figure 8-3 Substrate classification of the different scientific hauls. [A] Classification based on Al-Hamdani et al. (2015). Unlabeled hauls are located outside the Gule Rev area and thus have no classification. [B] Classification made on WASSP data. Figure taken from OceanBox B.V. (2025).

8.2. Reef Classification

8.2.1. Spatial mapping

In addition to the substrate detection, a spatial post-processing tool was developed that uses the output for the latter to make an estimation of the present habitat type, and more specifically, the presence of sensitive reef structures. Based on the presented reef definition in §3.2.1, three categories are defined: *Reef*, *Non-Reef* and *Reef Candidate*. The reef candidate category includes areas which show some indications of potential reef presence, but insufficient data is available to confirm reef presence.

Overall, an 80% accuracy level was reached when applying the tool to the validation dataset, and 70% when it was applied to the test data. Results are visualized in **Figure 8-4**. The upper panel (A) demonstrates the reef distribution according to Al-Hamdani et al. (2015), while the lower panel (B) presents the habitat predictions generated by the constructed model. On **Figure 8-4-B**, areas located inside the black boxes are considered as testing data, areas outside belong to the training dataset.

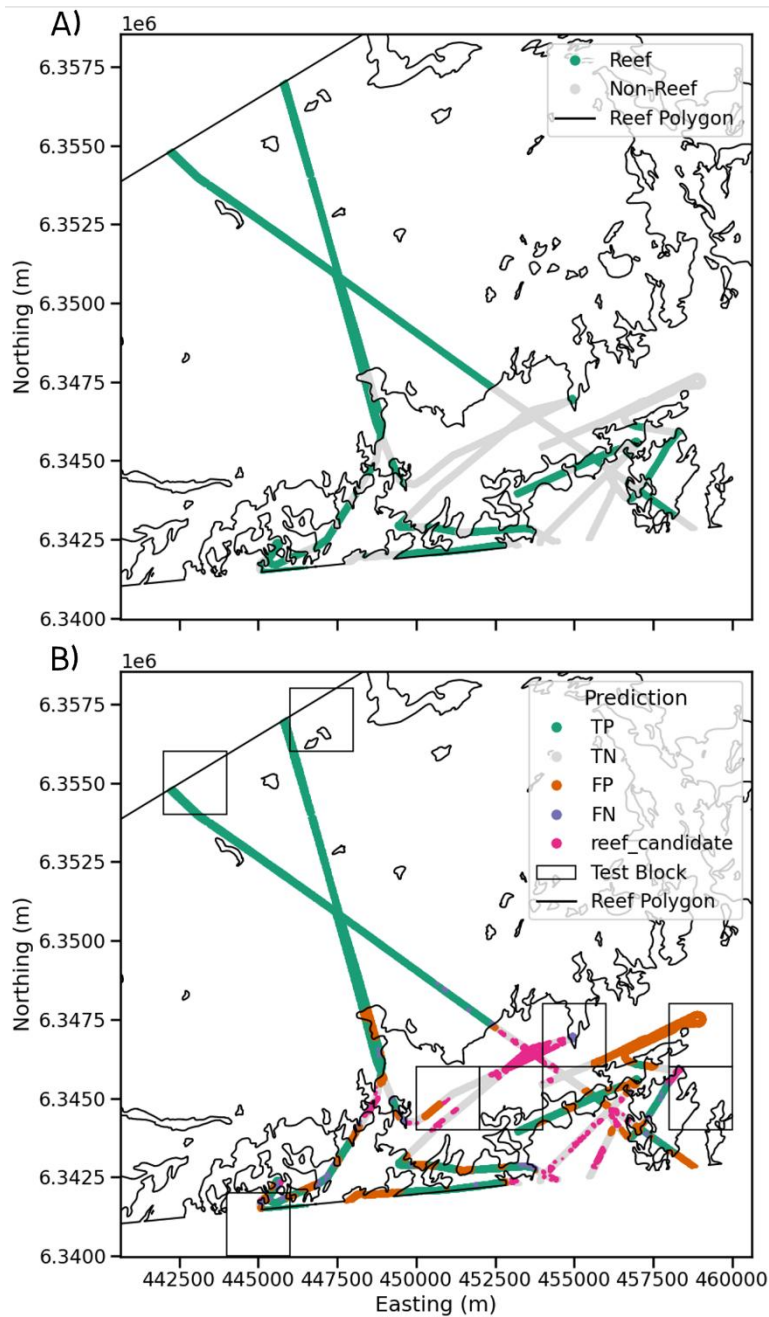


Figure 8-4 Comparison between [A] the reef presence described by Al-Hamdani et al. (2015) and [B] reef presence predicted by the model used by OceanBox B.V. (2025). True positives are highlighted in green, true negatives in grey, false positives in orange and false negatives in purple. Reef candidates are indicated with pink. The black shape file indicates the areas where reefs are present according to Al-Hamdani et al. (2015). Figures taken from OceanBox B.V. (2025).

To test the model's performance outside the study area, it was applied to a novel region beyond the Gule Rev region. Results are being displayed in **Figure 8-5**. The same habitat categories as earlier also apply to this figure, although there is an important remark to make. Since the model was constructed solely with data originating from inside Gule Rev, predictions may include extrapolations which go beyond conditions observed during training. This results in relatively high model uncertainty, making the results less reliable. This will be further elaborated in the discussion section (§13.1).

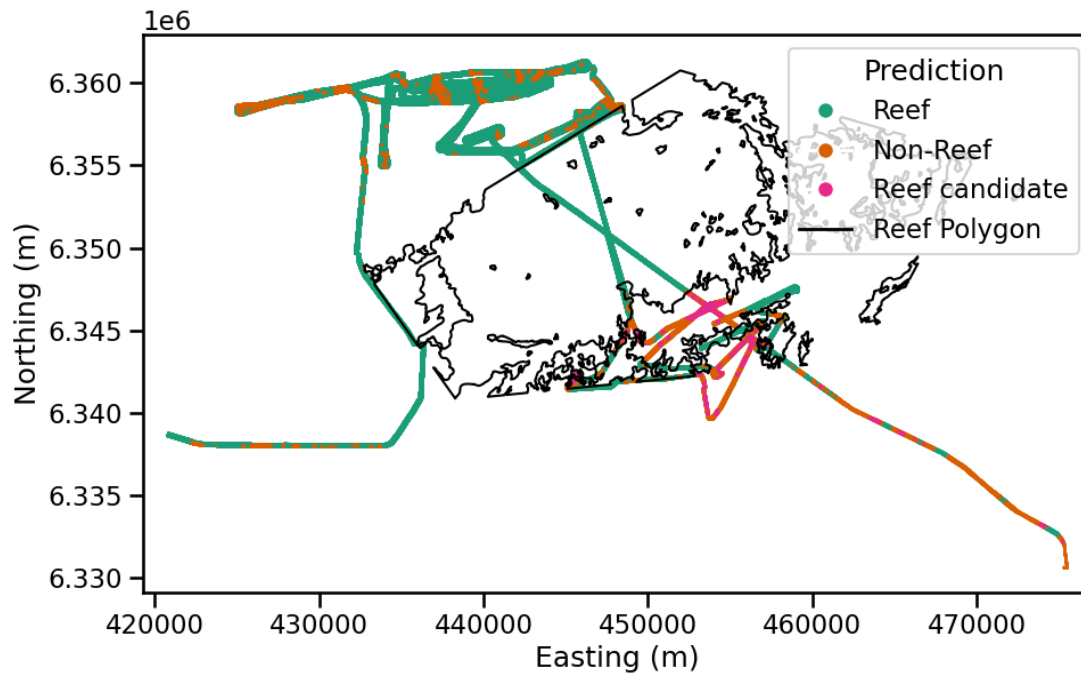


Figure 8-5 Predicted habitat classification of all scientific hauls. The black polygon indicates the presence of known reef locations based on Al-Hamdani et al. (2015).

8.2.2. Haul Labelling

Just as in §8.1.2, reef probabilities are determined for each individual haul, except haul DK_S_14 (**Figure 8-6**). Since no substrate proportions are available for this haul, no post processing analysis could be carried out, and therefore no habitat characterization could be conducted. This haul was therefore manually (i.e. length-based) classified as non-reef dominant. **Figure 8-6** also uses the “sampled station” on the x-axis instead of the haul ID’s. Sampled stations and corresponding haul ID’s can be found in **Table 4-2** (§4.1.1)

Hauls where reef classification is dominant are DK_S_3 (ID = 5.4), DK_S_5 (ID = 5.3), DK_S_7 (ID = 7.2), DK_S_10 (ID = 24.2), DK_S_11 (ID = 24.3), DK_S_12 (ID = 22.3), DK_S_13 (ID = 20.0) and DK_S_15 (ID = 19.1). Hauls classified as *Non-Reef* are DK_S_1 (ID = 6.0), DK_S_2 (ID = 25.0), DK_S_4 (ID = 27.0), DK_S_6 (ID = 7.0), DK_S_9 (ID = 23.0). No hauls classify as *Reef Candidate*.

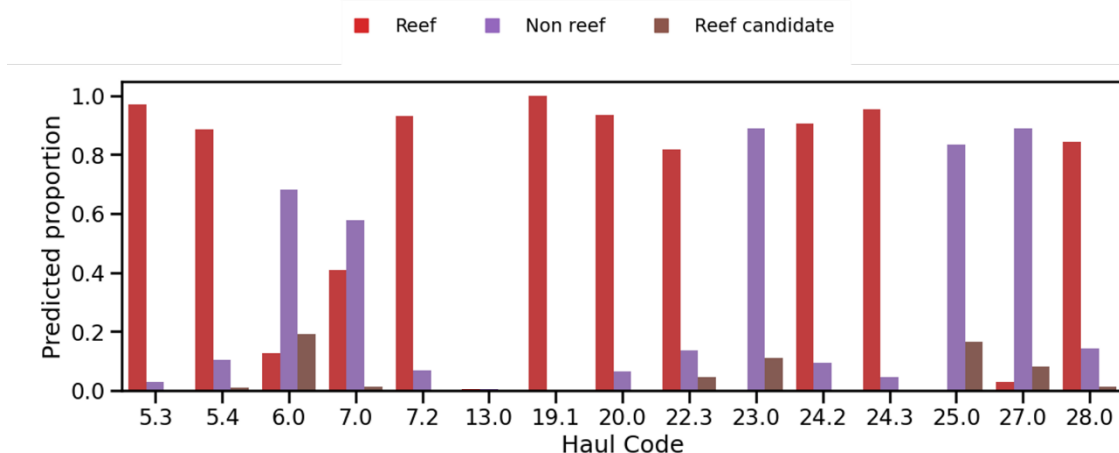


Figure 8-6 Habitat classification after spatial post-processing. The three categories are Reef (red), Non-Reef (purple) and Reef Candidate (brown).

9. VISTools

As discussed in §6.2, the VISTools digital twin collects a broad range of parameters during fishing activities. However, this report will solely focus on the abiotic parameters, such as fuel consumption or traction. General results are provided in §9.1, while a focus on the “traction” parameter is provided in §9.2. Substrate classification in this section is based on Al-Hamdani et al. (2015).

9.1. General results

All four studied parameters exhibit a similar trend: highest values were obtained for the “Sand” substrate type, whilst the “Mixed” substrate recorded lowest values across all parameters. Only one haul classifies as “Stone” dominated, and associated parameters are located in between highest and lowest values.

For Mean Fuel Consumption, Traction Left and Right, significant differences ($p < 0.05$) were found between the different substrate classes. For Mean Speed, no significant difference was found between substrate classes “mix” and “stone” ($p > 0.05$).

A summary of mean and median values of each parameter per substrate sample is provided in Table 9-1.

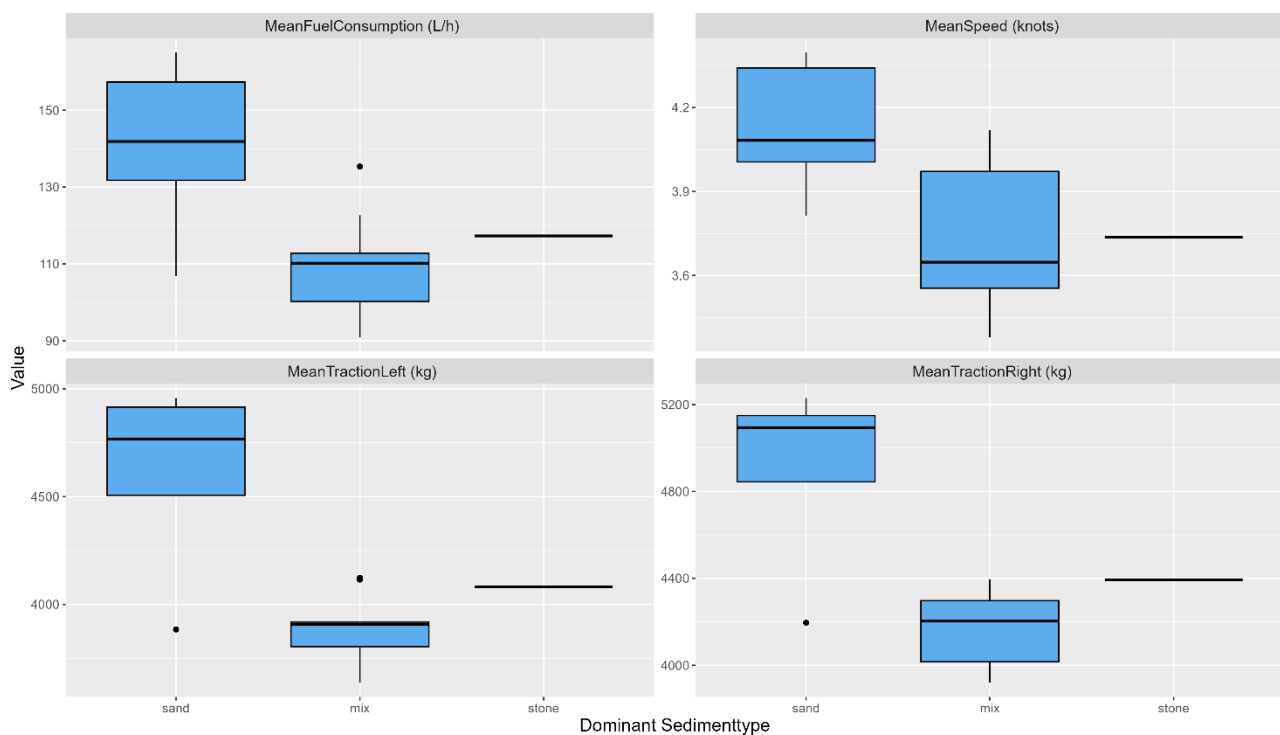


Figure 9-1 Boxplots representing the mean fuel consumption (L/h, top left), mean speed (knots, top right), mean traction on the left side of the vessel (kg, bottom left) and mean traction of the right side of the vessel (kg, bottom right) categorized per dominant substrate (x-axis). Different stations are sand ($n = 6$); mix ($n = 8$) and stone ($n = 1$).

Table 9-1 Mean and median values of the parameters fuel consumption ($L\ h^{-1}$), speed (knots) and traction left (kg) and right (kg) associated with the sampled substrate.

	Fuel consumption ($L\ h^{-1}$)		Speed (knots)		Traction Left (kg)		Traction Right (kg)	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Sand	142.5	141.844	4.099	4.082	4686.203	4767.509	4989.971	5093.750
Mix	108.07	110.196	3.731	3.647	38833.633	3908.019	4176.383	4203.302
Stone	117.228	117.228	3.737	3.737	4082.099	4082.099	4393.416	4393.416

9.2. Traction

This section pays special attention to the parameter “Traction”. The figures below represent the traction values measured on each side of the vessel at 10-second intervals. Mean traction values associated with each substrate type, as presented in **Table 9-1**, are also plotted in green (sand dominated), orange (mixed) and red (stone dominated). For each substrate type, most distinct traction plots are provided, remaining traction plots are added to the annex (Annex B: Results)

9.2.1. Sand Dominated

In this section, traction plots of “Sand-dominated” hauls DK_S_2 (**Figure 9-2**) and DK_S_6 (**Figure 9-3**) are plotted. Traction values of both hauls are mostly centered around the mean traction value associated with sand.

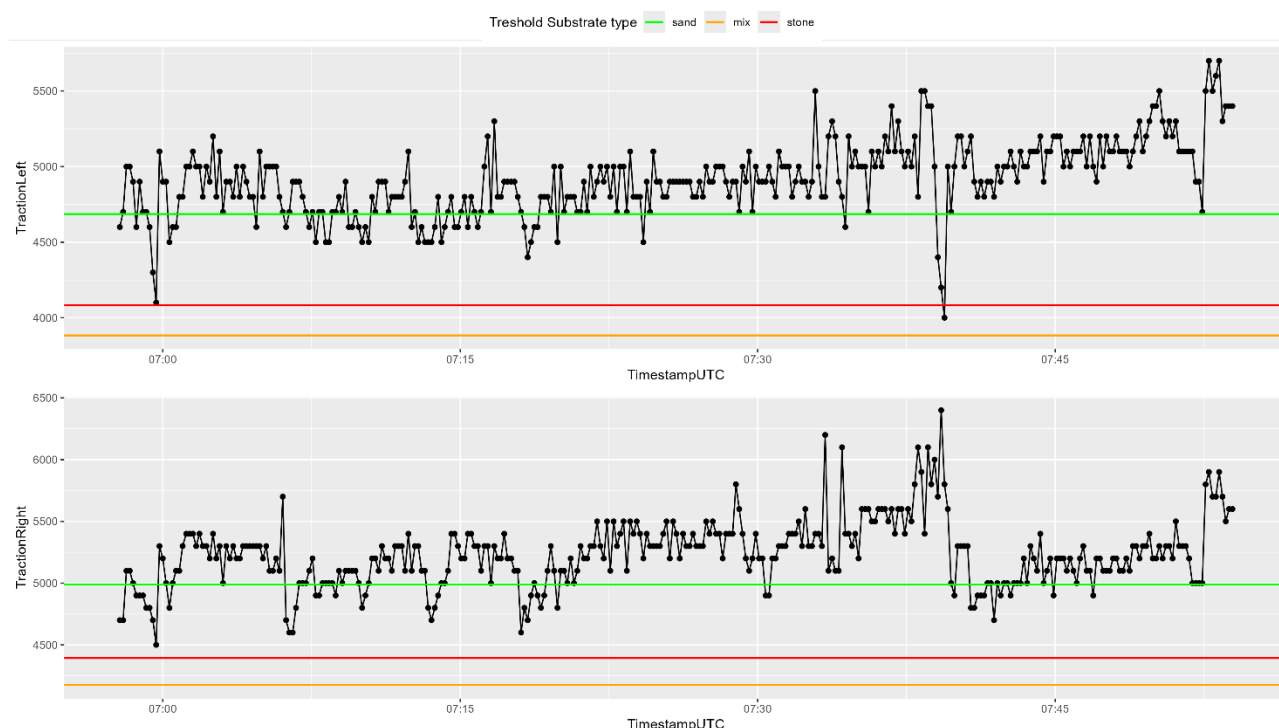


Figure 9-2 Traction values (y-axis, kg) of DK_S_2, measured every 10 seconds after shoot time (x-axis) on port (upper panel) and starboard (lower panel) side. Mean traction values associated with the different substrates, as discussed in §9.1, are indicated in green (sand), orange (mixed) and red (stone).

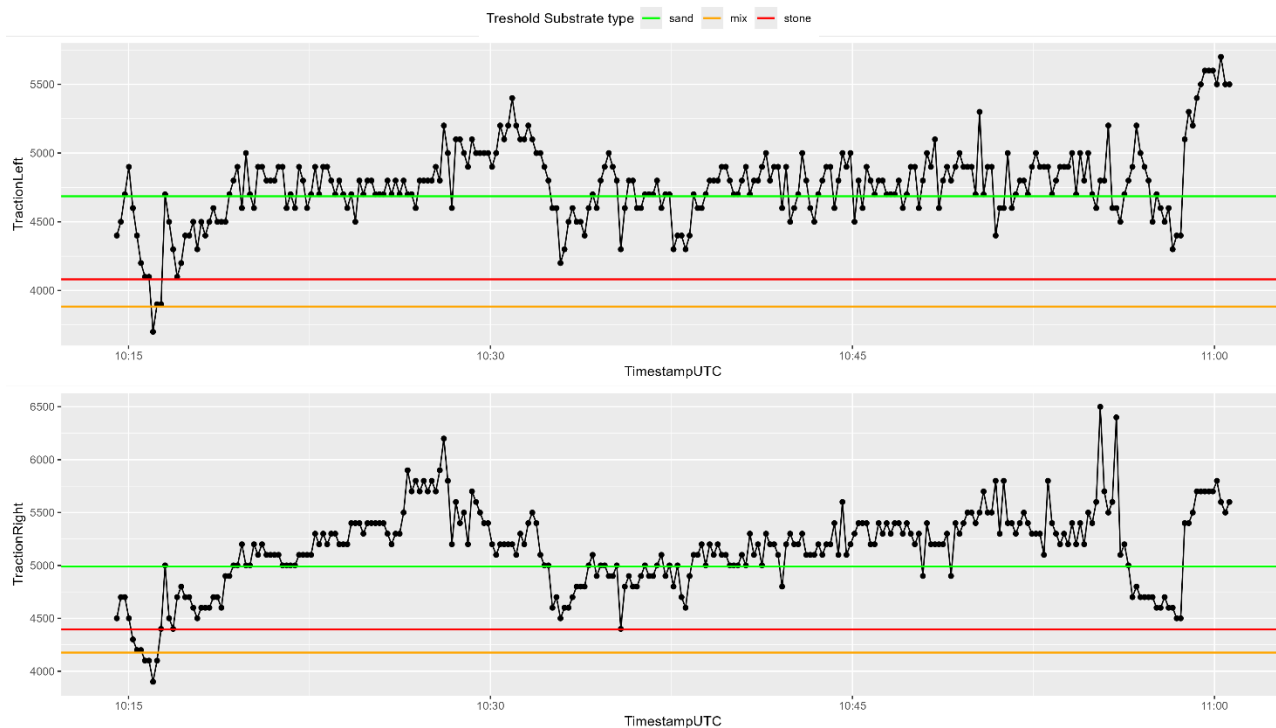


Figure 9-3 Traction values (y-axis, kg) of DK_S-6, measured every 10 seconds after shoot time. (x-axis) on port (upper panel) and starboard (lower panel) side. Mean traction values associated with the different substrates, as discussed in §9.1, are indicated in green (sand), orange (mixed) and red (stone).

9.2.2. Mixed Substrate

In this section, traction plots of “mixed” hauls DK_S_3 (Figure 9-4) and DK_S_11 (Figure 9-5) are plotted. Traction values of these hauls are mostly centered around the mean traction value associated with the mixed substrate sand, with some outliers located around the mean “stone-value”.

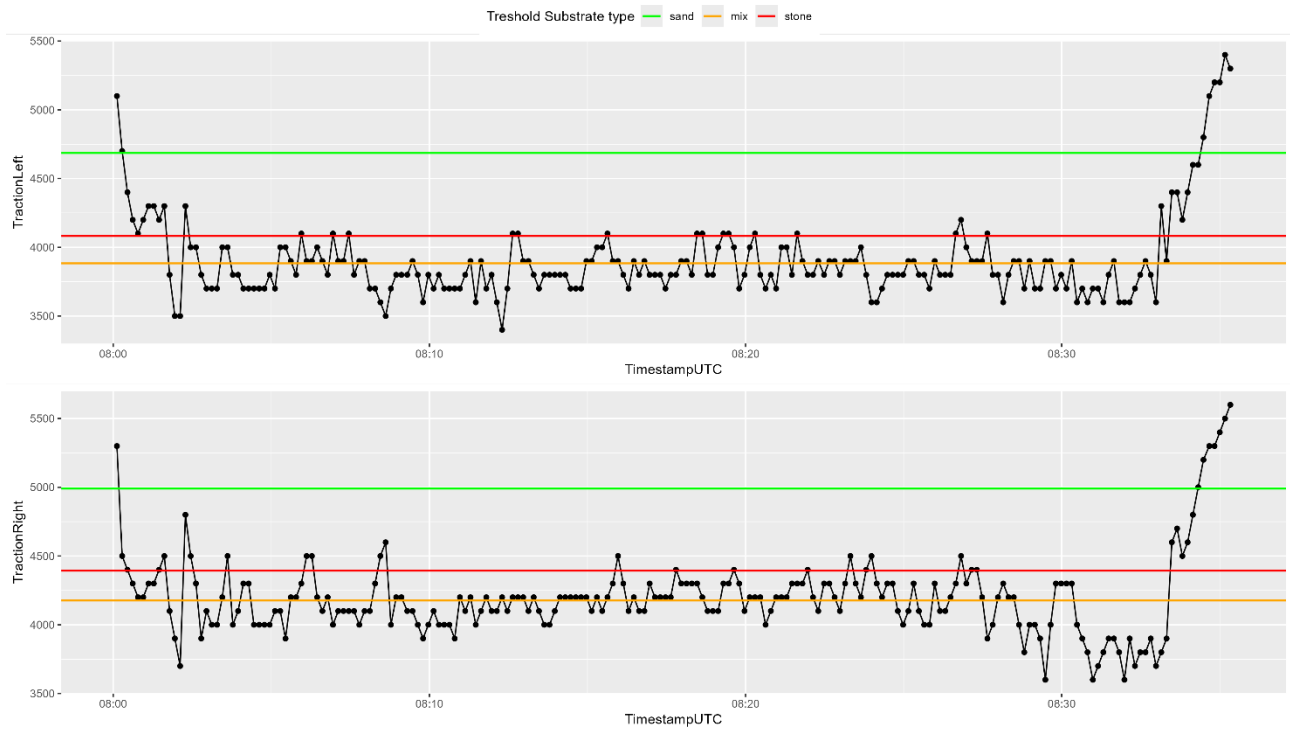


Figure 9-4 Traction values (y-axis, kg) of DK_S_3, measured every 10 seconds after shoot time. (x-axis) on port (upper panel) and starboard (lower panel) side. Mean traction values associated with the different substrates, as discussed in §9.1, are indicated in green (sand), orange (mixed) and red (stone).

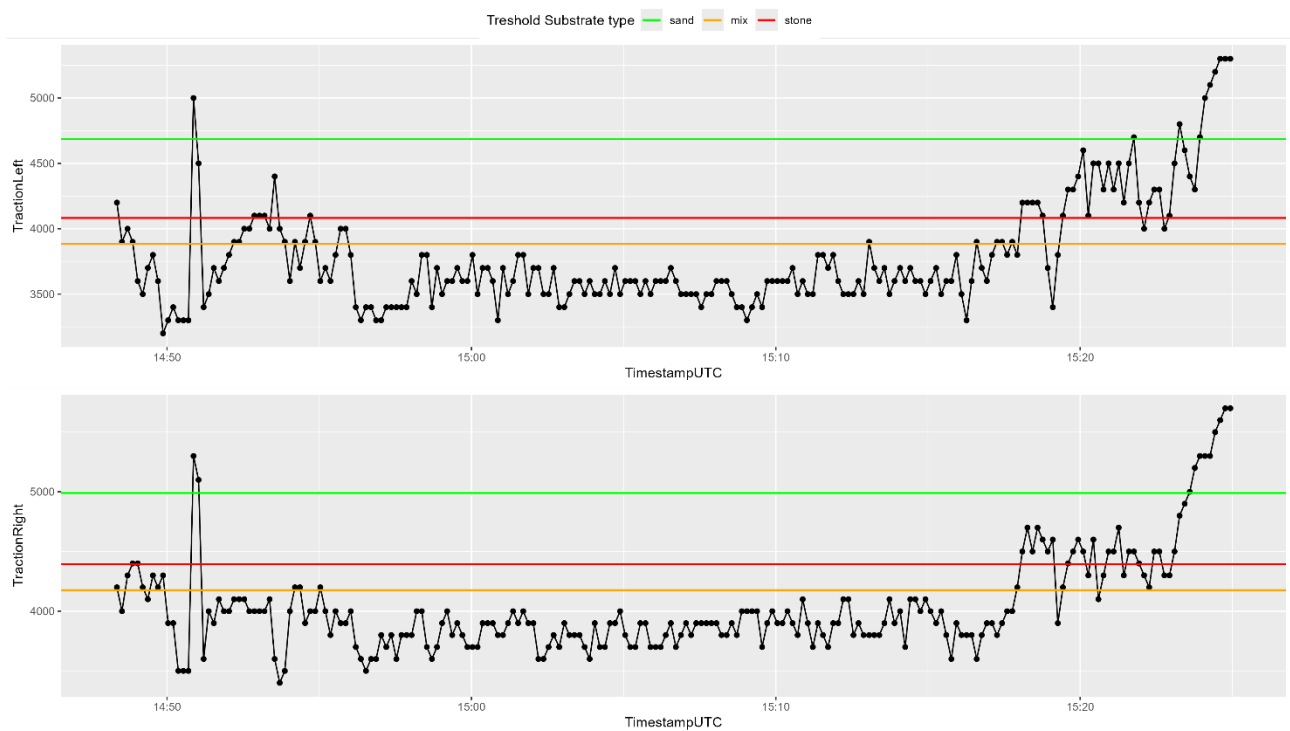


Figure 9-5 Traction values (y-axis, kg) of DK_S_11, measured every 10 seconds after shoot time. (x-axis) on port (upper panel) and starboard (lower panel) side. Mean traction values associated with the different substrates, as discussed in §9.1, are indicated in green (sand), orange (mixed) and red (stone).

9.2.3. Stone Dominated

In this report, only one haul (DK_S_13) is labeled as “stone dominated”. The traction plot of this haul is given by **Figure 9-6**, and suggests that the hauls consists of three major parts. In the beginning of the haul, traction values are situated below the mixed mean, after which they increase to a level just below the mean sand value. Finally, traction values drop again and fluctuate the mix and stone mean values until haul time.

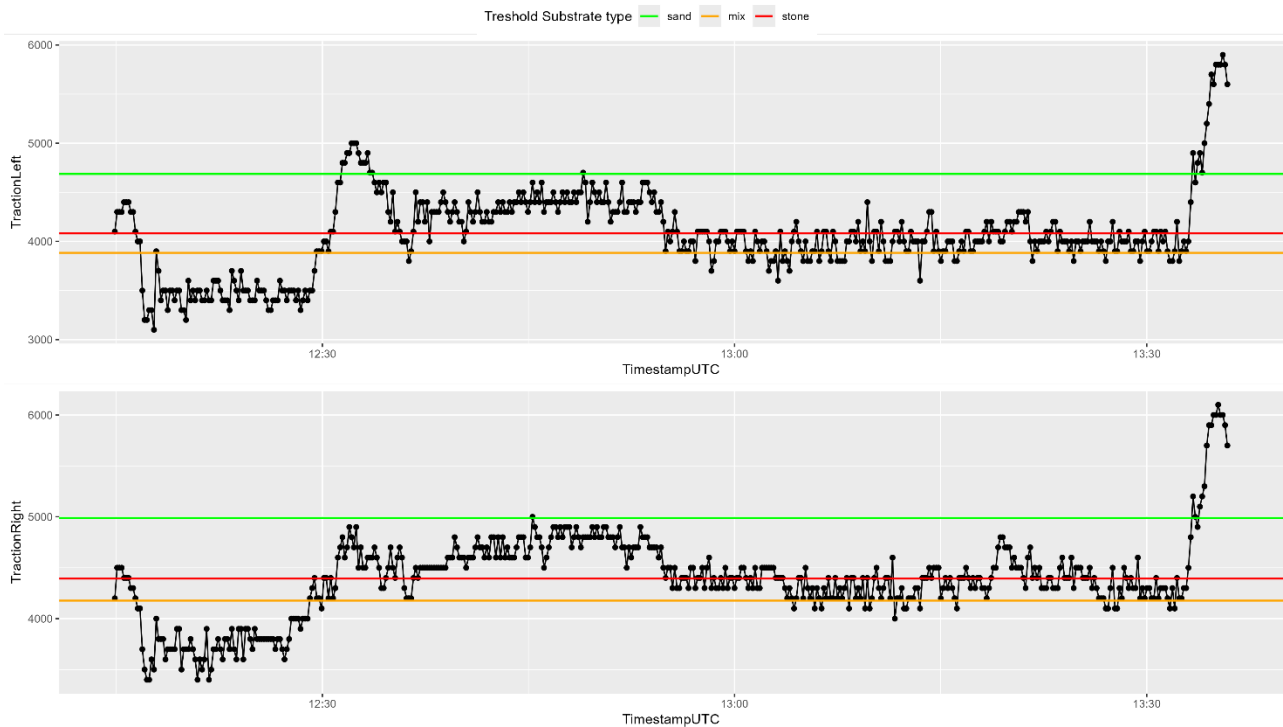


Figure 9-6 Traction values (y-axis, kg) of DK_S_13, measured every 10 seconds after shoot time. (x-axis) on port (upper panel) and starboard (lower panel) side. Mean traction values associated with the different substrates, as discussed in §9.1, are indicated in green (sand), orange (mixed) and red (stone).

To evaluate the above graph in more detail, **Figure 9-7** is created. The latter demonstrates the traction values across the different timestamps of the conducted haul. On this figure, it can be clearly seen that during the first part of the haul, before turning 180°, lowest traction values were recorded. After this turn, traction values increased, which was also observed on the traction plot. However, when the haul entered a first region which is labeled as “stone-dominated” (dark blue) and indicated on **Figure 9-7** (dashed box), traction values did not lower, as would be expected on harder substrates. Instead, they remain relatively high, and only halfway through this patch of hard substrate, traction values appear to lower down. This could also be observed in **Figure 9-6**, after which the traction values remain relatively stable compared to the rest of the haul, fluctuating between the mean values associated with the mixed and hard substrate.

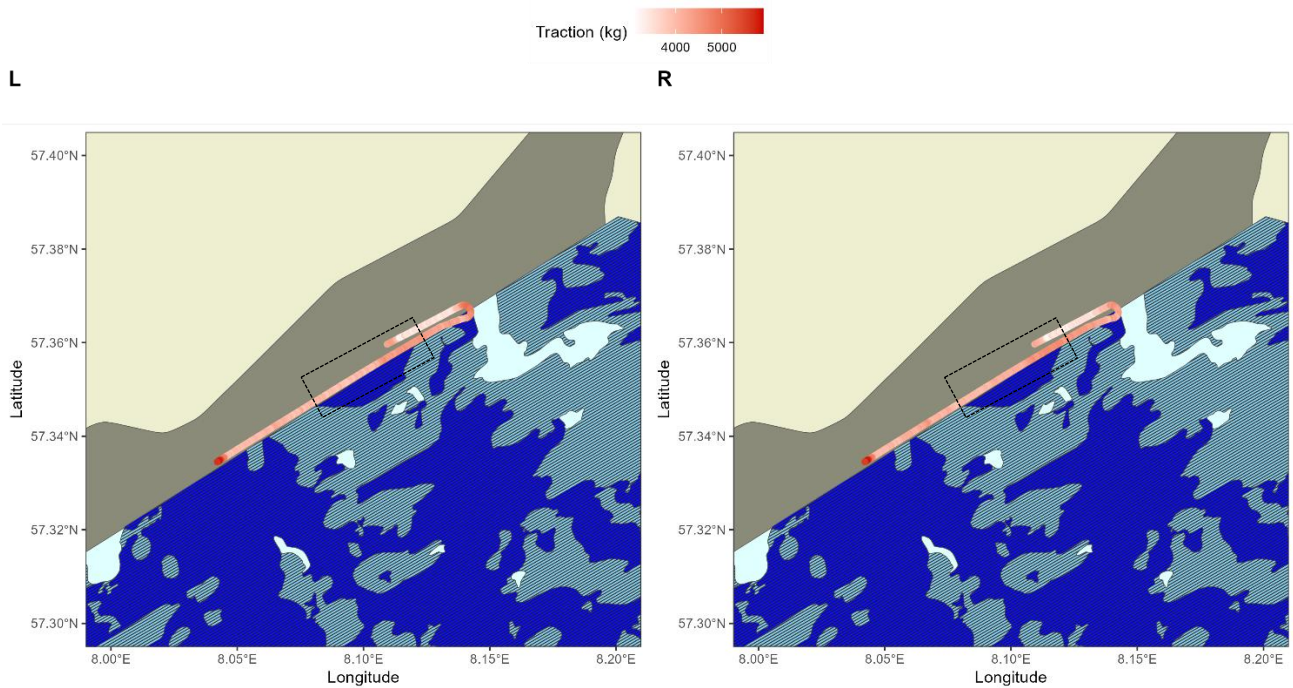


Figure 9-7 Heatmap of the traction values (kg) across haul DK_S_13 for the port (L) and starboard (R) side of the vessel. Low traction values are indicated in white, high traction values in red. The Gule Rev region is indicated with tones of blue: light blue indicates the presence of sandy substrate, blue indicates the presence of mixed substrate and dark blue indicates the presence of stone-dominated substrate, as described by Al-Hamdani et al. (2015) (see also §3.2.1). Regions outside Gule Rev are indicated with tones of yellow/brown, where yellow indicates sandy substrate, while brown indicates the presence of mixed substrate, as described by EMODnet (2022) (see also §3.2.2). Dashed areas indicated the presence of rocky reef structures (H1170). The dashed area was discussed above.

10. Catch Composition

10.1. Species Diversity

10.1.1. Landings & Discards

To observe the diversity of species during the PreciVis project, boxplots of the log-transformed ($\log_{10}$) CPUE (kg km^{-2}) were made (**Figure 10-1**). In total, 27 different fish species were caught, of which plaice (PLE) has the highest mean CPUE ($215.852 \text{ kg km}^{-2}$), followed by cod (COD; $56.670 \text{ kg km}^{-2}$) thornback ray (RJC; $46.757 \text{ kg km}^{-2}$) and haddock ($34.601 \text{ kg km}^{-2}$). However, since only two individuals of thornback ray (RJC) were present during the survey, this CPUE will be considered as an outlier and not be taken into account in further analysis. A more detailed selection of species to be analyzed will be discussed further in this section.

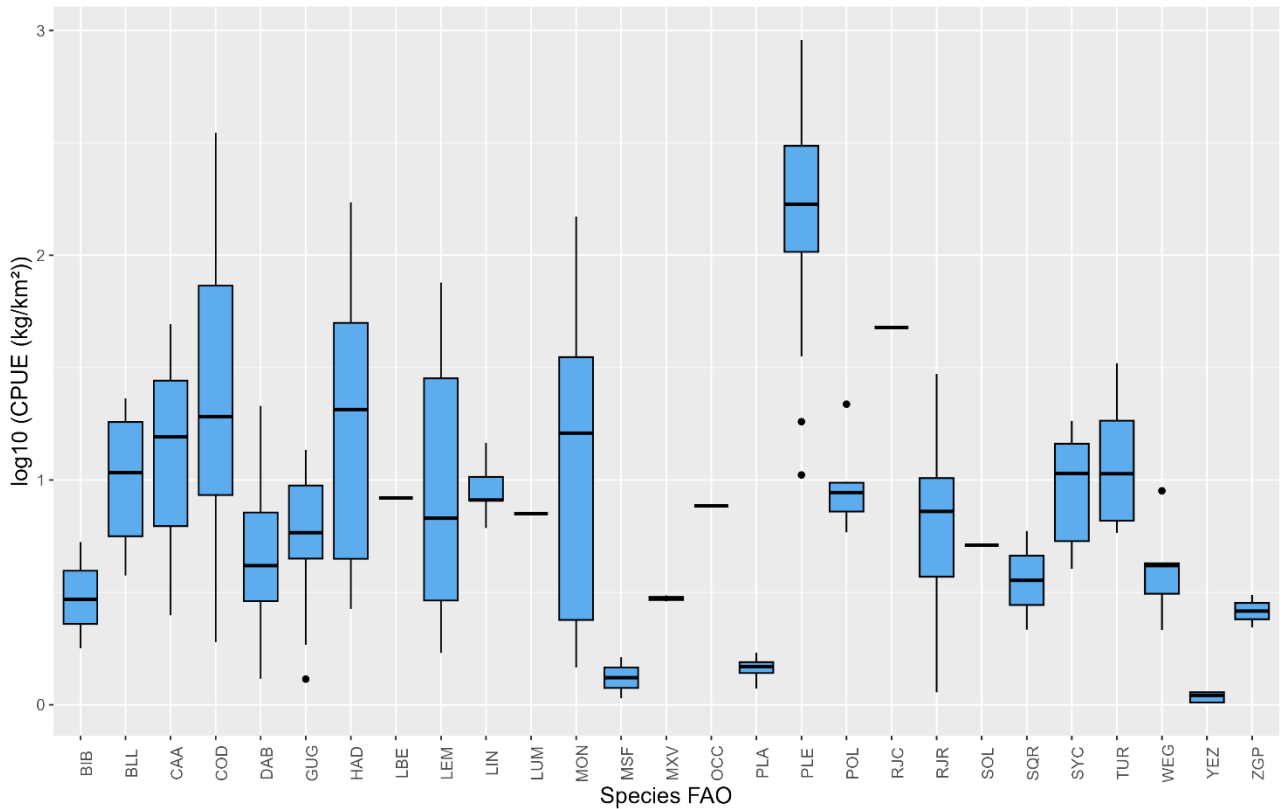


Figure 10-1 Boxplots of CPUE (kg km^{-2}) of the different fish species caught during the PreciVis project ($n = 15$). The CPUE is $\log_{10}$ -transformed, and pseudo count (all data + 1) is applied to take the logarithm of zero-values ($\log_{10}(1) = 0$).

Figure 10-2 displays an additional distinction between discards (22 species) and landings (18 species). In both categories, plaice exhibits the highest mean CPUE, with a value of $111.011 \text{ kg km}^{-2}$ as discard and $328.757 \text{ kg km}^{-2}$ as landed species. Additionally, commercial- and under-sized cod has the second highest CPUE, with respective values of $101.292 \text{ kg km}^{-2}$ and 9.204 kg km^{-2} . Because of the CPUE-differences between landings and discards, a clear distinction between these two categories will be made throughout the subsequent analysis.

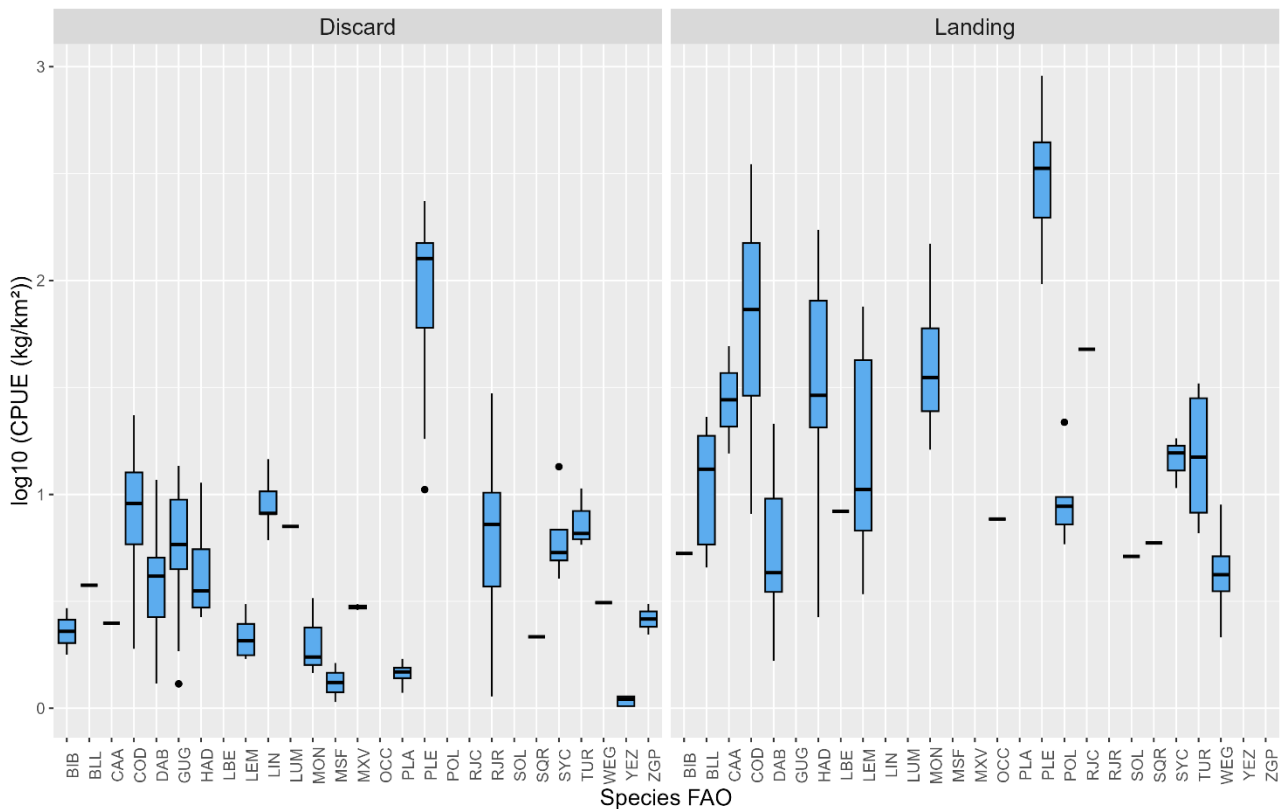


Figure 10-2 Boxplots representing the log10-transformed CPUE (kg km⁻²) of all fish species sampled during the PreciVis survey. A distinction is made between landing- and discard fraction. Pseudo-count (all data+1) was applied to account for zero values (log10 (1) = 0).

Given the total number of species present (n = 27), 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 10-1**).

Equation 10-1 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 PreciVis survey

The ten species with the highest rank are summarized in **Table 10-1**. These species will be mentioned in further analysis, other species will be referred to as “Other”.

Table 10-1 Selection of fish species which will be retained in further exploratory graphs. Species not mentioned in this table will be referred to as “Other”.

	Discard	Landing
1	Plaice (PLE)	Plaice (PLE)
2	Cod (COD)	Cod (COD)
3	Starry ray (RJR)	Haddock (HAD)

4	Grey Gurnard (GUG)	Lemon Sole (LEM)
5	Common Dab (DAB)	Monkfish (MON)
6	Ling (LIN)	Brill (BLL)
7	Haddock (HAD)	Turbot (TUR)
8	Lesser-spotted dogfish (SYC)	Common Dab (DAB)
9	Turbot (TUR)	Atlantic Wolffish (CAA)
10	Lemon Sole (LEM)	Pollack (POL)

10.1.2. Benthos

To illustrate the diversity within the benthos species, **Figure 10-3** was created, showing the log₁₀-transformed CPUE for the 37 species found. On this graph, seven-armed starfish (*Luidia ciliaris*) has the highest median CPUE (29.04 kg km⁻²), followed by edible crab (*Cancer pagurus*, 22.61 kg km⁻²) and dead man's fingers (*Alcyonium digitatum*, 19.39 kg km⁻²). The latter exhibits on the other hand a high variability, resulting in the highest mean CPUE of all benthic species (89.08 kg km⁻²), followed by seven-armed starfish (*Luidia ciliaris*; 36.43 kg km⁻²) and edible crab (*Cancer pagurus*, 32.69 kg km⁻²).

Both dead man's fingers and edible crab were most present during the survey, with records in 14 hauls. Spiny starfish (*Marthasterias glacialis*) recorded the third highest abundance, with records in 12 hauls.

On **Figure 10-3**, it can be seen that the fractions *Debris Wood* and *Debris Stone* have a relatively high CPUE. However, since these fractions were not sampled uniformly (i.e. some stones/wood too large to measure), they will be excluded from analysis.

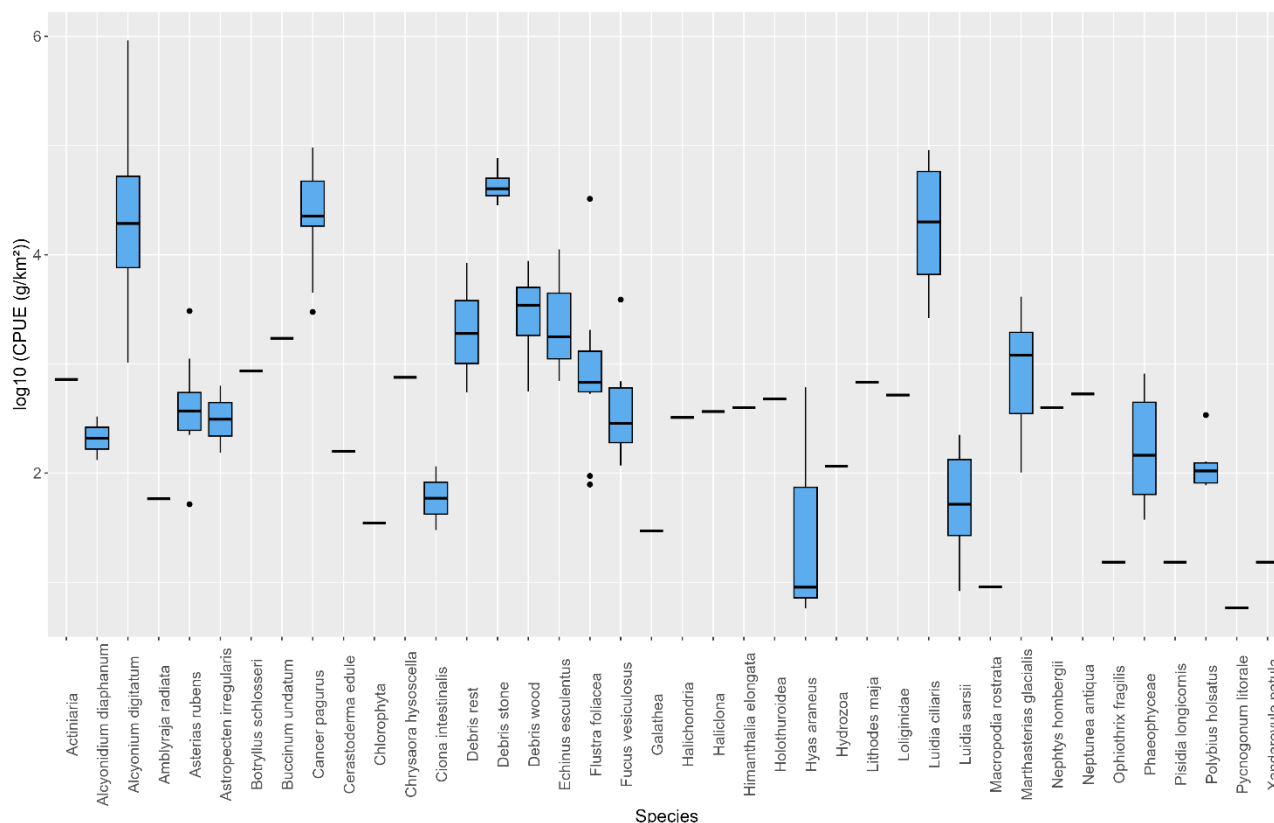


Figure 10-3 Boxplots representing the log10-transformed CPUE (kg km⁻²) of all benthic species sampled during the PreciVis survey. Pseudo-count (all data+1) was applied to account for zero values (log10 (1) = 0).

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 10-1**, which was presented in §10.1.1.

Species that will be retained for analysis are summarized in **Table 10-2**.

Table 10-2 Selection of benthic species which will be retained in further exploratory graphs. Species not mentioned in this table will be referred to as "Other".

Species	
1	Dead man's fingers (<i>Alcyonium digitatum</i>)
2	Edible crab (<i>Cancer Pagurus</i>)
3	Seven-armed starfish (<i>Luidia ciliaris</i>)
4	Hornwrack (<i>Flustra foliacea</i>)
5	Spiny starfish (<i>Marthasterias glacialis</i>)

6	Edible sea urchin (<i>Echinus esculentus</i>)
7	Common starfish (<i>Asterias rubens</i>)
8	Bladder wrack (<i>Fucus vesiculosus</i>)
9	Brown seaweeds (<i>Phaeophyceae</i>)
10	Waved whelk (<i>Buccinum undatum</i>)
11	Common swimming crab (<i>Polybius holsatus</i>)

10.2. Spatial Distribution

10.2.1. Landings

Figure 10-4 demonstrates the spatial distribution of the selected landing species. 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.

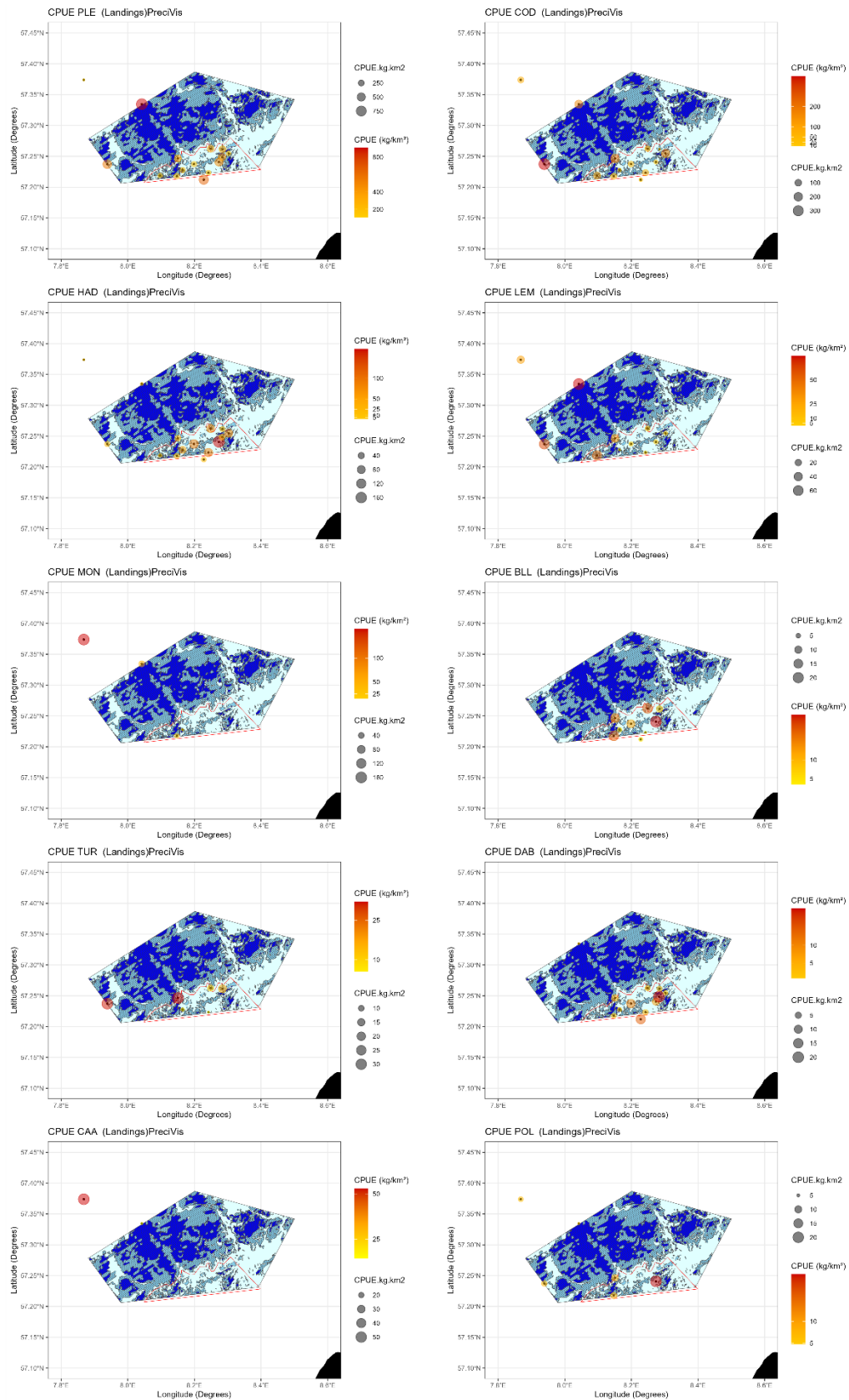


Figure 10-4 CPUE (kg/km²) of the selected fish species (landings) sampled during the PreciVis campaign. The color and size of the circles indicate the size of the CPUE; with higher CPUE values shown by larger and warmer (redder) colors. Color and size scales for each graph are provided on the right side. Point-coordinates used in the figure correspond to the haul location of each sampled haul.

10.2.2. Discards

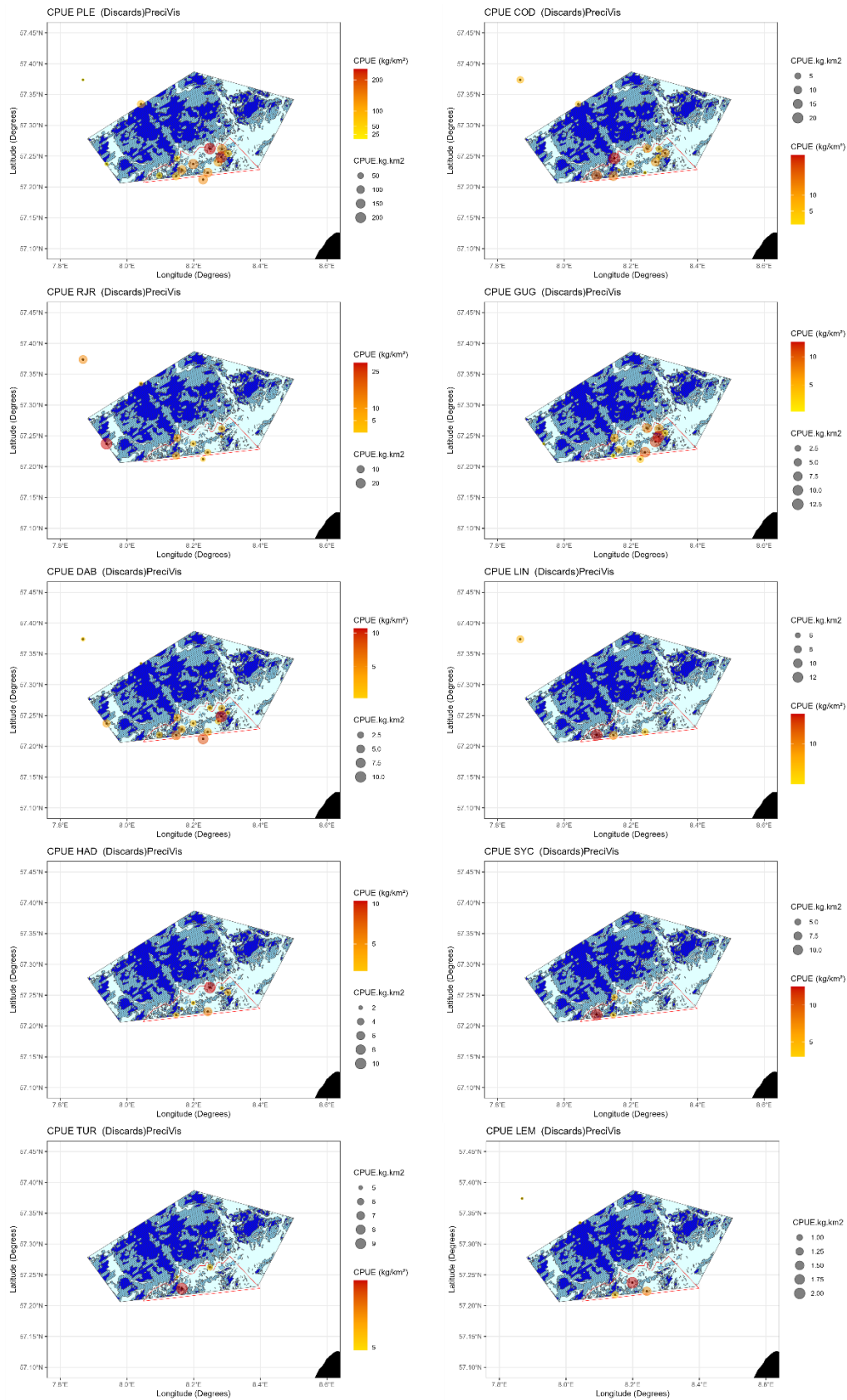


Figure 10-5 CPUE (kg/km²) of the selected fish species (*discards*) sampled during the PreciVis campaign. The color and size of the circles indicate the size of the CPUE, with higher CPUE values shown by larger and warmer (redder) colors. Color and size scales for each graph are provided on the right side. Point-coordinates used in the figure correspond to the haul location of each sampled haul.

10.3. Catch Composition

This section illustrates the catch composition per substrate (§10.3.1) and habitat type (§10.3.2), and on an individual haul level (§10.3.3).

10.3.1. Dominant Substrate

10.3.1.1. Landings & Discards

Figure 10-6 summarizes the general catch composition across the different sampled substrate types as defined by Al-Hamdani et al. (2015), both for landings (L) and discards (D). Regarding the landings, plaice (PLE) is dominating across all substrate types, with relative CPUE's of 72.32%, 52.01% and 74.88% for sand, mix and stone, respectively. With a relative CPUE of 7.36%, haddock (HAD) represents the second largest share of “sand” substrate, while cod (COD) holds the second largest share in the “mix” (24.42%) and “stone” (13.4%) category.

Regarding the discard fractions, a similar pattern can be observed: plaice is the most present species for all substrate types, with relative CPUE's of 84.74% for “sand”, 69.97% for mix and 91.94% for the “stone” substrate. Grey gurnard (GUG) has similar abundances in sand (3.33%) and mix (3.49%) but is absent in the stone substrate.

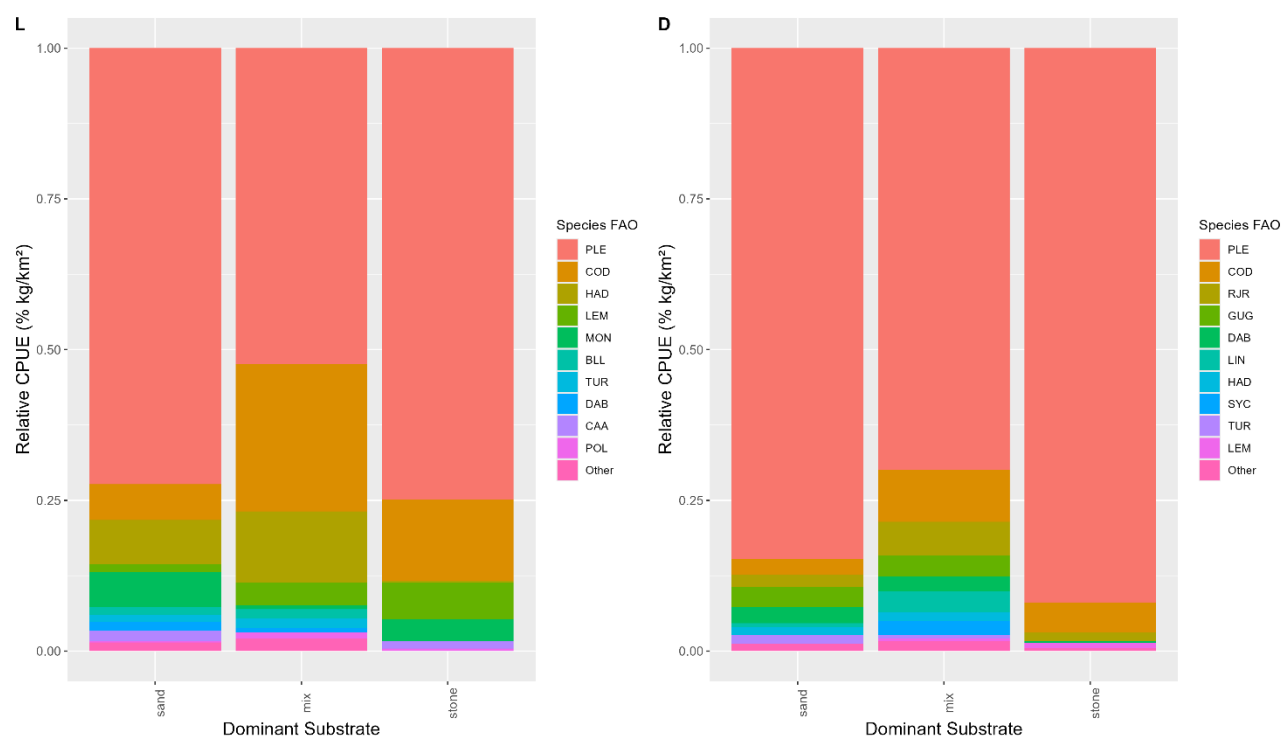


Figure 10-6 General catch composition of [L] landings and [D] discards, expressed as kg km^{-2} , across the different dominant substrate types according to Al-Hamdani et al. (2015) and EMODnet (2022). Substrate types are “Sand” ($n = 8$), “Mix” ($n = 6$) and “Stone” ($n = 1$).

10.3.1.2. Benthos

Surprisingly, the substrate class “stone” holds the smallest fraction of dead man’s fingers (*A. digitatum*), with only 2.96% of the total benthic CPUE. Largest fraction for this substrate class is seven-armed starfish (*L. ciliaris*), with a relative abundance of 80.40%. However, this class contains only one sampled haul and should therefore be interpreted with caution.

Regarding the “mixed” substrate class, it can be seen that dead man’s fingers do hold the largest fraction, with a relative abundance of 74.66%. Edible crab (*C. pagurus*) is the second most abundant species in this category, with a relative abundance of 15.18%, followed by seven-armed starfish (*L. ciliaris*; 4.50%) and hornwrack (*F. foliacea*; 2.56%). Regarding the “sand” category, edible crab (*C. pagurus*) is most dominantly present, with a relative abundance of 44.59%. Dead man’s fingers (*A. digitatum*) forms the second largest fraction, with a relative presence of 33.51%, followed by seven-armed starfish (*L. ciliaris*) which has a relative abundance of 17.70%. All other species have relative abundances smaller than 1%.

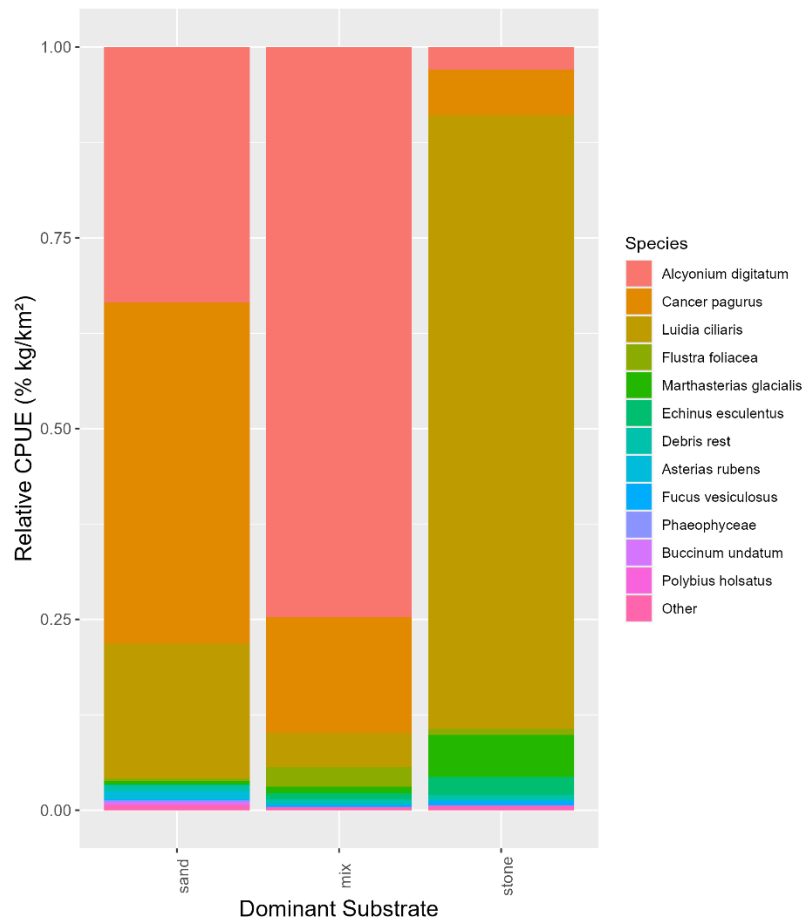


Figure 10-7 General catch composition of benthos, expressed as kg km^{-2} , across the different dominant substrate types according to Al-Hamdani et al. (2015). Substrate types are “Sand” ($n = 8$), “Mix” ($n = 6$) and “Stone” ($n = 1$).

10.3.2. Habitat Type

10.3.2.1 Landings & Discards

Figure 10-8 demonstrates the catch composition related to the different habitat types for both landings (L) and discards (D). Regarding the landing species, plaice (PLE) is the most abundant species in both the “reef” as “non-reef” category, with a relative abundance of 57.23% and 71.68%, respectively. In the non-reef category, haddock (HAD), has the second highest fraction (7.27%), followed by monkfish (MON; 6.16%), cod (COD; 6.08%) and Atlantic wolffish (CAA; 1.84%) and dab (DAB; 1.75%). Pollack (POL) has the lowest relative abundance, with a fraction of 0.22%. As mentioned before, plaice is the most prominent species in the reef category, followed by cod (22.06%), haddock (9.31%) and lemon sole (4.32%). Atlantic wolffish records the lowest relative CPUE (0.26%), followed by dab, with only 0.55% of the total CPUE identified as commercial-sized dab.

Similarly to the landings, discard plaice (PLE) is dominant in both non-reef (84.54%) and reef (71.91%) habitat type. In the non-reef category, plaice is followed by grey-gurnard (GUG; 3.33%) and dab (DAB; 2.63%). Lemon sole (LEM) has the lowest abundance with 0.07% of the total CPUE. In the “reef” category, cod registers the second highest abundance (8.26%), followed by starry ray (RJR; 5.21%) grey gurnard (GUG; 3.19%) and ling (LIN; 3.69%). Turbot registered the lowest abundance, with 0.43% of the total CPUE.

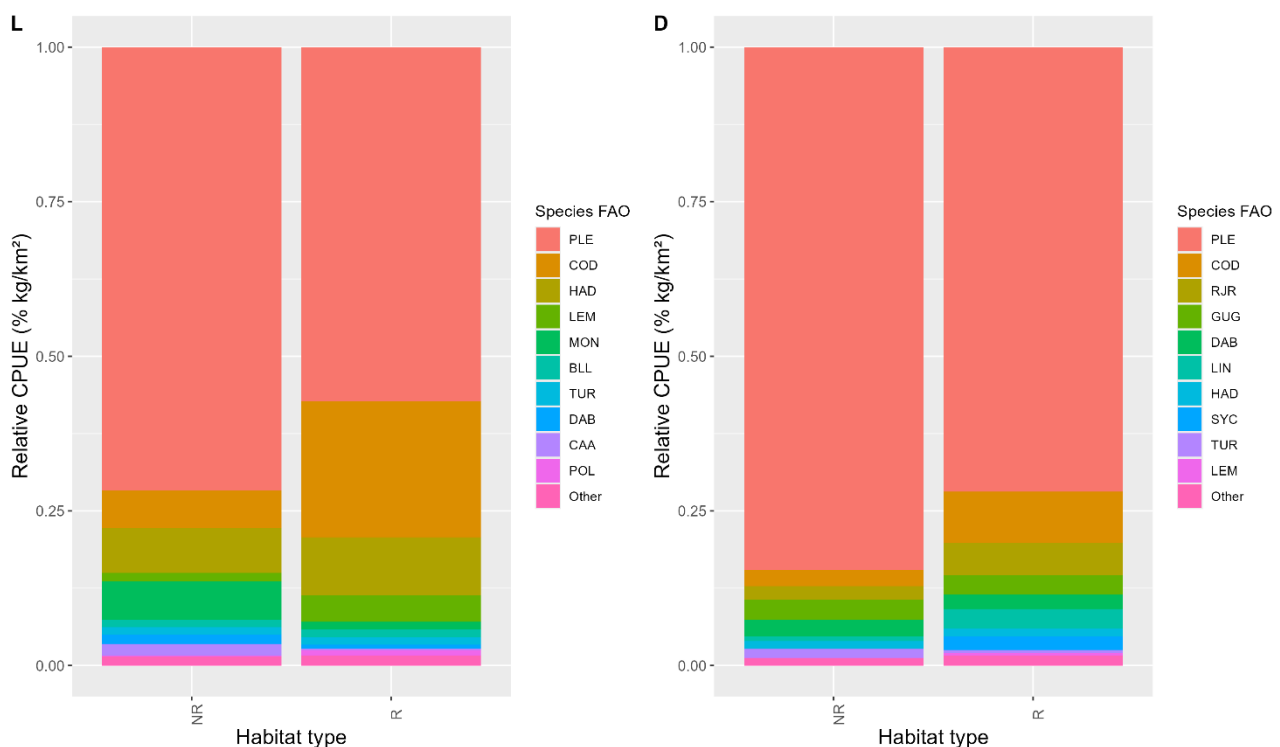


Figure 10-8 General catch composition of [L] landings and [D] discards, expressed as kg km^{-2} , across the different dominant substrate types according to Al-Hamdani et al. (2015) and EMODnet (2022). Habitat types are “Non-Reef” (NR) ($n = 5$) and “Reef” (R) ($n = 10$).

10.3.2.2. Benthos

Areas labeled as “non-reef” are mainly dominated by two species: edible crab forms the largest fraction, with a relative abundance of 43.38%, followed by dead man’s fingers (*A. digitatum*; 33.53%). Seven-armed starfish (*L. ciliaris*) completes the top three, with a relative abundance of 18.8%. Other species have all relative abundances equal to or smaller than 1%, such as common starfish (*A. rubens*; 1.00%), hornwrack (*F. foliacea*; 0.42%), spiny starfish (*M. glacialis*; 0.40%), and edible sea urchin (*E. esculentus*; 0.13%) (Figure 10-9).

In the reef category, dead man’s fingers forms the largest fraction, with an abundance of 71.07% of the total CPUE. Edible crab forms the second largest fraction (14.72%), followed by seven-armed starfish (*L. ciliaris*; 8.30%). Hornwrack (*F. foliacea*) represents 2.47% of the total CPUE, spiny starfish (*M. glacialis*) 1.08%, edible sea urchin 0.86%.

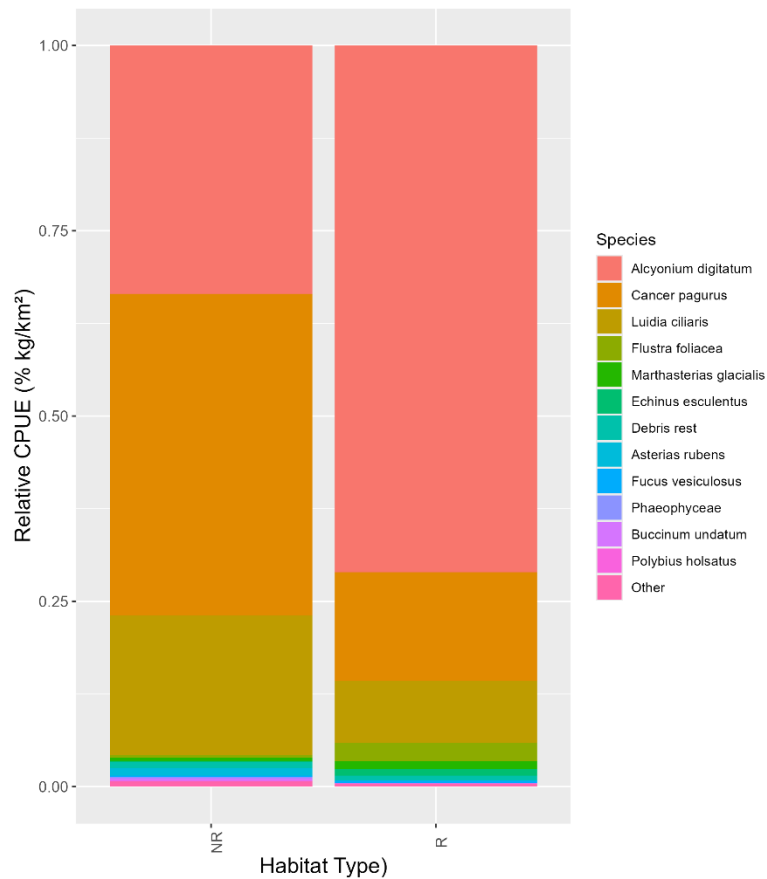


Figure 10-9 General catch composition of benthos, expressed as kg km^{-2} , across different habitat types according to OceanBox B.V. (2025). Habitat types are “Non-Reef” (NR) ($n = 5$) and “Reef” (R) ($n = 10$).

10.3.3. Haul level

This section contains the catch composition of landings (**Figure 10-10**), discards (**Figure 10-11**) and benthos (**Figure 10-12**) for each haul.

Regarding the benthic community, dead man’s finger (*Alcyonium digitatum*) was expected to be an indicator species for hard substrates, as it is typically attached to structures such as boulders or rocks (Budd, 2008). It is therefore surprising to see that this species is present in all sampled hauls (**Figure 10-12**). In Notably, haul DK_S_15 contained the largest abundance of dead man’s fingers and hornwrack (*Flustra foliacea*), as well as a relatively large share of edible sea urchin (*Echinus esculentus*), confirming that benthic composition is influenced by fine-scale substrate features. Additionally, **Figure 10-7**, which represents the catch composition for each substrate type, also exhibited a large share of edible crab in the sand category.

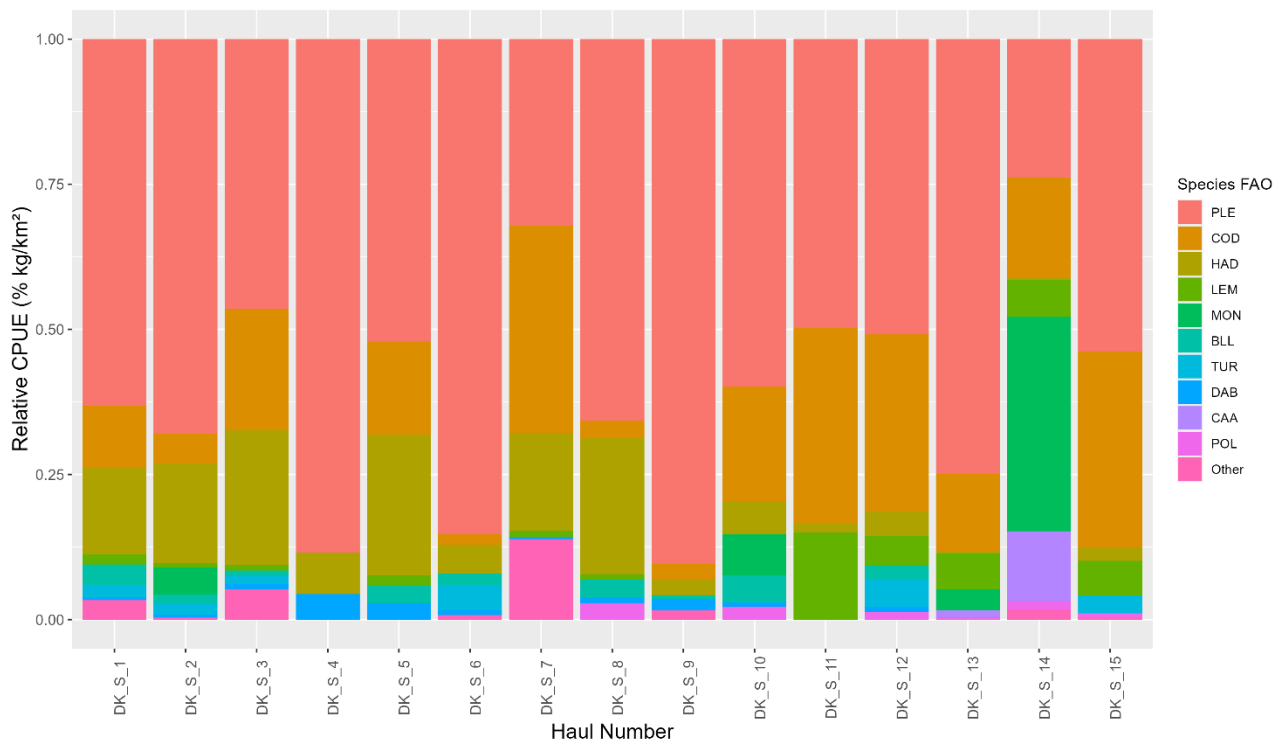


Figure 10-10 Catch composition of the landings for each sampled haul during the PreciVis project.

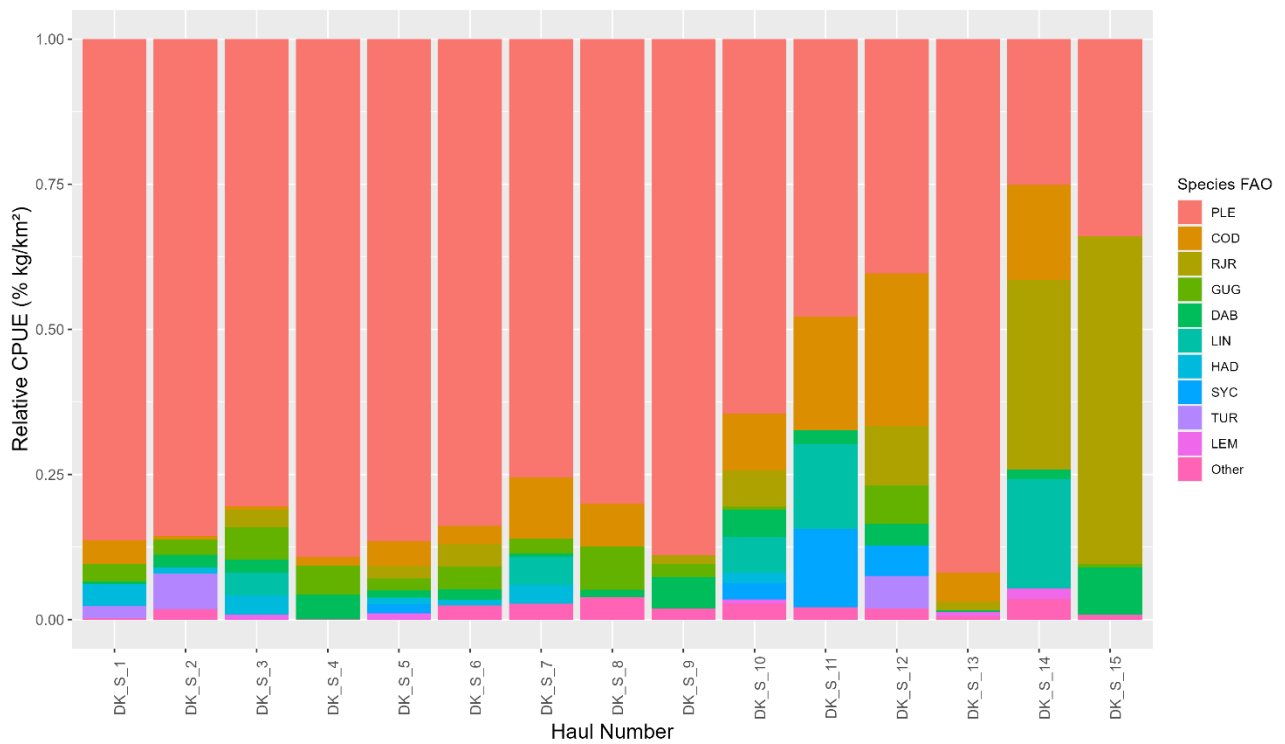


Figure 10-11 Catch composition of the discards for each sampled haul during the PreciVis project.

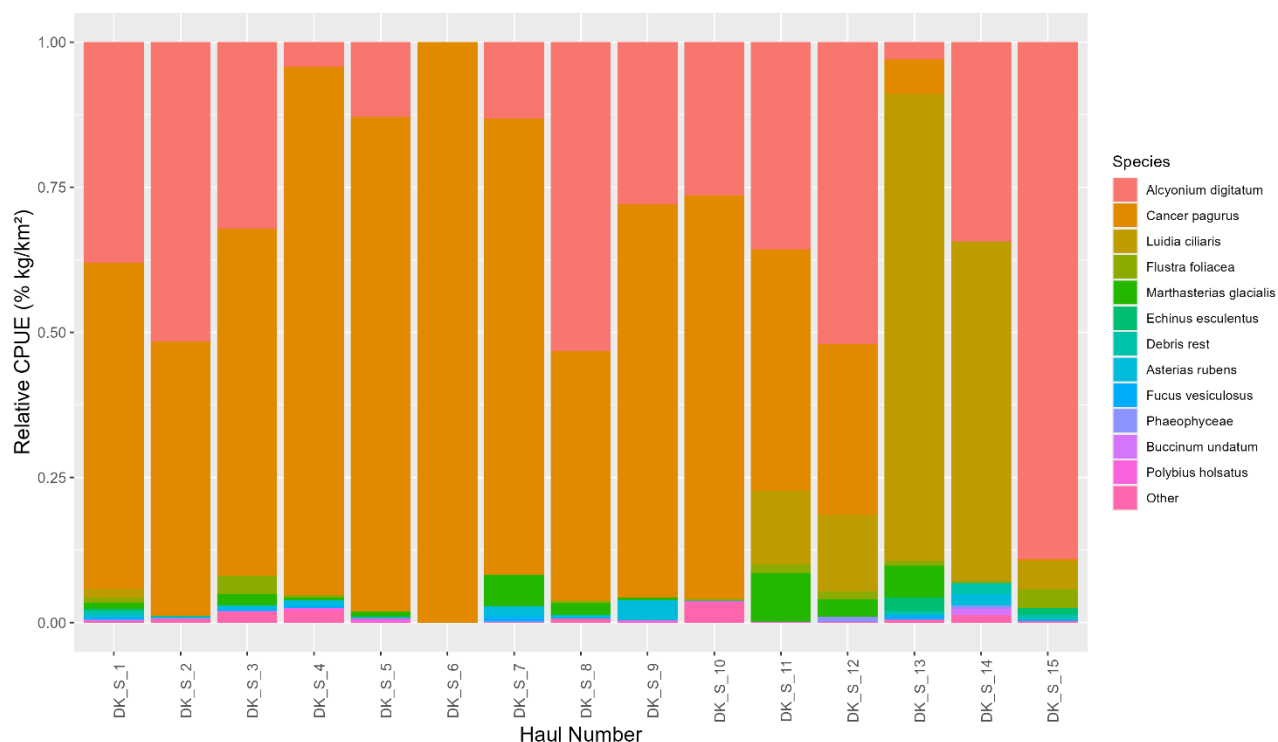


Figure 10-12 Catch composition of the benthos for each sampled haul during the PreciVis project.

Different catch compositions were also noted for a similar substrate type, as demonstrated by **Figure 10-14**. This figure exhibits species composition of Landings, Discards and benthos for three hauls: DK_S_13, DK_S_15 and DK_S_14. The latter is labelled as “Sand-dominated”, whereas the former two are classified as “Stone”. Although a similar substrate classification, hauls DK_S_13 and DK_S_15 exhibited different trends in catch composition. For example, a large fraction of *Alcyonium digitatum* can be noticed in DK_S_15, but DK_S_13 only records a small share of the latter. Additionally, DK_S_13 also exhibits a large discard plaice fraction, which is usually more associated with softer substrates. Haul DK_S_14 on the other hand holds the largest cod fraction of the three hauls.

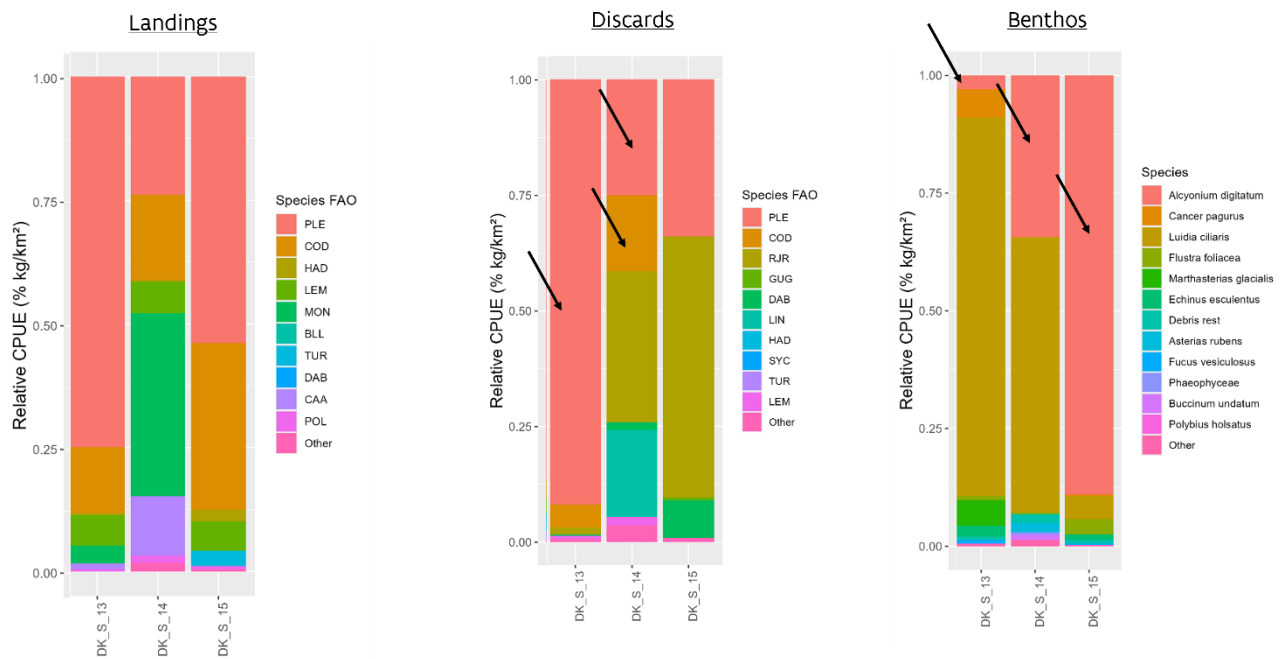


Figure 10-13 Catch composition of landings (left), discards (middle) and benthos (right) of hauls DK_S_13, DK_S_14 and DK_S_15.

10.4. Correlation plots

For each haul, OceanBox (OB) calculated the proportion of present substrate type (Sand-Mix-Stone)(Figure 8-3) and habitat category (Reef, Reef Candidate, Non-Reef) (Figure 8-6), based on WASSP images and results from their produced model. In this section, these results will be categorized as “WASSP” results.

In addition to these “WASSP percentages”, OB calculated the fraction of each substrate present based on the substrate maps produced by Al-Hamdani et al. (2015) (see §3.2.1). These percentages are referred to as “Literature percentages”. Both “WASSP” and “Literature” substrate and habitat proportions are also visualized in Figure 8-3 and Figure 8-6, respectively.

This section links these percentages to the CPUE of different landings, discard and benthos species by making linear correlations. All significant results are provided below; plots of non-significant correlations can be obtained upon request.

10.4.1. Landings

10.4.1.1. Substrate – Literature

Commercial-sized (i.e. landings) haddock (HAD) and pollack (POL) both exhibit a significant positive correlation between the sand proportion of a haul and the CPUE, expressed as kg km^{-2} , with a p-value of 0.03 and 0.017, respectively. On the other hand, commercial-sized lemon sole exhibited a significant negative correlation with the sand proportion, with a p-value of 0.023 (Figure 10-14). For the mixed substrate type, only haddock exhibited a significant result. This species is positively correlated with the proportion of mixed substrate in a haul ($p = 0.025$) (Figure 10-15). Additionally, cod (COD) was also found to be positively correlated with the stone proportion of the different hauls ($R = 0.65$, $p < 0.05$) (Figure 10-16).

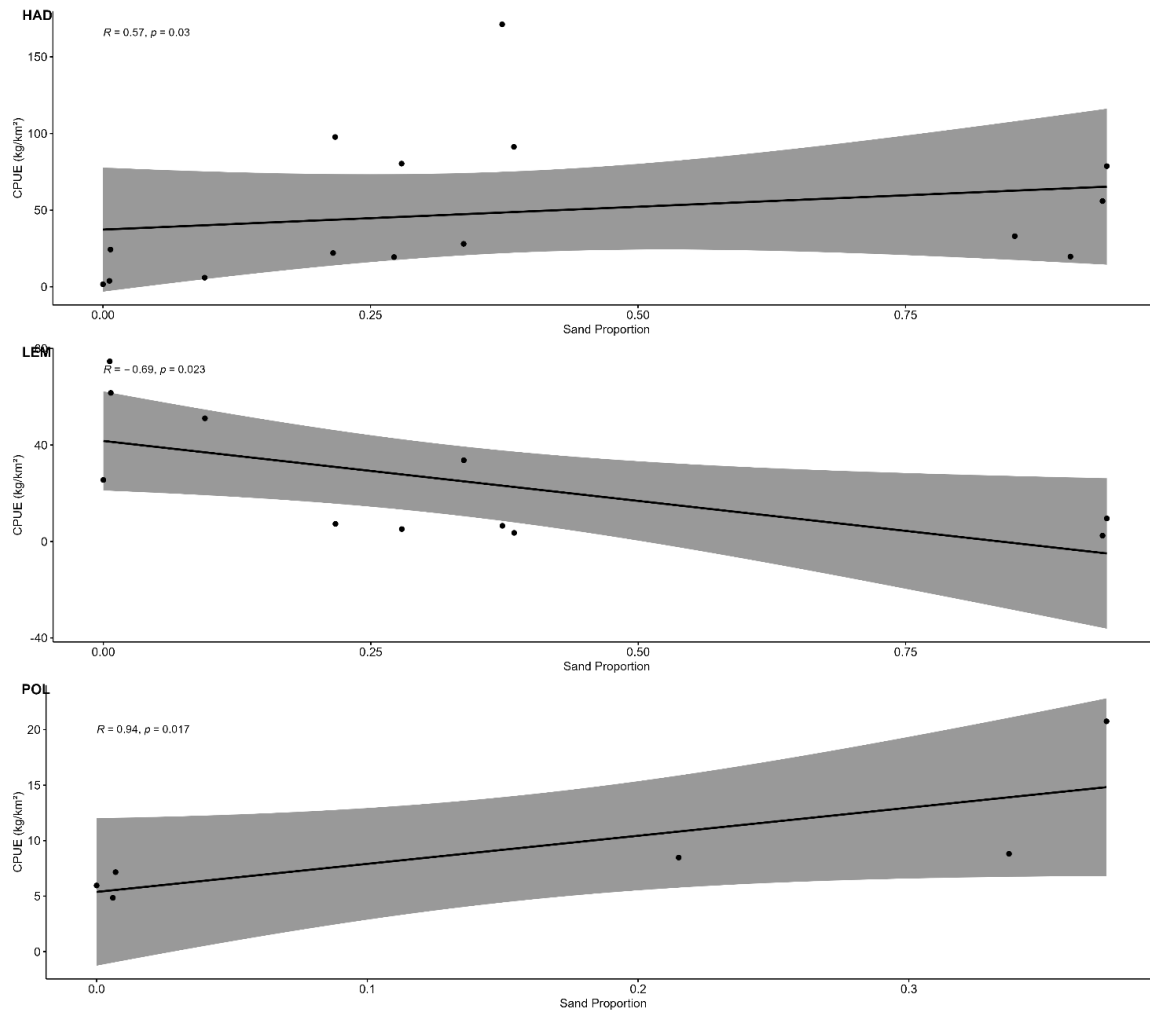


Figure 10-14 Linear correlations (Spearman method) between the sand proportion of a haul, based on Al-Hamdani et al. (2015), (x-axis) and the CPUE (kg km⁻²) of commercial-sized (i.e. landings) haddock (HAD), lemon sole (LEM) and pollack (POL) (y-axis). Shaded areas represent the 95% confidence interval.

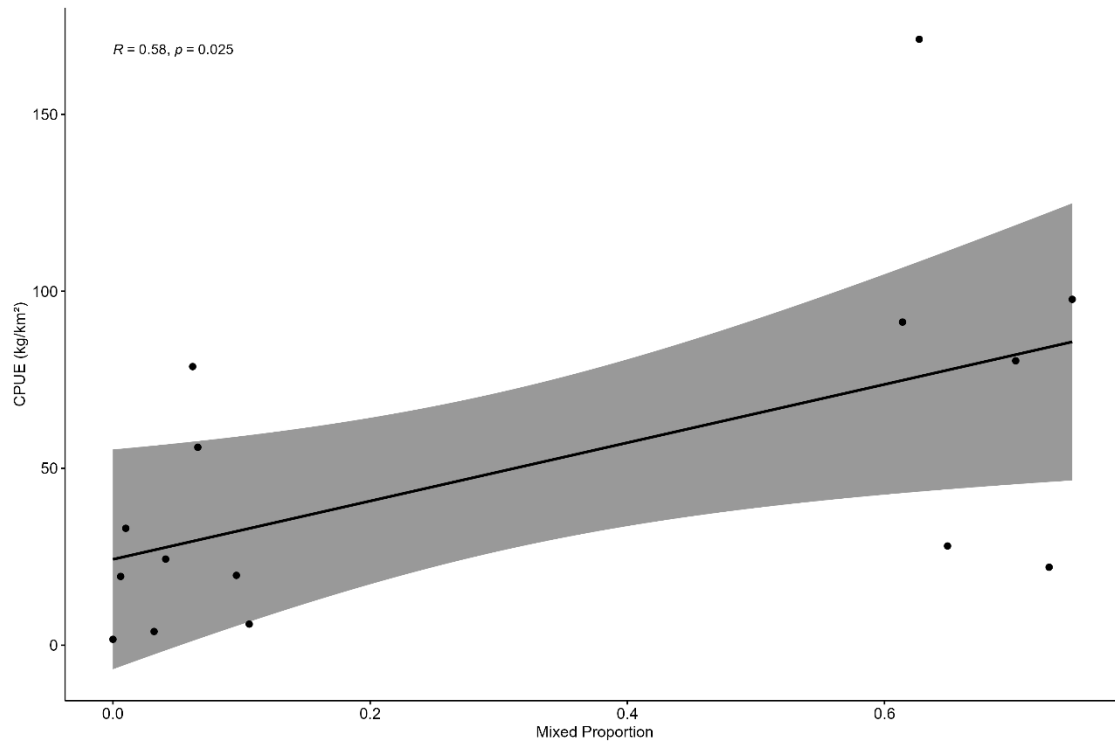


Figure 10-15 Linear correlation (Spearman method) between the mixed substrate proportion of a haul, based on Al-Hamdani et al. (2015), (x-axis) and the CPUE (kg km⁻²) of commercial-sized (i.e. landings) **haddock (HAD)** (y-axis). Shaded areas represent the 95% confidence interval.

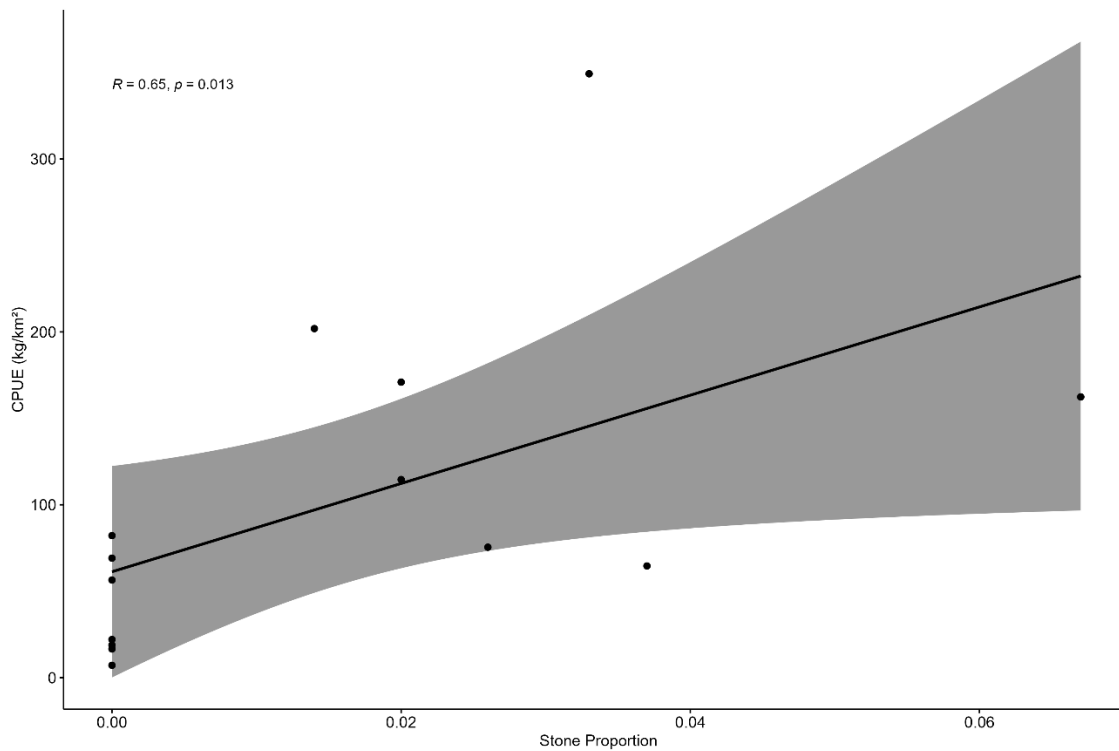


Figure 10-16 Linear correlation (Spearman method) between the stone substrate proportion of a haul based on Al-Hamdani et al. (2015), (x-axis) and the CPUE (kg km⁻²) of commercial-sized (i.e. landings) **cod (COD)** (y-axis). Shaded areas represent the 95% confidence interval.

10.4.1.2. Substrate – WASSP

Commercial sized plaice (PLE) exhibited a significant negative correlation ($p < 0.01$) to the mixed proportion of a haul, with an R value of -0.76 (Figure 10-17). Additionally, commercial-sized species -cod

(COD)- exhibited a significant correlation between its CPUE and the present substrate type: a negative correlation ($R = -0.6$, $p < 0.05$) was found between the sand fraction and the CPUE of cod (Figure 10-18).

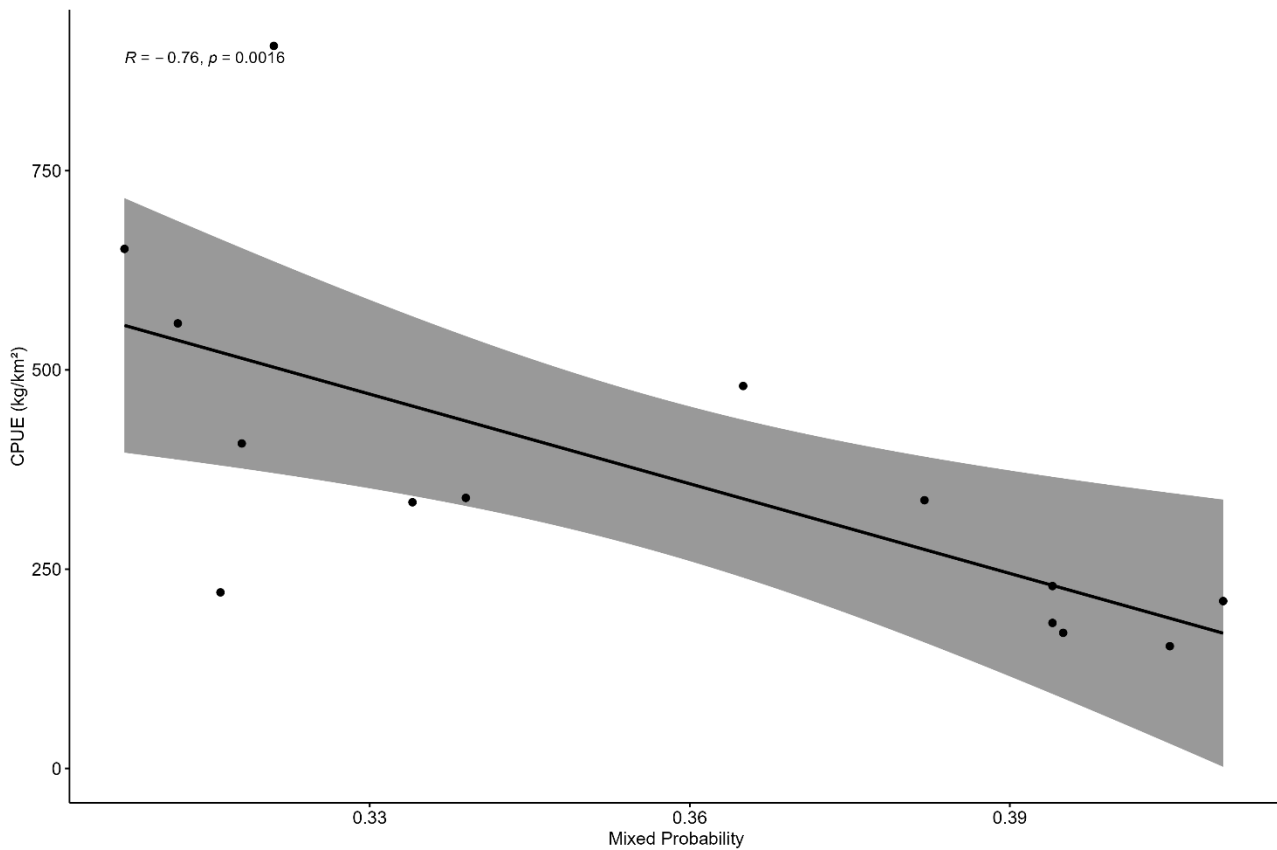


Figure 10-17 Linear correlation (Spearman method) between the mixed substrate proportion of a haul based on Al-Hamdani et al. (2015), (x-axis) and the CPUE (kg km⁻²) of commercial-sized (i.e. landings) **plaice (PLE)** (y-axis). Shaded areas represent the 95% confidence interval.

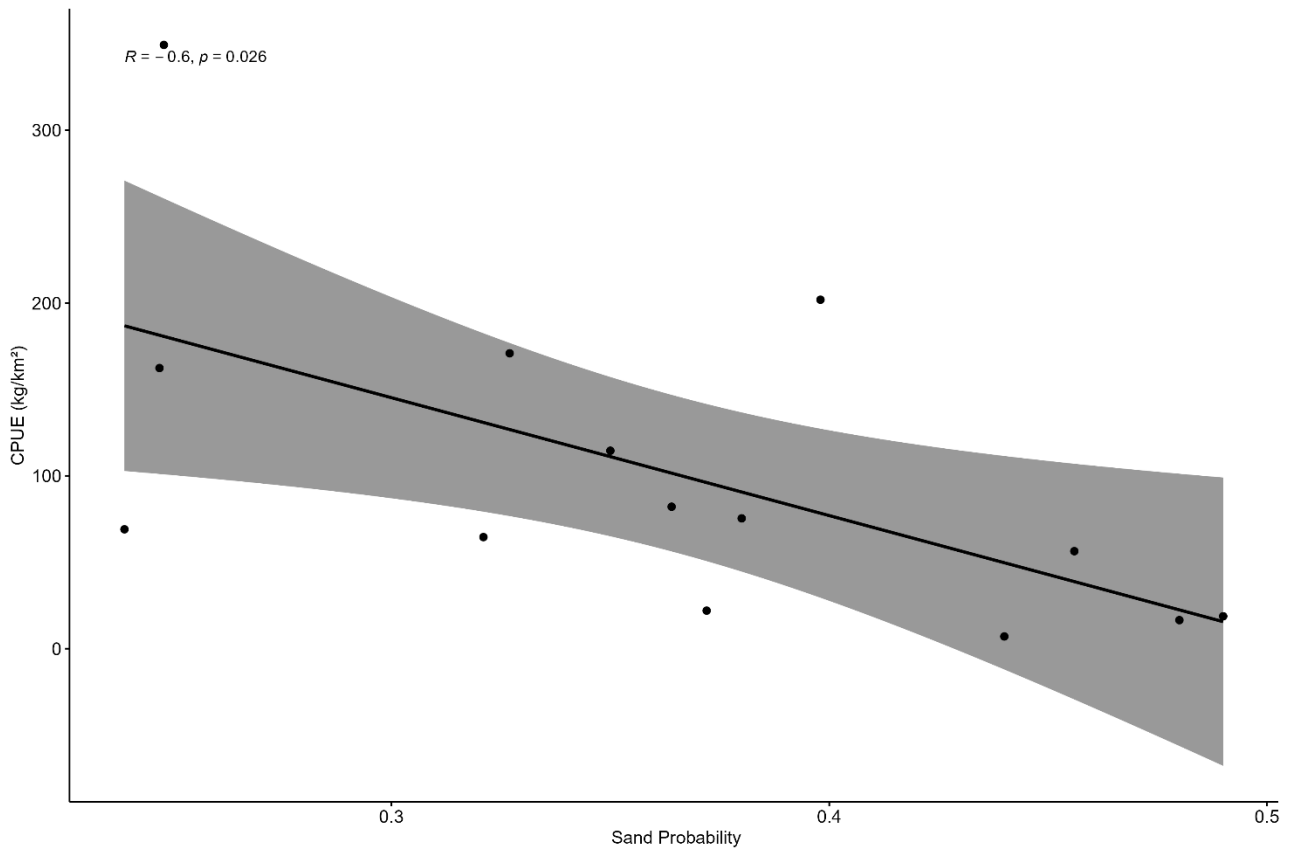


Figure 10-18 Linear correlation (Spearman method) between the sand substrate proportion of a haul, based on OceanBox B.V. (2025) (x-axis) and the CPUE (kg km⁻²) of commercial-sized (i.e. landings) **cod (COD)** (y-axis). Shaded areas represent the 95% confidence interval.

10.4.1.3. Habitat type – WASSP

Commercial-sized cod exhibited a correlation with all three habitat types. For the reef habitat, a significant positive correlation was found ($R = 0.67, p < 0.01$) (**Figure 10-19**), whilst negative correlation were observed for the reef candidate ($R = -0.56, p < 0.05$) (**Figure 10-20**) and non-reef ($R = -0.71, p < 0.01$) (**Figure 10-21**) habitat types.

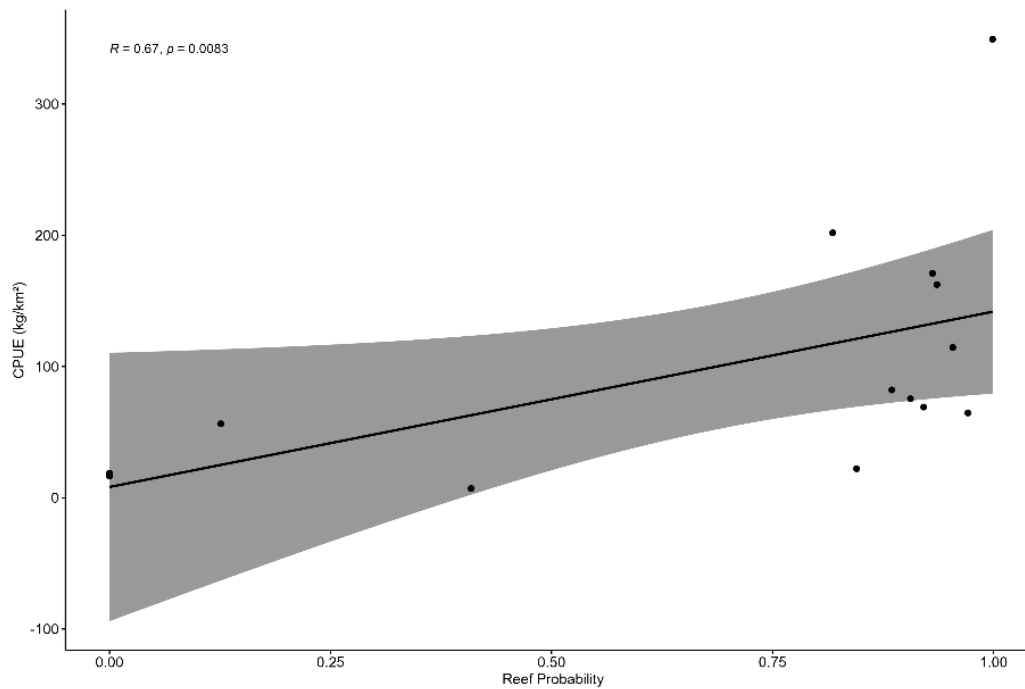


Figure 10-19 Linear correlation (Spearman method) between the reef habitat proportion of a FSSH, based on OceanBox B.V. (2025) (x-axis) and the CPUE (kg km⁻²) of commercial-sized (i.e. landings) **cod (COD)** (y-axis). Shaded areas represent the 95% confidence interval.

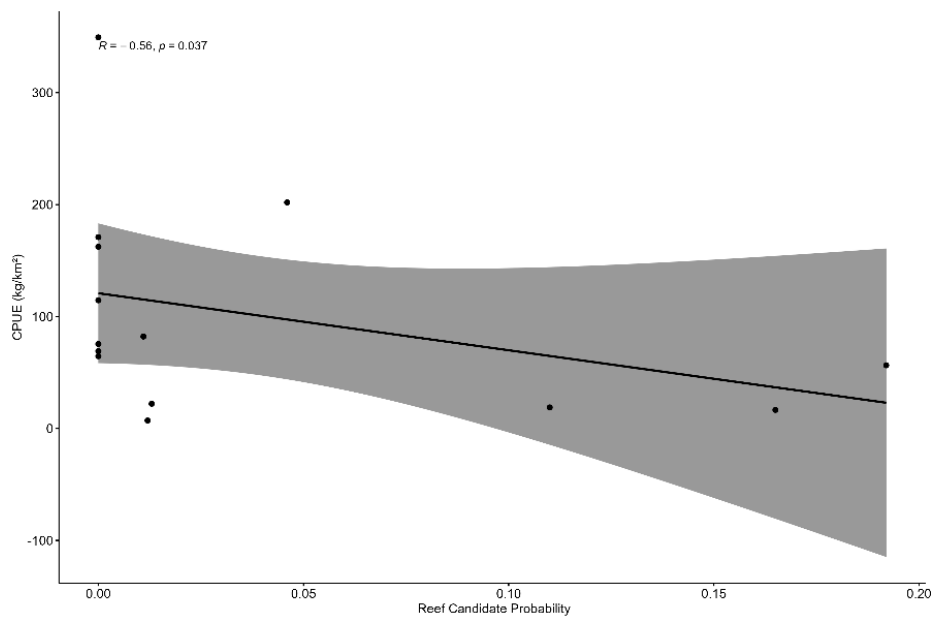


Figure 10-20 Linear correlation (Spearman method) between the reef candidate habitat proportion of a FSSH, based on OceanBox B.V. (2025) (x-axis) and the CPUE (kg km⁻²) of commercial-sized (i.e. landings) **cod (COD)** (y-axis). Shaded areas represent the 95% confidence interval.

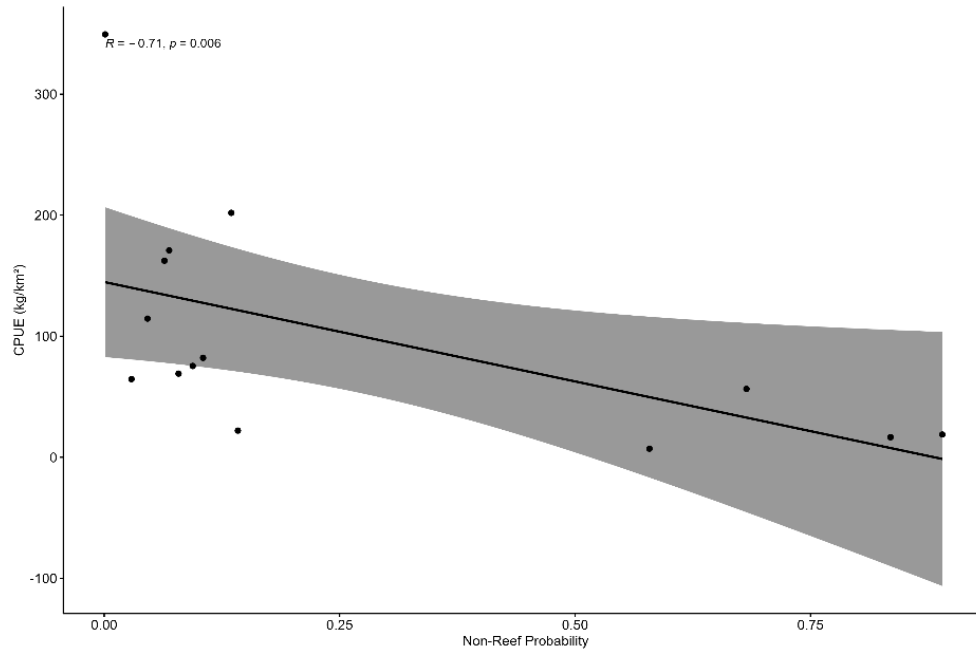


Figure 10-21 Linear correlation (Spearman method) between the non-reef habitat proportion of a FSSH, based on OceanBox B.V. (2025) (x-axis) and the CPUE (kg km⁻²) of commercial-sized (i.e. landings) **cod (COD)** (y-axis). Shaded areas represent the 95% confidence interval.

10.4.2. Discards

10.4.2.1. Substrate – Literature

Regarding the discards, plaice (PLE; $p = 0.0036$) and grey gurnard (GUG; $p = 0.0091$) both exhibit a positive response to an increased fraction of sandy substrate (**Figure 10-22**). No significant correlations were found between any discard species and the proportion of mixed substrate in the sampled hauls. Grey gurnard exhibited a negative correlation with the stone proportion ($R = -0.73, p < 0.01$) (**Figure 10-23**).

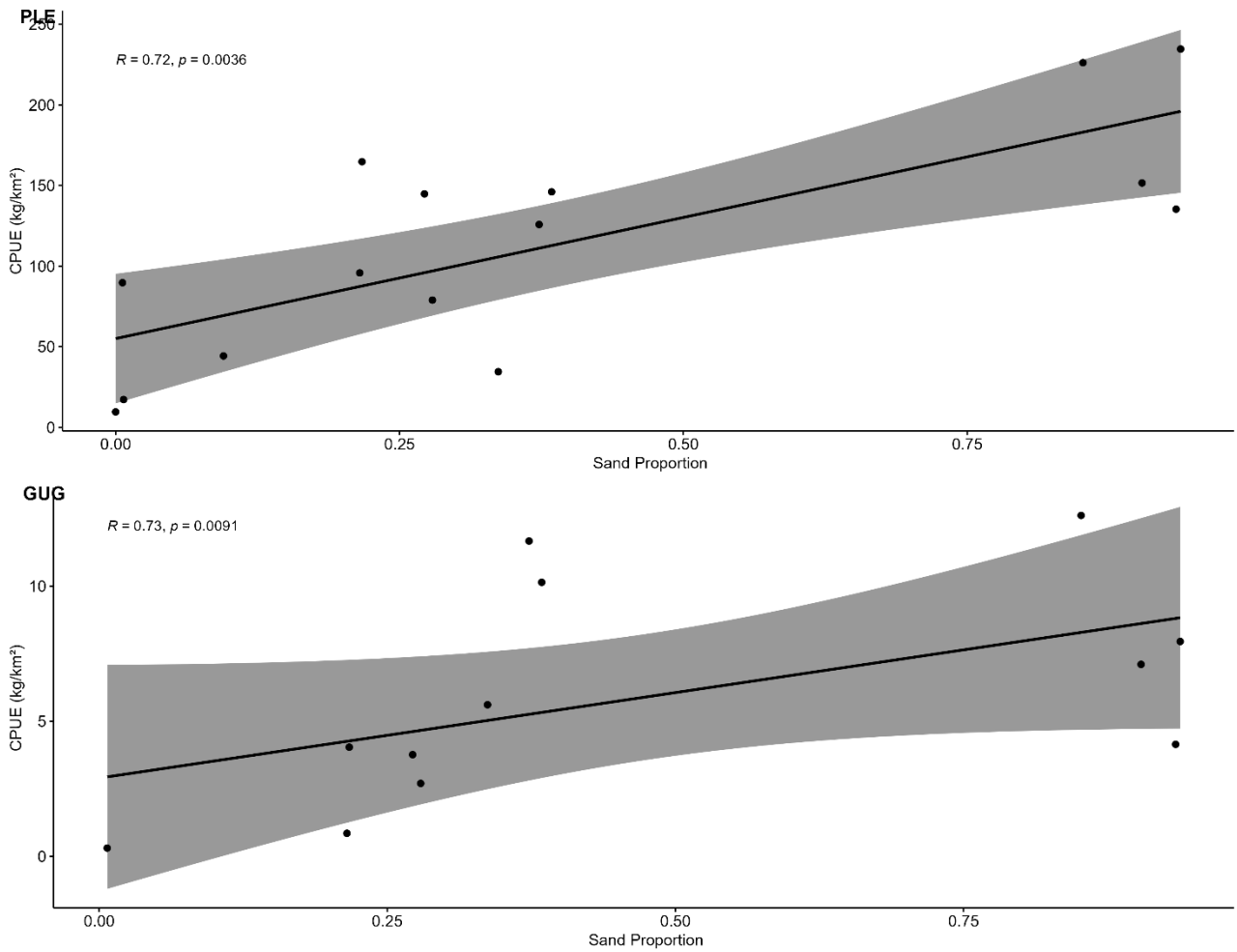


Figure 10-22 Linear correlations (Spearman method) between the “sand proportion” of a FSSH, based on Al-Hamdani et al. (2015), (x-axis) and the CPUE (kg km⁻²) of under-sized (i.e. discards) **plaice (PLE)** and **grey gurnard (GUG)** (y-axis). Shaded areas represent the 95% confidence interval.

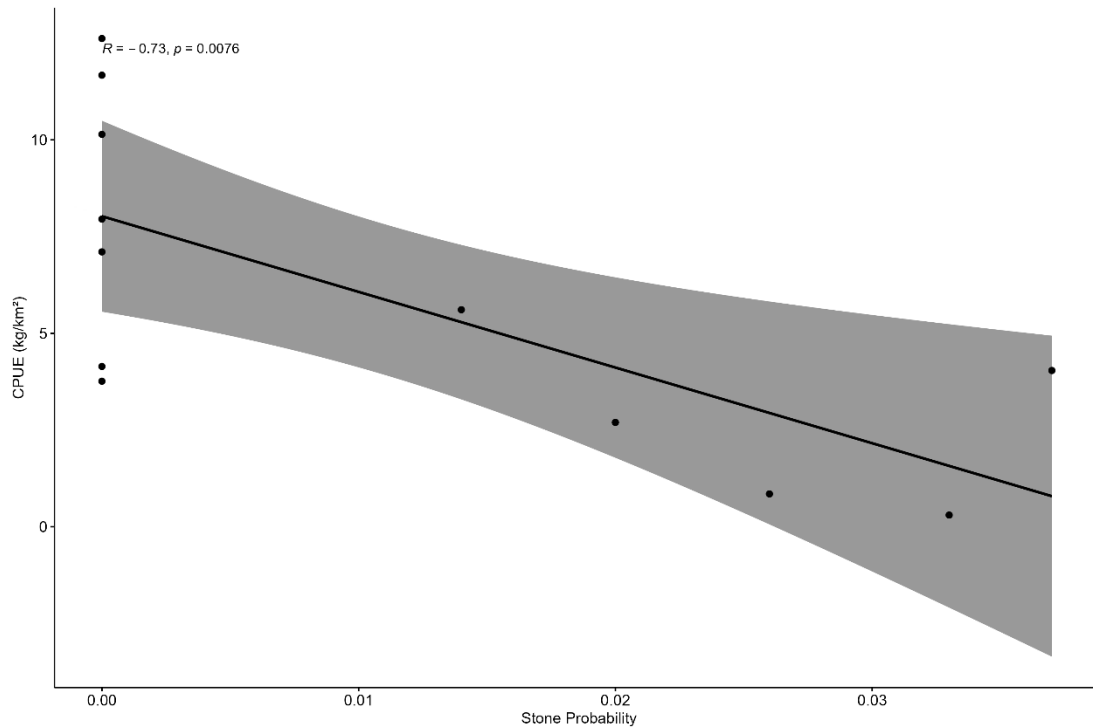


Figure 10-23 Linear correlations (Spearman method) between the “stone proportion” of a FSSH, based on Al-Hamdani et al. (2015), (x-axis) and the CPUE (kg km⁻²) of under-sized (i.e. discards) **grey gurnard (GUG)** (y-axis). Shaded areas represent the 95% confidence interval.

10.4.2.2. Substrate - WASSP

No species was found to be significant related to the substrate type, defined by OceanBox B.V. (2025).

10.4.2.3. Habitat type – WASSP

Discard plaice (PLE) is positively correlated with the non-reef ($R = 0.55$, $p < 0.05$) habitat type, illustrated by Figure 10-24.

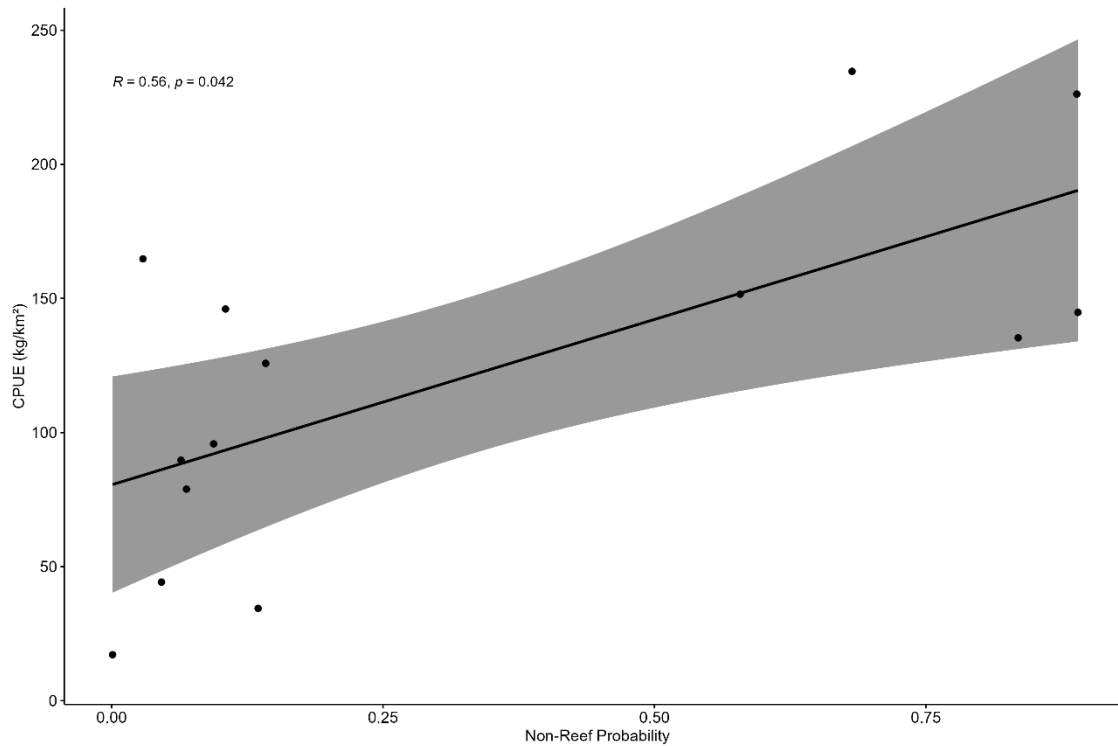


Figure 10-24 Linear correlation (Spearman method) between the non-reef habitat proportion of a FSSH, based on OceanBox B.V. (2025) (x-axis) and the CPUE (kg km⁻²) of under-sized (i.e. discards) **plaice (PLE)** (y-axis). Shaded areas represent the 95% confidence interval.

10.4.3. Benthos

10.4.3.1. Substrate-Literature

Regarding the benthic community, significant correlations were found for edible crab (*Cancer pagurus*), common starfish (*Asterias rubens*) and seven-armed starfish (*Luidia ciliaris*). Edible crab exhibited a negative correlation to the stone fraction of a sampled haul ($p < 0.05$, $R = -0.59$) (**Figure 10-25**), whilst a significant positive correlation was found for the sand substrate ($p < 0.01$, $R = 0.72$) (**Figure 10-26**). In addition, common starfish seems to be negatively correlated with the mixed substrate type ($p < 0.05$, $R = -0.85$) (**Figure 10-27**). Furthermore, seven-armed starfish exhibited a negative correlation with the sand substrate ($p < 0.05$, $R = -0.94$) (**Figure 10-28**).

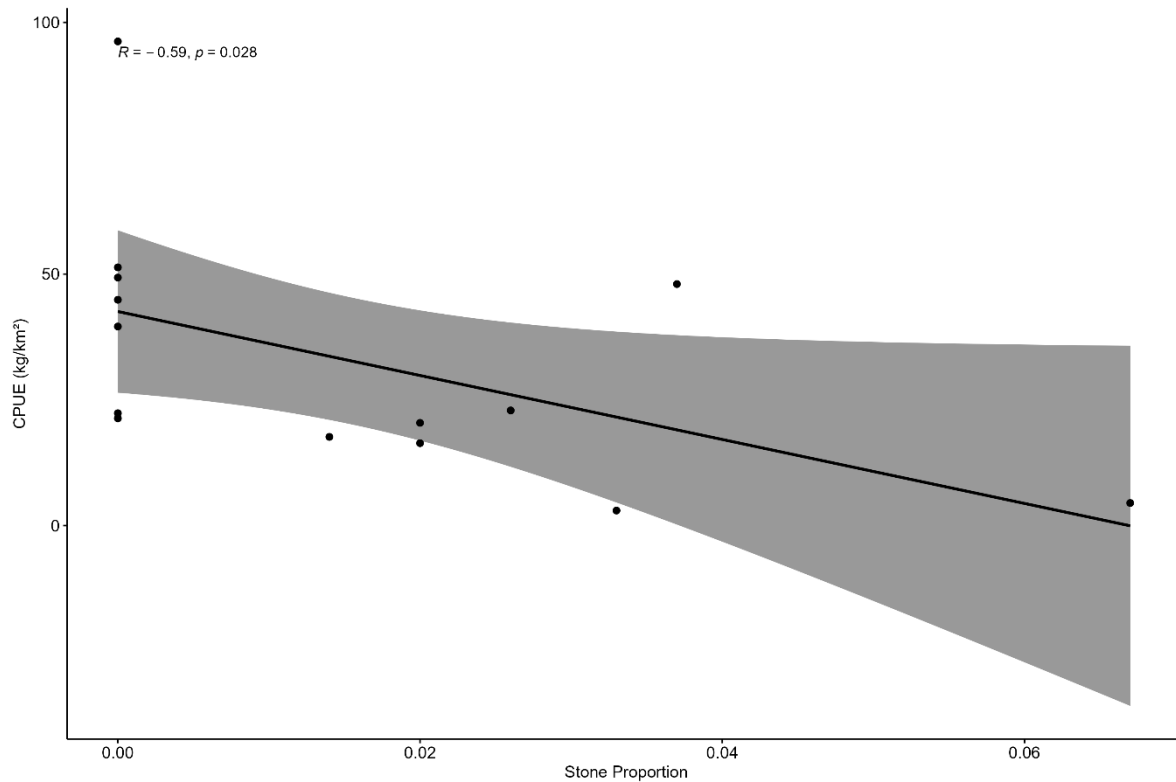


Figure 10-25 Linear correlations (Spearman method) between the “stone proportion” of a FSSH, based on Al-Hamdani et al. (2015), (x-axis) and the CPUE (kg km⁻²) of *edible crab (Cancer pagurus)* (y-axis). Shaded areas represent the 95% confidence interval.

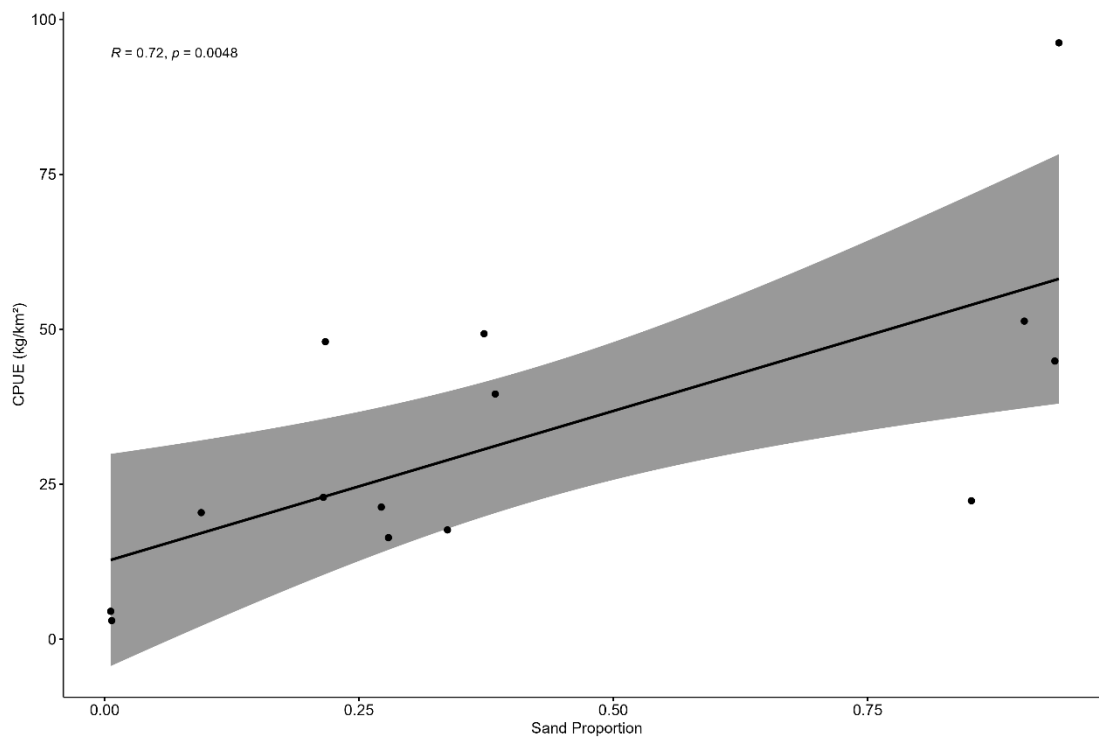


Figure 10-26 Linear correlations (Spearman method) between the “sand proportion” of a FSSH, based on Al-Hamdani et al. (2015), (x-axis) and the CPUE (kg km⁻²) of *edible crab (Cancer pagurus)* (y-axis). Shaded areas represent the 95% confidence interval.

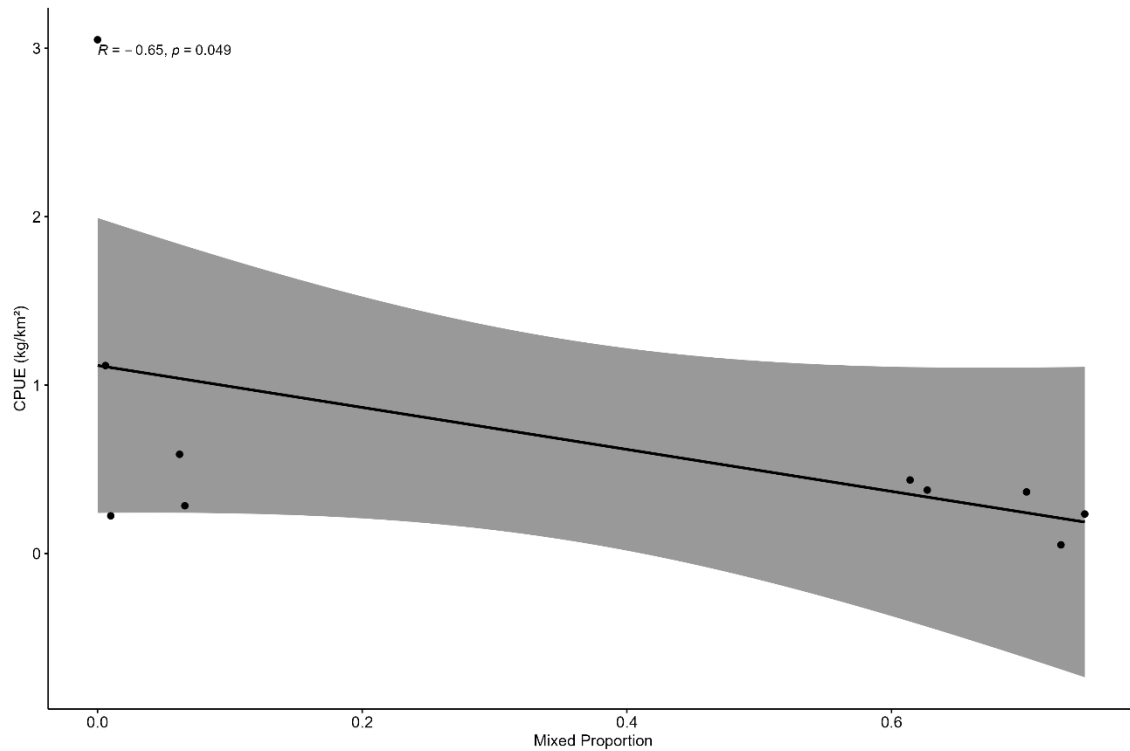


Figure 10-27 Linear correlations (Spearman method) between the “mix proportion” of a FSSH, based on Al-Hamdani et al. (2015), (x-axis) and the CPUE (kg km⁻²) of *common starfish (Asterias rubens)* (y-axis). Shaded areas represent the 95% confidence interval.

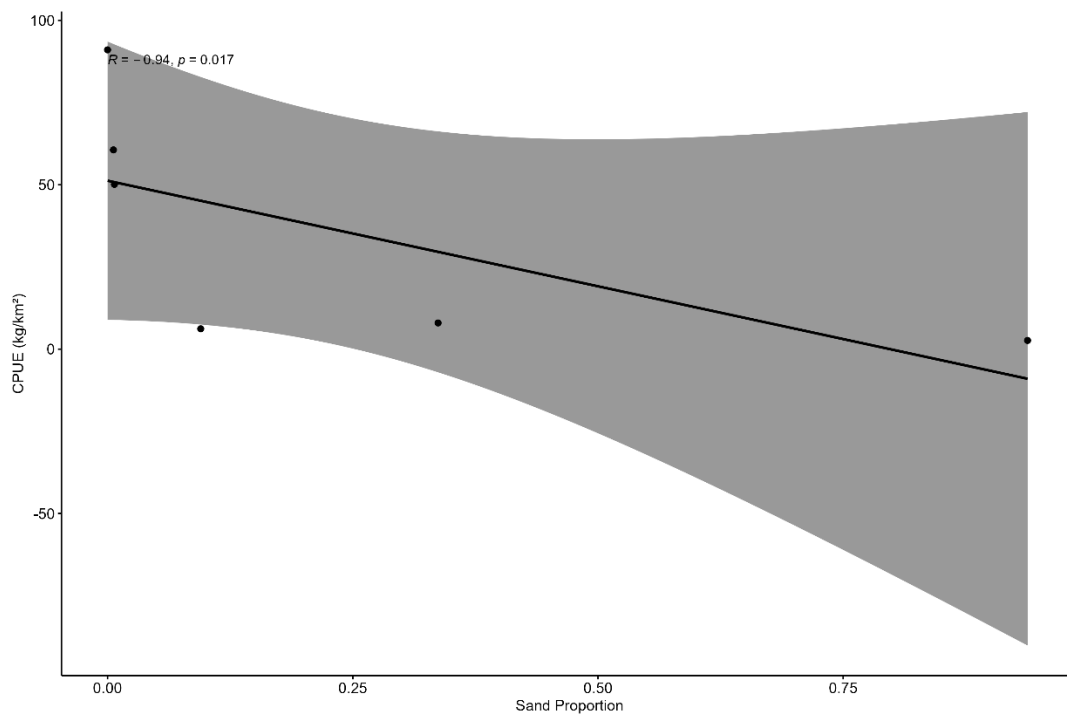


Figure 10-28 Linear correlations (Spearman method) between the “sand proportion” of a FSSH, based on Al-Hamdani et al. (2015), (x-axis) and the CPUE (kg km⁻²) of *seven-armed starfish (Luidia ciliaris)* (y-axis). Shaded areas represent the 95% confidence interval.

10.4.3.2. Substrate-WASSP

No significant linear correlations were found between the proportion of sand, mix or stone (WASSP-based) and the CPUE of the selected benthic species, likely due to the low sample amount.

10.4.3.3. Habitat type - Literature

No significant linear correlations were found between the proportion of non-reef, reef candidate or reef and the CPUE of the selected benthic species.

10.4.4. Summary

Table 10-3 summarizes the results of the above describe correlation analysis. Correlations were made between the CPUE of fish and benthos, and present substrate and habitat type. As described in the introduction of §10.4, substrate classification is based on two data sources: results of Al-Hamdani et al. (2015) (AL), and results of the conducted backscatter analysis by OceanBox B.V. (2025) (OB), as presented in this report. Regarding the habitat classification, only results from OceanBox B.V. (2025) were used.

***Table 10-3** Summary of the correlation plots as described in the previous sections. Species are divided into three categories: landings (L), discards (D) and benthos (B). Correlations were made between the CPUE of fish and benthos, and present substrate and habitat type. Classification of present substrate type is based on two data sources: based on the results of Al-Hamdani et al. (2015), indicated by AL, and results of the conducted backscatter analysis by OceanBox B.V. (2025), indicated by OB. Regarding the habitat classification, only one data was used, namely OceanBox B.V. (2025). This is indicated by N/A in the table. Species highlighted in green exhibited a significant positive correlation, species highlighted in red exhibited a significant negative correlation to the corresponding substrate or habitat type. When no significant correlations were found, a “/” is displayed.*

Size Class	Sand		Mix		Stone		Reef		Reef Candidate		Non-Reef	
	AL	OB	AL	OB	AL	OB	AL	OB	AL	OB	AL	OB
L	HAD											
	POL	COD	/	PLE	COD	/	N/A	COD	N/A	COD	N/A	COD
	LEM											
D	PLE											
	GUG	/	HAD	/	GUG	/	N/A	/	N/A	/	N/A	PLE
B	<i>C. pagurus</i>											
	<i>L. ciliaris</i>	/	<i>A. rubens</i>	/	<i>C. pagurus</i>	/	N/A	/	N/A	/	N/A	/

10.5. Cluster Analysis

A Hierarchical Cluster Analysis is performed to investigate potential clustering of hauls based on species composition (landings, discards, benthos) in accordance with substrate or habitat type. First, the different clusters are defined (§11.5.1), which represents samples that are more related to each other. Next, the correspondence with the different substrate or habitat types is calculated (§11.5.2). Finally, species composition of each cluster is also visualized.

10.5.1. Clustering groups

10.5.1.1. Landings

The landings tend to cluster into two main clusters on a high dissimilarity level (0.8) (Figure 10-29). However, on a lower level (e.g. 0.50) four main clusters are visible. The value of 0.50 (Figure 10-29, red line) is therefore arbitrarily chosen to divide FSSHs into four different clusters, which are visualized in Figure 10-30.

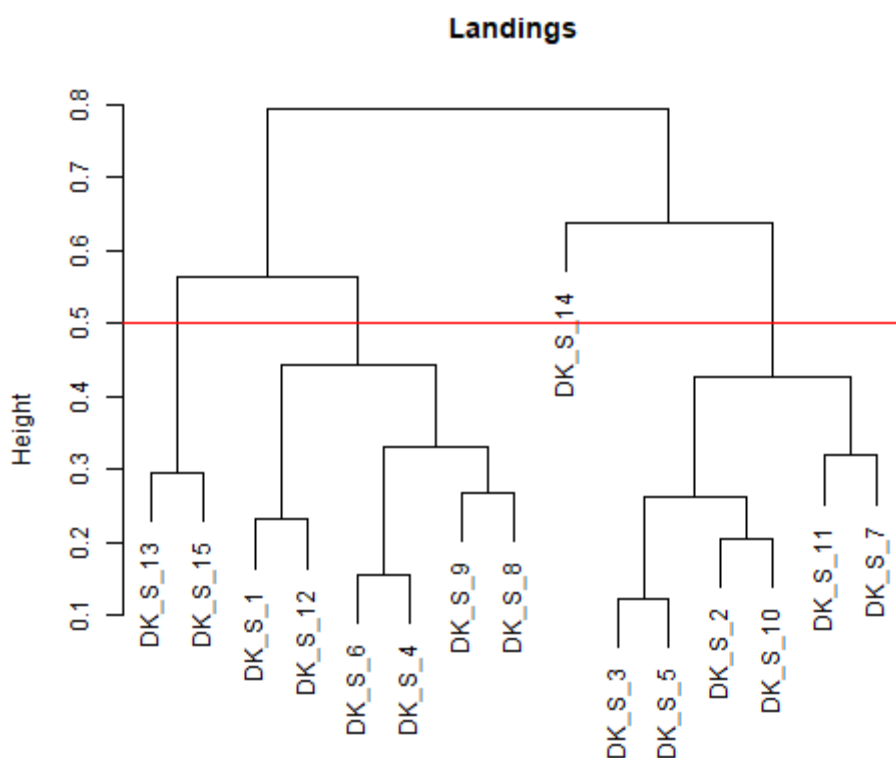


Figure 10-29 Cluster analysis of the CPUE of the landing species. The arbitrary level of 0.5 is highlighted with a red line.

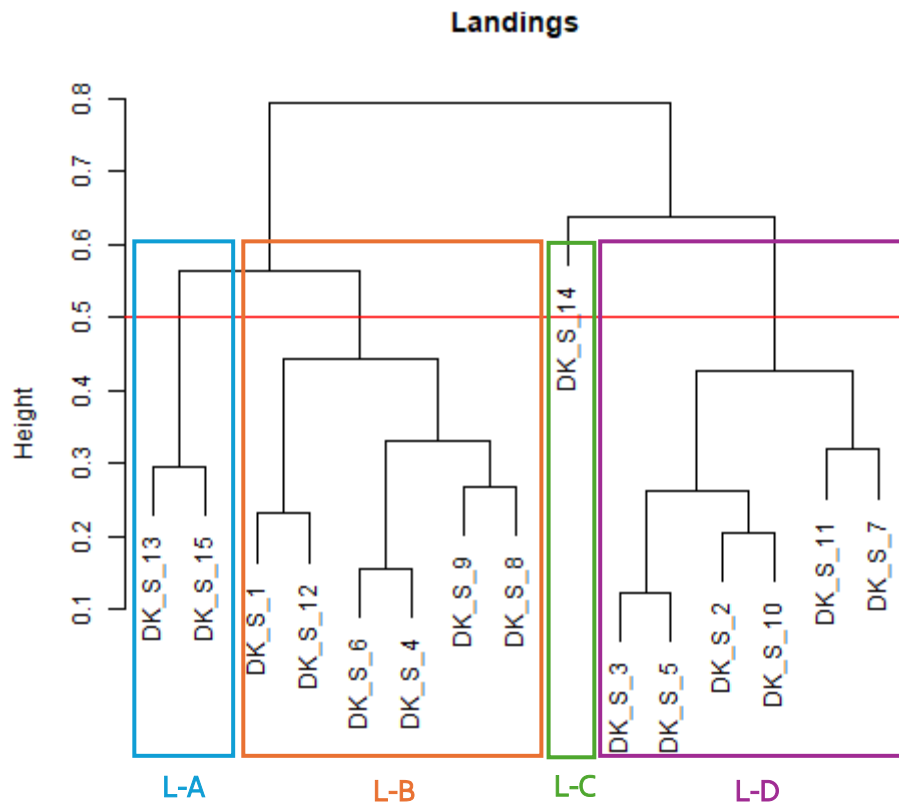


Figure 10-30 Cluster analysis of the CPUE of the landing species. The cut-off value of 0.50 is highlighted in red. The arbitrarily chosen clusters are highlighted by the colored rectangles.

10.5.1.2. Discards

Just like the landings, two main clusters are already formed on a high dissimilarity level (0.9) (**Figure 10-31**). Therefore, level 0.5 is chosen again to divide the various FSSHs into different clusters, which can be seen in **Figure 10-32**.

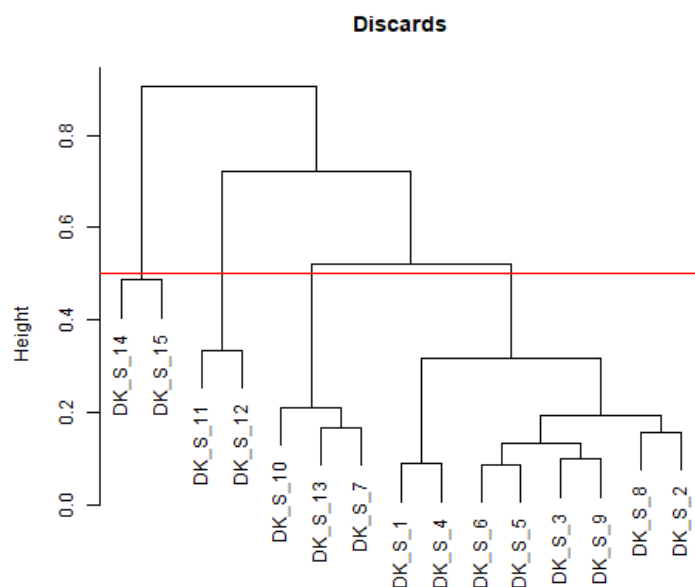


Figure 10-31 Cluster analysis of the CPUE of the discard species. The cut-off value of 0.5 is highlighted in red.

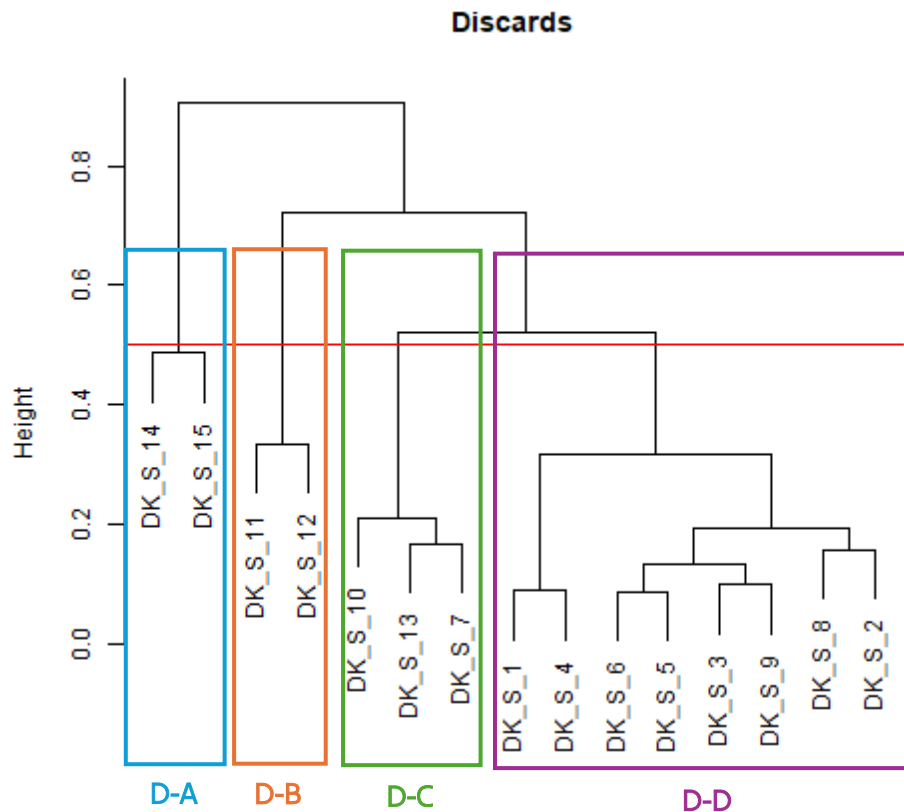


Figure 10-32 Cluster analysis of the CPUE of the discard species. The cut-off value of 0.5 is highlighted in red. The arbitrarily chosen clusters are highlighted by the colored rectangles.

10.5.1.3. Benthos

Within the benthos category, branches split up already on higher dissimilarity level (**Figure 10-33**). Therefore, the cut-off value for benthos is chosen to be 0.6, because for lower values, too many clusters would be formed, and results would be less distinct. It also indicates 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 10-34**.

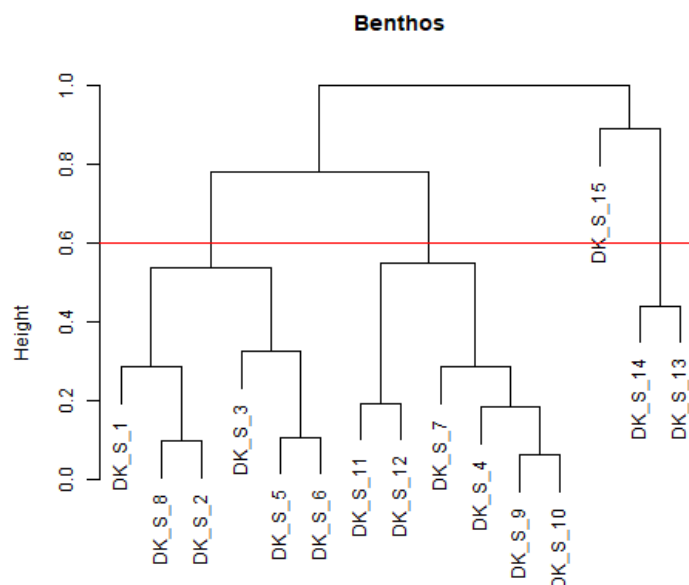


Figure 10-33 Cluster analysis of the CPUE of benthic species. The cut-off value of 0.6 is highlighted in red.

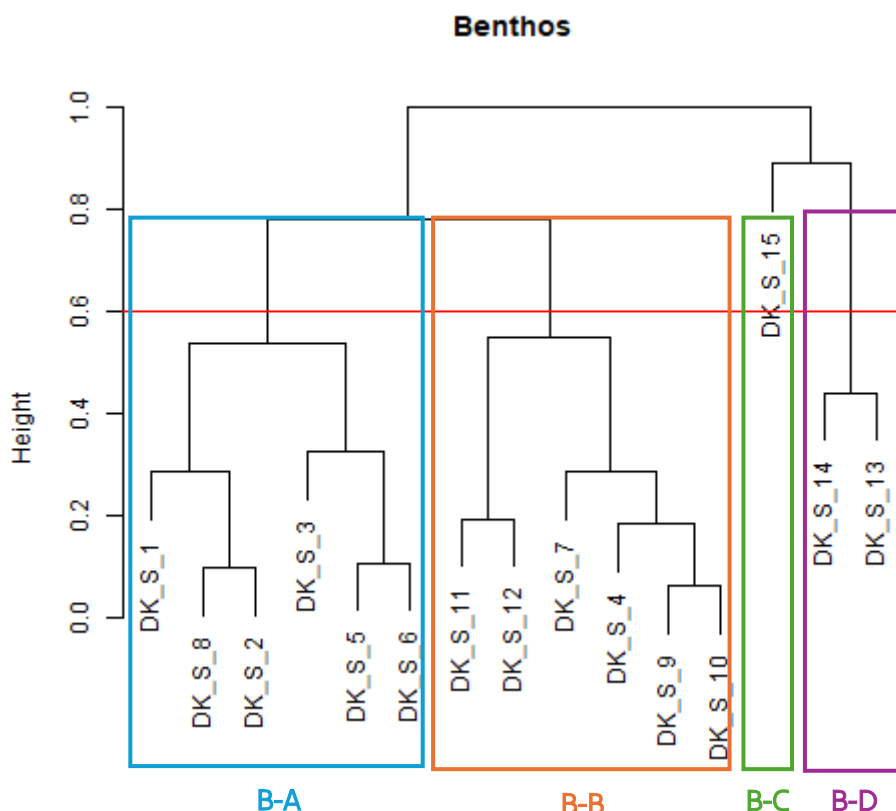


Figure 10-34 Cluster analysis of the CPUE of the benthic species. The cut-off value of 0.6 is highlighted with red. The arbitrarily chosen clusters are highlighted by the colored rectangles.

10.5.2. Cluster-Substrate/Habitat Relation

For each defined landing (L-), discard (D-) and benthic (B-) cluster, the percentage of present substrate and habitat type is calculated and summarized in **Table 10-4**, **Table 10-5** and **Table 10-6**, respectively. Just as in other sections of this report, two substrate classifications are made, one based on the results from Al-Hamdani et al. (2015) and EMODnet (2022), and one based on results from the presented backscatter analysis conducted by OceanBox B.V. (2025).

In addition to these percentages, stackplots are provided which demonstrate the catch composition per cluster.

10.5.2.1. Landings

For both data sources, cluster L-B seems to be dominated by the sand “substrate” and cluster L-D by the mixed substrate (**Table 10-4**). Cluster L-A contains, based on OceanBox B.V. (2025) two hauls which can be classified as “stone”, but based on literature results, this cluster forms a combination of one “mixed” and one “stony” haul. Additionally, the haul present in L-C is classified as “sand” by literature, but as “stone” by OceanBox B.V. (2025).

When looking at the catch composition per cluster (**Figure 10-35**), cluster L-B, which was associated with the substrate type “sand”, exhibits the largest plaice (PLE) fraction of all four clusters, with a total share of 72.83% of the total CPUE. Additionally, this cluster also holds the smallest cod (COD) fraction of all four landing clusters, with only 8.75% of the total CPUE. Furthermore, haddock (HAD) has the second largest CPUE of this cluster, with a share of 10.00%. common dab (DAB), which is usually also associated with sandy substrates, represents 1.56% of the total CPUE (Ruiz, 2008). Lemon sole, usually seen on rocky substrates, represents 1.42% of the total CPUE (Barnes, 2008).

Cluster L-D, which was classified as “mix”, is still dominated by a large plaice (PLE) fraction -50.19%-, although this percentage is one-third smaller compared to the fraction present in cluster L-B. Common dab (DAB) also records a slight decrease of CPUE compared to L-B, with a presence of 0.90% of the total CPUE in L-D. On the contrary, haddock (HAD; 15.21%), cod (COD; 22.57%) and lemon sole (LEM; 2.99%) all record a higher CPUE in cluster L-D compared to cluster L-B. Additionally, monkfish (MON), which was not present in cluster L-B, has a relative abundance of 1.82% in cluster L-D.

Table 10-4 Presence of the different substrate (S) and habitat (H) types defined by literature ((Al-Hamdani et al. (2015) & EMODnet (2022)) and the presented backscatter analysis (OceanBox B.V. (2025) within the different landing-clusters, as presented in §10.5.1.1. Sample sizes of the different clusters are given in the graph header (n = #).

	L-A (n = 2)	L-B (n = 6)	L-C (n = 1)	L-D (n = 6)
<u>Substrate: Al-Hamdani et al. (2015) & EMODnet (2022)</u>				
Sand	0.00%	66.67%	100.00%	16.67%
Mix	50.00%	33.33%	0.00%	83.33%
Stone	50.00%	0.00%	0.00%	0.00%
<u>Substrate: OceanBox B.V. (2025)</u>				
Sand	0.00%	83.33%	100.00%	16.67%
Mix	0.00%	0.00%	0.00%	83.33%
Stone	100.00%	16.67%	0.00%	0.00%
<u>Habitat: OceanBox B.V. (2025)</u>				
Reef	100.00%	33.33%	0.00%	83.33%
Non-Reef	0.00%	66.67%	100.00%	16.67%
Reef C	0.00%	0.00%	0.00%	0.00%

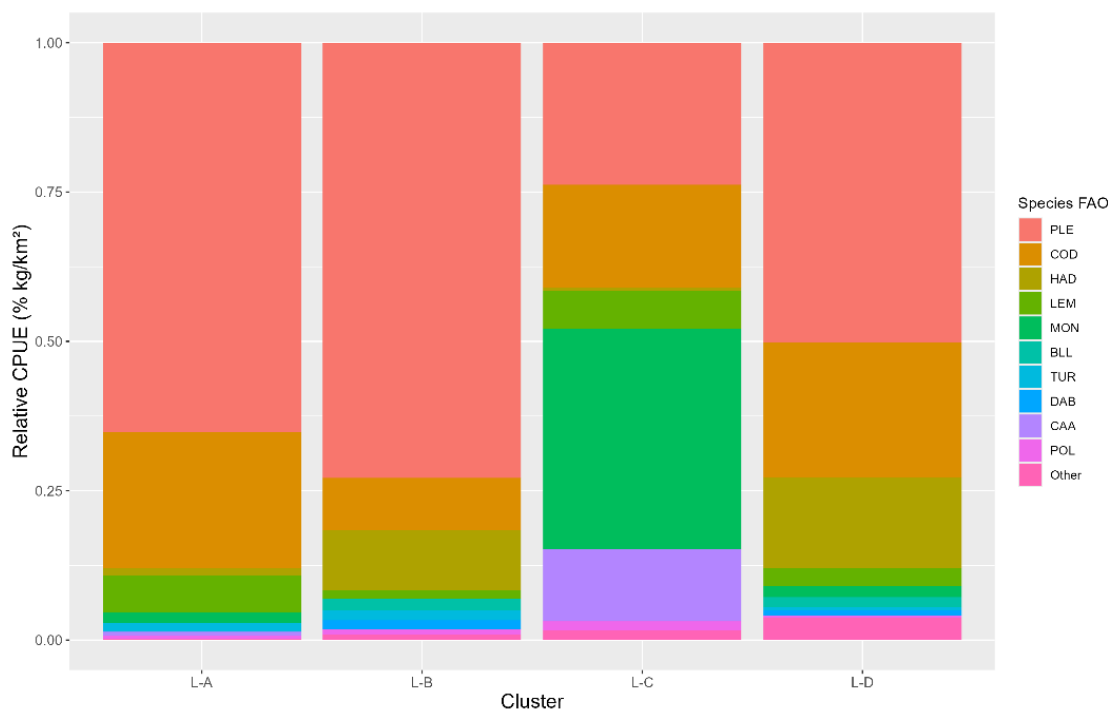


Figure 10-35 Catch composition of different landing clusters (L-) as presented by **Figure 10-30**. CPUE is expressed as relative abundance (% kg km⁻²).

10.5.2.2. Discards

Regarding the different discard clusters, both data sources indicate that cluster D-D contains primarily “sandy” hauls (62.5%) (**Table 10-5**). Additionally, cluster D-C contains two “mixed hauls” and one “stony” haul. Differences in classification occur in cluster D-A and D-B. ALH and EMODnet classify hauls in cluster D-A as “sand” or “mix”, whilst OB classifies these hauls as “stone”. On the contrary, hauls in cluster D-B are both classified as “mix” by ALH and EMODnet, while OB classifies one as “sand” and one as “mix”.

When looking at **Figure 10-36**, it can be seen that the different clusters are arranged by increasing plaice (PLE) fraction. Cluster D-A records the lowest fraction (30.17%), while cluster D-D holds the highest (85.44%). The latter is also, according to both ALH, EMODnet and OB, dominated by hauls labeled as “sand (62.5%)”. The second most abundant species in this cluster is grey gurnard (GUG; 3.95%), followed by cod (COD; 2.70%) and common dab (DAB; 2.30%). Besides cluster D-D, cluster D-C also holds a large share of plaice (PLE), with a relative abundance of 75.44%. In this cluster, cod is the second largest species present, with a share of 8.62% of the total CPUE, followed by ling (LIN; 4.12%) and starry ray (RJR; 3.07%). The latter is the most dominant species in cluster D-A, with a relative abundance of 46.33%. As said before, this cluster holds the lowest plaice fraction of all clusters, with only 30.17% of the total CPUE. Other species present are ling (LIN; 8.07%), cod (COD; 7.00%) and common dab (DAB; 5.27%). Finally, cluster D-B is also dominated by plaice, with a relative abundance of 44.21%, followed by lesser spotted dogfish (SYC; 9.51%), ling (LIN; 7.65%) and starry ray (RJR; 4.95%). In addition, grey gurnard (GUG) records a presence of 3.15%, common dab (DAB) 3.00% and turbot (TUR) 2.70%

Table 10-5 Presence of the different substrate (S) and habitat (H) types defined by literature (Al-Hamdani et al. (2015) & EMODnet (2022)) and the presented backscatter analysis (OceanBox B.V. (2025)) within the different discard-clusters, as presented in §10.5.110.5.1.2. Sample sizes of the different clusters are given in the graph header (n = ...).

D-A (n = 2) D-B (n = 2) D-C (n = 3) D-D (n = 8)

Substrate: Al-Hamdani et al. (2015) & EMODnet (2022)

Sand	50.00%	0.00%	0.00%	62.50%
Mix	50.00%	100.00%	66.67%	37.50%
Stone	0.00%	0.00%	33.33%	0.00%
<i>Substrate: OceanBox B.V. (2025)</i>				
Sand	50.00%	50.00%	0.00%	62.50%
Mix	0.00%	50.00%	66.67%	25.00%
Stone	50.00%	0.00%	33.33%	12.50%
<i>Habitat: OceanBox B.V. (2025)</i>				
Reef	50.00%	100.00%	100.00%	37.50%
Non-Reef	50.00%	0.00%	0.00%	62.50%
Reef C	0.00%	0.00%	0.00%	0.00%

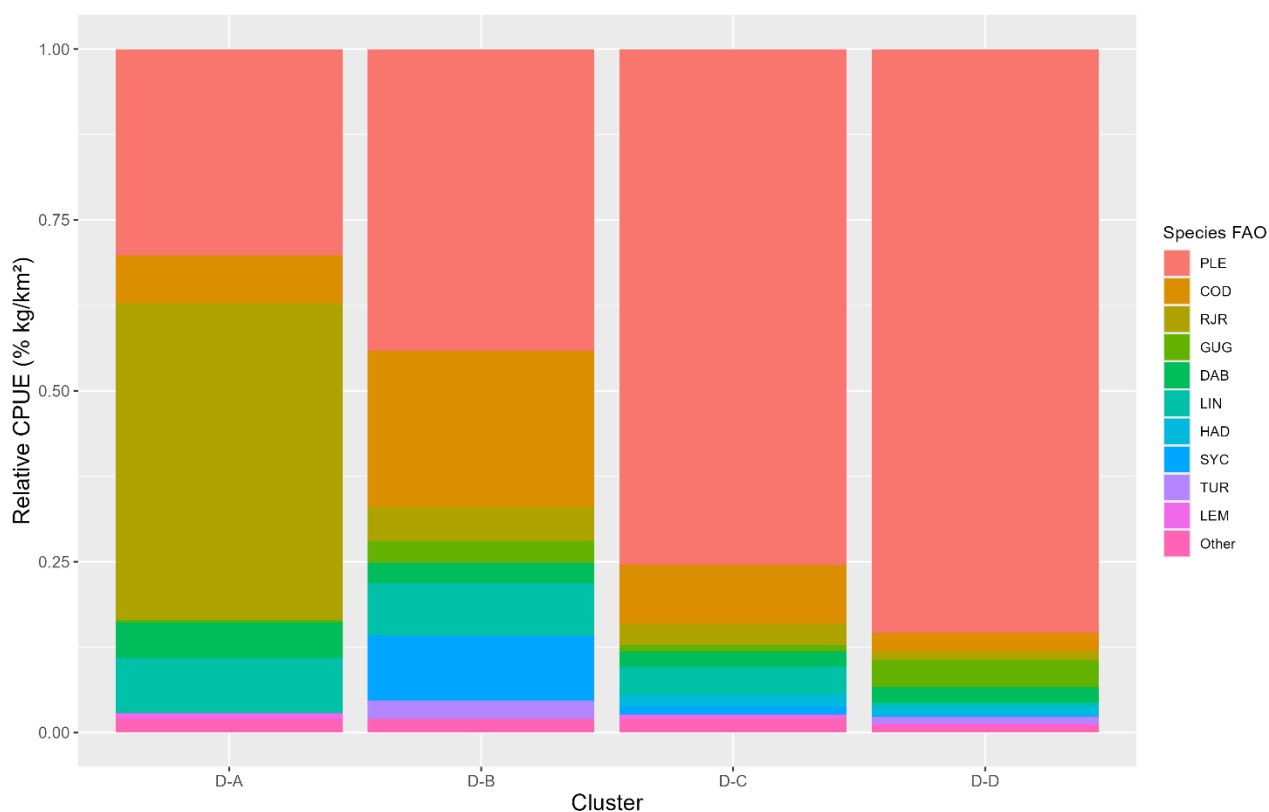


Figure 10-36 Catch composition of different discard clusters (D-) as presented by **Figure 10-32**. CPUE is expressed as relative abundance (% kg km⁻²). During haul DK_S_7, one (1) starry ray was present, but no weight was taken by accident. To create this graph, this abundance was discarded.

10.5.2.3. Benthos

Regarding the ALH and EMODnet classification in **Table 10-6**, cluster B-B records a dominance of hauls labeled as “mix” (“66.67%). Other cluster characterization, except for B-C which only contains one haul, is less pronounced. Both clusters B-A and B-D are fifty-fifty divided into two substrate types. Regarding

the OB classification, cluster B-A is dominated by “sandy” hauls, whilst cluster B-B is evenly divided into “sandy” and “mixed” hauls. Furthermore, hauls of cluster B-D are labeled as “stony”.

Regarding the stack plots of the benthic clusters (**Figure 10-37**), several trends can be observed. For example, dead man’s fingers (*Alcyonium digitatum*) is only dominant in cluster B-C (89.11%), which only contains one haul. Dominant species in other clusters are edible crab (*Cancer Pagurus*) (B-A, 59.33%; B-B, 55.29%) and seven-armed starfish (*Luidia ciliaris*) (B-D, 65.66%). Next, edible crab is predominantly present in clusters B-A and B-D but is (almost) absent in the other two clusters. In addition, hornwrack (*Flustra foliacea*), which is mainly present on rocky substrates (Tyler-Walters & Ballerstedt, 2007), has the highest abundance in cluster B-C (3.15%), followed by B-B (0.77%) and B-A (0.74). The species had the smallest relative CPUE in cluster B-D, only accounting for 0.55% of the total CPUE.

Table 10-6 Presence of the different substrate types defined by literature (Al-Hamdani et al. (2015) & EMODnet (2022)) and the presented backscatter analysis (OceanBox B.V. (2025)) within the different *benthic-clusters*, as presented in §10.5.110.5.1.3. Sample sizes of the different clusters are given in the graph header (n = ...).

	B-A (n = 6)	B-B (n = 6)	B-C (n = 1)	B-D (n = 2)
Substrate: Al-Hamdani et al. (2015) & EMODnet (2022)				
Sand	50.00%	33.33%	0.00%	50.00%
Mix	50.00%	66.67%	100.00%	0.00%
Stone	0.00%	0.00%	0.00%	50.00%
Substrate: OceanBox B.V. (2025)				
Sand	50.00%	50.00%	0.00%	50.00%
Mix	33.33%	50.00%	0.00%	0.00%
Stone	16.67%	0.00%	100.00%	50.00%
Habitat: OceanBox B.V. (2025)				
Reef	50.00%	66.67%	100.00%	50.00%
Non-Reef	50.00%	33.33%	0.00%	50.00%
Reef C	0.00%	0.00%	0.00%	0.00%

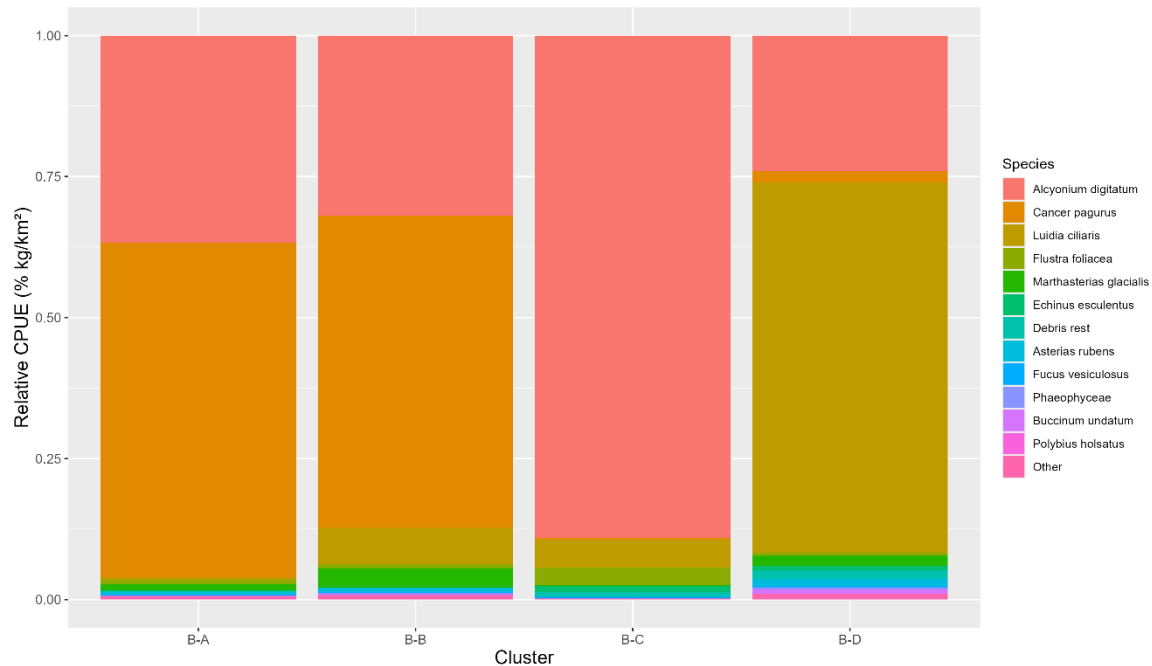


Figure 10-37 Catch composition of different benthos clusters (B-) as presented by **Figure 10-34**. CPUE is expressed as relative abundance (% kg km⁻²).

10.6. Principal Component Analysis – PCA

10.6.1. Landings

Figure 10-38 displays the relation of the different Fully-Sampled Scientific Hauls to the different present landing species. Potential clusters (4) are highlighted with red circles.

The first cluster (A) only contains haul DK_S_14, which differs from other hauls in terms of duration. In total, the haul lasted 150 minutes, approximately 2.5 times longer than other hauls, which lasted maximum 60 minutes. This haul is, according to the presented PCA, characterized by increased monkfish (MON) and Atlantic wolffish (CAA) abundances. Cluster B is mainly characterized by cod (COD), lemon sole (LEM), and to lesser extent turbot (TUR) and brill (BLL). Hauls part of this cluster were conducted on hard substrates (mix and stone). Especially haul DK_S_15 is characterized by a high abundance of boulders, as demonstrated by the underwater footage and experience of fishers. This group is also characterized by the abundance of plaice (PLE). This species is associated with softer substrates, which were more present during hauls in clusters C and D. Cluster C contains hauls which are almost completely located on soft substrates (e.g. DK_S_9) and are characterized by common dab (DAB). Lastly, cluster D is characterized by the presence of haddock (HAD) and small-spotted catshark (SYC).

In the annex, **Figure B- 16** and **Figure B- 17** show the same PCA plot as demonstrated above, but with an additional classification based on the present substrate and habitat type, respectively.

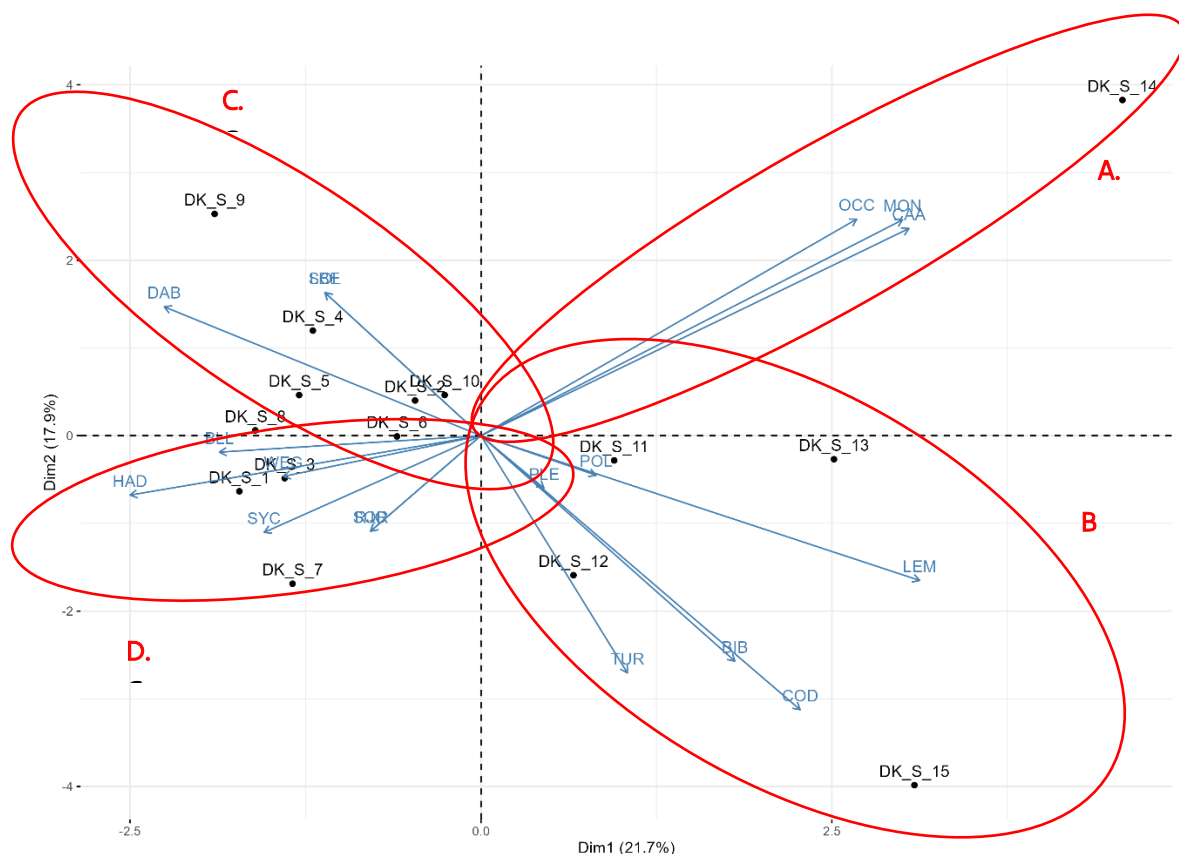


Figure 10-38 PCA plot of the different landing species. Potential clustering is highlighted with red circles.

10.6.2. Discards

Figure 10-39 displays the relation of the different FSSHs to the different present discard species. Just as the landing category, four different groups can be identified. one in each quadrant. Cluster A seems to hold five hauls and is characterized by the presence of cod (COD), ling (LIN), small-spotted catshark (SYC) and pouting (BIB). A second group (B) contains three hauls and is mainly characterized by starry ray (RJR). Third, group C also contains three hauls and is characterized by common dab (DAB). Lastly, cluster D contains four hauls, and is characterized by plaice (PLE), haddock (HAD) and grey gurnard (GUG).

Figure B- 18 and **Figure B- 19** represent the same PCA plot, but with an additional breakdown for the different substrate and habitat classes.

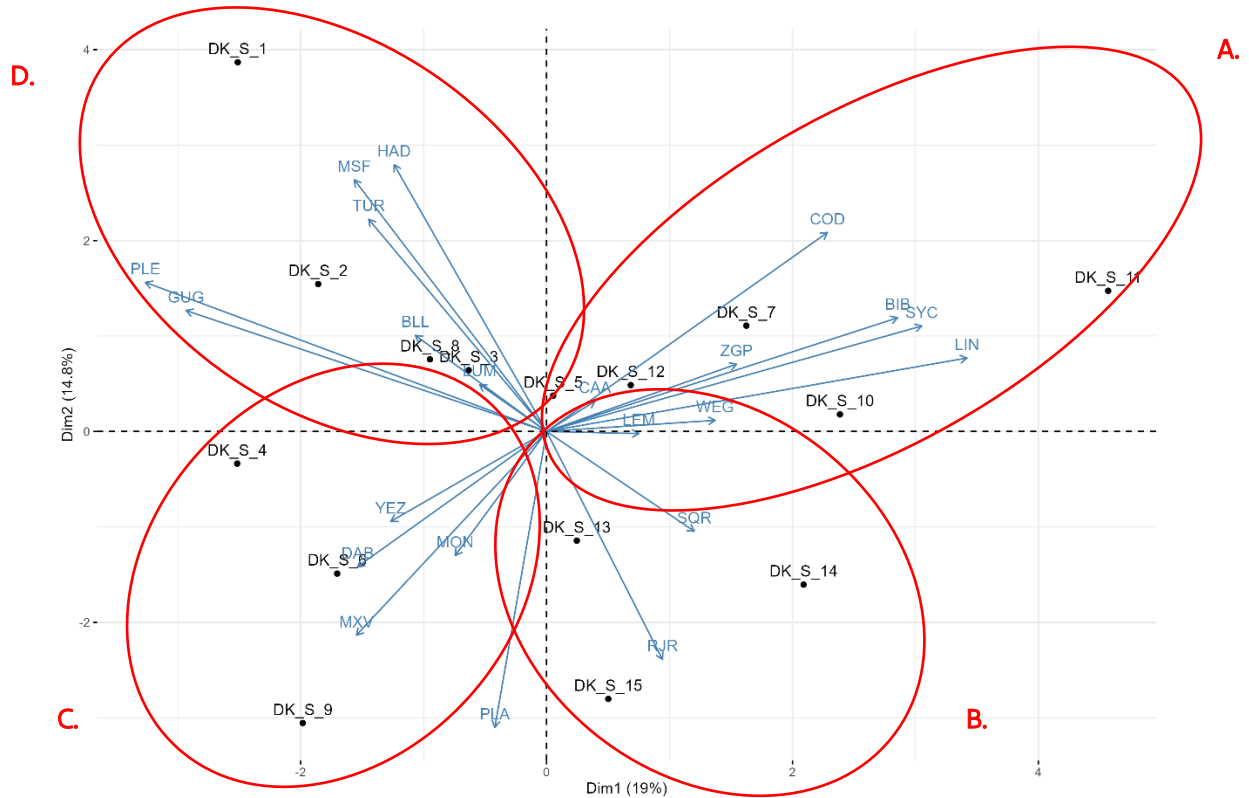


Figure 10-39 PCA plot of the different *discard* species. Potential clustering is highlighted with red circles.

10.6.3. Benthos

In contrast to the fish species, no clear clustering could be observed in **Figure 10-40** for the benthic species. Only two hauls can be distinguished from the rest: haul DK_S_14, characterized by e.g. common starfish (*Asterias rubens*), and haul DK_S_15, characterized by dead man's fingers (*Alcyonium digitatum*). All remaining hauls are grouped into a single cluster.

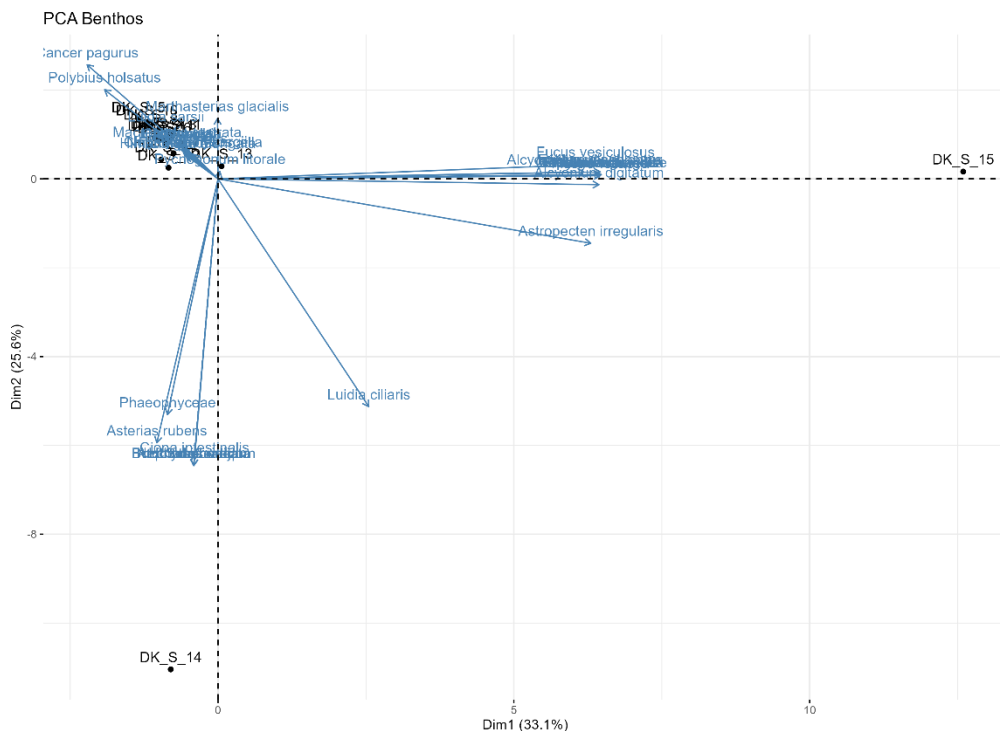


Figure 10-40 PCA plot of the different benthic species.

11. Underwater Footage

This section compares observations from underwater footage with findings reported in the literature (Al-Hamdani et al., 2015).

11.1. DK_S_3

11.1.1. Literature Profile

Based on literature, haul DK_S_3 can be split up into five sections: 3 parts (A, C, E) where a soft substrate is present, and two parts (B, D) where a mixed substrate is most dominant. Additionally, in the latter, reefs are also present. The five sections are also highlighted in **Figure 11-1**.

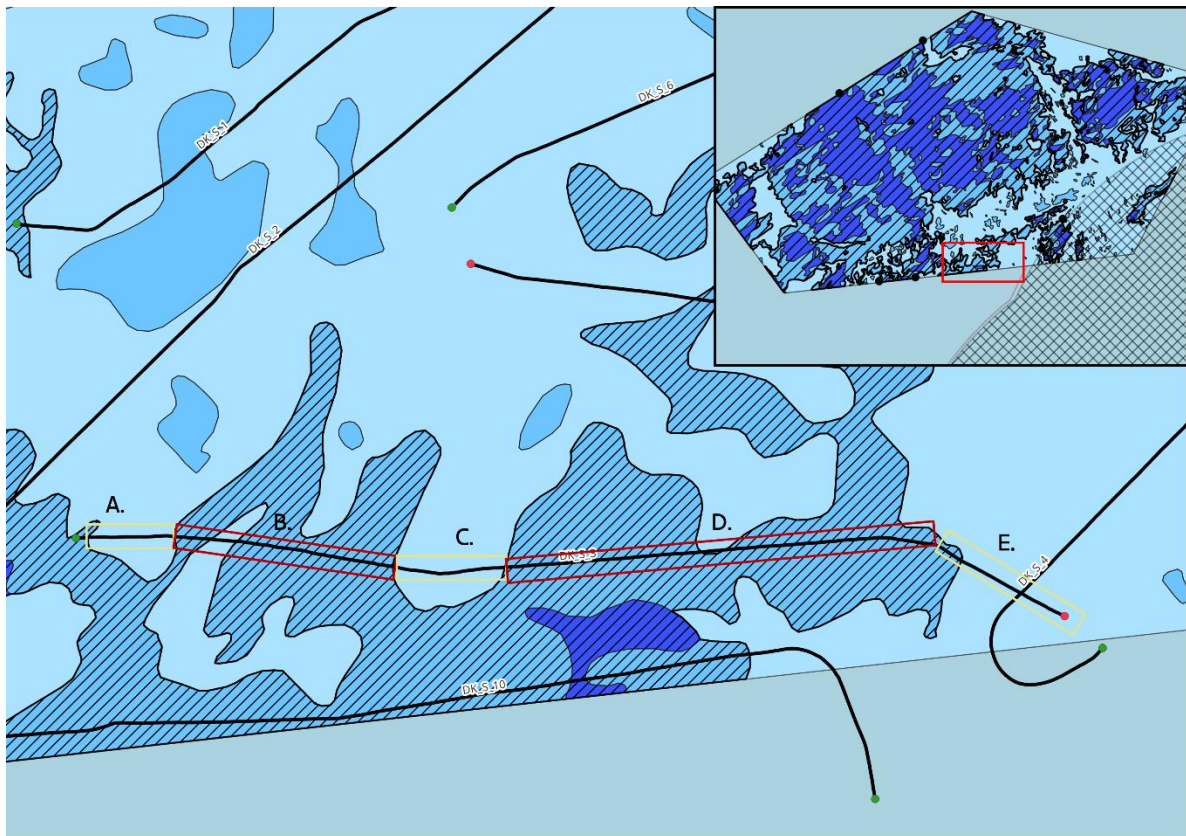


Figure 11-1 Trajectory of haul DK_S_3 with an additional breakdown in different segments. Yellow boxes indicate soft substrates; red boxes indicate the presence of harder substrates/reef structures. Shoot locations is highlighted with a green dot, haul location is highlighted with a red dot. Different substrate types are already identified in §3.2.1.

11.1.2. Underwater Footage

During the first five minutes of the recording, no boulders could be detected. At some points, the recordings also seem to be blurry, potentially caused by rising sediments (**Figure 11-2**). Seven minutes (± 0.4 nm) after the shoot, a first boulder was detected, after which various aggregates could be observed (**Figure 11-3**). The chains of the chain mat also start to vibrate fiercer compared to the first part of the recording, indicating harder substrates present (**Figure 11-4**). These boulder conglomerates could be seen for another ± 8 minutes (0.4 nm), after which the substrate seems to change again: no boulders can be detected, and chain vibration also seem to be reduced (**Figure 11-5**). After three minutes, chain vibration increases again, and more boulders also seem to be present (**Figure 11-6**). During the last part of the recording, a softer substrate is visible until the net is pulled back up again (**Figure 11-7**).

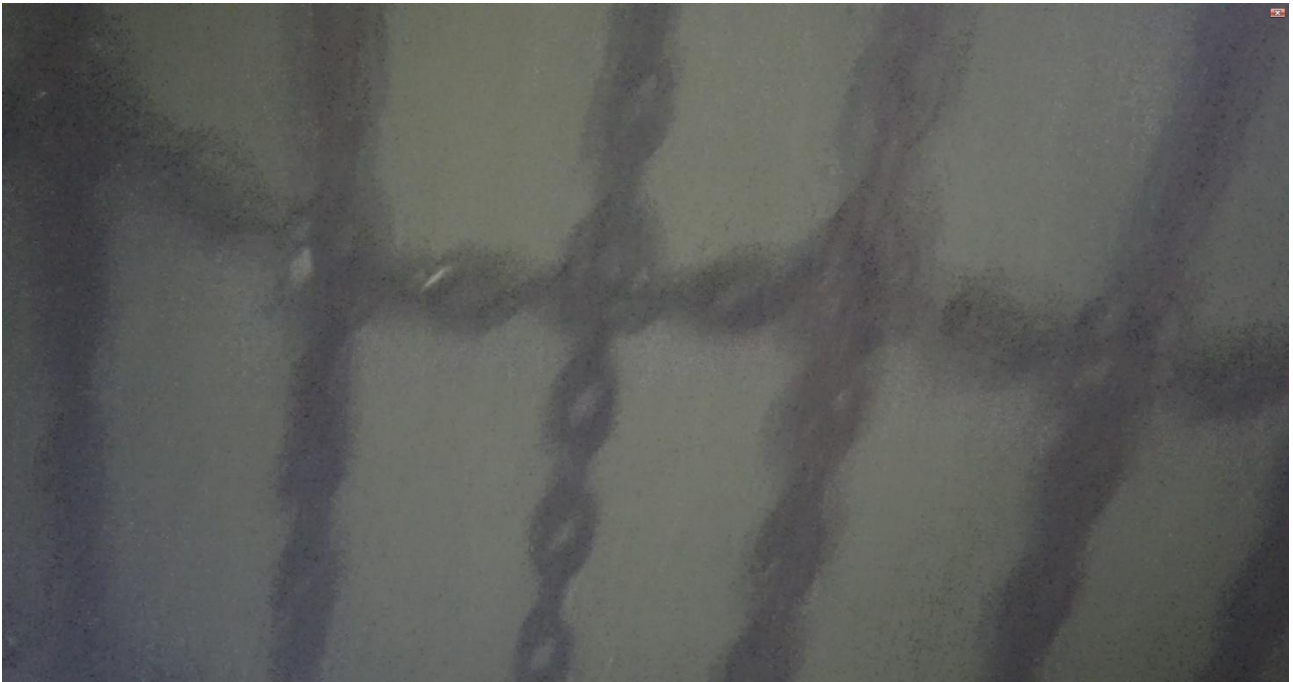


Figure 11-2 Substrate present during the first five minutes of haul DK_S_3. No boulders can be observed, and the image seems to be blurry, potentially caused by rising sediments.



Figure 11-3 First noticeable boulder that was detected during haul DK_S_3. Moment of detection occurred ± 5 minutes -0.29 nm- after shoot.



Figure 11-4 Snippets of observed aggregates of boulders after which the first boulder was noticed during DK.S.3.



Figure 11-5 Observed soft substrate during DK.S.3.



Figure 11-6 After several minutes of softer substrates, (big) boulders, such as on the top right, can be seen again.



Figure 11-7 During the final part of DK_S_3, no boulders can be seen, and chain vibration is also reduced.

11.2. DK_S_8

11.2.1. Literature Profile

Haul DK_S_8 is characterized by two sections where the mixed substrate dominates (A, C), altered by two sections where the sandy substrate is predominantly present (B, D) (**Figure 11-8**).

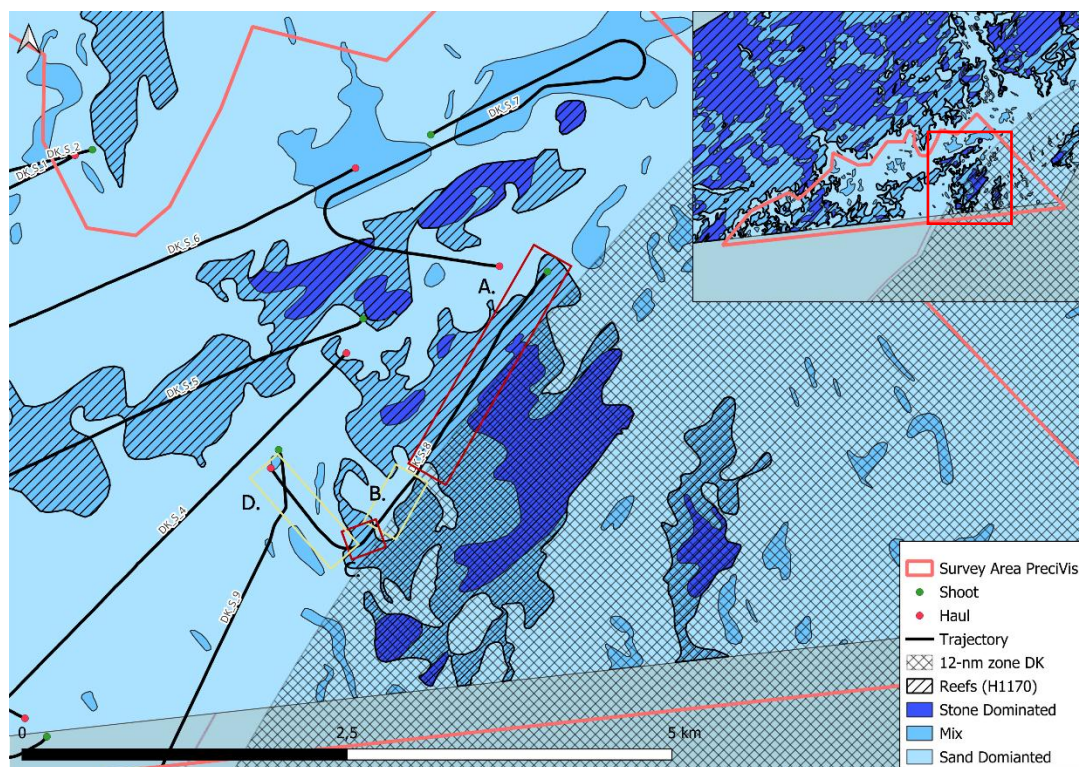


Figure 11-8 Trajectory of haul DK_S_8 with an additional breakdown in different segments. Yellow boxes indicate soft substrates; red boxes indicate the presence of harder substrates/reef structures. Shoot locations is highlighted with a green dot, haul location is highlighted with a red dot.

11.2.2. Underwater Footage

Unfortunately, due to low water temperatures, the mounted GoPro battery lasted only for ± 15 minutes into the haul. Therefore, it could only record section A, where the mixed substrate dominates, and where marine reefs are also identified.

At first, when the net reaches the seafloor, a sandy substrate appears to be present, as can be seen on **Figure 11-9**. However, after approximately one minute, the setting changes, and large boulders start to appear. The chain mat also experiences noticeably more stress than before, indicated by the increased movement and vibrations of the chains. This remains the same during the entire recording, as illustrated by **Figure 11-10** and **Figure 11-11**, which were made 5 and 10 minutes after bottom contact, respectively. Patches with soft substrates also seem to be present, as illustrated by **Figure 11-12**.



Figure 11-9 Recording of haul DK_S-8 directly after the net touches the bottom of the seafloor.



Figure 11-10 Recording of haul DK_S_8 5 minutes after seafloor contact. Large boulders can be seen in the center of the recording.

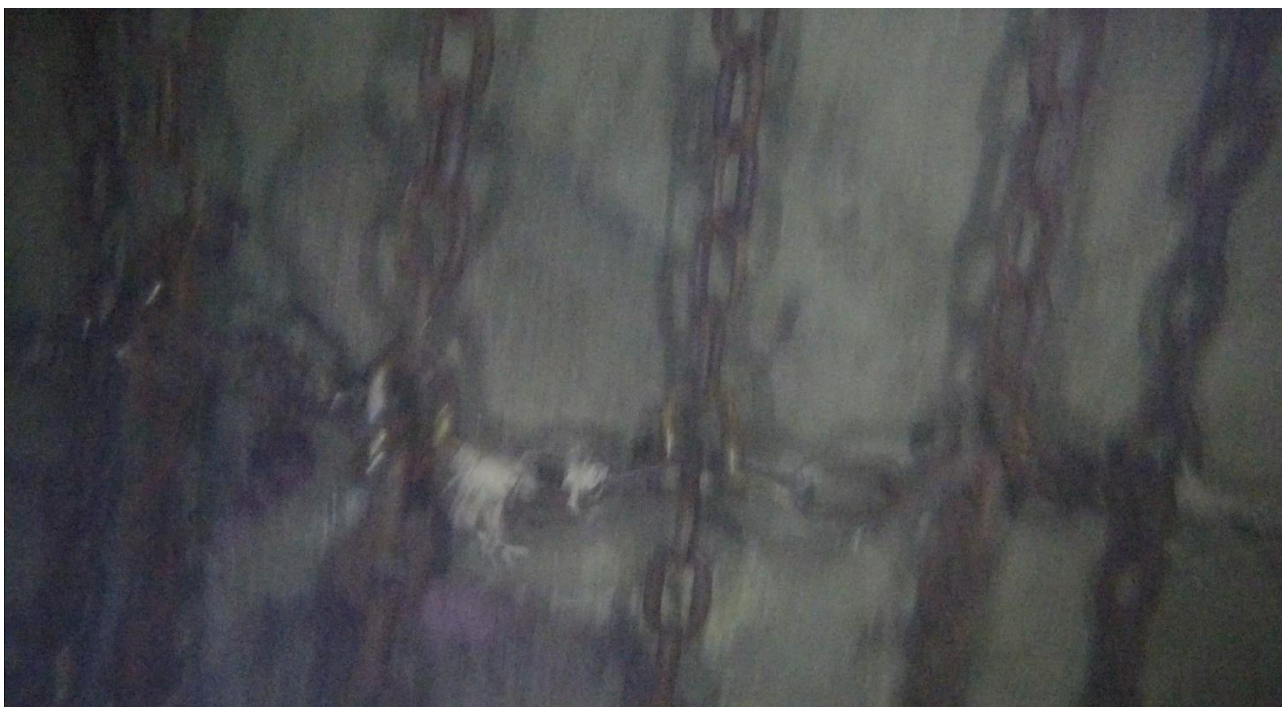


Figure 11-11 Recording of haul DK_S_8 10 minutes after seafloor contact. Large boulders can be seen in the center of the recording.

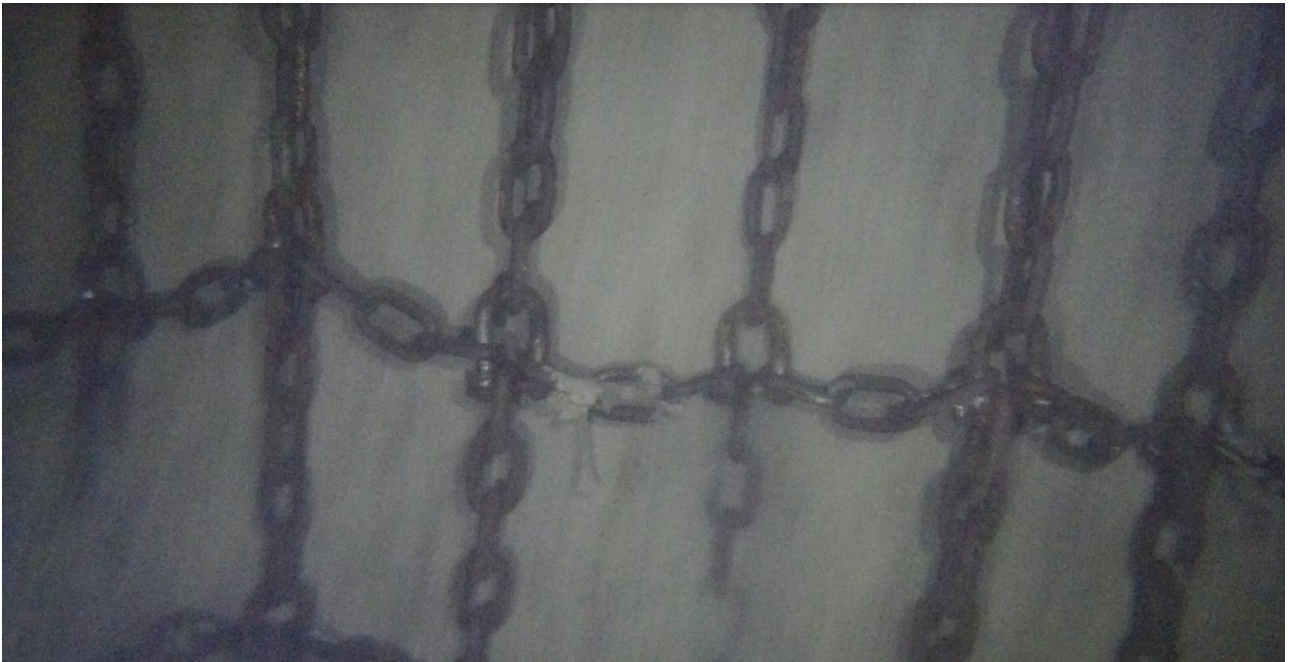


Figure 11-12 Recording of haul DK_S_8 12 minutes after seafloor contact. Soft substrate can be observed.

11.3. DK_S_15

11.3.1. Literature Profile

Haul DK_S_15 is characterized by eight sections: two sand sections (A, C), three stone sections (B, E, G) and three sections where the mixed substrate is dominant (D, F, H).

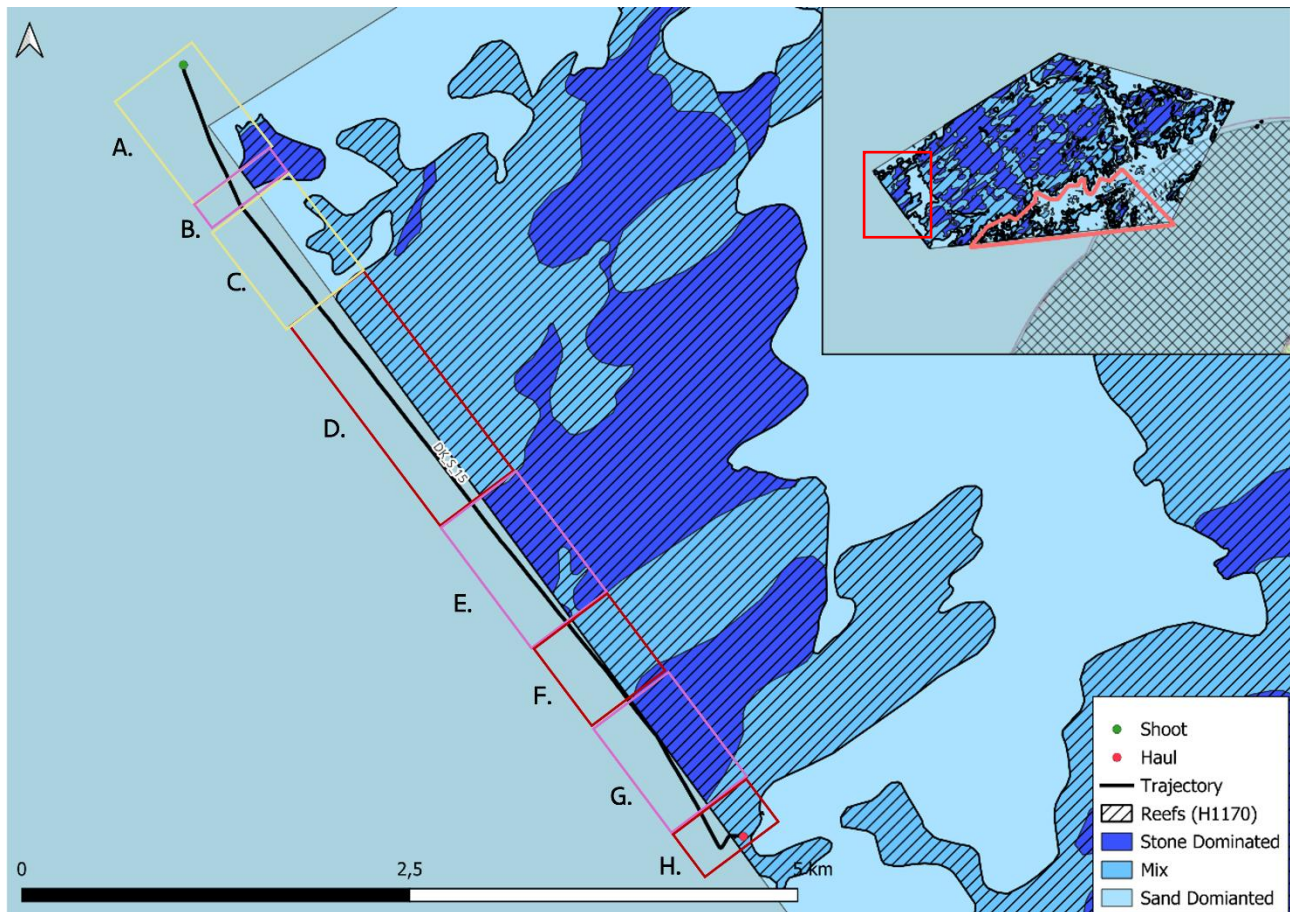


Figure 11-13 Trajectory of haul DK_S_15 with an additional breakdown in different segments. Yellow boxes indicate soft substrates; red boxes indicate the presence of harder substrates/reef structures. Shoot locations is highlighted with a green dot, haul location is highlighted with a red dot.

11.3.2. Underwater Footage

After the net touches the bottom, a soft substrate seems to be present: sediment arises occasionally due to bottom contact of the chains, chains are not vibrating, and the image appears to be stable (**Figure 11-14**). After ± 0.33 nm into the haul, a first boulder appears, after which tension on the chains increases and more patches of stones appear (**Figure 11-15**). However, this changes again quite rapidly to the softer substrates similar than the ones observed at the beginning of the haul (**Figure 11-16**). At ± 0.8 nm after the shoot, boulders are present again but alter with patches of softer substrates. Approximately halfway through the haul (1.5 nm), big patches of boulders start to appear more frequently again. The chains also start to vibrate more, and the recording begins to vibrate, both indicating rougher surfaces (**Figure 11-17**). This kind of surface remains present until the end of the recording. During this haul, a remarkably higher abundance of dead man's fingers (*Alcyonium digitatum*) and Hornwrack (*Flustra foliacea*) could be observed, as demonstrated by **Figure 11-18**, **Figure 11-19** and **Figure 11-20**.



Figure 11-14 Recording of haul DK_S_15 directly after seafloor contact.



Figure 11-15 Recording of haul DK_S_15 0.47 nm after seafloor contact. Boulders can be seen in the top left.

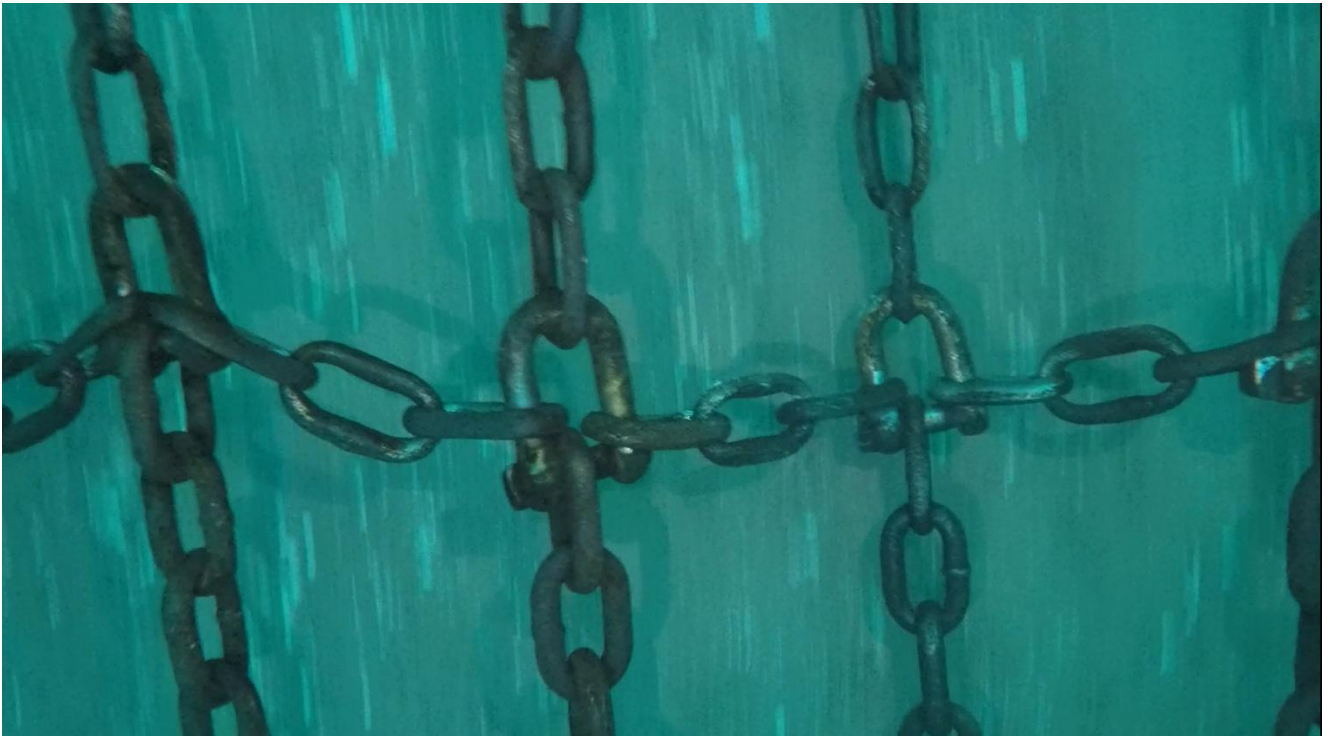


Figure 11-16 Recording of haul DK_S_15 0.6 nm after seafloor contact. Soft substrate is again present.

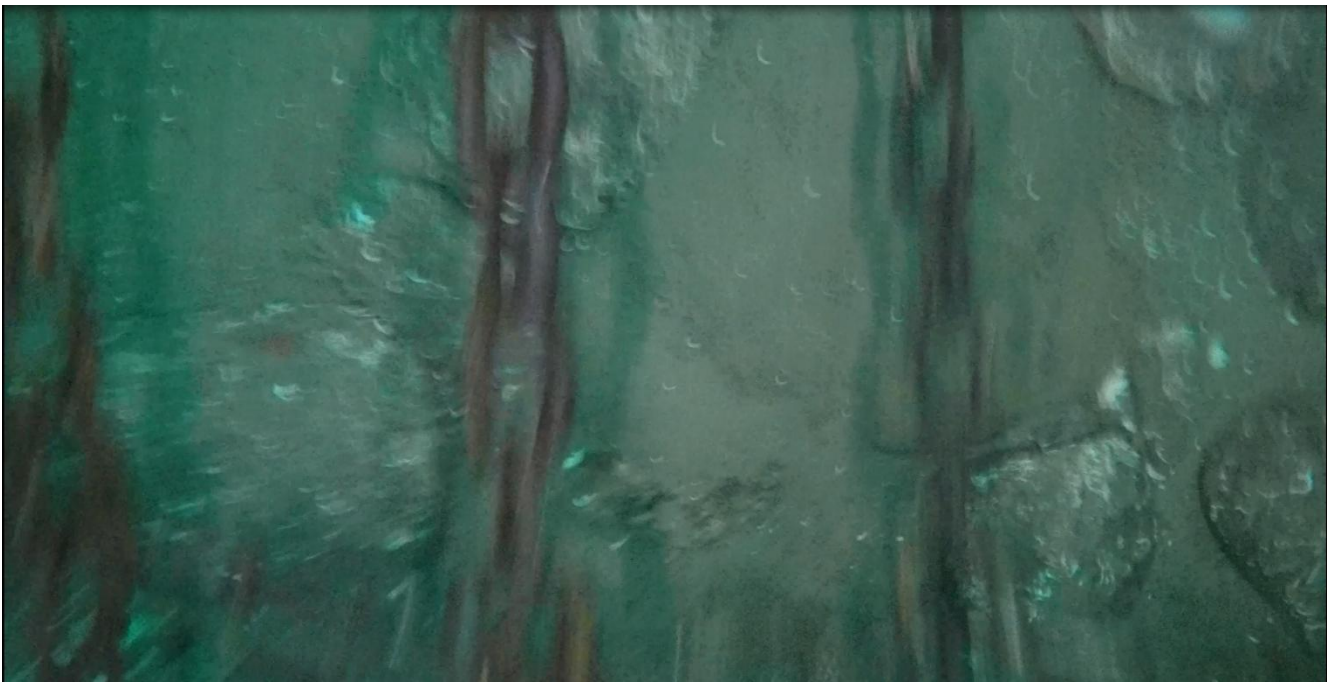


Figure 11-17 Recording of haul DK_S_15 1.5 nm after seafloor contact. Boulders are frequently present.



Figure 11-18 Dead man's fingers (Alcyonium digitatum) present during haul DK_S_15.

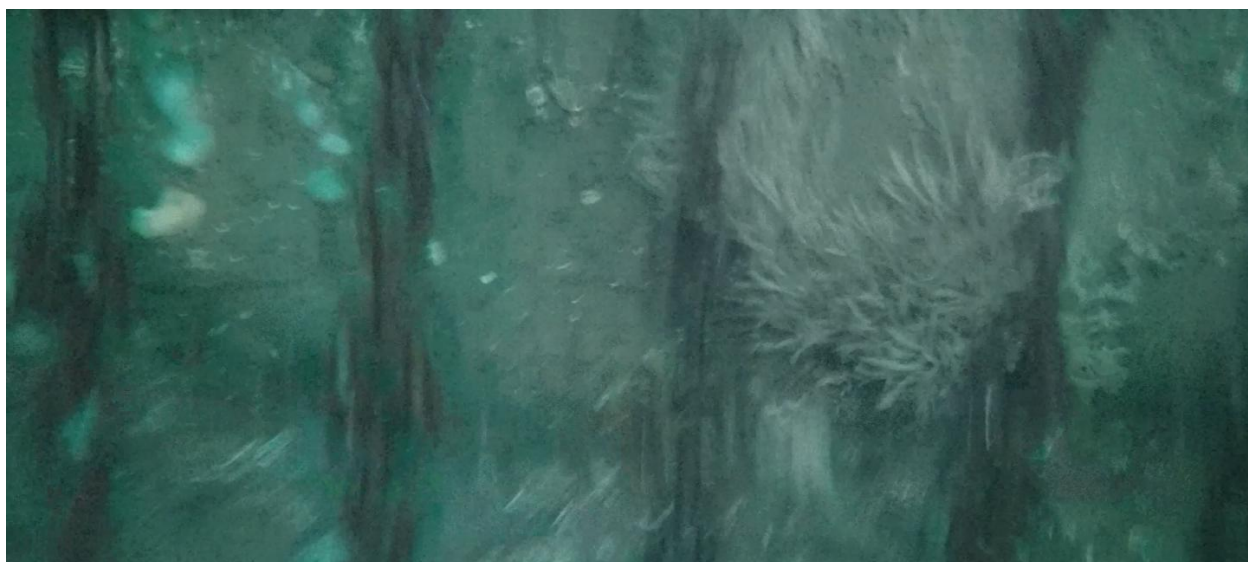


Figure 11-19 Hornwrack (Flustra foliacea) present during haul DK_S_15.



Figure 11-20 Dead man's fingers (*Alcyonium digitatum*) and Hornwrack (*Flustra foliacea*) present on the chain of the chain mat during haul DK_S_15.

12. VISIM-Camera

As stated earlier, VISIM-data will be 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 12-1 shows an image taken by the VISIM camera aboard the survey vessel during the sorting of the catch. On the picture, a plaice and starry ray can be observed, as well as some benthic species.

After applying the existing models to the image, **Figure 12-2** 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 minimized, as the picture is completely focused on the conveyor belt.

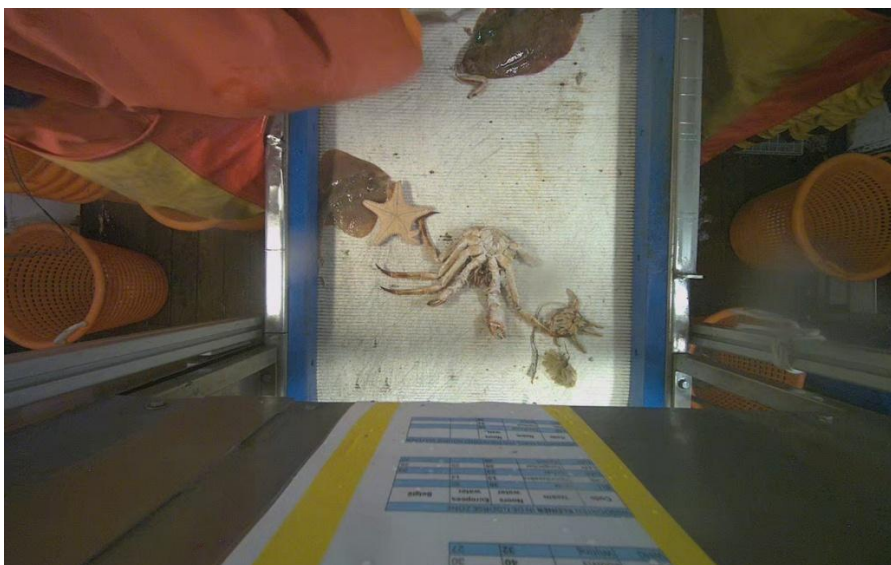


Figure 12-1 Picture taken during the sorting of the catch by the VISIM camera aboard the survey vessel Z.510-Dennis.



Figure 12-2 Processed image of **Figure 12-1**. 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

13. Evaluation of Precision Fishery Techniques

One of the main goals 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 and associated habitat type. In addition, this 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. Furthermore, data on the catch composition (fish and benthos) was also collected by three ILVO-scientists onboard and a VISIM-camera. Finally, underwater footage was obtained for a selection of hauls.

This section provides a first evaluation of the different data sources presented and their potential to precision fishery.

13.1. WASSP Multibeam Sensor

13.1.1. Substrate Classification

Results provided in this report demonstrate the potential of the WASSP multibeam echosounder to differentiate between the present substrate types. Although pre-processed data was used during the backscatter analysis, soft (i.e. sand) and hard (i.e. stone) substrates could be distinguished on a relatively high precision level, with an accuracy of 64% for the training- and 74% for the test dataset. However, the introduction of transitional substrates, such as the mixed class, created an additional complexity. The model correctly identified 62% of the novel “mixed” areas, which is significantly lower than the detection performance of unknown sand (81%) or stone (76%) areas. Identification of this substrate type, which overlaps with both the sand and stone substrate class, therefore remains challenging. This is important to mention, since the reef definition, as provided in this report (§3.2.1), partially correlates with the presence of the latter substrate.

Due to the absence of the WASSP Survey License, the collected multibeam data was already internally processed by the WASSP module itself, meaning that truly “raw” data were unavailable. This limits the possibilities of detailed seabed mapping and accurate model construction. Furthermore, substrate data extracted from EMODnet, as presented in §3.2.2 (**Figure 3-3**), exhibited low-resolution. This questions reliability of these substrate maps, since they seem to be generalized for a larger area. As a result, they are less suitable to be used for model construction or as control mechanisms.

13.1.2. Habitat Classification

Due to the difficulties encountered in detecting different substrate types -particularly the mixed substrate type- and the multi-layer definition of reef areas, the model experienced difficulties to correctly identify reef areas. This was, for example, demonstrated by **Figure 8-4-B**, which displays several false-negative and -positive predictions in the different test areas. In addition, the model predicted a large reef presence northwest of Gule Rev (**Figure 8-5**, haul DK_S_14). However, this area is not classified by the Danish Government or European Union as vulnerable reef area (e.g. GEUS (2025)). Furthermore, the skipper of the survey vessel Z.510-Dennis also confirmed that in this area, no reefs were present. This is also confirmed by the associated traction plot, which indicates that this haul predominantly occurred on soft substrates (

Figure 13-1).

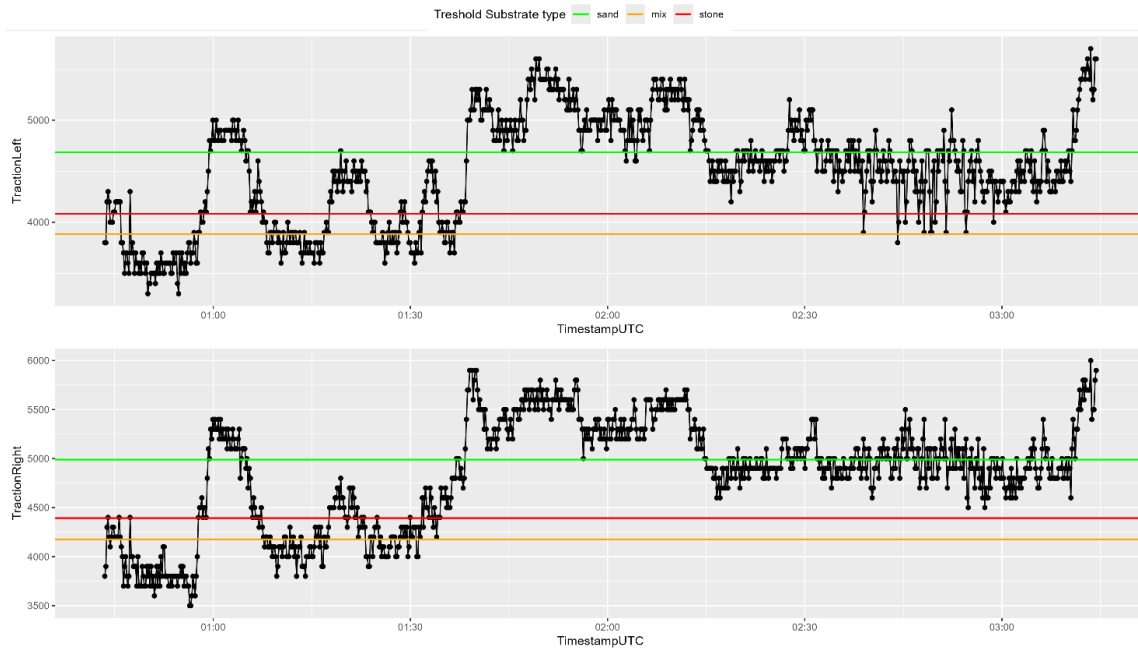


Figure 13-1 Traction values (y-axis, kg) of *DK_S_14*, measured every 10 seconds after shoot time. (x-axis). Mean traction values associated with the different substrates, as discussed in §9.1, are indicated in green (sand), orange (mixed) and red (stone).

These examples indicate that the model produced in this study is not suitable for real-time habitat monitoring of novel areas, as it was trained on a limited and spatially clustered dataset. Predictions outside the survey area may involve extrapolations which exceed the conditions observed during training and therefore result in misclassifications. Model training was also based on data originating from 2015 or older and could therefore be prone to errors. This introduces additional uncertainty which limits the model performance. Additional labeled data and improved annotation quality are needed to enhance robust exploration to unknown areas.

Additionally, the “rocky reef” (H1170) definition, as presented by the Danish Environmental Protection Agency, includes several layers, therefore increasing the difficulty of correctly classifying novel areas based on the present substrate type. Areas classified as “mixed” are classified as “reef” when they neighbor to reef areas but are classified as non-reef when they are surrounded by soft substrates.

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

13.1.3. Existing Maps

One of the goals of the project was to compare the collected multibeam data with existing substrate and/or habitat maps derived from multiple sources (e.g. EMODnet). However, these maps displayed some limitations, such as, for example, low-resolution (EMODnet) or outdated data (GEUS). Especially the low-resolution substrate maps extracted from EMODnet proved to be hard to work with in terms of substrate comparison or haul labelling. Future projects should therefore focus on the improvement of these maps.

13.1.4. Remarks & Recommendations

First, as discussed in the previous section, the seabed classification is made based on processed WASSP data (i.e. flattened backscatter. Instead, it is better to use raw, unprocessed WASSP data, expressed in decibels, which provides a better indication for the classification. 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.

In addition, the acoustic resolution of the WASSP F3i system is constrained by its beam geometry and operating frequency. With 224 equiangular beams spanning a 120° swath, the spacing between soundings on the seafloor ranges from approximately 0.6 m at 40 m depth to just over 1 m at 70 m depth. However, each beam covers a footprint of approximately 2–4 m, due to the system’s relatively wide beamwidth (around 3–4°). This means that small features such as 10–20 cm stones cannot be resolved individually, as the backscatter signal is spatially averaged within each footprint. As such, our classification approach relies not on detecting individual seabed features, but on analyzing patterns in backscatter strength and texture to infer substrate type. To identify individual objects such as boulders, more advanced (and expensive) techniques, such as the portable side-scan sonar, will be needed.

Second, because the results in this report are based on internally processed data and thus not calibrated over a reference area, collected data cannot be compared to other studies or surveys in different areas. WASSP has confirmed that backscatter characteristics can vary across instruments and deployments, requiring cross-survey normalization and standardization to develop operational models. 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>.

Thirdly, 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 (Kint et al., 2025).

Finally, 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.

Other recommendations or lessons learned are listed in OceanBox B.V. (2025).

13.2. VISTools

13.2.1. Current parameters

Graphs provided in §9.1 and §9.2 demonstrated that different substrates record different values for e.g. traction: highest values were recorded for softer substrates (i.e. sand), and lower substrate for harder substrates, such as the mixed substrate class. This could be explained by the type of equipment used. During the survey, a chain mat was used, adding 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.

The different traction plots demonstrate that this parameter provides a useful additional indication of substrate type: higher traction values are generally associated with softer substrates, while lower traction values indicate harder substrates. This pattern is clearly observed when comparing soft substrates such as sand with harder substrates such as stone. Within the group of hard substrates, however, differences are still observed. The “stone” class shows higher traction values than the “mix” class, which may be explained by the higher abundance of boulders in the stone class, potentially increasing traction.

13.2.2. Remark & 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 yet suitable for real-time monitoring applications, such as 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. Section 14: *Integration WASSP multibeam in VISTools dataflow* therefore provides an initial workflow of how this implementation should be carried out and what outputs should be expected.

13.3. Catch Composition

Throughout this report, several tests were performed to identify key species which could be associated with the present substrate or habitat type. This section will summarize the trends that could be observed and will also list the limitations of the survey and analysis.

13.3.1. General Trends

13.3.1.1. Substrate Types

Catch composition varied notably between hauls. As an example, catch compositions of haul DK_S_13, DK_S_14 and DK_S_15 are compared (**Figure 13-2**). Two of these hauls - DK_S_13 and DK_S_15- are classified as “stone”, while haul DK_S_14 is classified as “sand”. Despite these substrate classifications, opposing trends in catch compositions could be noticed.

Landings sampled in DK_S_14 are dominated by monkfish (MON) and Atlantic wolffish (CAA), species typically associated with harder substrates (**Figure 10-10**), which could also be observed in the

accompanying PCA plot (**Figure 10-38**). This is a rather surprising observation, as EMODnet classified this haul as predominantly “sandy”, whereas the latter species are typically associated with harder substrates. Haul DK_S_15, which was estimated by the vessels crew and the accompanying underwater footage (see §11.3.2) as the haul with the most boulders and rocks present, seems to be characterized by cod (COD), pouting (BIB) and lemon sole (LEM), species generally associated with coarser substrates (Ballerstedt, 2008; Barnes, 2008; ICES CIEM, n.d.).

Regarding the discards, several trends could be observed. Hauls DK_S_14 and DK_S_15 are grouped into cluster D-A, which is characterized by the smallest plaice and highest starry ray (RJR) abundances across all four clusters. Additionally, this cluster also holds the largest ling (LIN) fraction (8.49%), a species associated with rocky reefs (Danish Environmental Protection Agency, 2021; Rowley, 2008).

Despite this, haul DK_S_14 is classified as “sandy” according to EMODnet substrate maps, yet it records high abundances of species related to hard substrates, including cod and starry ray. Conversely, cluster D-D, dominated by sandy hauls, displayed the highest grey gurnard (GUG) and plaice fractions, indicating that the latter may correlate with softer substrates. This is confirmed by **Figure 10-22**, which demonstrated significant positive correlations between the latter species and softer substrates. Complementary, a significant negative correlation was found between the grey gurnard abundance and the stone fraction of a sampled haul. In addition, the PCA plot of discard species (**Figure 10-38**, **Figure B-18**) suggests that grey gurnard and plaice are more associated with hauls conducted in sandy areas (e.g. DK_S_2), indicating that they would be expected to occur predominantly in haul DK_S_14. However, as stated before, this haul records high abundances of species related to hard substrates, including cod and starry ray (**Figure 13-2**, discards). These discrepancies may be explained by a scattered substrate distribution which is not covered by the low-resolution EMODnet substrate maps. This was also indicated by the backscatter analysis OceanBox B.V. (2025), which revealed small hard substrate patches within sandy areas. These patches therefore could influence the catch composition, which could potentially explain these observations.

An opposing pattern was observed for haul DK_S_13 (see **Figure 13-2**). Although this haul was classified as “stone”, it exhibited the largest plaice fraction among all sampled hauls, together with species typically associated with hard substrates, such as cod, starry ray, and lemon sole. In terms of substrate distribution, as defined by OceanBox B.V. (2025), DK_S_13 is similar to hauls DK_S_14 and DK_S_15. This similarity is also reflected in the PCA results, where DK_S_13 clusters closely with these hauls despite differences in substrate classification. These findings suggest that catch composition alone may not reliably indicate substrate type. Instead, species composition may be influenced by local substrate heterogeneity and the presence of neighboring habitats. Alternatively, the observed mismatch could indicate inaccuracies in the current substrate classification, highlighting the need for more detailed or updated spatial data.

Another surprising pattern was observed in the benthos composition (**Figure 13-3**). Dead man’s finger (*Alcyonium digitatum*) was expected to be an indicator species for hard substrates, as it is typically attached to structures such as boulders or rocks (Budd, 2008). It is therefore surprising to see that this species is present in all sampled hauls (see §10.3.3; **Figure 13-3**). Additionally, a larger fraction of this species was also recorded in haul DK_S_14, which contained predominantly softer substrates, compared to haul DK_S_13, which classified as “Stone” (see **Figure 13-2**, benthos). These findings suggest that the presence of dead man’s fingers alone does not necessarily indicate the presence of hard substrates. Instead, the full benthic community composition and the potential overlap of substrate types within individual hauls should be considered when interpreting species–habitat relationships. Furthermore,

when this observation was discussed with the survey skipper, he noted that this phenomenon has developed only in recent years, mentioning that he now encounters dead man's fingers in areas where they were previously absent, especially in softer substrates.

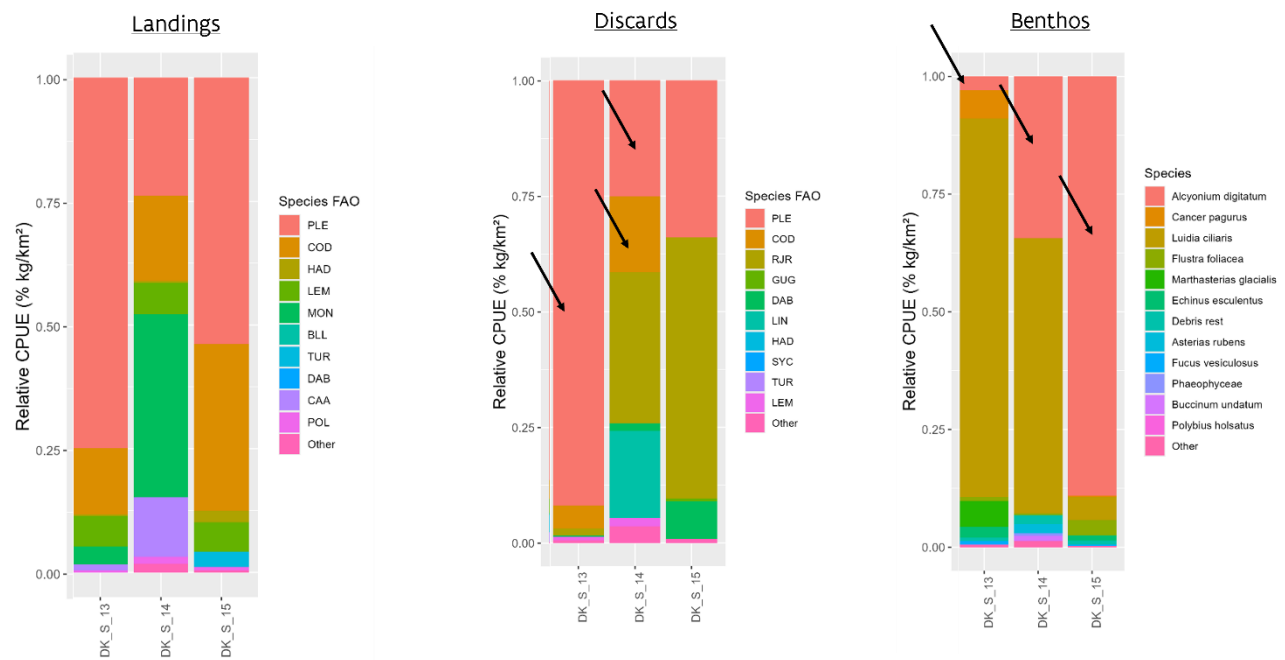


Figure 13-2 Catch composition of landings (left), discards (middle) and benthos (right) of hauls DK_S_13, DK_S_14 and DK_S_15.

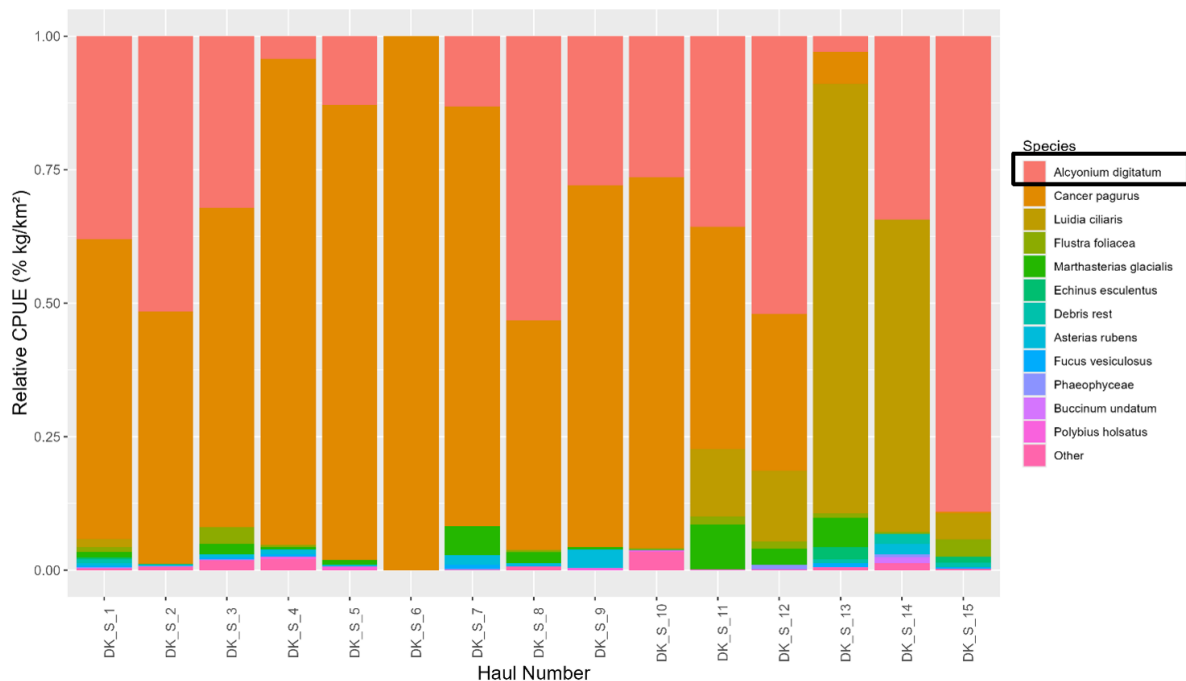


Figure 13-3 Benthic catch composition across the different sampled hauls. Dead man's fingers (*Alcyonium digitatum*) is highlighted with a black rectangle.

13.3.1.2. Habitat Types

Linear correlation analysis across landing, discard, and benthic categories revealed that only two species showed a significant correlation with the different habitat types: cod exhibited a significant positive correlation with reef presence, while plaice showed a significantly negative correlation. The lack of

correlations is remarkable, but not surprising with the low sample size in mind. Other expected reef-associated species, such as dead man's fingers (*Alcyonium digitatum*), hornwrack (*Flustra foliacea*), edible sea urchin (*Echinus esculentus*), ling (*Molva molva*) or pollack (*Pollachius pollachius*) did not show significant linear correlations, likely reflecting the uneven and limited sampling effort (Danish Environmental Protection Agency (2021)).

Furthermore, hauls conducted within the same habitat type did not consistently cluster together. For reef-designated hauls, some clustered closer to softer substrates, while others form a distinct group. A similar pattern was observed in the PCA analysis of landings, where certain reef hauls were grouped more closely with sandy hauls.

As stated in the previous section, dead man's finger (*Alcyonium digitatum*) and hornwrack (*Flustra foliacea*) were expected to be indicator species for the rocky reef habitat, since they are typically associated with sensitive marine habitats (Al-Hamdani et al., 2019; Danish Environmental Protection Agency, 2016, 2021). However, no linear correlation was found between these species and the present habitat type. Instead, correlations were found for edible crab (*Cancer Pagurus*), seven-armed starfish (*Luidia ciliaris*) and common starfish (*Asterias rubens*). The authors suggest that these results are more likely attributable to the reduced and non-uniform sample size than to a true absence of habitat association.

13.3.2. Evaluation as tool for precision fishery

The above-described findings demonstrate that distinguishing patches of harder substrate within predominantly softer areas is challenging when relying solely on catch composition. Although some trends could be observed regarding the catch composition of landings, discards and benthos, it remains challenging to link a specific species to a certain sensitivity level or substrate type with a high confidence (see also §13.3.1.) This is mainly because several hauls were conducted across areas containing multiple substrate or habitat types, combined with the reduced sample size ($n = 15$) and non-uniform sampling distribution. As a result, both the presence and absence of statistical correlations is hard to evaluate.

Several of the sampled hauls were also conducted across multiple substrate heterogeneous substrates. Although these hauls were classified according to the dominant substrate type, the presence of multiple substrate types likely influenced the observed catch composition, complicating the allocation of species to specific substrates. Therefore, it should be advised that information on the catch composition should be used in combination with other sources, such as WASSP images, to improve accuracy. Integrating these data sources would allow for a more complete and accurate characterization of the fished area and the underlying substrate or marine habitat. Deviations in catch composition could also be linked to insufficient haul labeling. As discussed previously, available substrate maps either have low resolution or are relatively outdated (up to 10 years old). This could have influenced the observed results and trends, as haul labeling might not accurately reflect the true substrate conditions.

13.4. Underwater Footage

13.4.1. Evaluation Setup Used

Despite the fact that a rather simple camera setup was used, recordings of the different hauls yielded better results than initially anticipated: underwater visibility was better than expected, resulting in clear images of the present seafloor substrate. After analysis, images seemed to correlate with the habitat maps provided by Al-Hamdani et al. (2015), although this is hard to quantify due to the limited image

resolution. The area observed covers only a few square meters, which therefore complicates comparison with the present substrate maps.

Despite the limited resolution, a clear difference could be observed between softer and harder substrates, where the latter are characterized by unstable images, increased noise originating from vibrating chains and the presence of large boulders. Softer substrates, in turn, are characterized by more stable images with minimal chain vibration and sediment risings, and noise levels are also reduced. These findings indicate that underwater footage, despite the current defects, has potential to act as a control mechanism for future studies or surveys.

13.4.2. Remarks & Recommendations

The biggest limiting factor during this survey was battery life span. Due to the low water temperatures, the battery only lasted between 30-60 minutes, which limited data collection. Future studies should take this into account and provide batteries with a sufficient life span. Additionally, to save time during data collection, attention should be given to ensuring efficient battery and/or camera replacement.

Finally, comparison between the collected images and substrate maps was difficult due to insufficient image labeling with e.g. coordinates or time stamps, and limited camera resolution. Therefore, future projects should include image labeling with coordinates to allow for a more precise substrate comparison.

13.5. Used Literature

Throughout this project, results from other studies -Al-Hamdani et al. (2015) & EMODnet (2022)- were used for survey design, model training or comparison of results. Just as the above discussed tools, a brief evaluation of these data sources will be made.

Al-Hamdani et al. (2015) provided detailed maps of the present substrate and habitat types of the Gule Rev area. These maps, however, date back from 2015, and are a combination of both extensive side-scan sonar surveys, as well as modelling. This introduces an additional uncertainty, since the reef distribution may be subjected to changes (Al-Hamdani et al., 2019). Future projects should therefore also focus on the collection of updated, observation-based training data to ensure model predictions remain valid and ecologically relevant.

14. Integration WASSP multibeam in VISTools dataflow

In addition to the previously discussed WASSP results, the potential integration of the output of the WASSP multibeam into the VISTools digital twin was assessed. Further information could be obtained by contacting Lancelot Blondeel (lancelot.blondeel@ilvo.vlaanderen.be).

14.1. Introduction

14.1.1. Objectives

The assessment presented is based upon three interrelated objectives:

- **Real-time support on board** for skippers during active fishing, so that adjustments can be made -timely- when an increased reef or hard habitat risk is detected.
- **Near-real-time evidence and archiving** at tow and trip level, enabling objective demonstration of the extent to which reef areas were avoided (audit trail and KPIs).

- **Optional:** the phased development of a collective reef map layer based on aggregated contributions from multiple vessels.

The assessment outlines the integration concept, the role of VISTools within this data processing chain, and the necessary boundary conditions. Concrete software choices, User Interface design, and detailed data models will be provided in a follow-up study.

14.1.2. Timescales

- **Real-time:** information that can be used for immediate operational adjustments during an ongoing fishing activity (order of magnitude: seconds to minutes).
- **Near-real time:** processing and access with limited delay (order of magnitude: hours), suitable for monitoring, reporting, and evaluation, but not for direct steering actions.

The core challenge is that WASSP generates large data volumes, and this data stream is not suitable for continuous transmission and cloud-based processing within a conventional VISTools analytics cycle.

14.2. Architectural Framework

The VISTools architecture can be considered as a chain with a clear separation between the different functional layers:

- **Onboard data collection:** sensors and instruments are connected to the concentrator, which acts as a central sensor hub.
- **Buffering and distribution layer:** via the DB Matic server, data are buffered and reliably forwarded, even in the event of temporary connectivity issues.
- **Azure Cloud (ILVO VISTools database):** secure reception, storage, and processing of data, with separate databases per vessel owner.
- **Application layer:** dashboards, web applications, and analysis tools for skippers, vessel owners, and researchers (PowerBI).

The concentrator and DB Matic are designed for connectivity, standardization, and buffering of relatively lightweight time-series data (e.g. GPS, towing force, fuel consumption, weighing events, weights per species). They are not designed for the processing or transmission of high-bandwidth data streams such as raw multibeam sonar.

WASSP multibeam data has a fundamentally different character: high resolution, large file sizes, and the need for specific processing steps (normalization, classification). Direct integration as a conventional sensor stream is therefore not suitable for the intended real-time use case.

14.3. Design Principle

An important finding of this study is that raw WASSP multibeam data cannot be transmitted to the data cloud due to its size. Instead, a two-step approach is suggested:

1. **Local, onboard processing** converts raw WASSP data into compact, interpretable outputs that can be used directly for operational decision-making.
2. Only these **derived products** are transmitted, stored, and accessed via the existing VISTools chain. This can be interpreted as a GPS point indicating whether the vessel has or has not encountered a (potential) reef. These results can also be used to build a collective reef map layer.

Raw data is considered as voluminous multibeam recordings, intended for detailed analysis and reprocessing, whereas derived products consist of summary indicators (e.g. risk scores, alarm events, aggregated map layers) that are suitable for transmission and interpretation.

14.4. Integration: three data products

14.4.1. Realtime warning onboard (reef detection)

The goal of this aspect is to enable the skipper to make timely adjustments during active fishing when an increased risk of interaction with reef or hard habitat is detected. Different components to achieve this are:

- **WASSP multibeam**: primary data source (bathymetry and backscatter).
- **Local, onboard processing module** (edge box) in addition to the already existing concentrator. This module focusses solely on the processing of incoming WASSP data.
- **Live view and/or plotter**: visual interface onboard.

Predetermined outputs are:

- **ReefRiskScore (0–1)**: probability of encountering reef/hard habitat.
- **Confidence**: reliability of the assessment.
- **AlarmState**: operational status (OK / Warning / Critical).
- **ReasonCodes**: indication of the underlying signals (e.g., roughness, slope, hardness proxy).
- **Optional**: local map overlay with limited resolution and time horizon.

14.4.2. Evidence and monitoring

This data product aims to objectively demonstrate that warnings are being followed and that exposure to high-risk zones is minimized. To achieve this, reef detection event logs (e.g. risk scores), haul locations based on existing VISTools knowledge and operational context (e.g. speed or course) will all be registered. Registration of these parameters will take place periodically and will solely focus on evaluation and reporting. It is not intended to use this information for continuous external monitoring of fishing activities, and therefore, data processing will take place according to the privacy regulations of VISTools, which protects sensitive information.

14.4.3. Collective Reef Map (Optional & Phased)

The goal of this data product is to develop a shared map layer that supports skippers in planning and situational awareness. The collective reef map layer is a probabilistic product, constructed from multiple independent observations. It does not represent absolute truth, but rather an updated interpretation with explicit uncertainty. During the process, it will be ensured that the contributors privacy will be guaranteed, and that commercial sensitivity will be reduced as much as possible.

14.5. Technical Integration Into VISTools

14.5.1. Aboard The Vessel

- The concentrator remains the central sensor hub.
- The local processing module processes incoming WASSP data and generates solely “reef detection” outputs. Currently, this module doesn’t exist (yet), unless the OceanBox module or a WASSP solution could execute this task.

14.5.2. Transmission

- Reef detection outputs are transmitted via DB Matic.
- DB Matic provides buffering and reliable transmission.

14.5.3. Cloud (ILVO)

- Data intake through existing, secured channels.
- Storage in accordance with the existing privacy architecture (private per vessel, aggregated outputs separated).

14.5.4. Applications

- **LiveView/plotter:** real-time alerts and situational awareness. In this case, the live view/plotter is directly linked to the concentrator.
- **Analytics:** periodic reporting and evaluation.

14.6. Decision-Critical Framework Conditions

The following points must be clarified when developing a test case:

1. WASSP licenses and accessible data products and accompanied costs.
2. Specification of the local processing module (hardware and software for model).
3. Definition of output data and data classification.
4. Validation strategy and performance goals.
5. UX-choices and alarm load control.

14.7. Phased Approach

Phase 1 – Test case: A suitable platform must be found that can perform local processing on the vessel. This could be the OceanBox module, a WASSP solution, or a new local device that can process and interpret the incoming WASSP data. This depends on the assumption that certain licenses give direct access to the raw data.

Phase 2 – MVP pilot: limited rollout on 1–2 vessels, with focus on real-time alerts and basic logging.

Phase 3 – Evidence gathering: consolidate KPIs and reporting.

Phase 4 – Collective map layer: phased development and distribution.

15. Recommendations & Lessons 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 Danish and international scientists would facilitate research and development in the field of precision fishery.

- **Substrate data** extracted from **EMODnet** exhibited a **low resolution**, resulting in some uncertainty on the present substrate type of hauls. Additionally, this makes it hard to compare with higher resolution data such as the collected WASSP images or results obtained through Al-Hamdani et al. (2015). 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 explore the use of **alternative fishing gear**, such as tickler beam trawling in combination with sumwing. During this survey, a 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.
- Due to the small sample size, observed or absent correlations remain uncertain; therefore, future studies should prioritize a greater number of sampling locations with adequate spatial variation.

15.2. Innovative Tools

15.2.1. WASSP multibeam echosounder

- Only the “**WASSP Backscatter license**” was installed on the WASSP module. As a result, raw-backscatter and -bathymetry data was already pre-processed by the WASSP module itself, which lead to undocumented corrections and an inhibition of external post-processing. To avoid this, the “**WASSP Survey-license**” should be installed in addition to the backscatter license on the used module. This license enables access to raw, unprocessed backscatter data, which can be used for a more detailed acoustic analysis.
- During the survey, **only an internal calibration was carried out**. This allows the comparison of the different readings within the same survey but makes it more difficult to compare results with other surveys or studies. Therefore, before the start of every survey, a **WASSP module should be calibrated against a reference area**, such as the Kwinte Bank reference site (KWGS) in the Belgian Part of the North Sea (see also [KWGS](#)).
- Training data of the developed model originated from a survey which was carried out in 2015, meaning that these **training labels may be outdated**. This potentially increases the risk of false results, and therefore, future projects should also focus on the **collection of updated, observation-based training data** to ensure model predictions remain valid and ecologically relevant.
- The used WASSP model (F3i) has a **limited acoustic resolution**. With 224 beams spanning 120°, each beam covers approximately 1 meter. Objects smaller than this (e.g. stones with diameter 10 cm) are therefore undetected and aggregated in a so-called “smeared signal”. To detect small features, other acoustic systems, such as Synthetic Aperture Sonar (SAS) or portable side-scan sonar, should be used.
- The **configuration** of beam density and spacing in the **WASSP system affected data quality**, particularly in the outer beam regions, leading to uneven sounding density and reduced reliability for habitat mapping.
- During the survey, **WASSP data** had been **auto corrected** for vessel motion data, but a **substantial offset** was found. A backup source for vessel GPS and motion data allows for re-processing raw data corrections.

- Future projects should include the **impact of rising sediments** originating from e.g. fishing activities on the WASSP readings. **Acoustic uncertainty** could arise due to suspended sediment above the seabed, as this affects the scattering and reflection of sound waves. Additionally, this suspended sediment could also cover harder substrates such as rocky reefs and therefore **mask the original seabed substrate**.
- The **WASSP Data Manager** experienced some **unexpected crashes**, which caused some **small-scale data losses**. The issue may have been caused by limited onboard computer resources, network instability, or conflicts with other running software, but no uniform solution was found. Future projects or applications 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.

15.2.2. Catch Composition

- Discard or benthic catch composition could, in combination with other technologies, imply certain substrate or habitat types. However, 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 PreciVis, tests were done with the in-house developed VISIM camera, but no significant results were obtained yet (more info on: [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 investigate this parameter for potential substrate or habitat characterization.

15.2.3. Underwater Camera

- The camera (i.e. GoPro) used during the PreciVis survey provided only a **limited view** of the net and the seafloor, excluding potential important occurrences or activities. Future projects should therefore consider a **different camera setup** which could record a **wider view** of the seafloor and its surroundings.
- The **camera battery** recorded only a **limited amount of time due to low water temperatures**, resulting in potential data losses. Especially when cameras are used as an additional control measure, it is important that all data that could be collected is collected. Therefore, when installing cameras onto the net, **sufficient battery capacity should be provided**.

15.3. Survey

- The PreciVis survey was characterized by a rather **non-uniform sampling**, meaning that certain areas were more sampled than others. This makes it hard to compare certain 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 **comparing hauls between day- and nighttime**.
- 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 habitat types**, 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

- Future research should prioritize the accurate positioning of the survey tracks and involve the **expertise of the participating country**. Such collaborative approach would not only improve the quality of the results but also strengthen cooperation and mutual understanding between the countries involved.
- 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 investigate this parameter for potential substrate characterization.
- 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.

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 habitat model of OceanBox predicted a large patch of reefs northwest of Gule Rev. This was however refuted by the skipper. He declared that this region was predominantly characterized by soft substrates, and that no reefs were present. Additionally, he also indicate where, according to him, reefs were localized and where softer substrates were present. He also assessed haul locations and concluded that haul DK_S_15 was located in a very stony region, but that haul DK_S_13 was rather softer than visualized on the substrate map. These assumptions were also observed during the analysis of the catch composition, with more “stone-associated” species present in haul DK_S_15 than DK_S_13.

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. 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.

Conclusion

The PreciVis project functioned as a pilot study to explore and evaluate different techniques within the context of precision fishery and to formulate recommendations for future research. Through the application of these 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 using pre-processed data, the WASSP multibeam echosounder demonstrated promising results for distinguishing different substrate types. In collaboration with OceanBox B.V., a machine learning model was developed to process collected multibeam data, assess seabed substrate and marine habitat characteristics. However, the model’s performance in novel and testing areas was limited due to the low spatial coverage of the trainings dataset and absence of correct licensing, and, therefore, not suitable yet for real-time applications.

Besides the WASSP multibeam, this project also studied catch composition and its potential link to different substrate or habitat types. Although some trends and indications could be observed, limited sample size prevented statistically robust conclusions. Furthermore, no distinct key species could be identified as indicators of specific substrate or habitat types. A more homogenous sampling design, with evenly distributed hauls across different habitat types, would allow for more detailed and confident interpretations. Additionally, due to low-resolution substrate maps, haul labelling proved to be uncertain, as illustrated by different species composition for similar substrate types.

In addition to the latter techniques, VISTools data and underwater footage were also sampled and analyzed. They proved to be valuable validation tools, which could be used complementary to the WASSP multibeam or catch composition to provide a complete and accurate assessment.

Overall, with this project, a first step was taken to explore the potential of precision fishery within the Belgian beam trawl industry. The studied techniques each proved their potential, and, when used in combination, they provide a detailed and complete image on the present substrate and habitat type. However, shortcomings still limit real-time applications and require more (international) research and knowledge.

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Annex A: Material & Methods

Joint Recommendation

Fisheries management measures for protection of reef structures in five Danish Natura 2000 Areas in the North Sea and Skagerrak

Joint recommendation regarding Fisheries Conservation Measures under Article 11 and 18 of Regulation (EU) No 1380/ 2013 of the European Parliament and of the Council of 11 December 2013 on the Common Fisheries Policy

Copenhagen, 17 July 2024

Proces

Denmark, as the initiating Member State, jointly recommend with Sweden, Germany, Belgium, the Netherlands and France, the proposed fisheries conservation measures, as described in detail in Annex I, to the Commission for adoption as a delegated act.

The Danish proposal for fisheries conservation measures for protection of reef structures have been coordinated with the representatives from Sweden, Germany, Belgium, the Netherlands and France having a direct management interest in the fisheries affected by these measures. No UK vessels have been present on the sites. The North Sea Advisory Council has been informed and consulted.

There is a common understanding and agreement among all relevant Member States to the proposed fisheries conservation measures, which are described in section 2 'Recommendations to be implemented'. The outcome of the consultations held within the framework of the Common Fisheries Policy is given in Annex I, section 3.

The overall aim of the proposed fisheries conservation measures is to ensure adequate protection of reef structures from fisheries with mobile bottom contacting gears, and in case of bubbling reefs all fisheries, thereby contribute to the obligations of achieving favorable conservation status under Article 6 in the Habitats Directive. Protection of reef structures will be ensured through a buffer zone approach, where a depth-dependent buffer zone is placed around the mapped reef structures and bubbling reefs.

The proposed measures are proportional with respect to the Habitats Directive 92/43/EEC and are applied in a non-discriminative manner due to close coordination with Member States having direct management interests in the concerned sites as described in Article 11 and 18 of the Basic Regulation.

Natura 2000 sites concerned

The present joint recommendation entails fisheries conservation measures in five Natura 2000 sites located in the Danish part of the North Sea and Skagerrak, which have been designated for reef structures with habitat code 1170 and 1180:

Four Natura 2000 sites are located in the Danish Exclusive Economic zone in the North Sea and Skagerrak (outside 12 nautical miles):

- *Thyborøn Stenvolde (EU site code: DK00VA348)*
- *Jyske Rev, Lillefiskerbanke (EU site code: DK00VA257)*
- *Store Rev (EU site code: DK00VA258)*
- *Gule Rev (EU site code: DK00VA259)*

One Natura 2000 site is located in the Danish part of the Skagerrak (between the baseline and 12 nautical miles):

- *Lønstrup Rødgrund (EU site code: DK00VA301)*

Recommendations to be implemented

The following recommendations are proposed adopted:

- A ban for fishing activities with mobile bottom contacting gear in areas mapped as reefs (H1170), including the surrounding buffer zones:

Gear types that are banned in the closed zones	Gear code Annex XI in EU Regulation No. 404/2011	International standard Classification of Fishing Gears (ISSCFG)
Beam trawl	TBB	TBB
Bottom trawl / otter trawl	OTB, OTT, PTB, TBN, TBS, TB	OTB, OTT, OT, PTB, PT, TBN, TBS, TB, TX
Seine nets	SDN, SSC, SX, SV, SPR	SB, SV, SDN, SSC, SPR, SX
Dredges	DRB, HMD	DRB, DRH, HMD, HMP, HMX

- A ban for all fishing activity in areas mapped as bubbling reefs (H1180), including the surrounding buffer zones.

Coordinates for the areas are given in section 6.A.

Control and enforcement

The following control measures are proposed to be adopted.

In case of revision of the existing EU fisheries control system, the amended rules will apply accordingly to the control measures as far as the rules proposed below do not foresee stricter control rules.

1. Fishing activities in the five Natura 2000 areas as set out in this proposal shall be controlled by the coastal Member State. The coastal Member State shall have a system to monitor fishing vessels in these areas under its jurisdiction or sovereignty.
2. Member States may for the monitoring of their vessels use one of the following systems:

- a) A vessel monitoring system, cf. Article 9 of Regulation (EC) 1224/2009.
- b) An automatic identification system referred to in Article 6a of Directive 2002/59/EC, which meets the performance standards of Article 10(1) of Regulation (EC) 1224/2009.
- c) For vessels below 12 meters length overall, an alternative system provided and approved by the flag Member State for its vessels allowing the vessel to be automatically located and identified while at sea through the transmission of vessel position data.

The flag Member State shall inform the coastal Member State of the system used on board its vessels.

The flag Member State shall transmit vessel position data to the coastal Member State when a vessel is present in the waters of the coastal Member State.

In case, the device on board the vessel used in this system is not within reach of a network, the vessel position data shall be recorded during that period of time and shall be transmitted automatically as soon as the vessel is in reach of such a network. Connection with the network must be re-established at the latest before entering a port or landing site.

At least the following data are to be sent to the fishing monitoring centre of the flag Member State and received and transmitted to the coastal Member State in the format used for systems under a):

- i. The fishing vessel identification.
 - ii. The most recent geographical position of the fishing vessel.
 - iii. Date and time (expressed in Coordinated Universal Time (UTC) of the fixing of the said position of the fishing vessel.
 - iv. The instant speed and course of the fishing vessel.
3. The frequency of transmission of the vessel position data shall be of at least once every 10 minutes for vessels present in one of the areas mentioned in paragraph 1.
 4. For vessels using systems described in paragraph 2(a), a 4 nautical miles alert zone around the areas mentioned in paragraph 1 shall be established for vessels equipped with devices, which do not support the automatic change of reporting frequency. In these alert zones, the same frequency of transmission of vessel position data shall apply as in the areas mentioned in paragraph 1. The coordinates of the alert zone are given in section 5.B.
 5. Fishing vessels that are not permitted to fish in the areas mentioned in paragraph 1 or carry on board gears prohibited to use in the areas may only transit through the areas subject to the following three conditions:
 - a) All fishing gear is lashed and stowed during the transit.
 - b) The transit is continuous and the speed during transit is not less than six knots except in cases of force majeure. In such cases, the master shall immediately inform the fisheries monitoring centre of the flag Member State, which shall then inform the coastal Member State.
 - c) The tracking device providing position of the vessel as referred to in paragraph 2 is functioning.
 6. If the devices on board the vessels of the systems referred to in paragraph (2) are not functioning, the vessels is not allowed to be present in the areas mentioned in paragraph (1).

7. All fishing activities in the areas referred to in paragraph 1 shall in periods, where certain fishing activities are restricted or prohibited, be subject to a fishing authorisation in accordance with Article 7 of Regulation (EC) 1224/2009.

Compliance with the requirements is controlled by the Danish Fishery Monitoring Centre (FMC). The FMC coordinates and evaluates the control and enforcement of the fishery management measures in marine Natura 2000 sites in Denmark.

Scientific research and data collection

To support scientific data collection and acquire more knowledge on fisheries using accurate fishing tools, which allow precision fisheries, it should be possible for Belgium to conduct a scientific project allowing beam trawl vessels equipped with VISTool-technology to fish in the southern part of the Natura 2000 site Gule Rev (H259). Fishing activity with mobile bottom contacting gear types in areas mapped as reefs (H1170) will not be allowed in the project. The outline of the project is given in Annex II, including the delimitation of the project area. In consultation with the Danish authorities, further similar projects may be developed in the area based on the findings of the project described in annex II.

Denmark as coastal state and the European Commission shall approve each project description in accordance with article 25 of the Technical Measures Regulation (EU) 2019/1241.

Outline and coordinates of the areas in which fishing activities are proposed to be restricted

A. Coordinates of the buffer zone

Gule Rev

Habitat No. 259, Natura 2000 Site No. 250 (EU Code: DK00VA259)

Coordinates of the buffer zone which form the protection of the stone reefs:

Reef 1

Point	x_dec	y_dec	x	y
1	7.9754	57.2035	007° 58.526' E	57° 12.211' N
2	7.8787	57.2746	007° 52.722' E	57° 16.473' N
3	7.8781	57.2804	007° 52.684' E	57° 16.821' N
4	7.8863	57.2824	007° 53.176' E	57° 16.944' N

5	7.9074	57.2857	007° 54.441' E	57° 17.140' N
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6	7.9229	57.2923	007° 55.373' E	57° 17.535' N
7	7.9573	57.3014	007° 57.439' E	57° 18.083' N
8	7.9668	57.3089	007° 58.009' E	57° 18.533' N
9	7.9791	57.3156	007° 58.748' E	57° 18.937' N
10	8.1999	57.3904	008° 11.993' E	57° 23.421' N
11	8.2503	57.3830	008° 15.018' E	57° 22.980' N
12	8.2888	57.3758	008° 17.327' E	57° 22.549' N
13	8.2935	57.3716	008° 17.612' E	57° 22.298' N
14	8.2944	57.3629	008° 17.661' E	57° 21.773' N
15	8.3054	57.3588	008° 18.322' E	57° 21.529' N
16	8.3078	57.3520	008° 18.469' E	57° 21.119' N
17	8.3299	57.3554	008° 19.794' E	57° 21.326' N
18	8.3312	57.3599	008° 19.873' E	57° 21.595' N
19	8.3370	57.3616	008° 20.222' E	57° 21.696' N
20	8.3430	57.3610	008° 20.577' E	57° 21.658' N
21	8.3474	57.3571	008° 20.846' E	57° 21.427' N
22	8.3559	57.3592	008° 21.351' E	57° 21.551' N
23	8.3583	57.3643	008° 21.499' E	57° 21.856' N
24	8.3630	57.3661	008° 21.780' E	57° 21.966' N
25	8.4340	57.3554	008° 26.038' E	57° 21.324' N
26	8.4350	57.3490	008° 26.101' E	57° 20.938' N
27	8.4323	57.3458	008° 25.938' E	57° 20.746' N
28	8.4364	57.3451	008° 26.184' E	57° 20.704' N
29	8.4418	57.3470	008° 26.509' E	57° 20.821' N
30	8.4528	57.3480	008° 27.169' E	57° 20.882' N
31	8.4664	57.3501	008° 27.981' E	57° 21.006' N
32	8.4784	57.3487	008° 28.706' E	57° 20.922' N
33	8.5057	57.3446	008° 30.344' E	57° 20.673' N
34	8.5072	57.3421	008° 30.432' E	57° 20.528' N
35	8.4673	57.3014	008° 28.037' E	57° 18.083' N
36	8.4269	57.3001	008° 25.611' E	57° 18.006' N
37	8.4044	57.2938	008° 24.264' E	57° 17.625' N
38	8.3809	57.2863	008° 22.853' E	57° 17.177' N
39	8.3352	57.2866	008° 20.112' E	57° 17.197' N

40	8.3131	57.2828	008° 18.788' E	57° 16.967' N
41	8.2883	57.2688	008° 17.300' E	57° 16.129' N
42	8.2713	57.2712	008° 16.275' E	57° 16.269' N
43	8.2672	57.2655	008° 16.031' E	57° 15.929' N
44	8.2607	57.2587	008° 15.640' E	57° 15.523' N
45	8.2563	57.2567	008° 15.380' E	57° 15.403' N
46	8.2501	57.2573	008° 15.007' E	57° 15.435' N
47	8.2445	57.2633	008° 14.670' E	57° 15.795' N
48	8.2447	57.2692	008° 14.682' E	57° 16.154' N
49	8.2390	57.2710	008° 14.339' E	57° 16.258' N
50	8.2335	57.2646	008° 14.012' E	57° 15.876' N
51	8.2166	57.2645	008° 12.997' E	57° 15.872' N
52	8.1994	57.2521	008° 11.966' E	57° 15.125' N
53	8.1867	57.2517	008° 11.204' E	57° 15.104' N
54	8.1613	57.2585	008° 09.680' E	57° 15.509' N
55	8.1600	57.2496	008° 09.601' E	57° 14.978' N
56	8.1740	57.2463	008° 10.441' E	57° 14.778' N
57	8.1750	57.2411	008° 10.499' E	57° 14.463' N
58	8.1705	57.2326	008° 10.230' E	57° 13.958' N
59	8.1770	57.2309	008° 10.619' E	57° 13.851' N
60	8.1830	57.2379	008° 10.980' E	57° 14.276' N
61	8.1916	57.2385	008° 11.497' E	57° 14.307' N
62	8.1966	57.2339	008° 11.796' E	57° 14.033' N
63	8.2009	57.2339	008° 12.052' E	57° 14.036' N
64	8.1994	57.2434	008° 11.965' E	57° 14.605' N
65	8.2166	57.2468	008° 12.996' E	57° 14.808' N
66	8.2310	57.2460	008° 13.859' E	57° 14.758' N
67	8.2322	57.2503	008° 13.933' E	57° 15.020' N
68	8.2556	57.2510	008° 15.336' E	57° 15.057' N
69	8.2581	57.2552	008° 15.483' E	57° 15.313' N
70	8.2621	57.2579	008° 15.726' E	57° 15.472' N
71	8.2739	57.2595	008° 16.435' E	57° 15.570' N
72	8.2793	57.2596	008° 16.759' E	57° 15.578' N
73	8.3034	57.2662	008° 18.205' E	57° 15.972' N

74	8.3059	57.2683	008° 18.352' E	57° 16.099' N
75	8.3154	57.2707	008° 18.921' E	57° 16.243' N
76	8.3438	57.2420	008° 20.628' E	57° 14.518' N
77	8.3369	57.2246	008° 20.211' E	57° 13.478' N
78	8.0117	57.2049	008° 00.704' E	57° 12.295' N
79	7.9754	57.2035	007° 58.526' E	57° 12.211' N

Reef 2

Point	x_dec	y_dec	X	y
1	8.4105	57.2493	008° 24.628' E	57° 14.957' N
2	8.4038	57.2466	008° 24.230' E	57° 14.795' N
3	8.3817	57.2482	008° 22.902' E	57° 14.893' N
4	8.3779	57.2551	008° 22.675' E	57° 15.304' N
5	8.3868	57.2644	008° 23.205' E	57° 15.864' N
6	8.3949	57.2702	008° 23.693' E	57° 16.211' N
7	8.4045	57.2760	008° 24.269' E	57° 16.561' N
8	8.4124	57.2789	008° 24.742' E	57° 16.732' N
9	8.4204	57.2781	008° 25.225' E	57° 16.683' N
10	8.4277	57.2813	008° 25.664' E	57° 16.877' N
11	8.4280	57.2842	008° 25.678' E	57° 17.052' N
12	8.4396	57.2902	008° 26.377' E	57° 17.413' N
13	8.4451	57.2902	008° 26.708' E	57° 17.412' N
14	8.4483	57.2884	008° 26.896' E	57° 17.302' N
15	8.4495	57.2830	008° 26.971' E	57° 16.977' N
16	8.4347	57.2679	008° 26.080' E	57° 16.072' N
17	8.4124	57.2609	008° 24.744' E	57° 15.652' N
18	8.4105	57.2493	008° 24.628' E	57° 14.957' N

Store Rev

Habitat No. 258. Natura 2000 Site No. 249 (EU Code: DK00VA258)

Coordinates of the buffer zone which form the protection of the bubbling reefs and the stone reefs:

Bubbling reef no. 1:

Point	x_dec	y_dec	X	y
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1	9.3066	57.7081	009° 18.397' E	57° 42.486' N
2	9.3162	57.6986	009° 18.974' E	57° 41.916' N
3	9.3162	57.6930	009° 18.974' E	57° 41.577' N
4	9.2920	57.6930	009° 17.518' E	57° 41.577' N
5	9.2920	57.6997	009° 17.518' E	57° 41.983' N
6	9.2960	57.7081	009° 17.758' E	57° 42.486' N
7	9.3066	57.7081	009° 18.397' E	57° 42.486' N

Bubbling reef no. 2:

Point	x_dec	y_dec	X	y
1	9.1650	57.6963	009° 09.899' E	57° 41.775' N
2	9.1650	57.6881	009° 09.899' E	57° 41.284' N
3	9.1506	57.6881	009° 09.037' E	57° 41.284' N
4	9.1488	57.6963	009° 09.929' E	57° 41.775' N
5	9.1650	57.6963	009° 09.899' E	57° 41.775' N

Bubbling reef no. 3:

Point	x_dec	y_dec	X	y
1	9.3440	57.6983	009° 20.637' E	57° 41.895' N
2	9.3440	57.6900	009° 20.367' E	57° 41.397' N
3	9.3286	57.6900	009° 19.713' E	57° 41.397' N
4	9.3286	57.6983	009° 19.713' E	57° 41.895' N
5	9.3440	57.6983	009° 20.637' E	57° 41.895' N

Bubbling reef no. 4:

Point	x_dec	y_dec	X	y
1	9.2666	57.7306	009° 15.994' E	57° 43.834' N
2	9.2665	57.7223	009° 15.987' E	57° 43.336' N
3	9.2379	57.7194	009° 14.274' E	57° 43.165' N
4	9.2378	57.7277	009° 14.267' E	57° 43.664' N
5	9.2666	57.7306	009° 15.994' E	57° 43.834' N

Bubbling reef no. 5:

Point	x_dec	y_dec	X	y
1	9.3429	57.7242	009° 20.571' E	57° 43.450' N
2	9.3429	57.7160	009° 20.571' E	57° 42.958' N
3	9.3275	57.7160	009° 19.652' E	57° 42.958' N
4	9.3275	57.7242	009° 19.652' E	57° 43.450' N
5	9.3429	57.7242	009° 20.571' E	57° 43.450' N

Bubbling reef no. 6:

Point	x_dec	y_dec	X	y
1	9.3775	57.7099	009° 22.649' E	57° 42.591' N
2	9.3895	57.7047	009° 23.371' E	57° 42.280' N
3	9.3849	57.7002	009° 23.091' E	57° 42.010' N
4	9.3540	57.6946	009° 21.240' E	57° 41.678' N
5	9.3537	57.7027	009° 21.219' E	57° 42.159' N
6	9.3775	57.7099	009° 22.649' E	57° 42.591' N

Stone reefs:

Point	x_dec	y_dec	x	y
1	9.3676	57.7165	009° 22.057' E	57° 42.987' N
2	9.3870	57.7129	009° 23.220' E	57° 42.776' N
3	9.3915	57.7100	009° 23.488' E	57° 42.600' N
4	9.3905	57.7057	009° 23.427' E	57° 42.339' N
5	9.3859	57.7009	009° 23.155' E	57° 42.055' N
6	9.3709	57.6895	009° 22.253' E	57° 41.368' N
7	9.3560	57.6825	009° 21.360' E	57° 40.950' N
8	9.3291	57.6752	009° 19.743' E	57° 40.510' N
9	9.3293	57.6729	009° 19.755' E	57° 40.375' N
10	9.3261	57.6696	009° 19.564' E	57° 40.175' N
11	9.3189	57.6677	009° 19.135' E	57° 40.064' N
12	9.3116	57.6673	009° 18.697' E	57° 40.036' N

13	9.3041	57.6693	009° 18.243' E	57° 40.160' N
14	9.2997	57.6691	009° 17.980' E	57° 40.146' N
15	9.2986	57.6675	009° 17.916' E	57° 40.052' N

16	9.2893	57.6636	009° 17.359' E	57° 39.814' N
17	9.2787	57.6617	009° 16.723' E	57° 39.703' N
18	9.2687	57.6627	009° 16.121' E	57° 39.763' N
19	9.2640	57.6629	009° 15.837' E	57° 39.771' N
20	9.2517	57.6612	009° 15.099' E	57° 39.674' N
21	9.2467	57.6632	009° 14.801' E	57° 39.793' N
22	9.2126	57.6617	009° 12.758' E	57° 39.701' N
23	9.2074	57.6622	009° 12.442' E	57° 39.729' N
24	9.2032	57.6609	009° 12.193' E	57° 39.655' N
25	9.1984	57.6606	009° 11.904' E	57° 39.633' N
26	9.1943	57.6614	009° 11.659' E	57° 39.685' N
27	9.1922	57.6627	009° 11.532' E	57° 39.760' N
28	9.1878	57.6629	009° 11.268' E	57° 39.773' N
29	9.1822	57.6637	009° 10.930' E	57° 39.821' N
30	9.1737	57.6658	009° 10.419' E	57° 39.948' N
31	9.1659	57.6686	009° 09.955' E	57° 40.116' N
32	9.1593	57.6717	009° 09.559' E	57° 40.304' N
33	9.1523	57.6804	009° 09.139' E	57° 40.825' N
34	9.1428	57.7199	009° 08.566' E	57° 43.193' N
35	9.1468	57.7241	009° 08.808' E	57° 43.448' N
36	9.1494	57.7256	009° 08.962' E	57° 43.533' N
37	9.1546	57.7262	009° 09.277' E	57° 43.573' N
38	9.1648	57.7253	009° 09.885' E	57° 43.515' N
39	9.1845	57.7329	009° 11.068' E	57° 43.973' N
40	9.2143	57.7417	009° 12.857' E	57° 44.500' N
41	9.2197	57.7425	009° 13.182' E	57° 44.551' N
42	9.2249	57.7431	009° 13.496' E	57° 44.588' N
43	9.2351	57.7431	009° 14.108' E	57° 44.584' N
44	9.2386	57.7423	009° 14.315' E	57° 44.536' N
45	9.2436	57.7431	009° 14.618' E	57° 44.585' N
46	9.2485	57.7464	009° 14.907' E	57° 44.782' N
47	9.2525	57.7474	009° 15.147' E	57° 44.844' N
48	9.2556	57.7476	009° 15.336' E	57° 44.854' N
49	9.2581	57.7477	009° 15.486' E	57° 44.860' N

50	9.2600	57.7488	009° 15.598' E	57° 44.928' N
51	9.2626	57.7503	009° 15.756' E	57° 45.017' N
52	9.2686	57.7516	009° 16.118' E	57° 45.095' N
53	9.2725	57.7515	009° 16.351' E	57° 45.089' N
54	9.2764	57.7501	009° 16.586' E	57° 45.005' N
55	9.2813	57.7502	009° 16.878' E	57° 45.011' N
56	9.2886	57.7530	009° 17.314' E	57° 45.180' N
57	9.2932	57.7538	009° 17.593' E	57° 45.228' N
58	9.2982	57.7537	009° 17.891' E	57° 45.220' N
59	9.3086	57.7533	009° 18.518' E	57° 45.195' N
60	9.3136	57.7508	009° 18.816' E	57° 45.050' N
61	9.3187	57.7474	009° 19.119' E	57° 44.845' N
62	9.3217	57.7478	009° 19.299' E	57° 44.869' N
63	9.3252	57.7477	009° 19.514' E	57° 44.863' N
64	9.3295	57.7465	009° 19.768' E	57° 44.791' N
65	9.3327	57.7440	009° 19.959' E	57° 44.638' N
66	9.3318	57.7408	009° 19.907' E	57° 44.447' N
67	9.3342	57.7383	009° 20.053' E	57° 44.296' N
68	9.3311	57.7326	009° 19.863' E	57° 43.955' N
69	9.3260	57.7293	009° 19.557' E	57° 43.756' N
70	9.3234	57.7272	009° 19.406' E	57° 43.634' N
71	9.3313	57.7267	009° 19.877' E	57° 43.601' N
72	9.3448	57.7265	009° 20.685' E	57° 43.589' N
73	9.3500	57.7248	009° 20.999' E	57° 43.490' N
74	9.3592	57.7218	009° 21.550' E	57° 43.307' N
75	9.3676	57.7165	009° 22.057' E	57° 42.987' N

Jyske Rev. Lillefiskerbanke

Habitat No. 257. Natura 2000 Site No. 248 (EU Code: DK00VA257)

Coordinates of the buffer zone which form the protection of stone reefs:

Point	x_dec	y_dec	x	y
1	6.5361	56.8364	006° 32.167' E	56° 50.184' N
2	6.5063	56.8807	006° 30.376' E	56° 52.841' N

3	6.5069	56.8825	006° 30.415' E	56° 52.948' N
4	6.5096	56.8834	006° 30.578' E	56° 53.006' N
5	6.8390	56.9152	006° 50.338' E	56° 54.911' N
6	6.8610	56.9104	006° 51.657' E	56° 54.621' N
7	6.9189	56.8639	006° 55.133' E	56° 51.833' N
8	6.9182	56.8612	006° 55.092' E	56° 51.672' N
9	6.8931	56.8514	006° 53.587' E	56° 51.084' N
10	6.8889	56.8483	006° 53.332' E	56° 50.898' N
11	6.8944	56.8427	006° 53.661' E	56° 50.563' N
12	6.9046	56.8412	006° 54.273' E	56° 50.471' N
13	6.9199	56.8429	006° 55.194' E	56° 50.571' N
14	6.9312	56.8425	006° 55.873' E	56° 50.548' N
15	6.9545	56.8354	006° 57.269' E	56° 50.126' N
16	7.0197	56.7829	007° 01.181' E	56° 46.971' N
17	7.0146	56.7773	007° 00.874' E	56° 46.639' N
18	6.9968	56.7780	006° 59.808' E	56° 46.680' N
19	6.5804	56.8287	006° 34.824' E	56° 49.722' N
20	6.5361	56.8364	006° 32.167' E	56° 50.184' N

Thyborøn Stenvolde

Habitat No. 256. Natura 2000 Site No. 247 (EU Code: DK00VA348)

Coordinates of the buffer zone which form the protection of the stone reefs:

Point	x_dec	y_dec	x	y
1	7.8533	56.7317	007° 51.199' E	56° 43.904' N
2	7.8566	56.7311	007° 51.398' E	56° 43.864' N
3	7.8626	56.7233	007° 51.756' E	56° 43.399' N
4	7.8628	56.7140	007° 51.767' E	56° 42.841' N
5	7.8637	56.6871	007° 51.819' E	56° 41.226' N
6	7.8640	56.6752	007° 51.841' E	56° 40.512' N
7	7.8646	56.6567	007° 51.876' E	56° 39.403' N
8	7.8559	56.6498	007° 51.356' E	56° 38.988' N
9	7.8321	56.6416	007° 49.924' E	56° 38.495' N
10	7.8298	56.6376	007° 49.785' E	56° 38.253' N

11	7.8110	56.6338	007° 48.660' E	56° 38.030' N
12	7.8102	56.6274	007° 48.612' E	56° 37.642' N
13	7.7759	56.6270	007° 46.552' E	56° 37.621' N
14	7.7678	56.6296	007° 46.068' E	56° 37.778' N
15	7.7661	56.6347	007° 45.966' E	56° 38.084' N
16	7.7535	56.6392	007° 45.209' E	56° 38.349' N
17	7.7469	56.6474	007° 44.816' E	56° 38.843' N
18	7.7371	56.6523	007° 44.226' E	56° 39.135' N
19	7.7345	56.6572	007° 44.068' E	56° 39.430' N
20	7.7296	56.6599	007° 43.776' E	56° 39.595' N
21	7.7190	56.6603	007° 43.141' E	56° 39.616' N
22	7.7144	56.6585	007° 42.866' E	56° 39.508' N
23	7.7146	56.6548	007° 42.877' E	56° 39.290' N
24	7.7112	56.6533	007° 42.672' E	56° 39.198' N
25	7.7104	56.6480	007° 42.621' E	56° 38.880' N
26	7.7185	56.6417	007° 43.107' E	56° 38.500' N
27	7.7200	56.6390	007° 43.198' E	56° 38.338' N
28	7.7183	56.6353	007° 43.097' E	56° 38.115' N
29	7.6986	56.6351	007° 41.913' E	56° 38.106' N
30	7.6857	56.6419	007° 41.140' E	56° 38.514' N
31	7.6735	56.6408	007° 40.412' E	56° 38.448' N
32	7.6694	56.6421	007° 40.161' E	56° 38.526' N
33	7.6675	56.6442	007° 40.048' E	56° 38.650' N
34	7.7656	56.6905	007° 45.937' E	56° 41.431' N
35	7.7932	56.6921	007° 47.594' E	56° 41.524' N
36	7.8048	56.7013	007° 48.288' E	56° 42.078' N
37	7.8169	56.7147	007° 49.012' E	56° 42.881' N
38	7.8533	56.7317	007° 51.199' E	56° 43.904' N

Lønstrup Rødgrund

Habitat No. 202. Natura 2000 Site No. 202 (EU Code: DK00VA301)

Coordinates of the buffer zone which form the protection of the stone reefs:

Reef 1:

Point	x_dec	y_dec	x	y
1	9.7888	57.4988	009° 47.328' E	57° 29.925' N
2	9.7378	57.4492	009° 44.268' E	57° 26.950' N
3	9.7347	57.4496	009° 44.084' E	57° 26.976' N
4	9.7329	57.4524	009° 43.973' E	57° 27.141' N
5	9.7252	57.4510	009° 43.509' E	57° 27.057' N
6	9.7237	57.4492	009° 43.423' E	57° 26.954' N
7	9.7185	57.4483	009° 43.112' E	57° 26.897' N
8	9.7220	57.4459	009° 43.321' E	57° 26.753' N
9	9.7274	57.4479	009° 43.644' E	57° 26.876' N
10	9.7356	57.4469	009° 44.137' E	57° 26.813' N
11	9.6911	57.4032	009° 41.467' E	57° 24.189' N
12	9.6892	57.4026	009° 41.351' E	57° 24.158' N
13	9.6872	57.4033	009° 41.234' E	57° 24.195' N
14	9.6688	57.4126	009° 40.128' E	57° 24.754' N
15	9.6685	57.4139	009° 40.108' E	57° 24.834' N
16	9.6815	57.4187	009° 40.891' E	57° 25.123' N
17	9.6803	57.4217	009° 40.818' E	57° 25.300' N
18	9.6851	57.4255	009° 41.108' E	57° 25.530' N
19	9.6890	57.4276	009° 41.337' E	57° 25.656' N
20	9.6937	57.4274	009° 41.620' E	57° 25.642' N
21	9.6976	57.4241	009° 41.854' E	57° 25.448' N
22	9.6991	57.4256	009° 41.945' E	57° 25.533' N
23	9.6943	57.4283	009° 41.660' E	57° 25.699' N
24	9.6871	57.4301	009° 41.225' E	57° 25.803' N
25	9.6746	57.4364	009° 40.476' E	57° 26.184' N
26	9.6772	57.4420	009° 40.631' E	57° 26.522' N
27	9.6826	57.4475	009° 40.957' E	57° 26.848' N
28	9.6821	57.4493	009° 40.923' E	57° 26.959' N
29	9.6790	57.4512	009° 40.740' E	57° 27.071' N
30	9.6758	57.4489	009° 40.545' E	57° 26.934' N
31	9.6678	57.4497	009° 40.070' E	57° 26.981' N
32	9.6627	57.4521	009° 39.763' E	57° 27.127' N

33	9.6535	57.4513	009° 39.207' E	57° 27.077' N
34	9.6478	57.4525	009° 38.870' E	57° 27.151' N
35	9.6437	57.4490	009° 38.619' E	57° 26.939' N
36	9.6562	57.4427	009° 39.371' E	57° 26.562' N
37	9.6612	57.4427	009° 39.671' E	57° 26.561' N
38	9.6633	57.4407	009° 39.799' E	57° 26.444' N
39	9.6633	57.4358	009° 39.795' E	57° 26.149' N
40	9.6687	57.4368	009° 40.119' E	57° 26.208' N
41	9.6710	57.4355	009° 40.262' E	57° 26.127' N
42	9.6702	57.4337	009° 40.211' E	57° 26.020' N
43	9.6785	57.4277	009° 40.708' E	57° 25.663' N
44	9.6739	57.4222	009° 40.434' E	57° 25.329' N
45	9.6621	57.4244	009° 39.725' E	57° 25.464' N
46	9.6576	57.4297	009° 39.454' E	57° 25.781' N
47	9.6536	57.4332	009° 39.218' E	57° 25.991' N
48	9.6370	57.4277	009° 38.219' E	57° 25.659' N
49	9.6337	57.4284	009° 38.020' E	57° 25.701' N
50	9.6315	57.4300	009° 37.891' E	57° 25.799' N
51	9.6292	57.4313	009° 37.752' E	57° 25.879' N
52	9.6251	57.4315	009° 37.504' E	57° 25.890' N
53	9.6227	57.4331	009° 37.362' E	57° 25.983' N
54	9.6208	57.4334	009° 37.246' E	57° 26.001' N
55	9.6159	57.4328	009° 36.955' E	57° 25.967' N
56	9.6132	57.4334	009° 36.789' E	57° 26.003' N
57	9.6134	57.4354	009° 36.801' E	57° 26.123' N
58	9.6177	57.4373	009° 37.062' E	57° 26.237' N
59	9.6179	57.4375	009° 37.071' E	57° 26.251' N
60	9.6168	57.4377	009° 37.008' E	57° 26.261' N
61	9.6157	57.4385	009° 36.944' E	57° 26.312' N
62	9.6158	57.4395	009° 36.946' E	57° 26.369' N
63	9.6193	57.4414	009° 37.157' E	57° 26.484' N
64	9.6182	57.4417	009° 37.091' E	57° 26.501' N
65	9.6143	57.4410	009° 36.858' E	57° 26.462' N
66	9.6120	57.4413	009° 36.722' E	57° 26.478' N

67	9.6105	57.4420	009° 36.628' E	57° 26.518' N
68	9.6100	57.4441	009° 36.600' E	57° 26.644' N
69	9.6085	57.4450	009° 36.508' E	57° 26.697' N
70	9.6073	57.4460	009° 36.437' E	57° 26.761' N
71	9.6038	57.4460	009° 36.228' E	57° 26.759' N
72	9.6022	57.4472	009° 36.131' E	57° 26.834' N
73	9.6019	57.4496	009° 36.111' E	57° 26.975' N
74	9.6022	57.4519	009° 36.134' E	57° 27.114' N
75	9.6043	57.4536	009° 36.259' E	57° 27.214' N
76	9.6063	57.4544	009° 36.379' E	57° 27.265' N
77	9.6036	57.4561	009° 36.214' E	57° 27.364' N
78	9.6031	57.4573	009° 36.185' E	57° 27.436' N
79	9.6041	57.4581	009° 36.244' E	57° 27.488' N
80	9.6063	57.4585	009° 36.377' E	57° 27.512' N
81	9.6050	57.4608	009° 36.298' E	57° 27.645' N
82	9.6020	57.4615	009° 36.120' E	57° 27.687' N
83	9.5984	57.4594	009° 35.902' E	57° 27.561' N
84	9.5946	57.4610	009° 35.673' E	57° 27.658' N
85	9.6406	57.4954	009° 38.436' E	57° 29.725' N
86	9.6463	57.4924	009° 38.777' E	57° 29.546' N
87	9.6522	57.4930	009° 39.130' E	57° 29.581' N
88	9.6546	57.4947	009° 39.278' E	57° 29.680' N
89	9.6522	57.4994	009° 39.134' E	57° 29.962' N
90	9.6554	57.5014	009° 39.326' E	57° 30.081' N
91	9.6580	57.5022	009° 39.478' E	57° 30.134' N
92	9.6605	57.5063	009° 39.628' E	57° 30.380' N
93	9.6952	57.5058	009° 41.713' E	57° 30.349' N
94	9.7827	57.5045	009° 46.961' E	57° 30.271' N
95	9.7885	57.5030	009° 47.307' E	57° 30.182' N
96	9.7888	57.4988	009° 47.328' E	57° 29.925' N

Reef 2:

Point	x_dec	y_dec	x	y
1	9.5758	57.4451	009° 34.549' E	57° 26.704' N

2	9.5814	57.4512	009° 34.882' E	57° 27.071' N
3	9.5896	57.4573	009° 35.376' E	57° 27.436' N
4	9.5915	57.4577	009° 35.491' E	57° 27.460' N
5	9.5934	57.4569	009° 35.604' E	57° 27.412' N
6	9.5938	57.4535	009° 35.627' E	57° 27.208' N
7	9.5922	57.4517	009° 35.534' E	57° 27.101' N
8	9.5793	57.4438	009° 34.755' E	57° 26.627' N
9	9.5758	57.4451	009° 34.549' E	57° 26.704' N

Reef 3:

Point	x_dec	y_dec	x	y
1	9.5788	57.4367	009° 34.726' E	57° 26.204' N
2	9.5800	57.4359	009° 34.800' E	57° 26.155' N
3	9.5830	57.4303	009° 34.979' E	57° 25.816' N
4	9.5898	57.4281	009° 35.390' E	57° 25.683' N
5	9.5909	57.4266	009° 35.454' E	57° 25.593' N
6	9.5908	57.4229	009° 35.446' E	57° 25.371' N
7	9.6029	57.4195	009° 36.172' E	57° 25.170' N
8	9.6034	57.4181	009° 36.201' E	57° 25.087' N
9	9.5956	57.4137	009° 35.736' E	57° 24.824' N
10	9.5915	57.4127	009° 35.488' E	57° 24.761' N
11	9.5850	57.4136	009° 35.101' E	57° 24.817' N
12	9.5844	57.4149	009° 35.063' E	57° 24.896' N
13	9.5876	57.4174	009° 35.257' E	57° 25.046' N
14	9.5808	57.4181	009° 34.851' E	57° 25.084' N
15	9.5750	57.4161	009° 34.502' E	57° 24.963' N
16	9.5705	57.4174	009° 34.232' E	57° 25.042' N
17	9.5690	57.4201	009° 34.141' E	57° 25.205' N
18	9.5666	57.4203	009° 33.995' E	57° 25.218' N
19	9.5572	57.4164	009° 33.431' E	57° 24.984' N
20	9.5436	57.4178	009° 32.613' E	57° 25.068' N
21	9.5446	57.4213	009° 32.675' E	57° 25.275' N
22	9.5466	57.4242	009° 32.795' E	57° 25.453' N
23	9.5555	57.4288	009° 33.328' E	57° 25.726' N

24	9.5595	57.4289	009° 33.569' E	57° 25.736' N
25	9.5627	57.4276	009° 33.763' E	57° 25.654' N
26	9.5641	57.4259	009° 33.845' E	57° 25.555' N
27	9.5701	57.4253	009° 34.204' E	57° 25.519' N
28	9.5719	57.4264	009° 34.315' E	57° 25.586' N
29	9.5798	57.4259	009° 34.788' E	57° 25.551' N
30	9.5820	57.4274	009° 34.923' E	57° 25.643' N
31	9.5775	57.4280	009° 34.651' E	57° 25.677' N
32	9.5643	57.4322	009° 33.861' E	57° 25.931' N
33	9.5694	57.4368	009° 34.163' E	57° 26.205' N
34	9.5788	57.4367	009° 34.726' E	57° 26.204' N

B. Coordinates of the 4-nm alert zone

Gule Rev

Habitat No. 259, Natura 2000 Site No. 250 (EU Code: DK00VA259)

Coordinates of the 4 nm alert zones:

Point	X dec	Y dec	X	y
1	8.1805	57.4625	008° 10.833' E	57° 27.752' N
2	8.5893	57.4022	008° 35.358' E	57° 24.136' N
3	8.6476	57.3425	008° 38.858' E	57° 20.552' N
4	8.4753	57.1654	008° 28.520' E	57° 09.929' N
5	7.9221	57.1300	007° 55.327' E	57° 07.802' N
6	7.6993	57.2967	007° 41.959' E	57° 17.802' N

Store Rev

Habitat No. 258. Natura 2000 Site No. 249 (EU Code: DK00VA258)

Coordinates of the 4 nm alert zones:

Point	X dec	Y dec	X	y
1	8.9763	57.7571	008° 58.578' E	57° 45.426' N
2	9.3327	57.8427	009° 19.967' E	57° 50.567' N
3	9.5424	57.7230	009° 32.547' E	57° 43.382' N
4	9.4348	57.598	009° 26.088' E	57° 35.894' N
5	9.0681	57.5861	009° 04.088' E	57° 35.167' N
6	8.9763	57.7571	008° 58.578' E	57° 45.426' N

Jyske Rev, Lillefiskerbanke**Habitat No. 257, Natura 2000 Site No. 248 (EU Code: DK00VA257)**Coordinates of the 4 nm alert zones:

Point	X dec	Y dec	x	y
1	6.8917	56.9953	006° 53.503' E	56° 59.718' N
2	7.1778	56.7892	007° 10.670' E	56° 47.354' N
3	7.0667	56.6986	007° 04.004' E	56° 41.916' N
4	6.4342	56.7797	006° 26.052' E	56° 46.787' N
5	6.3436	56.9376	006° 20.619' E	56° 56.260' N
6	6.8917	56.9953	006° 53.503' E	56° 59.718' N

Thyborøn Stenvolde**Habitat No. 256, Natura 2000 Site No. 247 (EU Code: DK00VA348)**Coordinates of the 4 nm alert zones:

Point	X dec	Y dec	X	y
1	7.5362	56.6723	007° 32.177' E	56° 40.340' N
2	7.8255	56.8079	007° 49.530' E	56° 48.474' N
3	7.9817	56.7802	007° 58.905' E	56° 46.814' N
4	7.9956	56.6333	007° 59.736' E	56° 37.999' N
5	7.8499	56.5485	007° 50.998' E	56° 32.914' N
6	7.5528	56.5854	007° 33.168' E	56° 35.124' N

Lønstrup Rødgrund**Habitat No. 202, Natura 2000 Site No. 202 (EU Code: DK00VA301)**Coordinates of the 4 nm alert zones:

Point	X dec	Y dec	X	Y
1	9.9199	57.5675	009° 55.198' E	57° 34.053' N
2	9.6392	57.3082	009° 38.355' E	57° 18.495' N
3	9.3657	57.3985	009° 21.946' E	57° 23.915' N
4	9.5896	57.5758	009° 35.379' E	57° 34.548' N

Annex I:

Proposal for Fisheries Management Measures for the protection of reef structures (H1170) and submarine structures made by leaking gasses (H1180) structures in five Danish Natura 2000 sites in the North Sea and Skagerrak.

Annex II:

Pilot study in Natura 2000 site in Danish waters.

Haul Coordinates

Table A- 1 Coordinates of the different haul locations of the “Fully-Sampled Scientific Hauls” of the PreciVis-project, as illustrated by Figure 4-2

Haul ID	Station	Shoot Latitude (N)	Shoot Longitude (E)	Haul Latitude (N)	Haul Longitude (E)
DK_S_1	6	57.238945	8.165477	57.262272	8.248605
DK_S_2	25	57.262661	8.250823	57.227657	8.164528
DK_S_3	5.4	57.226437	8.16982	57.223328	8.242235
DK_S_4	27	57.222061	8.245025	57.248596	8.283208
DK_S_5	5.3	57.250973	8.285347	57.237343	8.198745
DK_S_6	7	57.239578	8.197351	57.261391	8.284367
DK_S_7	7.2	57.263695	8.293962	57.254601	8.302729
DK_S_8	28	57.25423	8.30885	57.240635	8.273566
DK_S_9	23	57.241913	8.274569	57.212029	8.22806
DK_S_10	24.2	57.216053	8.228363	57.217735	8.147235
DK_S_11	24.3	57.217861	8.142734	57.218571	8.096965
DK_S_12	22.3	57.220585	8.098298	57.246452	8.150637
DK_S_13	20	57.35957	8.10902	57.334503	8.042055
DK_S_14	13	57.382813	7.916485	57.373894	7.867949
DK_S_15	19.1	57.281853	7.878678	57.237194	7.938483

Annex B: Results

VISTools: Traction Plots

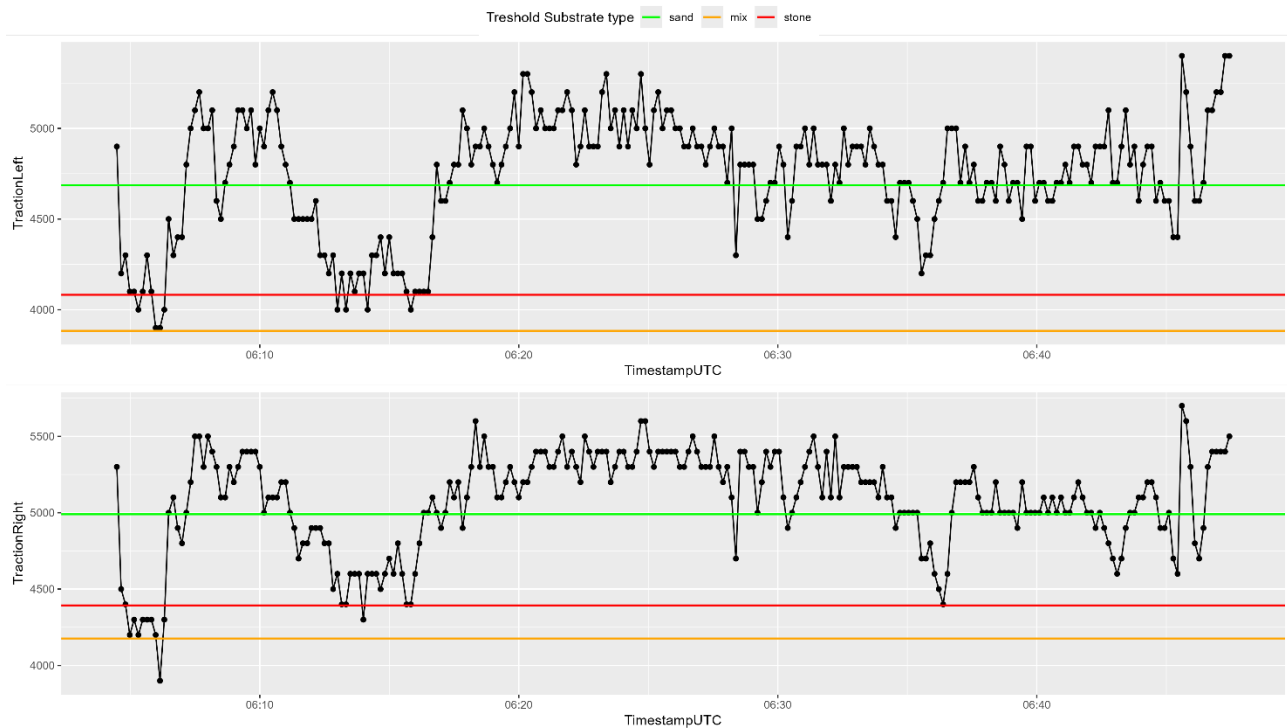


Figure B- 1 Traction values (y-axis, kg) of DK_S_1, measured every 10 seconds after shoot time. (x-axis). Mean traction values associated with the different substrates, as discussed in §9.1, are indicated in green (sand), orange (mixed) and red (stone).

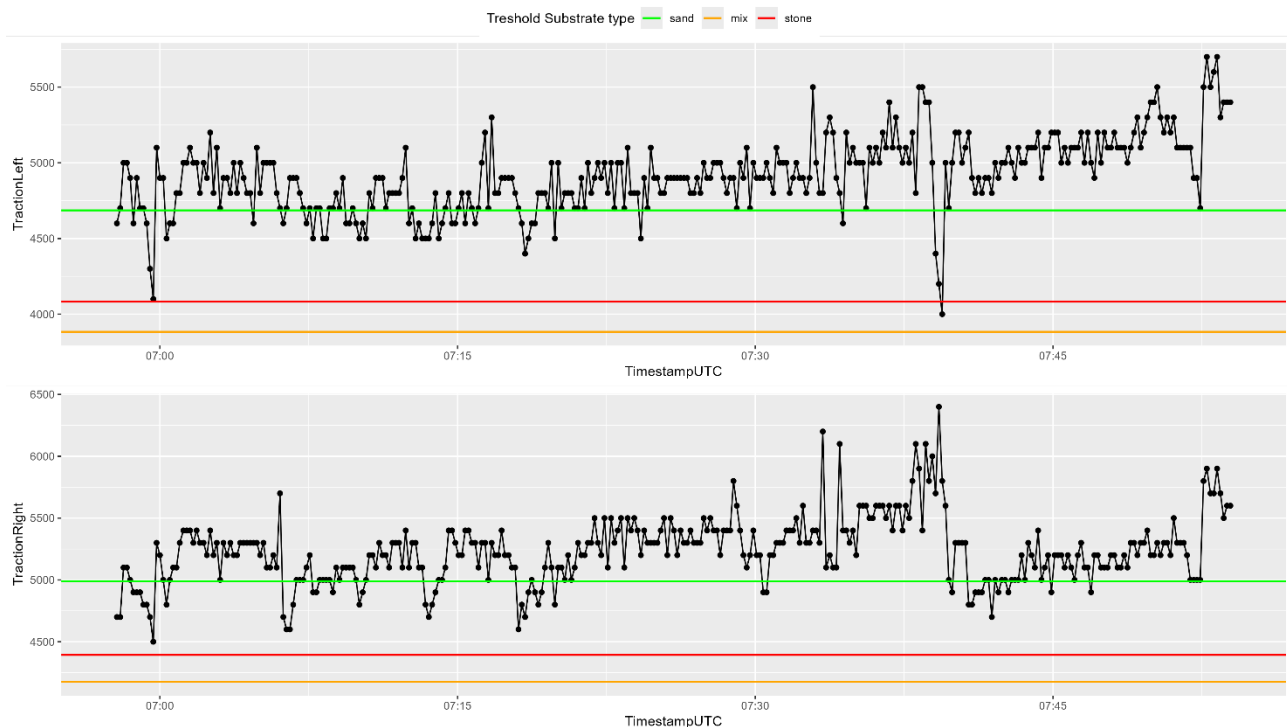


Figure B- 2 Traction values (y-axis, kg) of DK_S_2, measured every 10 seconds after shoot time. (x-axis). Mean traction values associated with the different substrates, as discussed in §9.1, are indicated in green (sand), orange (mixed) and red (stone).

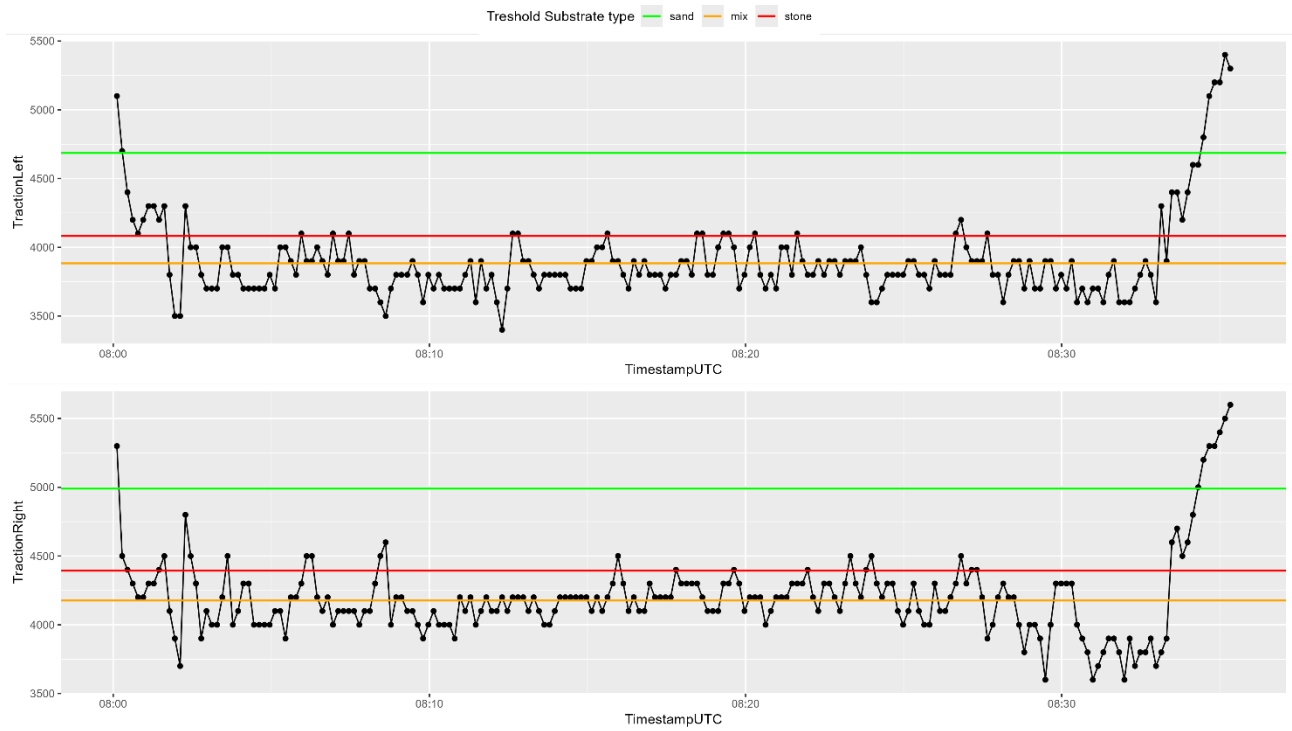


Figure B- 3 Traction values (y-axis, kg) of DK_S_3, measured every 10 seconds after shoot time. (x-axis). Mean traction values associated with the different substrates, as discussed in §9.1, are indicated in green (sand), orange (mixed) and red (stone).

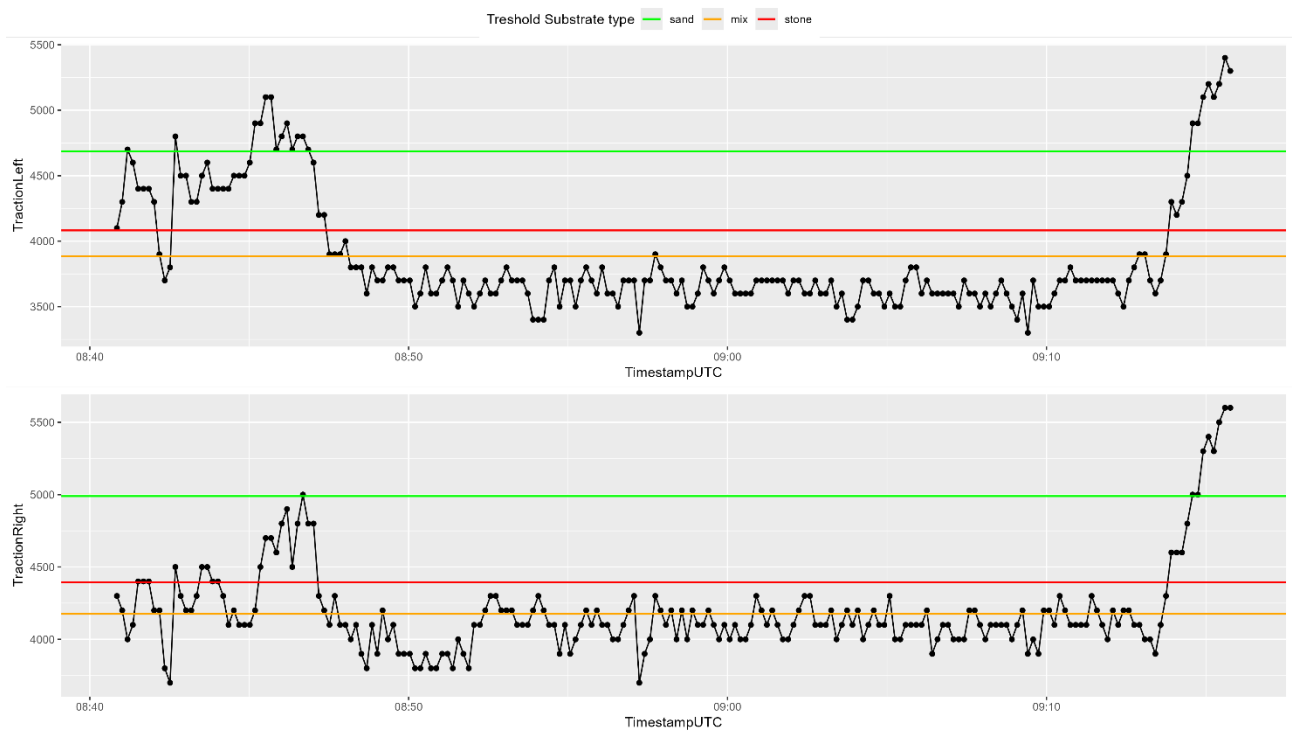


Figure B- 4 Traction values (y-axis, kg) of DK_S_4, measured every 10 seconds after shoot time. (x-axis). Mean traction values associated with the different substrates, as discussed in §9.1, are indicated in green (sand), orange (mixed) and red (stone).

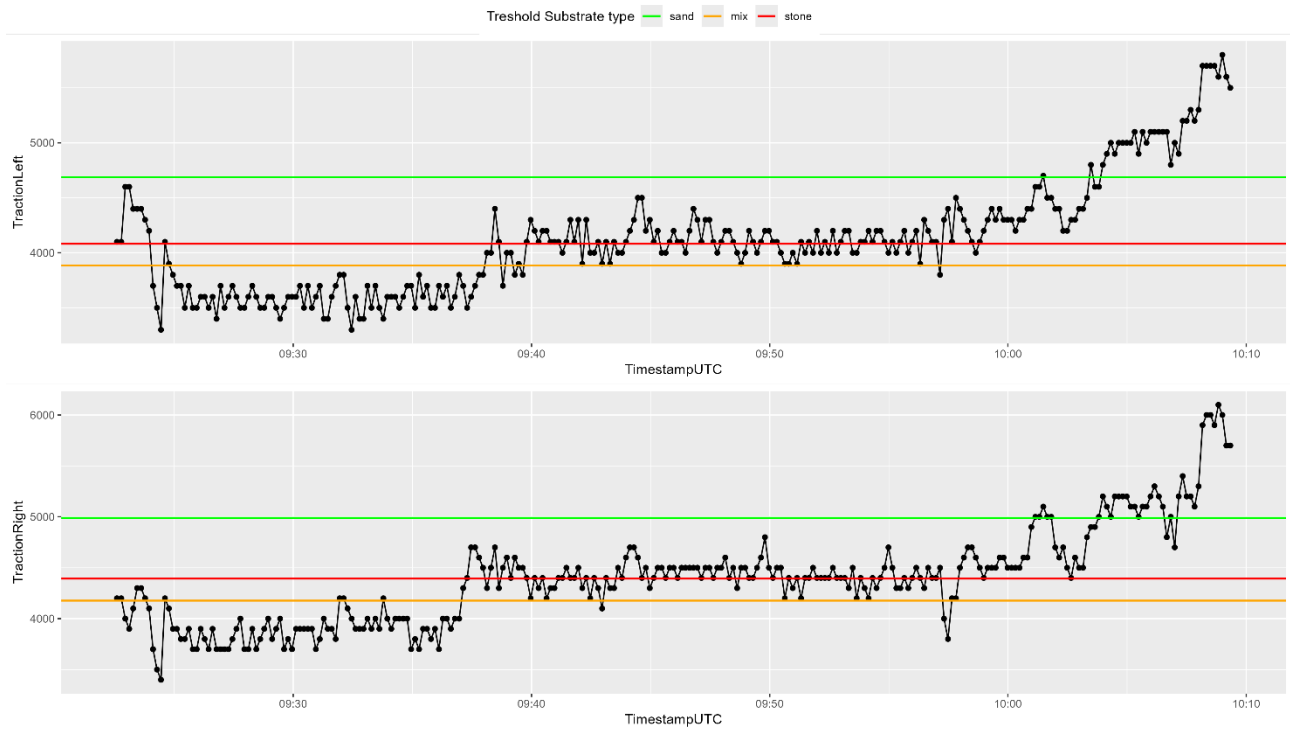


Figure B- 5 Traction values (y-axis, kg) of DK_S_5, measured every 10 seconds after shoot time. (x-axis). Mean traction values associated with the different substrates, as discussed in §9.1, are indicated in green (sand), orange (mixed) and red (stone).

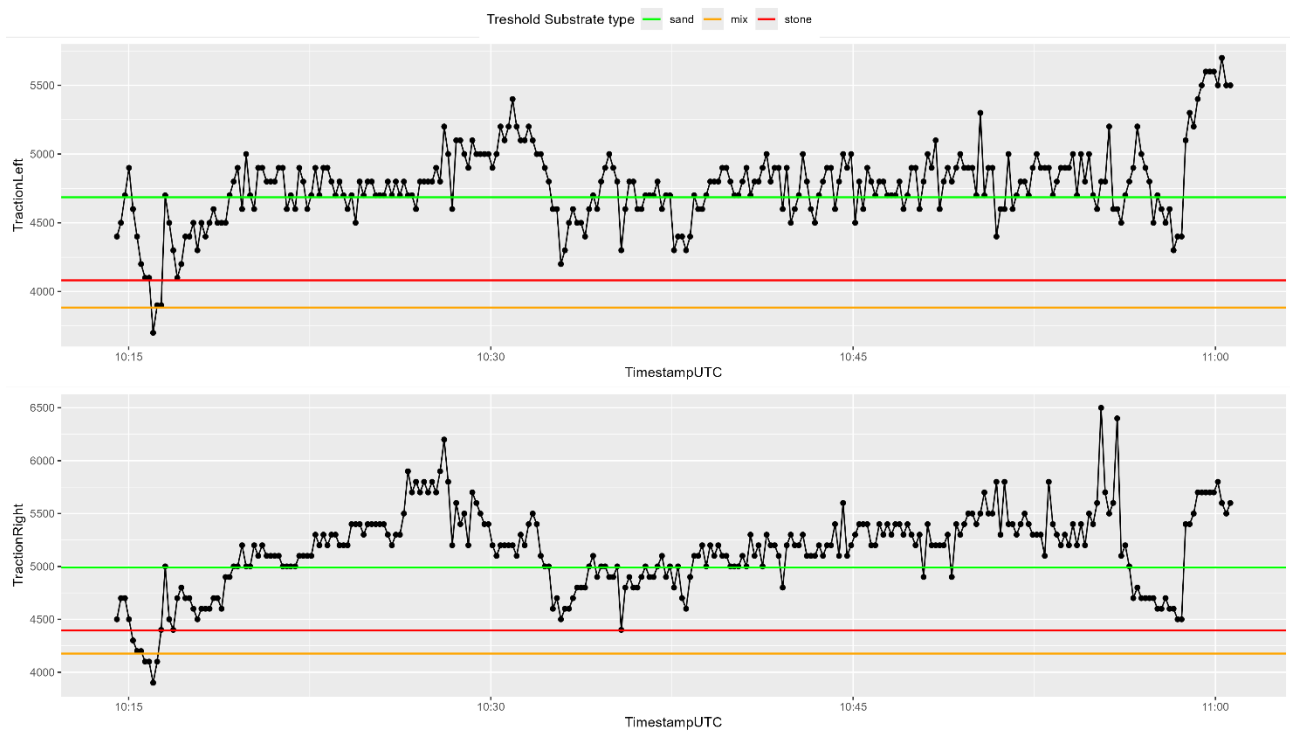


Figure B- 6 Traction values (y-axis, kg) of DK_S_6, measured every 10 seconds after shoot time. (x-axis). Mean traction values associated with the different substrates, as discussed in §9.1, are indicated in green (sand), orange (mixed) and red (stone).

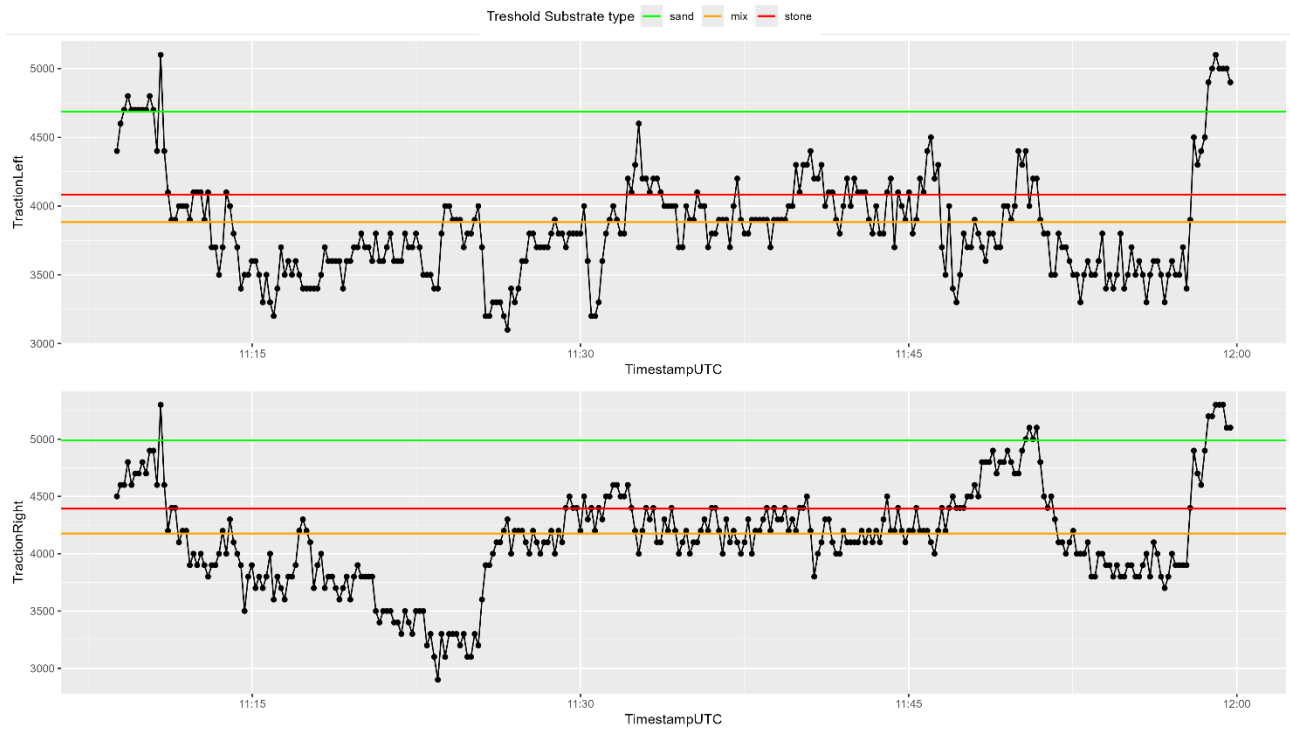


Figure B- 7 Traction values (y-axis, kg) of *DK_S_7*, measured every 10 seconds after shoot time. (x-axis). Mean traction values associated with the different substrates, as discussed in §9.1, are indicated in green (sand), orange (mixed) and red (stone).

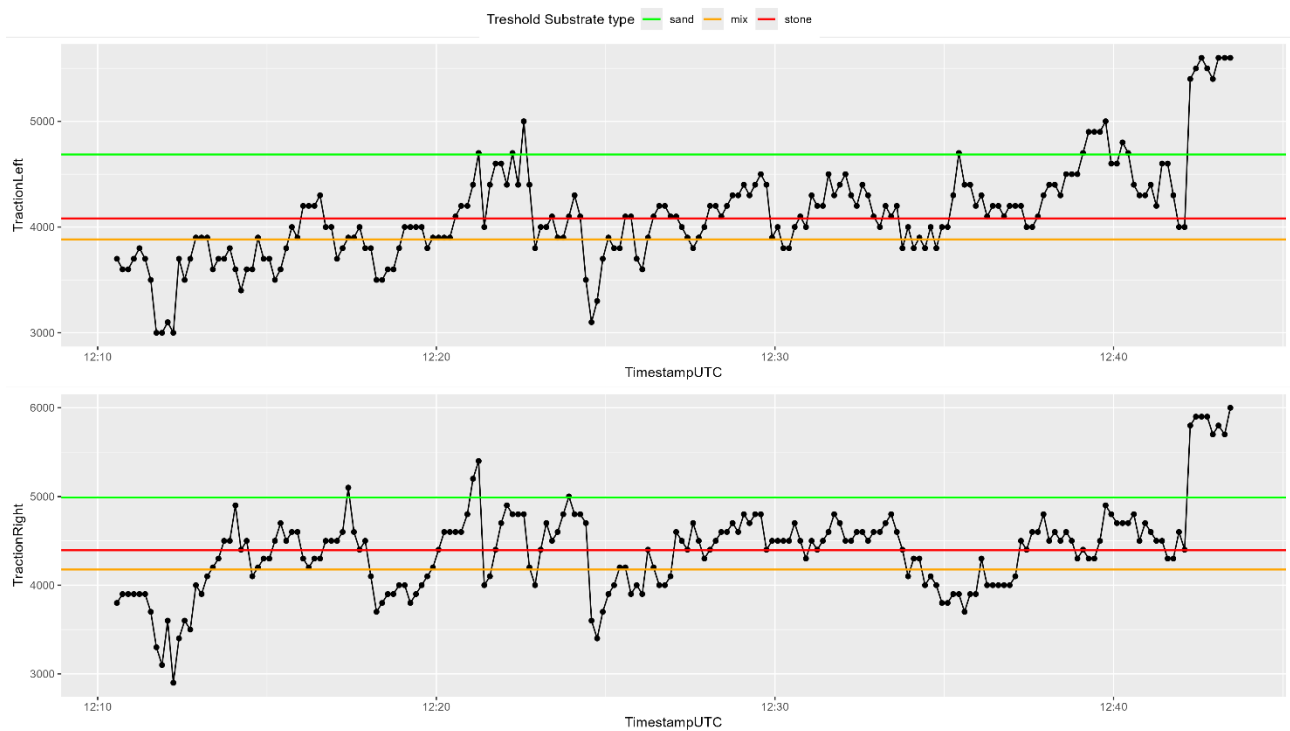


Figure B- 8 Traction values (y-axis, kg) of *DK_S_8*, measured every 10 seconds after shoot time. (x-axis). Mean traction values associated with the different substrates, as discussed in §9.1, are indicated in green (sand), orange (mixed) and red (stone).

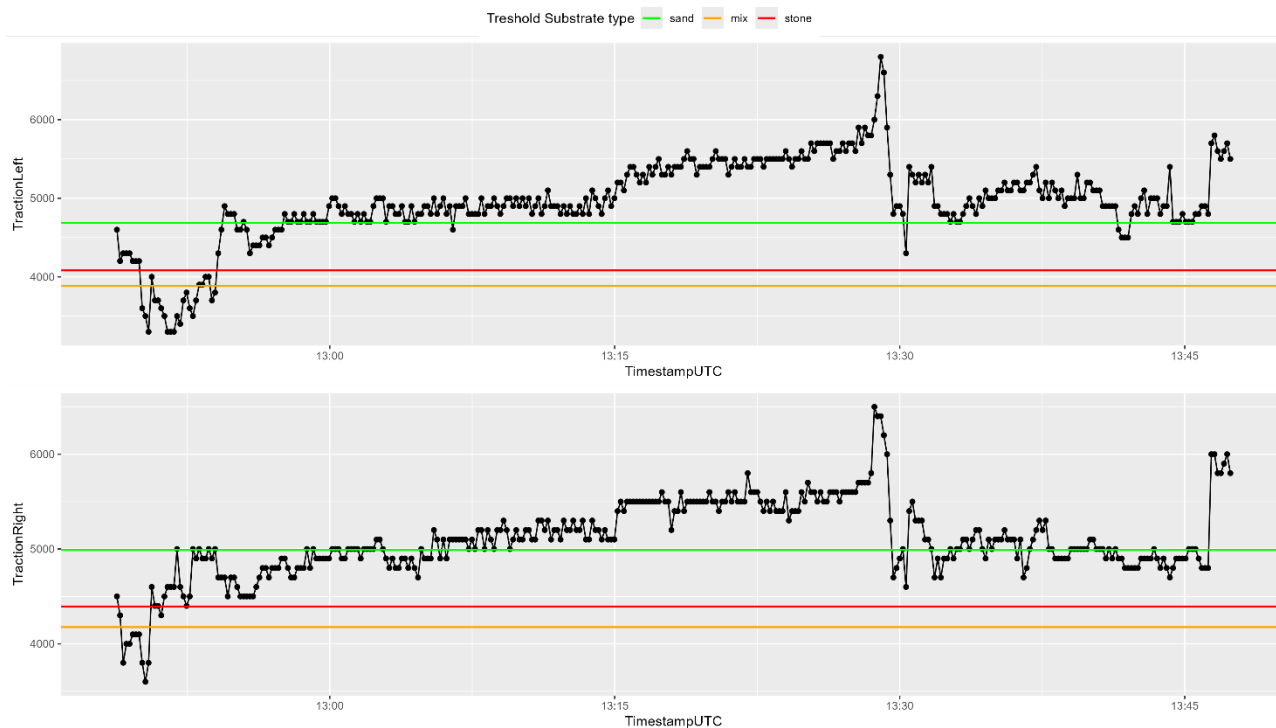


Figure B- 9 Traction values (y-axis, kg) of *DK_S_9*, measured every 10 seconds after shoot time. (x-axis). Mean traction values associated with the different substrates, as discussed in §9.1, are indicated in green (sand), orange (mixed) and red (stone).

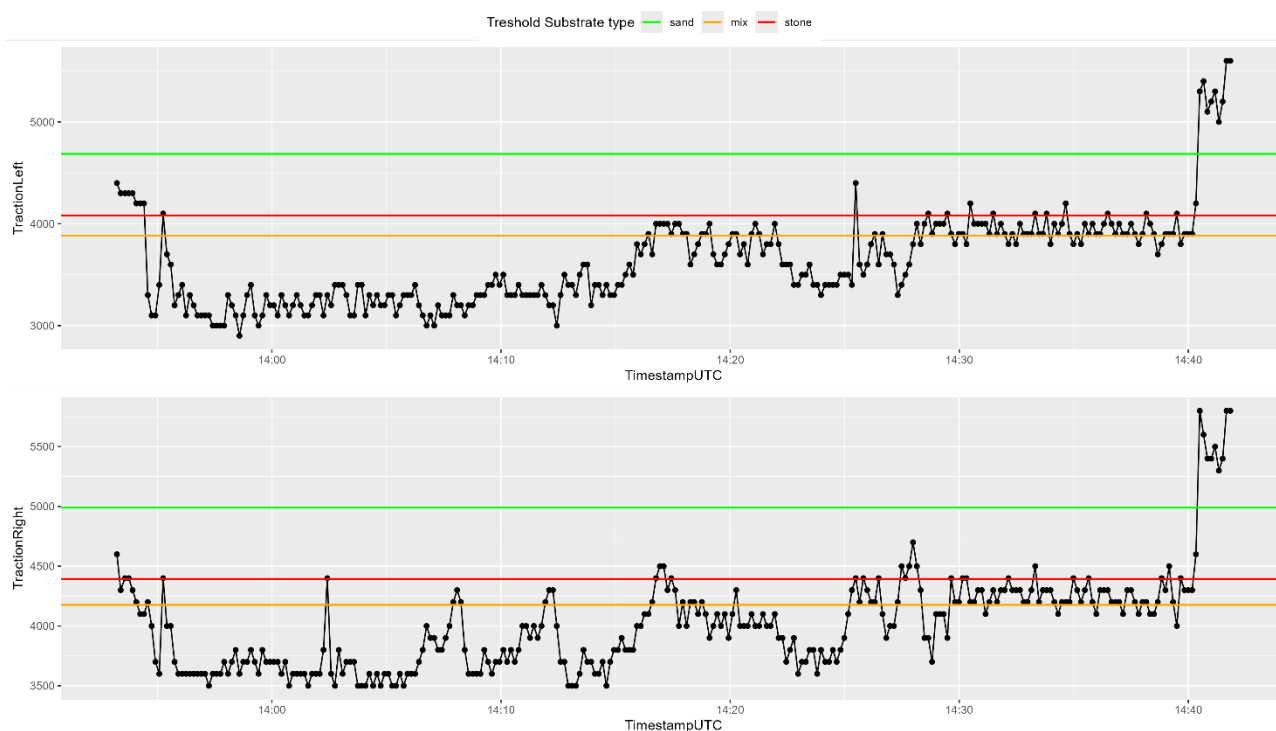


Figure B- 10 Traction values (y-axis, kg) of *DK_S_10*, measured every 10 seconds after shoot time. (x-axis). Mean traction values associated with the different substrates, as discussed in §9.1, are indicated in green (sand), orange (mixed) and red (stone).

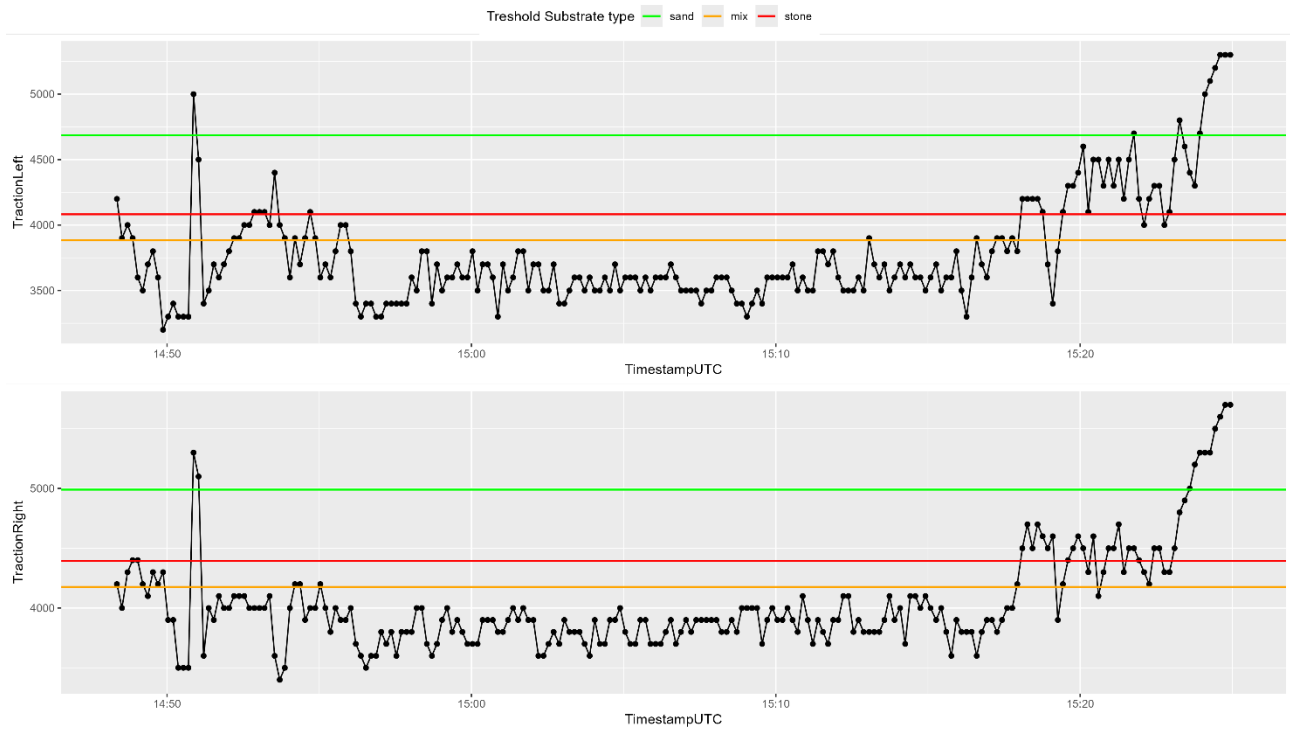


Figure B- 11 Traction values (y-axis, kg) of *DK_S_11*, measured every 10 seconds after shoot time. (x-axis). Mean traction values associated with the different substrates, as discussed in §9.1, are indicated in green (sand), orange (mixed) and red (stone).

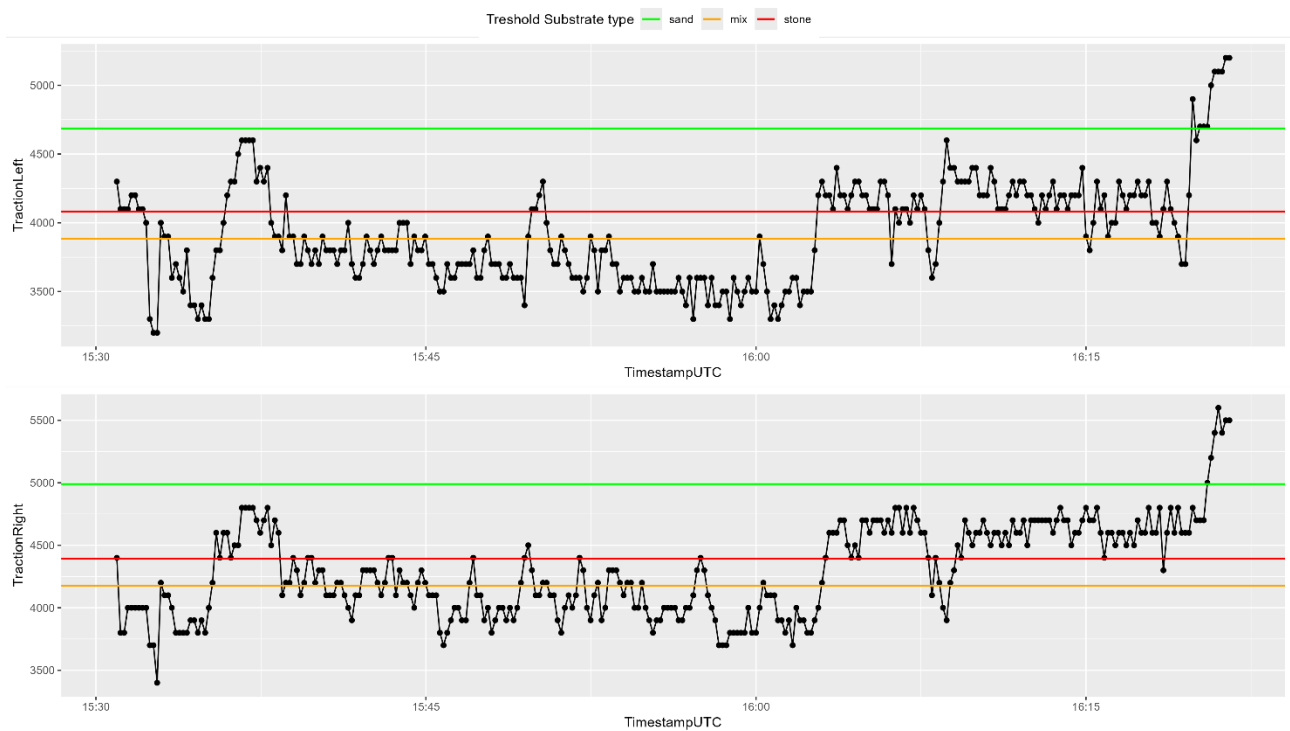


Figure B- 12 Traction values (y-axis, kg) of *DK_S_12*, measured every 10 seconds after shoot time. (x-axis). Mean traction values associated with the different substrates, as discussed in §9.1, are indicated in green (sand), orange (mixed) and red (stone).

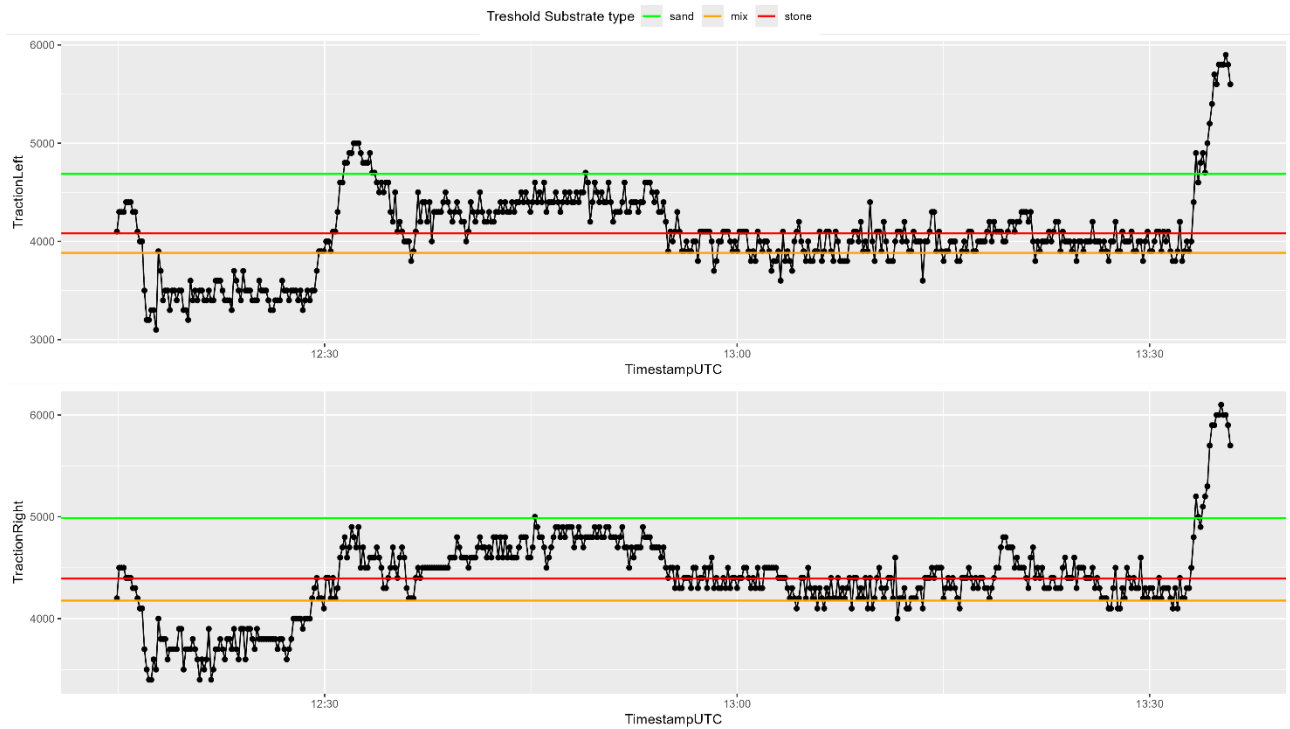


Figure B- 13 Traction values (y-axis, kg) of DK_S_13, measured every 10 seconds after shoot time. (x-axis). Mean traction values associated with the different substrates, as discussed in §9.1, are indicated in green (sand), orange (mixed) and red (stone).

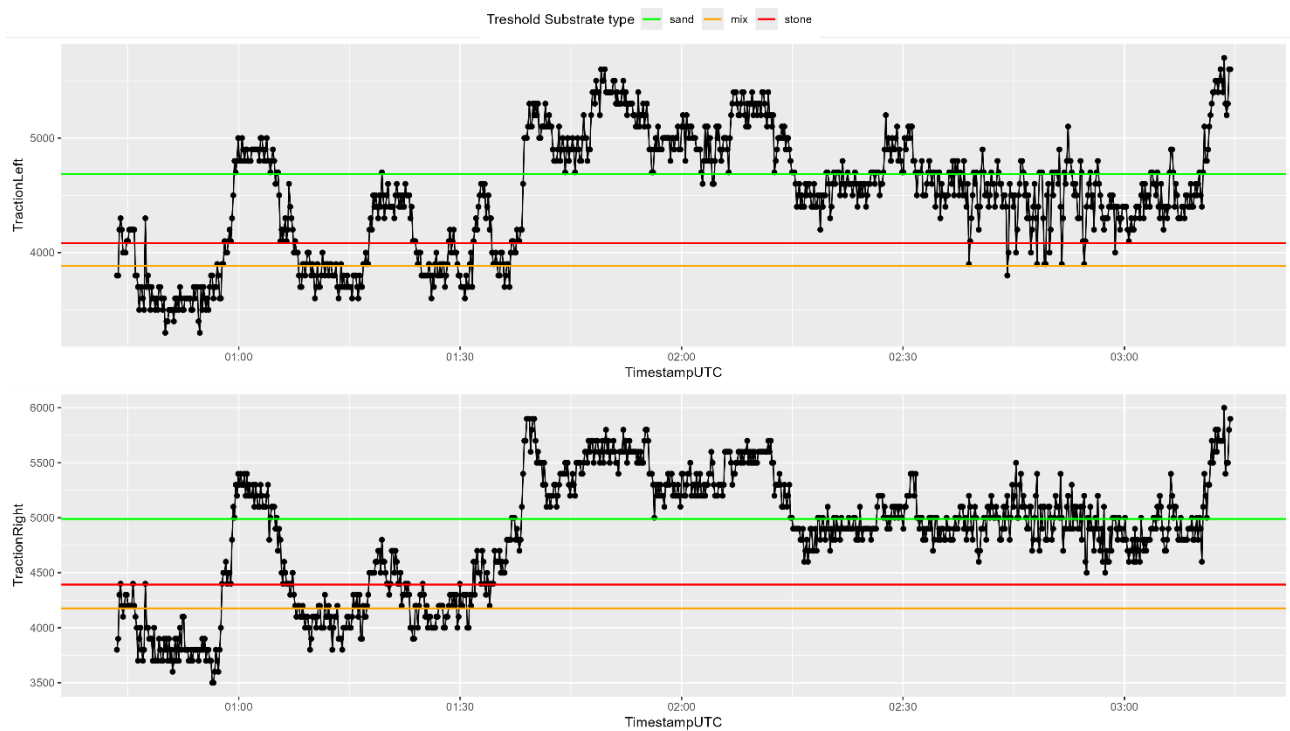


Figure B- 14 Traction values (y-axis, kg) of DK_S_14, measured every 10 seconds after shoot time. (x-axis). Mean traction values associated with the different substrates, as discussed in §9.1, are indicated in green (sand), orange (mixed) and red (stone).

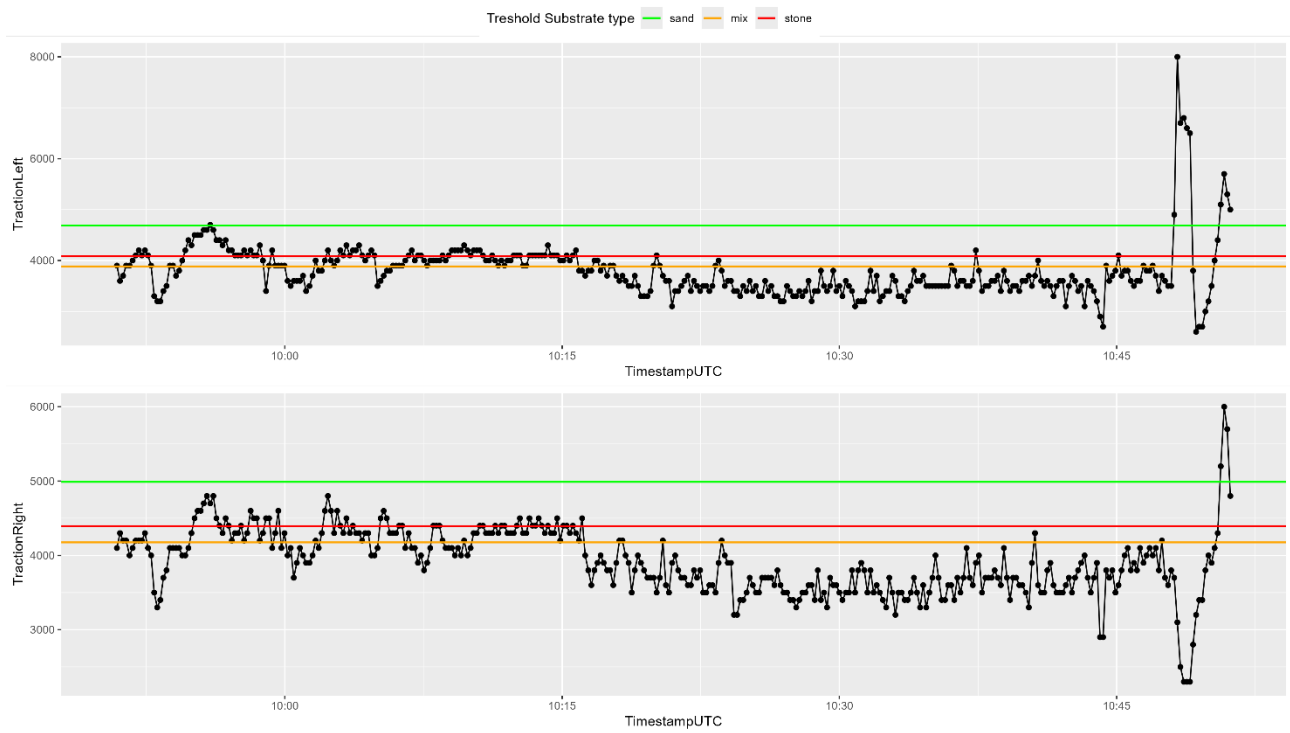


Figure B- 15 Traction values (y-axis, kg) of *DK_S_15*, measured every 10 seconds after shoot time. (x-axis). Mean traction values associated with the different substrates, as discussed in §9.1, are indicated in green (sand), orange (mixed) and red (stone).

Catch Composition

PCA

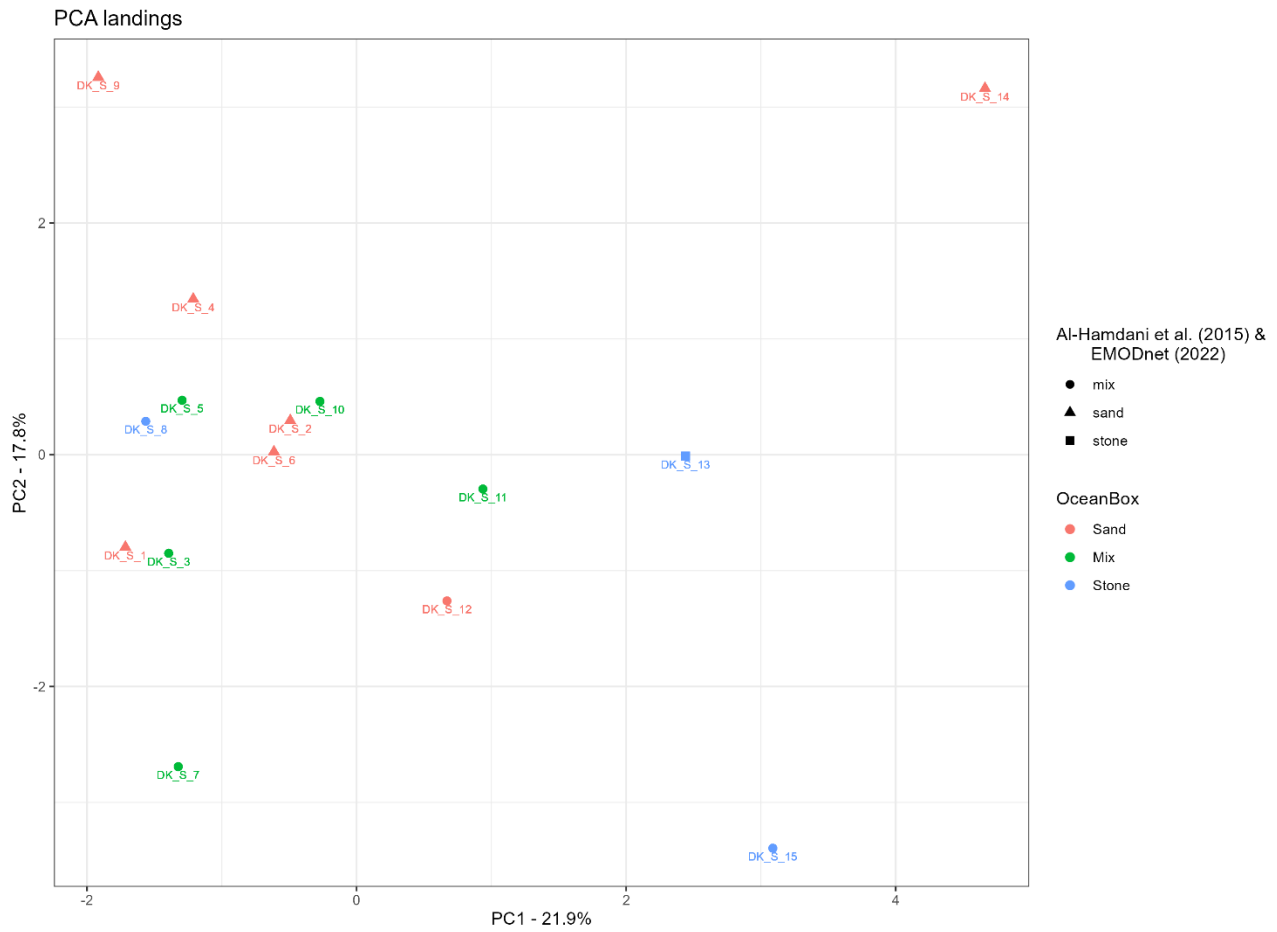


Figure B- 16 PCA plot of landings, with an additional breakdown per substrate type defined by Al-Hamdani et al. (2015)(shape) and OceanBox B.V. (2025) (color).

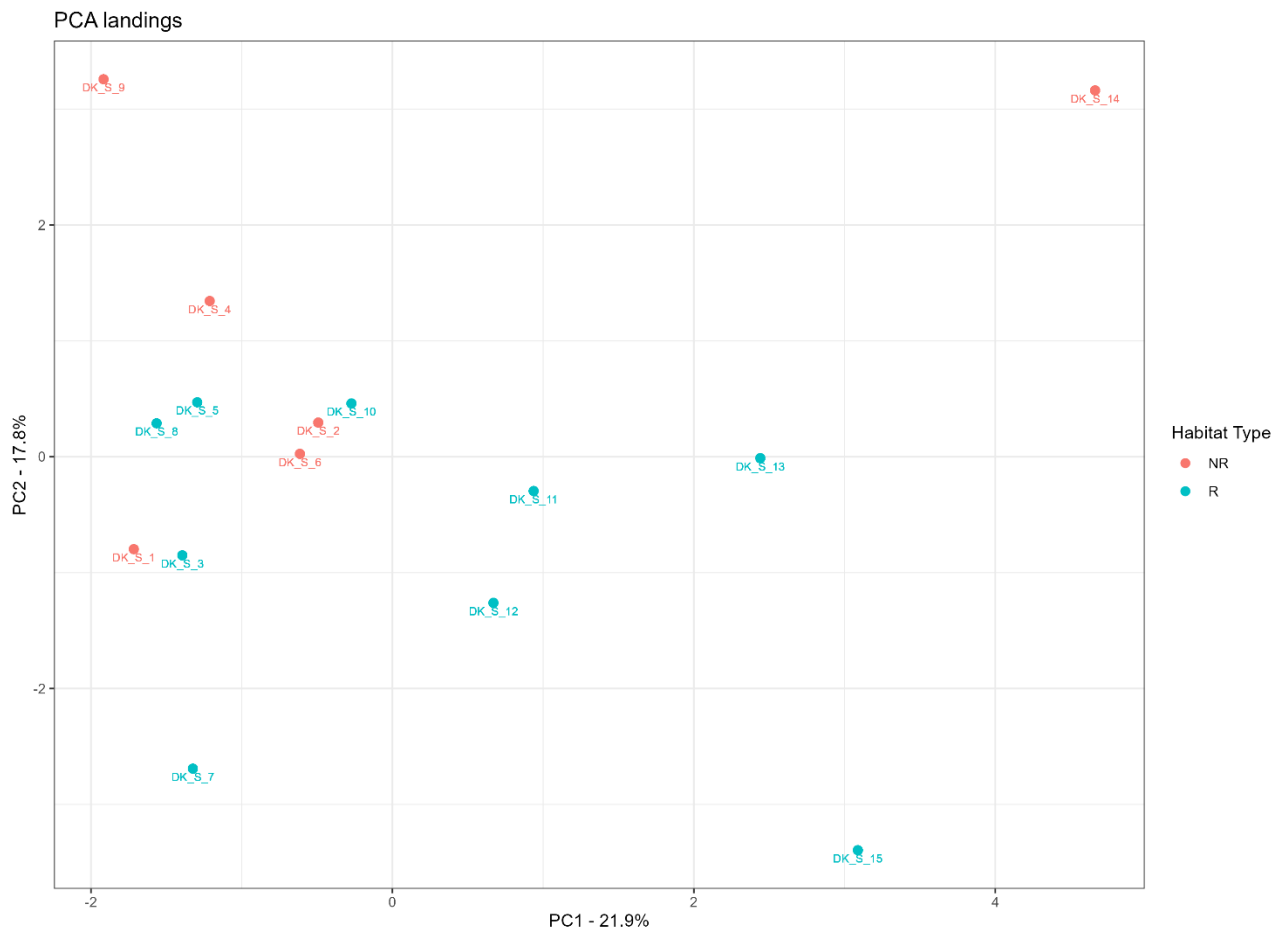


Figure B- 17 PCA plot of landings, with an additional breakdown per habitat type defined by OceanBox B.V. (2025) (color).

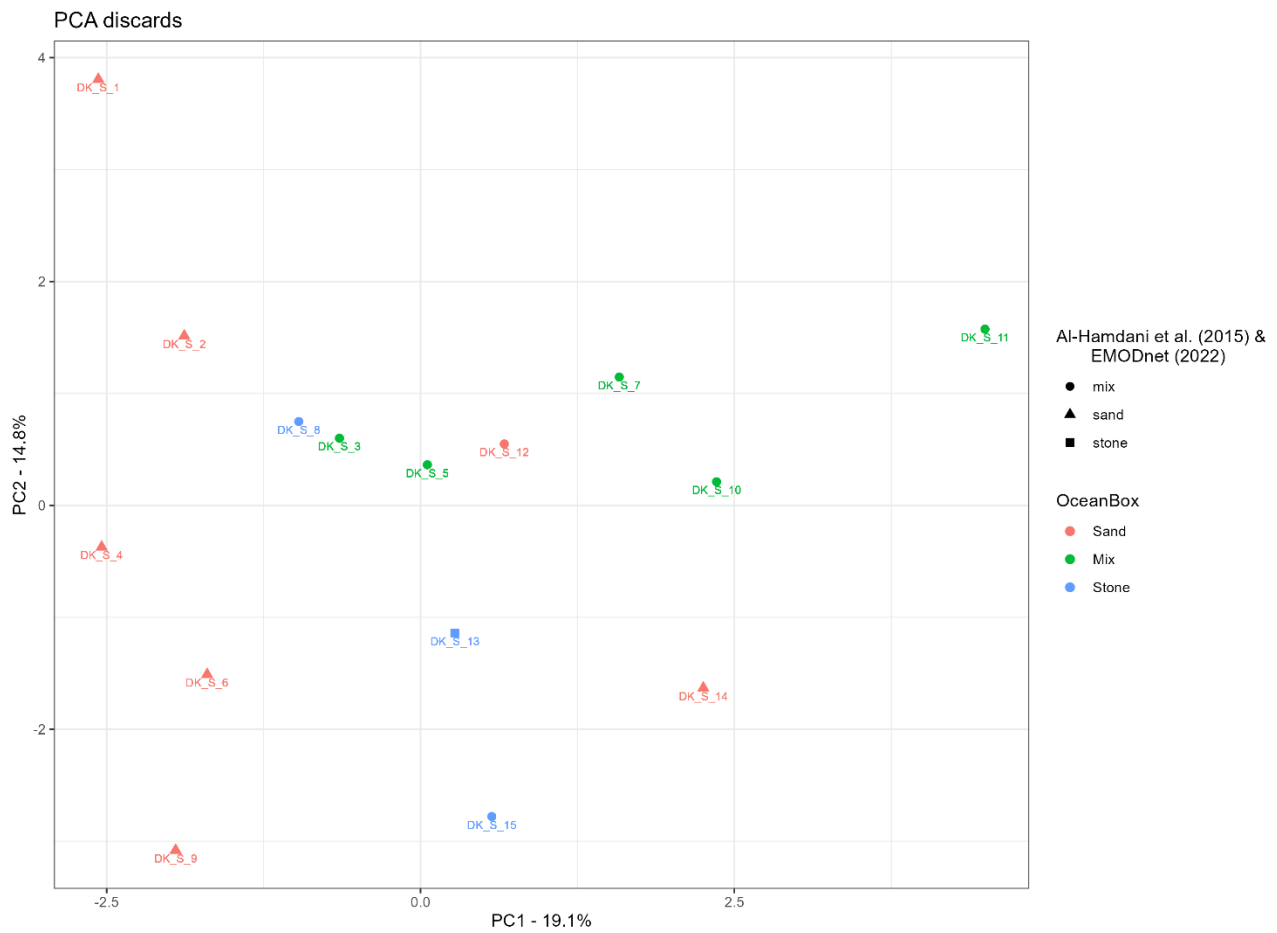


Figure B- 18 PCA plot of discards, with an additional breakdown per substrate type defined by Al-Hamdani et al. (2015) (shape) and OceanBox B.V. (2025) (color).

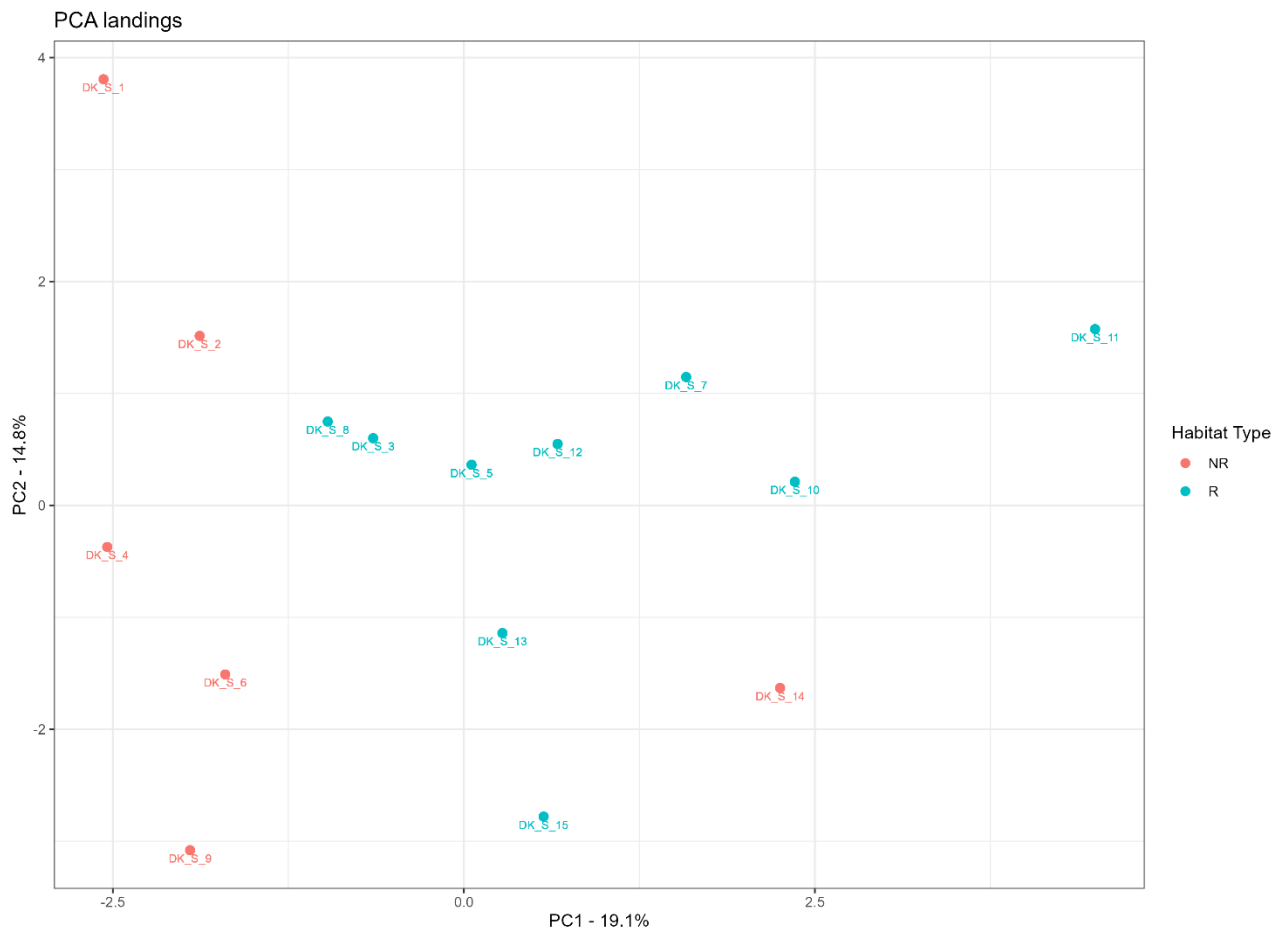


Figure B- 19 PCA plot of discards, with an additional breakdown per habitat type defined by OceanBox B.V. (2025) (color).



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