Pelagic fish in the Dutch coastal zone

Phase 1 of Monitoring, Research, Nature Enhancement, Species Protection (MONS)

Author(s): Bram Couperus, Joey Volwater, Ties Maris, Serder Sakinan, Lodewijk van Walraven and Ralf van Hal

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Contents

Summary

Project "Monitoring Pelagic Fish Phase 1" is part of the Monitoring, Research, Nature Enhancement, Species Protection (MONS) program, established according to agreements within the North Sea Agreement. The project began in early 2023 and consisted of the following components:

- Acoustic survey in the coastal zone in summer (June 2023)
- Acoustic survey in the coastal zone in winter (January 2024)
- Acoustic registrations during the regular 'fisheries' research survey IBTS Q1
- Surf zone monitoring in 2023, and complementary data of previous years (2020-2022)
- Stationary acoustic monitoring

The first four components have been completed, and the results are discussed in the following report. The last component has been postponed and will be reported separately.

The objective is to enhance our knowledge about pelagic fish in Dutch waters, with a particular emphasis on understanding their spatial and temporal distribution. This is to assess the future availability of 'pelagic fish food' for top predators, particularly birds. Currently our understanding of pelagic fish in Dutch waters is limited, despite their crucial role as food for birds and marine mammals in the North Sea food web. Understanding food availability and its spatial variation requires multi-year research. This first year of the program provides a first snapshot. The broader scope is on the integration of these new data with previous national, and international regular monitoring in a larger area. This serves as a foundation for efficiently gathering relevant data in the future to increase our understanding of pelagic fish.

Hydroacoustic surveys

Two hydroacoustic surveys were conducted, one in summer 2023 and the other one in winter 2024, following zigzag transects from the Belgium to the German coast, covering a depth range from approximately 10 m water depth near the coast to 20 nmi (nautical miles) offshore. Multiple transducers with a wide range of frequencies were used, the 38 kHz data are used for further analyses resulting in a focus on pelagic fish with a swim bladder. For species composition, 36 fishing hauls were performed in summer, and 10 in the winter. In summer, the hauls were distributed in grid, in winter fishing occurred based on high acoustic signals on the echogram. Both stratifications provided sufficient information to differentiate the acoustic signals to species level. The method used in winter is preferred as it required less effort and prevented fishing in areas without or with low concentrations of fish, unlike the grid system.

Both surveys indicate a patchy distribution of pelagic fish, with more pelagic fish found closer to the coast than at the offshore parts of the transects. The summer survey recorded a higher number of fish than the winter survey, with sprat being the dominant species. Herring was sparsely observed, mainly in the shallowest hauls near the coast, indicating a distribution closer to the shore. This is consistent with surf zone monitoring and previous work in shallower areas. Anchovy and sardine were only found in the summer survey indicating seasonal patterns.

Due to the similarity in design and methods, it was possible to compare the MONS survey with the regular acoustic survey in the North Sea (HERAS). The MONS survey in summer revealed higher densities compared to HERAS, where the density of the acoustic transects and the extent closer to the shore were important factors since patchiness increased in the nearshore zone.

To extend the winter survey, acoustic data were recorded during the first quarter International Bottom Trawl Survey (IBTS Q1). The current added value of the IBTS acoustics was very limited. Improvements are possible, but these require slight adjustments to the IBTS design which might impact on the primary objective of the IBTS, which is only possible when there is spare time, or additional time needs to be funded.

Surf zone monitoring

Surf zone monitoring conducted in IJmuiden was carried out by volunteers for several years prior to MONS. For MONS, sampling took place on ten days between April and October 2023. Although the gear (2m beam trawl) is designed for catching flatfish, various pelagic species were caught. The surf zone monitoring also can provide insight in the occurrence, timing, and growth of some pelagic species that utilise this zone at least part of the year, adding to the findings of the acoustic surveys. Along the beach, herring and sandeel were caught almost every monitoring day, with a similar pattern observed in previous years (2020-2022). The herring was found as larvae at the beginning of the season and showed growth to approximately 8 cm by the end of the season. The sandeel remained about 6-9 cm throughout the entire period. Sprat was caught sporadically, like previous years, indicating that sprat avoid the surf zone. Juvenile golden grey mullet and sea bass were mainly caught in the shallow channels from August onwards. Anchovies were also caught in August/September.

Conclusion
This study offers important insight in the food availability of the breeding bird colonies and wintering seabirds. Catches provide length and weight data of potential prey species for marine birds. For clupeids – mainly sprat - this study offers a detailed snapshot of species composition and density distribution in a crucial feeding habitat for birds. Consistent data gathering over multiple years is essential to monitor this habitat. Spatial patchiness of species is evident in the data, but temporal variability is also crucial in such studies. Consistent time series data are necessary for informing management decisions aimed at preserving marine birds in the region.

Samenvatting

Het project Monitoring pelagische vis fase 1 is onderdeel van het programma Monitoring, Onderzoek, Natuurversterking, Soortenbescherming (MONS) opgesteld conform afspraken uit het Noordzeeakkoord. Het project is voorjaar 2023 van start gegaan en bestond uit de onderdelen:

- Akoestische survey in de kustzone in de zomer (juni 2023)
- Akoestische survey in de kustzone in de winter (januari 2024)
- Akoestische registraties tijdens de reguliere visserij onderzoekssurvey IBTS Q1
- Strandbemonstering in 2023, aangevuld met data van voorgaande jaren (2020-2022)
- Stationaire akoestische monitoring

De eerste vier onderdelen zijn uitgevoerd en de resultaten hiervan worden in de voorliggende rapportage besproken. Het laatste onderdeel is uitgesteld en wordt later apart gerapporteerd.

Het doel van dit project is om de kennis over pelagische vis in de Nederlandse wateren te vergroten, en vooral het inzicht te vergroten in de ruimtelijke en temporele verspreiding van pelagische vis. Dan is evaluatie van de beschikbaarheid van voedsel voor toppredatoren, voornamelijk vogels, in de toekomst mogelijk. Kennis over pelagische vis in de Nederlandse wateren is op dit moment beperkt, terwijl pelagische vis een belangrijke schakel vormt in het voedselweb van de Noordzee, als voedsel voor visetende vogels en zeezoogdieren. Het eerste jaar van het programma is een momentopname. De rapportage bevat resultaten van het eerste jaar onderzoek, maar richt zich ook op de mogelijke koppeling van deze gegevens aan eerdere, nationale, monitoring en internationale reguliere monitoring in een groter gebied. Op basis daarvan wordt tevens bepaald hoe in het vervolg op een efficiënte manier relevante data verzameld kunnen blijven worden om de kennis over pelagische vis te vergroten.

Hydro-akoestische surveys

Twee hydro-akoestische surveys zijn uitgevoerd (in juni 2023 en januari 2024), via zigzag-transecten van de Belgische tot de Duitse kust, van ongeveer ~10 meter waterdiepte tot 20 nautische mijlen uit de kust. Meerdere transducers met een breed frequentiebereik zijn gebruikt, de gegevens van de 38 kHz zijn gebruikt voor verdere analyse, wat resulteert in een focus op pelagische vissen met een zwemblaas. Voor soortsamenstelling werden er (respectievelijk 36 en 10) vistrekken uitgevoerd. In de zomer zijn de vistrekken uitgevoerd verspreid over een rastersysteem, in de winter zijn de trekken uitgevoerd op basis van akoestische signalen op het echogram. Beide methoden leverden voldoende informatie op om de akoestische signalen te differentiëren naar soortniveau. De methode die in de winter werd gebruikt, verdient de voorkeur omdat deze minder inspanning vergt en vissen op locaties zonder of lage concentraties met vis voorkomt, in tegenstelling tot het rastersysteem.

Beide surveys tonen een fragmentarische verspreiding van pelagische vissen. Dichter bij de kust werd meer pelagische vis waargenomen dan in de offshore delen van de transecten en tijdens de zomersurvey meer dan in de wintersurvey. De dominante soort was sprot. Haring werd slechts beperkt waargenomen in de ondiepste vistrekken, wat aangeeft dat de verspreiding ervan zelfs nog ondieper is. Dit wordt ondersteund door de monitoring van de brandingszone en eerdere resultaten van onderzoek in de ondiepere gebieden. Ook ansjovis en sardine werden aangetroffen tijdens de zomersurvey. Tijdens de wintersurvey waren deze afwezig wat een indicatie is dat de Noordzee langs de Nederlandse kust nog te koud is in de winter voor deze zuidelijke soorten.

Omdat ontwerp en methoden vergelijkbaar zijn met de internationale methodieken, kunnen resultaten naast elkaar gelegd worden. Het MONS-zomeronderzoek toonde hogere dichtheden pelagische vis dan de internationale akoestische monitoring in de Noordzee (HERAS). Dichtheid van de akoestische transecten en afstand tot de kust verklaren het verschil grotendeels, aangezien de fragmentatie van pelagische vis in de kustzone toenam. Tijdens de International Bottom Trawl Survey in het eerste kwartaal (IBTS Q1) zijn ook akoestische gegevens geregistreerd. De bijdrage van deze akoestische gegevens is zeer beperkt. Er is echter ruimte voor verbetering als er aanpassingen worden gedaan aan de protocollen voor gegevensverzameling

en de uitvoering van de reguliere survey. Deze wijzigingen kunnen van invloed zijn op het aantal visstations dat op die dag wordt bevist, wat alleen mogelijk is als er tijd voor is of deze extra tijd gefinancierd wordt.

Strandbemonstering

De strandbemonstering vanaf het strand bij IJmuiden is in de jaren voor MONS uitgevoerd door vrijwilligers. Voor MONS is in de periode van april tot oktober op tien dagen bemonsterd. De strandbemonstering gaf inzicht in het voorkomen, de aankomstdatum, en de groei van sommige pelagische soorten die deze zone ten minste een deel van het jaar gebruiken. Deze informatie vult de bevindingen uit de hydro-akoestische surveys aan. Ondanks dat het tuig, 2m boomkor, ontworpen is voor het vangen van platvis, zijn er ook verschillende pelagische soorten gevangen. Op zo goed als alle dagen is haring en zandspiering gevangen, in lijn met de voorgaande jaren (2020-2022). Haring is vroeg in het seizoen nog larve en groeit gedurende het seizoen tot ongeveer 8 cm. De lengte van zandspiering was gedurende de gehele periode 6-9 cm. Sprot is maar sporadisch aangetroffen. Dit was ook in voorgaande jaren het geval, wat suggereert dat sprot de brandingszone vermijdt. Juveniele goudharder en zeebaars werden met name gevangen in de ondiepe geulen vanaf augustus. In augustus/september werd ook ansjovis gevangen.

Conclusie

Dit onderzoek biedt belangrijke inzichten voor voedselbeschikbaarheid van de broedvogelkolonies en overwinterende zeevogels. Vangsten leveren lengte- en gewichtsgegevens op van potentiële prooisoorten voor zeevogels zoals sprot, haring, ansjovis, kleine zandspiering en Noorse zandspiering. Voor clupeïden – voornamelijk sprot – biedt deze studie een gedetailleerde momentopname van de soortensamenstelling en de dichtheidsverdeling in een cruciaal voedselhabitat voor vogels. Het is essentieel om deze informatie consistent over meerdere jaren te verzamelen. Net zoals de ruimtelijke fragmentatie die duidelijk zichtbaar is in de gegevens, is de temporele variabiliteit ook cruciaal in dergelijke onderzoeken. Consistente tijdreeksgegevens zijn nodig om managementbeslissingen te nemen die gericht zijn op het beheer van de zeevogels in de regio.

1 Introduction

Maintaining the marine environment in a "healthy" condition is an important political and societal objective, which has to be achieved while the marine environment is already under pressure by anthropogenic activities, especially in the southern North Sea. The renewable energy transition introduces extra complexity into the activities in the marine environments, hence, complicates the implementation of such objectives. The North Sea Agreement (NSA) states that the planned transition should comply with the carrying capacity of the North Sea. The NSA outlines the need for an integrated and systematic research and monitoring program that forms the base for knowledge about the functioning of the North Sea.

The Monitoring-Research-Nature Recovery-Species Protection (MONS) program aims to answer the central question of how the changing use of the North Sea fits within the ecological capacity of the North Sea. The program should provide the knowledge needed for achieving a healthy and resilient ecosystem in which nature, the generation of sustainable wind energy and profitable food production go hand in hand. This knowledge is necessary to be able to determine how the transitions can be implemented in such a way that ecosystem functioning is not jeopardized, nature objectives are achieved, fisheries are ready for the future and remain within the carrying capacity of the North Sea.

To this end the MONS program developed an integral and systematic monitoring program that focuses on the physical, chemical, and biological parameters for the functioning of the ecosystem and on (the variation of) the occurrence of birds, bats, benthic animals, fish, and marine mammals. This forms the framework for research that was planned to be carried out over a ten-year period in order to be able to answer the knowledge questions as formulated in the NZA (Asjes *et al.*, 2021). A part of this program consists of monitoring activities to fill gaps in existing monitoring programs.

For fish, a substantial part of the existing monitoring has a fisheries management aim. For a long time, the fish stocks of many commercially important fish species have been monitored annually. This monitoring's design is driven by the needs of the stock assessment and advice process of commercial fish species, which requires year-on-year monitoring of fish stocks. Consequently, these surveys provide little information about seasonal dynamics. Because of the commercial focus, not all species in the fish community get the same attention in the monitoring. In the Dutch part of the North Sea this mainly concerns pelagic fish species that are either not sampled properly with commercial fishing gears and/or used sampling gear, or with life stages that only occur in places where no sampling or fishing is being done (the shallow surf zone). It applies also to species not landed by fishermen (such as sharks and migratory fish). The (small) pelagic fish are of great importance as food for top predators like marine mammals and birds, which are protected under various national and international laws and treaties. Insight in the quantities and distribution patterns of pelagic fish is crucial for understanding the food availability for higher trophic levels, and to accurately determine the carrying capacity of the North Sea.

Couperus *et al.* (2022) designed a monitoring program - as part of the MONS program - directed at (small) pelagic fish species in the North Sea. It considers pelagic fish as a source of food for higher trophic levels. It consists of two parts: 1) temporal and spatial distribution of pelagic fish in the offshore open waters, and 2) temporal distribution of fish in the surf zone. The program considers existing fish monitoring and cooperation with other MONS activities in development, e.g., on zooplankton.

The following activities of the proposed monitoring program (Couperus *et al.*, 2022) were granted:

1) A coastal hydroacoustic survey in January and June
2) Connection of these coastal surveys with international surveys
3) Sampling of the surf zone throughout the spring and summer season
4) Stationary year-round sampling: Wbat (pilot)
5) Gill net sampling near the stationary sampling

The stationary year-round-sampling (4 & 5) has been delayed owing to permit and permission processes. The details and outcomes of activities 1, 2, and 3 are provided here, with particular focus on situating the findings in the context of MONS' knowledge questions (Asjes *et al.*, 2021), especially as they relate to the food availability and its implications for bird populations.

2 Objectives

The overall objective of MONS is to collect and analyse data of the North Sea ecosystem in order to understand and assess the potential impacts of anthropogenic activities. The monitoring designed for pelagic fish must contribute to this overall objective by providing data on the temporal and spatial distribution of (small) pelagic fish. The central knowledge questions over a period of 10 years that the pelagic fish monitoring program should answer are:

1) *What is the distribution of small pelagic fish species in Dutch waters, by season and from year to year?*
2) *How can these geographical and temporal distributions be explained by the known natural history of the species involved, in terms of known behaviour and habitat requirements?*

These questions cannot be answered based on a single year of data collection. This report presents the results of the first monitoring year. In this first year, the program focused on evaluating the original design, refining details, and ensuring careful data collection to address the knowledge questions effectively. To this end, some preliminary analyses are presented to indicate the potential use of the collected data.

Regarding carrying capacity and food web interactions the emphasis should be on pelagic species with a key role in the food web. Specific focus is put on the species that serve as a major food source for top marine predators such as fish-eating birds and marine mammals, as well as predatory fish. By understanding the distribution of the pelagic species, we can gain insights into the availability and spatial distribution of food for predators over time.

Additionally, the monitoring could contribute to the knowledge required for answering other fish-related questions in MONS, with emphasis on behaviours such as foraging, spawning and courtship. The spatial and temporal distribution of fish is largely determined by the presence of food and suitable habitats (i.e., for living, spawning and growth). A suitable habitat is a complex combination of biotic (e.g., food) and abiotic (e.g., temperature) factors, which differ per species and per life stage within species. The monitoring program should also consider monitoring the environmental conditions to explain the found patterns in distribution.

Another knowledge gap pertains to pelagic fish species that are presently less common in the North Sea but abundant in adjacent southern regions, such as the Channel and the Bay of Biscay. These include species like pilchard (*Sardina pilchardus*), anchovy (*Engraulis encrasicolus*), and sea bass (*Dicentrarchus labrax*). Climate change may cause these species to become more common in the North Sea and nearby coastal areas in the near future. Monitoring their emergence and potential fluctuations is crucial, as their emergence could impact the presence of current dominant pelagic species such as herring (*Clupea harengus*) and sprat (*Sprattus sprattus*), via competition for food, predation, or habitat.

3 Method

3.1 Overall method considerations

The central research questions provided ample scope to investigate a wide range of topics on pelagic fish. To make the tasks manageable, decisions were made, and priorities were set (Couperus *et al.*, 2022). Two essential periods for monitoring pelagic fish were identified: 1) Winter: focusing on food availability for diving birds such as auks, grebes, and sea divers; 2) Early summer: Focussing on food availability for colony breeding birds such as terns and gulls.

Bird experts advised dense monitoring of nearshore coastal waters along the Dutch coastline, rather than aiming for a limited coverage of the whole Dutch Continental Shelf (DCS). This primary area of interest includes existing and planned wind farms in Dutch waters. It is considered that including these areas could support later research on the potential impact of wind farms. The nearshore focus is supported since the offshore areas are already regularly covered by the internationally coordinated International Bottom Trawl Survey (IBTS) and the Herring Acoustic Survey (HERAS).

The proposed method for monitoring the fast and free-moving pelagic fish was a hydroacoustic survey (using 38 kHz frequency) alongside fishing activities for species identification. The same approach is utilised during the HERAS and recommended for implementation during the IBTS. This integrated approach enables combining nearshore and offshore observations, thereby covering a substantial portion of the Dutch part of the North Sea.

This methodology, owing to the depth of the boat, is however unable to cover the waters shallower than 10m. To gather information on this area it was proposed to continue sampling in the surf zone from the beach in IJmuiden (Couperus *et al.*, 2021). The surf zone (0-2m) was sampled from April till October, providing information on timing of the arrival of species in the coastal waters and growth over the spring/summer season.

Monitoring the seasonal abundances was also proposed for the nearshore waters. Using unmanned drones to continuously collect hydroacoustic data throughout the season over a large spatial range was deemed unfeasible. The proposal for fixed, semi-continuously acoustic monitoring was included, but delayed owing to permit and permission challenges. Autumn 2024 the acoustic equipment was placed on the seafloor in the southern Dutch waters (Borssele windfarm) and further north (windfarm Hollandse Kust Noord).

The activities that have been executed in this first year of the monitoring program are described in more detail below.

3.2 Nearshore hydroacoustic surveys

Two nearshore acoustic surveys were carried out, one survey took place in June 2023 right before the International North Sea Acoustic Survey for herring and sprat (HERAS). The other survey took place in January 2024, prior to the yearly International Bottom Trawl Survey (IBTS). Both surveys used the same echo integration methods as HERAS (Simmonds and MacLennan, 2005): an EK80 echosounder and a 38 kHz split beam transducer located in the dropkeel (~0.5m below the vessel) of the vessel Tridens II. The 38 kHz transducer onboard Tridens II is part of a modular system including multiple transducers with a wide range of frequencies, collecting data for all frequencies at the same time. These higher frequencies (70, 120, 200 and 333 kHz) were operated as well during the surveys, as they can be helpful for the identification of species on the echogram (see also Discussion). The acoustic equipment continuously operates and while the vessel steams the pelagic fish in the water column below the echosounder is visualised (Figure 3-1) and the scatter data is stored. This way vast areas can be monitored.

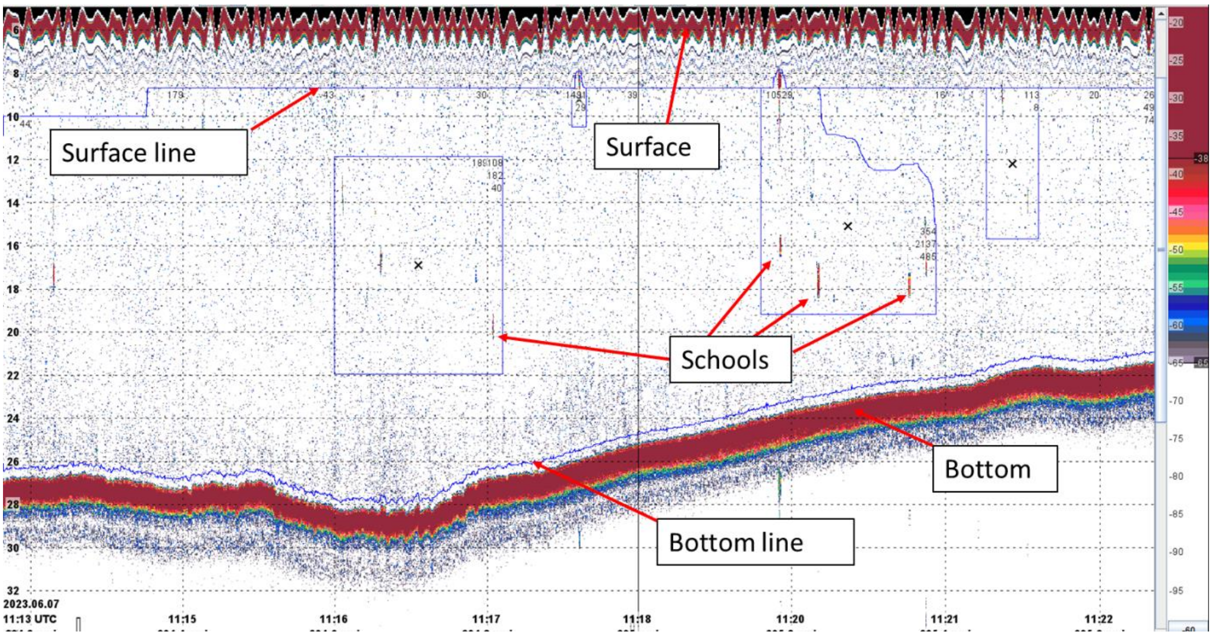

Figure 3-1: Example echogram near haul 19 of the summer survey in June 2023 (west of Texel). The bottom line and surface line form the part of the water column in which fish with a swim bladder can be detected.

On Tridens, the draught including the dropkeel is ~5m combined with the nearfield of the 38kHz of ~4.5m this results in a “dead zone” from the water surface to about 9.5m in which no fish can be detected. Also, near the bottom (~0.5 m), fish cannot be detected due to acoustic noise created by the substrate. The nearfield of higher frequencies is shorter reducing the surface dead zone.

The HERAS and similar acoustic surveys sail pre-determined transects at a constant speed (8-10 knots) combined with fish in the water column with a pelagic gear. The transects of the MONS survey were principally semi-random zigzags, adjusted to cross the marine traffic lanes perpendicular. The transect covers the Dutch coastal water from Belgium to the German border.
For Mons, a pelagic gear (Flex-net 480m), to fish through the water column without bottom contact in shallow waters, was developed. The back-up was the regular bottom gear (GOV) of the IBTS (ICES, 2020), which unfortunately had to be used during the largest part of the summer 2023 survey.
The regular practice during acoustic surveys is, when schools of pelagic fish are detected, the ship turns around to fish on these schools. The design of the summer survey deviated, as the fishing stations were strategically planned with one fishing tow in a grid cell (¼ of an ICES-rectangle). This way the fish data could potentially also be used as stratified design. The gridded fish sampling method used in the summer survey was not feasible in the winter due to time constraints. Therefore, the regular practice of fishing when schools are observed, was done during the winter survey. As pelagic fish behave differently during daytime than during nighttime, in the summer survey monitoring was limited to daylight hours, while in the winter survey due to the time constrains monitoring was extended to include dusk and dawn.

Although previous studies have identified which pelagic species are distributed in the shallow waters along the Dutch coast (van Hal *et al.*, 2012, Grift *et al.*, 2004, van Hal *et al.*, 2021), the composition and distribution of species on the scale of the full Dutch coastal zone was not known. The method of echo integration (Simmonds and MacLennan, 2005) can in theory be used to calculate biomass, when the echograms consist of few clearly identifiable species and subsequent ground truthing from catches with length frequency information and length weight relationships.
This straightforward transformation of the NASC to biomass should be carried out with care as it depends on the target strength relationship that is applied, and which varies per area. Moreover, the pelagic fish fauna consists of a relatively high number of species which may occur in mixed schools that cannot be separated

clearly based on the echogram. Therefore, we do not present biomass calculations by species but present the raw acoustic densities: Nautical Area Scattering Coefficients (NASC's).
The NASC is dominated by the reflection of pelagic species with a swim bladder. These species reflect more of the used acoustic signal – they have a much higher Target Strength (TS) - than species without swim bladder. The species without swim bladder are much weaker scatterers (Foote, 1980) and, when they occur in mixed schools with species having a swim bladder, they are not visible on the echogram. For example, a 15 cm sprat has a similar TS as approximately 200 sandeels of the same size.
Thus, when the catches consist of a mix of species with and without a swim bladder, demersal species, and rare species, the NASC only represent the pelagic species with swim bladder. Therefore, only the pelagic species with a swim bladder from the catch were used to split the NASC to species level. The following species are considered pelagic, have a swim bladder and are present in quantities large enough to be detected in acoustic surveys: sprat, herring, pilchard, anchovy, and horse mackerel (*Trachurus trachurus*). Species without swim bladder, such as mackerel (*Scomber scombrus*), lesser sandeel (*Ammodytes tobianus*), Raitt's sandeel (*Ammodytes marinus*), and greater sandeel (*Hyperoplus lanceolatus*) were excluded. Other pelagic species, such as smelt (*Osmerus eperlanus*), twaite shad (*Alosa fallax*), transparent goby (*Aphia minuta*), crystal goby (*Crystallogobius linearis*), and sand smelt (*Atherina sp.*), are considered too rare to be monitored effectively with echo integration and therefore also excluded. Demersal species, including whiting are also excluded.

For interpretation of the data the survey area covered by the acoustic transects is divided into six subareas dividing the area in south (S), middle (M) and north (N) and dividing the inshore coastal areas (E) from the deeper offshore area (W) (Figure 3-2). The border between the in– and offshore areas is 10 km off the coast.

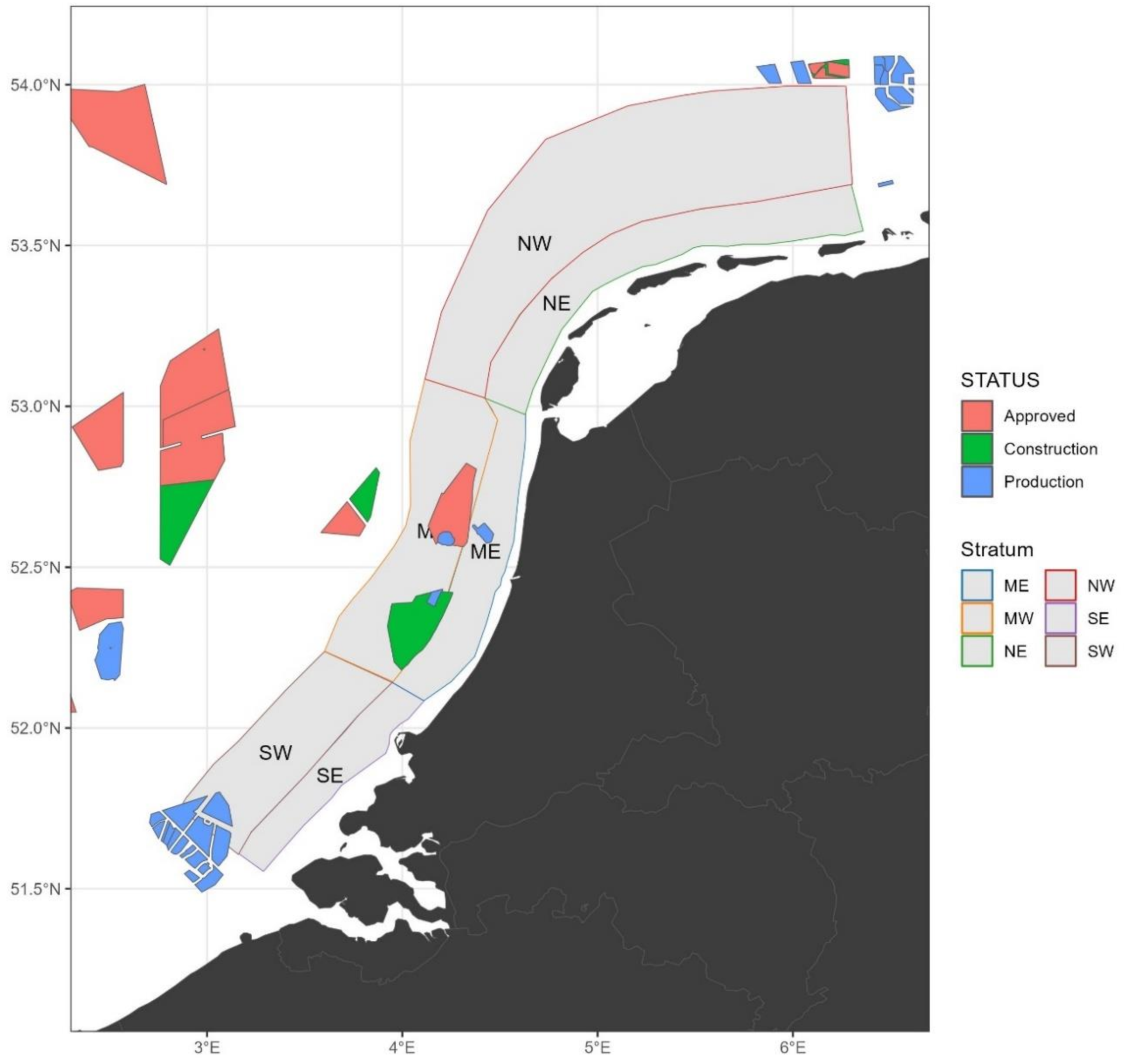

Figure 3-2: The survey area divided in six subareas for analysing the data, and the current or planned wind farm areas.

3.3 Connection to international coordinated surveys

3.3.1 IBTS Q1

The International Bottom Trawl Survey (IBTS) is an internationally coordinated survey targeting round fish and juvenile pelagic species to provide data for stock assessments. The survey is performed twice a year, in winter (quarter 1) and summer (quarter 3). The Netherlands only participates in quarter 1. As part of the Dutch quarter 1 IBTS 2024 (Figure 3-3), which was conducted on the Tridens II immediately after the MONS-weeks, acoustic recordings were made specifically for the MONS-program. Prior to each fishing tow the acoustic recordings were started, so that recordings were made during setting the net, fishing (~30 minutes) and hauling of the net. In some instances, the acoustic recordings continued after the tows, so that some recordings were made during steaming around maximum speed between the fish stations.

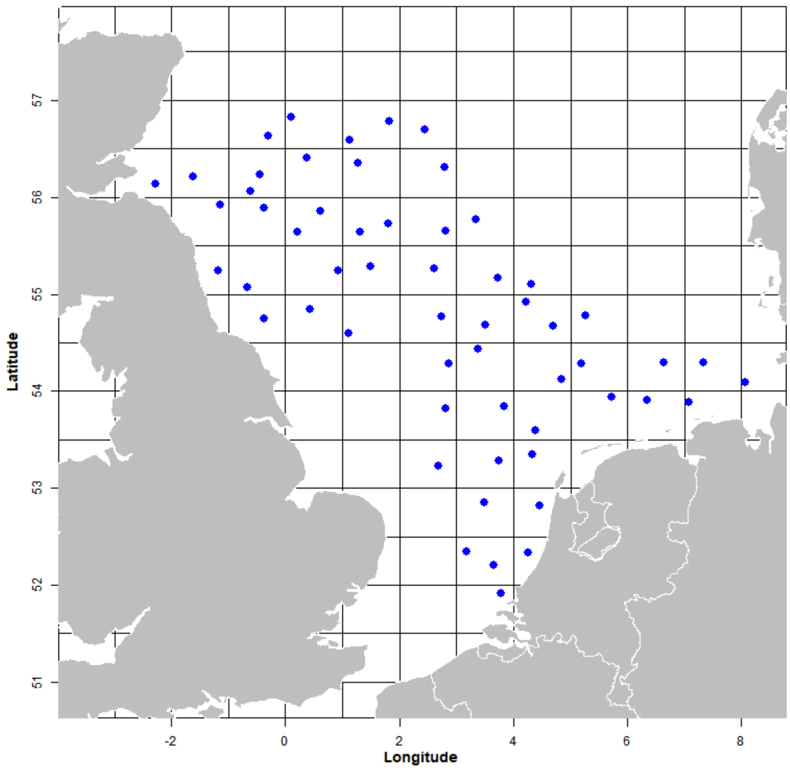

Figure 3-3: Spatial distribution of the fish stations of the NS-IBTS Q1 2024.

3.3.2 HERAS

The internationally coordinated Herring Acoustic Survey in the North Sea (HERAS) gathers standardised data on the distribution and abundance of pelagic schooling fish in July using scientific echosounders and pelagic trawls. The Dutch participation, aboard the Tridens, primarily focusses on UK waters. German participation covers the Dutch waters (Figure 3-4). The summer MONS-survey on board of Tridens preceded HERAS done with the same vessel. The German HERAS data closely collected after MONS allows to extend the June recordings for MONS across most Dutch waters.

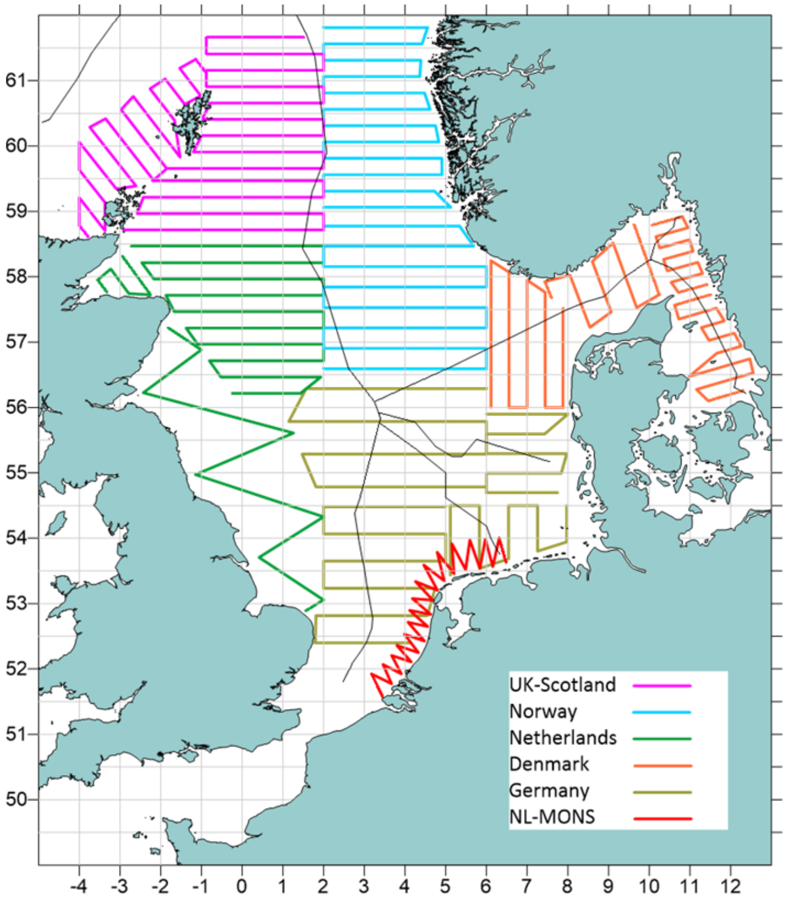

Figure 3-4: The zigzag transect of the MONS summer survey in 2023 was designed to join, and partially overlap, the international Herring acoustic survey (HERAS) displayed by the transects performed yearly by each participating country.

3.4 Combination with the zooplankton monitoring

The zooplankton monitoring is a standalone program within MONS (Jak *et al.*, 2022) with the objective of getting to understand the spatial and temporal distribution of zooplankton in the Dutch waters. A part of this program is a pilot to use a continuous plankton imager. A Plankton Analytics[1] Imager is installed on the Tridens II and during both hydroacoustic surveys and the IBTS, water was continuously pumped through the Imager from about ~4.5 m depth with a speed of ~34 l/min. The continuous stream of images (10.000 per minute) is automatically reduced to images including individual particles (Plankton, detritus, air bubbles) based upon settings of minimum and maximum size of the particles. The images are then, later in the lab, scanned and divided in taxonomic plankton groups using AI techniques.

As the Imager recorded data during both hydroacoustic surveys and the IBTS, the composition and abundance of plankton is available for the same transects as the pelagic fish data from those surveys. The zooplankton project is still ongoing and only the preliminary plankton data of the summer survey in 2023 is currently available.

A part of the zooplankton community is the main diet of the dominant small pelagic species (Van Ginderdeuren *et al.*, 2013, Raab *et al.*, 2012, Maathuis *et al.*, 2024). From the currently available preliminary data the total Copepod numbers are considered the best representation of available food for the small pelagic species, despite indications of opportunistic feeding behaviour by the small pelagics (Maathuis *et al.*, 2024). The hypothesis is that the distribution of the pelagic fish is partly driven by the food availability. As an indication of the potential of the collected data for further use, a preliminary analysis is performed in which the distribution of the Copepod numbers is correlated with the pelagic fish abundance, in NASC from the hydroacoustic survey.

[1] https://www.planktonanalytics.com/

3.5 Monitoring the surf zone

As part of the Rijkswaterstaat project "Natuurlijk Veilig" (van Hal *et al.*, 2021) frequent sampling of the surf zone was started in 2019. From 2020 to 2022 the sampling was continued whereby the surf zone was sampled on a bi-weekly basis from March to November by volunteers at the beach of IJmuiden. Additionally, a less frequent sampling was conducted by volunteers at Egmond aan Zee. The monitoring of the surf zone originally focussed on the arrival and growth of juvenile flatfish, but also provided insight in the occurrence of juvenile pelagic fish like herring, sprat, anchovy, sandeel (Ammodytes sp.), sea bass and golden grey mullet (*Chelon auratus*).

In 2023, as part of the MONS project, the monitoring of the surf zone at IJmuiden beach was continued to provide on a small local scale (the beach of IJmuiden) insight in the arrival and occurrence of pelagic species in shallower water then sampled in the nearshore hydroacoustic surveys. The monitoring was planned to be executed once every two weeks from March till October to provide insight in the occurrence and potentially growth over the spring/summer season. Fishing was done around low tide with a 2-m beam trawl with 1 cm stretched mesh size towed by two persons at a depth between 0.5-1.20 m over a distance of ~100 m. The fished surface is calculated as distance times the width of the beam (2m). One tow was done northward parallel to the beach, a second tow was done in the opposite direction. A third tow was done by walking from the surf zone into one of the tidal gullies. All fish in the catch were identified and measured (mm), all benthic organisms were counted. The results are presented as Catch per Unit of Effert (CpUE), being the counts divided by the fished surface.

Besides the data collected for MONS in 2023, the data of the previous years 2020-2023 were used in the analyses. In some of those years a larger number of hauls was done per sampling day.

4 Results

4.1 Nearshore hydro-acoustic surveys

4.1.1 Implementation

The summer survey took place from May 30 to June 16, 2023, covering a total of 980 nautical miles (nm), from Belgium to the German border (Figure 4-1), extending to approximately 20 nmi off the coast. The strategically planned fishing resulted in 36 hauls. The first haul was conducted using the Flex-net, which was damaged after this. The remaining hauls were executed using the demersal GOV (the standard gear in the IBTS surveys). At the survey's end, three comparison hauls were done between the two nets. The catch composition by haul is given in Annex 2 Table A2-1a-c.

The winter survey took place from January 8 to January 19, 2024, covering a total of 600 nm, from the Belgium to the German border (Figure 4-2). The zigzag pattern was at some locations slightly wider than in the summer survey. To accommodate the limited daylight hours during winter, observations were also conducted during dusk and dawn. Fishing occurred when schools were detected, in total 10 fishing tows with the Flex-net and two with the GOV were executed. The catch composition by haul is given in Annex 2 Table A2-2.

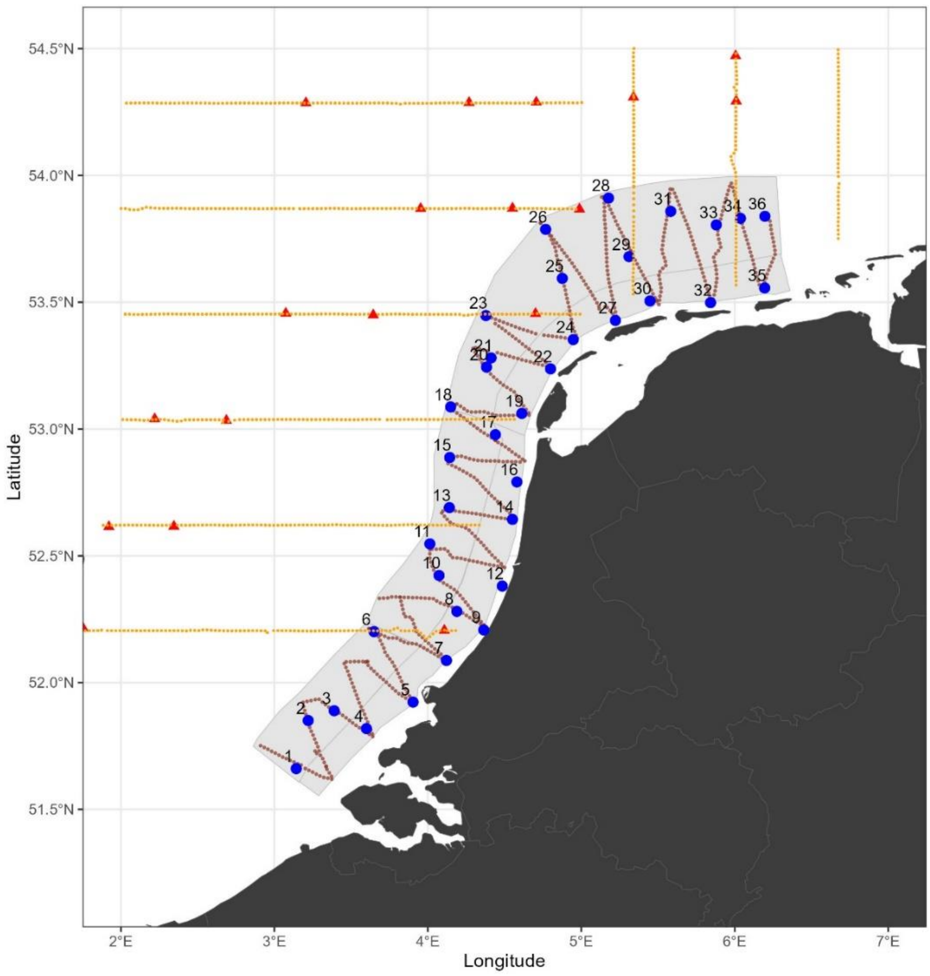

Figure 4-1: Transects executed during the MONS hydroacoustic survey in June 2023 (brown lines) and during HERAS (orange lines). The blue dots indicate the fishing locations of MONS (with the GOV-net) and red triangles of HERAS.

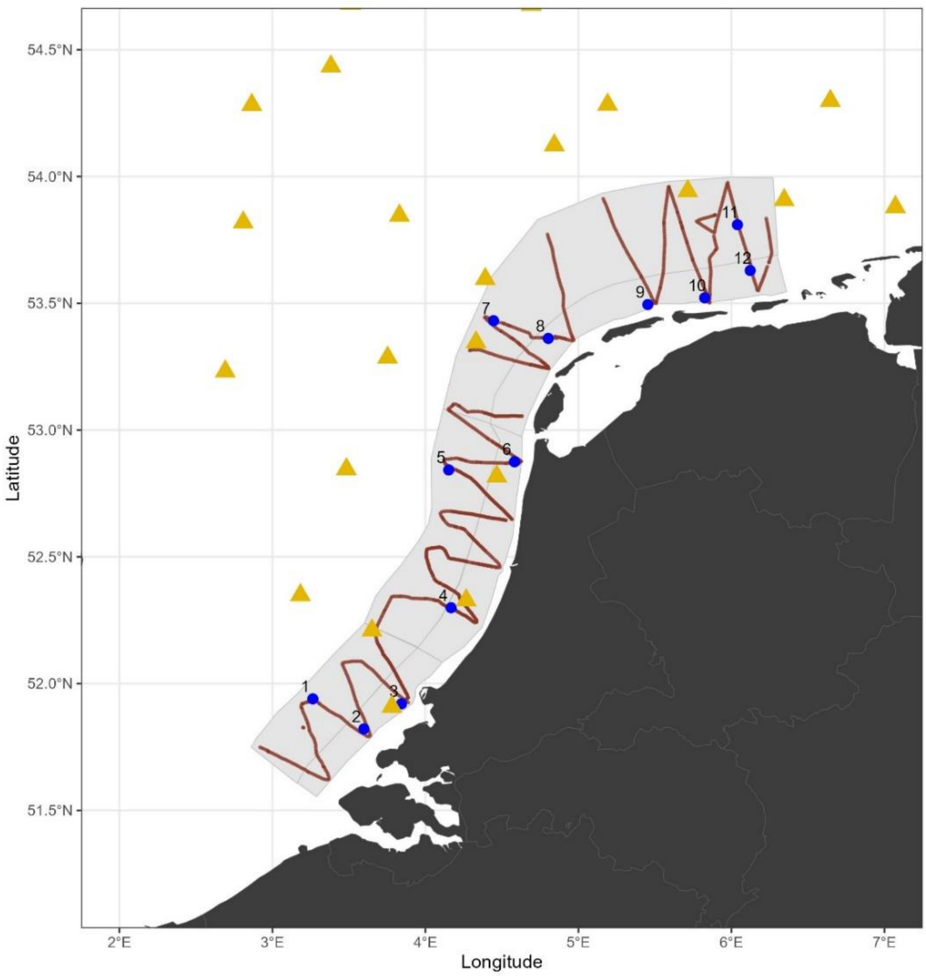

Figure 4-2: Transects executed during the MONS hydroacoustic survey in January 2024 (brown lines). The blue dots indicate the fishing locations of MONS (with the pelagic Flex-net) and yellow triangles show the IBTS fish stations.

4.1.2 MONS Flex-net vs GOV-net

The pelagic Flex-net to be used in the hydroacoustic surveys was damaged during the first haul in summer 2023 and replaced by the demersal GOV-net. The GOV-net, with a 5.5-6m vertical opening, was assumed to catch a similar segment of the fish community. This was tested through three comparison hauls at survey's end, in areas with limited scatter on the echogram. Despite the low scatter, both nets caught pelagic fish. Overall, both nets caught the same species, however as expected the demersal GOV caught more whiting that is considered a demersal species. While the pelagic Flex-net caught more pelagic species as sprat and pilchard (Figure 4-3). Horse mackerel is considered a pelagic species which often shows demersal behaviour (ICES, 2024b). This demersal behaviour is shown by the larger catches of horse mackerel in the GOV.

Despite differences, and the limited number of comparative hauls, the GOVs catches suggest it provides sufficient pelagic fish for interpreting the acoustic signals. For upcoming surveys, the Flex-net remains the preferred choice, as it excels at catching pelagic species and avoids unwanted demersal catches.

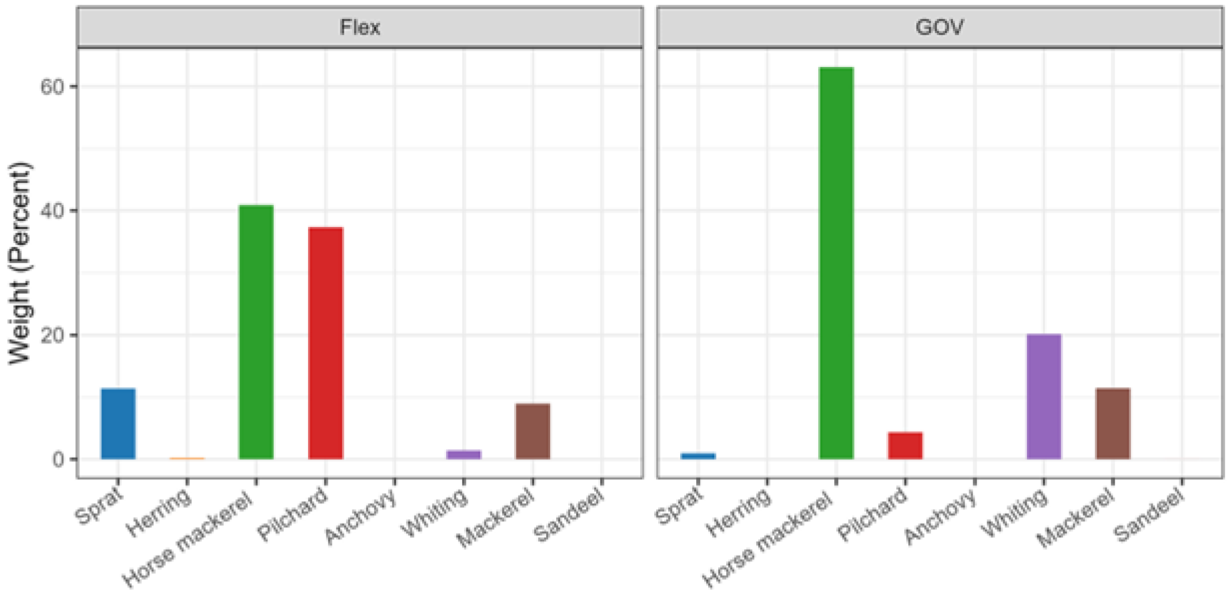

Figure 4-3: Catch composition of the three test-hauls with the Flex-net versus the GOV-net in percentages weight.

4.1.3 Acoustic densities

The acoustic densities or "Nautical Area Backscattering Coefficients" (NASC's) are reported by the six subareas along the coast and combinations of areas (Table 4-1). The highest NASC occur in both seasons in the nearshore waters, which means that the largest fish concentrations are in the shallowest parts of the survey area. The gradient of increasing NASC from offshore to nearshore indicates that potentially even more fish occur in the shallower parts, that our survey, limited to > ~10 m water depth, is unable to detect.
Highest NASC were in both seasons recorded in subarea ME (see Figure 3-2 for the subareas). The lowest NASC in summer were recorded in subarea MW, while in winter hardly anything was recorded in subarea NW. In subarea MW the NASC in January was higher than in June, in all other subareas higher NASC were recorded in June.
In the spatial plots, large areas of the transects indicate low or no NASC with only some aggregations determining the average NASC for a subarea (Figure 4-4, Figure 4-5). This is typical for the distribution of schooling pelagic fish.

Table 4-1: The Nautical Area Backscattering Coefficients (NASC) by subarea (Figure 3-2) for both survey periods by subarea.

Area	**Area (hectare)**	**June 2023 (NASC - m²/nmi2)**	**January 2024 (NASC - m²/nmi2)**
NE	222798	1205	225
NW	592169	538	2.5
ME	157913	1560	884
MW	261903	104	225
SE	102606	714	260
SW	193678	282	107
NE+ME+SE	483318	1117	448
NW+MW+SW	1047751	382	77
All	1531069	645	394

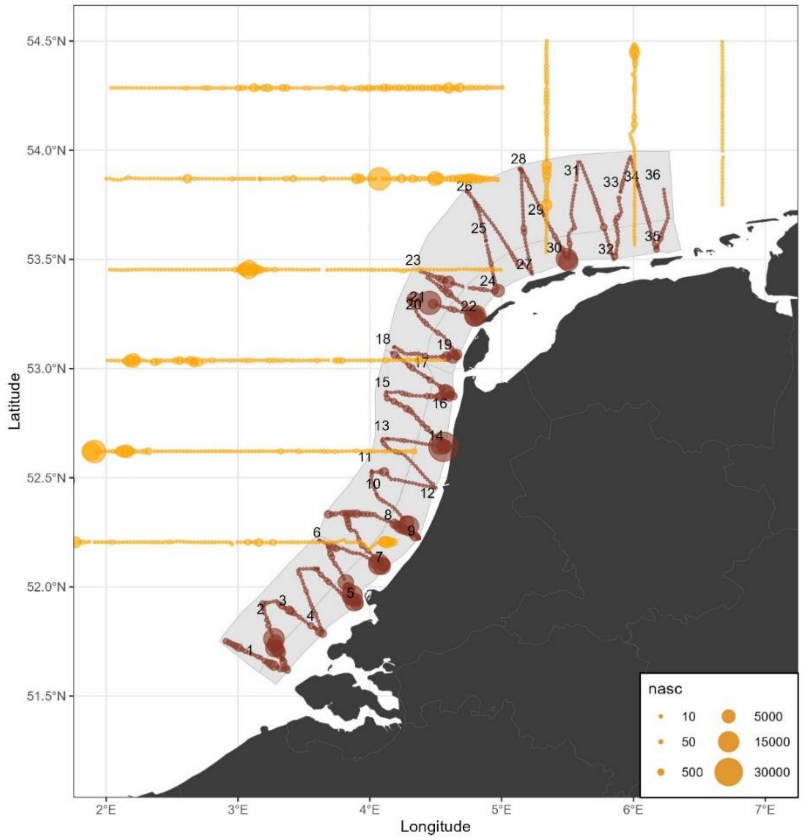

Figure 4-4: Bubble plot showing the acoustic density (by 1nmi interval) of the Clupeid category from HERAS 2023 (orange) and same category from MONS summer survey in June 2023 (brown) with a polygon in the background showing the subareas.

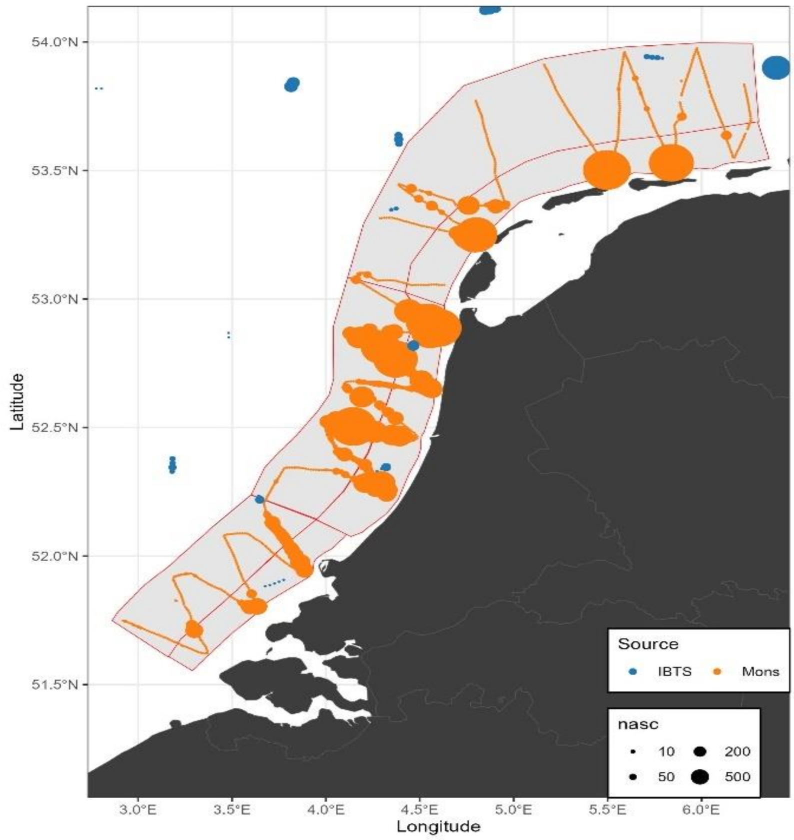

Figure 4-5: Bubble plot showing the acoustic density (by 1nmi interval) of the Clupeid category from IBTS 2024 (blue) and same category from MONS summer survey in January 2024 (orange) with a polygon in the background showing the subareas.

4.1.4 Catch composition

The catches of pelagic species in both seasons were dominated by sprat (Figure 4-6). In the summer, the dominance of sprat occurs mainly in the eastern part closest to shore. In summer also substantial amounts of mackerel, horse mackerel and pilchard were caught. The mackerel was present in almost all hauls, while the pilchard was present in all southern hauls up to 53 degrees latitude (off Texel). Horse mackerel were regularly present in quantities of the same order of magnitude as sprat. In winter, the number of species in the catch were lower. This lower number of species can partly be due to fewer hauls, but also seasonal effect is evident. As certain species avoid the coastal waters during winter or even the whole North Sea. Most of the herring in the winter was caught in a single haul (~80%) in the northeastern part of the area. Horse mackerel was absent in winter but might have been demersal and therefore missed by the pelagic net. Other pelagic species present in lower abundances were anchovy, lesser sandeel, Raitt's sandeel and greater sandeel. Further analyses of the catch data are provided in Annex 3, which applies cluster analysis to assess community structure based on similarity in the catch compositions.

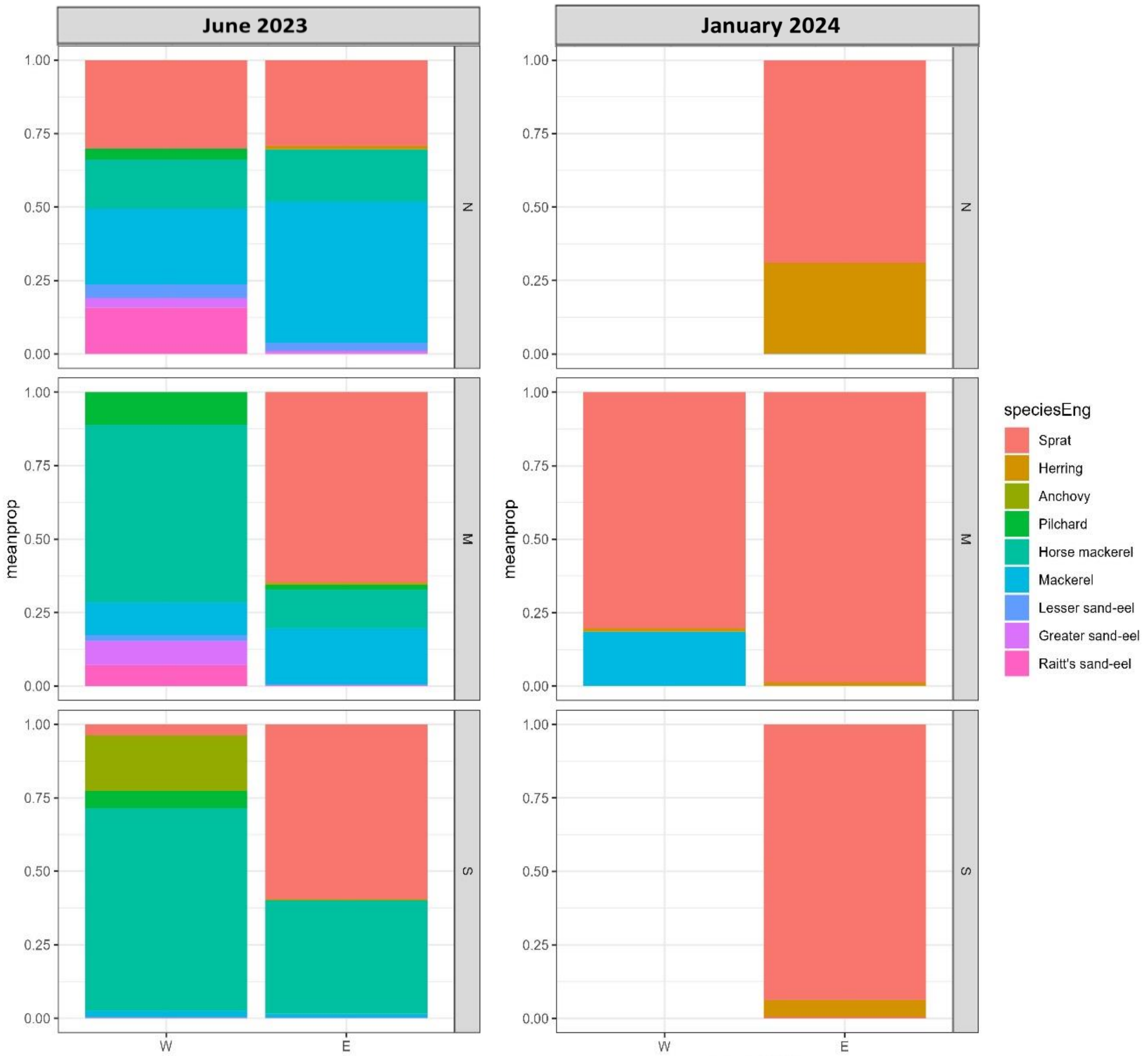

Figure 4-6: Catch proportions (percentage weight) by the six subareas (see Figure 3-2) in the summer survey in June 2023 (left, 36 hauls) and the winter survey in January 2024 (right, 10 hauls).

The length distribution of the pelagic species in the catches had a wide range of sizes from 6 cm sprat to 36 cm mackerel (Figure 4-7 - Figure 4-11), with various species overlapping in size. The length of sprat was similar in both seasons. The herring caught in winter were larger than those in summer, and the smallest size group caught in summer was not present in the winter survey. Herring in summer showed distinct size groups, likely age classes or the different spawning components. The mackerel in winter consisted of juveniles in a small length range, these same sizes were caught in summer along with older larger mackerel.

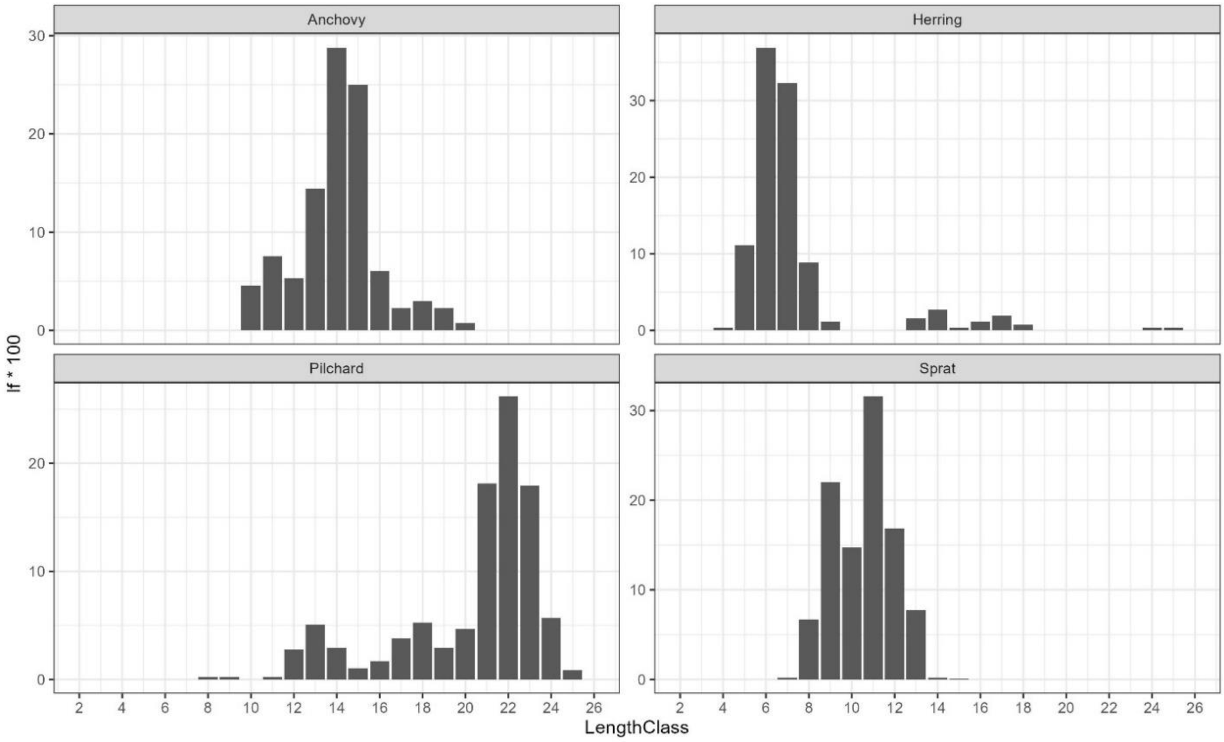

Figure 4-7: Length Frequency distribution of anchovy, herring, pilchard and sprat based on the catches of the MONS summer survey in June 2023.

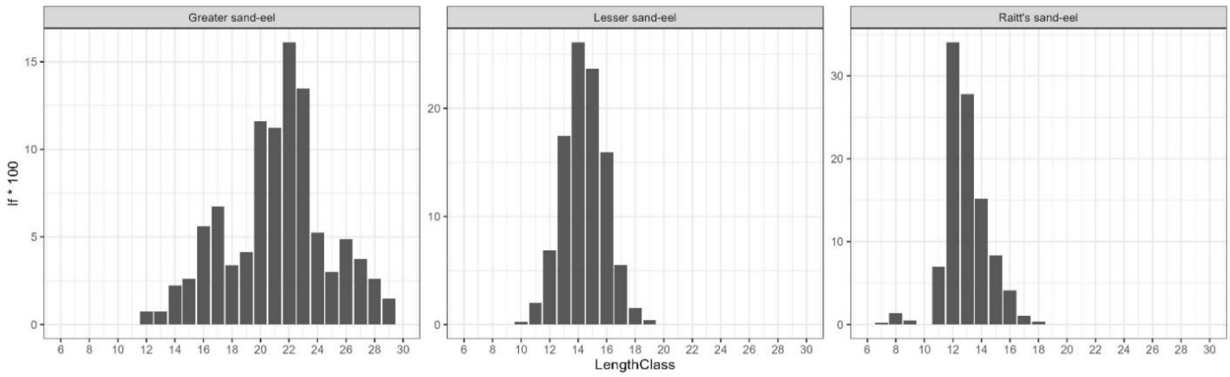

Figure 4-8: Length frequency distribution of (left to right) greater sandeel, lesser sandeel, and Raitt's sandeel based on the catches of the MONS summer survey in June 2023.

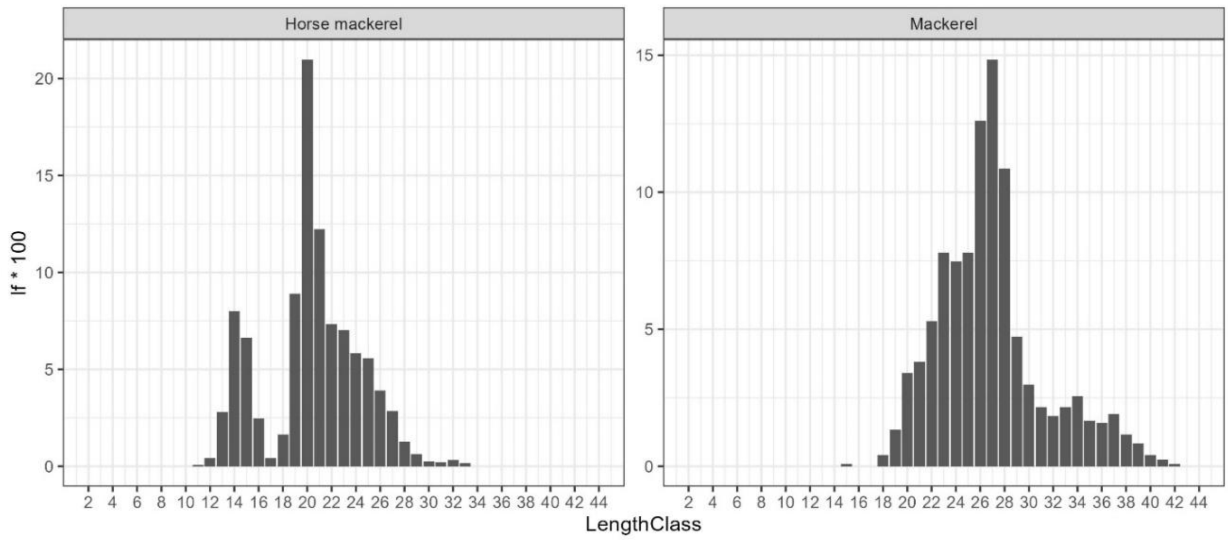

Figure 4-9: Length frequency distribution of (left to right) horse mackerel and mackerel based on the catches of the MONS summer survey in June 2023.

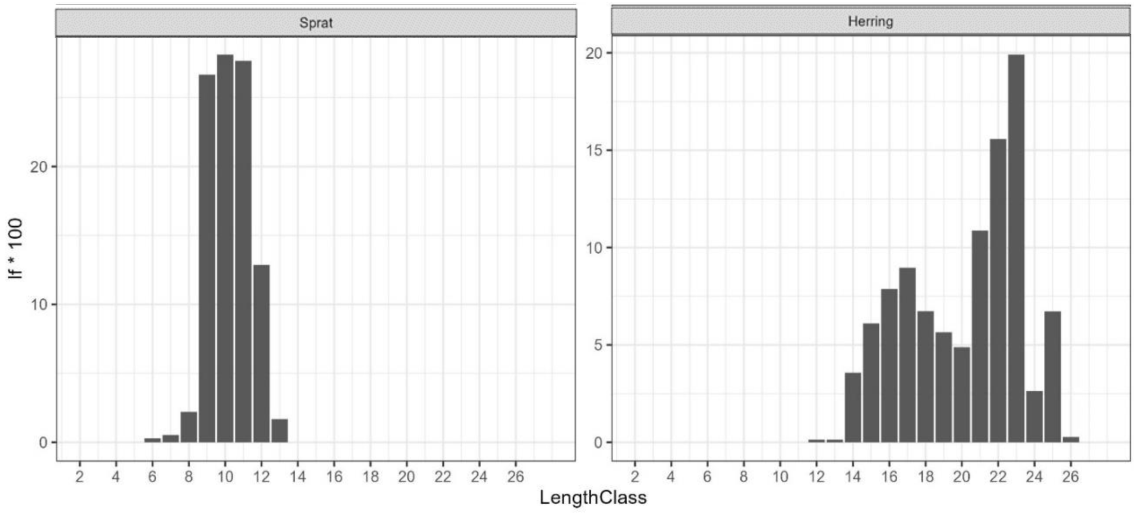

Figure 4-10: Length frequency distributions of sprat and Herring based on the catches of the MONS winter survey in January 2024.

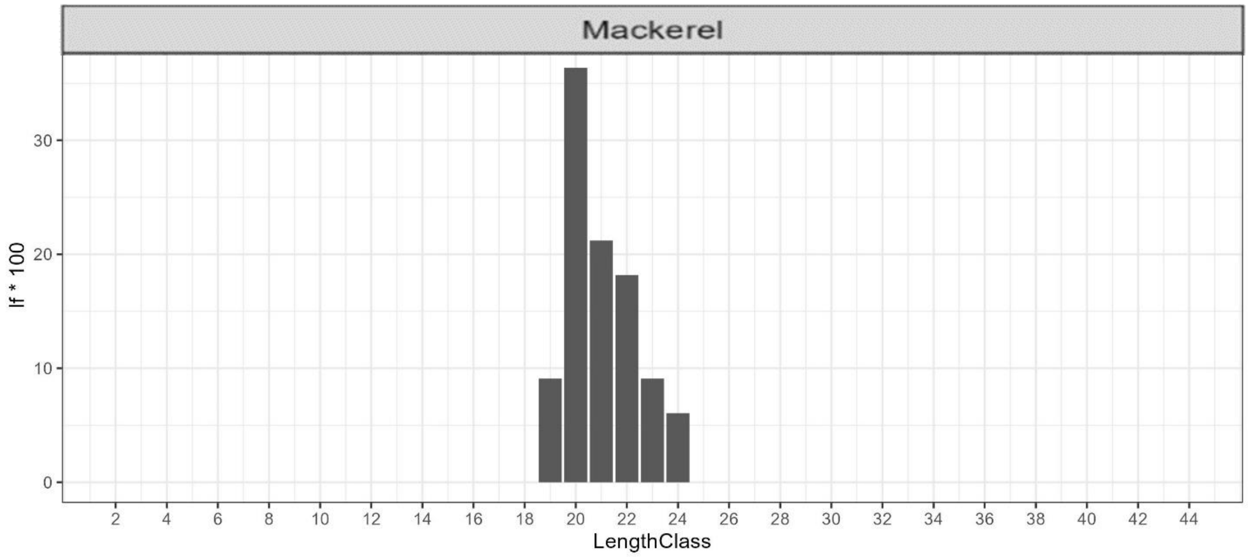

Figure 4-11: Length frequency distributions of mackerel based on the catches of the MONS winter survey in January 2024.

4.1.5 NASC to species

Transforming NASC to species abundances is straightforward with single-species schools. However, the GOV-catches in summer often contained a mix of up to nine pelagic species (Annex 2). Assuming the catches of the GOV were representative for the pelagic fish in the water column, ignoring the impact of catchability, the catch proportions are used to transform the NASC to species abundances. Therefore, the demersal species, non-swimbladder species and rare species were removed as their contribution to the NASC is limited. Based on the large catches of horse mackerel in the GOV compared to the Flex-net, horse mackerel was considered to behave as a demersal species in the area. As a result, the NASC was transformed to anchovy, herring, pilchard, and sprat. This shows for the summer that a low abundance of anchovy occurs in the southern part of the area, some herring in the most coastal locations, pilchard distribution up to 53.5 N, and sprat in most regions in highest abundance near the coast (Figure 4-12). Due to the overall dominance of sprat in winter, the winter distribution plot of sprat is similar to the map of overall NASC (Figure 4-5).

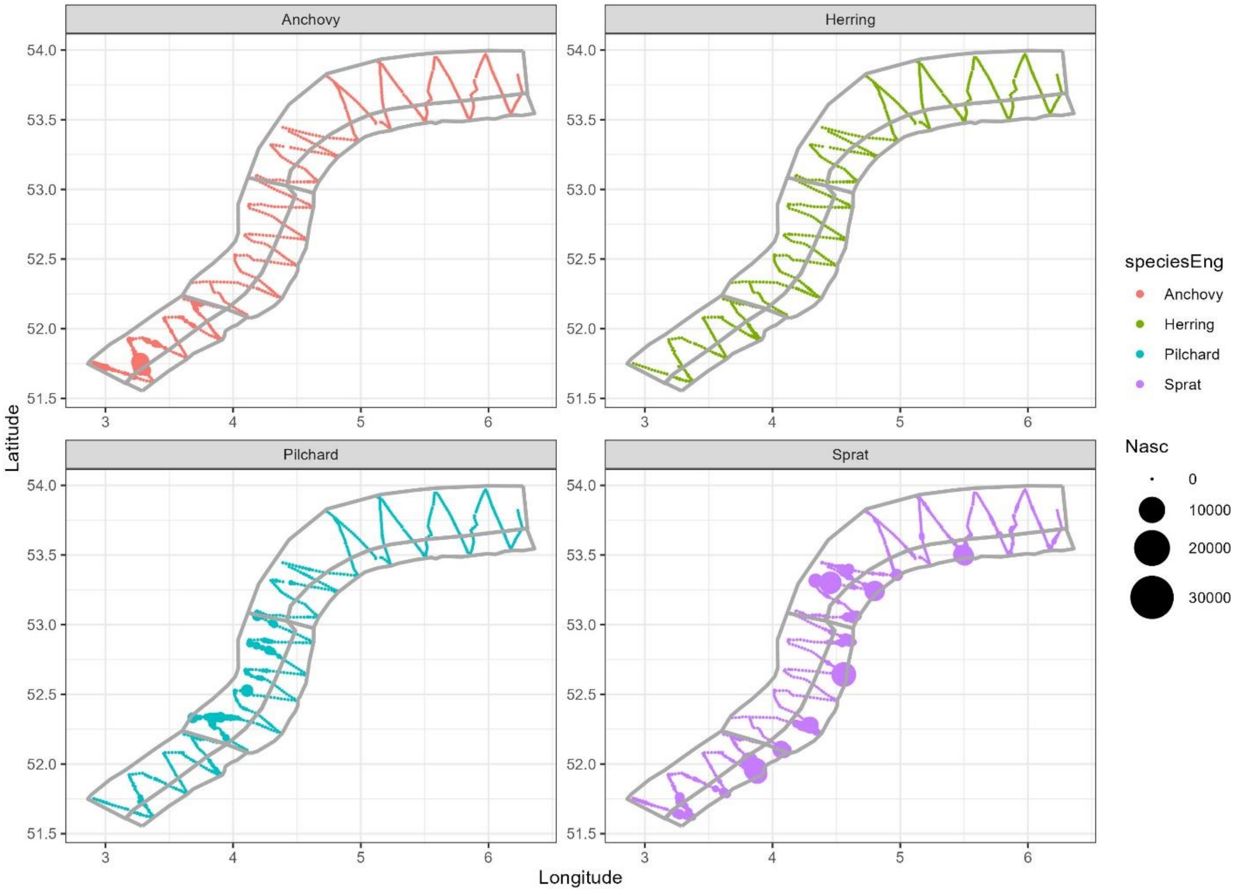

Figure 4-12: Bubble plot showing the acoustic density (by 1nmi interval) of anchovy, herring, pilchard and sprat in the MONS summer survey in June 2023 with a polygon in the background showing the subareas.

4.2 Connection with international coordinated surveys

4.2.1 IBTS Q1

The IBTS Q1 only recorded acoustic data during fishing activities. Data was also generated during the few times acoustic recordings continued during steaming. This information could not be used as the high speed led to significant noise in the acoustic recordings, particularly noticeable in the initial weeks when harsh weather conditions were common. Steaming speed between fish stations is above the speed advised for a hydroacoustic survey but is necessary in the IBTS to achieve the required number of hauls within the available time.

The Dutch section of the IBTS Q1 encompasses the Dutch coastal waters, the German Bight, the Dogger Bank, and a part of the Scottish waters. This area slightly overlaps with the area sampled by the MONS-survey (Figure 4-5). In the IBTS, an ICES-rectangle is sampled once, a process that takes approximately an hour for setting and hauling the net. During this time, acoustic recordings were performed. The complete acoustic coverage during the Dutch IBTS Q1 is detailed in Annex 1. The IBTS Q1 acoustic recordings indicate overall lower NASC values compared to MONS recordings from the preceding weeks (Table 4-2). Certain stations detected no pelagic fish, and NASC values in the southern and middle coastal sub-areas were significantly lower. However, in the northern offshore sub-area (NW), the IBTS recorded higher NASC values than the very low values recorded by the MONS winter survey.

Table 4-2: Comparison by sub-areas of average Nautical Area Backscattering Coefficients (NASC) between IBTS and MONS January 2024. Percentage IBTS compared to MONS.

Stratum	Nasc IBTS	Nasc Mons	Percentage
SW	92	109	84
SE	0	257	0
MW	0	203	0
ME	103	700	15
NW	37	3	1233
NE	NA	224	NA

The IBTS Q1 targets herring and sprat and provides yearly and index for age-1 in the North Sea (Figure 4-13) and the spatial distribution of the age-1 of these species (ICES, 2022, ICES, 2023, ICES, 2024 (in prep.)). Those yearly maps show that most young herring and sprat occur in the German Bight north of the German Islands. High yearly variation in abundance of both species is shown in the Dutch waters. The IBTS Q1 2024 showed hardly any herring in the Dutch waters; young herring was mostly caught in the most eastern part of the German Bight (ICES, 2024 (in prep.)).

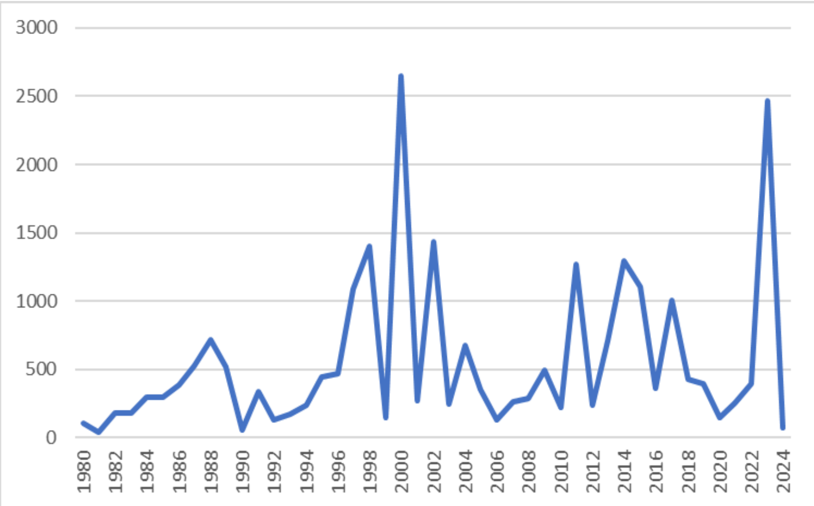

Figure 4-13: Age-1 herring North Sea index based on the IBTS Q1 catches. Indicating one of the lowest age-1 catches in 2024 since 1980.

4.2.2 HERAS

Both HERAS and MONS surveys show large spatial variability in the acoustic densities (Figure 4-4), although the general pattern is that the values found in the MONS-survey are higher than in HERAS (Table 4-3). The difference is partially a result of lower effort resulting in a reduced chance to encounter large schools, it also indicates that higher densities occur in the shallower parts that are not or for a short time covered by HERAS.

Table 4-3: Comparison by sub-areas of average Nautical Area Backscattering Coefficients (NASC) between HERAS and MONS June 2023. Percentage HERAS compared to MONS.

Stratum	NASC HERAS	NASC MONS	Percentage
SW	2.7	538	1
SE	0	1205	0
MW	19	104	18
ME	1025	1560	66
NW	188	282	67
NE	8	714	1

Following the standard method for HERAS most of the HERAS echoes off the Dutch coast are assigned to Clupeids (**Figure 4-14**a; (ICES, 2024b)) and further disaggregated to species level using the catch compositions (**Figure 4-14**b; (ICES, 2024b)). In a first step clearly distinguishable species are split, while in the case of mixed hauls with multiple clupeids (clu) or even more species (mix) they are not split. This first step also indicates for HERAS that the small pelagics in the Dutch coastal waters are various clupeids.

In the second step the mixed groups are further split using the splitNASC-process in StoX-software using the length information from the catches combined with predefined values for each species to split the NASC to species level. This results in sprat being the dominant species along the Dutch coast (**Figure 4-14**; (ICES, 2024b)), similar to the findings in the MONS survey.

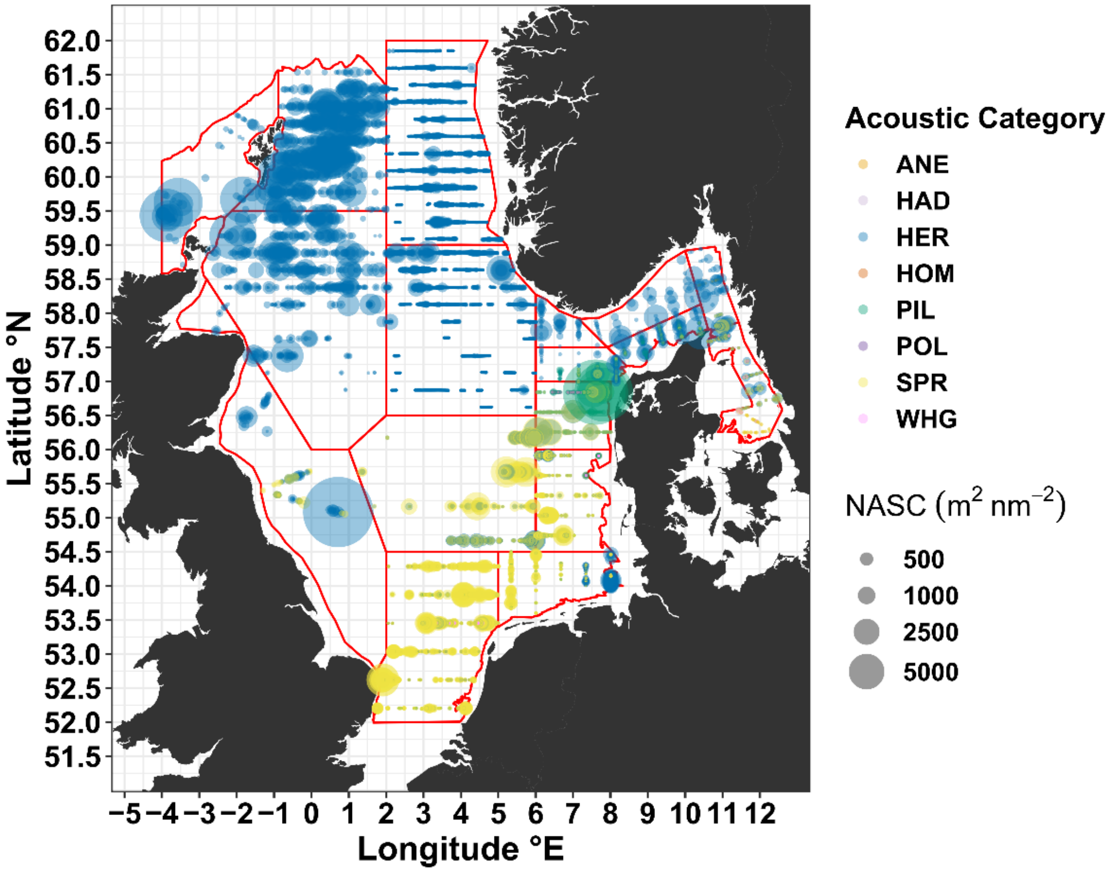

Figure 4-14: HERAS 2023 – Disaggregated hydroacoustic categories assigned to hydroacoustic data after implementing the splitNASC-process in StoX software. Aggregated acoustic categories: CLU – Clupeids. MIX – Clupeids plus various other fish species. Disaggregated acoustic categories: ANE – anchovy. HAD – haddock; HER – herring; HOM – horse mackerel; PIL – pilchard; POL – pollock; SPR – sprat; WHG – whiting.

The HERAS 2023 data also indicate that the overall NASC recorded along the Dutch coast is low compared to some other regions in the North Sea. In the northern North Sea higher NASC, e.g., higher abundances of herring are found. North of the Dutch and German Islands towards the Skagerrak also higher abundances of sprat are found than in the MONS survey area along the Dutch coast. Historic HERAS data indicate that the dominance of Clupeids is consistent, but the distribution of the high densities along the transects are variable between years (Figure 4-15). Similar variabilities are indicated in the spatial plots by species made by the IBTSWG (ICES, 2023, ICES, 2022, ICES, 2024 (in prep.)).

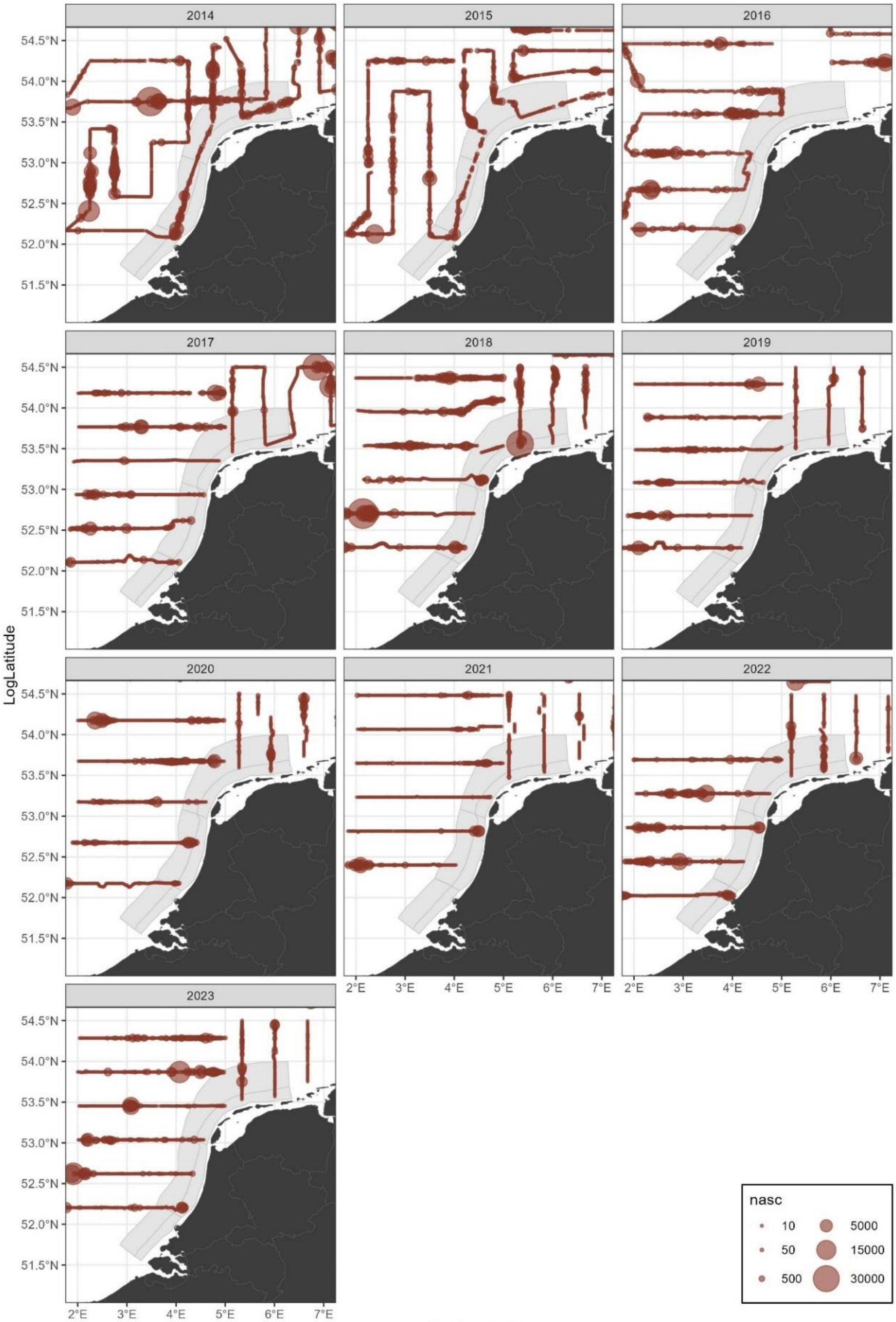

Figure 4-15: Bubble plots of acoustic values (NASC) of clupeids in HERAS 2017-2023 to illustrate the inter yearly variability of clupeid distribution.

4.3 Zooplankton

Pelagic fish distribution is likely significantly influenced by the presence of one of their main food sources, zooplankton. Therefore, gathering and analysing data on both pelagic fish and zooplankton, as was done in the MONS pilot study with the plankton Imager during acoustic survey activities, is of great interest.

Currently, only some zooplankton data of the summer survey are available, with the primary information being the number of particles observed by the plankton imager. Larger number of particles were found in the southern waters, while in the northern waters in most coastal areas the number of particles were lower (Figure 4-16). These particles were predominantly phytoplankton (including diatoms, *Noctiluca scintillans*, and *Phaeocystis*), although zooplankton, characterized by high abundances of echinoderm larvae, tunicates, and Cladocera, were also present. Notably, copepods, considered a main food source for small pelagic fish, were observed, mainly *Temora longicornis* and *Acartia spp*. AI is currently used to categorize images of zooplankton and other particles (van Walraven *et al.*, 2023).

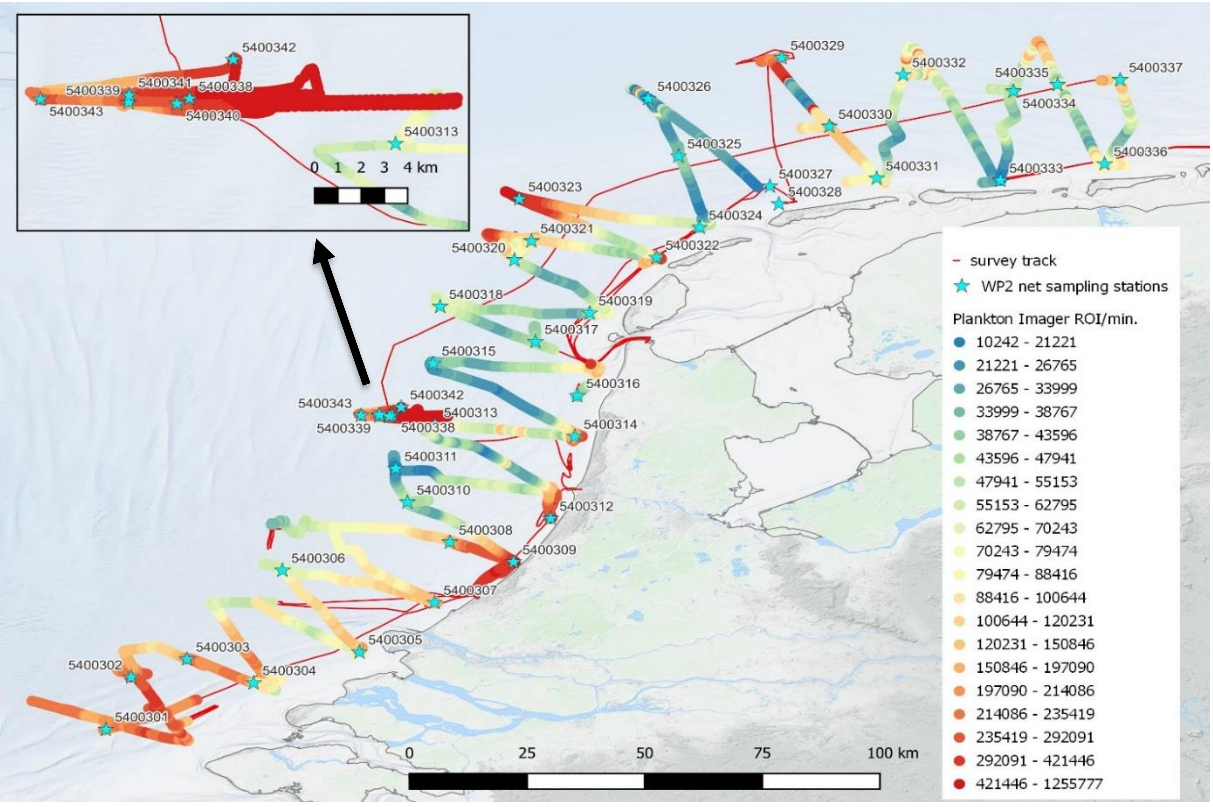

Figure 4-16: The transect of summer survey in June 2023, colours indicate the number of particles (ROI) observed per minute. The fish stations, also a sample with a plankton net (WP2), are represented by the stars. The caption indicates the area were test fishing with the Flex-net and GOV was performed.

4.4 Monitoring the surfzone

The surf zone is a dynamic area influenced by the tide, waves, storms, climate and human activities. The storms affect the morphology of the beach, resulting in the disappearance/appearance and movement of gullies. Waves hamper consistent sampling and impact the water visibility, both affecting the catchability of fish. The presence of bathers, anglers or gillnet fishery nearby also influences the catchability of fish. Due to this, large variability in catch composition and abundances limits day-by-day comparisons. The knowledge provided by this monitoring lies in the overall patterns of occurrence of species, the length composition, and the change in size of the fish over a season. Yearly patterns become clear by combining the multi-year data.

Originally, the monitoring was developed to determine the arrival of juvenile flatfish and their growth (van Hal *et al.*, 2021). For MONS, the focus is on the pelagic species in the catches, of which some were only caught on a single day while others were caught throughout the season (Table 4-4).

Table 4-4:Overview of the pelagic species caught in 2023 by month, colour indicates if species was caught.

Species		April	May	June	July	August	September	October
Clupeidae	*Clupeidae*	■	■					
Herring	*Clupea harengus*		■	■	■	■	■	
Sprat	*Sprattus sprattus*						■	
Pilchard	*Sardina pilchardus*					■		
Anchovy	*Engraulis encrasicolus*					■	■	
European smelt	*Osmerus eperlanus*	■						
Sandeel	*Ammodytes sp.*	■	■		■	■	■	■
Golden grey mullet	*Chelon auratus*		■			■	■	■
Sea bass	*Dicentrarchus labrax*		■			■		

The most abundant pelagic species was Clupeidae/herring. Early in the season, April/May, the catches consisted of late larval or very early juvenile stage *Clupeidae* that are difficult to identify to species level in the field. These could potentially be herring, sprat, or pilchard. However, considering the timing, these individuals were most likely herring. Combining *Clupeidae* with the identifiable herring, gives the result that juvenile herring were caught in all months except for the last sampling day in October. A similar pattern was seen in the years 2020-2022 (Figure 4-17), when from March till May large amounts of unidentifiable larvae (*Clupeidae*) and throughout the rest of the year identifiable juvenile herring were caught. The average length of the juvenile herring increases, in all years, from 4 to 8 cm between March and November (Figure 4-18).

Sprat, in appearance very similar to herring and potentially misidentified in some instances, were only identified in the catch in September 2023. Also, in the other years sprat was only rarely caught. While abundant in the slighter deeper water along the coast (see 4.1), sprat seems to avoid the surf zone.

Sandeel was caught in the surf zone throughout the entire sampling period. If identified to species level, all were lesser sandeel (*Ammodytes tobianus*), which is in line with the more coastal distribution of this species compared to Raitt's sandeel. The latter is known to have a distribution further offshore (Tien *et al.*, 2017). The combined data of the four years of sampling show that sandeel is caught slightly more from July onwards. However, in 2021 the highest amounts were caught early in the year (Figure 4-19). Sandeel is caught in the surf zone during a large part of the year. The average length of the sandeel was between 6 and 9 cm, and no clear change in mean length was seen throughout the season.

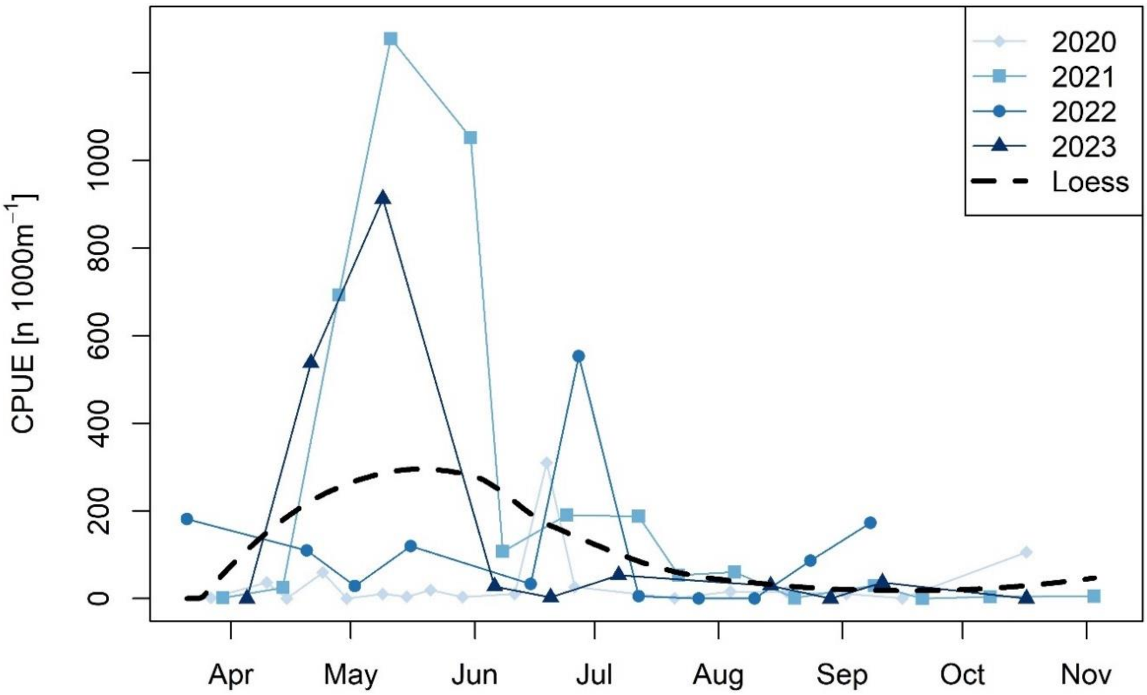

Figure 4-17: Average abundance of Clupeidae and herring in the catches of the surf zone monitoring at IJmuiden beach in 2020-2023, including a Loess smoother over all the data.

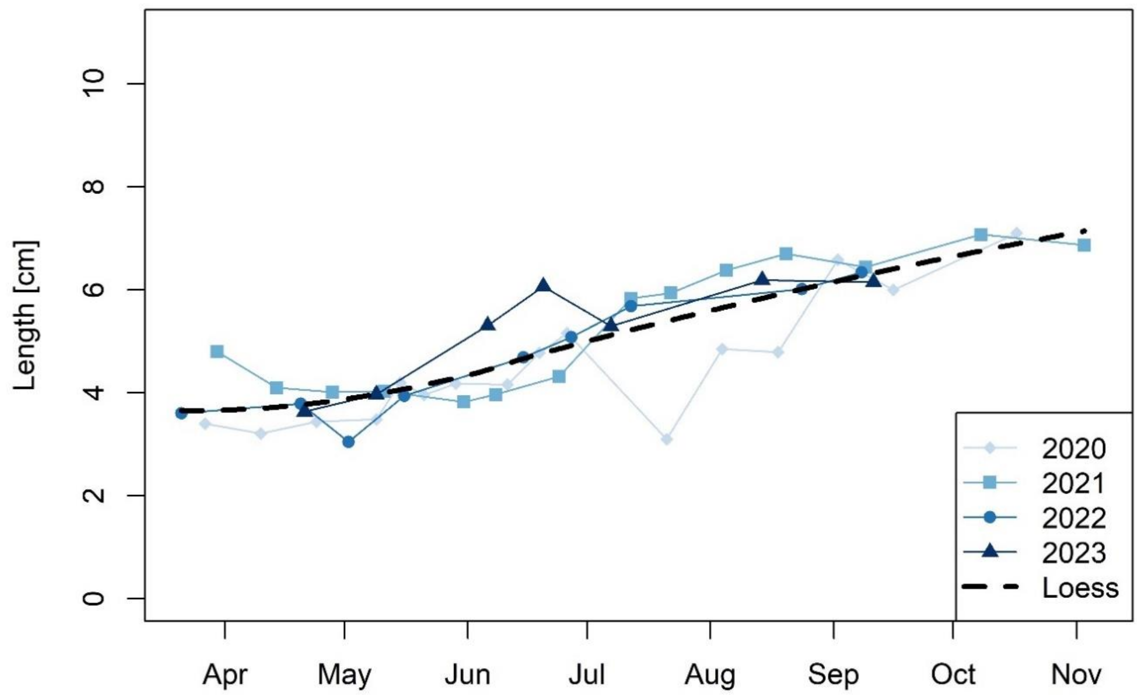

Figure 4-18: Average length of the Clupeidae and herring in the catches of the surf zone monitoring at IJmuiden beach in 2020-2023, including a Loess smoother over all the data.

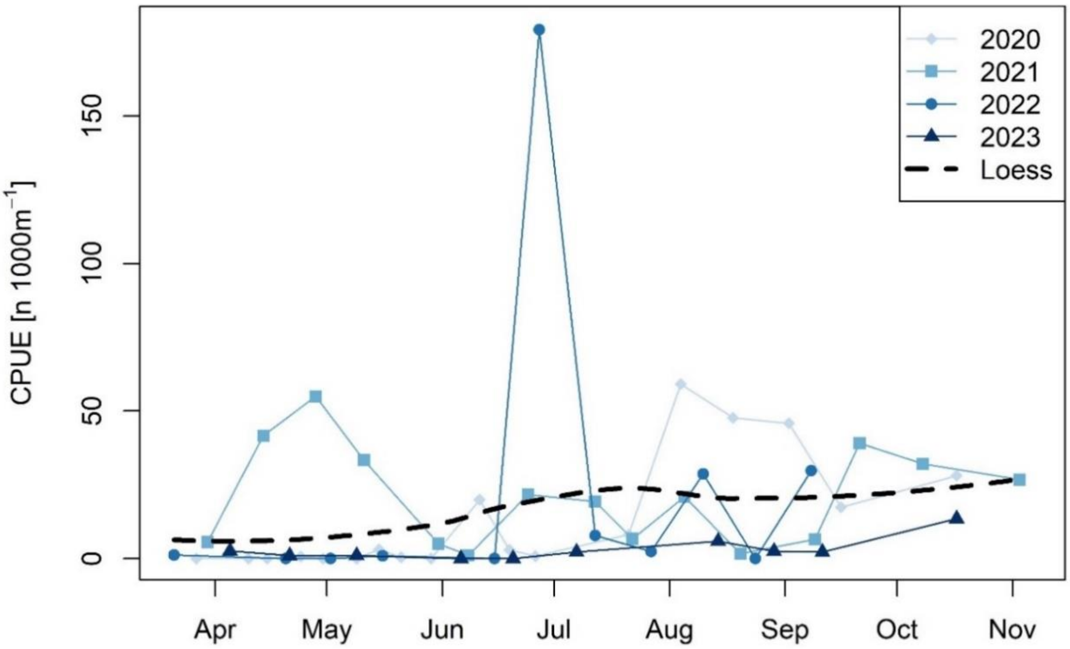

Figure 4-19: Average abundance of sandeel in the catches of the surf zone monitoring at IJmuiden beach in 2020-2023, including a Loess smoother over all the data.

Anchovy was caught in August and September, length ranging from 3.5-8 cm. This matches with the known spawning in May-June and development time, depending on temperature, of 60-120 days (Petitgas *et al.*, 2012). The presence of anchovy in the surf zone seems short as they were rarely caught in October.

Two other species of interest are the sea bass and golden grey mullet. Both were caught in May and then again from August onwards (Table 4-4). Both species were mainly caught in the tows done in the shallow tidal gullies, indicating a different use of the surf zone compared to most other species caught. The catches of sea bass were overall low in 2023 compared to the earlier years (Figure 4-20). At the same time, the catches of golden grey mullet were much higher in late summer than in the previous years (Figure 4-21). For both species most of the individuals caught were small 0-goup fish (Figure 4-22), however some older fish were caught as well. In 2023 catches of sea bass were actually all older fish in the length range 10-15 cm. It is likely that more large individuals of sea bass and golden grey mullet occur in the surf zone, but these fast-swimming individuals are able to avoid/escape the net. To catch larger individuals of these species a pilot was done with a beach seine in late September early October, but none of the species were caught.

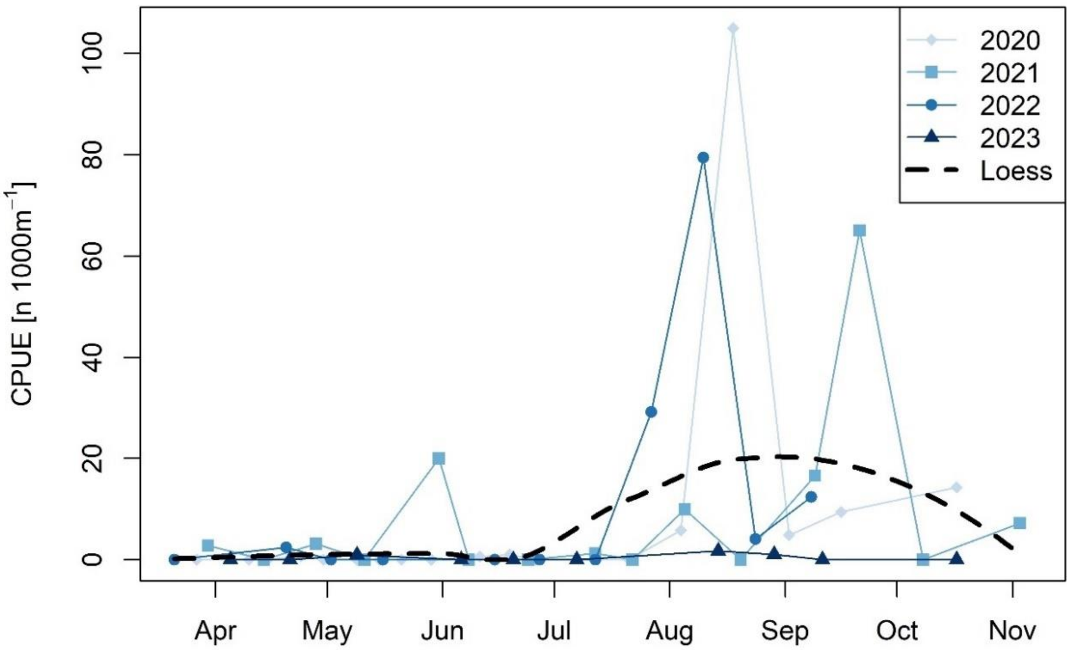

Figure 4-20: Average abundance of sea bass in the catches of the surf zone monitoring at IJmuiden beach in 2020-2023, including a Loess smoother over all the data.

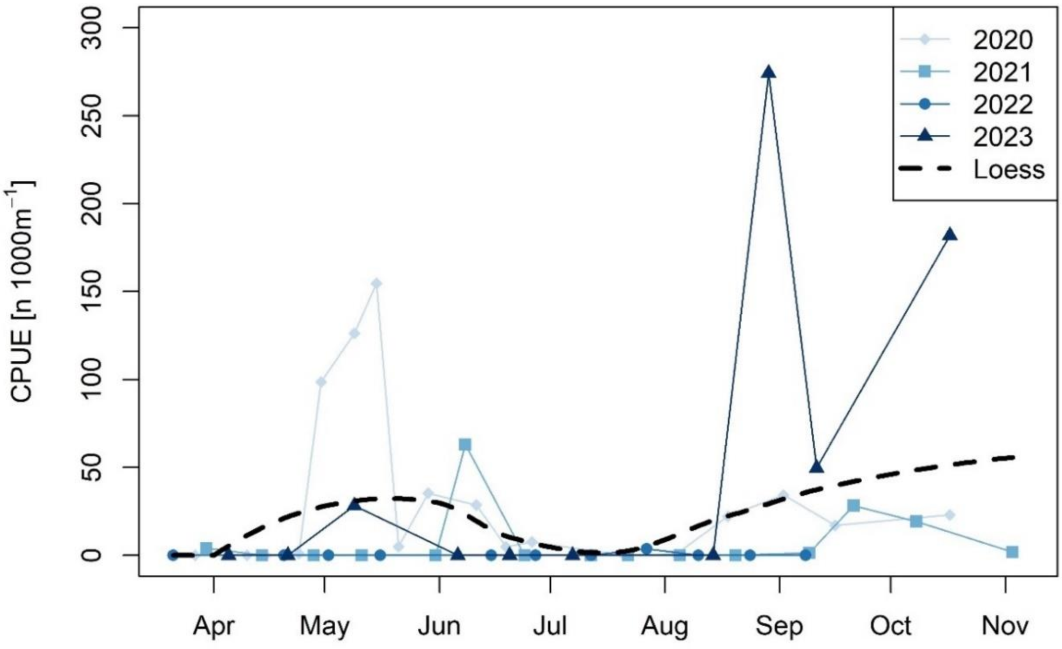

Figure 4-21: average abundance of golden grey mullet in the catches of the surf zone monitoring at IJmuiden beach in 2020-2023, including a Loess smoother over all the data.

Figure 4-22: Golden grey mullet <5 cm on a measuring board.

5 Discussion

5.1 Fishing in next MONS acoustic surveys

Comparison of the pelagic Flex-net and GOV-net catches shows that both nets catch similar pelagic species, and in addition the GOV-net catches demersal species from the bottom, which were rarely found in the Flex-net catches. This suggests that the GOV-net can be used to describe the pelagic fish composition, when the demersal species are excluded from the catches. Consequently, the GOV-net can verify species composition in recorded schools. However, it doesn’t guarantee that the IBTS, using the GOV-net, provides accurate distribution and abundance indices, as significant parts of the pelagic fish community may occur in the water column above the net. For upcoming surveys, the Flex-net remains the preferred choice, as it excels at catching pelagic species and avoids unwanted demersal catches. Further, Flex-net monitoring could improve our understanding of the representativity of the pelagic fish abundances the GOV detects during IBTS surveys.

The two acoustic surveys used different methods: a grid-based sampling scheme in summer and a traditional method in winter, which involved targeted fishing when fish schools were detected and manually assigning catch compositions during post-processing. These methods showed in both surveys a clear dominance of sprat. The traditional method provided a good indication of the pelagic fish distribution but may overlook species present in small quantities. For example, proportions of a few percent anchovy in the catches amid sprat, will not show up in biomass estimates. These species would need to be assessed through catches in the survey or in additional studies. On the other hand, the grid-based sampling method, often perceived as more scientific, may not be as accurate due to the trawl's selectivity, and catching non-schooling species from the bottom. These would need to be excluded during echogram interpretation, which requires expert judgement.

Since the catches of pelagic species are dominated by sprat and the distribution over the area is very patchy, traditional assigning of species to the detected schools is more efficient as it required less time spent on fishing. If fish distributions change over the years – with a larger contribution of other species than sprat and a more even distribution in the survey area – it may be necessary to switch to a grid-based sampling scheme.

5.2 The effect of the acoustic ‘dead zone’

The comparison hauls with the two nets in summer 2023 were conducted when the echogram indicated absence of pelagic fish. Despite the absence of pelagic fish according to the echogram both nets caught (pelagic) fish. These fish were likely present in the acoustic dead zone near and on the bottom. Notably, horse mackerel and whiting, abundant in many catches, were likely caught from the bottom while not visible on the echogram. The terms 'pelagic' and 'demersal' often create a rigid division, yet species can overlap in their environments. For instance, horse mackerel, typically considered pelagic, can switch between pelagic and demersal states based on feeding needs (e.g., feeding on planktonic organisms in the water column vs. feeding on small benthic invertebrates). Gadoids are generally demersal, but whiting, haddock (*Melanogrammus aeglefinus*), and Norway pout (*Trisopterus esmarkii*) are regularly observed in pelagic schools during the HERAS survey.
The species that are typically classified pelagic but were not visible on the echogram consisted of horse mackerel (not visible because it swims too close to the bottom) and weak scatterers such as mackerel, lesser sandeel, Raitt's sandeel, and greater sandeel. These species are included in the catch composition graphs but are excluded from the acoustic plots. So, eleven species considered as pelagic have been found in the catches, but the current design of the acoustic survey is not suited for providing information on all these species, only four are actually considered.

The "dead zone" near the bottom and surface is caused by substrate reflection and the nearfield of the 38 kHz splitbeam transducer, extended by the vessel's draught and dropkeel. This results in a total dead zone of approximately 9.5 m, limiting the observed water column in shallow waters. The assumption, based on observations during other acoustic surveys, is that a part of the pelagic fish that stays within the path of the boat tends to show vertical avoidance, diving towards the bottom, due to the ships noise (Soria *et al.*, 1996). Thus, despite the fact that only a very small part of the water column is observed with the acoustics, it still provides a reasonable indication of the presence of pelagic fish in the water column.

The Tridens' multibeam has benefits, however a shallower-draught vessel or a simpler acoustic setup in a towed body alongside the ship could reduce the surface dead zone. As the towed body operates approximately 1-1.5m under the surface, this would result for the 38 kHz transducer in a dead zone of 6 m from the surface (1.5 + 4.5 m nearfield of the 38 kHz). The towed body can be equipped with a 38 kHz and a 200 kHz transducer. The latter has a nearfield of 50 cm, which would result in a dead zone of 2m below the surface.

While the setup on the Tridens enables data collection of multiple frequencies, currently, only the 38 kHz data is presented as this is the frequency used worldwide as standard n fisheries acoustics, including in HERAS. The use of higher frequencies may be beneficial for shallow water surveys as higher frequencies have much lower nearfields and a higher resolution, resulting in a better detection of small targets (young pelagic fish, for example young sprat and herring of a few centimeter and sandeel) at the cost of a smaller vertical range and a higher sensitivity for acoustic noise. The (standard) use of these higher frequencies requires investment in data handling and survey protocol development to combine and compare the data with HERAS and other coastal surveys. This additional work currently has not been anticipated.

5.3 Species composition in the MONS acoustic surveys

The MONS surveys show a patchy distribution of pelagic fish along the Dutch coast which is typical for schooling species as can be seen in the HERAS results. The pelagic fish community was dominated by sprat in June 2023 and January 2024. The contribution of the other swimbladdered pelagic species, herring, anchovy and pilchard, was in the order of a few percent in June. In January, herring's contribution was slightly larger, due to a concentration of a single haul in the northeastern part of the area. The domination of sprat was also previously observed in acoustic surveys in the Dutch coastal zone in different months in 2002/2003 (Grift *et al.*, 2004) and 2007/2011 (van Hal *et al.*, 2012). This dominance of sprat thus seems to be consistent throughout the years at various times in the year.

In June 2023, anchovy and pilchard were among the main constituents of the pelagic fish community but appeared in lower densities than sprat. In June, these species had a larger length than the sprat and most herring caught. In the January survey these species were absent. One of the expected effects of climate change is expansion of the distribution range of southern species towards northward habitats (Alheit *et al.*, 2012). Species such as anchovy and pilchard have been indicators of such changes in the past couple of decades (Petitgas *et al.*, 2012, Alheit *et al.*, 2012). Their absence in winter could be an indication that the North Sea environment along the Dutch coast in winter is not ready yet to host these species year-round, potentially due to the low water temperature. Variable amounts of pilchard (<10cm) and anchovy are however regularly caught during the IBTS Q1 (Heessen *et al.*, 2015). Larger catches have been seen in recent years. However, their numbers were very low again in 2024 (van Hal, 2024).

The January (spatial) distribution of herring was likely not representative for an average year. The catches of one year old herring (1 winter ring: this corresponds with 0-winter ring herring in June in the year before) in the IBTS Q1 were one of the lowest since the closure of the fishery in the 1977, when the stock of North Sea herring was fished down to an historic low (ICES, 2024 (in prep.)).

The low abundance of herring in the June survey was in agreement with the IBTS Q3 2023 in which hardly any herring was caught in the Dutch waters (ICES, 2024 (in prep.)). In contrast, the first results of the

Swimway project[2] show that juvenile herring in the Wadden Sea are much more abundant than sprat (Maathuis *et al.*, in prep.). The results of that study indicate that the proportions of the two species vary in the inlets between the isles. Similarly, in the yearly stow net survey in the Western Scheldt, the other estuary along the Dutch coast, juvenile herring is more abundant than sprat (de Boois and Couperus, 2022, de Boois and Dammers, 2023), and also in the monitoring of fish in the surf zone (this report), young herring showed up more frequent than sprat. As the June-survey did not catch herring, is it likely that during summer herring is distributed in a narrow strip of about 1-2 km along the Dutch coast, in the Wadden Sea and the southwest Delta. That the herring are likely present in this narrow strip is confirmed by a study on the effects of sand nourishments in 2017 (Couperus *et al.*, 2020, van Hal *et al.*, 2021), when the shallow area was surveyed with high frequency (200kHz) acoustics, combined with beam trawl catches. This survey took place in the zone between 4 and 10m depth in which many schools of pelagic fish were observed. Despite fishing with a shrimp trawl (demersal gear), the catches contained large quantities of clupeids with a clear domination of herring compared to sprat. As shown above, the surf zone monitoring also provided information on the pelagic fish in a difficult zone to monitor which seems to be relatively important for herring, but also for juvenile mullets and sea bass which were also not abundant in the acoustic survey. In winter, herring is known to migrate from cold shallow coastal waters into deeper water (Corten, 1996) which might explain that in the January survey herring was still less abundant than sprat, but it composed a larger part of the pelagic fish community than in June.

The NASC's (or: S^A) found by Couperus et al. (2016) in the Marsdiep area in May 2010-2011 were 1193-1433 during low tide and 2655-1965 during high tide. The values of low tide are similar to the value (1117) found in this study for the combined eastern area. Couperus et al. (2016) explain the higher NASC's in the Marsdiep during high tide by high concentrations of clupeids in the near coastal zone that migrate into the Marsdiep with incoming tidal water. The fact that in the present study the NASC's measured in the eastern area are much lower than at high tide in the Marsdiep may therefore indicate that the clupeid biomass missed in the shallow coastal zone in the June survey is considerable.

The species without a swimbladder (mackerel and sandeel) have a much lower acoustic reflection compared to species with a swimbladder. Therefore, they are hard to detect or cannot be discriminated. This is not believed to be problematic for mackerel from the perspective of pelagic fish as food for seabirds, because the length distribution shows that the individuals are too large as food. However, the two sandeel species *Ammodytes tobianus* and *A. marinus* were caught in the length range preferred by birds, and are important food species, that should be sampled in a different way (Camphuysen, 2005b). In general, these species bury in the sand under poor light conditions, that is at night and in winter. Both species have different spawning periods in which they leave the sand (van Deurs *et al.*, 2011). This means individuals of both species can be in the water column or in the bottom at any time. The exact behaviour of sandeel species in the Dutch coastal zone is not known. A PhD-study, (NWO-project "Forage fish") is currently investigating the behaviour and life history of these species in the coastal zone. For the planning of monitoring, it is recommended to take (preliminary) findings of this PhD-study into account.

Sprat dominates the acoustic findings providing the possibility to carry out a yearly acoustic survey without fishing. The acoustic data could then be used as an index for food availability for seabirds. However, this approach has some limitations that should be considered: (1) By not collecting catch information, data on weight and nutritional values will not be available for species that are visible on the echogram and for species that are only found in the catches. Because the total abundance of small pelagic fish is far more than needed for seabirds (Grift *et al.*, 2004, Couperus *et al.*, 2016), and this report), we expect that these are the main parameters that explain food availability. (2) Possible inter-yearly changes in ratio between species distribution and abundance will not be noted. Thus, important signals on climate change and variations in recruitment could be missed.

[2] Study on how pelagic fish uses the Wadden Sea.

5.4 The added value of the coastal surveys to the international surveys

The acoustic surveys in June and January expand the coverage of the HERAS, and due to the relatively dense transects they offer more detailed data than the catches of the IBTS. In July, HERAS and MONS surveys use similar methods, but HERAS has less coastal transects, resulting in insights on the finer scale distribution of pelagic fish in the nearshore waters by MONS.

HERAS aims to estimate herring and sprat abundance in the whole North Sea. MONS survey results show higher NASCs and a reduced chance of detecting schools, partly due to HERAS' lower transect coverage. However, the main reason seems to be that the HERAS transects extend less eastwards (towards the coast) than the MONS-transects. It is likely that HERAS, if extended further inshore, would record some higher NASC's (at the same level as in the MONS-survey). Although the inter yearly variability would still be higher in HERAS than MONS (due to the lower resolution of the transects).

The IBTS Q1 2024 showed hardly any herring in the Dutch waters; young herring was mostly caught in the most eastern part of the German Bight (ICES, 2024 (in prep.)).This resulted in one of the lowest abundances of age-1 herring since 1980 (Figure 4-13). This sparked debate in the herring assessment working group (HAWG) as this low abundance did not match with expectations coming from the prior larvae-surveys (ICES, 2024a). The formulated hypotheses for this finding were 1) a change in spatial distribution to more coastal waters, 2) a change in vertical distribution to avoid turbidity at the sea floor caused by the extended period of harsh weather, or 3) higher mortality due to predation. There is currently no answer to that yet, but this indicates that the absence in the MONS survey is in line with the IBTS findings.

The current collection of hydroacoustic data in the International Bottom Trawl Survey (IBTS) is clearly insufficient, as data is only recorded during hauls. This results in extremely short transects of less than 1 nautical mile (nmi). However, there is potential for the IBTS to enhance its contribution to the recording of pelagic fish:
(1) Sail in silent mode: the vessel can sail in silent mode, rather than at full speed with two engines (this would also reduce the carbon print of the survey considerably). This would increase the number of acoustic intervals, thereby collecting more data and improving the quality of the acoustic recordings. Likely impacting the main objective of the survey which results in additional days at sea.
(2) Additional Coastal Transects: extra transects closer to the coast could be added during the survey. These transects should be extended as close to the coast as possible, increasing the coverage and amount of acoustic data collected in coastal zones.

Implementing these changes would create a low-effort acoustic survey like the Herring Acoustic Survey (HERAS). This approach would generate data comparable to the MONS surveys, albeit with lower resolution and precision. While not as precise as a dedicated survey, this strategy would significantly enhance the IBTS' ability to contribute valuable data on pelagic fish distributions in coastal areas. These changes can only be made if the survey's primary objective, e.g., the number of fishing and larvae hauls, is not at risk. When fully acoustic coverage is required, this will result in higher costs due to extra shipping time.

5.5 The use of the data as an index for food availability of sea birds

The background of monitoring pelagic fish in the coastal zone is to be able to assess future availability of small pelagic fish as food for sea birds.

The acoustic surveys give a more detailed distribution of pelagic fish in the nearshore waters than existing surveys. Therefore, they may be more likely to give an indication of potential food resources for seabirds. However, the distribution of pelagic fish is not the only factor that determines the value of small pelagic fish as food. Food availability is a complex result of a list of factors including horizontal and vertical distribution, visibility, distance from breeding/resting locations, size, and nutritional value.

5.5.1 Location of available food

The exact depth at which pelagic fish are recorded during hydro acoustic surveys is much less relevant than one would expect. The survey data are however very relevant in determining the potential abundance of pelagic fish food for seabirds.
Pelagic fish can easily adapt and change swimming depth, in response to the conditions. Plunge diving seabirds worldwide tend to concentrate where prey is temporarily available. This may be hydrographical or tidal fronts, discarded fish behind fishing vessels or fish schools that are hunted upon by aquatic predators towards the surface. All these feeding aggregations are very local and temporal. The premise behind this is that pelagic fish respond quickly to changing conditions (Krijgsman, 1971, Camphuysen and Webb, 1999).

Seabirds, like sandwich tern and lesser black backed gull hunt small fish by sky diving and plunging into the water. The range at the water surface where they can reach their prey is therefore limited. Diving depth is not known as it is difficult to measure in the field. Cabot and Nisbet (2013) mention 1.5m as a maximum depth. Terns that plunge dive to this depth will not be successful. Baptist and Leopold (2010) found a non-linear relationship of dive success with transparency of the water, while other authors did not find higher success rates. This is most likely due to the response of pelagic fish that might respond to higher visibilities by moving deeper out of reach of their predators (Haney and Stone, 1988). The foraging range of seabirds varies between colonies and with season. A maximum foraging distance of 54 km has been recorded. The mean of all the maximum foraging ranges recorded by different studies is 49 km (Thaxter *et al.*, 2012).

In summer, one of the important seabird species is the sandwich tern (*Sterna sandvicensis*) (Kleunen *et al.*, 2017). This species depends on small pelagic fish to raise their chick. This species has its colonies in the Wadden area (Texel, Ameland, Griend) and in Zeeland. The diet of sandwich terns consists exclusively of herring, sprat (*Clupeidae*) and sandeel (*Ammodytidae*) (Courtens *et al.*, 2017, Stienen and Van Beers, 2000). They seem to have a complex foraging strategy taking advantage of nearby areas for finding food to sustain themselves or nourish their chicks. Additionally, they venture further offshore to secure larger prey to feed their older offspring (Fijn *et al.*, 2017, Fijn *et al.*, 2022). Sandwich terns on Texel appear to prefer the outer deltas of the tidal inlets as a foraging location (Leopold and Baptist, 2016, van den Bogaart *et al.*, 2019). This is probably related to wave action and strong currents and the occurrence of current seams in the outer deltas, which can drive fish to the surface and thus make them more accessible to foraging seabirds that attack their prey from the air (Leopold and Baptist, 2016, Scales *et al.*, 2014).

Poot *et al.* (2004) observed lesser black backed gulls and herring gulls, feeding on small sprat at the surface along a current sim off the Dutch coast at the entrance of the Nieuwe Waterweg. On the echogram (38 and 200 kHz) a mackerel school was observed feeding on the same sprat, chasing it to the surface in the process.

5.5.2 Preferred fish length range for food

The MONS monitoring showed that pelagic fish in the length ranges preferred by the above-mentioned seabird species were present in the coastal zone and the surf zone in summer. The species that were available in the preferred size ranges were sprat, herring, anchovy, lesser sandeel and Raitt's sandeel. The abundance of the smallest sizes (< 8cm) was low, especially in winter. However, this lower abundance is partially related to the size selectivity of used fishing gear. The overall estimated densities of clupeids were in the order of tens to hundreds of kg/ha which is far more food than required for the seabirds in the area (Couperus *et al.*, 2016).

The sizes of clupeids and sandeels eaten by adult seabirds in the Wadden Sea during the breeding season ranged from 5 to 17 cm. The chicks were fed with fish in the range of 5-12 cm, gradually increasing with the size of the chicks (Stienen and Van Beers, 2000). In the winter common guillemots (*Uria aalge*) and razorbills (*Alca torda*) are abundant in the Dutch coastal zone. They feed mainly on clupeids and sandeels in the range of 5 to 20 cm (Depooter, 2010). van der Have and Potiek (2021) provide a further lengthy list of bird species predating mainly on small pelagic fish.

Pilchard and horse mackerel were only present in June, ranging 9-26 cm and 12-30 cm, respectively. The smaller sizes may contribute to the food availability of sandwich terns. However, both species had a western distribution, and the presence of horse mackerel was bottom bound, which reduces the likelihood of being available as bird food. Relatively large mackerel was caught in the western area. Size ranged from 18-41 cm in June and 19-24 cm in January, and therefore the mackerel is not likely to contribute as food for birds. Moreover, they are fish predators themselves.

5.5.3 Timing of food availability

The timing of the availability of fish in the sizes that matches the size of the chicks, may be critical in summer. Rindorf *et al.* (2000) found evidence for guillemots that the timing of peak sandeel availability influenced reproductive output such that success was lower when availability peaked early (Rindorf *et al.*, 2000).

5.5.4 Bird observations

Currently, the acoustic surveys were only combined with the continuous monitoring of zooplankton. The set up of an acoustic survey, however, provides the opportunity to collect data on seabirds simultaneous with pelagic fish (Camphuysen, 2005a). The transects sailed for the acoustics could be used for bird observations as well. When fishing on schools is limited, the attraction of birds by the vessel is limited compared to fishing surveys like the IBTS. The Tridens has a bird observation platform installed already, so when this vessel is used in future monitoring it is relatively easy to additionally do observations on birds.

5.5.5 Zooplankton as food for fish

The use of the plankton imager simultaneous with the acoustic recording provides the opportunity to compare potential food resources directly with pelagic fish. Multi-year data are preferred to do such a comparison. However, as a first indication we showed a preliminary comparison of NASC’s by transect against the number of copepods. The AI-algorithms used to extract the copepods have not been tested and the accuracy of the input data needs further investigation.

6 Conclusions

6.1 Survey results

Two successful surveys, conducted in summer and winter along the Dutch coast, provided a detailed characterization of pelagic fish density and community structure. While the acoustic measurement methods were the same in both surveys, the trawl sampling strategies differed. The summer survey was designed following an experimental approach by fishing in predefined locations based on a grid design, whereas in winter the traditional method targeting areas of higher acoustic densities detected by the echosounder was used. The latter method proved more suitable for the main questions as it effectively characterised species and size composition with an optimal number of trawl hauls. Although the grid method used in summer also yielded accurate results, it required excessive effort for marginal additional gain in answering the main questions. However, the additional hauls did provide information on the pelagic species without swimbladder and the rarer pelagic species.

The distribution of pelagic fish was found to be very patchy, which is typical for schooling species. The survey design and effort effectively resolved this patchiness, revealing a clear dominance of sprat, as expected. This dominance - relative to other species – seems connected with surprisingly low densities of herring during both summer and winter surveys. Herring is known to be one of the most common members of the pelagic fish community in the region, however also in the regular international monitoring the densities of herring were low in the same periods. Juvenile herring is known to occur in the shallow zone between 2 and 10 m depth which was not covered by the acoustic surveys. This was confirmed by the dominance of young herring in the surf-zone sampling. Herring was caught throughout the spring and summer season and displayed a clear increase in length. One of the hypotheses is that herring had a more coastal distribution for yet unknown reasons, resulting in the species being largely missed by the regular monitoring and the MONS acoustic survey.

Where sprat and juvenile herring occur through the year in the coastal water, seasonal migration of anchovy and sardine was observed with clear presence in June and absence in January. This seasonal migration might be an indicating that the Dutch coastal waters in winter, despite the increasing temperatures, are still too cold for these species to stay there year-round.

The surf zone sampling – though carried out with demersal gear – is an adequate addition to the acoustic survey in June, because it gives information of the coastal distribution of juvenile herring as well as (the juveniles of) some other pelagic species which are hardly sampled in the acoustic surveys.

6.2 Extending the surveys to a monitoring program

A comprehensive, multi-year monitoring program is essential to understand the underlying causes of fish composition and distribution. This involves observing fish densities, environmental data, and potentially zooplankton data over several years. These combined observations may help explain the patterns observed in this first year. The combination of observations will only be possible on larger research vessels like the Tridens. In case smaller (and cheaper) vessels are used data from various sources need to be combined. These sources will have temporal and spatial differences complicating straightforward analyses.

It was possible to compare and combine the MONS survey with the regular acoustic survey in the North Sea (HERAS), due to their similarity in design and methods. The summer MONS survey revealed higher fish densities compared to HERAS. This was primarily due to MONS extending closer to shore, with higher effort in these shallower waters. This increased the chance of detecting patchy distributed fish schools in the area where higher fish abundances were observed. The MONS survey is thus an extension of the long running

HERAS, and the combination of both surveys provides a good indication of the spatial distribution of pelagic fish in June/July. For MONS to serve as an extension, it necessitates transects more closely together with higher effort in areas closer to shore than in HERAS. With a less dense transect design, the additional value compared to HERAS would be minimal. A MONS survey solely covering the shallowest parts with dense transects additional to HERAS, in line with the current MONS setup, would be an option for the future. Some spatial overlap between the surveys is however preferred. This would lead to a survey with dense short transects in shallow water, and a number of long offshore transects in line with the HERAS transects. The focus on short coastal transects could also be the backup plan in case the survey is hampered by weather or technical issues. No amendments have to be made to the HERAS survey setup to combine it with the MONS acoustic survey.

Comparison of MONS surveys with IBTS Q1 was challenging due to differences in methods and design. The results indicated that IBTS, with its current coverage, does not add sufficiently to the MONS acoustic survey. The acoustic data collected in IBTS is so confined that it does not add to the understanding of the spatial distribution of the pelagic fish community. However, there is potential for improvement if enhancements are made to data collection protocols and slight adjustments to the design are implemented in IBTS. However, this will result in higher costs due to extra shipping time.

6.3 Index of food availability for birds

Data collected by this study offer important insights into the food availability of the breeding bird colonies and wintering seabirds in the region. Potential prey species for marine birds such as sprat, herring, anchovy, lesser sandeel, and Raitt’s sandeel were successfully detected in the study area, and particularly estimated densities of clupeids seem to be adequate for supporting the feeding needs of the birds.

The sizes of horse mackerel, pilchard and mackerel observed during the surveys, especially in winter, may be often too large as food for seabirds. While this study offers a detailed snapshot of species composition and density distribution in a crucial feeding habitat for birds, it is essential to gather this information consistently over multiple years. Just as spatial patchiness is evident in the data, temporal variability is also crucial in such studies. Consistent time series data are necessary to inform management decisions aimed at maintaining the environmental health of marine birds in the region.

7 Quality Assurance

Wageningen Marine Research utilises an ISO 9001:2015 certified quality management system. The organisation has been certified since 27 February 2001. The certification was issued by DNV.

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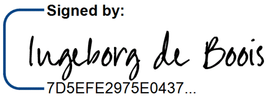
Justification

Report C070/24
Project Number: 4316100315

The scientific quality of this report has been peer reviewed by a colleague scientist and a member of the Management Team of Wageningen Marine Research

Approved: I.J. de Boois
Colleague scientist

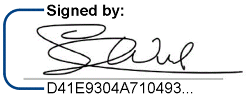
Signature:



Date: 21 November 2024

Approved: C.J. Wiebinga, PhD
Business Manager Projects

Signature:



Date: 21 November 2024

Annex 1 Dutch IBTS Q1 including all acoustic recordings.

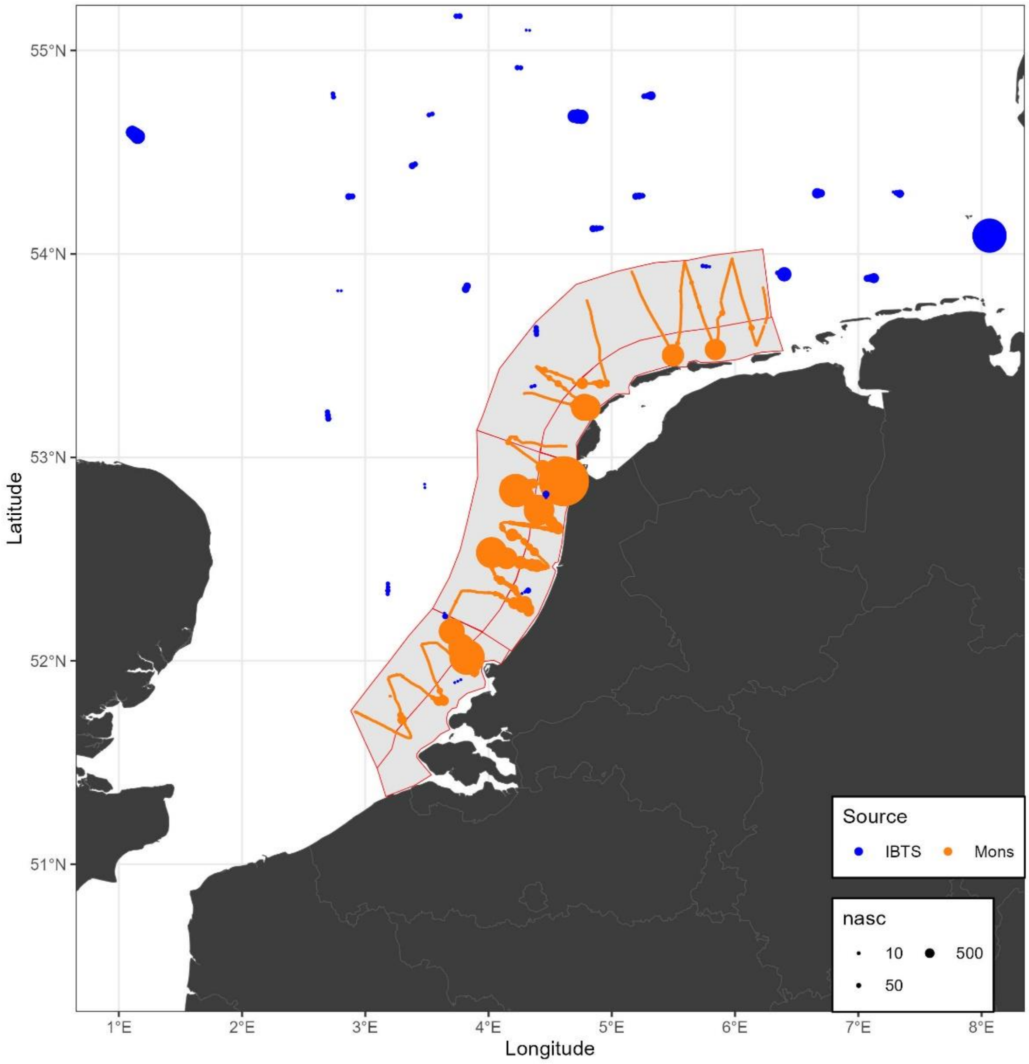


Figure showing the NASC of the winter MONS survey and the all the NASC recordings done during the NS-IBTS Q1 2024.

Annex 2 Hydro-acoustic survey catches

Table A2-1a Catch table June 2023 survey – catch weights in kg, haul 1-17

group	Latin name	English name	Dutch name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
pelagic	*Sprattus sprattus*	Sprat	Sprat	2.8			36.6	397.5		266.1	343.0	4.2	0.0		132.2		109.6		0.0	
pelagic	*Clupea harengus*	Herring	Haring					3.6		0.7	0.1	0.2					1.2			
pelagic	*Sardina pilchardus*	Pilchard	Pelser	0.4	13.9	7.2	0.4		17.2	0.2	0.2	0.0	0.1	0.0		0.0	12.4	11.9	0.6	0.8
pelagic	*Engraulis encrasicolus*	Anchovy	Anjovis	14.2			0.0			0.2	0.0	0.1			1.4	0.0	1.3			
pelagic	*Scomber scombrus*	Mackerel	Makreel	0.3	2.5	0.8	3.8	2.3	17.3	5.3	5.2	22.1	21.9	3.7	9.5	10.5	2.1		32.3	3.5
pelagic	*Ammodytes tobianus*	Small sandeel	Kleine zandspiering		0.1	0.0			0.0		0.4		4.9		0.0	0.4		0.3	3.2	0.2
pelagic	*Ammodytes marinus*	Raitt's sandeel	Noorse zandspiering		0.4	0.4	0.1		0.6		0.5		9.5	2.1		0.6		0.7	0.3	5.0
pelagic	*Hyperoplus lanceolatus*	Greater sandeel	Smelt		0.2	0.0	0.7		0.1		0.0	0.1	25.1		0.3	1.0	0.1	0.0	0.9	0.1
pelagic	*Osmerus eperlanus*	Smelt	Spiering									0.0								
pelagic	*Alosa fallax*	Twaite shad	Fint					0.1												
pelagic	*Aphia minuta*	Transparant gobies	Glasgrondel																	
other	*Aurelia aurita*	Moon jelly	Oorkwal	0.1		2.4	1.0	0.3	0.3	0.4	1.1	1.6	0.7	486.4	221.9	375.0	293.1	134.8	0.0	0.2
other	*Cyanea lamarckii*	Blue jellyfish	Blauwe haarkwal	3.8		2.4	1.0		0.3	0.4		1.6	0.7			0.1	293.1	0.3	0.0	0.2
other	*Liocarcinus holsatus*	Flying crab	Gewone zwemkrab	0.1		0.0	0.1	0.3	0.3	0.4	0.1		0.7	1.2	221.9			134.8	0.8	
other	*Chrysaora hysoscella*	Compass jellyfish	Kompaskwal															0.3	0.0	
other	*Aequorea vitrina*	Crystal jellyfish	Lampenkapje																	0.2
other	*Alloteuthis subulata*	Common squid	Dwergpijlinktvis	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.2	0.3	0.1	0.1	3.8	0.4	0.1	0.0	1.1	0.4
other	*Loligo sp.*	Longfinned squid	Pijlinktvis			0.1				0.5	1.6		0.3						0.7	0.9
other	*Illex coindetii*	Shortfin squid	Slanke pijlinktvis																	
other	*Todaropsis eblanae*	Lesser flying squid	Ierse pijlinktvis																	
dem	*Trachurus trachurus*	Horse mackerel	Horsmakreel	1.2	119.2	109.1	137.2	0.5	300.8	1.0	4.1		2.3	165.1		122.9	0.5	9.8	124.9	20.8
dem	*Merlangius merlangus*	Whiting	Wijting		0.0	0.0	17.7	296.7		253.8	277.4	402.1	0.9	3.5	57.9	0.5	123.1		100.8	132.1
dem	*Trisopterus luscus*	Bib	Steenbolk					18.3		4.1		1.5			0.6					
dem	*Melanogrammus aeglefinus*	Haddock	Schelvis																	
dem	*Gadus morhua*	Cod	Kabeljauw							0.2										
dem	*Mullus surmuletus*	Striped red mullet	Mul			0.0	0.1	0.1	0.4	0.6	0.1	1.2	0.0	0.5	0.4	0.7	0.1	0.1	0.1	0.4
dem	*Eutrigla gurnardus*	Grey gurnard	Grauwe poon							0.1		0.0			0.0			0.2	0.1	
dem	*Chelidonichthys cuculus*	Red gurnard	Engelse poon																	
dem	*Chelidonichthys lucerna*	Tub gurnard	Rode poon																	
dem	*Syngnathus rostellatus*	Nilsson's pipefish	Kleine zeenaald					0.0		0.0		0.0								
dem	*Entelurus aequoreus*	Snake pipefish	Adderzeenaald															0.0		
dem	*Scyliorhinus canicula*	Lesser spotted dogfish	Hondshaai																	
dem	*Trachinus draco*	Greater weever	Grote pieterman																	
dem	*Echiichthys vipera*	Little weever	Kleine pieterman		0.1				0.3				0.4	1.8		0.4		1.2		0.3
dem	*Dicentrarchus labrax*	Bass	Zeebaars											0.9						
dem	*Pholis gunnellus*	Rock Gunnel	Botervis												0.0					
dem	*Pomatoschistus sp.*	Sandgoby	Dikkopje																	
dem	*Anguilla anguilla*	Eel	Aal										0.1							
dem	*Callionymus lyra*	Dragonet	Pitvis							0.2				0.0		0.0			0.0	
dem	*Agonus cataphractus*	Hooknose	Harnasmannetje							0.0										
dem	*Limanda limanda*	Dab	Schar	0.1	0.1	0.1	0.1	0.3	0.9	31.8	1.1	0.5	4.2	22.3	4.0	1.8	0.9	3.0	1.5	0.8
dem	*Pleuronectes platessa*	Plaice	Schol					0.2	0.1	0.6			0.1	0.1	0.1	0.2		1.3		
dem	*Arnoglossus laterna*	Scaldfish	Schurftvis																	
dem	*Platichthys flesus*	Flounder	Bot					0.3			0.3	0.6	0.7	0.4	0.8		0.2		0.2	
dem	*Scophthalmus maximus*	Turbot	Tarbot																	
dem	*Solea solea*	Sole	Tong																	
dem	*Buglossidium luteum*	Solenette	Dwergtong																	

Table A2-1b Catch table June 2023 survey – catch weights in kg, haul 18-36

group	Latin name	English name	Dutch name	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
pelagic	*Sprattus sprattus*	Sprat	Sprat	0.0	29.6		1.5	1133.5	136.6	38.6		0.1	2.0	18.2	30.2	0.3	3.3		0.0	0.0		0.2
pelagic	*Clupea harengus*	Herring	Haring		0.1		0.3	4.2		7.4		0.1				0.1		0.0	0.0		0.1	
pelagic	*Sardina pilchardus*	Pilchard	Pelser	3.2	0.1										0.4					1.6		
pelagic	*Engraulis encrasicolus*	Anchovy	Anjovis		0.1			0.1		0.1			0.0		0.0						0.6	
pelagic	*Scomber scombrus*	Mackerel	Makreel	7.2	12.9			55.8		47.2	0.8		21.5		24.4	101.8	10.9	107.4	5.6	0.3	25.0	0.6
pelagic	*Ammodytes tobianus*	Small sandeel	Kleine zandspiering				0.1	1.2	0.2		1.2		13.5						0.0	1.2	0.0	0.0
pelagic	*Ammodytes marinus*	Raitt's sandeel	Noorse zandspiering	1.8	0.3		0.1		2.0		1.2		0.9						1.5	10.0		1.3
pelagic	*Hyperoplus lanceolatus*	Greater sandeel	Smelt	0.1	1.1		0.0	0.5	0.1	0.1	1.0		1.1			0.2	0.2	0.0	0.2	0.1	0.3	0.0
pelagic	*Osmerus eperlanus*	Smelt	Spiering																			
pelagic	*Alosa fallax*	Twaite shad	Fint																			
pelagic	*Aphia minuta*	Transparant gobies	Glasgrondel									0.0										
other	*Aurelia aurita*	Moon jelly	Oorkwal	0.1	0.8	0.4	55.4	22.0	1.1	14.7	6.8	0.1	1.8		241.2	1466.4	1.7	23.0	0.4	0.7	0.9	0.3
other	*Cyanea lamarckii*	Blue jellyfish	Blauwe haarkwal	0.1	0.8		55.4	22.0	1.1	43.3	6.8	0.1	1.8	0.3	241.2	0.6	1.7	23.0	0.4		0.9	0.3
other	*Liocarcinus holsatus*	Flying crab	Gewone zwemkrab		0.8	0.4			1.1		6.8	0.1	1.8		11.2	0.6	1.7	23.0	0.4	0.7	0.9	0.3
other	*Chrysaora hysoscella*	Compass jellyfish	Kompaskwal	0.1	0.8																	
other	*Aequorea vitrina*	Crystal jellyfish	Lampenkapje						1.1													
other	*Alloteuthis subulata*	Common squid	Dwergpijlinktvis	0.7	0.7	0.5	0.0	2.9	4.4	1.7	6.3	0.0	0.4	2.5	1.0	0.7	15.0	0.8	20.8	0.6	0.7	0.8
other	*Loligo sp.*	Longfinned squid	Pijlinktvis	0.5									0.1					0.1			0.4	
other	*Illex coindetii*	Shortfin squid	Slanke pijlinktvis						0.0													
other	*Todaropsis eblanae*	Lesser flying squid	Ierse pijlinktvis								0.0											
dem	*Trachurus trachurus*	Horse mackerel	Horsmakreel	4.7	1.3			4.4		1.2	0.1	0.1	29.0		105.6	1.8		0.0	3.1	1.0	76.7	0.3
dem	*Merlangius merlangus*	Whiting	Wijting	0.2	10.0			20.8	0.2	31.9	0.1	18.5	58.2	6.2	0.6	22.8	2.8	14.8	0.1	0.0	0.8	
dem	*Trisopterus luscus*	Bib	Steenbolk		0.0								0.8					0.0				
dem	*Melanogrammus aeglefinus*	Haddock	Schelvis									5.1		0.8			0.1					
dem	*Gadus morhua*	Cod	Kabeljauw																			
dem	*Mullus surmuletus*	Striped red mullet	Mul	0.4		0.1			0.3			0.3	0.0	0.4	0.1	0.1	0.1		0.1	0.2	0.1	
dem	*Eutrigla gurnardus*	Grey gurnard	Grauwe poon	0.6	0.2	0.2			1.3		0.6	3.7		1.4	2.6	0.4	6.0	1.0	2.1	0.5	0.2	1.5
dem	*Chelidonichthys cuculus*	Red gurnard	Engelse poon						0.5													
dem	*Chelidonichthys lucerna*	Tub gurnard	Rode poon								0.3		0.5	0.1	0.5			0.6				0.3
dem	*Syngnathus rostellatus*	Nilsson's pipefish	Kleine zeenaald					0.1		0.0								0.0	0.0	0.0	0.0	0.0
dem	*Entelurus aequoreus*	Snake pipefish	Adderzeenaald						0.0													
dem	*Scyliorhinus canicula*	Lesser spotted dogfish	Hondshaai											0.3			0.4					
dem	*Trachinus draco*	Greater weever	Grote pieterman																			
dem	*Echiichthys vipera*	Little weever	Kleine pieterman	0.0		0.5			0.5	0.0	0.2											
dem	*Dicentrarchus labrax*	Bass	Zeebaars														1.2					
dem	*Pholis gunnellus*	Rock Gunnel	Botervis																			
dem	*Pomatoschistus sp.*	Sandgoby	Dikkopje			0.4																
dem	*Anguilla anguilla*	Eel	Aal																			
dem	*Callionymus lyra*	Dragonet	Pitvis	0.1		0.0							0.1	1.4	0.2	0.1	0.1	0.2	0.1		0.0	
dem	*Agonus cataphractus*	Hooknose	Harnasmannetje																			
dem	*Limanda limanda*	Dab	Schar	10.9	0.8	2.7		0.2	13.7	0.4	2.6	10.2	1.4	20.9	23.6	1.2	13.6	2.2	20.2	1.4	0.7	18.0
dem	*Pleuronectes platessa*	Plaice	Schol	0.1					0.7		0.2	0.7	0.1	2.0	1.7	0.1	6.2	0.2				1.3
dem	*Arnoglossus laterna*	Scaldfish	Schurftvis									0.0		0.1	0.0				0.5			
dem	*Platichthys flesus*	Flounder	Bot										1.2					0.3			0.5	0.2
dem	*Scophthalmus maximus*	Turbot	Tarbot																1.4			
dem	*Solea solea*	Sole	Tong											0.5								
dem	*Buglossidium luteum*	Solenette	Dwergtong	0.0		0.0								0.1	0.0							

Table A2-1c Catch table June 2023 survey – catch weights in kg, haul 37-42; Haul numbers in *Italics* were executed with the GOV.

These hauls were part of the test at the end of the survey

group	Latin name	English name	Dutch name	***37***	**38**	***39***	**40**	***41***	**42**
pelagic	*Sprattus sprattus*	Sprat	Sprat	0.0	10.2	1.2	2.2	0.1	0.0
pelagic	*Clupea harengus*	Herring	Haring		0.1				
pelagic	*Sardina pilchardus*	Pilchard	Pelser		4.2	1.3	5.2	2.4	17.9
pelagic	*Engraulis encrasicolus*	Anchovy	Anjovis						
pelagic	*Scomber scombrus*	Mackerel	Makreel	2.6	0.8	10.9	2.5		3.6
pelagic	*Ammodytes tobianus*	Small sandeel	Kleine zandspiering			0.0			
pelagic	*Ammodytes marinus*	Raitt's sandeel	Noorse zandspiering	0.0					
pelagic	*Hyperoplus lanceolatus*	Greater sandeel	Smelt	0.1		0.2	0.0	0.4	0.2
pelagic	*Osmerus eperlanus*	Smelt	Spiering						
pelagic	*Alosa fallax*	Twaite shad	Fint						
pelagic	*Aphia minuta*	Transparant gobies	Glasgrondel						
other	*Aurelia aurita*	Moon jelly	Oorkwal	0.9	27.6	0.4	94.4	0.5	40.5
other	*Cyanea lamarckii*	Blue jellyfish	Blauwe haarkwal	0.9	27.6		94.4	0.5	40.5
other	*Liocarcinus holsatus*	Flying crab	Gewone zwemkrab	0.9		0.4		0.5	
other	*Chrysaora hysoscella*	Compass jellyfish	Kompaskwal						
other	*Aequorea vitrina*	Crystal jellyfish	Lampenkapje						
other	*Alloteuthis subulata*	Common squid	Dwergpijlinktvis	1.5	0.0	0.2	0.0	0.0	0.0
other	*Loligo sp.*	Longfinned squid	Pijlinktvis	0.5				1.3	
other	*Illex coindetii*	Shortfin squid	Slanke pijlinktvis						
other	*Todaropsis eblanae*	Lesser flying squid	Ierse pijlinktvis						
dem	*Trachurus trachurus*	Horse mackerel	Horsmakreel	52.8	2.2	23.1	17.4	375.7	65.8
dem	*Merlangius merlangus*	Whiting	Wijting	37.6	0.4	131.3	0.1	0.5	
dem	*Trisopterus luscus*	Bib	Steenbolk						
dem	*Melanogrammus aeglefinus*	Haddock	Schelvis						
dem	*Gadus morhua*	Cod	Kabeljauw						
dem	*Mullus surmuletus*	Striped red mullet	Mul	0.1		0.2		0.0	
dem	*Eutrigla gurnardus*	Grey gurnard	Grauwe poon			0.1		0.4	
dem	*Chelidonichthys cuculus*	Red gurnard	Engelse poon						
dem	*Chelidonichthys lucerna*	Tub gurnard	Rode poon			0.1			0.5
dem	*Syngnathus rostellatus*	Nilsson's pipefish	Kleine zeenaald	0.0					
dem	*Entelurus aequoreus*	Snake pipefish	Adderzeenaald						
dem	*Scyliorhinus canicula*	Lesser spotted dogfish	Hondshaai						
dem	*Trachinus draco*	Greater weever	Grote pieterman	0.3		0.6			
dem	*Echiichthys vipera*	Little weever	Kleine pieterman	3.8		3.3	0.0	0.5	0.0
dem	*Dicentrarchus labrax*	Bass	Zeebaars					0.8	
dem	*Pholis gunnellus*	Rock Gunnel	Botervis						
dem	*Pomatoschistus sp.*	Sandgoby	Dikkopje						
dem	*Anguilla anguilla*	Eel	Aal						
dem	*Callionymus lyra*	Dragonet	Pitvis						
dem	*Agonus cataphractus*	Hooknose	Harnasmannetje						
dem	*Limanda limanda*	Dab	Schar	3.7		3.4	0.0	1.3	
dem	*Pleuronectes platessa*	Plaice	Schol	0.2		1.8		0.2	
dem	*Arnoglossus laterna*	Scaldfish	Schurftvis						
dem	*Platichthys flesus*	Flounder	Bot						
dem	*Scophthalmus maximus*	Turbot	Tarbot					0.8	
dem	*Solea solea*	Sole	Tong						
dem	*Buglossidium luteum*	Solenette	Dwergtong						

Table A2-2 Catch table January 2024 survey – catch weights in kg

group	Latin name	English name	Dutch name	1	2	3	4	5	6	7	8	9	10	11	13
pelagics	Sprattus sprattus	Sprat	Sprot	0.4	59.3	2.3	560.3	10.0	187.8	0.4	72.3	492.5	873.7	0.1	
pelagics	Clupea harengus	Herring	Haring		1.4	0.3	0.2	0.1	5.0	0.1	2.6	4.1	217.8	0.3	42.1
pelagics	Engraulis encrasicolus	Anchovy	Anjovis					0.0		0.0	0.0				
pelagics	Ammodytes marinus	Raitt's sandeel	Noorse zandspiering	0.0		0.0	0.0						0.0		
pelagics	Scomber scombrus	Mackerel	Makreel					2.3		0.2					0.0
pelagics	Atherina presbyter	Sand smelt	Koornaarvis										0.1		
pelagics	Crystallogobius linearis	Crystal gobies	Kristalgrondel												0.0
pelagics	Salmo trutta trutta	Salmon	Zalm						2.2		1.7				0.7
other pelagics	Liocarcinus holsatus	Flying crab	Gewone zwemkrab	0.3	0.1	0.0	0.0	0.1			0.0	0.1	0.0	0.1	
other pelagics	Alloteuthis subulata	Common squid	Dwergpijlinktvis								0.0		0.0		
other pelagics	Loligo sp.	Longfinned squid	Pijlinktvis								0.7		0.1		
other pelagics	Sepia officinalis	Common cuttlefish	Gewone zeekat		0.7										
other pelagics	Necora puber	Velvet swimming crab	Fluwelen zwemkrab	0.2	0.1										
demersal	Merlangius merlangus	Whiting	Wijting	7.1	13.1	164.0	1.1				0.1	0.1	2.3		
demersal	Trisopterus luscus	Bib	Steenbolk			0.3									
demersal	Gadus morhua	Cod	Kabeljauw			0.2									
demersal	Chelidonichthys lucerna	Tub Gurnard	Rode gurnard			0.0									
demersal	Syngnathus acus	Greater pipefish	Grote zeenaald										0.0		
demersal	Dicentrarchus labrax	Bass	Zeebaars			0.2									
demersal	Pomatoschistus	Gobies	Grondel			0.0							0.0		
demersal	Agonus cataphractus	Hooknose	Harnasmannetje	0.0		0.0									
demersal	Limanda limanda	Dab	Schar	0.5		50.1	0.0					8.3	6.0	0.3	
demersal	Pleuronectes platessa	Plaice	Schol	0.2		0.2									
demersal	Platichthys flesus	Flounder	Bot			1.9							0.5	0.6	
demersal	Solea solea	Sole	Sole			0.5									
demersal	Myoxocephalus scorpius	Shorthorn sculpin	Zeedonderpad			0.1									
demersal	Hippocampus hippocampus	Short snouted seahorse	Kortsnuit zeepaardje									0.0			
demersal	Gasterosteus aculeatus	Threespined stickleback	Driedoornige stekelbaars								0.0		0.0		0.0

Annex 3 Internship report acoustic surveys

MONS: Acoustic surveys give insight on pelagic fish in Dutch coastal waters

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Results

The catch data of the June 2023 survey consisted of 4 species of pelagic fish, namely sprat (*Sprattus sprattus*), pilchard (*Sardina pilchardus*), herring (*Clupea harengus*) and anchovies (*Engraulis encrasicolus*). 97.4% of total caught biomass consisted of sprat, 1.8% consisted of pilchard, 0.5% consisted of herring and 0.3% consisted of anchovies. Using MDS, the 33 hauls were separated in four main clusters which showed significant statistical differences using ANOSIM (p = 0.001) (figure 3A). The hauls were plotted and coloured according to their assigned cluster (figure 3B). Geographical patterns of the clusters are identified in this figure and touched upon in the discussion.

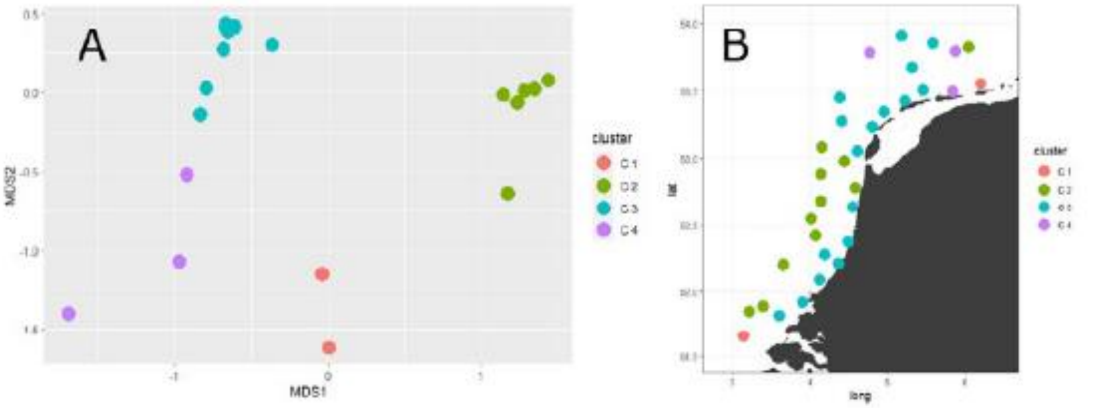

Figure 3 A) Multi-dimensional scaling plot of the catch data from the first survey. Hauls were separated in 4 main clusters using Bray-Curtis dissimilarity index and coloured accordingly (ANOSIM; p = 0.001). B) Geographical representation of the cluster-coloured haul based on the Bray-Curtis dissimilarity index.

Finally, the clusters were allocated to certain species using 4 proportion-of-catch plots. For each of the 4 species, a cluster-coloured plot was made which shows that species' percentual biomass contribution to each of the hauls. It was visually deduced that cluster 1 was characterized by anchovies, cluster 2 was characterized pilchard, cluster 3 was characterized by sprat, and cluster 4 was characterized by herring (figure 4A). The s_a-values from the first survey are plotted in figure 4B. While these values are not incorporated in the analysis, they will be addressed in this discussion

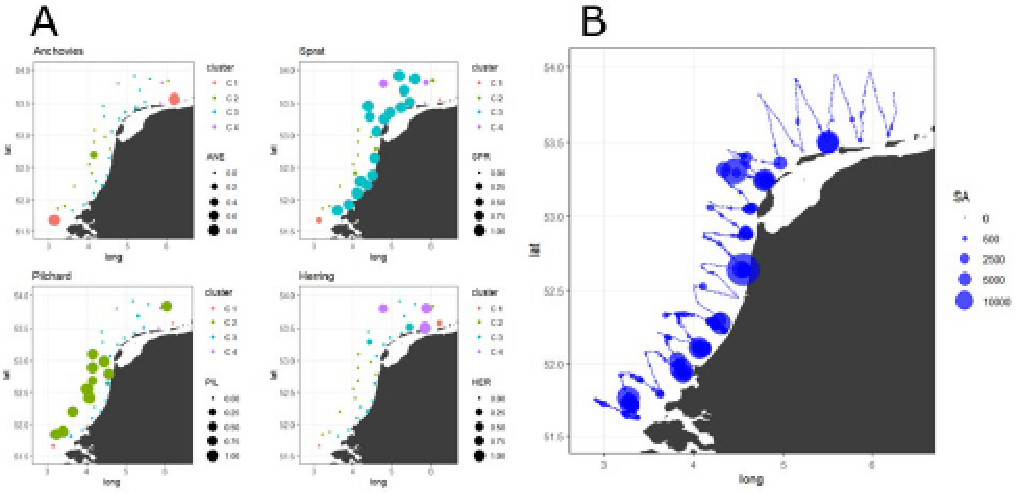

Figure 4 A) Percentual contribution to biomass in each haul of the first survey plotted for each of the 4 pelagic species encountered, and cluster-coloured based on the Bray-Curtis dissimilarity index. B) s_A-values recorded by the echosounder during the first survey. Points were sized according to the level of s_A measured.

In the second survey, where hauls were only done when a school was visible on the echogram, there were a total of 12 hauls. 89.9% of total caught biomass consisted of sprat, and the remaining 10.1% consisted of herring. Sprat was found in high densities in multiple parts of the survey area, and 79.5% of all herring was caught in a single haul. Due to the high localization of herring, a biomass estimate was only made for sprat.

The sprat biomass per ha was separately calculated for the southern-central area and the northern area due to high differences in s_A. The southern-central area sprat density was estimated at 105 kg/ha and the northern area sprat density was estimated at 25 kg/ha (figure 5).

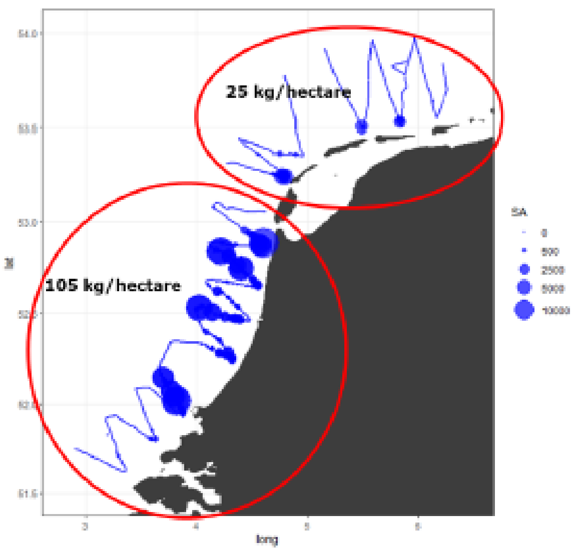

Figure 5 s_A-values recorded by the echosounder during the second survey. Points were sized according to the level of s_A measured. The sprat biomass per ha was calculated separately for the areas indicated by the red ovals.

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