Industry survey turbot and brill in the North Sea

Set up and results of a fisheries-independent survey using commercial fishing vessels 2018-2020

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Samenvatting

De platvissen tarbot (*Scophthalmus maximus*) en griet (*Scophthalmus rhombus*) in de Noordzee zijn belangrijke commerciële bijvangsten voor de Nederlandse visserij. De Internationale Raad voor Onderzoek der Zee *(*ICES) geeft op basis van zogenaamde bestandsschattingen advies aan de Europese Commissie over de maximale hoeveelheid te vangen vis. Dit advies vormt de basis voor het vaststellen van de vangstquota door de Europese visserijministers.

Griet is momenteel een data-arme soort ('data limited stock'). Daarom gebruikt ICES voor de bestandsschatting een methode die is gebaseerd op trends in de commerciële aanlandingen per eenheid visserijinspanning (LPUE, 'landings per unit of effort'). Vanwege deze methode valt griet voor ICES in categorie 3 en is deze bestandsschatting met veel onzekerheden omgeven. Voor tarbot zijn er meer gegevens beschikbaar, waardoor de advisering gebaseerd kan worden op een volledige analytische beoordeling. Desondanks bestaat er nog aanzienlijke onzekerheid in de beschikbare gegevens over het bestand, wat de algehele kwaliteit van de beoordeling ondermijnt.

Volgens de ICES moet een nieuwe gestandaardiseerde bestandsopname met een hogere vangstefficiëntie van grote platvis worden ontwikkeld om de beoordeling van deze soorten te verbeteren. Om deze reden werd een speciale bedrijfssurvey voor tarbot en griet ontworpen en uitgevoerd. Het project besloeg een periode van drie jaar en werd gefinancierd uit de regeling Samenwerkingsprojecten Wetenschap en Visserij in het kader van het Nederlandse operationele programma voor het Europees Fonds voor Maritieme Zaken en Visserij.

Het ontwerp van de survey is het resultaat van drie jaarlijkse cycli van uitvoering, evaluatie met vissers en met onderzoekers binnen ICES en wijziging van het oorspronkelijke ontwerp. Het oorspronkelijke ontwerp is gemaakt bij de start van het project in 2018. In het definitieve ontwerp (2019-2020) is het onderzoeksgebied gebaseerd op de vangst van tarbot en griet en de ruimtelijke spreiding van de boomkorvloot (VMS-data). Het gebied werd bijgesneden tot een haalbare grootte voor drie kotters, waarbij rekening werd gehouden met hun normale visgronden. Huidige en toekomstige voor visserij gesloten gebieden (bijv. N2000-gebieden, windparken) werden uit het surveygebied verwijderd en er werd een raster van 5x5 km toegepast op het surveygebied.

In het definitieve surveyontwerp wordt het onderzoek jaarlijks uitgevoerd in september-oktober. De meetstations worden jaarlijks opnieuw vastgesteld door een willekeurige trekking van 60 rastercellen, die vervolgens gelijk worden verdeeld over drie schepen. De meetstations worden tijdens gewone visweken bevist door de deelnemende schepen. De schippers krijgen de opdracht hun vistuig in de geselecteerde rastercellen uit te zetten om een surveytrek te starten. Daarna zijn schippers vrij om de route van de surveytrek te bepalen. Voor elke surveytrek worden alle tarbot en griet uit de vangst gesorteerd. De aantallen per soort en lengte en gewicht van individuele vissen worden bepaald door onderzoekers aan boord. Geslacht en leeftijd (op basis van otolieten) worden bepaald voor een subgroep.

In 2020 konden onderzoekers niet mee aan boord van de kotters vanwege COVID-19-beperkingen. Daarom werden alle op de meetstations gevangen tarbot en griet door de bemanningen van de schepen verzameld, gelabeld en aan het einde van de visweek overgedragen aan de onderzoekers voor verwerking van de survey-vis aan land.

De data die in 2019 en 2020 met de bedrijfssurvey zijn verzameld, zijn beschikbaar gesteld via de ICES-databank voor surveygegevens, DATRAS.

Geconcludeerd wordt dat het huidige surveyontwerp uitvoerbaar is en kan worden gebruikt voor de voortzetting van de bedrijfssurvey. De bedrijfssurvey levert naast bestaande surveys een aanzienlijke hoeveelheid extra gegevens op. De toegevoegde waarde van deze extra gegevens voor de

toestandsbeoordelingen van de tarbot en griet bestanden moet echter nog worden bepaald in een ICES-benchmark. Om een ICES-benchmark aan te kunnen vragen en om de minimaal vereiste tijdreeks van 5 jaar te verkrijgen voor gebruik van de data, moet de survey nog minstens drie jaar worden voortgezet (tot 2023). De schippers en bemanning van de deelnemende schepen en de sectorvertegenwoordigers zijn gemotiveerd om de survey de komende jaren voort te zetten. De subsidieaanvraag voor de voortzetting van de bedrijfssurvey tot en met 2023 werd begin 2021 gehonoreerd.

Summary

The flatfish species turbot *(Scophthalmus maximus)* and brill *(Scophthalmus rhombus)* in the North Sea are important commercial bycatches for the Dutch commercial fleet. Based on so-called stock assessments, the International Council for the Exploration of the Sea (ICES) advises the European Commission on fishing opportunities. Brill is currently a data-limited species, which is why ICES for its stock assessment uses a method based on trends in the commercial landings per unit of effort. Because of this method, brill falls into ICES category 3 and its assessment is associated with uncertainties. For turbot more data are available and the advice for turbot is currently based on a full analytical assessment. Nevertheless, there is still considerable uncertainty in the input data which undermines the overall quality of the assessment. According to ICES a new standardized survey with higher catch rates for large flatfish should be developed to improve assessments for these species. For this reason a dedicated industry survey for turbot and brill was designed and implemented. The project covered a period of three years and was funded by a science-fisheries partnership grant under the Dutch Operational Programme for the European Maritime and Fisheries Fund.

The survey design is the result of three annual cycles of implementation, evaluation with fishermen and international scientists in the context of ICES and modification of the original survey design. The original design was made at the start of the project in 2018. In the final design (2019-2020), the survey area was based on turbot and brill catches (LPUE), spatial distribution of the beam trawl fleet (VMS data). The area was cropped to a feasible size for three vessels taking into account their normal fishing grounds. Current and future areas closed for fisheries (e.g. N2000 areas, wind farms) were removed and a 5x5 km grid was applied to the survey area.

In its final design, the survey is conducted annually in September-October. The survey stations for each year result from a random draw of 60 grid cells, which are then equally divided over three vessels. Survey stations are fished during regular fishing weeks by the participating vessels. The skippers are instructed to deploy their fishing gear and start a survey haul anywhere within the grid cells selected as survey stations. After that, skippers are free to determine the route of the survey haul. For each survey haul all turbot and brill are sorted from the catch. Numbers per species and length and weight of individual fish are determined by researchers on board. Sex and age (based on otoliths) are determined for a subset. In 2020 researchers were unable to board the fishing vessels due to COVID-19 restrictions. Therefore all turbot and brill caught at the survey stations were collected and labelled by the vessel's crews for processing onshore by researchers.

Survey data collected in 2019 and 2020 according to the final survey design have been made available via the ICES database DATRAS.

It is concluded that the current survey design is appropriate and feasible and can be readily used for continuation of the industry survey. The survey provides a significant amount of data in addition to existing surveys. However, the added value of these data for stock assessments remains to be determined in an ICES benchmark. To successfully request an ICES benchmark as well as obtain the minimal required timeseries of 5 years to use the survey data in stock assessments, the survey needs to be continued for at least another three years (until 2023). The skippers and crew are motivated to continue the survey in the next years. Also the fisheries associations are fully committed to this survey and its continuation. A follow-up grant proposal (2021-2023) has been successfully submitted.

1 Introduction

1.1 Background

Turbot *(Scophthalmus maximus)* and brill *(Scophthalmus rhombus)* in the North Sea are important commercial bycatches for the Dutch commercial fleet. While the International Council for the Exploration of the Sea (ICES) provides individual advice on fishing opportunities for both species, they are managed under a joint Total Allowable Catch (TAC) under the European Common Fisheries Policy (CFP). Since 2019, both species are managed under the European landing obligation, which means that discarding is no longer allowed unless an exemption has been granted. Currently, turbot is exempt from the landing obligation for beam-trawlers (80-199mm mesh and >120mm mesh) (VisNed, 2021). While discarding of these high-value species historically has been limited, there are indications that in the years prior to 2019, discarding increased as a result of quota restrictions and the response of Dutch Producers' organisations (POs). Within their remit under the market policy of the CFP, the POs took measures to prevent early exhaustion of the quota and increased the minimum landing size for turbot. While these PO measures where relaxed as of 2017, discarding in 2017 and 2018 remained high. Discards are not included in the assessment (ICES, 2019a).

The reliability of the catch data, which is the most important link in the status assessment, especially for turbot, and the commercial biomass index based on it have thus decreased. This in turn leads to further catch limits and more discards. This situation has direct consequences for the sustainable management of these stocks. Another factor in this context is that both turbot and brill form a 'choke species' in the context of both the CFP's landing obligation and the multi-annual management plan for North Sea demersal fisheries (MAPNS) (EU, 2018). In its advice for fishing opportunities for turbot and brill, ICES indicates that an index based on a fisheries-independent survey that covers the distribution area and the different length classes would improve the stock assessments (ICES, 2015; 2019a).

Brill is currently a data-limited species and ICES advice is given on the basis of a category 3 assessment, which is based on commercial landing per unit of effort trends. Turbot in the North Sea is currently a category 1 stock, with a full analytical assessment. The stock was upgraded following the 2018 ICES inter-benchmark (ICES, 2018a). The stock is assessed using an age-structured model (SAM), which relies on age-composition data from two fisheries-independent surveys (SNS and BTS-ISIS), commercial landings (discards currently not included), as well as a commercial LPUE index. Despite recent improvements in the assessment methodology, there is still considerable uncertainty in the input data which undermines the overall quality of the assessment. The ICES inter-benchmark therefore recommended: "Currently, scientific surveys show relatively poor performance (due to low catch rates) in assessments of large flatfish. A new standardized survey with higher catch rates for large flatfish should be developed to improve assessments for these species" (ICES, 2018a).

1.2 Initial pilot industry survey

In 2013-15, the Dutch fishing company Ekofish Group and the NGO *Stichting de Noordzee* (North Sea Foundation) commissioned a study into the possible contribution of a fisheries-independent industry survey towards improving the status assessments of four flatfish species associated with the target species common sole *(Solea solea)* and plaice *(Pleuronectus platessa)*: (1) turbot, (2) brill, (3) lemon sole *(Microstomus kitt)*, and (4) dab *(Limanda limanda)*. This study showed that an industry survey is technically feasible and for turbot and brill can make an important contribution to the improvement of the stock assessments. There are two reasons for this. First, in the pilot industry survey the catch success of turbot and brill was larger compared to the annual research survey, the Beam-Trawl Survey (BTS, see ICES, 2019b). Second, in the pilot industry survey also the age groups 1-9 were caught whereas the BTS catches are limited to 1-4 years. Inclusion of new (industry) survey data in the ICES stock assessments requires, however, a longer time series (Van der Reijden *et al*., 2015). This longer time series could not be developed as the pilot study did not continue. First, , it was not possible to raise the funding to set up an industry survey for turbot and brill. Second, at the time, the development of an industry survey was complicated by concerns amongst the main national fisheries associations. They worried that improvements in the stock assessment for the 'associated species' turbot and brill would eventually lead to their inclusion in the Individual Transferable Quota (ITQ) system for the target species common sole and plaice (Van Hoof *et al.,* 2020). The industry considers ITQs for associated species undesirable.

1.3 Industry survey turbot and brill

The persistent catch restrictions and increasing discards, the landing obligation and the Multi Annual Plan North Sea (MAPNS), caused a shift in the Dutch industry's support for conducting a turbot and brill industry survey and finding long-term funding to build up a time series. It is also clear that an improved stock assessment does not have to translate into an ITQ system; after all, this would be a national policy decision for which there must be support. A dedicated industry survey for turbot and brill designed to complement the shortcomings of the current research surveys funded under the European Data Collection Framework (DCF) would improve the knowledge base in support of sustainable mixed fisheries management in the North Sea. This is also highlighted in the ICES advice for both stocks (ICES, 2015; 2019a). As there were no funding resources under the Dutch DCF, a science-industry research collaboration project proposal (*Onderzoekssamenwerking 2.0*) was successfully submitted under the European Fund for Maritime Affairs and Fisheries (EMFF). The project consortium comprises Wageningen Marine Research (WMR), the main fisheries organisations (Nederlandse Vissersbond, VisNed, Redersvereniging voor de Zeevisserij), and the environmental NGO Stichting de Noordzee and educational NGO ProSea.

The fisheries-independent industry survey turbot and brill (BSAS) started in 2018. EMFF funding covered the period until 2020. For the continuation of the time series a follow up project (2021-2023) has been successfully submitted. Three beam-trawl vessels cover the survey area and, together with scientists from Wageningen Marine Research, sample a total of ca. 60 survey stations. The survey was set up and improved along the way in consultation with the ICES Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK). This report provides information on the set up of the survey, its results and conclusions and recommendations.

1.4 Guide for readers

In chapter 2, we present the BSAS survey methodology. This includes the initial set up and changes that were made following evaluation with the participating skippers and the WGNSSK. It also includes otolith sampling and data management, including availability for the ICES DATRAS database. Chapter 3 presents the results of the first 3 years of the BSAS, followed by conclusions and recommendations in chapter 4. The report is written in English to make it accessible to an international audience and in particular the ICES WGNSSK and future benchmarks groups.

2 Survey design and implementation

2.1 Introduction

The design for the industry survey turbot and brill *(bedrijfssurvey tarbot en griet,* BSAS) is the result of three annual cycles of implementation, evaluation and modification of the original survey design made at the start of the project. This process is chronologically described below with the objective to document all considerations and decisions made that led to the final survey design.

2.2 Survey 2018

2.2.1 Original survey design

2.2.1.1 Sources of variation

At the start of the project in 2018 a first survey design was made. The design was bound to the availability of three commercial fishing vessels and one fishing week per vessel per year for a period of three years. The survey design aimed to reduce or eliminate all factors that may contribute to variation in yearly catches, except changes in stocks. An analysis of potential sources of variation in turbot and brill catches in consecutive years and options for their elimination or reduction resulted in the following conditions to be met by the survey design (Table 1).

Table 1 *Sources of variation in turbot and brill catches and conditions to be met by the survey design to eliminate or reduce variation.*

Sources of variation to be eliminated or reduced	**Conditions**
Inhomogeneous distribution of fish	Once chosen, locations of hauls are fixed: hauls are always at the same locations.
Seasonal variation in fish density due to (spawning) migration.	Survey period is fixed, same period every year
Fishing effort / Haul duration	Fishing effort (haul duration, fishing speed) will be standardized as much as possible and documented at haul level.
Catch efficiency of gear	Per vessel always use the same standardized gear.
Fishing conditions	Survey period is fixed, same period every year. Conditions with known (negative) effects on catches (e.g. strong NW winds) will be avoided at the costs of not doing the surveys in exactly the same weeks every year.
Vessels	The same vessels with their standardized gears are used each year.
Gear type	Fixed combinations of gear type and survey locations.
Survey area	The survey area is fixed

2.2.1.2 Survey area

First we selected ICES rectangles based on LPUE data. Figure 1 (taken from Van der Hammen *et al*., 2013) shows the LPUE of turbot heavier than 4 kg and brill heavier than 1 kg by beam trawling outside and during the respective spawning seasons. Because the survey was scheduled to be conducted in September, only the LPUE data outside the spawning season (panels a) and c) in Figure 1) were considered. We distinguished four different types of locations: hot spots, warm spots, cold spots and no go-areas (Table 2). Given Figure 1, two hotspots roughly appear: 1) German bight –

Danish west coast (mainly turbot) and 2) most Southern North Sea (mainly brill). Other maps with beam trawl LPUE for 2007 to 2016 (not shown) showed annual variation in LPUE for both turbot and brill indicating that local abundancy may vary between years. Brill seems less patchy than turbot.

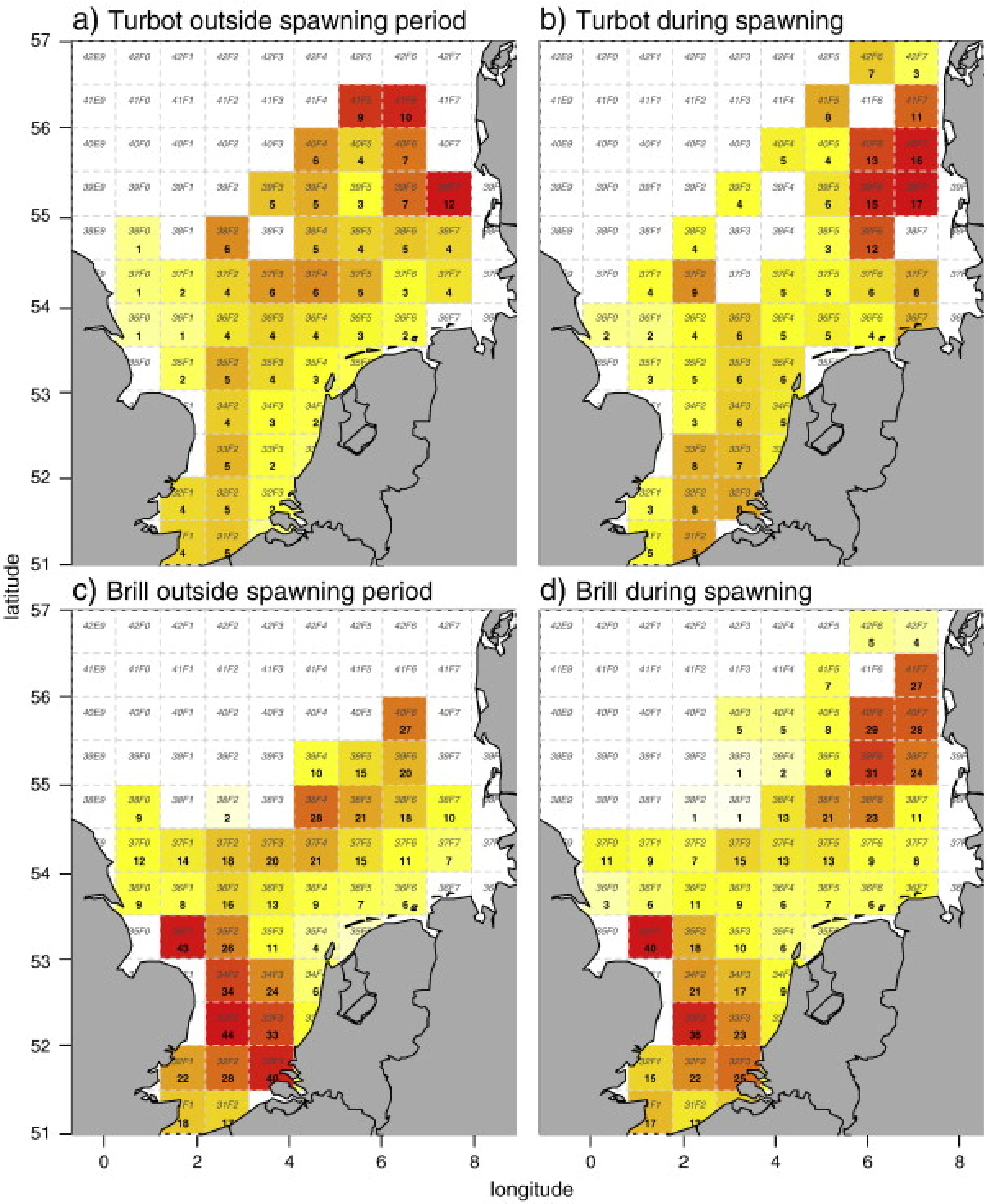

Figure 1. *LPUE (kg/day at sea) per ICES rectangle for the Dutch beam trawl fleet > 221 kW, of the largest market category (1) consisting of > 4 kg turbot or > 1 kg brill, averaged over 2004–2010. a,c: outside spawning period (turbot: Jan–Apr and Aug–Dec, brill: Jan–Feb and Aug–Dec). b,d: during spawning period (turbot: May–Jul, brill: Mar–Jul). Only those rectangles are selected where turbot (a,b) or brill (c,d) was caught in all years 2004–2010. The colours indicate the levels of the LPUE. (taken from Van der Hammen et al., 2013).*

It was decided that the survey area will include 'hot spots' and 'warm spots' but not 'cold spots' and (obviously) 'no-go areas'. The rationale behind this survey location selection is that surveying 'cold spots' was considered non informative. At the hotspots, large catches can be expected as required to obtain sufficient numbers of fish in the survey. However, changes in abundance are probably not easily or early detected at hot spots as the abundancies at hot spots may be the last to decline in case of population decline while population increase may not be detected at hot spots where the maximum density possibly already has been reached. We expected that population increase and decrease are easiest and earliest detected at locations that provide suboptimal habitats; the 'warm spots'.

Table 2. *Types of locations with the survey area.*

Type of location	Characteristics	Included in the survey?
Hot spots	Locations with an (expected) relatively high abundance of turbot and brill.	Yes
Warm spots	Locations around or between hot spots where turbot and brill are expected to be present but in lower numbers.	Yes
Cold spots	Locations where turbot and brill are expected to be absent, either based on anecdotic information, previous surveys on habitat characteristics.	No
No-go areas	Areas that cannot be fished or were fishing is not permitted now or in the near future (wind farms, wrecks, etc.)	No

Hot spots and warm spots were identified at the level of ICES rectangles based on LPUE and/or CPUE data. Fishermen were consulted to identify areas that cannot be fished. This resulted in three survey areas (Figure 2). Each area consisted of 6-7 ICES rectangles, including some half rectangles and resulting in 5.5 ICES rectangles per sub-area and vessel. Per ICES rectangle two haul locations (stations) were randomly selected from a list of BTS survey stations. In addition the skippers were allowed to choose two additional 'free' survey stations in each ICES rectangle. This resulted in a total of four survey hauls per ICES rectangle, 22 survey stations (11 assigned, 11 freely chosen) per sub-area and vessel, and 66 survey stations in total.

Survey stations were considered starting points for the survey hauls. In year 1 skippers were free to choose the route of the haul starting from a survey station. Once these routes were established in year 1 (and recorded in the vessels' navigation equipment) they were considered fixed for the entire life-span of the survey as well as linked to one vessel with its gear. The skippers determined an optimal route passing all stations assigned to their vessel.

2.2.1.3 Data and otolith collection

Data and otoliths are collected during survey hauls. Survey hauls are regular commercial hauls of approximately 100-120 min. For each survey haul all turbot and brill were sorted from the catch. Upon completion of the sorting of the entire catch, two researchers processed the collected turbot and brill. For each fish its species, length, weight and sex were determined. Otoliths were collected from two fish per cm-class per ICES rectangle (subject to availability in the catches). A trawl list was completed by the skipper to record conditions at haul level. The gears were characterized by completing a 'benthis list' for each vessel (confidential) and mesh size measurements (20 stretched meshes per cod-end, using an OMEGA meter).

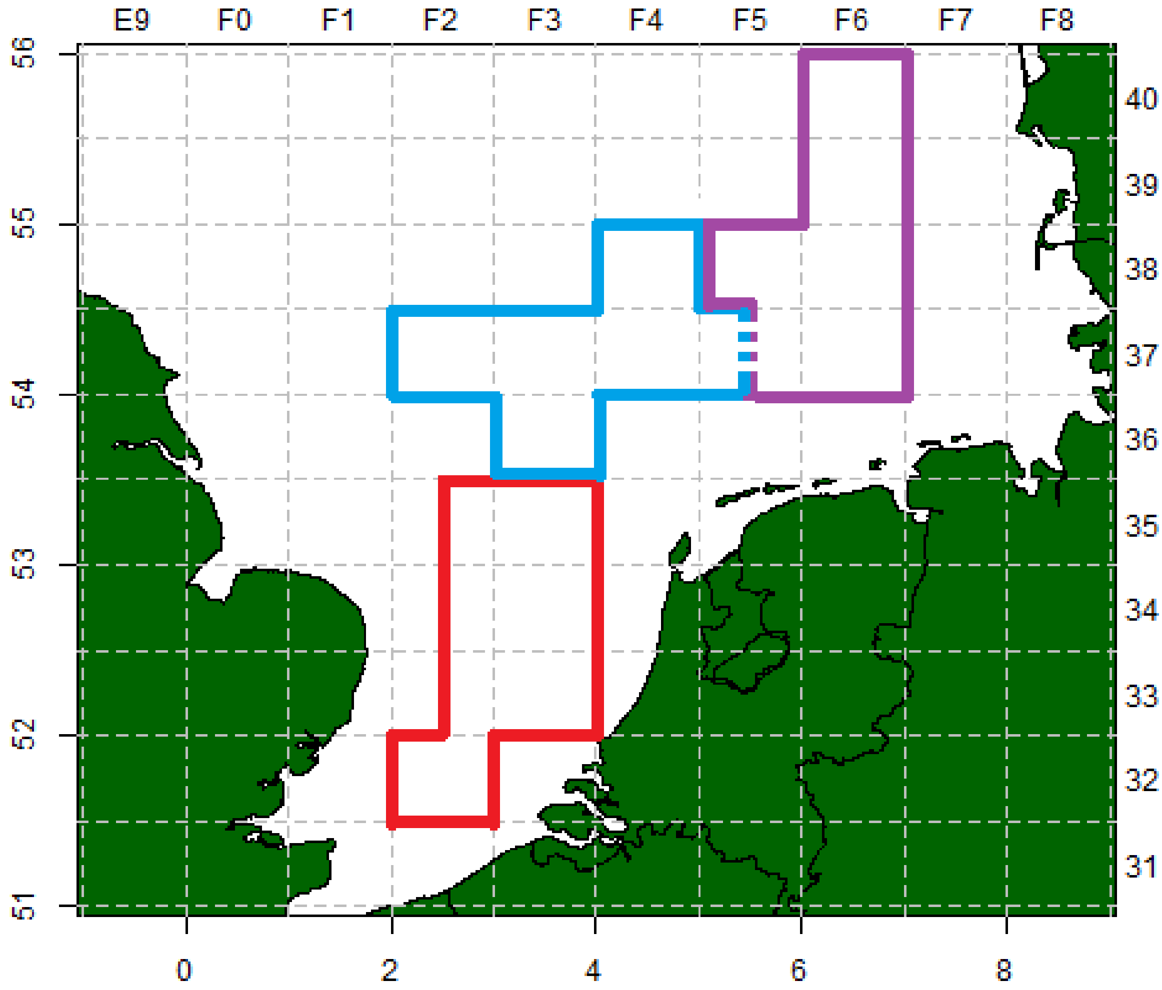

Figure 2. *Survey areas for the 2018 industry survey turbot and brill.*

2.2.2 Practical implementation and evaluation of the 2018 survey

2.2.2.1 Evaluation by project team

Two survey weeks with two vessels were completed in 2018. The third week with the third vessel was postponed multiple times due to poor weather conditions before being cancelled because it could no longer be conducted in the same period of the year as the other two survey weeks. The combination of fixed and free survey locations was not successful. The main reason for introducing the 'free hauls' was an interest in the ability of skippers to actively target turbot and brill. Addressing this question was however never an objective of the industry survey. In practice it appeared that the 'free hauls' were not free. Instead their starting location and route was dictated by the surrounding fixed survey locations.

2.2.2.2 ICES WGNSSK 2018 and 2019

Prior to the first survey, Wouter van Broekhoven, scientist of VisNed, presented the plans for the BSAS survey and initial survey design to the ICES WGNSSK in 2018 (ICES, 2018b). Various possibilities and considerations for the survey design were given by the group. For example, a short discussion was held on the pros and cons of aiming for the three survey vessels to undertake the survey in the same week versus in separate weeks. The former has the advantage of reducing variability due to factors such as the weather or moon phase, but practical considerations such as availability of staff would probably dictate carrying out the survey in separate weeks. Another discussion concerned criteria for defining the survey area, such as known occurrence based on surveys, or landings combined with VMS, or anecdotal evidence. Individual conversations were held following the plenary presentation to

get a broader perspective on these and other points of consideration for the survey design. Input was taken into account in the above described survey design for 2018.
The survey design and practical experiences of the first survey year (2018) were presented to the 2019 meeting of the WGNSSK by Wouter van Broekhoven (VisNed) with the objective of informing the WG on the survey and to receive feedback. Feedback by the working group was deemed useful to further improve the survey design as well as facilitate future acceptance of the survey data for use in stock assessments.
Specific issues relating to the design of the survey were put to the WGNSSK group for discussion. Useful feedback was provided by the group (ICES, 2019c), which then fed into the design of the survey from 2019 onwards. One issue which was discussed was the gear used, because one of the vessels in 2018 used a pulse gear. After the survey had started it became clear however, that this gear would be banned as of 2021. The WGNSSK advised to switch from the pulse gear to an alternative gear immediately as of 2019, rather than continue using the pulse gear and risk causing an irreparable break in the data series in 2021. Comparative fishing between the pulse gear and the alternative e.g. classic beam trawl with tickler chains in order to establish a conversion factor was considered very uncertain in terms of expected success. The issue with the distance between survey stations needing to be covered in the current survey design was also discussed, in conjunction with perceived difficulties relating to the statistical treatment of the combination of predetermined and free hauls. An arrangement used in a joint Danish / Swedish survey using a relatively fine-scale permanent grid from which cells are randomly assigned each year within which skippers are free to execute the hauls as they see fit was offered as a potential alternative setup. In general it was advised not to maintain the ICES rectangles as the basis for the definition of the survey zones if this leads to overly large distances to be covered. The discussions on gear and spatial survey design together led the group to advise to redesign the survey from 2019 and consider 2018 as a pilot year. A redesign which will be kept stable starting from 2019 was considered the most robust approach to building a data series which is likely to be used in the stock assessments of turbot and brill in future.

2.2.3 Conclusions and lessons learned

The survey design seems feasible in terms of the ability of the participating vessels to cover their share of the survey stations within the survey area in a regular fishing week. The survey area nor the number of stations seem too large. However, the WGNSSK gave clear recommendations for modification of the survey design to be addressed before the next survey in 2019 (WGNSSK, 2019c).

2.3 Survey 2019

2.3.1 Modifications to the survey design

For 2019 the survey design was revised. The main reason for the revision was the ban on pulse trawling. Catch efficiency of turbot and brill probably differs between pulse and conventional tickler chain beam trawling. As a consequence, replacing a pulse trawler by a beam trawler will result in a break in the time series of data. Given the possible complete ban on pulse trawling, WGNSSK recommended to replace the participating pulse trawler by a conventional beam trawler using tickler chains immediately to secure continuity of the survey (ICES, 2019c). This combined with only two of the three survey weeks being completed in 2018, rendered the data collected in 2018 unusable for a time series. Now that 2018 was lost for the time series anyway, we were free to completely revise the survey design for 2019 and years beyond based on the lessons learned in 2018. The revision of the survey design included the following changes compared to the 2018 design:

1. The use of ICES rectangles as a grid defining the survey area was abandoned;
2. The inclusion of two types of survey hauls, fixed and free, was abandoned;
3. The fixed survey locations, i.e., return to each location every year was abandoned.

Survey area
To (re)define the survey area data on turbot and brill catches (LPUE) and beam trawl fleet data (VMS) were considered in the following step-wise process:

1. Calculate LPUE for turbot in the southern North Sea over a 6 year period (2007-2009 and 2012-2014) (Figure 3A)
2. Define the positions were 60% of the LPUE is realized, combine these positions and draw a polygon around it (Figure 3B)
3. Crop the area to a feasible size for three vessels, taking into account their normal fishing grounds (Figure 3C).
4. Remove current and future areas closed for fisheries (N2000, wind farms) and apply a 5x5 km grid to the survey area (Figure 3D)

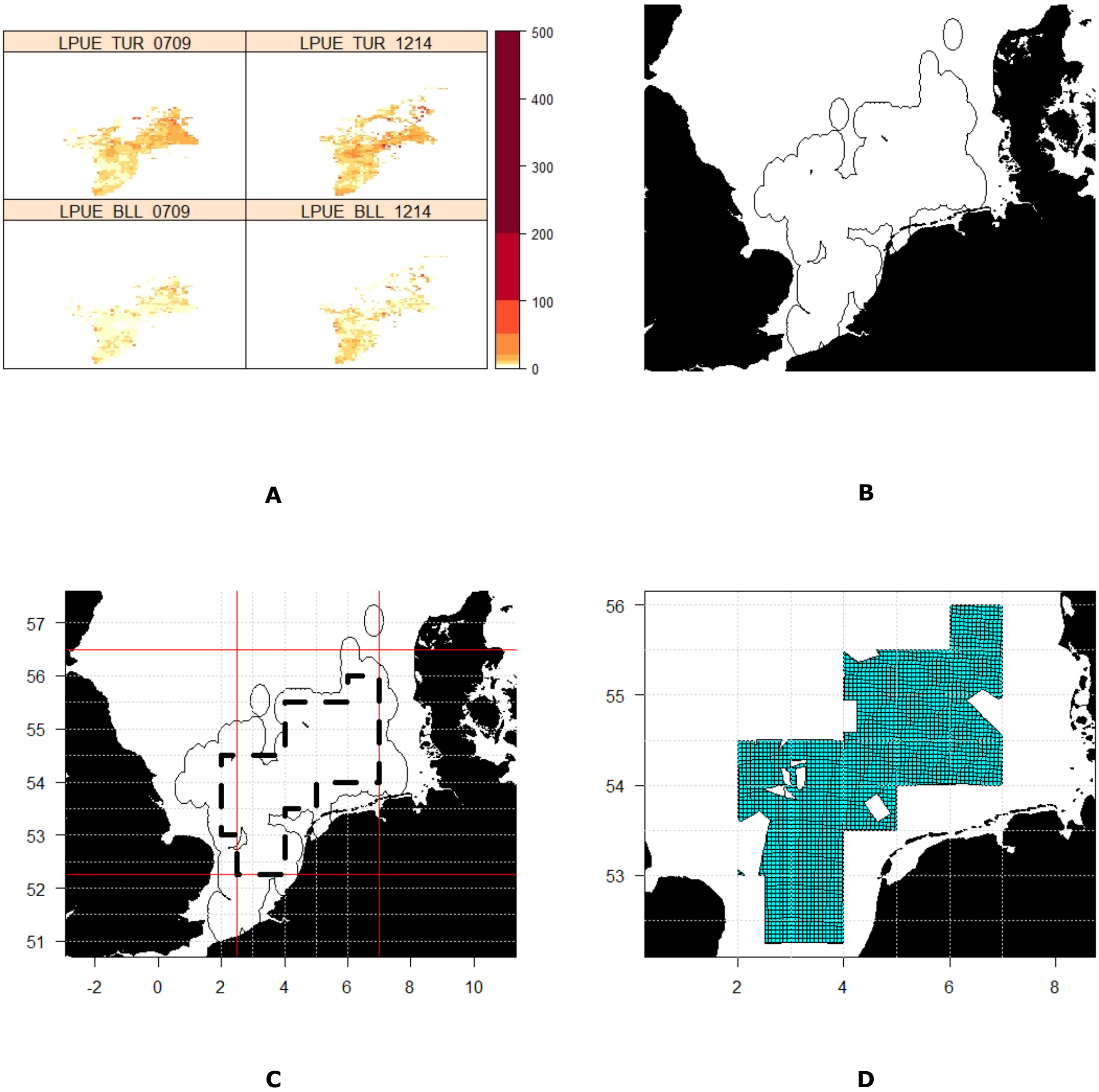

Figure 3. *Stepwise construction of the survey area.*

Assignment of survey stations

Each grid cell in the survey area is a potential survey station. Each year 60 grid cells are to be randomly selected using an R-script. Because the cutting out of unfishable areas resulted in some cells having irregular shapes and smaller surface areas than regular 5x5 km grid cells, the probability of being randomly selected as survey station was made proportional to their surface areas. The selected survey stations are then equally (~ 20 survey stations each) distributed over the participating vessels on the basis of their normal fishing grounds. A detailed protocol for the random selection of survey stations using the R-script and their distribution of the vessels was written (in Dutch, not included in this report).

Survey hauls

The skippers are instructed to start the survey hauls, i.e., deploy their fishing gear anywhere within the grid cells selected as survey stations between 7:00 a.m. and midnight. After that, the skippers are free to determine the route of the survey haul. Thus only the starting point of a survey haul and the period during the day are dictated by the survey protocol. Other than that, survey hauls are no different from regular, 100-120 min commercial hauls. Next to the approximately 20 survey hauls, each skipper conducts some 20 regular 'no survey hauls' to fill up the fishing week to a regular total of some 40 hauls. The skippers are free to choose in which order the survey stations assigned to them are fished and how they alternate survey hauls with 'no survey hauls'. In practice the 'no survey hauls' are either used to cover distances between survey stations while fishing or for fishing in the period between midnight and 7:00 a.m.

Data collection

Data are collected during survey hauls at the survey stations. Data collection was not modified from the 2018 design except for the collection of otoliths (see next paragraph). For each survey haul all turbot and brill were sorted from the catch. Upon completion of the sorting of the entire catch, two researchers determined species, length, weight and sex for the collected turbot and brill.

Otolith collection

Analysis (see 3.5) of age-length relations for turbot and brill revealed no spatial effects within the survey area. In other words, the length of each age group is the same throughout the survey area. This means that otoliths can be collected from anywhere within the survey area to obtain an age-length key which is representative for the entire survey area. The protocol to collect otoliths from each subsection within the survey area (e.g. ICES rectangles) as was done in the 2018 survey could thus be abandoned. Instead, a desired number of otoliths per cm-class for each species and sex (within species) was determined. These otoliths can be collected from any survey station. In practice, otoliths were collected starting from the first survey haul until the desired numbers had been collected. This otolith sampling schedule is subject to annual reconsideration based on the construction of age-length keys using the data collected till then.

2.3.2 Practical implementation of the 2019 survey

For the 2019 survey, 60 grid cells were randomly selected to serve as survey station. These 60 stations were manually distributed over the three participating vessels on the basis of their normal fishing grounds (Figure 4). All three survey weeks were realized as scheduled. A detailed practical protocol for researchers on-board the participating vessels was written (in Dutch, not included in the report).

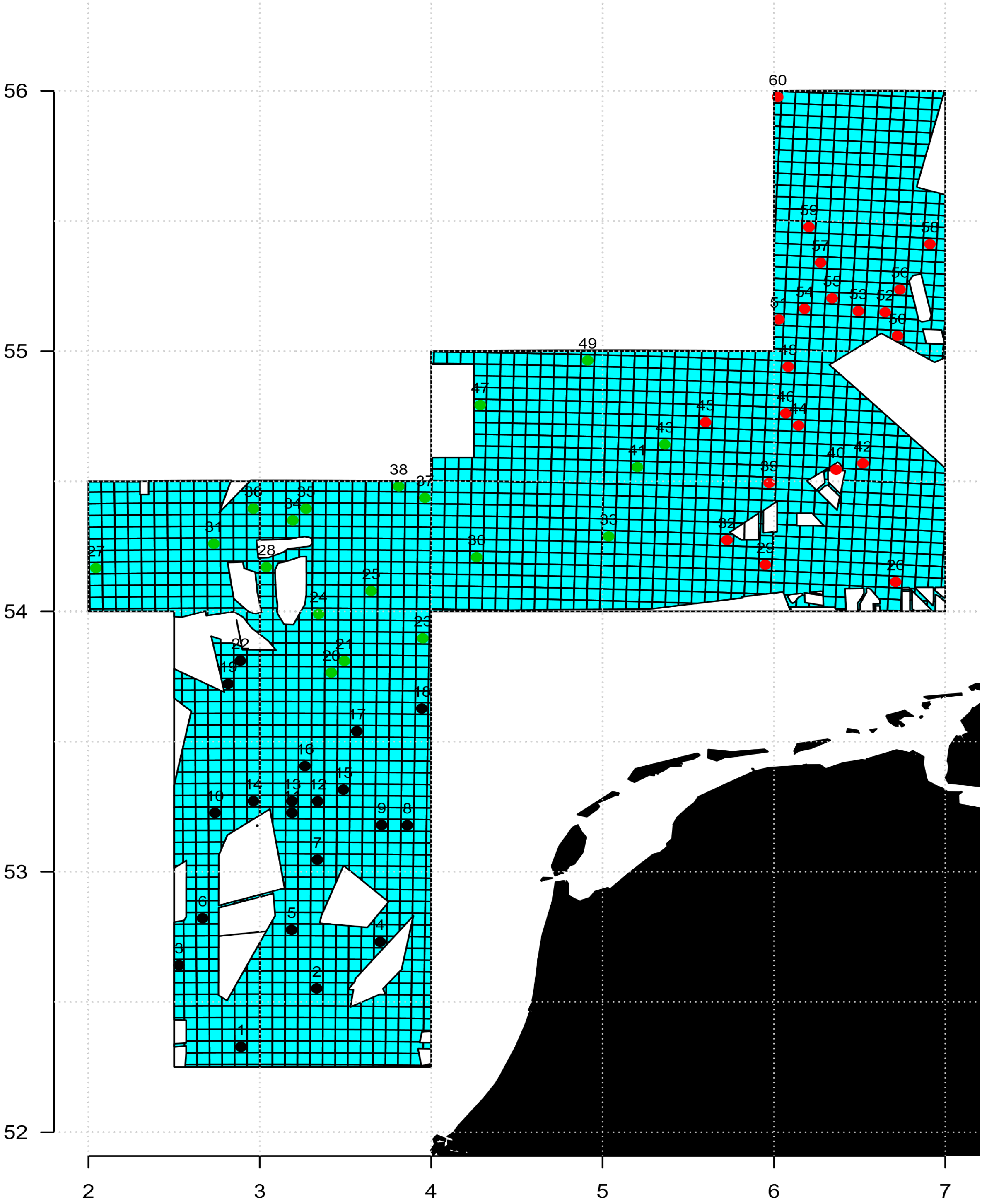

Figure 4. *Survey stations and their distribution over the vessels for the 2019 survey*.

2.3.3 Evaluation 2019 survey

2.3.3.1 Skippers

The survey design proved to be practically feasible, meaning that the number of survey stations and their spatial distribution could be adequately covered by the participating vessels. Out of the total of 60 survey stations, 50 stations were sampled. The main reason for not sampling a station was that the location was deemed unfishable by the skipper as for the sea floor conditions.

2.3.3.2 ICES WGNSSK 2020

The 2019 survey was again presented and discussed in the WGNSSK meeting in 2020 by Wouter van Broekhoven of VisNed with the objective to inform the WG on the survey and to receive feedback.

WGNSSK raised several points (ICES, 2020) that will be investigated further by the BSAS project partners (Table 3).

Table 3 *Points raised by WGNSSK 2020 and the responses to these points by Wouter van Broekhoven of VisNed.*

Points raised by WNSSK 2020	Response / follow up
The question was asked whether maturity is recorded on the survey.	This is not currently the case, but the feasibility and the merits of adding this to the survey in future could be investigated further.
The survey area was discussed in terms of the sufficiency of the total area covered. Ideally a larger area would be covered	Budgetary restrictions allow for the current design using a maximum of three vessels, leading to the current survey area which can be covered in practice.
There was a question from Germany whether a vessel could potentially be added to the survey by Germany, in order to improve coverage in the German Bight. This could provide a useful expansion of the survey area covered (see previous point).	The programme partners intend to share their project proposal intended to cover the cost of the survey years 2021 – 2023 with the German representative once it is sufficiently ready, so that a discussion can be held to explore options to try and achieve this.
An issue was raised in relation to the determination of an index intended to identify trends over time, where the question was whether abundance trends can be distinguished from spatial distribution shifts.	This issue will be investigated further by WMR.

2.3.4 Conclusions and lessons learned

Based on the 2019 survey it can be concluded that at least 50 survey stations can be covered by three vessels in three fishing weeks within the survey area. Not all 60 survey stations were sampled in 2019 and this was attributed to part of the survey area being unsuitable or unsafe for beam trawl fisheries. It was concluded that covering 60 stations seems feasible and that necessary to re-address the survey area and remove grid cells that cannot be fished to ensure the sampling of all stations in future surveys.

2.4 Survey 2020

2.4.1 Modifications to the survey design

Survey area
In 2019 not all selected survey stations were surveyed and some survey hauls were shorter than the regular 120 min. The reason for this is that the locations of these survey stations were deemed unfishable or unprofitable by the skippers at the time of the survey. To ensure as much as possible that all selected survey stations are surveyed in the future we aimed to remove cells from the survey area that either:

1. Cannot be fished.
2. Are unprofitable fishing grounds during the survey period.

The removal of cells that cannot be fished is appropriate when the fishing ground is unsuitable or too dangerous for the fishing gears used by the participating vessels. The removal of cells that are unprofitable fishing grounds is appropriate because the principal idea of this industry survey is that data are collected during regular commercial sole fishing activities. Commercial fishing does not take place in areas that are deemed unprofitable fishing grounds by skippers.
Cells were removed in a two-step procedure. First the skippers were asked to review the survey area. To this end the survey area was made available to the participating skippers and one other skipper familiar with part of the survey area as a file that can be viewed on the 'plotters' of the vessels

(TimeZero / MaxSea). All cells were numbered (1 to 2219). The skippers were instructed to use only the criterion of 'unfishable' or 'unprofitable' for the elimination of cells. The criterion of 'no or low turbot or brill catches' was not allowed to exclude cells. The skippers provided lists of cells that according to them should be removed from the survey area (red and green cells in Figure **5**).
In the second step the list provided by the skippers was reviewed using the following information:

- VMS data describing historic fishing activity in the survey area (2007-2009 data => only beam trawl, 2017-2019 => beam trawl & pulse trawl).
- LPUE data for turbot

For both data sets we mainly considered data from October, the month in which the survey takes place (as opposed to data of a full year). This way we accounted for seasonality in the use of fishing grounds. We accepted the removal of cells with no or low fishing activity in October according to VMS data. Low or no fishing activity was defined as less than 4 'pings' in a cell for which turbot landings <0 kg were recorded. This is visualized in Figure 5. Red cells are accepted for removal and green cells show too high historic fishing activity data to justify removal (note that this depends on months and years).

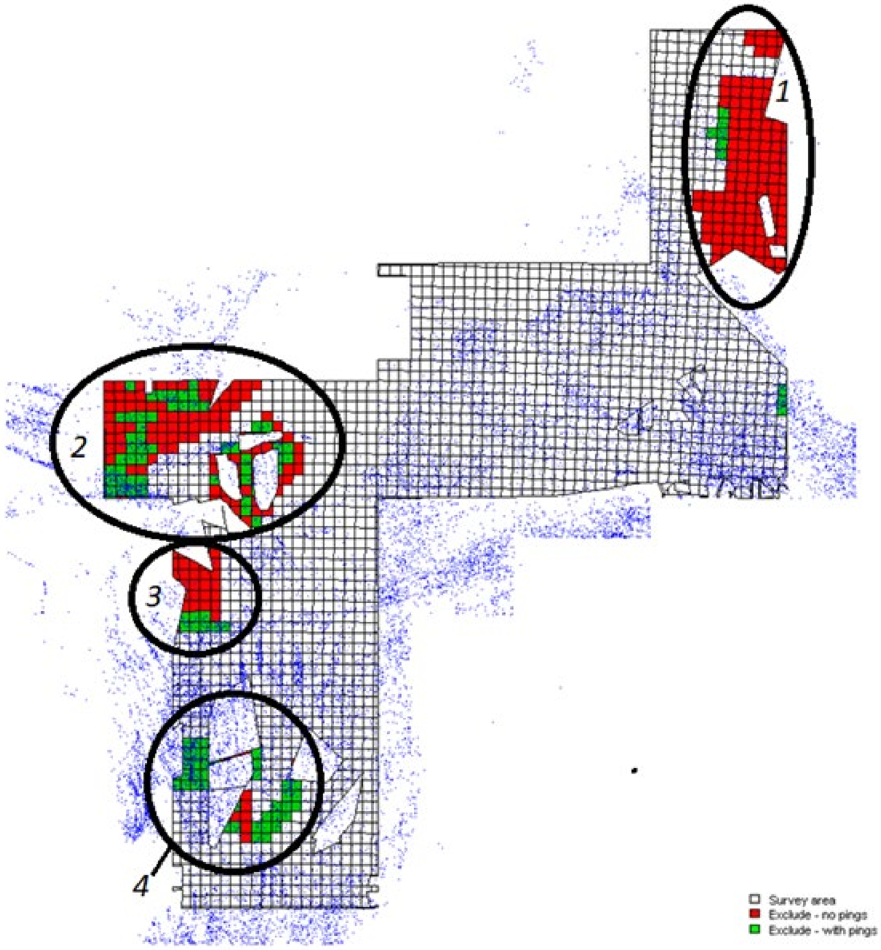

Figure 5. *Survey area with fishing activity (VMS-pings, blue dots) in October 2007-2009. Circles and numbers indicate the reviewed areas. Green and red coloured cells have to be removed according to the skippers. Red cells have low fishing activity. Fishing activity in the green cells is too high to justify their removal from the survey area (for the period and years considered).*

Given the fishing speed (6-7 knots) and haul duration (120 min) a single haul in a straight line passes through 4 to 5 grid cells (5x5 km). Therefore single green cells enclosed by red cells were also excluded from the survey area.

Draft updates of the survey area were reviewed by the skippers several times. These iterations are not described in detail. Instead considerations and final conclusions are presented below for four separate areas within the survey area.

Area 1 shows low fishing activity in October both in the period 2007-2009 (only beam trawl with tickler chains, Figure 5) and 2017-2019 (mainly pulse trawl, not shown). Year-round however, the majority of cells in the area show fishing activity (not shown). According to skipper's information the sole fishery is seasonal in this area. In October sole catches are very small while unwanted bycatches of undersized plaice and dab are large. Also the area is shallow and prone to poor catches as soon as it gets more windy. The area is consequently avoided and there is no regular commercial sole fishing in autumn. The red cells within Area 1 as shown in Figure 5 are therefore removed from the survey area.

Area 2 and 3 shows a mixture of low (red) and higher (green) fishing activity in October 2007-2009 (Figure 5). Year-round most of the areas show fishing activity (not shown). In 2017-2019 however, almost the entire area 2 is not fished in October (not shown), probably because pulse fisheries moved its activity elsewhere at the cost of this area. Because it cannot be excluded that with the ban on pulse fisheries, beam trawlers will start fishing the area again in the coming years, we do not want to exclude it from the survey area. We therefore consider the fishing activity in area 2 in 2007-2009 (Figure 5) and only exclude the red cells. Area 3 shows mainly low fishing activity in October based on 2007-2009 data (Figure 5). Year-round however, the area is fished (not shown). Also in 2017-2019 the area is fished in October (not shown). We therefore only exclude the red cells.
Area 4 shows high fishing activity, in October in both periods (2007-2009, Figure 5; 2017-2019, not shown) as well as year-round (not shown), expect for some cells. These red cells are removed. Also the two corridors of very small cells between the three future wind mill parks are removed for practical reasons.

The final survey area (and the stations for 2020) is shown in Figure 6. It should be noted that this update of the survey area before the execution of the 2020 survey does not affect the usability of the data of the 2019 survey. In 2019 none of the actually surveyed stations lie in the areas that are now removed from the survey area.

COVID-19 restrictions
The survey involves the boarding of the participating fishing vessels by two researchers. This was not possible under the restrictions implemented in 2020 to prevent the spreading of the COVID-19 virus. Therefore an alternative protocol was developed in liaison with ICES turbot and brill stock coordinators to ensure the continuity of the survey. In brief: the survey design remained unchanged but instead of the direct on-board processing by researchers of turbot and brill caught at the survey stations, the survey fish were sorted from the catches and then labelled per station and stored by the vessel's crews. At the end of the survey week all collected survey fish was handed over to a team of researchers for processing. All procedures were detailed in protocols for skippers and crews and researchers (in Dutch, not included in the report).

Assignment of survey stations
The procedure for the random selection of survey stations and their assignment to the vessels remained unchanged from 2019 except for the number of selected stations. Instead of selecting the required 60 stations, a total of 75 stations were selected. Sixty stations were manually assigned to the vessels (20 each) and the remaining 15 stations were kept as 'spares', undisclosed to the skippers. Stations among the first 60 stations that were considered not feasible by the skippers could then be replaced by spare stations without the need for a new draw of stations. The procedure is described in detail in a protocol for the random selection of survey stations using the R-script (in Dutch, not included in the report). Because of the removal of unfishable areas from the survey area, it is expected that the need to replace stations will be a rare event.

Data and otolith collection
Data and otolith collection remained as in 2019.

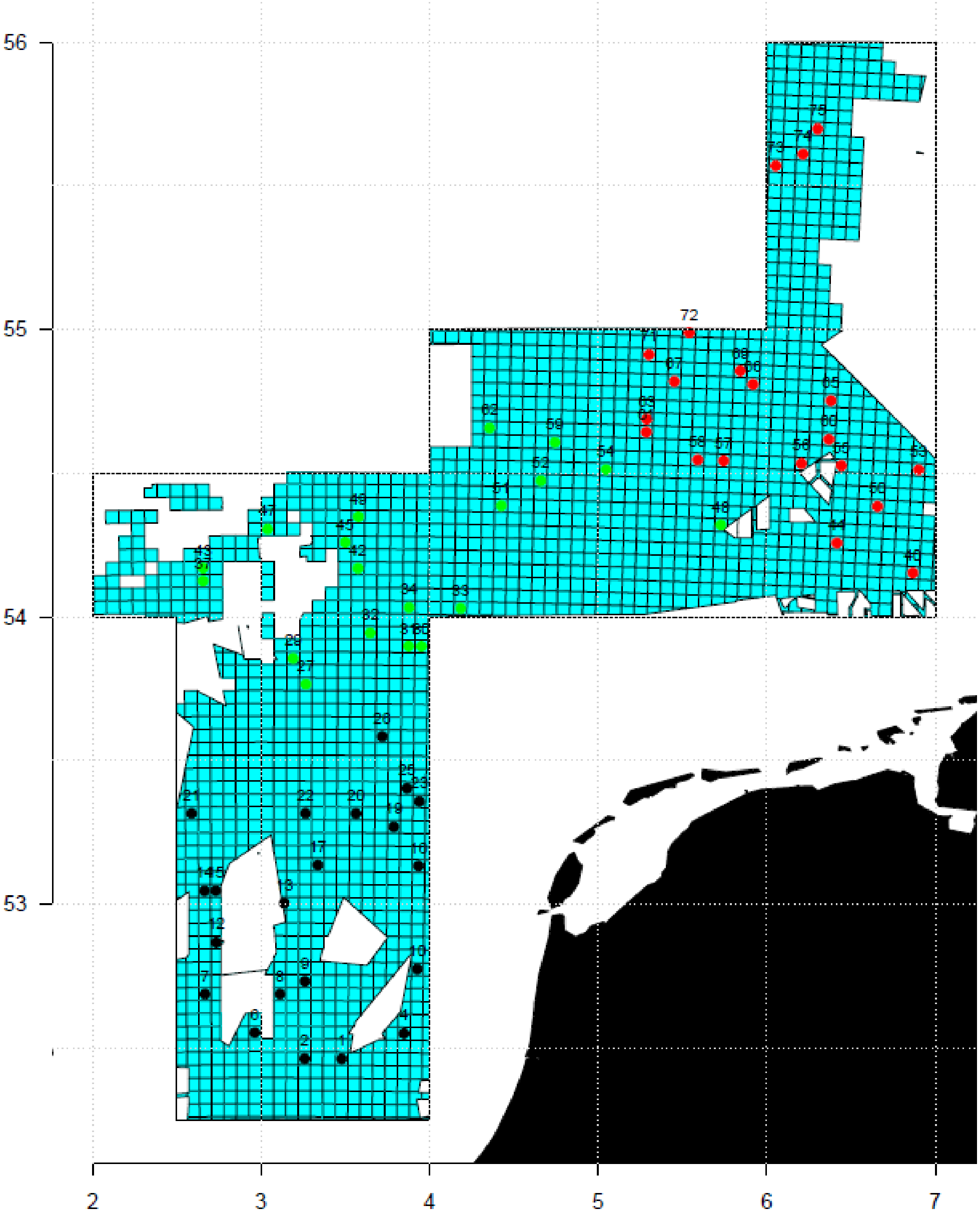

Figure 6. *Final survey area and survey stations for 2020.*

2.4.2 Practical implementation 2020 survey

For the 2020 survey all three survey weeks were completed as scheduled. This survey fish were collected, labelled by haul and corresponding station number and stored at sea by the crews of the vessels and processed by researchers at the end of the fishing week, all according to protocol.

2.4.3 Evaluation 2020 survey

2.4.3.1 Skippers

The modifications to the survey area proved to be successful as 59 of the 60 survey stations were sampled in 2020 (compared to 50 out of 60 in 2019 due to stations deemed unsuitable for fisheries by the skippers). No further refinement of the survey area will take place prior to the 2021 survey. However, the 60 stations drawn for 2021 will be reviewed by the skippers well in advance of the survey to allow for planning of optimal routes and replace any station that cannot be fished. The 2020 survey was successfully implemented with no researchers on board under the COVID-19 protocol described above. In the 2020 BSAS evaluation meeting, one of the skippers mentioned that he prefers to have researchers on board to be able to discuss and jointly decide on any deviations from the original plan in case of unexpected changes in conditions.

2.4.3.2 ICES WGNSSK 2021

The experiences and findings of the 2020 BSAS survey will be shared with the WGNSSK in 2021 together with the current report covering the EMFF project period 2018-2020. Reporting feedback from WGNSSK 2021 will be part of the follow-up project.

2.4.4 Conclusions and lessons learned

The 2020 survey showed that the industry survey can be successfully executed by having the fishermen independently collect, store and label survey fish. Data collection was not hampered by the COVID-19 restrictions. In 2020 59 out of the 60 assigned stations were actually surveyed whereas this was 50 out of 60 in 2019. This improvement may be attributed to the refinement of the survey area by removing unfishable cells prior to the 2020 survey.

2.5 Otolith sampling

In the 2018 survey, two fish per cm-class per ICES rectangle were sampled for otoliths, depending on the availability of these numbers in the catches. The age-data from these samples, together with the age-data from the market, BTS and SNS surveys, were used to determine the number of otoliths to sample in the subsequent survey years.
Age-data was used to fit one age-length key (ALK) with BSAS samples, and one ALK with samples from the other surveys. This was done for both species and sexes separately. There was no difference in length distribution and age-at-length within the survey area for both turbot and brill in the 2018 survey. Therefore we applied the ALK for the entire survey area.
The fitted ALK was then applied to all samples with known ages to estimate age-at-length. We then looked at deviations from predicted to observed ages (assuming that observed ages are true ages). As larger, and thus older, individuals have a larger variation in age-at-length compared to smaller individuals, it was decided to split the individuals in three length groups (<28 cm, 28-45 cm, > 45 cm) and generate an ALK separately for each of these length groups. In order to determine the number of otoliths to sample, multiple ALKs were generated using different sample sizes (e.g. 25%, 50% or 75% of samples taken). The ALKs were again applied to all samples to predict the age and look at deviations from predicted to observed ages. Based on this ad hoc approach, the number of otoliths sampled per length group and sex was decided and split among cm classes. As a precautionary approach it was decided to multiply the number of samples per length group with 1.5 to get the final numbers per length group to be sampled. The final number of otoliths per cm-class targeted per species, sex and length group during the 2019 and 2020 surveys are presented in Table 4.

Table 4 *Targeted number of otoliths per species, length-range and sex*.

Species	Sex	Length group	# otoliths per cm-class
Turbot	Male	≤ 27 cm	1
		≥ 28 cm, ≤ 45 cm	4
		≥ 46 cm	1
Turbot	Female	≤ 27 cm	1
		≥ 28 cm, ≤ 45 cm	4
		≥ 46 cm	1
Brill	Male	≤ 27 cm	2
		≥ 28 cm, ≤ 45 cm	6
		≥ 46 cm	2
Brill	Female	≤ 27 cm	1
		≥ 28 cm, ≤ 45 cm	3
		≥ 46 cm	1

2.6 Data management

All data have been entered in the WMR in-house developed software Billie Turf. After data entry, data have been checked for completeness and outliers of numerical variables (i.e. haul duration, distance towed, fish length, fish weight, fish age, including length-weight and age-length relationships, fishing positions) and for completeness and consistency of text variables (i.e. station coding, ship names, fishing gear). The quality control checks have been carried out using standardised SAS scripts, full version of scrips available via WMR upon request.

After quality control and -if needed- data correction, the data have been imported into the WMR database FRISBEE. This oracle based relational database contains information from all fisheries-related sampling types carried out within WMR projects. The database contains a number of quality assurance checks, such as consistency of species coding, ship coding, gear coding, on top of format checks for all fields.

From the WMR database the data have been exported and transferred into the unified format with header needed for submission to the ICES database DATRAS. Submission possibilities for the industry survey had to be created in collaboration with ICES Data Centre. Although the format had been agreed upon in July 2020, the ship codes for the vessels used had to be put on the NOAA list of vessels before the upload of the survey data could be tested. Ship codes were available since 11th December 2020. Submission of the data was completed in February 2021 and the data are available at https://datras.ices.dk/Data_products/Download/Download_Data_public.aspx , choose NL-BSAS for exchange data download, or for selection of the data when using the webservices use https://datras.ices.dk/WebServices/Webservices.aspx.

3 Results

3.1 Contribution to stock assessment data

The industry survey for turbot and brill (BSAS) was set up because two age-structured index time-series of the fisheries independent surveys, i.e. the Dutch beam trawl survey (BTS-ISIS) and the Sole Net Survey (SNS), currently used in the assessment show a poor internal consistency, especially for older ages, leading to a poor tracking of cohorts over time. To evaluate the contribution of BSAS to data available for future turbot and brill stock assessments, we present descriptive statistics on turbot and brill catches by each of the surveys (Table 5), for each survey (BSAS, BTS, SNS), year (2019, 2020) and species the number of fish caught per haul (Figure 7) and the length distributions (Figure 8). BSAS clearly catches more turbot and brill than BTS and SNS. Both, the occurrence (Table 5) and the number of fish in hauls with occurrence (Figure 7) are highest for BSAS. The catch index normalizes the different survey hauls for haul duration and this also clearly shows that BSAS catches more turbot and brill than BTS and SNS (Table 5). The length distributions (Figure 8) also show that BSAS yields a lot more observations than BTS and SNS and that BSAS adds observations for larger fish. The survey areas of BSAS, BTS and SNS, as illustrated by the locations of survey stations (Figure 9), show some degree of overlap. The overlap is larger with the BTS, especially in the more offshore sampling locations where it is expected the larger and as such older individuals in the population occur. Most noticeable is that survey hauls with no turbot or brill catches are frequent for BTS and SNS and rare for BSAS.

Table 5. *Descriptive statistics for BSAS, BTS and SNS.*

Species	Survey	Year	Total # caught	Total # hauls	Occurrence (%)[1]	CPUE (#/h)
Turbot	BSAS	2018	1035	45	100.0	42.1
		2019	1709	50	98.0	57.8
		2020	1415	59	98.3	55.7
	BTS	2018	181	82	65.9	5.2
		2019	191	73	84.9	6.3
		2020	162	74	82.4	5.2
	SNS	2018	37	45	51.1	1.0
		2019	30	44	40.9	1.0
		2020	23	46	32.6	0.7
Brill	BSAS	2018	518	45	58.7	14.9
		2019	785	50	100	26.4
		2020	454	59	81.4	17.3
	BTS	2018	67	82	35.4	1.8
		2019	85	73	53.4	2.7
		2020	47	74	33.8	1.7
	SNS	2018	30	45	31.1	0.8
		2019	10	44	14	0.4
		2020	0	46	0	0.0

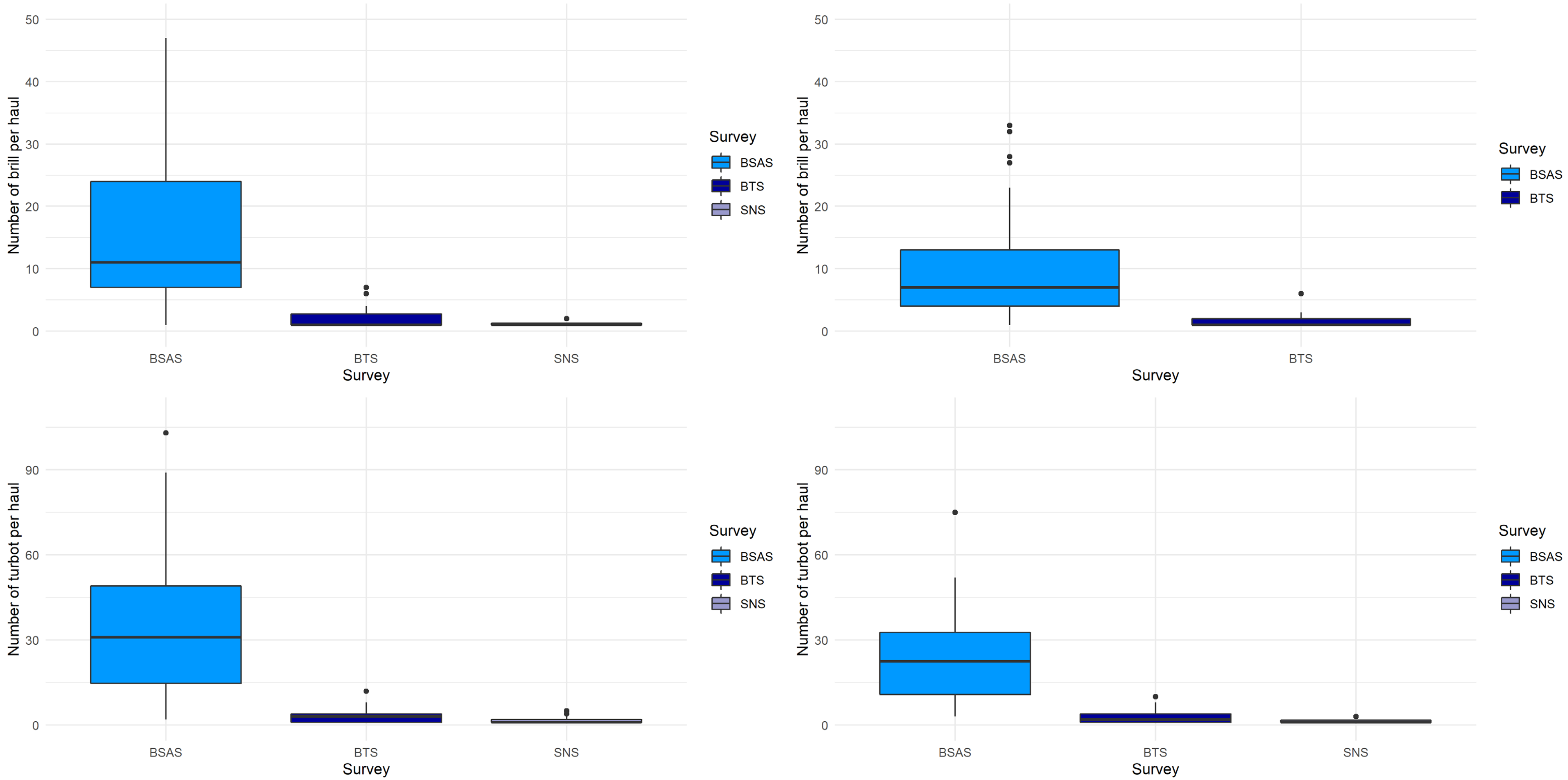

Figure 7. *Number of fish caught per survey haul by the BSAS, BTS and SNS for brill (top panels) and turbot (bottom panels) in 2019 (left panels) and 2020 (right panels). Note that hauls with no occurrence of brill or turbot are not included.*

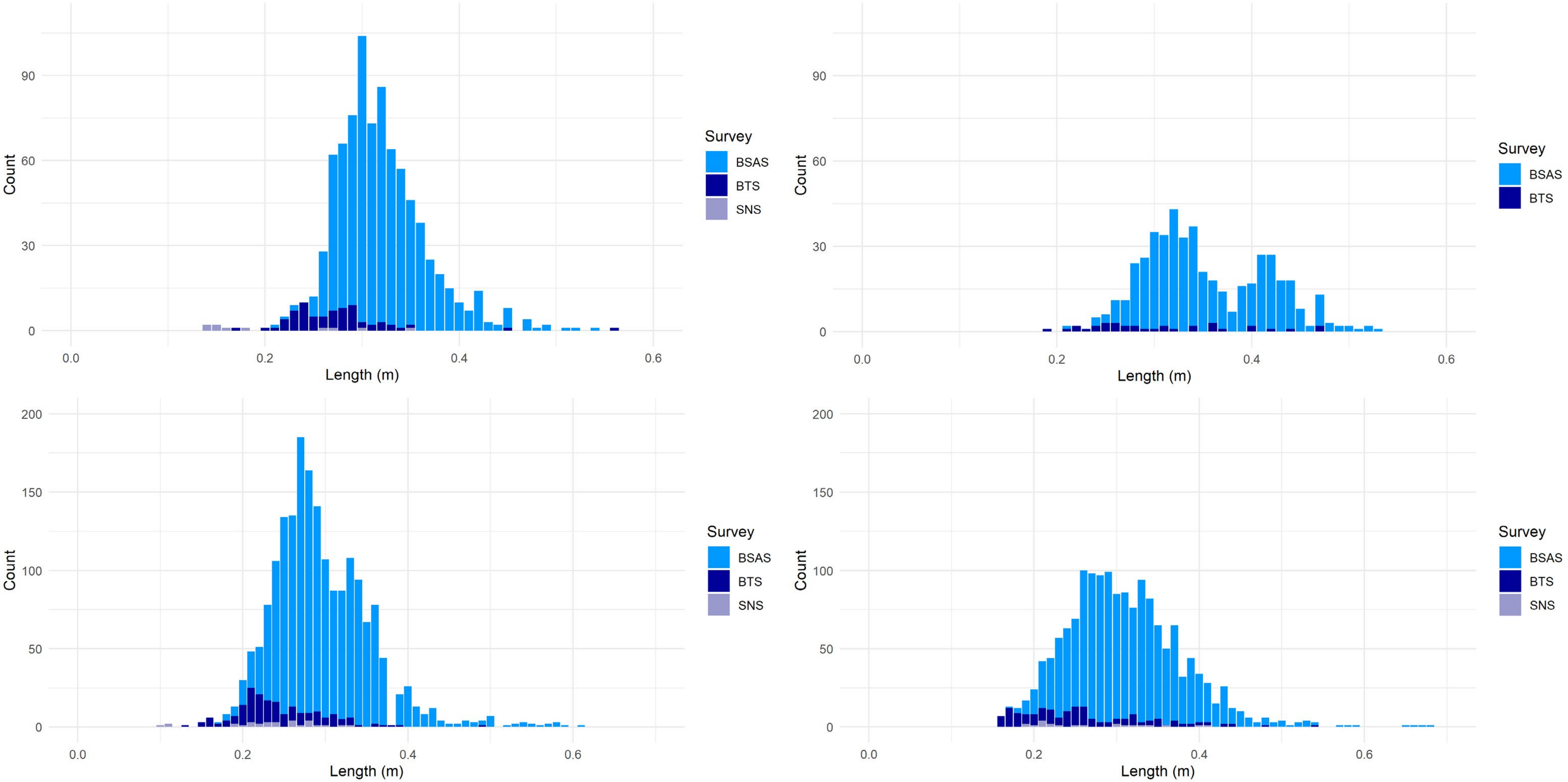

Figure 8. *Length distributions (cm-classes) for BSAS, BTS and SNS for brill (top panels) and turbot (bottom panels) in 2019 (left panels) and 2020 (right panels).*

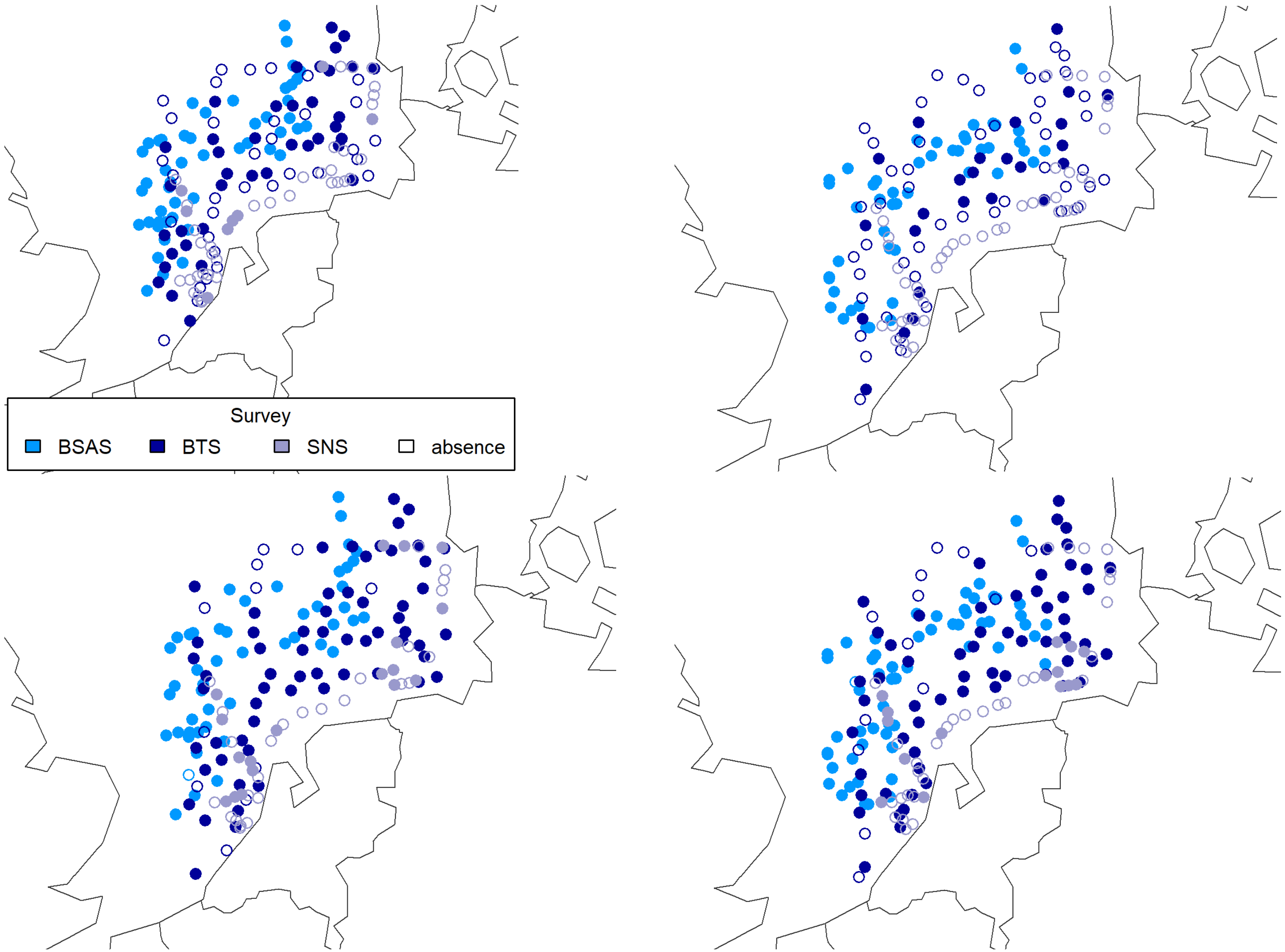

Figure 9. *Survey stations for BSAS, BTS and SNS for brill (top panels) and turbot (bottom panels) in 2019 (left panels) and 2020 (right panels). Note that open circles indicate survey stations for which either turbot or brill was absent in the catch.*

3.2 Age-length keys

3.2.1 Model selection and parameterization

Turbot and brill in the North Sea are both species for which age-length data is sparse. The industry survey is implemented as an alternative method to collect age data. For a selection of length-measured fish the age was determined by otolith readings (see chapter 2.5), allowing the estimation of an age-length relation (ALK, age-length key). Such ALK is used to convert the numbers-at-length to numbers-at-age for those fish for which only length measurements were taken.

ALKs can be constructed by calculating the proportion of ages within a length-bin (cm-classes). This method can be applied when all length-bins are sufficiently sampled, i.e. for all lengths age is determined for a representative number of individuals. When age-length relations are missing, e.g. when lengths were not sampled, the ALK can also be estimated using statistical models. Here, the ALK for each survey year and each species individually was first determined by calculating the proportions (enclosed in Annex 1). As for certain lengths, mainly the larger fish, only few or no fish were sampled in 2019 and 2020 (Figure 12) a modelling approach using non-linear least squares was applied. In both ALK estimates no distinctions were made between males and females. Combining sexes in the ALK, may cause a bias in the age-length conversion as growth rates of both sexes are different (i.e. males remain smaller). Yet, the sex of an individual fish can only be determined by cutting open the fish which was only done for those fish from which otoliths were extracted. As such, the sex was determined from a sample of the total number of individuals caught in the survey. Due to uncertainty in the representativeness of the ratio between males and females the ratio was not extrapolated over those individuals for which sex was not determined.

The age-length keys were treated as a non-linear least-squares, and as such can de described mathematically as follows:

$Age \sim Normal(\mu, \sigma^2)$
$\mu = t_0 + \log\{1 - (Length / L_{inf})\} (-K)^{-1}$

Where μ is the mean age and σ2 is the age variance. The parameters Linf, K, and t0 were estimated using non-linear least squares and represent the following:

- **L_{inf}**: The asymptotic length (in meters); the length that the fish of a population would reach if they were to grow indefinitely. L_{inf} must be larger than the maximum length in the data to prevent that 1 – (Length / L_{inf}) becomes negative (you cannot take the logarithm of a negative number). So by definition L_{inf} is not necessarily a biologically realistic length.
- **K**: The growth rate per year at which the asymptotic length is approached.
- **t_0**: The hypothetical age at which a fish of a population would have zero length, had their early life stages grown in the manner described by the Von Bertalanffy growth function (using parameters L_{inf} and K).

The age-length keys for brill were fitted as straight-forward non-linear least-squares. This method did not result in converging age-length keys for turbot. Hence a more advanced method was applied.

For survey years 2018 and 2020, the age-length key of turbot was fit by limiting the Linf parameter between a minimum and maximum limit value. Linf is defined as the length a fish would reach when growing indefinitely. The minimum limit for Linf was therefore set to be the maximum length found for turbot in the data of a given year, max(Ldata). The maximum limit was more difficult to choose: it turned out that Linf tended to be estimated to whatever maximum limit was chosen. For example, if the limit maximum for Linf was set to 10 m for 2018 and 2020, Linf was estimated to be 10 m for both 2018 and 2020. When the maximum limit value became too high (i.e. >50 m), there was no convergence. We eventually chose the limit maximum for Linf to be 5 m for 2018 and 2020.

For the 2019 turbot data a Bayesian non-linear least-squares method was applied because the age-length key did not converge when applying a simple frequentist non-linear least squares method. The following priors were used for the age-length key parameters:

- L_{inf} ~ Uniform(max(L_{dat}), 1.5)
- K ~ Uniform(0, 1)
- t_0 ~ Uniform(-∞, ∞)
- σ ~ Uniform(0, ∞)

Similar to the 2018 and 2020 analysis of turbot, max(L_{data}) is defined as the maximum length, in meters, but this time for the 2019 data. The parameters estimates for both species and all survey years is presented in Table 6.

Table 6 Table of the age-length key parameter for each year and species.

year	species	L_{inf}	K	t_0
2018	Brill	0.9534176	0.1431089	-1.5595339
2018	Turbot	5.0000000	0.0184248	-1.2951641
2019	Brill	0.5620167	0.6538433	0.2303506
2019	Turbot	1.2265008	0.0849295	-1.1248260
2020	Brill	0.5407781	0.7859878	0.4085185
2020	Turbot	5.0000000	0.0179182	-1.2565011

The fact that a rather complex approach was required to get the age-length keys to fit properly for turbot suggests a more detailed look at the approach in fitting the age-length key is required. A possible first avenue would be to look at the differences in growth rate of males and females. Such differences may affect the age-length relationship in both sexes requiring separate age-length keys to be fitted.

3.2.2 Goodness of fit of the age-length keys

In correspondence with the use of age data in stock assessments, ages predicted by the age-length key were rounded down to the nearest whole year prior assessing the goodness of fit.

The goodness of fit quantifies how accurate the age-length key predicts the age of individuals based on their length.

The goodness of the fit was checked in 2 ways:

- The mean absolute deviation ("MAD") was calculated. This is the mean of the absolute difference between the predicted age and the observed age. It shows how far off, on average, the ages predicted by the age-length key are from the observed ages. The smaller this number, the more accurate the age-length key.
- The predicted ages (on the x-axis) were plotted against the observed ages (on the y-axis), and a straight line was fitted through the points using an ordinary least-squares. The closer the slope of this line (the "fit slope") is to 1, the more accurate the age-length key.

The age-length keys for both turbot and brill had reasonably good fit, though the fit for brill was considerably better than for turbot. The mean absolute deviations and the fitted slopes, as described above, can be found in Figure 10. The observed and predicted age by the age-length key, against the length of an individual is shown in Figure 11.

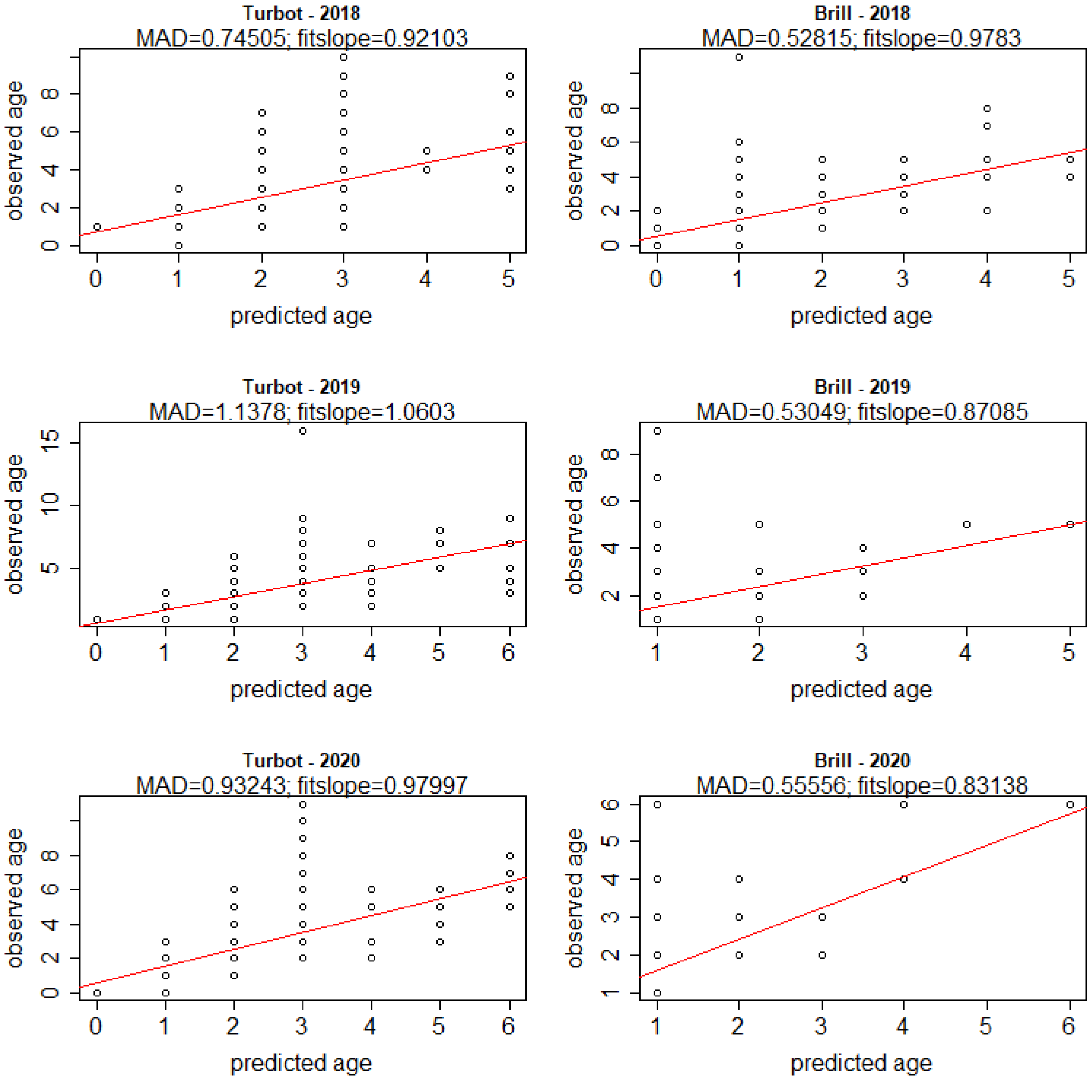

Figure 10. *The age predicted by the age-length key is plotted against the observed age. The mean absolute deviation ("MAD"; the lower, the better) and the slope of the fitted red linear line ("fitslope"; the closer to 1, the better) are displayed for each plot. The plots on the left are for turbot, and the plots on the right are for brill. Each row is a different year (from top to bottom the years are 2018, 2019, and 2020).*

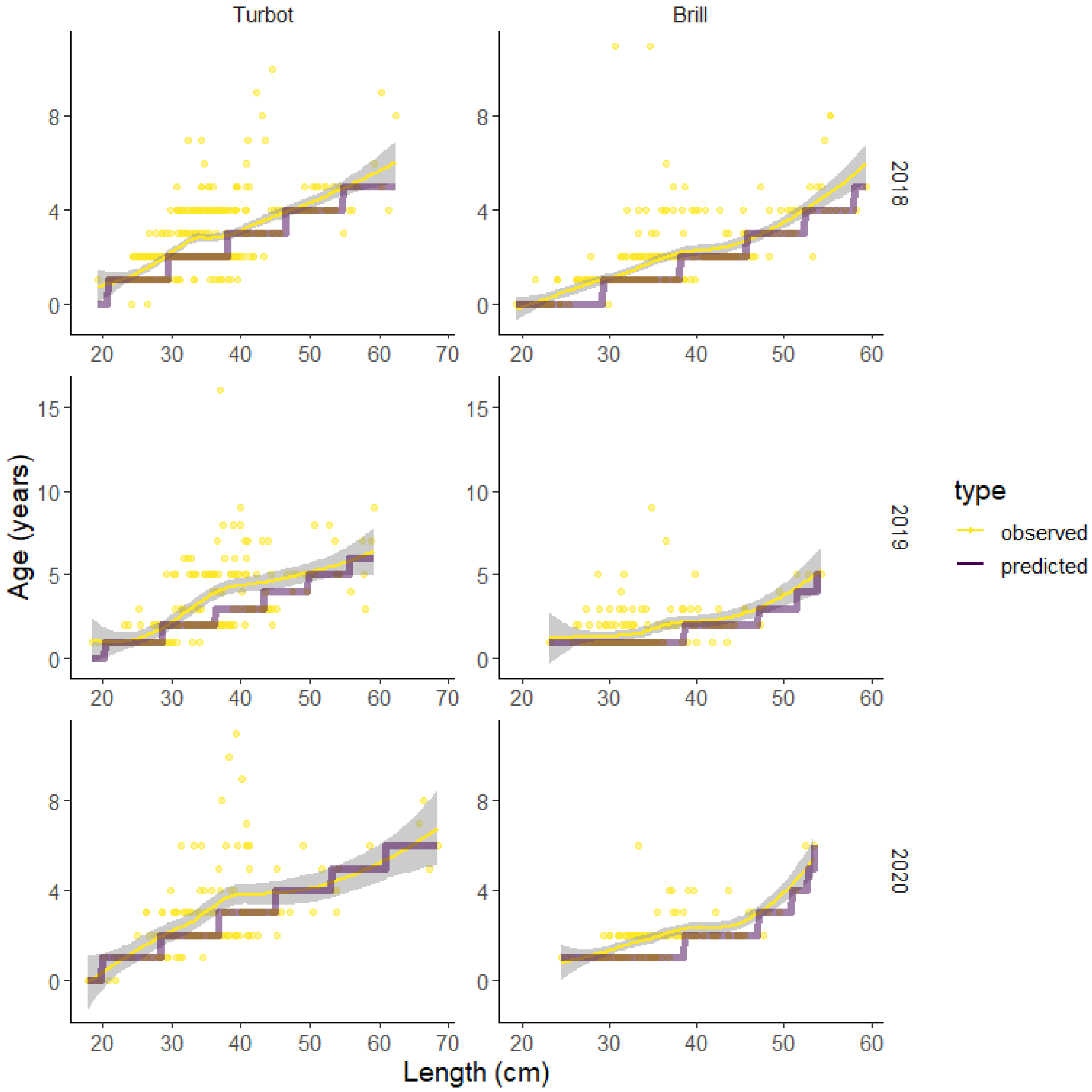

Figure 11. *Each plot shows the observed age and the age predicted by the age-length key, against the length of an individual by year (top = 2018, middle = 2019 and bottom = 2020) and species (left = turbot, right = brill). Each observed ages is displayed as a (yellow) point. Simple curves were fitted through the observed ages to aid visualization, where the grey background indicates the 95% confidence interval of these curves. The predicted ages are displayed as (purple) lines. Because the predicted ages were rounded down to the nearest whole year, the lines for the predicted ages somewhat resemble staircase-functions.*

3.2.3 Temporal distributions

For further analysis length and age data from the survey in the years 2018 to 2020 were used. A first step was to get insight into the distributions of age, length and number of fish caught, over the years and for both species (Figure 12, Figure 13, Figure 14). In 2018 more fish were sampled for age-determination compared to 2019 and 2020. The first year of the industry survey was used as a pilot. As such, the data from 2018 were used to determine how many fish are needed to construct an age-length key.

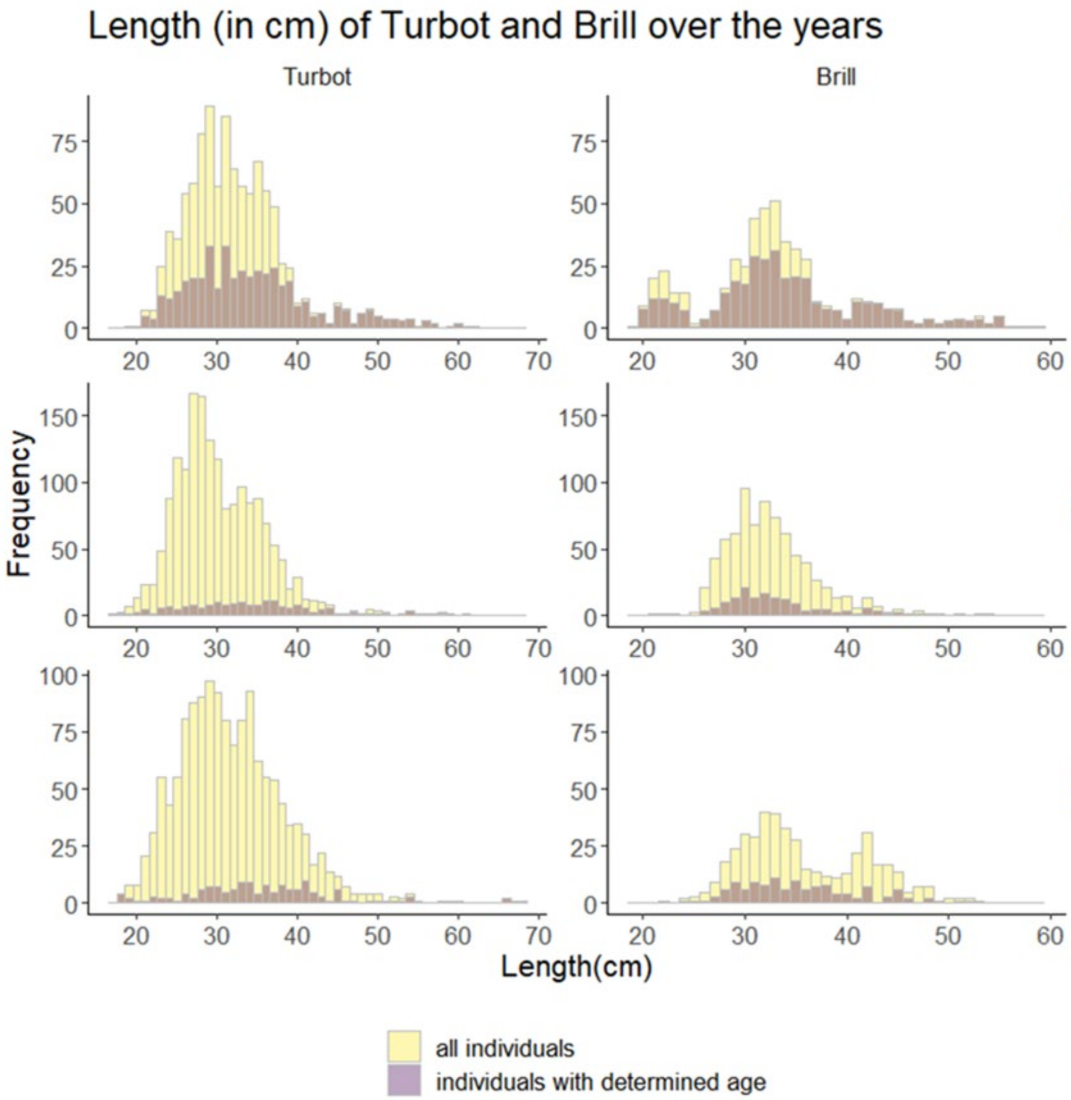

Figure 12. *Overlapping histograms of the length (in cm) of all individuals (light coloured) caught in the survey, and of those whose age was determined (dark coloured). To make comparisons between the groups, the width of the bins was set to 1 cm (with respect to the length). Please note that these are overlapping histograms, not stacked histograms.*

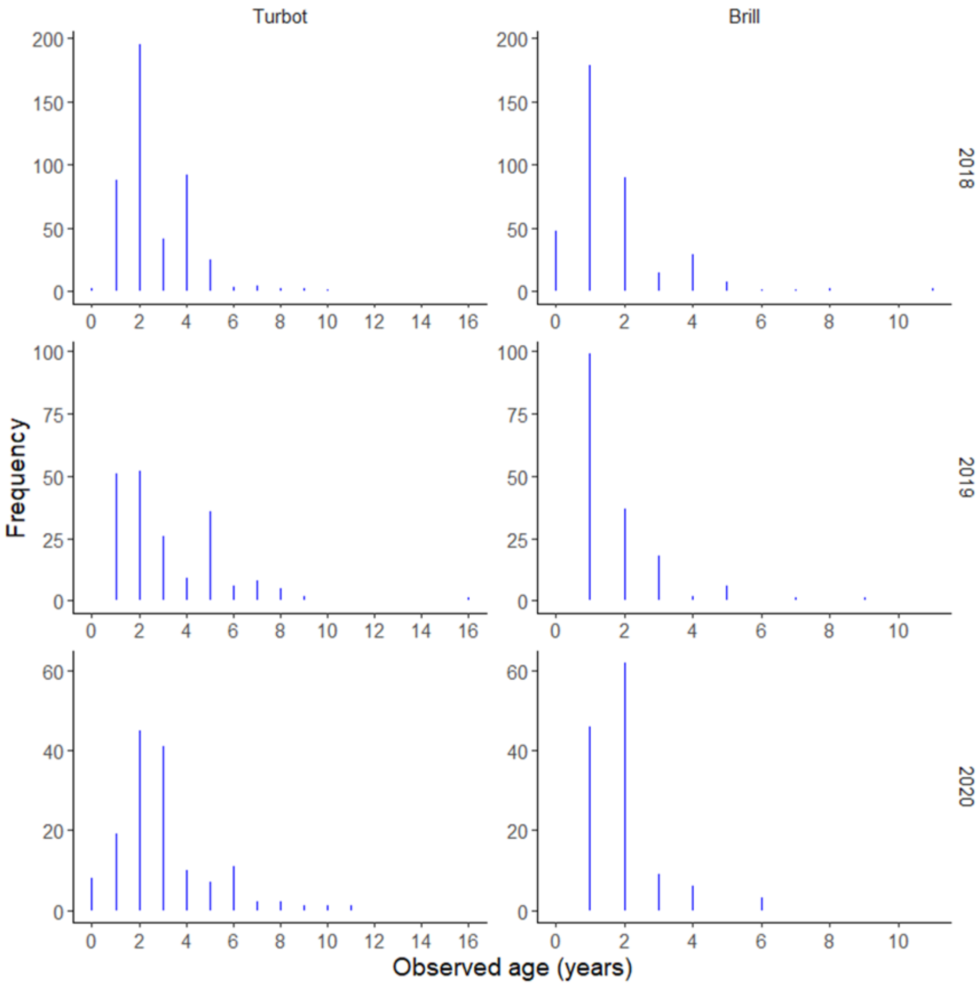

Figure 13. *Frequency plots displaying the distributions of the observed age by year and species. turbot is on the left, brill on the right. Each row is a different year (from top to bottom the years are 2018, 2019, and 2020).*

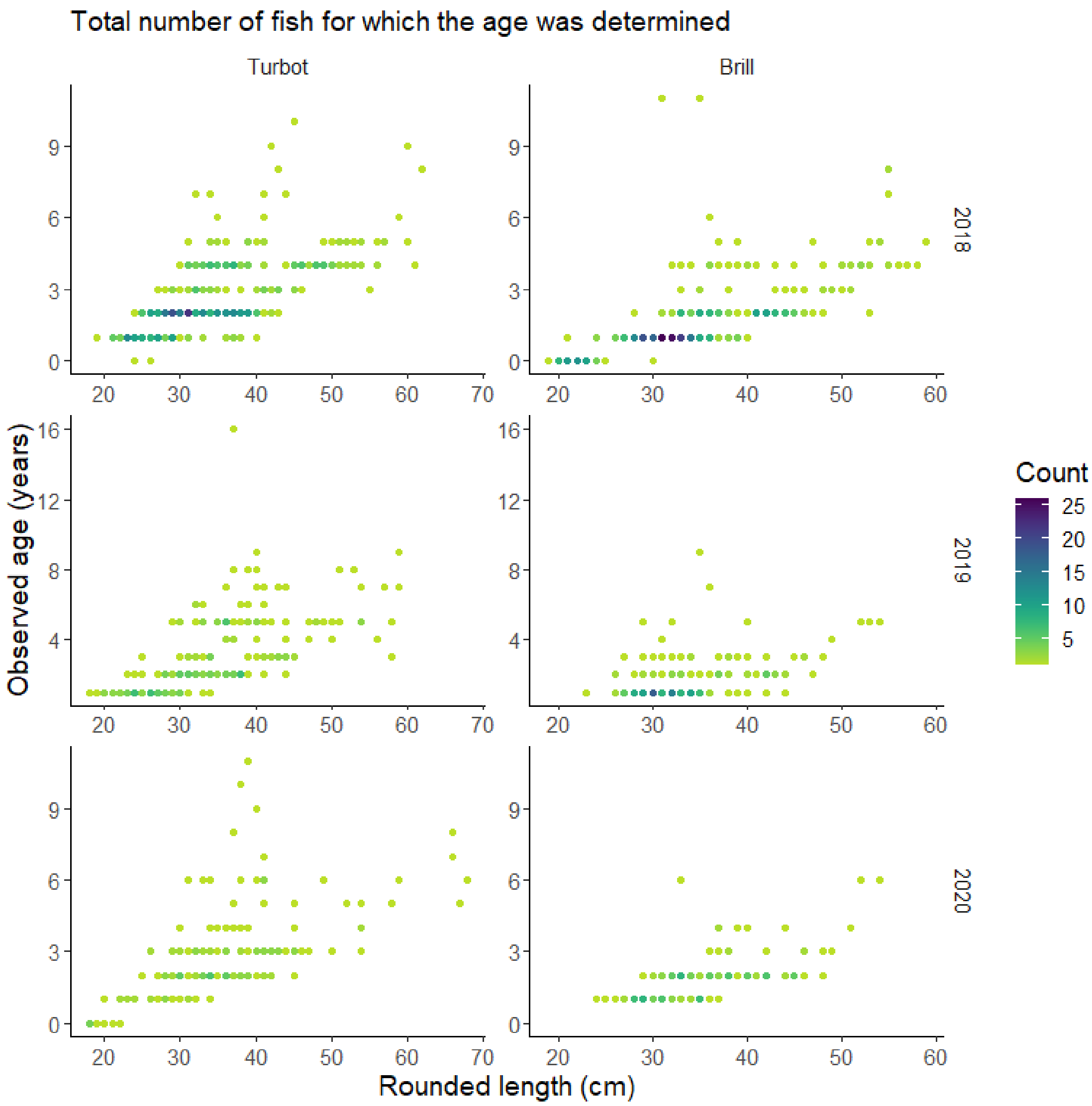

Figure 14. *The total number of fish for which age was determined for each age (in years) and each length (rounded to the nearest cm) for both turbot (left) and brill (right). The colour of a point indicates the total number of fish for each age and rounded length.*

3.2.4 Spatial-temporal distribution of survey locations

The mean length of all individuals caught by survey location is plotted in Figure 15. The plot shows a shift in catches of smaller, i.e. younger, individuals in the more coastal part of the survey area, whereas, bigger and older individuals are caught further away from the coast in deeper waters. This pattern is seen in all years. Between years there are no large differences in the overall mean length distribution.

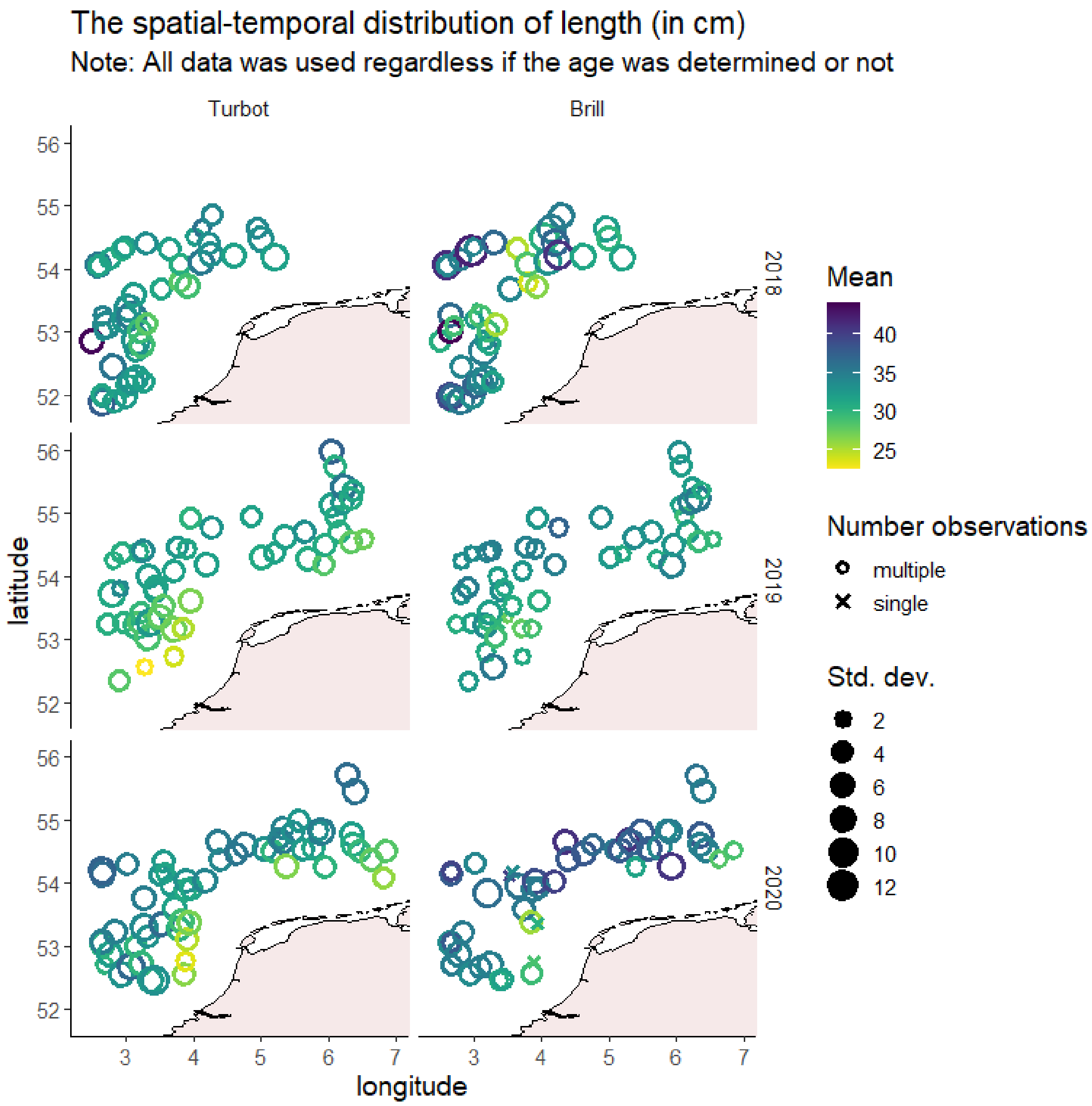

Figure 15. *Spatial-temporal distribution by length (cm) for all turbot (left) and brill (right) caught in the survey. Mean and standard deviation were calculated for each species, year, and 0.01 degrees C-Squares location. The colour indicates the mean length for a location, period, and species: the brighter (more yellow) the colour, the lower the mean, the darker (more purple) the colour, the higher the mean length. The size of the points indicates the standard deviation of the length for a location, period, and species: the larger the point, the larger the standard deviation. Some combinations of location, year, and species only had a single observation, and no standard deviation could be calculated. For those observations, an "X" is plotted instead of a circle.*

3.2.5 Outcomes ALK

Two methods to construct the ALK were used. The ALK using only proportions per length bin showed that certain age-length relations were missing. With a modelling approach we were able to fill in the age-length relations for missing length bins. Following this approach, each length gets a fixed age including age with decimal numbers (e.g. 3.6 years). For assessment purposes we are interested in tracking cohorts over time which means that we are interested in the birth year of an individual. If to be used in assessments numbers are rounded to the lowest rounded age. A fish of 3.6 years old will be categorized as 3 years old. To account for variability one could use a stochastic approach.

The procedure to create an age-structured index series from the BTS-ISIS was updated during the 2017 turbot interbenchmark (ICES, 2017). Previously, each individual fish caught was linked to an age–length key based on its length. The age–length key was based on all age samples in the BTS survey since 1991. The updated procedure first links the age of the individual fish from which the otoliths are taken to the length sample. This allows direct ageing of the fish in the index. Those fish for which no direct age sample is available are subsequently assigned to ages using the age–length key based on all fish in the survey period. Over time, the BSAS age data may complement the age data obtained from otoliths taken of turbot and brill within the existing surveys. By combining age data of the different surveys the accuracy of the age-length relation, in which for each length class the likelihood of being a certain age is determined, will increase. This is especially important to track the older part of the population over time. In addition, under the continuation of the industry survey in the future, a comprehensive time series on age-length information for both species in the North Sea can be developed. More analyses are needed to determine whether the BSAS ALK in itself is sufficient for future use in the assessments or a combined ALK is more appropriate. So far only two years of survey data are available which was deemed insufficient to create an index by age for the survey. This work will be taken up in a future project (provided funding is secured).

4 Conclusions and recommendations

4.1 Survey design

The evolution of the survey design during this project resulted in an appropriate and feasible design that provides a significant amount of data additional to already existing surveys. The survey design was presented and discussed at two meetings of the WGNSSK and the recommendations of this WG (ICES, 2019c; ICES, 2020) were implemented. The design is feasible because the survey area and the 60 survey stations can be covered by the three participating fishing vessels during regular commercial fishing weeks.

Further refinement of the survey design is possible provided this does not lead to a break in the time series of data build up hitherto. Further refinement may include additional removal of any still remaining unfishable grid cells. Expansion of the survey area and the number of participating vessels is worth pursuing as more data can then be collected.

The COVID-19 restrictions for observer trips forced us to develop an alternative method for the practical implementation of the survey design. The collection of survey fish by the fishermen instead of external researchers during the 2020 survey proved to be practically feasible and there were no indications of (noticeable) irregularities in sample collection. In other words, from a practical point of view the presence of researchers on-board does not seem to be a strict requirement for proper sample collection and data quality. As such, sample collection by fishermen could be part of future practical implementation of the survey design, also when current COVID-19 restrictions are no longer in place. However, the potential importance of sample collection by independent researchers should not be overlooked. Therefore the involvement of fishermen in sample collection should be implemented in liaison with relevant ICES working groups, the ultimate users of the data.

We conclude that the current survey design is appropriate and feasible and can be readily used for the continuation of BSAS.

4.2 Added value of the industry survey

Within the 2018 inter-benchmark for turbot it was decided to upgrade turbot in the North Sea to a category 1 stock (ICES, 2018a). The stock is assessed using an age-structured model (SAM), which relies on age-composition data from two fisheries-independent surveys (SNS and BTS-ISIS), commercial landings (discards currently not included), as well as a commercial LPUE index. Despite recent improvements in the assessment methodology, there is still considerable uncertainty in the input data which undermines the overall quality of the assessment.

The two main limitations in the assessment are the low sampling intensity (especially regarding age-length information) of the commercial catches and the poor quality of the two survey indices. The SNS is mainly an inshore survey performed in quarter 3 and designed to monitor flatfish; the Beam Trawl Survey (BTS-ISIS) is an offshore beam trawl survey also performed in quarter 3. Although both surveys have been carried out since 1969 and 1985, respectively, abundance indices for turbot are only available since 2004 and 1991, due to the lack of reliable age-length keys for the earlier period. Improving on these two aspects is an absolute prerequisite to ensure reliable assessments and sustainable exploitation of North Sea turbot.

This BSAS has the potential to provide better information on turbot because:

1) BSAS is conducted on a commercial vessel with commercial gear specifications and as such has a higher catchability of turbot compared to vessels and gears currently used for scientific surveys.
2) BSAS catches a larger age range (ages 1 to 9) compared to the current regular scientific surveys (mainly ages 1 to 4).

The quantitative contribution of BSAS to the data available for turbot and brill stock assessments seems evident. It can be concluded that BSAS provides a significant amount of data in addition to existing surveys. These data will help to counteract the lack of appropriate indices for turbot and brill from existing surveys and may increase the precision of the assessments. However, the added value of BSAS data in terms of differences in estimates of SSB and F in the assessments cannot be determined as this project yields only two years of usable data.

In addition to its quantitative contribution, the added value of an industry survey also lies in increasing fishers' confidence in (input data for) the assessment. Experiences with industry surveys in New England (USA) and The Netherlands show that involvement of fishers in the design and implementation of industry surveys contributes to growing support for management (DeCelles *et al.*, 2012; Van der Reijden *et al.*, 2015; De Boois *et al.*, in press).

4.3 Requirements for implementation in stock assessments

For the BSAS data to be applied in actual stock assessments, a minimum of five year time series of data is required as well as a successful benchmark by ICES. This project provided not more than the first two years of the time series. Continuation of the industry surveys is needed if data are to be used for assessment purposes. Assuming continuation of BSAS beyond this project, will require a yearly update on the survey design and data analysis. Such an update will firstly involve the stock coordinators of turbot and brill. It is important the coordinators are involved to keep track of the data gathering and processing as they will be in charge of incorporating the data into the assessments. Secondly, an annual update of the survey to the ICES North Sea, Skagerrak and Kattegat Working Group (WGNSSK) is needed. The annual reflections by WGNSSK on the survey design and collected data (ICES, 2019c; 2020) provide an external peer review and quality control that may facilitate the acceptance of the data as well as the process towards initiating the benchmark procedure. Given the required use of a five year time series of data this process will commence earliest in 2023. In this context, it is import to develop the age-structured index in advance (i.e. 2022) and make a trial assessment including the "new" index into the assessment. In 2023, age data for that year can be analysed and merged with the already existing BSAS catch data and age-based index. The "new" index can be presented in a data-compilation workshop before the actual benchmark which will probably be organised earliest in 2024 (Figure 16). Until then actual use of the data is uncertain. Overall, it can be concluded BSAS provides a significant amount of data in addition to existing surveys but the added value of BSAS data will only become clear when the index is included into the stock assessment (i.e. 2022).

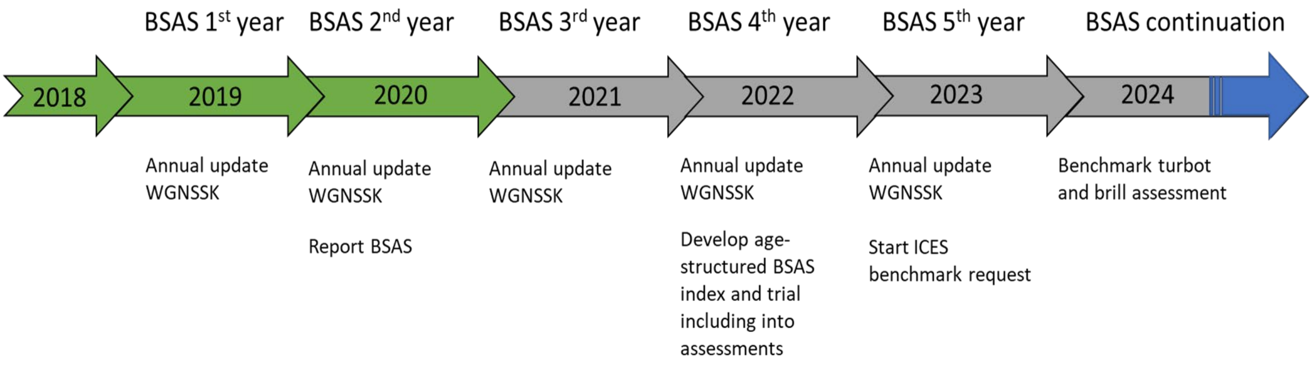

Figure 16. *Projected time line for the industry survey to be included in the turbot and brill assessments. The green arrows indicate the current project. The grey arrows indicate the required continuation phase. The blue arrow indicates the continuation of the industry survey beyond the 5-year time series.*

4.4 Collaboration

4.4.1 Science industry research collaboration

Wageningen Marine Research has a long history of collaborating with the Dutch demersal North Sea fleet. Over the years, this research collaboration evolved to include a focus on improving the knowledge base for data-limited species and fishers experiential knowledge. Another change was the employment of scientists by some of the fisheries associations (Steins *et al.,* 2020). The BSAS is an example where fishers experiential knowledge of fishing grounds and distribution of turbot and brill was used in: (a) the setup of this fisheries-independent industry survey, (b) the survey's initial design for year one (2018), and (c) subsequent adaptations to the initial design based on practical experiences while conducting the survey work. The collaboration between the scientists (WMR, VisNed) and the skippers and crew during preparations, the actual surveys and evaluations went smoothly. All meetings with skippers were well facilitated by the two fisheries associations (Nederlandse Vissersbond and VisNed). The participating vessels were compensated for loss of revenue by their fishery association, based on a comparable reference fishing vessels carrying out regular commercial operations.

The research collaboration was put to a real test following the Covid-19 outbreak. As it was not possible for the scientists and research assistants to join the vessels, the execution of BSAS was at risk. The skippers responded positively to the idea of an alternative set up, where they and the crew were responsible for carrying out the survey hauls, sorting the hauls, labeling and storing the catch from these hauls separately, with 'WhatsApp based assistance' from the cruise leader on shore. This meant the crew had to carry out additional work but, for both skippers and crew, also taking on responsibility for the correct collection of the data. The skippers explicitly expressed their appreciation for the trust the scientific team put in them. The data collection during the 'Covid-19 BSAS' went well and there are no indications that the absence of observers on board has significantly impacted the quality of the time-series. This provides opportunities in case future BSAS surveys have to be carried out again under pandemic conditions or to reduce costs (as scientific staff on board is expensive).

In science industry research collaboration, communication with participating fishers throughout all phases of the project is key (Johnson and Van Densen, 2007; Steins *et al.,* 2020). Communication with the skippers was done through live and online meetings (survey design, protocols, evaluation) and WhatsApp (logistics, additional questions following meetings, Covid-19 operations). It is also important to inform the non-participating fleet. To this end, short reports were written about the survey in the newsletters of the fisheries organizations and the Dutch Fishing News (*Visserijnieuws*). Fishing News also included an interview with participating skipper Jan Koffeman of UK284 about his motives for participating in the BSAS. In addition, social media (Facebook, Twitter) were used to show images from work on board during the surveys and, with help of the participating skippers, a short video was made about the 'Covid-19 BSAS' (https://www.youtube.com/watch?v=4w6IM22SEe8). Finally, an infographic about the survey was made (enclosed in Annex 2). All communications are also made available on the online educational platform for prospective and active fishers, Vistikhetmaar.nl These communications targeting the fishing fleet as well as a wider audience contribute to understanding of the importance of research collaboration and support for the survey amongst the fishing fleet in particular.

The skippers and crew are motivated to continue the BSAS in the next years. Also the fisheries associations, which in the past had reservations about improving the knowledge base for turbot and brill (Chapter 1), are fully committed to this survey and its continuation. A follow-up grant proposal for 3 years of further funding has been successfully submitted.

4.4.2 International Research partnership

The current turbot assessment is tuned using two survey abundance indices, the Sole Net Survey (SNS) and the Beam Trawl Survey (BTS ISIS), and one standardized commercial LPUE abundance index based on the Dutch 80 mm beam trawl fleet (BT2). In terms of commercial data, all North Sea countries submit their landings and discard data but age is only derived from landing samples taken by the Netherlands (2004 – present), Denmark (2014 – present) and more recently also Belgium (2017 – present). Prior to 2004, the landings-at-age information is from an old Dutch monitoring scheme from the 1980s. In this context one can conclude that the turbot assessment is strongly influenced by Dutch data.

The industry survey is run with Dutch vessels. It would be worthwhile to explore the option of extending the industry survey internationally. Other Member States with a commercial interest in turbot and brill would carry out a similar survey and would start to collect age information in order to estimate the age composition in their fisheries. Complementing the Dutch industry survey may lead to the implementation of improved data collection schemes, resulting in more accurate estimates of the age composition of turbot and brill catches.

4.5 Summarising conclusions and recommendations

- We conclude that the current survey design is appropriate and feasible and can be readily used for the continuation of BSAS.
- Further refinement of the survey design is appropriate under the condition that the time-series for data collection is not broken.
- BSAS provides data in addition to existing surveys but the added value of these data for stock assessments remains to be determined.
- The required number of otoliths that needs to be collected annually to construct ALKs should be reviewed following the expansion of the database to limit the use of experimental animals to a minimum.
- The construction of sex-specific ALKs should be considered. If it is decided to construct sex-specific ALKs, sex determination of all sampled fish should be adopted in the survey protocol. Note that this leads to an increase in the number of experimental animals.
- Continuation of the industry survey for a minimum of three years (until 2023) is needed to obtain a timeseries of at least five years as minimally required for use of the data in stock assessments.
- This continuation is also needed to successfully request an ICES benchmark to determine the added value of the industry survey data for the turbot and brill stock assessments and establish the need for continuation of the survey beyond 2023.

4.6 Acknowledgements

The authors would like to thank the following persons for their indispensable contributions to the set-up and execution of the industry survey for turbot and brill: the skippers, owners and crews of the participating fishing vessels OD17, UK64, UK284 and UK237; all Wageningen Marine Research, Nederlandse Vissersbond and VisNed staff who contributed. The Hollandse Visveiling IJmuiden B.V. for facilitating sample processing for the 2020 survey under COVID-19 restrictions. Lies van der Steenbrugge (ILVO) for contributing to the COVID-19 survey protocol. We also thank the ICES WGNSSK for their valuable feedback on the survey design and implementation throughout the project. This project was funded under a science-fisheries partnership grant (Partnerschappen Wetenschap en Visserij) under the Dutch Operational Programme of the European Maritime and Fisheries Fund.

5 Quality Assurance

Wageningen Marine Research utilises an ISO 9001:2015 certified quality management system. This certificate is valid until 15 December 2021. The organisation has been certified since 27 February 2001. The certification was issued by DNV GL.

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Justification

Report C037/21
Project Number: 4311400012

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: Ir. Ralf van Hal
Onderzoeker

Signature:

Date: 22 April 2021

Approved: Drs. Jakob Asjes
MT lid Integratie

Signature:

Date: 22 April 2021

Annex 1 Age-Length Keys (ALK)

Per year and species the ALKs constructed by calculating the proportion of ages within a length-bin (cm-classes).

ALK brill 2018

Length\Age	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
12	1	0	0	0	0	0	0	0	0	0	0	0
15	1	0	0	0	0	0	0	0	0	0	0	0
16	0.67	0.33	0	0	0	0	0	0	0	0	0	0
17	0.88	0.12	0	0	0	0	0	0	0	0	0	0
18	0.83	0.17	0	0	0	0	0	0	0	0	0	0
19	0.86	0.14	0	0	0	0	0	0	0	0	0	0
20	0.75	0.25	0	0	0	0	0	0	0	0	0	0
21	0.74	0.26	0	0	0	0	0	0	0	0	0	0
22	0.72	0.28	0	0	0	0	0	0	0	0	0	0
23	0.36	0.64	0	0	0	0	0	0	0	0	0	0
24	0.36	0.64	0	0	0	0	0	0	0	0	0	0
25	0.14	0.86	0	0	0	0	0	0	0	0	0	0
26	0	0.91	0.09	0	0	0	0	0	0	0	0	0
27	0	0.88	0.12	0	0	0	0	0	0	0	0	0
28	0	0.76	0.24	0	0	0	0	0	0	0	0	0
29	0.02	0.78	0.19	0.02	0	0	0	0	0	0	0	0
30	0	0.53	0.42	0.03	0.01	0	0	0	0	0	0	0.01
31	0	0.46	0.46	0.05	0.04	0	0	0	0	0	0	0
32	0	0.42	0.42	0.09	0.08	0	0	0	0	0	0	0
33	0	0.41	0.34	0.1	0.14	0.02	0	0	0	0	0	0
34	0	0.29	0.4	0.1	0.17	0.02	0	0	0	0	0	0.02
35	0	0.21	0.47	0.16	0.16	0	0	0	0	0	0	0
36	0	0.23	0.5	0.02	0.18	0.05	0.02	0	0	0	0	0
37	0	0.18	0.36	0.09	0.16	0.11	0.07	0	0.02	0.02	0	0
38	0	0.12	0.24	0.12	0.24	0.16	0.08	0	0.04	0	0	0
39	0	0.09	0.5	0.06	0.21	0.06	0.06	0.03	0	0	0	0
40	0	0.05	0.75	0.05	0.15	0	0	0	0	0	0	0
41	0	0	0.76	0.1	0.1	0	0	0.05	0	0	0	0
42	0	0	0.55	0.29	0.13	0.03	0	0	0	0	0	0
43	0	0	0.59	0.33	0.07	0	0	0	0	0	0	0
44	0	0	0.42	0.31	0.15	0.08	0	0	0.04	0	0	0
45	0	0	0.26	0.22	0.44	0.07	0	0	0	0	0	0
46	0	0	0.16	0.36	0.36	0.08	0	0	0	0	0.04	0
47	0	0	0.03	0.3	0.55	0.12	0	0	0	0	0	0
48	0	0	0.05	0.1	0.75	0.1	0	0	0	0	0	0
49	0	0	0	0.11	0.79	0.11	0	0	0	0	0	0
50	0	0	0	0.2	0.53	0.23	0	0.03	0	0	0	0
51	0	0	0	0.03	0.59	0.28	0.03	0	0.07	0	0	0
52	0	0	0	0.04	0.73	0.12	0.08	0	0.04	0	0	0
53	0	0	0.04	0	0.6	0.28	0.04	0	0	0	0.04	0

54	0	0	0	0	0.25	0.35	0.05	0.15	0.15	0.05	0	0
55	0	0	0	0	0.5	0.14	0.14	0	0.14	0.07	0	0
56	0	0	0	0	0.36	0.21	0.14	0.07	0.14	0	0.07	0
57	0	0	0	0.12	0.12	0.12	0.12	0.38	0	0.12	0	0
58	0	0	0	0	0.25	0	0	0.25	0.25	0.25	0	0
59	0	0	0	0	0.2	0.4	0	0	0.2	0.2	0	0
61	0	0	0	0	0	0	0	0	1	0	0	0
66	0	0	0	0	0	0	0	0	0	0	1	0
67	0	0	0	0	0	0	0	0	0	0	1	0

ALK brill 2019

Length\Age	**1**	**2**	**3**	**4**	**5**	**7**	**9**
23	1	0	0	0	0	0	0
25	1	0	0	0	0	0	0
26	0.5	0.5	0	0	0	0	0
27	0.6	0.2	0.2	0	0	0	0
28	0.82	0.06	0.06	0	0.06	0	0
29	0.88	0.12	0	0	0	0	0
30	0.8	0.13	0.07	0	0	0	0
31	0.67	0.11	0.11	0.06	0.06	0	0
32	0.69	0.25	0.06	0	0	0	0
33	0.91	0	0.09	0	0	0	0
34	0.7	0.1	0.1	0	0	0	0.1
35	0.83	0.17	0	0	0	0	0
36	0.14	0.57	0.14	0	0	0.14	0
37	0	1	0	0	0	0	0
38	0.25	0.25	0.5	0	0	0	0
39	0.33	0.33	0.17	0	0.17	0	0
40	0	0.5	0.5	0	0	0	0
41	0.33	0.67	0	0	0	0	0
42	0	0.83	0.17	0	0	0	0
43	0.33	0.67	0	0	0	0	0
44	0	1	0	0	0	0	0
45	0	0	1	0	0	0	0
47	0	0.5	0.5	0	0	0	0
49	0	0	0	1	0	0	0
51	0	0	0	0	1	0	0
52	0	0	0	0	1	0	0
54	0	0	0	0	1	0	0

ALK brill 2020

Length\Age	**1**	**2**	**3**	**4**	**6**
24	1	0	0	0	0
25	1	0	0	0	0
26	1	0	0	0	0
27	1	0	0	0	0
28	1	0	0	0	0
29	0.89	0.11	0	0	0
30	0.57	0.43	0	0	0
31	0.56	0.44	0	0	0
32	0.33	0.67	0	0	0
33	0.25	0.62	0	0	0.12
34	0.5	0.5	0	0	0
35	0.56	0.33	0.11	0	0
36	0.12	0.75	0	0.12	0
37	0	0.4	0.4	0.2	0
38	0	0.83	0.17	0	0
39	0	0.67	0	0.33	0
40	0	1	0	0	0
41	0	1	0	0	0
42	0	0.75	0.25	0	0
43	0	0.67	0	0.33	0
44	0	1	0	0	0
45	0	0.67	0.33	0	0
46	0	0	1	0	0
47	0	1	0	0	0
48	0	0	1	0	0
49	0	0	1	0	0
51	0	0	0	1	0
52	0	0	0	0	1
53	0	0	0	0	1

ALK turbot 2018

Length\Age	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
10	1	0	0	0	0	0	0	0	0	0	0	0	0	0
11	1	0	0	0	0	0	0	0	0	0	0	0	0	0
12	1	0	0	0	0	0	0	0	0	0	0	0	0	0
13	1	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	1	0	0	0	0	0	0	0	0	0	0	0	0
15	0	1	0	0	0	0	0	0	0	0	0	0	0	0
16	0	1	0	0	0	0	0	0	0	0	0	0	0	0
17	0	1	0	0	0	0	0	0	0	0	0	0	0	0
18	0	1	0	0	0	0	0	0	0	0	0	0	0	0
19	0	1	0	0	0	0	0	0	0	0	0	0	0	0
20	0	1	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0.93	0.07	0	0	0	0	0	0	0	0	0	0	0
22	0	0.89	0.11	0	0	0	0	0	0	0	0	0	0	0
23	0	0.74	0.22	0.04	0	0	0	0	0	0	0	0	0	0
24	0.04	0.38	0.58	0	0	0	0	0	0	0	0	0	0	0
25	0	0.39	0.54	0.04	0	0.04	0	0	0	0	0	0	0	0
26	0.02	0.33	0.61	0.02	0	0	0.02	0	0	0	0	0	0	0
27	0	0.15	0.74	0.08	0.03	0	0	0	0	0	0	0	0	0
28	0	0.13	0.74	0.07	0.03	0.03	0	0	0	0	0	0	0	0
29	0	0.1	0.65	0.15	0.08	0.01	0	0	0	0	0	0	0	0
30	0	0.04	0.6	0.15	0.15	0.05	0	0	0	0	0	0	0	0
31	0	0.02	0.48	0.18	0.24	0.05	0.02	0.02	0	0	0	0	0	0
32	0	0	0.36	0.22	0.27	0.09	0.02	0.03	0.02	0	0	0	0	0
33	0	0.04	0.32	0.19	0.4	0.04	0.02	0	0	0	0	0	0	0
34	0	0	0.31	0.08	0.41	0.17	0.02	0.02	0	0	0	0	0	0
35	0	0.02	0.41	0.12	0.24	0.17	0	0	0.03	0	0	0	0	0
36	0	0.05	0.35	0.19	0.33	0.07	0	0.02	0	0	0	0	0	0
37	0	0.06	0.42	0.14	0.33	0.03	0	0	0.03	0	0	0	0	0
38	0	0.04	0.42	0.12	0.2	0.14	0.04	0.02	0	0	0.02	0	0	0
39	0	0.03	0.3	0.09	0.27	0.24	0	0	0	0.03	0	0	0	0.03
40	0	0	0.13	0.22	0.35	0.17	0.09	0.04	0	0	0	0	0	0
41	0	0	0.1	0.34	0.38	0.1	0	0	0.03	0	0	0.03	0	0
42	0	0	0.04	0.52	0.36	0.04	0	0	0	0.04	0	0	0	0
43	0	0	0.04	0.43	0.3	0.04	0	0.04	0.04	0.04	0	0	0	0.04
44	0	0	0	0.19	0.73	0.04	0	0	0	0	0.04	0	0	0
45	0	0	0	0.12	0.88	0	0	0	0	0	0	0	0	0
46	0	0	0	0.12	0.79	0.06	0.03	0	0	0	0	0	0	0
47	0	0	0	0.07	0.73	0.17	0	0.03	0	0	0	0	0	0
48	0	0	0.02	0.02	0.66	0.24	0.02	0.02	0	0	0	0	0	0
49	0	0	0	0.03	0.65	0.26	0.03	0.03	0	0	0	0	0	0
50	0	0	0	0.04	0.64	0.32	0	0	0	0	0	0	0	0
51	0	0	0	0	0.42	0.38	0.12	0.08	0	0	0	0	0	0
52	0	0	0	0.03	0.44	0.33	0.08	0	0.08	0.03	0	0	0	0
53	0	0	0	0	0.51	0.37	0.09	0.03	0	0	0	0	0	0
54	0	0	0	0.03	0.16	0.5	0.19	0.03	0.09	0	0	0	0	0
55	0	0	0	0	0.19	0.42	0.13	0.19	0.06	0	0	0	0	0
56	0	0	0	0.04	0.26	0.35	0.13	0.04	0.04	0.09	0.04	0	0	0
57	0	0	0	0	0.06	0.47	0.12	0.18	0.06	0.06	0	0	0.06	0

58	0	0	0	0	0.06	0.17	0.11	0.39	0.22	0	0.06	0	0	0
59	0	0	0	0	0.06	0.17	0.22	0.11	0.44	0	0	0	0	0
60	0	0	0	0	0	0.06	0.31	0.25	0.12	0.12	0.06	0	0	0.06
61	0	0	0	0	0.08	0.08	0.15	0.31	0.23	0.15	0	0	0	0
62	0	0	0	0	0	0.2	0	0.2	0.4	0	0.2	0	0	0
63	0	0	0	0	0	0	0.11	0.33	0.22	0	0.22	0	0	0.11
64	0	0	0	0	0	0	0	0	0.33	0	0.33	0	0.33	0
65	0	0	0	0	0	0	0	0.25	0	0.25	0.25	0	0	0.25
67	0	0	0	0	0	0	0	0	0	1	0	0	0	0
68	0	0	0	0	0	0	0	0	1	0	0	0	0	0
69	0	0	0	0	0	0	0	0	1	0	0	0	0	0
76	0	0	0	0	0	0	0	1	0	0	0	0	0	0

ALK turbot 2019

Length\Age	1	2	3	4	5	6	7	8	9	16
18	1	0	0	0	0	0	0	0	0	0
19	1	0	0	0	0	0	0	0	0	0
20	1	0	0	0	0	0	0	0	0	0
21	1	0	0	0	0	0	0	0	0	0
22	1	0	0	0	0	0	0	0	0	0
23	0.67	0.33	0	0	0	0	0	0	0	0
24	1	0	0	0	0	0	0	0	0	0
25	0.71	0.14	0.14	0	0	0	0	0	0	0
26	1	0	0	0	0	0	0	0	0	0
27	0.57	0.43	0	0	0	0	0	0	0	0
28	0.62	0.38	0	0	0	0	0	0	0	0
29	0.44	0.44	0	0	0.11	0	0	0	0	0
30	0.2	0.5	0.1	0	0.2	0	0	0	0	0
31	0	0.38	0.5	0	0	0.12	0	0	0	0
32	0	0.56	0.11	0	0.11	0.22	0	0	0	0
33	0.1	0.3	0.3	0	0.3	0	0	0	0	0
34	0.14	0.43	0.14	0	0.29	0	0	0	0	0
35	0	0.44	0	0	0.56	0	0	0	0	0
36	0	0.4	0	0.2	0.3	0	0.1	0	0	0
37	0	0.44	0	0.22	0	0.11	0	0.11	0	0.11
38	0	0.56	0.11	0	0.22	0	0	0.11	0	0
39	0	0.17	0.17	0	0.5	0.17	0	0	0	0
40	0	0.11	0.11	0.11	0.22	0.11	0.11	0.11	0.11	0
41	0	0	0.75	0	0	0	0.25	0	0	0
42	0	0	0.5	0	0.5	0	0	0	0	0
43	0	0	0.57	0.14	0	0	0.29	0	0	0
44	0	0.25	0.5	0	0.25	0	0	0	0	0
45	0	0	1	0	0	0	0	0	0	0
46	0	0	0	0	1	0	0	0	0	0
47	0	0	0	0.5	0.5	0	0	0	0	0
48	0	0	0	0	1	0	0	0	0	0
49	0	0	0	0.5	0.5	0	0	0	0	0
50	0	0	0	0	0.67	0	0	0.33	0	0
52	0	0	0	0	0	0	0	1	0	0
53	0	0	0	0	0.5	0	0.5	0	0	0
54	0	0	0	0	1	0	0	0	0	0
55	0	0	0	1	0	0	0	0	0	0
57	0	0	0	0	0.5	0	0.5	0	0	0
58	0	0	0.5	0	0	0	0.5	0	0	0
59	0	0	0	0	0	0	0	0	1	0

ALK turbot 2020

Length\Age	0	1	2	3	4	5	6	7	8	9	10	11
17	1	0	0	0	0	0	0	0	0	0	0	0
18	1	0	0	0	0	0	0	0	0	0	0	0
19	1	0	0	0	0	0	0	0	0	0	0	0
20	0.5	0.5	0	0	0	0	0	0	0	0	0	0
21	0.5	0.5	0	0	0	0	0	0	0	0	0	0
22	0	1	0	0	0	0	0	0	0	0	0	0
23	0	1	0	0	0	0	0	0	0	0	0	0
24	0	1	0	0	0	0	0	0	0	0	0	0
25	0	0.5	0.5	0	0	0	0	0	0	0	0	0
26	0	0.25	0.25	0.5	0	0	0	0	0	0	0	0
27	0	0.5	0.5	0	0	0	0	0	0	0	0	0
28	0	0.43	0.29	0.29	0	0	0	0	0	0	0	0
29	0	0.33	0.5	0	0.17	0	0	0	0	0	0	0
30	0	0.12	0.5	0.38	0	0	0	0	0	0	0	0
31	0	0.33	0.17	0.33	0	0	0.17	0	0	0	0	0
32	0	0	0.62	0.38	0	0	0	0	0	0	0	0
33	0	0	0.57	0.29	0	0	0.14	0	0	0	0	0
34	0	0.12	0.38	0.12	0.25	0	0.12	0	0	0	0	0
35	0	0	0.67	0.17	0.17	0	0	0	0	0	0	0
36	0	0	0.5	0.33	0	0.17	0	0	0	0	0	0
37	0	0	0.29	0.29	0.14	0	0.14	0	0.14	0	0	0
38	0	0	0.4	0.2	0.2	0	0	0	0	0	0.2	0
39	0	0	0.57	0	0.14	0	0.14	0	0	0	0	0.14
40	0	0	0.11	0.56	0	0	0.11	0.11	0	0.11	0	0
41	0	0	0.29	0.29	0	0.14	0.29	0	0	0	0	0
42	0	0	0.25	0.75	0	0	0	0	0	0	0	0
43	0	0	0	1	0	0	0	0	0	0	0	0
44	0	0	0	0.75	0.25	0	0	0	0	0	0	0
45	0	0	0.25	0.5	0	0.25	0	0	0	0	0	0
47	0	0	0	1	0	0	0	0	0	0	0	0
49	0	0	0	0	0	0	1	0	0	0	0	0
50	0	0	0	1	0	0	0	0	0	0	0	0
51	0	0	0	0	0	1	0	0	0	0	0	0
53	0	0	0	0.33	0.67	0	0	0	0	0	0	0
54	0	0	0	0	0	1	0	0	0	0	0	0
57	0	0	0	0	0	1	0	0	0	0	0	0
58	0	0	0	0	0	0	1	0	0	0	0	0
65	0	0	0	0	0	0	0	1	0	0	0	0
66	0	0	0	0	0	0	0	0	1	0	0	0
67	0	0	0	0	0	1	0	0	0	0	0	0
68	0	0	0	0	0	0	1	0	0	0	0	0

Annex 2 Infographic Industry Survey

With knowledge, independent scientific research and advice, **Wageningen Marine Research** substantially contributes to more sustainable and more careful management, use and protection of natural riches in marine, coastal and freshwater areas.

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