Fishing for knowledge:
A pilot industrial survey for associated species

A project by Ekofish Group, IMARES, The North Sea Foundation and WWF-Netherlands

Final project report
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1 INTRODUCTION

1.1 Project background

Mixed fisheries management is big on the EU agenda. The reformed Common Fisheries Policy requires stocks of all commercial species to be managed above levels that can produce the maximum sustainable yield (MSY) by 2020. This is also required to achieve Good Environmental Status by 2020, as specified under the EU’s Marine Strategy Framework Directive. This requirement also applies to commercial by-catch species. For the North Sea flatfish fishery targeting plaice and sole, this concerns associated species such as brill, dab, lemon sole and turbot. In order to meet these management goals in a mixed fisheries context, the Commission, together with the Member States and Advisory Councils, is exploring how the management of demersal harvested species can be brought together into a single mixed fisheries management plan for the North Sea.

To manage fish stocks at MSY and develop effective (mixed) fisheries long term management plans, requires a sound understanding of the status of the impacted stocks. However, for many commercially exploited by-catch species, including North Sea dab, brill, lemon sole and turbot, such comprehensive information is not available. These ‘data-limited species’ are assessed by ICES using data limited stock assessment approaches.

To compensate for the uncertainty in these assessments, managers apply extra precaution when setting the associated TACs. In practice, this can imply that annual TACs are frozen or reduced. Under the landing obligation, this potentially frustrates fishing opportunities for the target species of mixed fisheries. Therefore, to develop optimal harvest strategies for mixed fisheries whilst managing associated species sustainably scientific knowledge of these stocks needs to improve. A more profound understanding of the resource will also improve prospects for MSC certification for these commercial by-catch species. In a market where demand for MSC certified products is growing this could prove essential to secure market access for businesses.

Against this background, the EKOFISH Group, the North Sea Foundation (NSF) and WWF-Netherlands partnered up with IMARES in 2013 to explore whether an industrial survey can be used to strengthen scientific assessment of key commercial by-catch species in the North Sea flatfish fishery. Several industrial surveys are already being performed, however these focus on commercial target species. In an earlier, explorative study by IMARES (Quirijn and Miller, 2011), it was suggested that industrial surveys could also be used to improve data collection and stock assessment opportunities for data-limited species. The current project was used to explore this in depth and to develop and test a survey design, focusing on the four most important commercial by-catch species in the North Sea plaice twin-rig fishery: brill (Scophthalmus rhombus), dab (Limanda limanda), lemon sole (Microstomus kitt) and turbot (Scophthalmus maximus).

1 The Netherlands (sole and plaice), Denmark (cod), UK (cod), Norway (ling, blue ling, tusk).

1.2 Project aims and activities

The overarching aim of this project is to contribute to better management of by-catch species in the North Sea flatfish fishery by exploring whether and how an industrial survey can improve stock assessment of North Sea brill, dab, lemon sole and turbot. To answer this, the project was broken down in two consecutive phases, which were carried out between January 2014 and January 2015.

The first phase of the project served to establish the potential role of an industrial survey by identifying the information needs for an analytical stock assessment for North Sea brill, dab, lemon sole and turbot. This was explored through desk research by IMARES and NSF in spring 2014 and involved close examination of the data already collected for these species under the EU’s Data Collection Framework (DCF). Based on this, conclusions were drawn about the relevance of an industrial survey. Recommendations were made for survey design. The research done in the context of project phase I has been reported by IMARES and NSF in Doeksen and van der Reijden (2014).

The second phase of the project was used to run a pilot-survey and served to determine the practical feasibility of an industrial survey and to test whether and how the survey improves data collection and stock assessment opportunities for these species. A pilot-survey was designed for the EKOFISH GROUP twin-rig vessel PD147 “Enterprise” and was tested in September/October 2014. The data collected during these weeks was processed and analysed by IMARES and compared to data collected during a research vessel survey carried out under the DCF. The research done in the context of project phase II has been reported by IMARES in Reijden et al. (2015).

1.3 This report

This report synthesises the findings of the research that was carried out in phase one and two of the project (chapter 2 and 3 respectively). The final chapter (chapter 4) takes a helicopter view and discusses the main findings to give answer to the main question that has guided this research project ‘can an industrial survey for North Sea brill, dab, lemon sole and turbot strengthen scientific assessment of these stocks?’.
2 Explorer the need for an industrial survey

To assess the relevance of an industrial survey for brill, dab, lemon sole and turbot, phase one of the project researched the information gap for each of these species. This gap can be conceptualized as the discrepancy between the data that is already available through ongoing data collection programs and the data inputs required to perform an analytical assessment. To contextualize the research findings, this chapter begins with a brief introduction to analytical stock assessments and the role of surveys therein.

2.1 Analytical stock assessment and data demands

To manage a stock at MSY and determine biological and MSY reference points, an analytical stock assessment is required. An analytical stock assessment estimates absolute population size (biomass) and fishing mortality. The type of model that is used by the International Council for the Exploration of the Sea (ICES) to perform an analytical stock assessment is called a 'Virtual Population Analysis model' (a VPA model). The VPA assessment model uses catch-at-age information (catch specified by age) and information about the natural mortality to reconstruct the size and composition of a population at a specific historical point in time. The idea behind this approach is that, by knowing how many fish died (due to fisheries and natural causes) you can back-calculate how many fish were once present in the sea.²

Catch-at-age information is derived from landings data. Landings are aged using a so-called 'age-length key' (the ALK). The ALK is derived from biological data and establishes the relationship between length and age. Of course, not every fish that is landed is individually measured and aged. Instead, a representative sample is taken from the landings and this sample is used to estimate the age composition of the total reported landings. Under the EU's Data Collection Framework (DCF), all member states are required to carry out such market sampling. Due to discarding, catches are not always equivalent to landings. Therefore, for species with high discards relative to landings (such as dab), age-structured discard data is required in addition to landings data to construct the catch-at-age data series. To estimate discards, member states run discard sampling programmes.

Because a VPA model cannot accurately estimate population abundance in the most recent years, catch-success time series are used to calibrate model estimates of the most recent years. Catch-success time series are based on catch and effort data, where catch-success is expressed as catch per unit of fishing effort (CPUE). CPUE is also referred to as the 'catch rate.' Catch-success is an index for relative population abundance and is used to monitor how a population develops over time (an increasing CPUE value indicates a growing population).

² A very instructive and concise guide to stock assessments has been written by ProSea. This brochure is available from their website at: www.prosea.info

For data-limited species, catch-success time series are used to evaluate population trends and provide qualitative catch advice. In a VPA model, catch-success time series are used to determine, for the most recent years, which model estimate is the best (i.e. is most likely to represent the true development of the stock). Catch-success time series are constructed using catch and effort data from research vessel surveys (see next section) or using data from commercial vessels. In the latter case, the abundance index is usually based on reported landings rather than catches and expressed as landings per unit effort (LPUE).

2.2 Role of (industrial) surveys

Over time, fishers adapt their fishing grounds, gear and methods. Therefore, commercial LPUE series can give misleading impressions of population trends. A population decline can for instance be masked when fishers find more efficient ways of fishing. In this case the LPUE may go up, suggesting that the population is growing whilst in reality the population is declining or stable. Also for species with high discard rates (such as dab) LPUE series can be misleading. For this reason, fishery independent, survey-based CPUE series are often preferred over LPUE series as a relative abundance index.

Surveys are scientific monitoring programmes to monitor stock developments and collect biological information for stock assessment purposes. Unlike commercial fishing, surveys are standardised and randomised, meaning that they are carried out each year in the same way, with the same gear, at the same towing speed, and across the entire distribution of the stock, at locations that are randomly selected. Surveys are usually carried out on board research vessels (referred to here as ‘research vessel surveys’). Under the EU’s Data Collection Framework, several fisheries-independent research vessel surveys are run. The four surveys that are relevant for demersal species in the North Sea are: the (North Sea) International Bottom Trawl Survey, the Beam Trawl Survey, the Demersal Young Fish Survey and the Sole Net Survey (see text boxes).

The International Beam Trawl Survey (IBTS).

The International Bottom Trawl Survey (IBTS) in the North Sea is an internationally coordinated research vessel survey for groundfish. It involves eight countries, each running their own (but standardized) IBTS survey. The IBTS uses otter trawl gear and covers the entire North Sea. The IBTS serves to provide consistent and standardised data for examining spatial and temporal changes in the distribution and relative abundance of fish stocks and for developing biological parameters of commercial fish species for stock assessment purposes. As part of this, the IBTS collects data on young fish (to develop recruitment indices) and hydrographical and environmental information. The IBTS is not designed to catch flatfish species, therefore catches of brill and turbot are low. Lemon sole and dab are caught more frequently in this survey as they are more abundant in the North Sea than brill and turbot.
The offshore Beam Trawl Survey (BTS)
The offshore Beam Trawl Survey (BTS) is a Dutch research vessel survey for sole and plaice. It covers the entire North Sea (offshore) and is carried out in the 3rd quarter of every year by two research vessels both using an 8m beam trawl with 40mm meshes. The survey was originally set up (in 1985) to develop fisheries independent abundance indices for plaice and sole, but the BTS collects data on all species caught, including lemon sole, dab, brill and turbot. Although similar surveys are run by Belgium and Germany in the North Sea, the international surveys are not standardised and the data are not integrated.

The Demersal Young Fish Survey (DYFS) and Sole Net Survey (SNS)
The Demersal Young Fish Survey (DYFS) and the Sole Net Survey (SNS) are Dutch research vessel surveys for juvenile flatfish. Both surveys have been carried out annually since 1969. The DYFS uses shrimp beam trawl gear and covers the Dutch shallow coastal zone and inshore waters. It targets juvenile sole and plaice and monitors distribution patterns and changes in the abundance of 0-year sole and plaice. It also collects data for brown shrimp and other fish and invertebrate species in the catch. The DYFS is run in collaboration with Germany and Belgium, who survey German and Belgian coastal waters. The SNS targets 1-4 year old sole and plaice with beam trawl gear and covers the deeper coastal zone. The juvenile abundance indices of these surveys are used to predict stock developments and to calibrate analytical stock assessment models. These surveys also serve to monitor trends in non-commercial fish species. Both surveys catch turbot and brill frequently and age readings are performed.

Industrial survey
Recently surveys are also being carried out on commercial vessels - with fishers. Like the research vessel surveys, these industrial surveys are standardized and randomized and fishing takes place according to a scientific protocol. Industrial surveys are used to provide additional CPUE data that complement CPUE series of the research vessel surveys. Industrial surveys can be particularly meaningful for species that are poorly covered by research vessel surveys. Because most research vessel surveys are designed to monitor commercial target species (e.g. sole and plaice), secondary commercial species (lemon sole, turbot, brill) tend to be under-represented in these surveys. In this case, a targeted industrial survey, designed especially to monitor these secondary species, presents an opportunity to improve data collection and stock assessment for these species.

There is an industrial survey for plaice and sole in the North Sea, operated by the Dutch industry since 2011. This survey is carried out on board two commercial vessels: a traditional beam trawler and a pulse trawl vessel. Both use 80mm cod end meshes. The survey samples the southern North Sea, the German Bight and the Dogger Bank. Length and age data are collected for plaice and sole. The purpose of the survey is to strengthen sole and plaice stock assessments and to promote industry confidence in scientific stock assessment. This survey does not collect information on by-catch species such as lemon sole, dab, turbot and brill.

2.3 Information gap and relevance of an industrial survey

Dab
To assess dab and provide catch advice, ICES applies a data limited assessment approach. This assessment is based on catch-success time series and is indicative of population trends. No analytical assessment is currently performed for dab.

Dab is covered well in both the BTS and the IBTS surveys, so there are abundance indices available for dab. Therefore, it was concluded from this explorative study that an industrial survey for dab is redundant. The main obstacle to perform an (VPA based) assessment for dab is the high discard ratio: Dab is a typical by-catch species, but because of its low market value is prone to discarding. Depending on the métier, discard ratios can be up to 90% of the total dab catches. Because dab discards are high relative to the landings, an accurate catch-at-age series for dab relies heavily on discard information. This is problematic because discard estimates are based on sampling and therefore contain large margins of uncertainty. Catch-at-age series of species with a high discard rate (such as dab) will therefore be much less precise than those of species with a low discard rate (such as sole). Another issue that complicates an analytical assessment for dab is the missing historical discard data (prior to 2009). Although coverage of dab in discard sampling programmes has improved since 2009, it will take several years of data collection before a sufficiently long catch-at-age series can be constructed and a VPA-based assessment for this long-lived species can be done. To get around this problem, an option is to develop a model that reconstructs this missing historical data.

Brill
To assess brill and provide catch advice, ICES applies a data limited assessment approach. This assessment is based on catch-success time series and is indicative of population trends. No analytical assessment is currently performed for brill.

Brill catches in the research vessel surveys (IBTS and the BTS) are low, especially for the older/larger brill. This results in inaccurate and incomplete CPUE time series. Because of the low brill catches in the research vessel surveys, biological information is also poor for brill. Discarding is assumed to be very low for brill, relative to landings. Therefore, landings are assumed to give a good enough representation of the catches.

Despite the inaccuracy of the CPUE series, it was concluded from this explorative study that enough information is already available to perform an analytical stock assessment for brill. Nevertheless, an industrial survey that covers the full age spectrum of the stock with higher catches per age class will improve the CPUE series and hence the accuracy of the population trends estimates. Therefore, an industrial survey designed to catch brill, was considered worth exploring. This survey must take into consideration that brill is a species that occurs at low abundance over a large area.
Lemon sole
To assess lemon sole and provide catch advice, ICES applies a data limited assessment approach. This assessment is based on catch-success time series and is indicative of population trends. No analytical assessment is currently performed for lemon sole.

Although the BTS survey catches larger numbers of lemon sole (especially in the northern areas), ICES currently uses IBTS survey data to assess the stock. Even though the BTS catches good numbers of lemon sole, neither IBTS nor BTS catch juvenile lemon sole. This also applies to the DYFS and SNS surveys. This is due to the spatial distribution of juvenile lemon sole. However, if the survey catches a wide range of ages, missing data on juveniles should not be a problem: There are numerous stocks for which an analytical assessment is performed but that lack data on juveniles. Discarding is assumed very low for lemon sole, relative to landings. Landings are therefore assumed to give a good enough representation of the catches.

It was therefore concluded from this explorative study that enough information is already available to perform an analytical stock assessment for lemon sole. Nonetheless, an industrial survey generates additional biological data and a second CPUE series that could be used for calibration in the analytical assessment. An industrial survey for lemon sole was however not considered a priority.

Turbot
In 2013, ICES performed the first analytical stock assessment for turbot. This model uses age-structured landings data, two survey-based CPUE series (BTS and SNS) and a commercial LPUE series to calibrate the model. Turbot discards are low, so landings can be assumed representative of the catch.

Because turbot occurs in low abundance over a large area, both the SNS and the BTS catch low numbers of turbot. This results in an inaccurate CPUE time series. Secondly, biological data for turbot (for instance the length-age relationship) is poor. For these reasons ICES still considers this stock as data-limited and the analytical assessment is treated qualitatively (i.e. indicative of trends in biomass and fishing mortality).

Based on this explorative study it was therefore concluded that, to improve turbot stock assessment, it would be interesting to explore the potential of an industrial survey. For the survey to generate a better CPUE series than the BTS, it would need to realise a higher catch and cover a large area to get sufficient coverage of the population. By designing the survey especially for turbot, these two aspects could be addressed.

2.4 Conclusions
To assess whether an industrial survey can potentially improve stock assessment for North Sea dab, brill, lemon sole and turbot, the first phase of the project explored the gap between data collection and data needs for these data-limited stocks. The following conclusions were drawn:

- To manage a stock at MSY requires an analytical stock assessment. No analytical assessment is currently available for dab, brill and lemon sole. These data-limited stocks are assessed by ICES through a data limited stock assessment method that uses catch-success time series as an index of relative population abundance. These assessments show trends in abundance, but do not provide estimates of absolute population abundance or fishing mortality. For turbot, ICES applies an analytical model (since 2013). However, due to uncertainties in model settings and inputs, this assessment is currently only used as indicative of trends in biomass, recruitment and fishing mortality.
- Surveys are used to monitor population trends and to collect biological information that is used in stock assessment. Analytical stock assessment models use information about population trends (catch-success time series) to calibrate model estimates of population biomass. This is particularly important to get better model estimates of population developments in the most recent years. From a management perspective, these are also the most important years.
- Various research vessel surveys are performed in the North Sea. Although these surveys collect data for dab, brill, lemon sole and turbot, catchability of these species is not necessarily very good: Due to the low abundance and wide spatial distribution of turbot and brill, survey catches of these two species are low. Brill catches are particularly poor for the older age classes. This means that a lot of uncertainty surrounds the abundance indices and biological parameters of the stock. Dab is a highly abundant species and is well covered in the research vessel surveys. Like dab, lemon sole is considered well covered in the surveys (particularly the BTS), although juveniles are underrepresented in survey catches. The latter is not considered to present a major problem in stock assessment.
- An industrial survey provides an opportunity to tailor survey design to the data needs of by-catch species and improve their survey coverage. This would strengthen data collection and hence assessment opportunities for data-limited by-catch species. Because research vessel surveys cover dab and lemon sole quite well, an industrial survey for these species was considered redundant. For turbot and brill an industrial survey was considered worth exploring.
- A survey needs to be run for at least 5 consecutive years before it shows trends and can be used in an assessment. Therefore the project partners agreed that this project would be used to trial a pilot survey design, allowing for a more informed decision about whether to proceed with the survey, and providing information about how to optimise survey design.
- Notwithstanding the above, it was concluded that for lemon sole and brill, the available data is likely to be sufficient to perform an analytical assessment, as has already been done for turbot. This would “immediately” strengthen our ability to manage these stocks at MSY.
- For dab, the major obstacle for an analytical assessment is the high discard ratio and missing discard data prior to 2009. Despite better discard sampling for dab since 2009, catch-at-age data for dab will continue to contain major uncertainties due to the uncertainty surrounding sampling-based discard estimates. This is problematic for analytical assessment. The landing obligation, when implemented effectively, should improve catch data for dab and hence analytical assessment opportunities. To resolve the issue of missing historical discard data (>2009) a stock assessment model could be developed that can cope with this missing catch data.
3 PILOT TESTING A SURVEY DESIGN

In the second phase of the research project, a pilot survey was performed for turbot, brill and lemon sole. This pilot served to determine whether the survey design is workable and whether an industrial survey improves data collection with respect to research vessels surveys. Based on this, a more informed decision could be made about whether or not to proceed with the industrial survey, and if so, how the survey design could be optimised. The industrial survey is hereafter referred to as BSAS (Bedrijfssurvey geAssocieerde Soorten - Industrial Survey for Associated Species).

3.1 Survey design and activities

Based on the outcomes of project phase one, IMARES designed a pilot survey to collect data for North Sea brill, turbot and lemon sole. Several other species were also included in the survey. The survey was carried out on board the Ekofish Group otter trawler PD147, the “Enterprise”. This 44.9 by 9.4 meter vessel (2514 hp) uses twinrig gear with 120mm meshes to target plaice in the central North Sea. It has a net opening of 200m, and a towing speed of 3 knots/hour.

The sampling area was chosen on the basis of Ekofish Group fishing grounds and spatial abundance indices for brill, turbot and lemon sole, derived from commercial LPUE’s and survey-based CPUEs. This resulted in a sampling area of 24 ICES rectangles in the central North Sea (see figure 1). Each rectangle was sampled once, so that a total of 24 hauls were done during the survey.

To test the effect of haul duration on the catches of brill, turbot and lemon sole, two different towing times were tested: 12 tows of 2 hours and 12 hauls of 3 hours. To test the effect of cod-end mesh-sizes on the catches, two different mesh sizes were trialled: 100mm on starboard and 120mm on port side.

The survey took place between September the 15th and October the 3rd of 2014, during weekdays. The survey was performed during daylight hours. The night was used to fish for commercial purposes. Throughout the three weeks of the survey one or two IMARES scientists were on board to carry out the research activities, assisted by crew members and North Sea Foundation staff (in week 2). Starboard and port side catches of brill, lemon sole and turbot were separately sorted, counted and measured. To determine the age of the different length classes, otoliths were collected for three fishes per length class. Also the sex of these sampled fish was determined. During the survey, data was also collected for a range of other species. These will not be discussed in this report.

Table 1. Number of fish caught, number of fish measured and sampled for otoliths.

<table>
<thead>
<tr>
<th>Species</th>
<th>Caught</th>
<th>Measured</th>
<th>Otoliths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lemon sole</td>
<td>3974</td>
<td>2628</td>
<td>851</td>
</tr>
<tr>
<td>Turbot</td>
<td>384</td>
<td>384</td>
<td>333</td>
</tr>
<tr>
<td>Brill</td>
<td>174</td>
<td>174</td>
<td>142</td>
</tr>
<tr>
<td>TOTAL</td>
<td>4532</td>
<td>3186</td>
<td>1226</td>
</tr>
</tbody>
</table>

The survey was performed on board the Ekofish Group otter trawler PD147, the “Enterprise”. This 44.9 by 9.4 meter vessel (2514 hp) uses twinrig gear with 120mm meshes to target plaice in the central North Sea. It has a net opening of 200m, and a towing speed of 3 knots/hour.

Figure 1. Planned sampling area of survey
3.2 Survey results

The survey was performed according to plan. In three weeks, 4532 fish were caught and 3186 fish were measured across 24 hauls (see table 1). The collected data was analysed by IMARES in January and February of 2015. To assess the effect of haul duration on total catch (kg) and catch-success (CPUE in kg/hour) the catch data collected during these different hauls was statistically compared. To assess the effect of mesh size on catch numbers and length composition, the catches of starboard and port side were statistically compared. To evaluate how the industrial survey (BSAS) performed relative to the research vessel surveys, the data collected in the industrial was visually compared to the data of the BTS survey. Because the BTS is the only survey in the North Sea that is specifically aimed at flatfish species and because it is performed in the central and southern North Sea, the BTS was considered to be the most appropriate research vessel survey for this comparative analysis. The sampling area of the industrial survey overlaps with that of the BTS survey, but the spatial extent of the BTS survey is larger and covers most of the North Sea.

Brill

Analysis of the BSAS data showed that brill is concentrated in the south-eastern parts of the sampling area (See figure 2a). This was consistent with BTS survey results. Juvenile brill seem to occur closer to shore (to the south-east). This is depicted by the peak in the age distributions of the south eastern rectangles, which corresponds to the youngest age classes (See figure 2b). Haul duration and mesh sizes does not appear to have a significant effect on brill catches.

Comparative analysis of the BSAS and BTS data showed that BSAS caught much higher numbers of brill compared to the BTS (see figure 2c). This is probably due to the differences in the gear type and haul duration. In contrast to the BTS however, BSAS did not catch the smaller (<23cm) length classes. Closer analysis reveals that this is probably because juvenile brill do not occur in the BSAS sampling areas, in contrast to the areas sampled by the BTS.

Comparative analysis of the BTS and BSAS age distributions (see figure 2d) suggests that both the BTS and BSAS catch young brill (age 1) well - particularly the BSAS. One year old brill fall into the length range of 12-18cm. Therefore, even though the BTS survey catches more small brill, this does not significantly affect the age distribution of the catches. In contrast to the BTS, BSAS catches a wider range of ages, with better coverage of older brill (+4 years).

3 The twinrig net of the BSAS has a much larger opening than the beam trawl used in the BTS survey: 200m instead of 8m. The BSAS also makes longer hauls: 2-3 hours instead of 30 minutes. The wider net means that turbot and brill have a harder time escaping the net. The longer haul duration combined with a wider net means that the effective swept area is larger in the BSAS.
Lemon sole

In contrast to brill, lemon sole is concentrated in the north-western part of the sampling area (see figure 3a). Noticeable for lemon sole, is the ‘flatter’ age distributions in the four southwest rectangles of the sampling area (i.e., less skewed towards the younger age classes) (see figure 3b). This suggests that lemon sole in these areas are on average ‘older’ and that juveniles are concentrated more north-west.

The different haul durations did not have a significant effect on lemon sole catches. Mesh size seemed to affect total catch numbers, however, it did not significantly affect the length distribution of the catch: the difference between the average length of the fish in the starboard and portside catch was not statistically significant.

Both BTS and BSAS catch ‘good numbers’ of lemon sole, across a wide range of length classes. However, the length distributions of the two surveys indicate that the BSAS is better at catching the larger length classes and the BTS is better at catching the smaller length classes (see figure 3c). Closer analysis reveals that this is probably due to the large meshes that were used in the BSAS survey (compared to standard BTS-gear).

Interestingly, comparative analysis of the age distributions of the lemon sole catches in the BTS and the BSAS surveys (see figure 3d), suggest that BSAS and BTS have an almost identical catch composition: Catches of both surveys peak around age 4, moreover both surveys cover more or less the same age range and do not catch very young lemon sole (<2 years) or the old ages (>13 years). A plausible explanation for the different observations when comparing the length or the age distributions of the two surveys is that lemon sole grows slowly at higher ages. This means that a small difference between the age distributions of the two surveys shows up as a large difference between the length distributions of the surveys.
**Turbot**

Like brill, turbot is concentrated in the south-eastern parts of the sampling area (See figure 4a) and juveniles occur closer to shore (to the south-east). This is depicted by the peak in the age distributions of the south eastern rectangles, which corresponds to the youngest age classes (See figure 4b). No effect was found of haul duration and mesh size on catches.

Like for brill, the BSAS caught much higher numbers of turbot compared to the BTS (see figure 4c). Again, this is probably due to the differences in the gear type and haul duration. In contrast to the BTS however, BSAS did not catch the smaller (<21cm) length classes. Closer analysis reveals that this is probably because juvenile turbot do not occur in the BSAS sampling areas, in contrast to the areas sampled by the BTS.

Comparative analysis of the BTS and BSAS age distributions (see figure 4d) suggests that the age ranges of the BTS and BSAS are very similar, but catches in the BSAS peak at slightly older age classes than the BTS. Catches of turbot older than 4 years are very low in the BTS, therefore the BSAS significantly improves survey coverage of the older age classes. In contrast, the BTS covers young (<2 years) better than the BSAS.
3.3 Conclusions

Project phase two tested a pilot survey for brill, lemon sole and turbot. This served to assess whether and how a survey directed at brill, turbot and lemon sole can improve data collection and strengthen assessment of these data-limited species. It also provided insights on how to optimise survey design. The following conclusions and recommendations were made:

- This pilot shows that an industrial survey for brill, turbot and lemon sole using twin-rig gear is technically feasible. The survey design was performed according to scientific protocol and to the satisfaction of all project partners.
- To be usable in stock assessment models, a survey needs to catch a wide range of age classes to allow cohorts to be followed through the years. It is also important that across the age classes, enough fish are caught to allow population trends to be observed. In this light, the survey catches were analysed and compared to the catches of the research vessel (BTS) survey.
- Brill: BSAS catches brill more frequently and has higher catches per age class than the BTS. Moreover, the BSAS covers a larger range of ages: from age 1-9 instead of 1-4 in the BTS. This means that an industrial survey can improve the accuracy of the catch-success time series. Based on this, it was concluded that an industrial survey for brill can make a substantial contribution to improving stock assessment for brill.
- Lemon sole: BSAS catches good numbers of lemon sole, across a wide range of ages. The same applied for the BTS. Moreover, the age ranges covered by the two surveys are very similar. Neither surveys are good at catching very young lemon sole, but this is not considered a serious obstacle to perform an analytical assessment. Therefore, it was concluded that an industrial survey for lemon sole is redundant, from an informational perspective. BTS data is considered adequate to allow population trends to be estimated accurately and can be potentially used in stock assessment. This confirms the conclusions drawn in phase one of the project with respect to lemon sole.
- Turbot: BSAS catches turbot more frequently and has higher catches per age class than the BTS. This difference is particularly strong for the 4-7 age classes. This means that an industrial survey can improve the accuracy of the catch-success time series. Based on this, it was concluded that an industrial survey for turbot can make a substantial contribution to improving the analytical stock assessment for turbot.

For survey data to monitor population trends and be incorporated in a stock assessment, the survey needs to run for at least 5 consecutive years. A longer time series is better, as trends will be more precise. To optimise the survey for turbot and brill the following should be taken into consideration when designing a survey for these species: (i) The sampling area should be adjusted to the southeast, ensuring better overlap with brill and turbot habitat; (ii) Haul duration should be standardised and set at two hours, allowing for a larger sampling size; (iii) Mesh size should be standardised at either 100 or 120mm and selected on the basis of other species being targeted in the survey; (iv) It is recommended that the survey includes all other (bycatch) species that are caught in the survey and that have a similar spatial distribution as brill and turbot.
4 TAKING STOCK & LOOKING FORWARD

To strengthen the scientific basis for catch advice and (mixed) fisheries management, this project explored whether an industrial survey for North Sea dab, brill, lemon sole and turbot can improve data collection and assessment of these data-limited species. For dab, brill and lemon sole, ICES currently applies trends-based stock assessment approaches to provide catch advice. These assessments use fishery-independent, survey-based catch-success time series to monitor relative changes in abundance. Due to the uncertainty in the assessments a precautionary TAC is set.

In order to manage a stock at MSY, a more comprehensive, analytical stock assessment is required. An analytical stock assessment model uses biological information (about population growth, maturity, and natural mortality) and information about fishing removals (catch-at-age) to estimate abundance and fishing mortality in absolute terms. For turbot, ICES applies an analytical model since 2013. However, due to inaccuracies in the catch-success time series and uncertainties in the biological parameters used in this model, model estimates are only indicative of trends in biomass and fishing mortality. An analytical stock assessment model uses (survey-based) catch-success time series to calibrate model estimates. Hence, surveys play a key role in both trends-based and analytical stock assessment. Surveys also collect biological data, which are used to estimate the biological parameters of the stock assessment model. Although multiple surveys are already being performed in the North Sea, these research vessel surveys have been designed to monitor key commercial species. Coverage of other species is therefore not always good: catch numbers are too low, catches are not representative for the total population, or both. Against this background, it was considered that an industrial survey for typical by-catch species of the flatfish fishery could provide a valuable opportunity to improve stock assessment of these species. Whether this is indeed the case was explored in this study.

Although the existing research vessel surveys are not directed at the species subject to this study, closer analysis of this survey data revealed that coverage of both lemon sole and dab in research vessel surveys is actually quite good. An industrial survey for lemon sole and dab was therefore not considered relevant. Based on this initial evaluation of the available lemon sole data it was also concluded that data for this stock is good enough to perform a benchmark analytical assessment, as has been done for turbot. For dab, the main obstacle for an analytical assessment is the missing discard data (<2009) and the high discard ratio. Despite better discard sampling for dab since 2009, catch-at-age data continues to contain large margins of uncertainty due to the uncertainty surrounding sampling-based discard estimates. Under the landing obligation catch data for dab should improve, which in turn will improve stock assessment opportunities for dab. Finally, to deal with the missing historical discard data an assessment model could be developed that can reconstruct this data.

In contrast to lemon sole and dab, research vessel survey coverage of turbot and brill appeared to be poor. Better coverage and more accurate catch-success time series therefore present an opportunity to improve stock assessments for these species. Based on this, an industrial survey was considered worth exploring for turbot and brill. Notwithstanding this, it was also concluded that, in principle, data availability for brill is sufficient to develop a basic analytical assessment, like has been done for turbot.

To assess whether an industrial survey can indeed achieve better coverage of brill and turbot and strengthen data collection for these species, a pilot survey was designed and tested. Analysis of this survey data and comparison of this data with research vessel survey data showed that an industrial survey for brill and turbot is technically feasible and results in better coverage of both species: higher numbers of brill and turbot were caught, across a wide range of ages. Therefore, this study concludes that, for brill and turbot, an industrial survey can significantly improve catch-success time series and hence stock assessment possibilities. It would also improve biological data collection, which will allow more accurate estimates of the biological parameters of the stock. The survey also collected data for lemon sole. Analysis of the lemon sole data confirmed the conclusion drawn earlier, in phase I of the project.

To optimise survey design for turbot and brill the survey areas should be adjusted to the southeast. Haul duration and mesh sizes should be standardised. Finally, by involving more commercial vessels with a good catchability for brill and turbot, greater survey coverage of brill and turbot habitat and a larger sampling size could be achieved. This would benefit the accuracy of the survey-based CPUE indices. Against this background, and to achieve efficiency gains, it makes sense to explore how this industrial survey - if proceeded with - can be integrated with the industrial survey for plaice and sole. Also, in the case that an industrial survey for brill and turbot is continued, it is recommended that the survey includes other (by-catch) species that have a similar spatial distribution as brill and turbot and are currently poorly covered by research vessel surveys.

For survey data to be used in stock assessment, the survey needs to be run for at least 5 consecutive years. The findings of this research project allow for a more informed decision to be made about whether to proceed with an industrial survey for brill, dab, lemon sole and turbot. This study concludes that an industrial survey would only have added value for brill and turbot. Notwithstanding this, the study also concludes that assessments of North Sea brill, dab and lemon sole stocks can also be improved by developing the models underlying these stocks assessments. In sum, there are two ways through which we can improve our knowledge of these typical by-catch species: (i) improving the data used in assessment, by stepping up data collection efforts and improving data collection methods (e.g. through industrial surveys); (ii) improving the use of and usability of the data that is already available, by stepping up stock assessment efforts and/or developing stronger stock assessment models and methods.