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Executive summary

Aims and approach

The aims of this desk study were to determine the intensity and economic value of the national and international gillnet fishery and the possible risk of bycatch of seabirds in the possible Natura 2000 area Brown Ridge, for which five geographic variants are considered. The impact of gillnet fishery in the Brown Ridge for these species is not known from monitoring and observations of bird victims in the bottom set gillnets. Therefore, another approach had to be followed. This was conducted in a desk study by collecting information for the Brown Ridge area on gillnet fishery intensity, seabird density, diving behaviour and bycatch vulnerability in order to assess the spatial and temporal overlap of seabirds with gillnet fishery and comparing with their population criteria. The results for these aspects are summarised below and conclusions are drawn whether this is sufficient for providing sufficient insight into answering the aims. Recommendations are given for the opportunities to achieve the aims. The present study is an update of the impact assessment of Jongbloed et al. (2015) in order to incorporate recent information on gillnet fishery intensity and seabird density in the Brown Ridge area, seabird bycatch vulnerability and new options for the geographical borders of the Brown Ridge as a possible Natura 2000-area.

Dutch gillnet fishery effort

Very few large Dutch gillnet fishery ships (ships with VMS) were active in the Brown Ridge area and their efforts were decreasing in the period 2012 to 2017. There were many small Dutch gillnet fishery ships (ships without VMS) active in the ICES rectangles (33F2, 33F3 and 34F3) that include the Brown Ridge. The exact fishing location of these small ships are unknown and the effort in the Brown Ridge area is not certain. The effort can be zero or intense. It is assumed that the effort of these small ships is homogeneously distributed over each ICES rectangle. This is probably an overestimation as steaming distance from the Dutch coast to the Brown Ridge is large and small ships might stay closer to the coast. In the Brown Ridge area sole fishing is the main type of Dutch gillnet fishery, whereas seabass and cod gillnet fishery effort are marginal.

Foreign gillnet fishery effort

The German gillnet fishery in the Brown Ridge area was carried out with less than 5 large vessels carrying VMS. The Danish gillnet fishery in the Brown Ridge was carried out with less than 5 large vessels with VMS, all targeting sole and less than 5 small vessels targeting both sole and cod in the ICES rectangles 33F3 and 34F3 (including the Brown Ridge area). The German and Danish fishing effort in the variants decreased over time for all gillnet fleets.

Gillnet fishery effort in five geographical variants

Gillnet fishery intensity by Dutch and German fishers was higher in ICES rectangle 33F3 as compared to 34F3. Concomitantly in the southern part of the Brown Ridge area the gillnet fishery intensity was always higher than in the northern part of the Brown Ridge area. The Dutch gillnet fishery intensity varied among the five Brown Ridge variants and decreased in the order: A1-3, A1-1, A1-2, A2, B1 with maximum differences ranging between 10 and 35%.

Economic value of gillnet fishery

The value of landings for the Dutch gillnet fisheries in the Brown Ridge area decreased in the period 2014 to 2017 especially for seabass and cod fishery. The difference in value of the Dutch gillnet fisheries between the variants of the Brown Ridge was relatively small. It ranged between EUR 37,746 and EUR 47,021 in 2014 and down to EUR 20,027 and EUR 24,914 in 2017. The value was structurally the highest in variant A1_3 while the lowest value was structurally observed in variant B1. On average more than EUR 22,000 was fished in the Brown Ridge variants in 2017, which corresponds to, about 1% of the value of gillnet landings for the Dutch fishery and represents a gross value added (GVA) of almost EUR 10,000. It cannot be excluded that there are fishers for which up to 30% of his total

revenue originates from the Brown Ridge. However, this cannot be demonstrated due to the uncertainty of the fishing locations of the small fishing vessels.
The average economic value of gillnet fishery in the Brown Ridge area was the highest for the Danish gillnet fishery as compared to the German and Dutch gillnet fishery. It should be realised that the revenue is probably seriously underestimated because not all landings have to be recorded in the logbooks and gillnetters receive better prices than the average auction price used in estimation. On the other hand, the revenue from small Dutch ships may be overestimated because it is based on a homogenous distribution of the effort over an ICES rectangle.

Seabird density
All five Brown Ridge variants qualify as Natura 2000-area for two seabird species and are also of special importance to for four other species due to their numbers. We selected three of those six seabird species for the impact assessment on bycatch in gillnets in the Brown Ridge area based on the potential bycatch sensitivity due to diving behaviour. These species are common guillemot, razorbill and northern gannet for which the number as well as the density in the five Brown Ridge variants decreased in the order: A2, B1, A1-1, A1-2, A1-3. However, the differences were relatively small.

Spatial overlap of gillnet fishery with seabirds
There was a considerable difference between fishery intensity and seabird density in the spatial scale as well as in the temporal scale of the data. For fishery intensity maps the grid size is large, namely either 1/16 ICES rectangle or an entire ICES rectangle. For seabird density maps the grid size is small with a resolution of 2 x 2 km and seabirds numbers per km^2 per species.
Gillnet fishery effort data are available for each month of the year, whereas seabird numbers are counted four times per year (January, February, August, November). In these four months the gillnet fishery effort is low as compared to the other months (Jongbloed et al., 2015). Thus, the compatibility between fishery data and seabird data is low, which seriously hampers the analysis of spatial and temporal overlap between fishery and seabirds in the Brown Ridge area.
The spatial and temporal overlap between seabirds and gillnet fishery in the five Brown Ridge variants decreased in the order: A1-3, A1-1 and A1-2, A2, B1. This can be explained by the surface area these Brown Ridge variants occupy in ICES rectangle 33F3 where the Dutch sole and cod gillnet fishery effort and German sole gillnet fishery effort was much higher than in ICES rectangles 34F3 and 32F3.

Bycatch vulnerability and risk
From the scarce information on diet and diving behaviour, razorbills and northern gannets would seem to be mainly shallow divers in the Brown Ridge area, which would significantly reduce their risk of being by-caught in bottom set nets. Common guillemots dive deeper and a significant portion of their prey spectrum consists of demersal fish like sandeels *(Ammodytes sp.)*. Although the true bycatch risk is unknown, probably the risk is considerably higher for common guillemots than for razorbills and northern gannets.
The bycatch of a single common guillemot, razorbill or northern gannet in the Brown Ridge is already critical for the population in case the Ornis criterion for extra mortality is applied for this area. In case the Potential Biological Removal (PBR) criterion is applied much more victims can be allowed before the populations of the sea birds are regarded to become threatened. Despite major knowledge gaps due to the low gillnet fishery intensity, limited temporal overlap and the seabird diving behaviour, no measures might be necessary for the razorbill and the northern gannet, whereas measures may be necessary for the common guillemot for precautionary reasons. However, a maximum allowable level for gillnet fishery effort in the Brown Ridge area cannot be derived with the present impact assessment for these seabird species.

Knowledge gaps and recommendations
Many knowledge gaps are revealed. The major ones are mentioned here.

- The estimation of the gillnet fishery intensity and economic value of their landings by small Dutch ships in the Brown Ridge area is accompanied by a high uncertainty because their distribution within ICES rectangles is unknown. Installation of VMS on board of these small vessels could provide this information.

- MWTL-monitoring data for seabird densities is not available for each month in the period October-May. Data from previous years (before 2014) could fill this gap and be used for extrapolation but this is less reliable.
- Information for the effort of foreign gillnet vessels in the Brown Ridge area is incomplete. Danish gillnet fishing effort does not contain information on net lengths and spatial distribution of the effort. Data for the effort of British gillnet fishery is lacking.
- The estimation of the economic value of the fisheries contains large uncertainties, and the estimated values can only be crude estimates. Recommendations for future research are insisting data on VMS activity for small vessels or a survey among fishermen.
- There is insufficient insight in the occurrence and probability of bycatch of common guillemots, razorbills and northern gannets in gillnets in the Brown Ridge area. It can be recommended to monitor bycatch carried out by the fishers and independent researchers. Electronic Monitoring (EM) on board could be more effective for gillnet fisheries in relative small areas like the Brown Ridge. An indirect way to rule out or confirm bycatch vulnerability of seabird species is to investigate the diet of bycaught seabirds from their stomach content.

Nederlandse samenvatting

Doel en benadering

De doelen van deze bureaustudie waren de bepaling van de intensiteit en economische waarde van de nationale en internationale staandwantvisserij en het mogelijke risico van bijvangst van zeevogels in het mogelijke Natura 2000-gebied Bruine Bank, waarvoor vijf geografische varianten zijn beschouwd. De impact van staandwantvisserij in de Bruine Bank op deze soorten is niet bekend uit monitoring en observaties van vogelslachtoffers in staandwant. Er moest daarom een andere benadering worden gevolgd. Dit is gedaan in een bureaustudie door middel van het verzamelen van informatie over staandwantvisserij intensiteit en zeevogeldichtheid in het Bruine Bank gebied, duikgedrag en bijvangstkwetsbaarheid voor de schatting van de ruimtelijke en temporele overlap van zeevogels met staandwantvisserij en de vergelijking met hun populatiecriteria. De resultaten voor deze aspecten worden hieronder samengevat en conclusies worden getrokken of dit voldoende inzicht kan bieden voor de beantwoording van de doelen. Aanbevelingen worden gegeven voor de mogelijkheden deze doelen te bereiken. De huidige studie is een update van de risicoschatting door Jongbloed et al. (2015) om daarmee mee te nemen de recente informatie over staandwantvisserij-intensiteit en zeevogeldichtheid in het Bruine Bank gebied, alsmede eventuele nieuwe inzichten in zeevogelbijvangstgevoeligheid en nieuwe opties voor de geografische grenzen van de Bruine Bank als een mogelijk Natura 2000-gebied.

Nederlandse staandwantvisserij effort

Zeer weinig grote Nederlandse staandwantvisserij schepen (schepen met VMS) waren actief in het Bruine Bank gebied en hun effort nam af in de periode 2012 tot 2017. Er waren veel kleine Nederlandse staandwantvisserij schepen (schepen zonder VMS) actief in de ICES rechthoeken (33F2, 33F3 en 34F3) waarin de Bruine Bank ligt. De exacte vislocaties van deze kleine schepen zijn onbekend en de visserij-intensiteit in het Bruine Bank gebied is niet zeker. De visserij-intensiteit kan nihil maar ook hoog zijn. In deze studie is aangenomen dat de intensiteit van deze schepen homogeen is verdeeld over een ICES rechthoek. Dit is mogelijk een overschatting omdat de vaarafstand van de Nederlandse kust tot de Bruine Bank groot is en kleine schepen daarom dichter bij de kust blijven. In het Bruine Bank gebied was tongvisserij het meest voorkomende type van Nederlandse staandwantvisserij, terwijl staandwantvisserij op zeebaars en kabeljauw marginaal van omvang was.

Buitenlandse staandwantvisserij effort

De Duitse staandwantvisserij in het Bruine Bank gebied werd uitgevoerd met minder dan 5 grote schepen met VMS. De Deense staandwantvisserij in het Bruine Bank gebied werd beoefend met minder dan 5 grote schepen met VMS, alle gering op tong, en minder dan 5 kleine schepen gericht op zowel tong en kabeljauw in de ICES rechthoeken 33F3 en 34F3 (inclusief het Bruine Bank gebied). De Duitse en Deens visserij inspanning in de varianten nam af over de periode 2012-2017 voor alle typen staandwantvisserij.

Staandwantvisserij intensiteit in vijf geografische varianten

Staandwantvisserij intensiteit door Nederlandse en Duitse visserij was hoger in ICES rechthoek 33F3 wanneer vergeleken met 34F3. Hierdoor was de staandwantvisserij intensiteit in het zuidelijke deel van het Bruine Bank gebied altijd hoger dan in het noordelijke deel van het Bruine Bank gebied. De Nederlandse staandwantvisserij intensiteit varieerde tussen de vijf Bruine Bank varianten en nam af in de volgorde: A1-3, A1-1, A1-2, A2, B1 met maximale verschillen tussen 10 en 35%.

Economische waarde van staandwantvisserij

De waarde van aanlandingen voor de Nederlandse staandwantvisserij in het Bruine Bank gebied nam af in de periode 2014-2017, vooral voor zeebaars- en kabeljauwvisserij. Het verschil in waarde van de Nederlandse staandwantvisserij tussen de varianten van de Bruine Bank was relatief klein. Het varieerde tussen EUR 37,746 en EUR 47,021 in 2014 en EUR 20,027 en EUR 24,914 in 2017. De waarde was structureel het hoogste in variant A1_3 terwijl de laagste waarde structureel gezien werd

in variant B1. Er werd gemiddeld voor meer dan EUR 22,000 gevist in de Bruine Bank varianten in 2017, hetgeen correspondeert met ca. 1% van de waarde van staandwant aanlandingen voor de Nederlandse visserij en representeert een bruto toevoegde waarde van bijna EUR 10,000. Het kan niet worden uitgesloten dat er vissers zijn die voor tot 30% van de totale opbrengst behalen uit visserij in het Bruine Bank gebied. Dit kan echter niet worden aangetoond als gevolg van de onzekerheid over de visserijlocaties van de kleine visserijschepen.
De gemiddelde economische waarde van de staandwantvisserij in het Bruine Bank gebied was het hoogste voor de Deense staandwantvisserij in vergelijking met de Duitse en de Nederlandse staandwantvisserij. Men dient zich te realiseren dat de opbrengst waarschijnlijk serieus wordt onderschat omdat niet alle aanlandingen hoeven te worden geregistreerd in de logboeken en staandwantvissers betere prijzen ontvangen dan de gemiddelde veilingprijzen die worden gebruikt in de schattingen. Anderzijds kan de opbrengst van kleine Nederlandse schepen uit de Bruine Bank zijn overschat omdat deze is gebaseerd op een homogene verdeling van de inspanning over een ICES rechthoek.

<u>Dichtheid van zeevogels</u>
Alle vijf Bruine Bank varianten kwalificeren als Natura 2000-gebied voor twee zeevogelsoorten en zijn van speciaal belang voor vier andere soorten op basis van hun aantallen. We selecteerden drie van de zes zeevogelsoorten voor de impact schatting van bijvangst in staandwant in het Bruine Bank gebied gebaseerd op de potentiele bijvangst als gevolg van duikgedrag. Deze soorten zijn zeekoet, alk en jan van gent voor welke zowel het aantal als de dichtheid in de vijf Bruine Bank varianten afnam in de volgorde: A2, B1, A1-1, A1-2, A1-3. De verschillen waren relatief klein.

<u>Ruimtelijke overlap van staandwantvisserij met zeevogels</u>
Er bestond een aanzienlijk verschil tussen visserij-intensiteit en zeevogeldichtheid op zowel ruimtelijke schaal als temporele schaal. Voor visserij intensiteit kaarten is de grid grootte groot, namelijk een 1/16 ICES rechthoek of een hele ICES rechthoek. Voor zeevogeldichtheidskaarten is de grid grootte klein met een resolutie van 2 x 2 km en zeevogelaantallen per km^2 per soort.
Staandwantvisserij intensiteit gegevens zijn beschikbaar voor elke maand van het jaar, terwijl zeevogelaantallen vier keer per jaar worden geteld (januari, februari, augustus, november). In deze vier maanden was de staandwantvisserij intensiteit klein in vergelijking met maanden (Jongbloed et al., 2015). De compatibiliteit van de visserij data en de zeevogel data is dus laag, hetgeen de analyse van ruimtelijke en temporele overlap tussen visserij en zeevogels in het Bruine Bank gebied serieus hindert.
De ruimtelijke en temporele overlap tussen zeevogels en staandwantvisserij in de vijf Bruine Bank varianten nam af in de volgorde: A1-3, A1-1 en A1-2, A2, B1. Dit kan worden verklaard door het oppervlak dat deze Bruine Bank varianten bezetten in ICES rechthoek 33F3 waar de Nederlandse tong en kabeljauw staandwantvisserij-inspanning en de Duitse tong staandwantvisserij inspanning veel groter zijn dan in ICES rechthoeken 34F3 en 32F3.

<u>Bijvangst kwetsbaarheid en risico</u>
Uitgaande van des schaarse informatie over dieet en duikgedrag, zou kunnen worden afgeleid dat alken en jan van genten in het Bruine Bank gebied voornamelijk ondiepe duikers zijn, hetgeen het risico op bijvangst in op de bodem geplaatst staandwant significant reduceert. Zeekoeten duiken dieper en een significant deel van hun prooi spectrum bestaat uit demersale vis zoals zandspiering *(Ammodytes sp.)*. Het werkelijke risico op bijvangst is onbekend maar het is waarschijnlijk dat het bijvangstrisico belangrijk groter is voor zeekoeten dan voor alken en jan van genten.
De bijvangst van een enkele zeekoet, alk of jan van gent op de Bruine Bank is al kritisch voor de populatie in geval het Ornis criterium voor extra mortaliteit wordt toegepast voor dit gebied. In geval het Potential Biological Removal (PBR) criterium wordt toegepast, kunnen veel meer slachtoffers worden toegestaan voordat de populaties van deze zeevogels in gevaar komen. Ondanks grote kennisleemten, lijken vanwege de lage staandwantvisserij intensiteit, beperkte temporele overlap en het duikgedrag van de zeevogels, maatregelen niet noodzakelijk voor de alk en de jan van gent, maar zouden uit voorzorg wel noodzakelijk kunnen zijn voor de zeekoet. Een maximaal toelaatbaar niveau voor de staandwantvisserij inspanning in het Bruine Bank gebied kan niet worden afgeleid met de huidige risicoschatting voor deze zeevogelsoorten.

Kennisleemten en aanbevelingen

Er is veel kennisleemten geconstateerd. De belangrijkste worden hier genoemd.

- De schatting van de staandwantvisserij intensiteit en economische waarde van de aanlandingen door kleine Nederlandse schepen in het Bruine Bank gebied gaat gepaard met een hoge onzekerheid omdat hun verspreiding binnen ICES rechthoeken onbekend is. Installatie van VMS aan boord van deze kleine schepen zou deze informatie kunnen leveren.
- MWTL-monitoring gegevens voor zeevogel dichtheden is niet beschikbaar voor elke maand in de periode oktober-mei. Die gegevens zijn er wel voor voorgaande jaren (voorafgaande aan 2014) en zouden deze leemte kunnen vullen en worden gebruikt voor extrapolatie maar dit is minder betrouwbaar.
- De informatie over de inspanning van buitenlandse staandwantschepen in het Bruine Bank gebied is incompleet. Deense staandwant visserij-intensiteit bevat geen gegevens over netlengte en ruimtelijke verspreiding van de intensiteit. Data voor de inspanning van Britse staandwantvisserij ontbreekt.
- De schatting van de economische waarde van de staandwantvisserij bevat grote onzekerheden en de geschatte waarden zijn slechts ruwe schattingen. Aanbevelingen voor toekomstig onderzoek betreffen de vraag om VMS activiteit data voor kleine schepen of een survey onder vissers.
- Er is onvoldoende inzicht in het optreden van en de kans op bijvangst van zeekoeten, alken en jan van genten in staandwant in het Bruine Bank gebied. Daarom wordt aanbevolen de bijvangst te laten monitoren door de vissers en onafhankelijke onderzoekers. Electronische Monitoring (EM) aan boord zou effectiever kunnen zijn voor staandwantvissers in relatief kleine gebieden zoals de Bruine Bank. Een indirecte manier om bijvangst kwetsbaarheid van zeevogelsoorten uit te sluiten of te bevestigen is door onderzoek te doen naar het dieet van bijgevangen zeevogels op basis van hun maaginhoud.

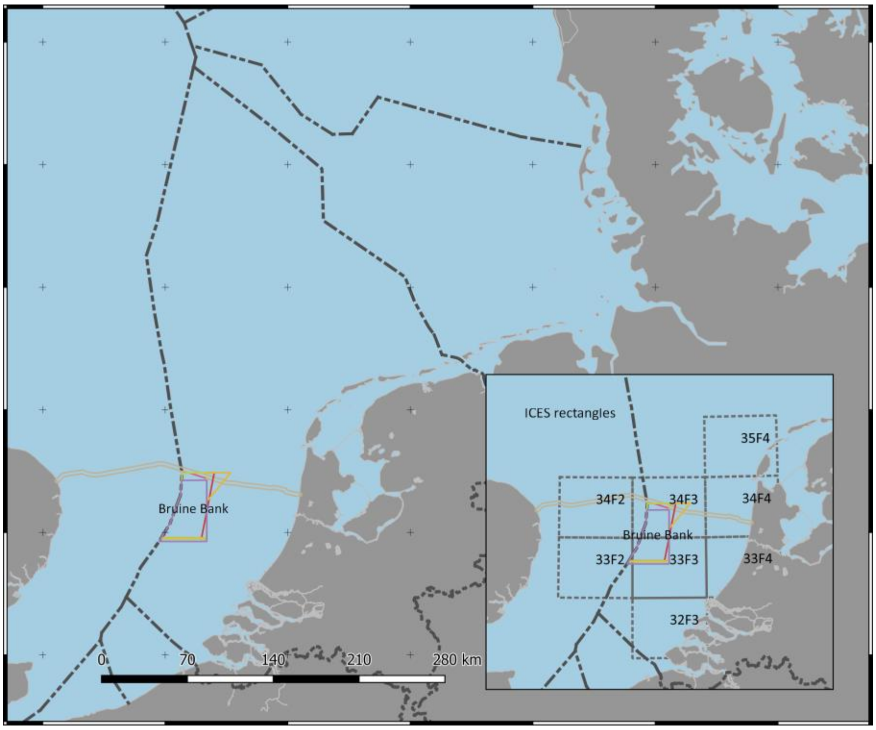
1 Introduction

1: Aim of the study

The Dutch Ministry of LNV asked Wageningen Marine Research and Wageningen Economic Research i) to investigate the intensity of Dutch and foreign gillnet fisheries for five geographical variants for the Brown Ridge area (in Dutch: Bruine Bank); ii) to investigate the potential effects of gillnet fisheries on common guillemots, razorbills as qualifying seabird species and other seabird species for which the 0.1% criterion of the biogeographical population is exceeded (referred to in Dutch as 'begrenzende zeevogelsoorten'[1]) and undertake an impact assessment and, if necessary, iii) to indicate the mitigation options available, iv) to investigate the economic values of Dutch and foreign gillnet fisheries. The present study is an update of the impact assessment of Jongbloed et al. (2015) in order to incorporate recent information on gillnet fishery intensity and seabird density in the Brown Ridge area, seabird bycatch vulnerability and new options for the geographical borders of the Brown Ridge as a possible Natura 2000-area.

The minister of Agriculture, Nature and Food Safety (LNV) considers designating the Brown Ridge area (in Dutch: Bruine Bank) as Natura 2000-area in the North Sea because the area qualifies for certain seabird species according to the Bird Directory criteria (Van Bemmelen et al., 2012; De Jong et al., 2018; Fijn et al., 2019). The surface area of the Brown Ridge area is about 1,500 km^2 (ca. 30km x 50km) and is used as fishing ground by the fishing fleets of The Netherlands and neighbouring countries. The determination of the boundaries of the area and eventual measures may have consequences for existing human use, one of them is the gillnet fishery.

2: Brown Ridge characteristics and borders
The Brown Ridge (in Dutch: Bruine Bank) is a sandbank with patchy peat packets situated in the southern North Sea. The location of this area on the western edge of the Dutch EEZ is indicated in *Figure 1*



[1] An English denotation of 'begrenzende' is not available in this context and therefore only the Dutch denotation is used in this report

Figure 1 Location of the Brown Ridge (in Dutch: Bruine Bank) in the southern North Sea, inset showing selected ICES rectangles (from par. 2.2)

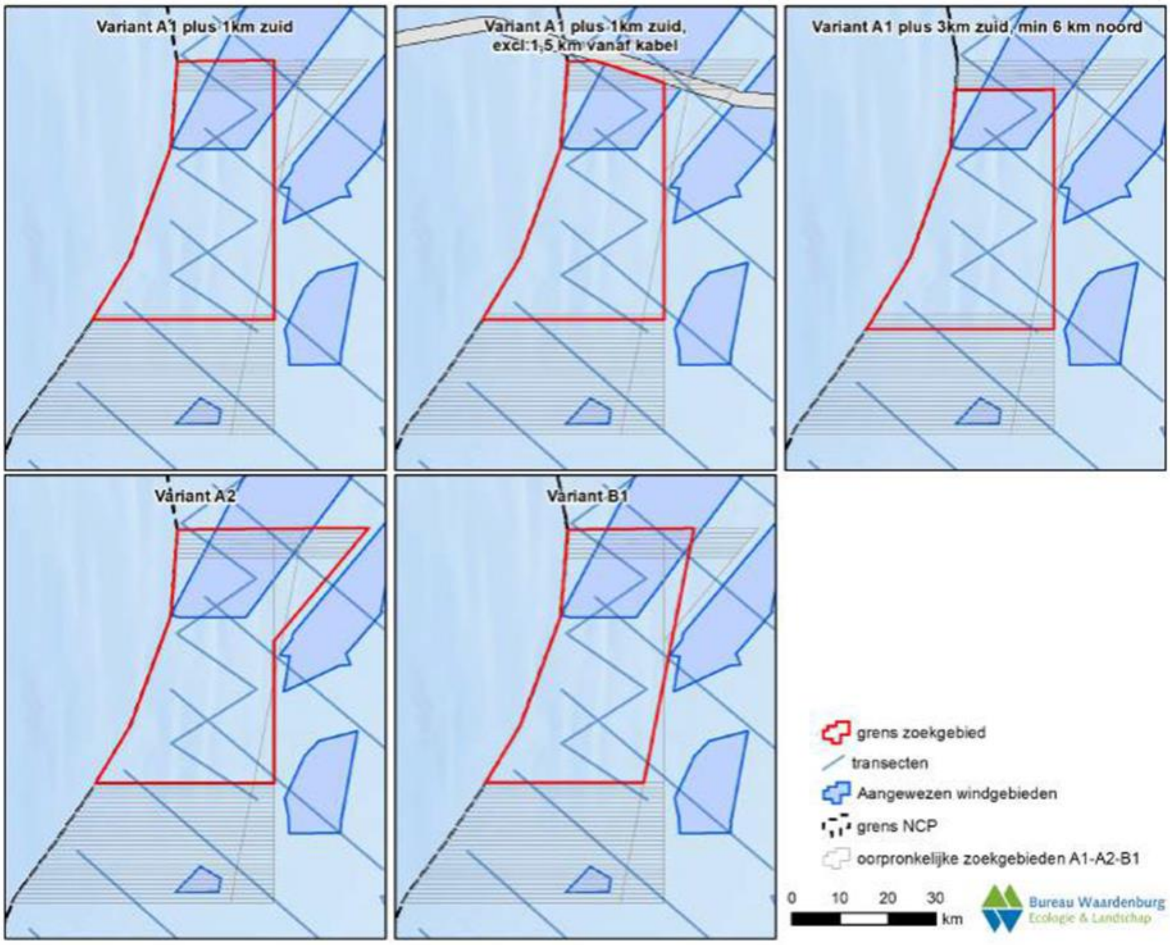


Figure 2 Five variants as options for the borders of the Brown Ridge (source: Fijn & de Jong, 2019). Transect lines for aerial monitoring of seabirds are indicated

The border of the Brown Ridge intended as Natura 2000-area is not definitively established. Lindeboom *et al.* (2005) suggested that the Brown Ridge would be of special value for gulls and auks and did a proposal for the border of a possible Natura 2000-area. After that the process to focus on an area containing the highest concentrations of the qualifying species continued. At present, five options for geographical areas are considered. The names, geographical locations and surface areas are shown in Figure 2 and in *Table 1*. Recently these five geographical areas were analysed for the numbers and possible qualification status of 14 seabird species by De Jong et al., 2018; Fijn & de Jong. 2019). This possible new delineation of the site asks for an update of the report by Jongbloed et al. (2015). In this update we make use of more recent data on numbers and spatial distribution of the seabirds in the area, as well as data for the recent intensity and economic value of gillnet fishery of the Dutch fleet and foreign fleets.

There is a high level of spatial overlap between the geographical areas for the Brown Ridge (see **Fout! Verwijzingsbron niet gevonden.**): 85% of the maximum search area is part of each of all five areas. The other 15% belongs to one or more of the variants. The variants A1-1 and A1-2 have no unique area, meaning no area that is only found in these variants. Variant A2_plus_0_zuid has the most unique area, but that is only 6% (see *Table 1*).

Table 1 Surface area of the five geographical variants of the Brown Ridge

BB-number	BB-variant	Opp. km^2	Part of the search area for BR	Unique area within the geographical search area
A1-1	A1_plus1_zuid	1399	75%	0.0%
A1-2	A1_plus1_zuid_min_pijplijn	1366	73%	0.0%
A1-3	A1_min6_noord_plus3_zuid	1354	73%	3.9%
A2	A2_plus_0_zuid	1590	91%	6.0%
B1	B1_plus0_zuid	1411	81%	0.8%
	Joint area (part of all 5 variants	1308	68%	0.0%
	Search area (Maximum area (part of at least one of the 5 variants)	1932	100%	10.8%

3: Threat by gillnet fishery
The gillnet fishery in the Brown Ridge may threaten diving birds. Several studies in other marine areas have shown that diving birds can get caught in large numbers in gillnets (ICES, 2013; Žydelis *et al.*, 2009, 2013). Structural monitoring of seabirds as bycatch victims in gillnets in the Brown Ridge has not been carried out up to now. In order to be able to assess the potential impact of gillnet fishery on the seabirds in the Brown Ridge, insight has to be gained in a desk study by combining information from the presence of both seabirds and gillnet fishery in the Brown Ridge and their overlap in place and time, supplemented with information on the bycatch sensitivity reported for other comparable locations. Such an analysis will be conducted in this report and follows the design of Jongbloed et al. (2015).

In addition to common guillemot and razorbill, other seabird species need to be included in the risk assessment especially as far as these seabird species belong to the group of 'begrenzende zeevogelsoorten' meeting the criterion that 0.1% of the biogeographical population is present in the Brown Ridge and dive to moderate or large depth during foraging thereby potentially exposing themselves to bottom-set gillnets in the Brown Ridge area.

In 2014, the MWTL airplane programme was adjusted to a new survey design with improved seabird species recognition and coverage. Applying these new data, De Jong et al. (2018) and Fijn & de Jong (2019) demonstrated that common guillemot and razorbill are qualifying species for the five Brown Ridge variants described above. In addition, northern gannet, great skua, little gull and greater black-backed gull are 'begrenzende soorten'. The seabird distribution data from this MWTL airplane programme in the period 2014-2017 will be used in the present gillnet fishery impact assessment replacing the data from MWTL and ESAS monitoring programmes from the period 2004-2013 used by Jongbloed et al. (2015).

4: Economic value of gillnet fishery
The economic value of the Brown Ridge for the gillnet fishery is of importance when considering possible management measures for the gillnet fishery in order to achieve Natura 2000- goals. At first the importance of the Brown Ridge area for the gillnet fishery should be quantified. Secondly, the extent and location of the Natura 2000-area may influence the extent of the reduction of gillnet effort and concomitant economic value in case exclusion or mitigation measures for gillnet fishery are endorsed for Natura 2000-area. The previous study of Jongbloed et al. (2015) revealed that the fishing activity of gillnetters (both Dutch and foreign) in the period 2012 to 2014 was fairly limited in the Brown Ridge consisting of less than 1% of the overall effort of both the Dutch and the foreign fleets. Although the value of landings in the Brown Ridge is low relative to the total revenue from Dutch gillnetters, a few vessels gained up to 30% of their revenue from the Brown Ridge. The present study will investigate whether the economic significance of the Brown Ridge changed in recent years and how this differs among the five geographical variants.

5: Approach

This analysis is aimed at providing insight into the potential bycatch risk of gillnet fishery for seabirds based on the spatial and temporal overlap between diving seabird species at the one side and gillnet fishery types at the other side. Five Brown Ridge area options will be compared regarding the potential threat of Dutch and foreign gillnet fishery for the seabirds. Besides, the economic value of gillnet fishery in the Brown Ridge will be quantified, discriminating the five Brown Ridge area options.

This analysis consists of the following steps, applying the most recent and reliable data available and elaborating for five options for limitation of the Brown Ridge:

1. *Gillnet fishery distribution and intensity in the Brown Ridge for three types of gillnet fishery: cod, sole, seabass for the Dutch fleet and the foreign fleet#. This is described in chapter 2.*
2. *Economic value of recent Dutch and foreign (Danish and German) gillnet fishery in or around the Brown Ridge. This is described in chapter 3.*
3. *Distribution and density of qualifying and 'begrenzende' seabird species. These data were collected with airplane surveys and analysed against the Bird Directive criteria by Bureau Waardenburg. Application of a dataset existing of 3 years with 4 counts per year between August 2014 and February 2017 (Fijn & De Jong, 2019). This is described in chapter 4.*
4. *Impact analysis of gillnet fishery for seabirds with additional seabird bycatch data from a search of recent literature (from 2015). This is described in chapter 5, 6 and 7*
5. *Concise evaluation of draft measures for gillnet fishery and the expected effectivity on protection of seabirds and influence on economic value. This is described in chapter 8.*
6. *An overview of the knowledge gaps that emerged in this analysis is given in chapter 9.*

in case less than 5 fishing vessels are recorded active, the numbers of these fishing vessels are not reported because of privacy rules. In that case the notation <5 vessels is used.

2 Intensity of the gillnet fishery

In this chapter information on the geographical distribution and the intensity of the Dutch and foreign gillnet fisheries in the Brown Ridge area is presented. The method of collection and analysis of the data is described as well.

2.1 Categories for gillnet fishery

In the Dutch part of the North Sea three commercial gillnet fisheries are found. *Table 2* provides an overview of the characteristics of these gillnet categories.

Table 2 Characteristics of the gillnet categories.

Cat.	Target species	Net type	Net code	Mesh width (mm stretched)	Max. net height (m)	Net length (m)
a	Seabass	Set gillnets (anchored)	GNS	90 - 130	2.0	50 - 2500
b	Sole	Set gillnets (anchored)	GNS	90 - 110	1.0	10000 - 25000
c	Cod	Trammel nets	GTR	> 130	2.5	50 - 5000

2.2 Data for gillnet fishery

Since the 1st of January 2005, all fishing vessels longer than 15 meters are equipped with VMS (Vessel Monitoring System), while VMS was introduced on-board of vessels larger than 12 meters since the 1st of January 2012. A VMS transponder sends approximately every 2 hours a signal to a satellite providing information on the vessel's ID, position, time & date, direction and speed. Since 2015, the interval time between registrations has shortened form every 2 hours to 30 minutes for some of the vessels. Hence, VMS is a useful data source to study the distribution of the fishing fleet in both time and space. The Dutch ministry of Economic Affairs is tasked with the collection of VMS data of all (sizable) Dutch fishing vessels. VMS data of foreign vessels, even inside the Dutch EEZ, are made irregularly available for scientific purposes. All VMS positions are collected in the WGS84 coordinate reference system.

VMS does not contain any information on the activities of the fisheries itself, e.g. regarding fishing gear, catch composition, departure harbour or vessel dimensions. For many fisheries related studies, VMS is coupled to fisheries logbooks. These logbooks report per fishing trip when fishermen leave harbour, what gear has been used, the catch composition and a rough estimate of the location of the catches for each 24-hour period. Both VMS and logbook data relate on the fishing vessel ID, which allows for the coupling of the two datasets and for studying fisheries distribution at smaller spatial and temporal scales. WMR receives logbook and VMS information of the Dutch fishing fleet from the Ministry and the information is stored in a database called "VISSTAT". A detailed description on the processing and assumptions made during the process can be found in Hintzen *et al.* (2013).

From 2014 to 2017 there were 21 unique Dutch VMS-fishing vessels using gillnets in an area around the Brown Ridge, namely our study area with ICES-rectangles 34F2, 33F2, 34F3, 33F3, 34F4, 33F4, 32F3 & 35F4 (see *Figure 1*). The information from these vessels is used to quantify the spatial distribution of the fishing effort at a high resolution. Logbook information extracted from the VISSTAT database reveals that 115 unique Dutch vessels were using gillnets as fishing gear during the period,

including the 21 VMS vessels and 94 vessels smaller than 15 meters and without VMS. Records of vessels with a cumulative effort of less than 1 day at sea per year on average are omitted.
By selecting fishing trips with gear codes GNS, anchored gillnets, and GTR, trammel nets, a total of 8238 unique trips of vessels fishing in ICES rectangles 34F2, 33F2, 34F3, 33F3, 34F4, 33F4, 32F3 & 35F4 were selected from the VISSTAT database.

Net length: "Kenniskring Staandwantvisserij" provided information on the gillnet lengths used by vessels targeting seabass (category a), sole (category b), or cod (category c), supplemented with vessel specific information of 27 vessels (Jongbloed *et al.*, 2013). The average minimal number of used nets of 50 m each is 240, ranging from 50 to 400. The maximal amount is on average 330, ranging from 150 to 500. The net lengths of the remaining vessels was assumed to be minimal 50, 10,000 and 50 meters for categories a (seabass), b (sole)and c (cod) respectively. The maximal net lengths are 2500, 25,000 and 500 meters of the three categories respectively.

Duration of fishing trips: The duration of fishing trips, the time period the gillnets were actually set in the water, is difficult to assess from logbook information. Often fishers leave the harbour to set the nets and collect these nets the day after. The days at sea estimated from logbook information does not reflect the actual fishing effort in these cases. The patterns of times leaving and returning to the harbours and the time period out at sea are depicted in Annex 1. The estimation of the net set times can also be found in Annex 1.

2.3 Results for the Dutch gillnet fishery

Based on VMS, logbook, assumed net lengths and fishing duration rules maps are made to depict the distribution of the (Dutch) gillnet fishing intensity from 2014 to 2017 (*Figure 3* - *Figure 5*).

The results for the gillnet fisheries intensity are shown in the three maps below.

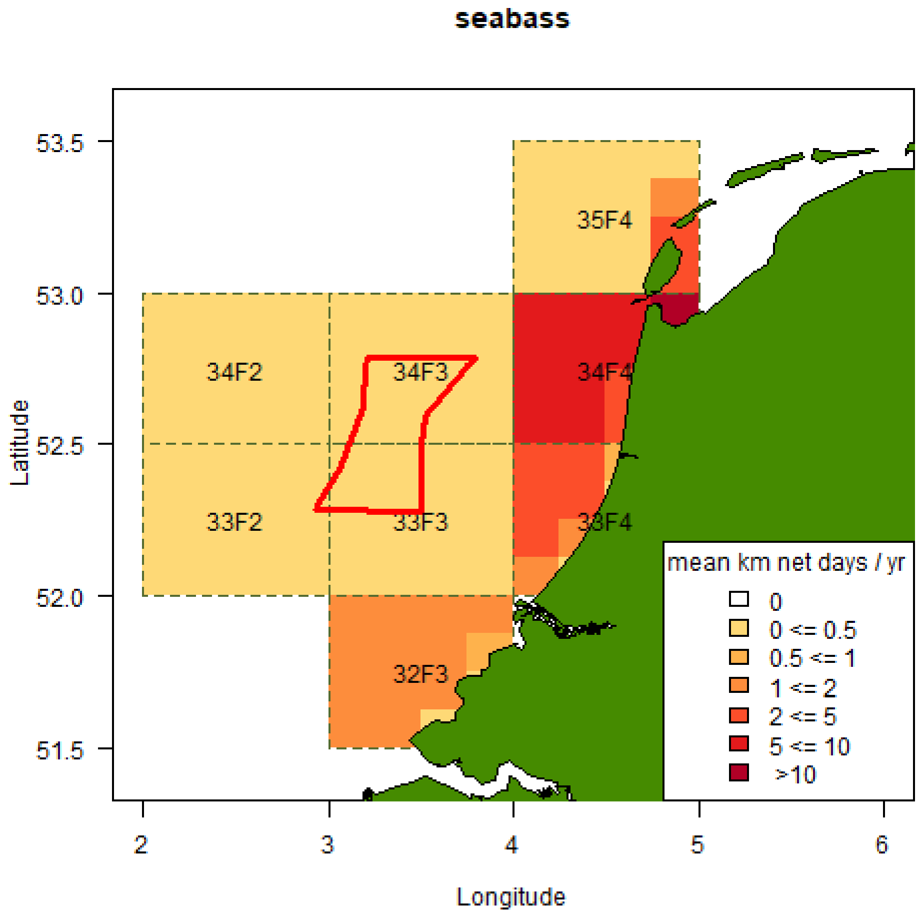


Figure 3 The intensity of gillnet fishery on seabass in the Dutch coastal zone, including the Brown Ridge area, per 1/16 ICES square. Annual average for the period 2014 to 2017. Expressed in number km-net-days per year.

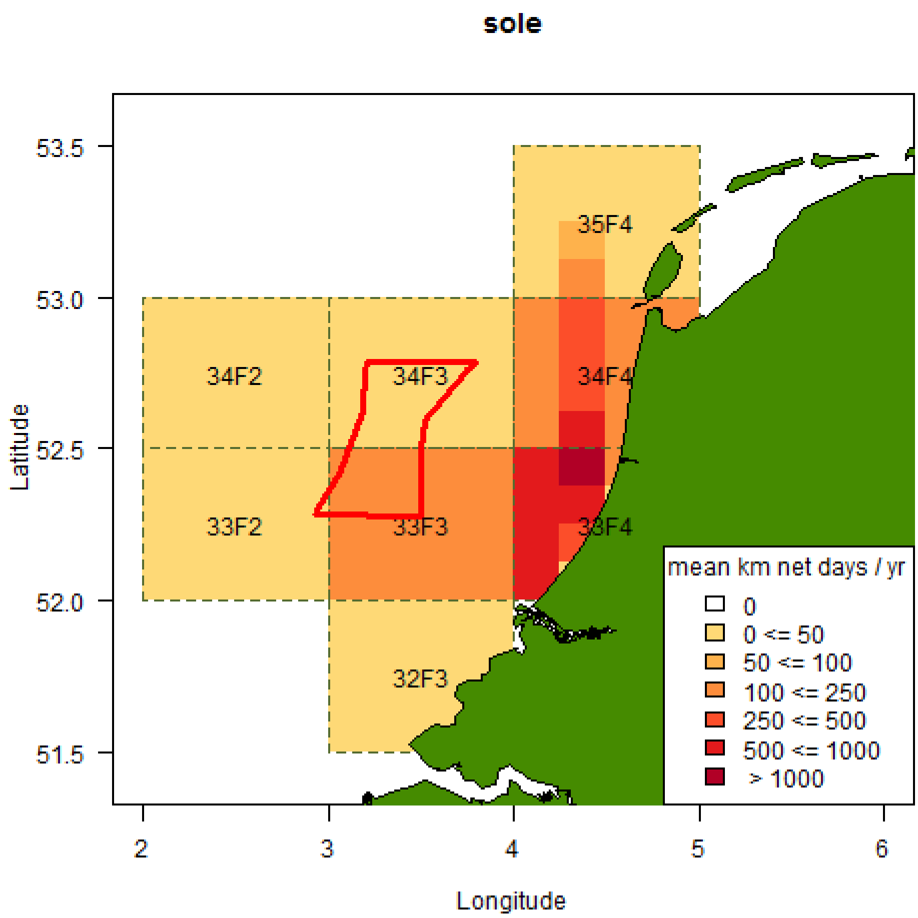


Figure 4 The intensity of gillnet fishery on sole in the Dutch coastal zone, including the Brown Ridge area, per 1/16 ICES square. Annual average for the period 2014 to 2017. Expressed in number km-net-days per year.

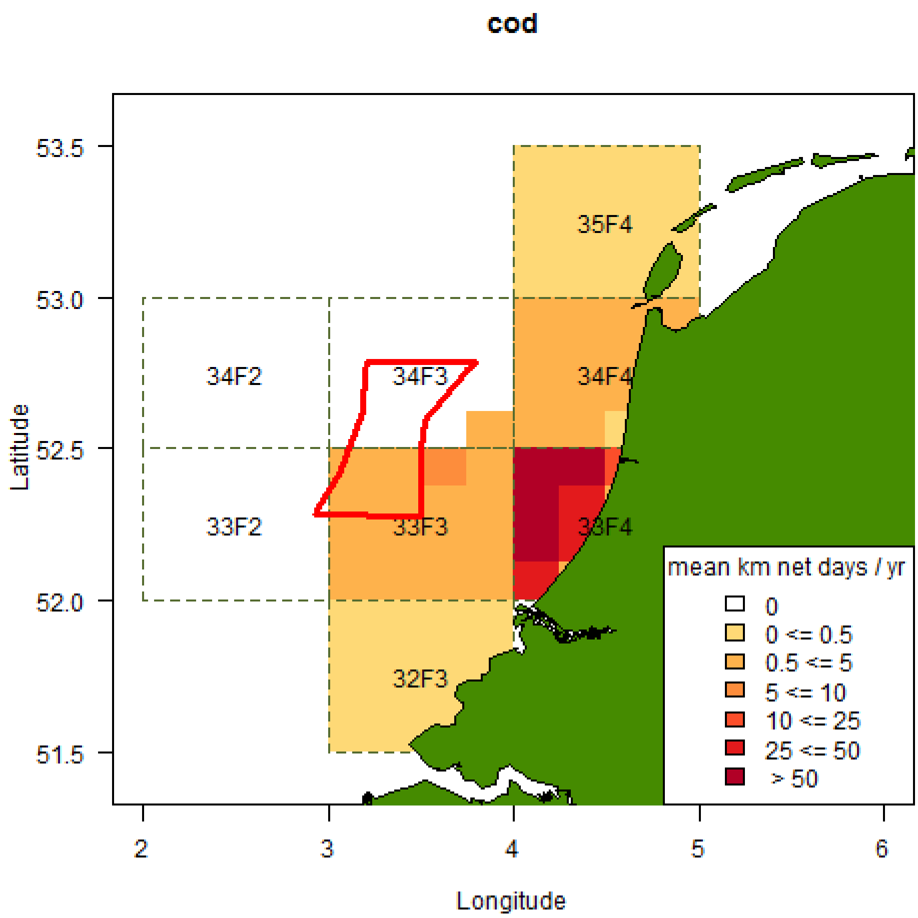


Figure 5 The intensity of gillnet fishery on cod in the Dutch coastal zone, including the Brown Ridge area, per 1/16 ICES square. Annual average for the period 2014 to 2017. Expressed in number km-net-days per year.

These maps show the fishing intensity of the three gillnet categories as number of km-net-days per year. Note that the scale of the intensity differs per fishing type. The intensity of sole fishery is much higher than those of seabass fishery and cod fishery. The maps are based on VMS data supplemented with logbook information of vessels without VMS. The spatial scale is a raster of 1/16 ICES squares (of approximately 300 km^2). In case of logbook information, the estimate of the fishing intensity has a spatial scale of one ICES square, that is proportionally divided over the 16 squares within one ICES rectangle considering the areas covered by land. Effort registered by VMS comes with a geographical position and are summed for each 1/16 ices square. Km-net-days are calculated per fishing trip by multiplying the average net lengths with fishing days. The intensities presented in the three maps show the average net length used, multiplied with the average number of days fished per year of the three categories.

The intensity of the sole and cod gillnet fishery is higher in the southern part of the Brown Ridge (33F3 as compared with 34F3). For seabass gillnet fishery there is a very low intensity with no clear difference between the northern and southern part.

The intensity of the three gillnet categories in the proposed Natura 2000 site Brown Ridge is listed in *Table 4*. The intensity of sole fishery is the highest of the three categories studied. The maximum intensity of the sole fishery among the 1/16 ICES rectangles lying completely or partly within the Brown Ridge amounts to 116 km.net days per year. This value belongs to the 1/16 ICES-rectangle (grid cell 187) in the south-western part of the Brown Ridge (Figure 4). This value is much lower than the maximum intensity observed in the coastal zone between IJmuiden and Hoek van Holland amounting to 1026 km-net days (Figure 4). The Brown Ridge covers approximate 8 1/16 ICES squares with sole fishery intensity around 362 km-net days per year.

Like the sole fishery, the highest cod fishery is observed in the coastal zone between IJmuiden and Hoek van Holland. The intensity of this category within the Brown Ridge area is limited, around 4.17 km-net days per year, see Table 5.

During the period 2014 to 2017 the effort of the Dutch gillnet fisheries decreased in de Brown Ridge and in a much larger area including and surrounding the Brown Ridge (*Table 3*, *Table 4*, *Figure 10*). It should be noted that in the period 2014-2017 gillnet fishery with larger fishing boats (containing VMS) in the Brown Ridge only occurred in 2014 (*Table 3*). Gillnet fishery with small fishing boats was assessed to have a much higher fishery intensity than the one of the large fishing boats. However, this could not be demonstrated because precise spatial data (VMS) for small fishing boats is lacking.

Table 3 Time series for the Dutch gillnet fishery ship numbers

Year	ICES rectangles 33F3, 34F3 33F2 including Brown Ridge (logbook and VMS data)		Brown Ridge (only VMS data)	
	Number of ships	Number of fishing days	Number of ships	Number of fishing days
2014	18	157	<5	0.7
2015	10	87	0	0
2016	11	80	0	0
2017	9	92	0	0

For the small vessels, an estimation of the fishery effort (in days at sea and km net days) in the five Brown Ridge variants was made. We used the logbook information only (at the ICES rectangle level) and assumed a homogenous repartition of the value of fishery effort within an ICES rectangle for allocation to the Brown Ridge area (five variants). The results are listed in *Table 4*, together with the results for the larger vessels.
The fishery intensity varies among the five Brown Ridge variants and decreases in the order: A1-3, A1-1, A1-2, A2, B1. The maximum differences in fishery intensity based on days at sea per year was 10%, 20%, 35% for seabass, sole, cod fishery. The maximum differences in fishery intensity based on km net days per year was 26%, 20%, 29% for seabass, sole, cod fishery. The sole fishing represents about 95% of the total gillnet fishery effort in days at sea and 98% effort in km net days. Seabass as well as cod gillnet fishery effort remain marginal with 4 and 1% for seabass fishery and 2 and 1% for cod fishery.

Table 4 Estimated fishing intensity of the Dutch gillnet fishery in three categories (1: seabass; 2: sole; 3: cod) and in five variants of the Brown Ridge in the period 2014-2017. Fishing intensity is shown in 2 units (days at sea per year, km net days per year).

CAT	Brown Ridge variant	Days at sea per year			Km net days per year		
		VMS	Logbook	Total	VMS	Logbook	Total
1: Seabass	A1_1	0.11	0.47	0.58	0.91	1.80	2.71
	A1_2	0.11	0.46	0.57	0.91	1.77	2.68
	A1_3	0.17	0.45	0.62	1.36	1.82	3.19
	A2	0.08	0.55	0.62	0.61	1.93	2.54
	B1	0.08	0.48	0.56	0.61	1.74	2.35
	Total	0.17	0.58	0.75	1.36	2.13	3.49
2: Sole	A1_1	0.11	17.9	18.0	0.9	330	331
	A1_2	0.11	17.9	18.0	0.9	330	330
	A1_3	0.17	19.7	19.8	1.4	362	363
	A2	0.08	17.1	17.2	0.6	314	314
	B1	0.08	15.9	15.9	0.6	291	292
	Total	0.17	19.7	19.9	1.4	362	364
3: Cod	A1_1	0.11	0.18	0.30	0.91	3.80	4.71
	A1_2	0.11	0.18	0.30	0.91	3.80	4.71
	A1_3	0.17	0.20	0.37	1.36	4.17	5.54
	A2	0.08	0.18	0.25	0.61	3.61	4.22
	B1	0.08	0.16	0.24	0.61	3.36	3.96
	Total	0.17	0.20	0.37	1.36	4.17	5.54

Spatial distribution of the Dutch gillnet fleet

A map of the registered VMS pings of the Dutch gillnet fleet in the period 2014-2017 is shown in *Figure 6*. The clear majority of the VMS pings is found at relatively short distance from the Dutch North Sea coast. Very few VMS pings are located within the borders of the Brown Ridge.

The total effort of the Dutch gillnet (VMS!) fleet in the Greater North Sea is estimated at 2781 km-net-days per year (average of period 2014 till 2017). In the Brown Ridge, the effort of the VMS vessels is on average 1.36 km-net days per year and comprehends only 0.049% of the total (VMS) effort in the Greater North Sea. For the smaller vessels (logbook) the effort in the Brown Ridge is estimated at 3.2% of the total effort (keep in mind that the spatial resolution of the logbook vessels is low (ICES-rectangle).

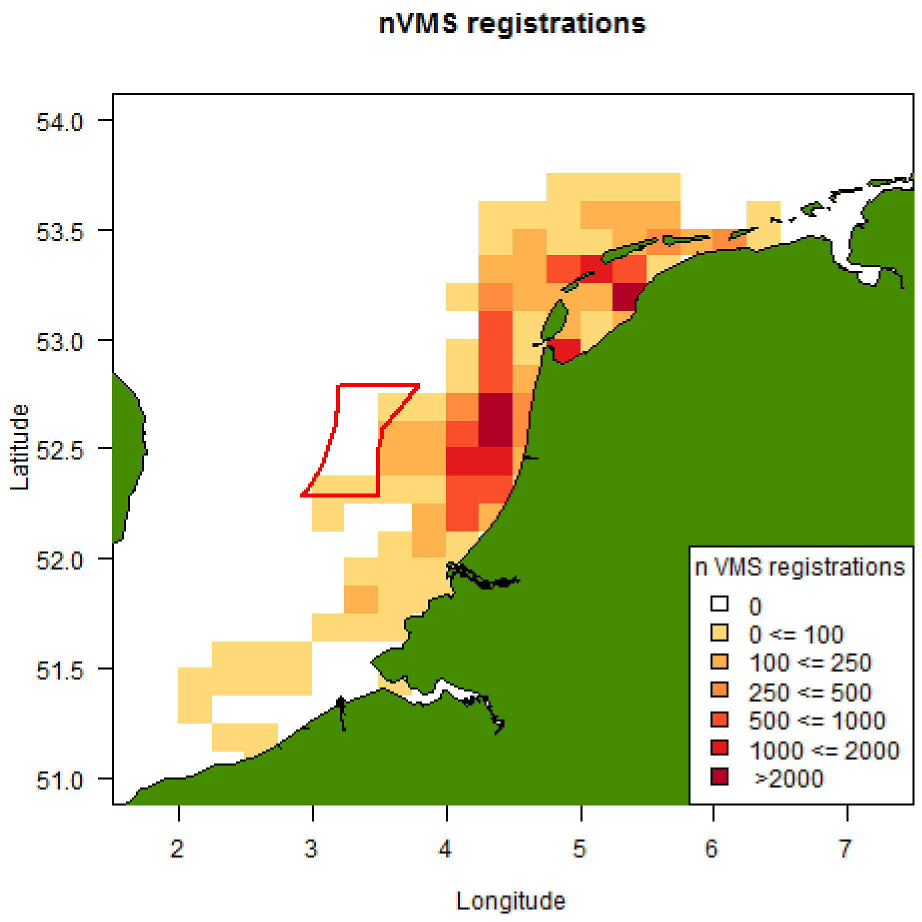


Figure 6 Map of fishing based on VMS pings by the Dutch gillnet fleet in the period 2014 - 2017

The estimation of the gillnet fishery effort of the small fishing vessels on the Brown Ridge applied in this study may be overestimated due to a number of observations (Pieke Molenaar, WMR, personal communication).

- Large Dutch fishing vessels maybe do not fish with gillnets on the Brown Ridge. VMS records of such ships may originate from vessels with 2 permits, including a gillnet permit that is not utilised on the Brown Ridge. On the other hand, large Danish gillnet vessels may be active on the Brown Ridge.
- The cod stock on the southern North Sea has dropped to a very low level. Therefore, it is not expected that targeted fishing on cod occurred recently. An exception may exist for gillnet fishing on cod nearby ship wrecks.
- Small gillnet fishing vessels probably do not go beyond 20 miles out of the coast and therefore will probably not fish on the Brown Ridge.
- Gillnet fishing on seabass probably does not occur offshore on the NCP.

2.4 Seasonal variation

The different types of gillnet fishing are carried out at different seasons. Based on the 2014-2017 data, the seasonality of the three gillnetting types is shown in *Figure 7*. Seabass gillnetting mainly take place in May (52% of the total effort in the Brown Ridge was in May) while sole and cod gillnetting are predominantly distributed over longer periods (March to October for sole, and throughout the year with peaks in May, November and December for cod). In absolute terms, sole fishing represents about 97.5% of the effort and cod and seabass effort remains marginal.

It can be seen in *Figure 8* that there is a lot of variation between years in the distribution of the gillnet fishery intensity over the months. Seabass fishery also varies in intensity from year to year, with negligible intensity in 2015 and 2017. Cod fishery was absent or almost absent in 3 of the 4 years: 2014, 2015 and 2017. The sole gillnet fishery is (nearly) absent in the period November to February.

When the gillnet fishery effort in the period 2012 up to 2014 (Jongbloed et al., 2015) (see Annex XX) is compared with the period 2014 up to 2017 (this report) (*Figure 7*, *Figure 8*) it can be seen that in 2012 and 2013 cod fishery took place during all months of the year, especially in January, whereas in December there was less cod fishery. The Seabass fishery pattern in 2012-2014 resembles the one in the resent study (2014-2017). About half of the months of the year there is some seabass fishery. Also, the sole fishery pattern is quite comparable. Although in February, March and June there is in 2015-2017 less sole fishery effort than in the previous years (2012-2014).

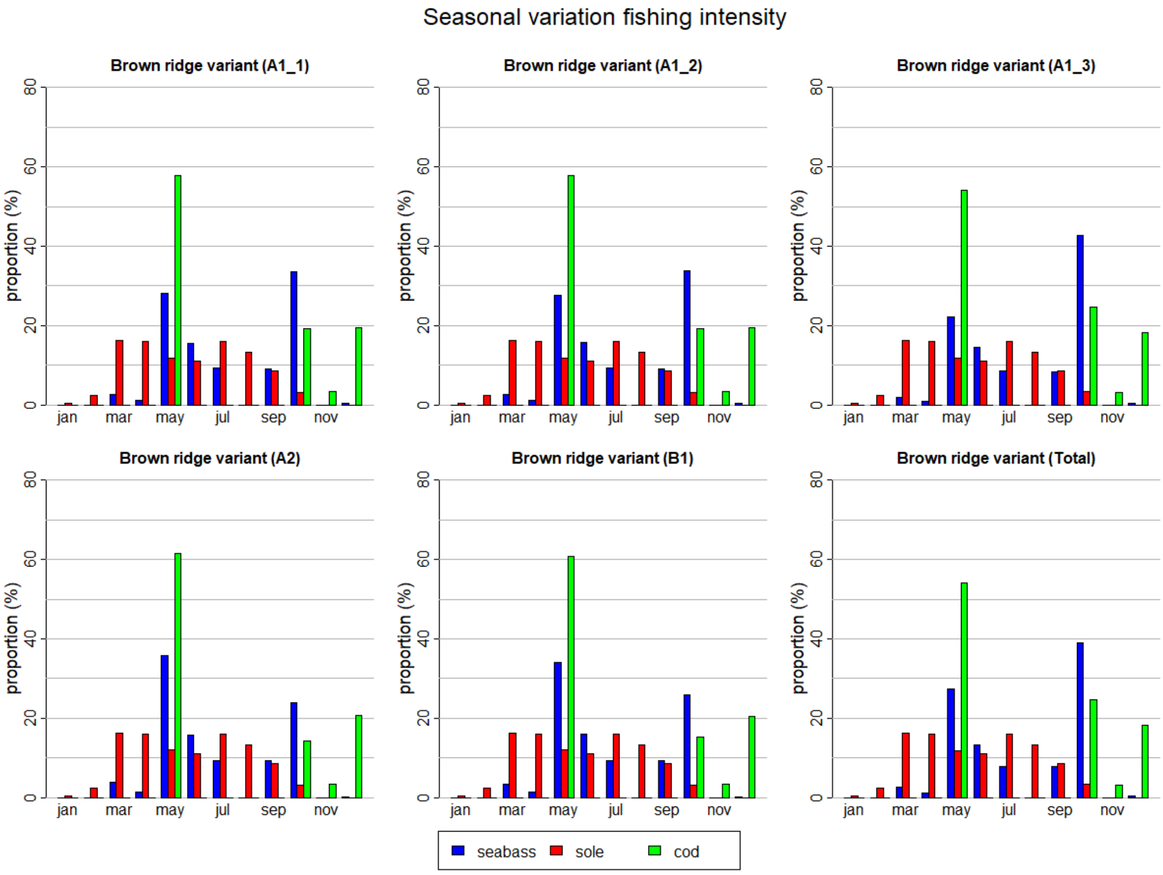
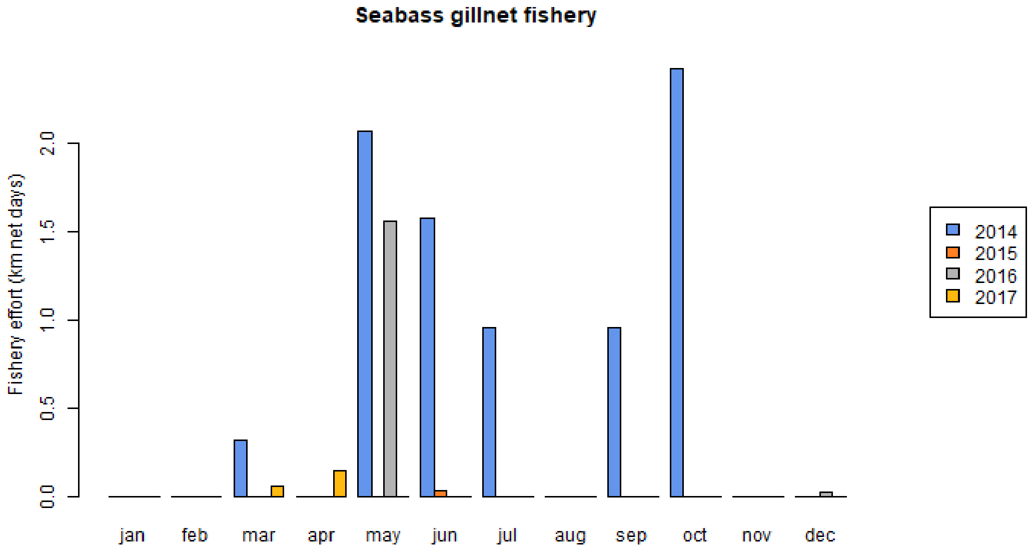
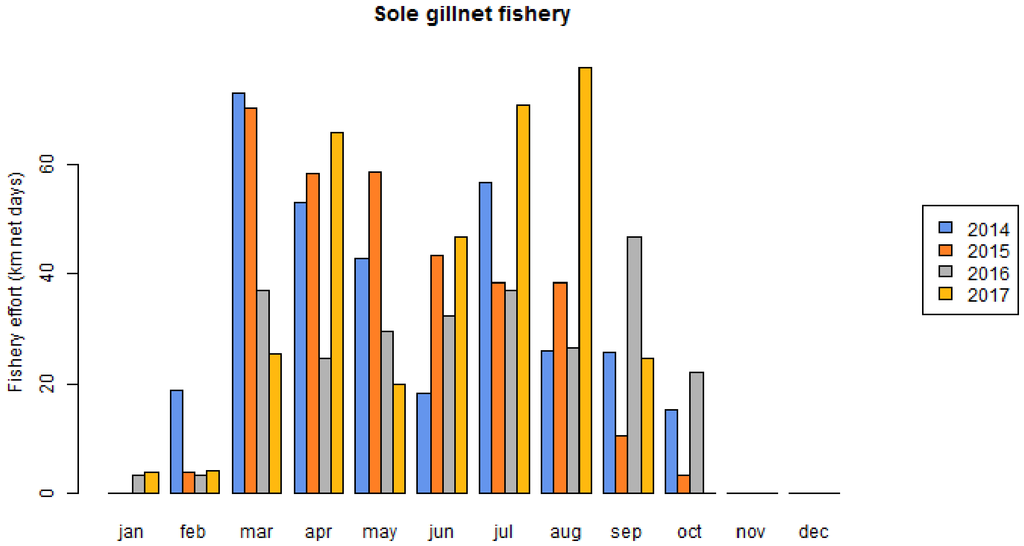


Figure 7 Relative presence of the different types of gillnet fisheries during the year on the Brown Ridge in the period 2014-2017. The fishing intensity per month was divided by the sum of fishing intensity over the year per gillnet fishery type. The bars add up to 1 (100%) for each gillnet fishery type represented by colours. Please note that the absolute fishing intensity of the sole gillnet fishery covers approximate 90% of the total fishing intensity with all three gear types (in km net days).


Seabass gillnet fishery
Fishery effort (km net days)
0.0
0.5
1.0
1.5
2.0
jan
feb
mar
apr
may
jun
jul
aug
sep
oct
nov
dec
2014
2015
2016
2017


Sole gillnet fishery
Fishery effort (km net days)
0
20
40
60
jan
feb
mar
apr
may
jun
jul
aug
sep
oct
nov
dec
2014
2015
2016
2017

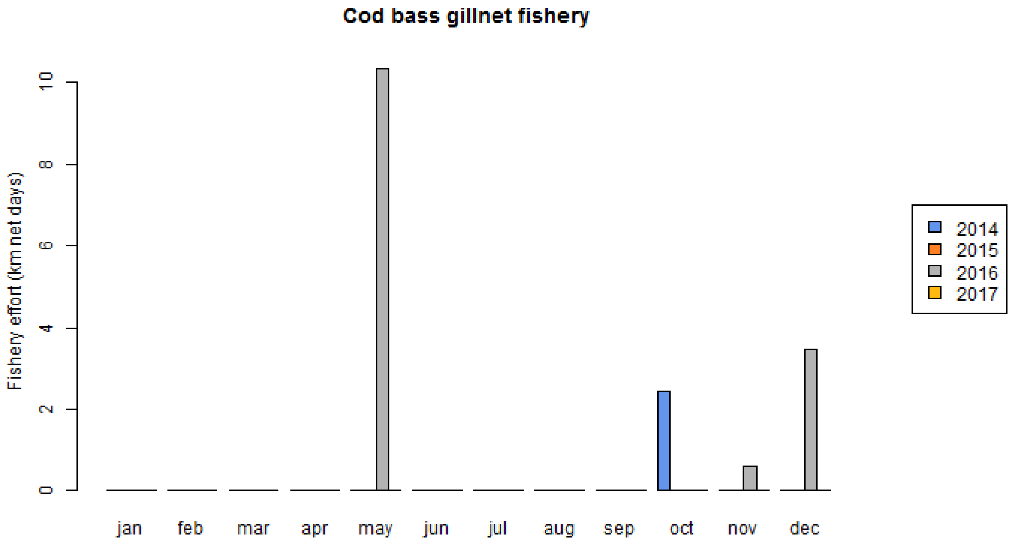

Cod bass gillnet fishery
Fishery effort (km net days)
0
2
4
6
8
10
jan
feb
mar
apr
may
jun
jul
aug
sep
oct
nov
dec
2014
2015
2016
2017

Figure 8 Effort (km net days) of the three types of gillnet fisheries during the year on the Brown Ridge variant A2 for separate years in the period 2014 to 2017. Note that the scale differs among the three gillnet fisheries.

2.5 Results for foreign gillnet fisheries

WMR requested fishery data from Danish, German and British fishery institutes in order to assess the foreign gillnet fishery effort in the Brown Ridge area for the years 2014-2017. Data sets were received for the Danish and German gillnet fleet. We chose to limit out request to these three countries due to the information on effort of gillnet fishery of national fleets on the North Sea retrieved from a source on European fishing data collected by the Scientific, Technical and Economic Committee for Fisheries (STECF) and accessible via the link: https://stecf.jrc.ec.europa.eu/dd/effort/graphs-quarter

German gillnet fishery

There were <5 larger sized (VMS) German gillnet vessels active in the ICES rectangles 33F3-34F3-33F2 and no smaller sized (logbook) vessels. The German gillnet fishery in the area was limited to sole. This fleet fishes on average 284 days per year in the ICES rectangles 33F3-34F3-33F2. The effort decreased over time (from 599 days in 2014, to 294 days in 2015, 153 days in 2016 and to 89 days in 2017). In the Brown Ridge area, vessels fished a total of approx. 60 days per year in the period 2014-2017 and also here effort decreased over time (94 days in 2014, 115 days in 2015, 18 days in 2016 and 14 days in 2017). Figure 11 shows the intensity of the German gillnet fishery with a resolution of 1/16th ICES rectangle. Highest fishing intensities are found in the south-west and north-west corners of the Brown Ridge area.

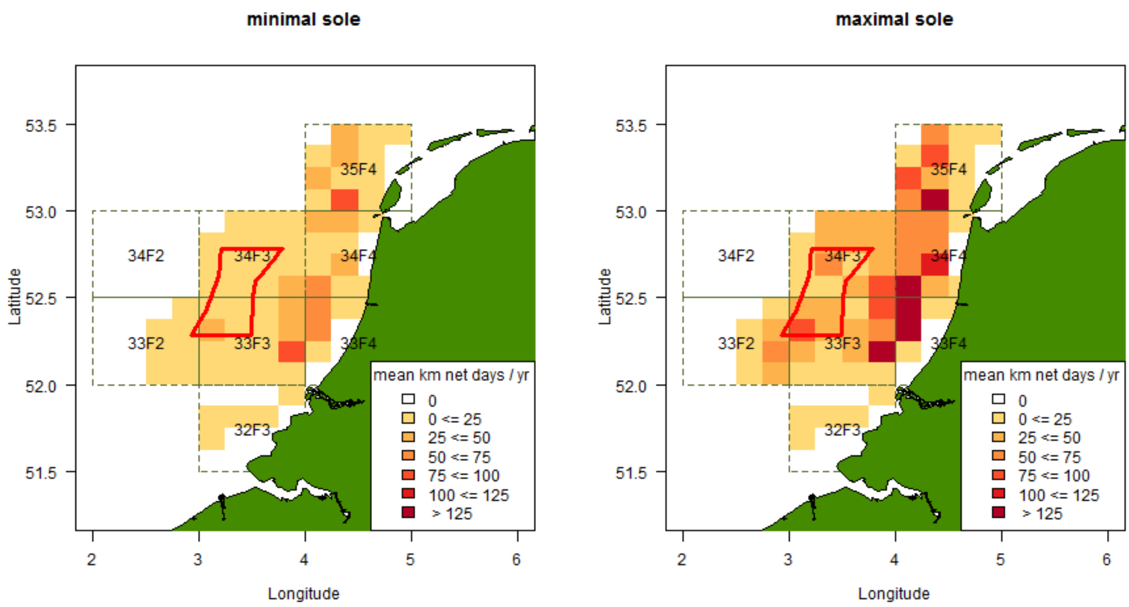


Figure 9 The intensity of the German gillnet fishery on sole in 8 ICES rectangles of the Dutch EZ (ICES rectangles 32F3, 33F2, 33F3, 33F4, 34F2, 34F3, 34F4, 35F4), including the Brown Ridge, shown per 1/16 ICES rectangle. Expressed in number km-net-days per year.

Danish gillnet fishery

The fishing effort data sent by Denmark did not contain information on net lengths and spatial distribution of the effort. In the ICES rectangles 33F3-34F3 (including the Brown Ridge) <5 smaller sized (logbook) vessel were active in 2014 targeting both sole and cod. Effort was limited to 1-2 days per year in 2014 by these vessels. In the other years, no small sized vessels (logbook) were active in the area.

Less than 5 larger sized vessels (VMS) were active in the Brown Ridge area, all targeting sole. These vessels fished on average 13 days per year in the Brown Ridge area. Fishing effort is decreasing over time, from 32, 15, 4, 0 days in respectively 2014, 2015, 2016, 2017. The limited effort (few days, see above) of the smaller sized vessels (logbook) in the ICES rectangles surrounding the Brown ridge area was not included in the effort of the different Brown Ridge variants.

Comparison with Dutch gillnet fishery

While the German effort is a result of larger sized vessels (VMS), the biggest part of the Dutch effort comes from small sized (logbook) vessels (*Table 5*). Sole is the main target species for all fleets. Compared to the Dutch fishing effort, the total (VMS and logbook) effort of the German fleet was much higher in 2014 and 2015 and comparable in 2016 and 2017, whereas the effort by the Danish fleet was lower in all years op the period 2014 to 2017 (see *Figure 10*). The fishing effort in the variants decreases over time for all fleets. Gillnet fishery effort is the highest in variant A1.3 for Dutch and German gillnet fishery, and second highest in A1.3 for Danish gillnet fishery. Gillnet fishery effort is the lowest in variant B1 for these three gillnet fleets. After correction for the differences in surface area the gillnet fishery effort is the highest in variant A1.3 for Dutch, German and Danish gillnet fishery.

Table 5 Registration and estimated intensity of the foreign gillnet fisheries in the ICES rectangles and the Brown Ridge. For comparison the data for the Dutch gillnet fisheries with VMS are shown.

Nationality	Period	ICES rectangle 33F3 ,34F3 and 33F2 including Brown Ridge			Brown Ridge	
		Mean number ships per year (demonstrated)	Mean number of fishing days per year	Mean fishing effort (fishing days/year)	Mean number of ships per year (demonstrated)	Mean number of fishing days per year[1]
		VMS	VMS	Logbooks	VMS	VMS
Dutch	2014 – 2017	<5	15	104	<5	0.11
German	2014 - 2017	<5	284	0	<5	60
Danish	2014 - 2017	not reported*	not reported*	<5	<5	13

* No information of larger sized 'VMS' vessels outside the Brown Ridge variants was provided.

[1] Values are the average of the average VMS effort per year for all variants.

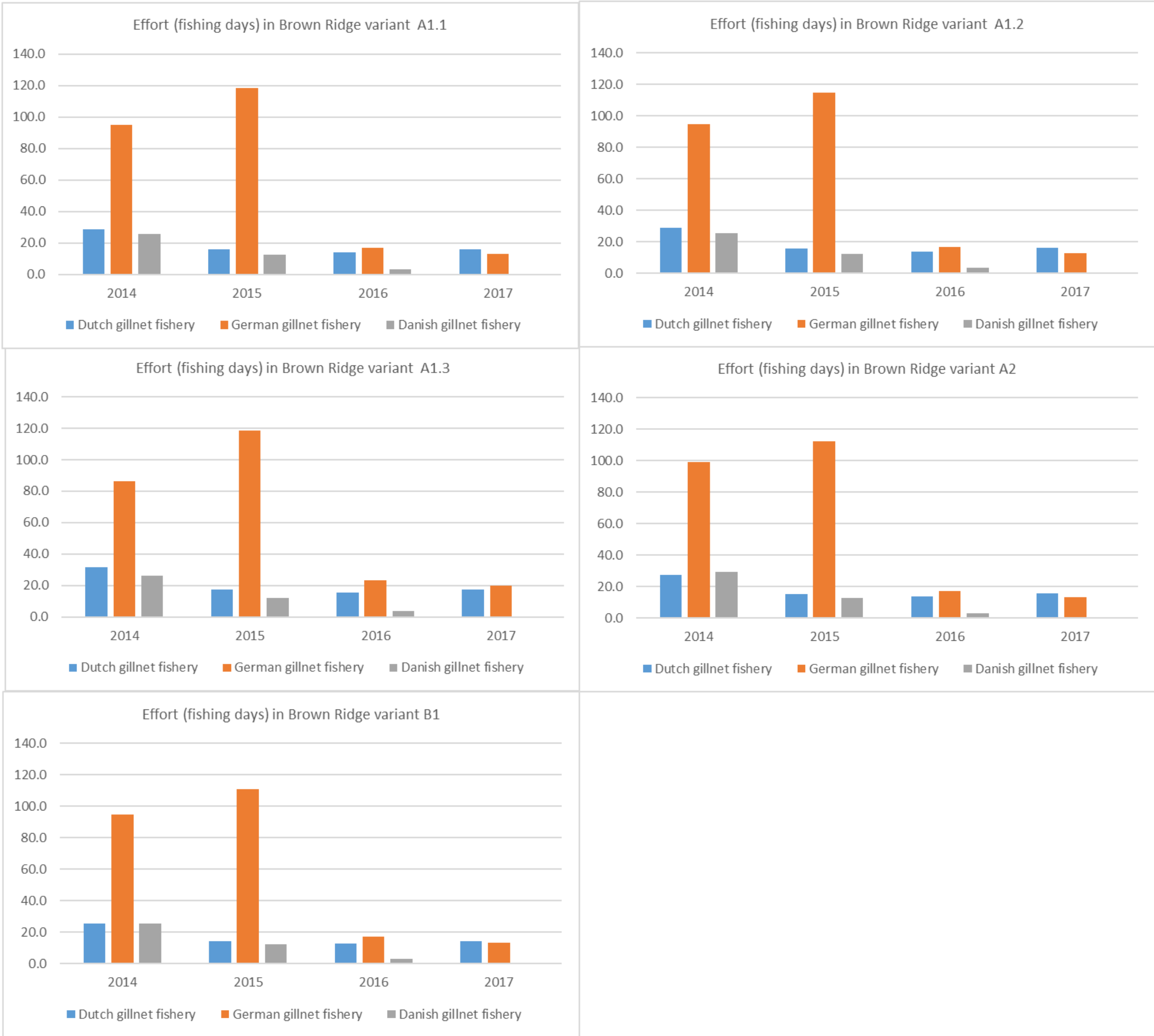


Figure 10 Overview of the Dutch, German and Danish gillnet fishery effort in the Brown Ridge variants in the period 2014 up to 2017. (The Danish effort includes only the VMS vessels, the limited (few days) effort of Danish small (logbook) vessels in ICES rectangles surrounding the Brown Ridge is not included).

3 Economic values of gillnet fishery

3.1 Results for the Dutch gillnet fishery

Based on logbook information and average first sale prices, the total value of the landings from the Dutch gillnet fishery was almost EUR 2.3 million in 2014. However, the total value of the landings dropped towards less than EUR 1.4 million in 2017 (BIN, 2018). To estimate the value of the landings coming from the Brown Ridge, we combined VMS data with logbooks as described in Hintzen et al. (2013). We only had VMS data in the Brown Ridge in 2014, since there was no VMS activity recorded in the area in 2015, 2016 and 2017. Hence, in fact only logbook information that was not coupled with VMS records was used for the period 2015-2017. This information is available at the ICES rectangle level and we assumed a homogenous repartition of the value of landings within an ICES rectangle (i.e. the area of the Brown Ridge overlaps with 24% of ICES rectangle 34F3, so for vessels without VMS 24% of the value of the landings reported in 34F3 is allocated to the Brown Ridge).

In Figure 11, estimates of the value of landings for the Dutch gillnet fisheries in the various variants of the Brown Ridge are shown for 2014, 2015, 2016 and 2017 for fisheries targeting different species (including seabass, sole and cod). For 2014, the revenues from the Brown Ridge for the Dutch gillnet fisheries are lower compared to the revenues presented in Jongbloed et al. (2015). This is because 4 out of 5 Brown Ridge variants are smaller compared to the Brown Ridge area considered in the previous study. The value of the landings was estimated by Wageningen Economic Research. The difference in value between the different variants of the Brown Ridge is relatively small. The value of the Dutch gillnet fisheries was structurally the highest in variant A1_3 while the lowest value was structurally observed in variant B1. After 2014, the only fishing activity assigned to the Brown Ridge variants is from vessels without VMS, so based on data at the ICES rectangle level (so in fact, activity is recorded in the rectangles overlapping with the Brown Ridge, not on the Brown Ridge itself per se). The difference between the 5 variants is therefore entirely due to the overlapping surface of each variant with ICES rectangle. What also seems to be important is that relatively much more fishing has occurred in the rectangles including the southern half of the Brown Ridge than in the rectangles including the northern half of the Brown Ridge. Variant A1-A3 has the largest share of all variants in the southern part (i.e. ICES rectangle 33F3) and has therefore been allocated the most effort and economic value. Variant B1 has the smallest part of ICES rectangle 33F3. In addition, a decreasing trend with respect to the value of the Dutch gillnet fisheries was observed in all variants of the Brown Ridge. It ranges between EUR 37,746 and EUR 47,021 in 2014 and down to EUR 20,027 and EUR 24,914 in 2017. Based on our estimates, the average value of landings of the Brown Ridge variants in 2017 was more than EUR 22,000 which corresponds to about 1% of the value of gillnet landings for the Dutch fishery and represents a gross value added of almost EUR 10,000.

In some cases, VMS data can be missing. However, data regarding the ICES rectangle is always available. Therefore, the value of landings for Dutch gillnet fisheries was analysed for ICES rectangle 33F3 and 34F3 to see whether a similar pattern can be observed as the variants of the Brown Ridge. In Figure 12, estimates of the value of landings for the Dutch gillnet fisheries in 33F3 and 34F3 are shown for 2014, 2015, 2016 and 2017 for fisheries targeting different species (including seabass, sole and cod). A similar pattern of decreasing revenues as shown for the different variants of the Brown Ridge was observed in 33F3 and 34F3 (see Figure 12).

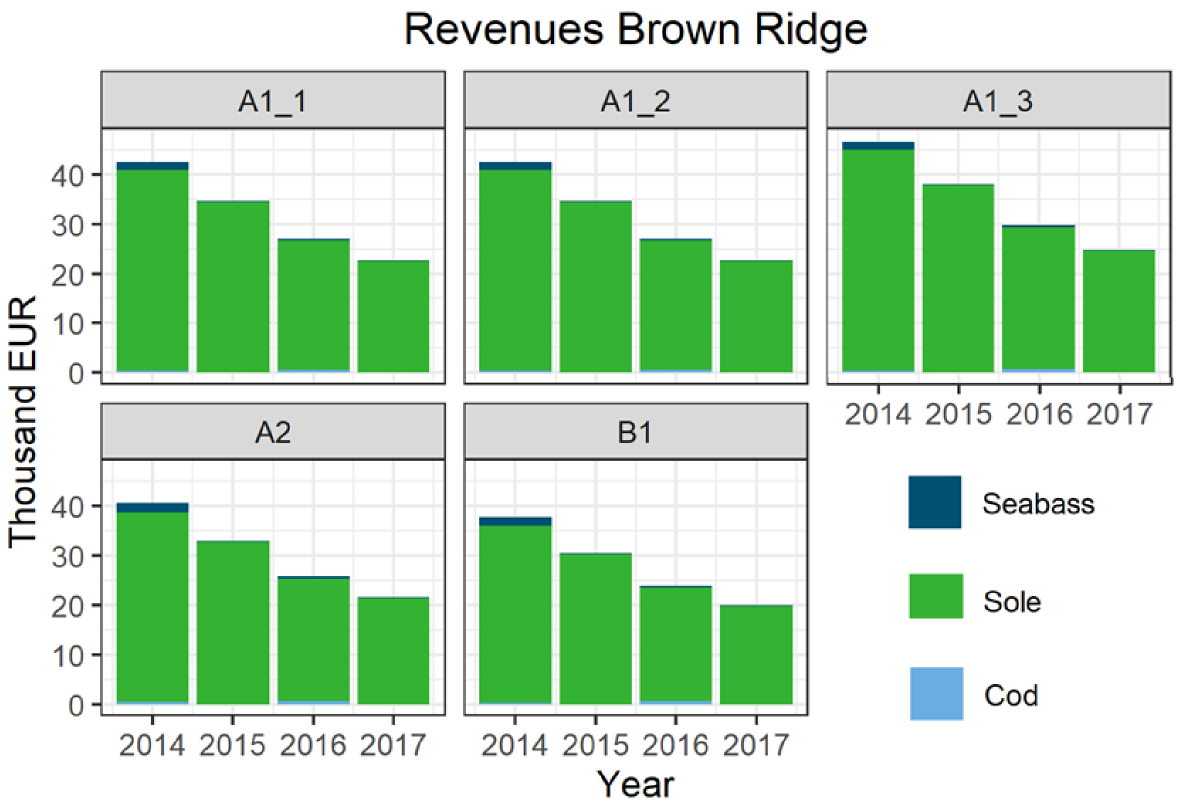


Figure 11 Value of landings in the Brown Ridge variants by Dutch gillnet fisheries defined by their target species (Seabass, Sole and Cod).

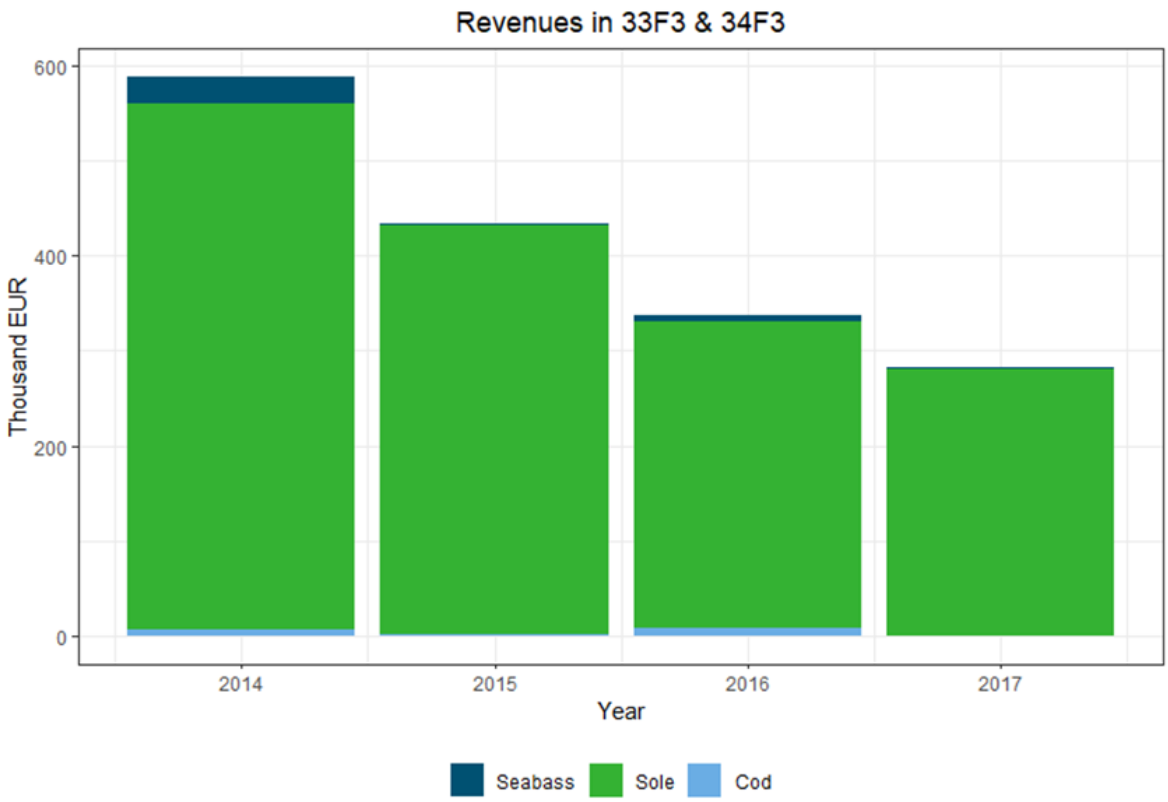


Figure 12 Value of landings in 33F3 and 34F3 by Dutch gillnet fisheries defined by their target species (Seabass, Sole and Cod).

Even though the total amount of revenue coming from the Brown Ridge is low for the total fleet, for a few fishers it represents a substantial part of their total revenue. In 2014, 10 Dutch vessels fished in Brown Ridge with gillnets, with 6 vessels fishing more than 10% of their revenue (between 11 and 20%) in this area (see previous report). In the period 2015-2017, the lack of VMS data in the area prevented us from making the same analysis. Looking at the importance of the two main ICES rectangles overlapping with the Brown Ridge (33F3 and 34F3), the total number of gillnetters fishing there to 9 vessels and 4 vessels with 11-20% of their revenue (Figure 13). The total number of Dutch gillnet vessels fishing in the North Sea (with and/or without fishing in the Brown Ridge) also dropped in the period 2014-2017. In Figure 14, the number of Dutch gillnet vessels for which the revenue in 33F3 and 34F3 are shown for 2014, 2015, 2016 and 2017. A similar pattern as indicated in Figure 13 was observed in ICES rectangle 33F3 and 34F3 (see Figure 14).

The revenues from the logbooks and average prices are most probably an underestimate of the actual revenues obtained by the gillnet fishermen. Information from questionnaires of fishermen shows that the actual revenue might be 50% higher than estimated here (Taal et al., 2014). This is because not all landings have to be recorded in the logbooks and because gillnetters receive better prices than the average auction price used in estimation.

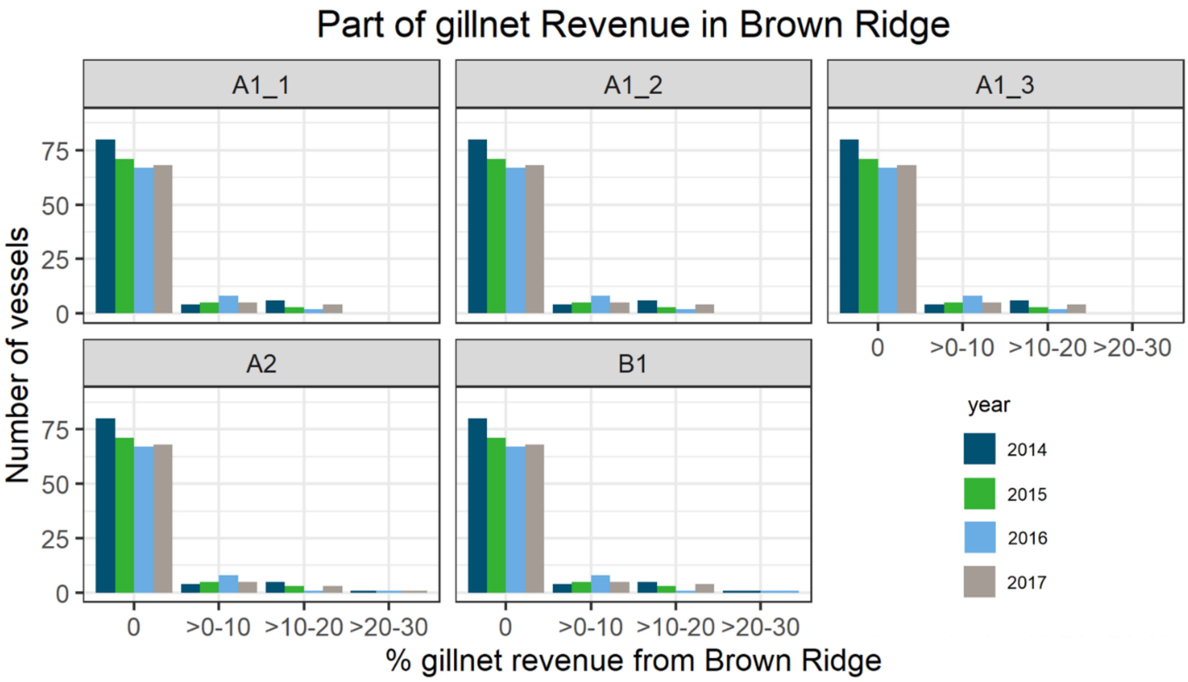


Figure 13 Number of Dutch gillnet vessels for which the revenue in the Brown Ridge variants is null, less than 10%, between 10 and 20% or between 20 and 30% of their total revenue in 2014, 2015, 2016 and 2017.

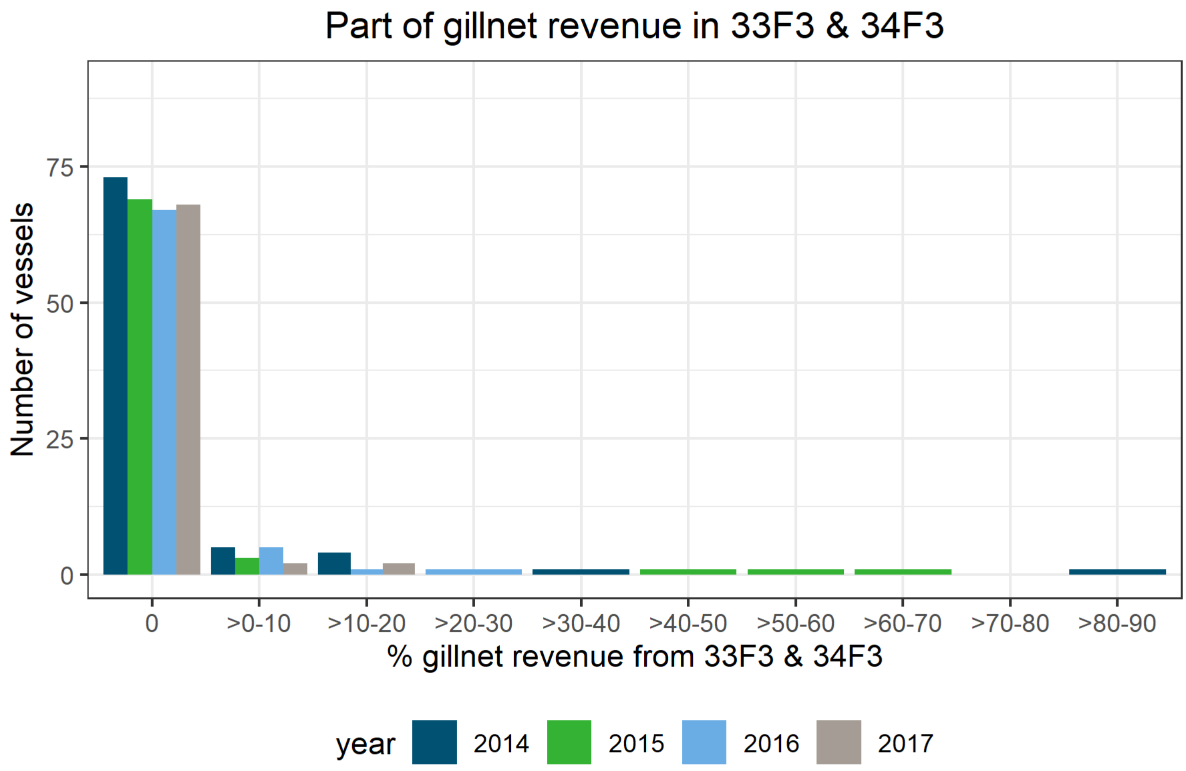


Figure 14 Number of Dutch gillnet vessels for which the revenue in 33F3 and 34F3 is null, less than 10%, between 10 and 20% or between 20 and 30% of their total revenue in 2014, 2015, 2016 and 2017.

3.2 Results for foreign gillnet fishery

The value of landings from the Brown Ridge in the various variants of the Brown Ridge for foreign fleets are estimated for the German and Danish fleets based on VMS data (respectively by the Thünen Institute for Sea fisheries and DTU Aqua, see Figure 15). For both countries, the full period was covered with fishing activity of gillnetters with VMS (except in 2017 where no Danish vessels were recorded in the area). The estimates of the value of landings in the Brown Ridge (calculated at the trip level with VMS data) are provided by national institutes and expected to be more precise than the previous report (see Jongbloed et al., 2015) in which we estimated the value of landings in the Brown Ridge for the German and Danish fleets based on the effort in the Brown Ridge (provided by national research institutes) and on the value per unit of effort (VPUE) using gillnets in the southern North Sea (extracted from the DCF database of the Annual Economic Report, STECF, 2015). In this report, the values of the landings are based on VMS data and logbook data which are more accurate. An R-script has been sent to national institutes with which they can precisely generate the output that was needed. While Germany ran the script provided, Denmark provided data based on their own script. This can have consequences for the quality and interpretation of the results of the Danish fleets.

Depending on the year, different variants have different importance for the foreign fleets. In all areas a common pattern can be observed for the German fleet. The value of the landings of the German gillnetters in the Brown Ridge dropped to EUR 13,510 – EUR 17,636 in 2016 (min in variant A1_1, A1_2, A2 and B1, and max in variant A1_3 and Total) after a peak value in 2015 of EUR 101,050 – EUR 115,280 euro (min in variant B1 and max in variant Total). The decreasing trend can be explained by the decreasing effort over time (from 599 days in 2014 to 89 days in 2017). In the Brown Ridge Area vessels fish a total of 69 days per year on average and also here effort is decreasing over time (107 days in 2014 and 20 days in 2017). A decreasing trend was also observed for the value of the landings of the Danish gillnetters in the Brown Ridge, with peak values of EUR 166,048 – EUR 221,452 in 2014 (min in variant A1_2 and max in variant Total) that dropped sharply towards EUR 13,984 – EUR 19,924 in 2016 (min in variant A2 and B2 and max in variant A1_3 and Total). Foreign gillnet fishing in and around the Brown Ridge only represents a small share of the total gillnet revenue of the fleets.

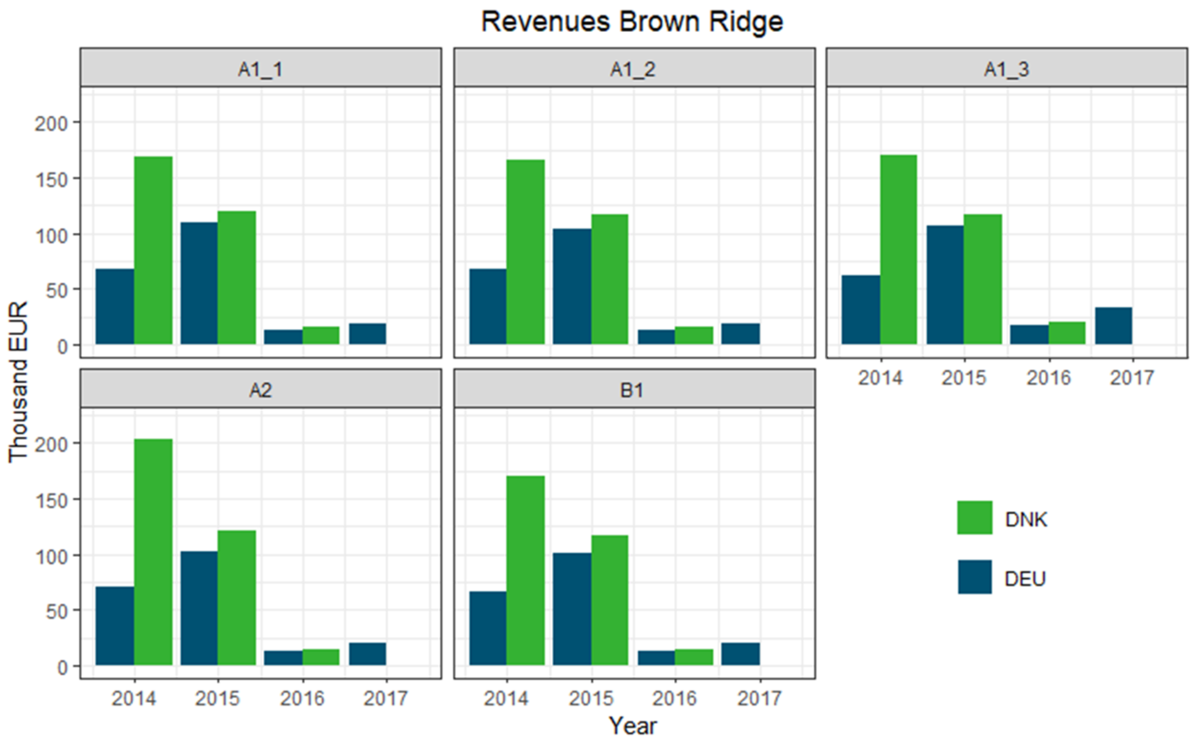


Figure 15 Overview of the total value of landings of the foreign gillnet fisheries for all variants of the Brown Ridge (averages from the period 2014-2017). Reference: processed data from the Thünen Institute for Sea fisheries and DTU Aqua.

4 Density of seabirds

Selection of relevant seabird species

Recently the aforementioned five geographical Brown Ridge variants were analysed for the numbers and possible qualification status of 14 seabird species by De Jong et al., (2018) and Fijn & de Jong (2019). Results are summarised in *Table 6*.
Common guillemot and razorbill are relevant seabird species to consider in the present study because of the high numbers in the Brown Ridge, meeting the requirements of the Bird Directive (Fijn & De Jong, 2019, chapter 6 of the present report) in combination with a potential risk for entanglement in gillnets. Both species dive when foraging on fish and can easily reach the sea floor in the study area (Piatt & Nettleship, 1985; Jury, 1988; Hedd et al., 2009).
In addition to common guillemot and razorbill, there are four so-called 'begrenzende' soorten (northern gannet, great skua, little gull, greater black-backed gull) and two potentially 'begrenzende' species (lesser black-backed gull, sandwich tern) based on their status in one or more of the BD/Natura 2000-areas in the international North Sea in combination with meeting the 0.1% criterion of the biogeographical population for the Brown Ridge (Leopold & Van der Wal 2015; Fijn & De Jong, 2019). Only the northern gannet is a deep diver, reaching average diving depths of 19,7 meter (SD 5 7.5, range 8,0 to 34,0 m), as reported (Brierley & Fernandes, 2001). This means that a considerable part of the Brown Ridge seafloor is within reach for Northern gannets, but not to any of the other species, which are shallow divers at best. Therefore, the northern gannet will be selected for the risk assessment.

For the Brown Ridge three diving seabird species have thus been identified to be of interest both with respect to the (considered) designation as an MPA as part of Natura 2000 as well as the gillnet fisheries (*Table 6*):

- Common guillemot (*Uria aalge)*
- Razorbill (*Alca torda*)
- Northern gannet (*Morus bassanus)*

Table 6 Status of seabird species for a possible Natura 2000-area Brown Ridge (adapted from Fijn & De Jong, 2019) and diving behaviour. The seabird species selected for the impact assessment of gillnet fishery are shown in bold

Bird species	Dutch name of bird species	Status of species for Brown Ridge	Diving
Northern fulmar	Noordse stormvogel	Not qualifying, not 'begrenzend'	shallow
Northern gannet	**Jan van Gent**	**'Begrenzend'**	**moderately deep**
Great skua	Grote Jager	'Begrenzend' *	no
Little gull	Dwergmeeuw	'Begrenzend'	no
Black-legged kittiwake	Drieteenmeeuw	Not qualifying, not 'begrenzend'	no
Common gull	Stormmeeuw	Not qualifying, not 'begrenzend'	no
Lesser black backed gull	Kleine mantelmeeuw	Not qualifying, not 'begrenzend', but not counted in the proper time*	no
Herring gull	Zilvermeeuw	Not qualifying, not 'begrenzend'	no
Greater black backed gull	Grote mantelmeeuw	'Begrenzend'	
Sandwich tern	Grote stern	Not qualifying, not 'begrenzend', but not counted in the proper time*	shallow
Common tern/Arctic tern	Visdief/Noordse stern	Not qualifying, not 'begrenzend', but not counted in the proper time	shallow
Razorbill	**Alk**	**Qualifying**	**deep**
Common guillemot	**Zeekoet**	**Qualifying**	**deep**
Atlantic puffin	Papegaaiduiker	Not qualifying, not 'begrenzend'	Yes

Potentially a higher category in case counted in the proper period

Seabird species, including common guillemot, razorbill and northern gannet have been monitored by airplane (MWTL ((Monitoring Waterstaatkundige Toestand des Lands)) in the Brown Ridge and its surroundings in four months of the year (January, February, August, November) since 2014. The method and the data have been described and evaluated by Fijn & De Jong (2019). Monitoring data for the years 2014, 2015, 2016, 2017 are provided for the present project. Since 2014 the MWTL airplane programme is adjusted to a modern counting method with better recognition of species (De Jong et al., 2018). This method and more recent count data were used to determine the borders of a possible Natura 2000-area Brown Ridge.

Fijn & de Jong (2019) concluded that the set-up of the MWTL-monitoring in the Brown Ridge area met the three criteria for sufficient completeness. There was sufficient counting in space, counting in time (frequency), counting technique according to ESAS (European Seabirds at Sea) standards, and monitoring included the period in which the area is significant (moulting period (autumn) and overwintering (winter)). It should be noted that for the present study aimed at assessing the potential bycatch risk, other criteria for seabird density information may also be of importance. For instance, monitoring data for seabirds with a higher frequency in order provide the information for the period that high numbers of seabirds are present in the area in combination with a high intensity of gillnet fishery. Jongbloed et al. (2015) showed that this period is October to May for common guillemots and October to March for razorbills with seabird density data being important for each month with these periods.

The average season maximum values of common guillemot, razorbill and northern gannet have been calculated by Fijn & De Jong (2019). The numbers of the counted birds for one of the five Brown

Ridge-variants, namely variant A2+0km, are listed in **Fout! Verwijzingsbron niet gevonden.***Table 7*. Data for the other BR-variants, including more background information, can be found in the report of Fijn & De Jong (2019). The variant A2+0km is chosen here because it is the largest area and contains the highest number of the selected seabird species.

Table 7 MWTL-based numbers of Common guillemot, Razorbill and Northern gannet in the Brown Ridge (A2 variant in Fijn & De Jong (2019).

Seabird species	Season	A	N	J	F
Common guillemot	2014/2015	2014	2339	7589	5815
Common guillemot	2015/2016	363	3512	8016	10511
Common guillemot	2016/2017	1420	4904	35824	15008
Razorbill	2014/2015	150	869	937	3813
Razorbill	2015/2016	0	545	2192	7968
Razorbill	2016/2017	12	1110	2326	4739
Northern gannet	2014/2015	1028	433	345	193
Northern gannet	2015/2016	379	1077	399	920
Northern gannet	2016/2017	433	889	1190	734

Maps of the density of the seabirds in the Brown Ridge can be found in Fijn & de Jong (2019). For common guillemot and razorbill we constructed maps for separate estimations based on MWTL counts (*Figure 16*, *Figure 17*) and the derived mean season distribution across the three winter seasons 2014-2015, 2015-2016, 2016-2017 (*Figure 18*, *Figure 19*).

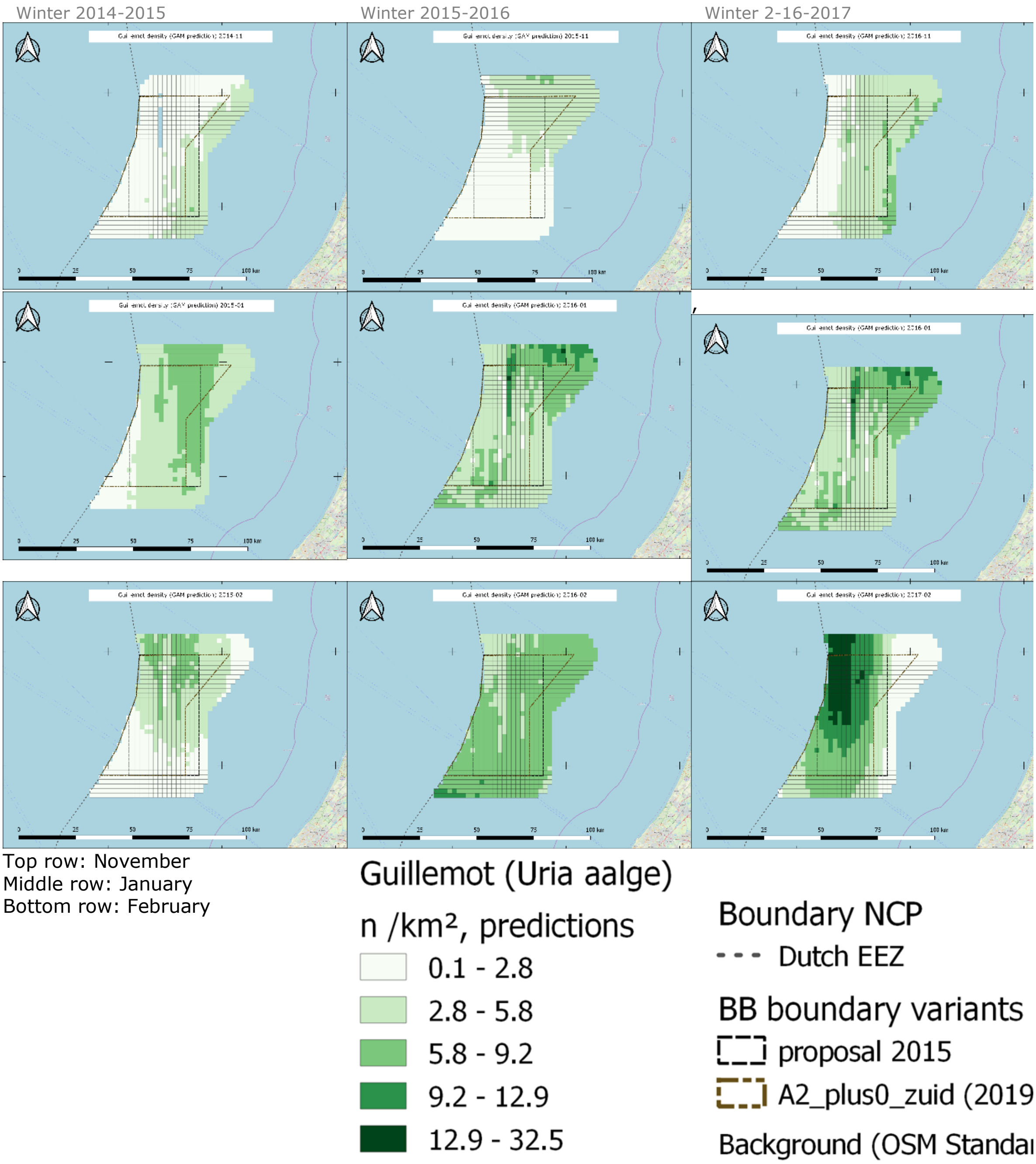
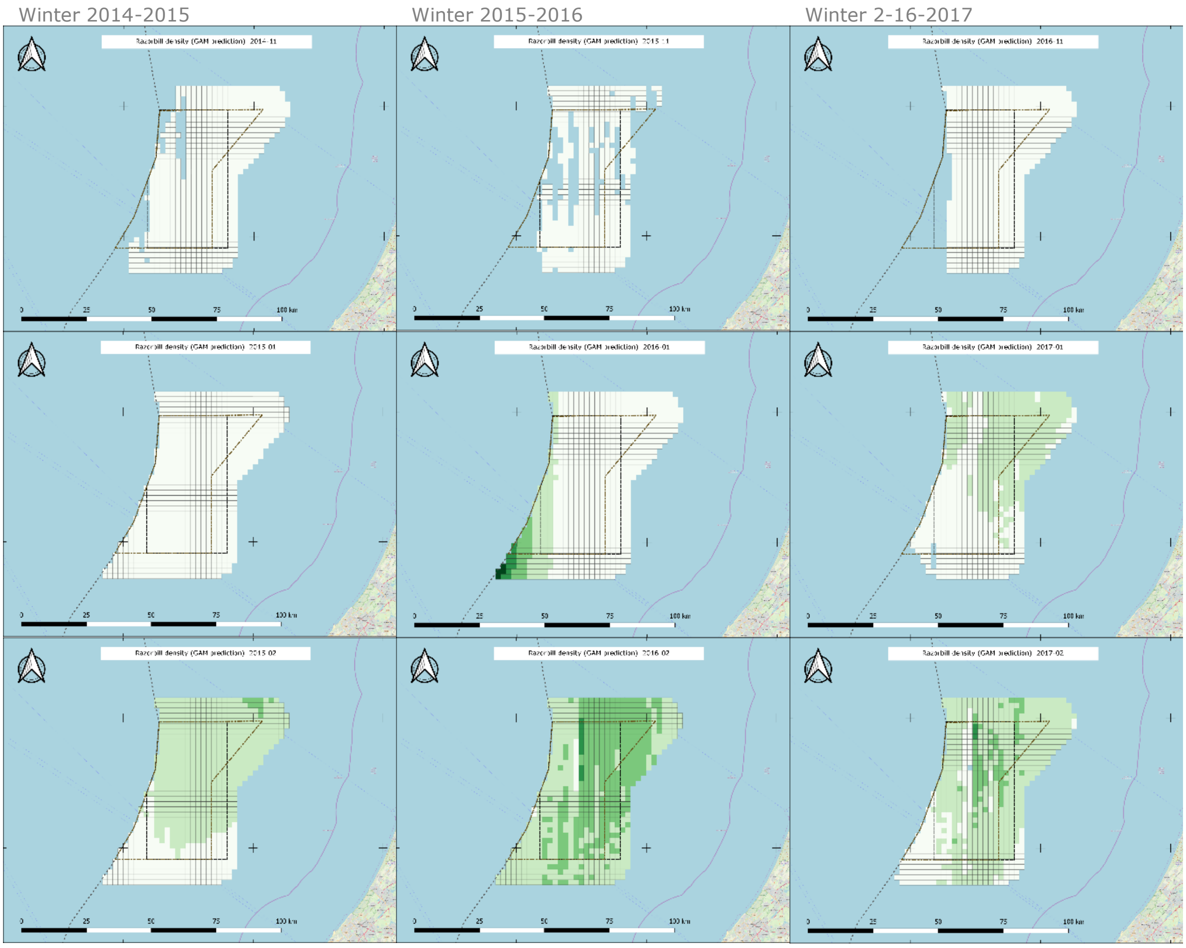


Figure 16 Distribution of maximum number of the common guillemot in 3 months of 3 successive winter seasons in one of the options for geographical areas of the Brown Ridge - variant A2_plus 0_zuid.



Top row: November
Middle row: January
Bottom row: February

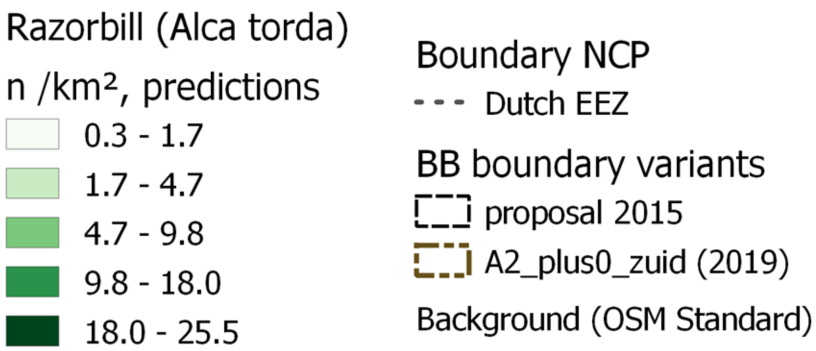


Figure 17 Distribution of maximum number of the razorbill in 3 months of 3 successive winter seasons in one of the options for geographical areas of the Brown Ridge, namely – variant A2_plus 0_zuid.

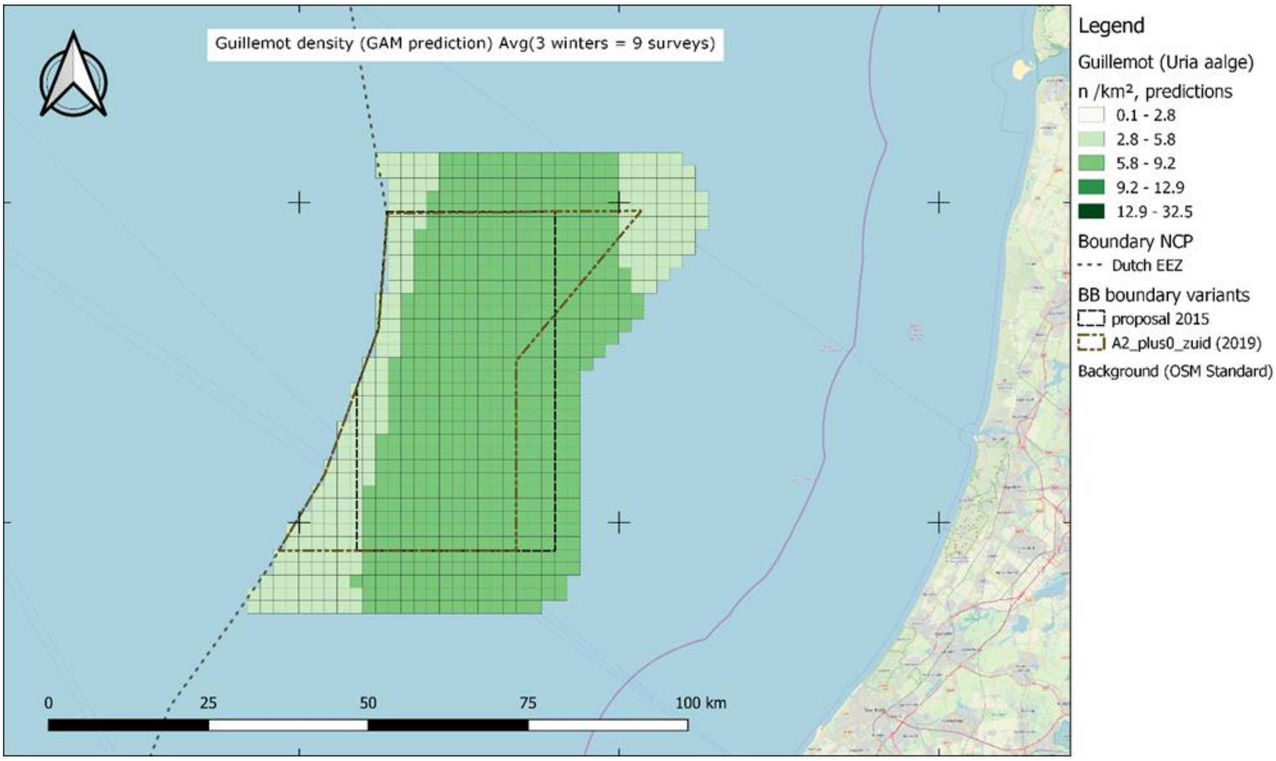


Figure 18: Common guillemot (Uria aalge) mean season maxima distribution across the Brown Ridge area across 3 winter seasons (2014-2015, 2015-2016 and 2016-2017, includes 9 surveys).

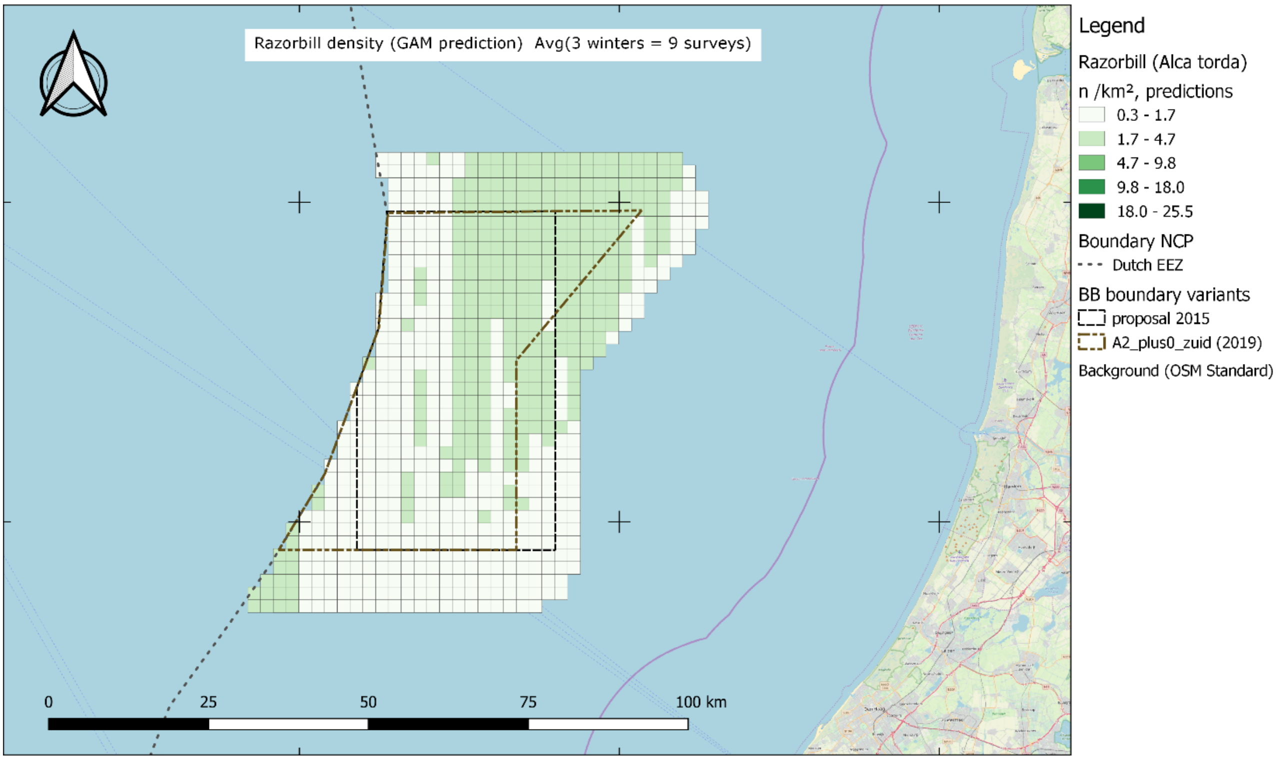


Figure 19: Razorbill (Alca torda) mean of season maxima distribution across the Brown Ridge area across 3 winter seasons (2014-2015, 2015-2016 and 2016-2017, includes 9 surveys).

From these data we made three bar plots to visualise the variation in the average maximum bird numbers among the five geographical variants of the Brown Ridge (*Figure 20*), variation among the three seasons (2014/2015, 2015/2016, 2016/2017) (*Figure 21*) and among the four months (January, February, August, November) (*Figure 22*).

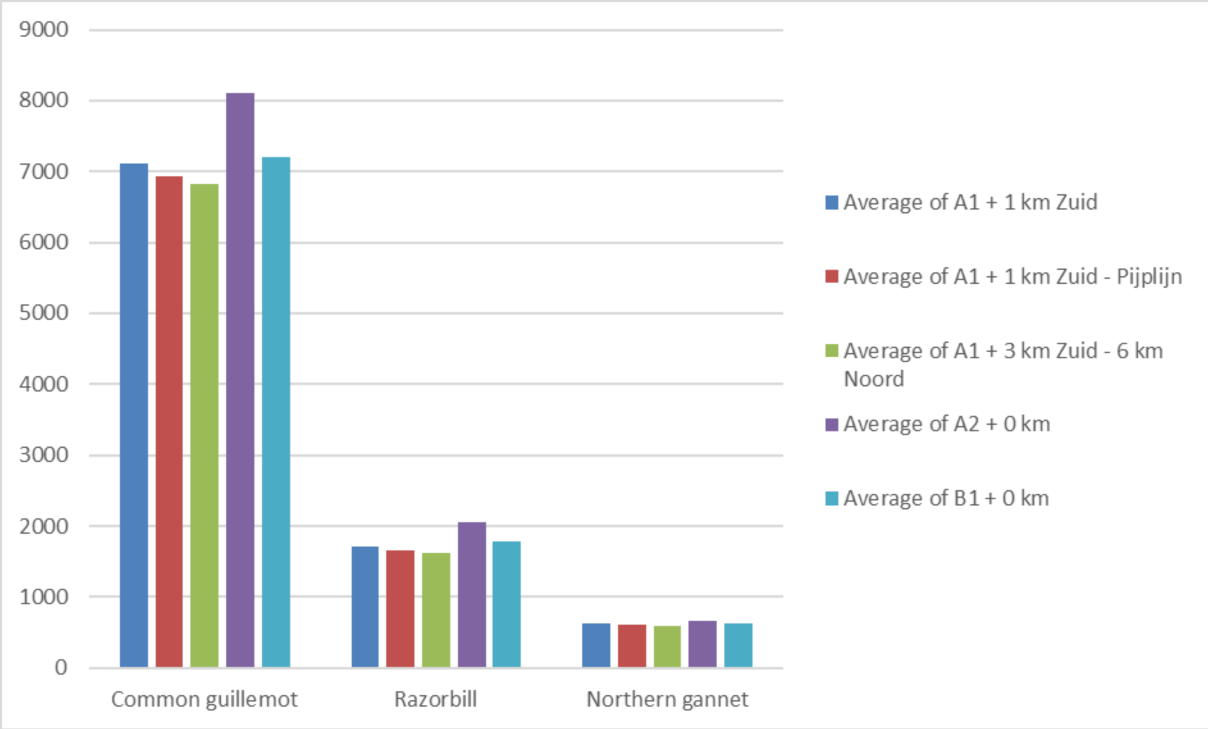


Figure 20 Presence of the protected seabirds in the Brown Ridge according to five options for the geographical area. Average of the maximum numbers of the months January, February, August, November in the seasons 2014/2015 to 2016/2017.

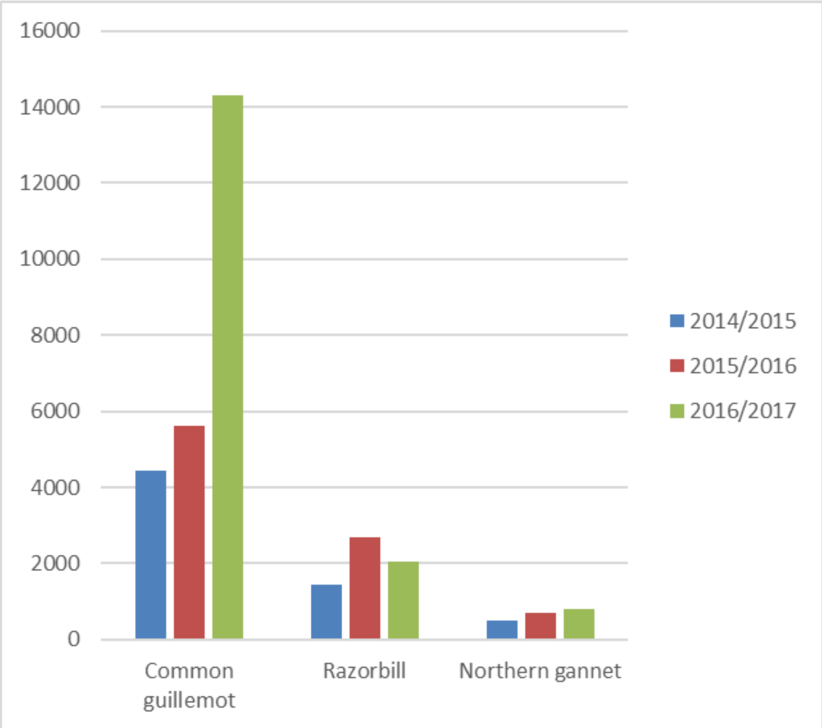


Figure 21 Presence of the protected seabirds in the Brown Ridge area option A2 + 0 km in three seasons 2014/2015, 2015/2016, 2016/2017. Average of the maximum numbers of the months January, February, August, November.

The relative presence of the common guillemot and the razorbill during the four monitored months of the year of the three seasons 2014/2015, 2015/2016, 2016/2017 is shown in *Figure 22*. The common guillemot has the highest abundance in January, followed by February, November and August. The razorbill has the highest abundance in February, followed by January, November and August. For the gannet difference between months in relative abundance are much less pronounced.

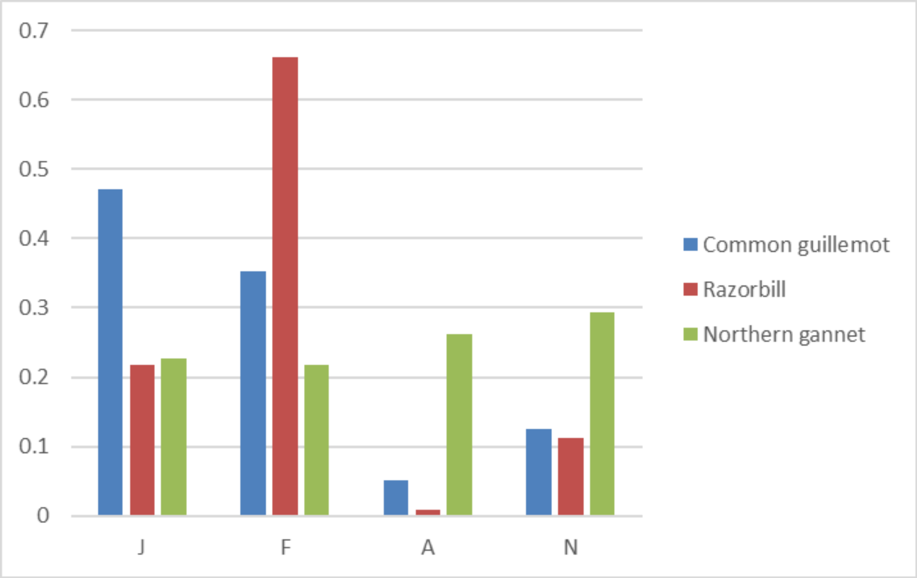


Figure 22 Relative presence during the year of protected seabirds in the Brown Ridge option A2 + 0 km. For each bird species the maximum presence per month was divided by the sum of presence over the year. The bars add up to 1 for each bird species represented by colours. J: January; F: February; A: August; N: November

It should be noticed that this study can only use monitoring data for four months of the year. It is known from previous studies using monitoring data for all months of the year that a relative high presence is found for six months (October to March) for the common guillemot and for four months (December-March) for the razorbill (see Figure 23 taken from Jongbloed et al. (2015)). During spring and summer (April-September) the presence is much lower, but for the common guillemot still a considerable presence is found in the months April and May.

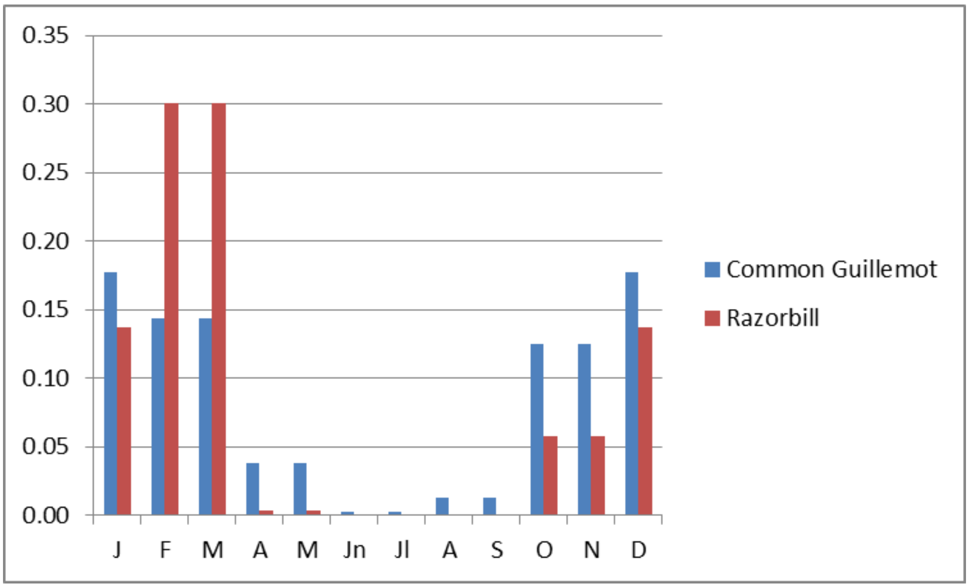


Figure 23 Relative presence during the year of common guillemots and razorbills in the Brown Ridge. For each bird species, the presence per month was divided by the sum of presence over the year. The bars add up to 1 for each bird species represented by colours. Data are based on monitoring with ESAS and MWTL for the period 2004-2013. Figure is taken from Jongbloed et al. (2015).

5 Bycatch of seabirds in gillnet fishery

Factors determining sensitivity of bycatch

A comprehensive review of the bycatch of seabirds in gillnets is provided by Žydelis et al. (2013). They concluded that bycatch of seabird in gillnets has been reported in various regions but the risk for populations is still poorly known. The Alcidae are among the birds most susceptible to bycatch in gillnets. There are a few examples of significant impacts of gillnet mortality for local colonies of auks, namely off the Atlantic Iberian coast and islands in the Northwest Pacific. The occurrence of bycatch of seabirds is largely determined by the spatial distribution of susceptible species.
According to Žydelis et al. (2013) the following factors determine the probability of bycatch in gillnets:

- Bird foraging behaviour (diving for fish or benthic fauna)
- Fishing characteristics (mesh size, setting depth, time of day, period of net soaking)
- Environmental conditions (water transparency, weather conditions)
- Spatial overlap (net setting location in relation to seabird abundance).

Studies on seabird bycatch in the North Sea are relatively scarce and even absent in the eastern North Sea (Durinck et al., 1993; Žydelis et al., 2013). Incidental gillnet bycatch is reported for other North Sea regions and victims include guillemots, razorbills and gannets. Local colony impacts may be possible but in the UK bycatch in gillnet fisheries was not seen as a significant threat to birds at a regional scale as indicated by the growth of auk colonies (BirdLife International, 2004).
ICES organised a workshop to review and advise on seabird bycatch (WKBYCS, 2013). In order to define the significance of seabird bycatch the first step is an assessment of the size of the bycatch in the fisheries of interest, and the necessary and desirable metrics that contribute to this assessment are identified and reiterated from previous initiatives. WKBYCS (2013) elaborates criteria or metrics that could be used to define a seabird bycatch problem. They suggest to follow a stepwise approach, beginning with a simple initial step. More detailed steps may be considered when earlier stages indicate a potential problem, but these steps have to be defined. Furthermore, it is recommended that fishing effort should be described at least in terms of days at sea, but where feasible using more gear-specific metrics. The application of "days at sea" is preferred for analysis on fleet level, because (1) (inter)national fishery effort data are mainly available as days at sea and (2) days at sea allows to simply aggregate fishery effort and observer effort of different fishery types. The existing bycatch database for protected species compiled by the ICES Working Group on Bycatch of Protected Species (WGBYC) should be adequate to register and analyse bird bycatch data. The current study determines and applies fishery effort in the number of km net days for three distinguished gillnet types. Both the fishing effort unity and gear-specific metrics meet the requirements of WKBYCS (2013).

Northridge et al. (2017) conducted a comprehensive literature study to identify the mechanisms of gillnet bycatch of birds, mammals and turtles. They found that many studies are reported in technical papers, government reports, and university theses. They reviewed many published and unpublished studies of bycatch in which causal or correlative factors were considered and identified therein 28 environmental, operational, technical, and behavioural factors that may be associated with high or low bycatch rates of birds, mammals and turtles. *Table 8* summarises the 13 factors identified as correlated with bycatch rates of birds. The majority of many other factors was not studied for birds. It should be noted that part of the factors mentioned by Northridge et al. (2017) and listed in *Table 8* were also identified by Zydelis et al. (2013) and some factors are additional. Northridge et al. (2017) state that their findings provide a basis to guide further experimental work to test hypotheses about which factors most influence bycatch rates and to explore ways of managing fishing activities and improving gear design to minimize the incidental capture of species of conservation concern while ensuring the viability of the fisheries concerned.

Table 8 Factors identified as correlated with bird bycatch rates. Source: Northridge et al. (2017)

Factor category	Factor with a demonstrated correlation with bycatch rate
Environmental	Wind or weather #
Environmental	Water depth
Operational	Location #
Operational	Time of day #
Operational	Time of year or season
Gear design	Mesh size #
Gear design	Net height
Gear design	Depth set #
Gear design	Twine type
Gear design	Lead line
Behavioural and physiological	Vision and light
Behavioural and physiological	Acoustic
Behavioural and physiological	Other behaviour #

This factor was also identified by Zydelis et al. (2013)

Northridge et al. (2017) conclude that there is no obvious single factor that provides the key to minimizing bycatch seabird. Although some factors, like water depth, net height, mesh size, have a marked influence on the bycatch rates, and these factors require much more detailed work, including more comprehensive monitoring and experiments at sea to test their effects on bycatch in situ. The authors state that monitoring and experiments at sea are relatively expensive to undertake but given the absence of a single solution to this problem, more work must be undertaken if bycatch of vulnerable species is to be addressed in a balanced and productive manner. Further work to examine how fishing practices, technologies, and animal behaviour influence bycatch is urgently required.

Reported bycatch victims

ICES WGBYC reviews data collated from Regulation 812/2004 annual reports (ToR-A). The 812/2004 regulation requires only cetaceans to be monitored. However, some countries also report bycatches of other vertebrate groups. For efficiency and funding reasons, most Member States combine the on-board sampling of fish catch under the Data Collection Framework (DCF) ((EC) No 2017/1004). Only the UK and Italy are known to have dedicated observer programmes under the 812/2004 regulation. In the past the EC expressed the intention to cancel the regulation and cover the monitoring of all protected species under the DCF. From January 2017 onwards, Member States are obliged to record incidental bycatch of protected species under the DCF. Since then, Member States struggle with the implementation: on board sampling protocols need to be altered and National databases need to be adjusted to be able to hold incidental bycatch data and the coverage. Also, the spreading of observer effort needs to be review. Currently effort is based on the landings of targeted fish species, which are mainly caught in trawl fisheries. Incidental bycatch of protected species (including birds) take place mainly in set net fisheries. Since 2017 WGBYC, requests data on the catch of all protected species sampled and recorded under the DCF. As the sampling of protected species under the DCF is not yet (fully) implemented in most Member States, WGBYC continues to highlight the inconsistent submission and content of annual data submissions provided by some Members States. Despite the earlier intention to stop continuing the 812/2004 Regulation, the EC is currently preparing an extension of the 812/2004.

Joint OSPAR/HELCOM/ICES Working Group on Seabirds (JWGBIRD) and WGBYC acknowledged efficiencies that can be achieved by working together on further developing JWGBIRD bycatch risk assessments for seabird species where data allow. The continued development and maintenance of WGBYC database collating data on seabird bycatch from both dedicated and opportunistic is integral to this effort (ICES WGBYC REPORT 2017).

The objective of an ICES-convened Workshop to Review and Advise on Seabird Bycatch (WKBYCS) (ICES, 2013) was to address three issues:
• to review and update current seabird bycatch data and identify fisheries where appropriate follow up monitoring to establish bycatch levels would be desirable;
• to explore the criteria and/or metrics that could be used to define a seabird bycatch problem; and
• to establish a standard data reporting format for recording seabird bycatch and develop a database of seabird bycatch data in EU fisheries, similar to the database developed by ICES WGBYC for marine mammal bycatch..

The workshop saw no need to design a new database to host bird bycatch data; the existing bycatch database for protected species compiled by the ICES Working Group on Bycatch of Protected Species (WGBYC) should be adequate and be maintained by the ICES DataCentre.

The marine areas comprise the North Sea, Celtic Sea, Iceland Sea, and Baltic Sea. For the present study the characteristics of gillnet fisheries, seabirds and environment of the studied marine area should be comparable with the ones of the Brown Ridge. Therefore, offshore (Greater) North Seas areas, preferable offshore areas within the southern part of the North Sea, should be considered only. The conditions in the Celtic sea, Iceland Sea and Baltic Sea differ too much from the southern North Sea. For this report, we made a selection of data for common guillemot, razorbill and gannets in the North Sea from recent ICES reports on the bycatch (ICES, 2013; 2017; 2018). Bycatch victims and gillnet fishery effort are listed in *Table 9*. It should be noted that the ICES areas are known but details concerning the exact positions of the observed gillnets and bycatch victims is lacking and therefore a discrimination between coastal and offshore locations could not be made, although this is an important factor determining the abundance of seabird species and chance of bycatch (to Žydelis et al. 2013; Northridge et al., 2017).

Table 9 Compilation of bycatch specimens for the selected seabird species in set gillnets reported by ICES (2013, 2017, 2018) and Northridge et al. (2017) and derived bycatch rates (number of specimens/days at-sea)

Species (scientific name)	Species (English name)	RCM	ICES Area Code	Year(s)	Total No. Specimens	Total Observed Effort (Days at sea)	Bycatch rate (n/days at sea)	Reference
Uria aalge	Common guillemot	North Sea	UK waters	1990s - 2013	54	20000	0.00270	ICES (2013)
Uria aalge	Common guillemot	North Sea	27.4a; 27.4b; 27.4c; 27.7d	2016	0	23	0.00000	Northridge et al. (2017)
Uria aalge	Common guillemot	Greater North Sea	27.7.e	2016	14	122	0.11	ICES (2018)
Morus bassanus	Northern gannet	North Sea	UK waters	1990s - 2013	3	20000	0.00015	ICES (2013)
Morus bassanus	Northern gannet	North Sea	27.4a; 27.4b; 27.4c; 27.7d	2016	3	23	0.1304	Northridge et al. (2017)

It can be concluded from *Table 9* that high variation in the bycatch rate is found between bird species in the same study as well as between studies for the same bird species.

The important kind of information that is lacking is the abundance and density of the seabirds at the locations the observed gillnets were set. In order to assess the bycatch chance of seabirds it is essential to know the sea surface area and the number of seabirds with that area that is potentially exposed to gillnets during the soaking time.

Conclusion

There is a lack of information on the occurrence of bycatch victims in gillnets in the North Sea due to a lack of observer-programs. In addition, the number of seabirds in the vicinity of the gillnets at these nets were set out for fishing is often not reported, hampering the assessment of the potential exposure and the concomitant risk of bycatch. Therefore, quantification of bycatch risks for bird species for certain gear types and certain locations is not possible. However, the available information allows the qualitative evaluation of differences among bird species, gear types and locations in bycatch vulnerability. This will be applied in the risk assessment of the Brown Ridge (chapter 7) in the present study.

6 Conservation objectives for seabirds

6.1 Natura 2000

For the designation of the Brown Ridge as Natura 2000-area three main criteria apply. These criteria are extensively described by Leopold & Van der Wal (2015) and are also applied by De Jong et al. (2018). An area qualifies in case one of the following criteria are met:

Criterion 1: An area is of international importance when at least 1% of the biogeographical population of a waterbird species is regularly present. This matches with a 1% criterion for 3.240 razorbills and 15.620 common guillemots.

Criterion 2: An area is of international importance when there is a regular presence of at least 20.000 water birds of one or more species.

Criterion 3: In an area, so-called 'begrenzingssoorten' are determined: this applies in case at least 0.1% of the biogeographical population is regularly present in the area. Species that meet that 0,1% criterion are considered 'begrenzende soorten'[2]. In the case of the Brown Ridge the 0,1% criterion value is 418 northern gannets (Leopold & Van der Wal 2015).

Table 10 Population estimates for common guillemot and razorbill and the concomitant threshold values used for comparison with the results of this study.

Species	Estimated size biogeographical population (n)	Reference	1% threshold value (n)
Common guillemot	1562000	Skov *et al.* (2007)	15620
Razorbill	324000	Skov *et al.* (2007)	3240
Northern gannet	418000	BirdLife International (2004)	4183

[1] Calculated by dividing the population estimate (from Skov *et al.* (1995) for both bird species by the area of the North Sea; 750,000 km^2 – equal to the area analysed by Skov *et al.* (1995).

The Brown Ridge qualifies as Special Protection Area under the Bird Directive and is intended to be assigned as a Natura 2000-site (Van Bemmelen *et al.*, 2012; Leopold & van der Wal, 2015; Fijn & De Jong, 2019). The intended conservation objectives are:

- Common guillemot: maintain extent and quality of the habitat to sustain maintenance of the population
- Razorbill: maintain extent and quality of the habitat to sustain maintenance of the population
- The northern gannet: maintain extent and quality of the habitat to sustain maintenance of the population.

[2] An English denotation of 'begrenzende' is not available in this context and therefore only the Dutch denotation is used in this report

6.2 Quantitative criteria for protection

In risk assessment it is helpful to work with quantitative criteria for protection. In this section we therefore derive threshold values for maximum allowed number of bycatch victims of the protected seabird species in the Brown Ridge variants.

In the ICES Workshop to Review and Advise on Seabird Bycatch (WKBYCS, 2013) recommendations were made to elaborate criteria for bycatch. The following approaches were mentioned:

- The Potential Biological Removal (PBR) tool would appear to be an appropriate method, although there are others, to assess the conservation consequences of bird bycatch.
- Some ‘maximum allowable catch’ of seabirds, like PBR, would appear not to be acceptable from a cultural or societal point of view.
- The European Union Plan of Action (EU PoA) overall objective is to "minimise and where possible eliminate" bycatch. This objective derives directly from Article 5 of the Birds Directive (EU, 2009), which requires Member States to take measures prohibiting the "deliberate killing or capture [of birds] by any method".

We elaborated the PBR approach for the common guillemot, razorbill and northern gannet in the Brown Ridge. The biogeographical population level determines the 1% threshold value. For the three selected seabird species the North Sea population is considered the biogeographical population (Fijn & de Jong, 2019). For this study the selected values and their references are shown in *Table 11*.

The PBR is derived for the five variants of the Brown Ridge and listed in *Table 12*. In addition, we applied another criterion that is more protective than the PBR. This is the Ornis Committee criterion for bird populations which is 1% of the annual mortality.

Table 11 Number of birds for the North Sea according to the PBR and the Ornis criterion for the sea bird species. Source: Leopold et a;. (2014)

Species	Potential Biological Removal (PBR) for North Sea #	Ornis criterion (1% of annual mortality) for North Sea
Common guillemot	26641	681
Razorbill	7129	249
Northern gannet	5245	143

The surface area of the Brown Ridge variants ranges from 2.26 to 2.65% of the NCP, depending on the variant.

Table 12 Maximum allowed number of seabird victims for the Brown Ridge geographical area options according to the PBR criterion for the seabird species

BB-variant	Common guillemot	Razorbill	Northern gannet
A1_plus1_zuid	50	13	10
A1_plus1_zuid_min_pijplijn	49	13	10
A1_min6_noord_plus3_zuid	48	13	9
A2_plus_0_zuid	56	15	11
B1_plus0_zuid	50	13	10

Table 13 Maximum allowed number of seabird victims for the Brown Ridge options according to the Ornis criterion for the seabird species

BB-variant	Common guillemot	Razorbill	Northern gannet
A1_plus1_zuid	1.27	0.46	0.27
A1_plus1_zuid_min_pijplijn	1.24	0.45	0.26
A1_min6_noord_plus3_zuid	1.23	0.45	0.26
A2_plus_0_zuid	1.44	0.53	0.30
B1_plus0_zuid	1.28	0.47	0.27

It should be noticed that the bycatch of one single common guillemot, or razorbill or northern gannet on the Brown Ridge is already critical in case the Ornis criterion is chosen. Thus, application of the Ornis criterion is comparable with application of the EU PoA's overall objective to "minimise and where possible eliminate" bycatch. In case the PBR criterion is applied much more victims can be allowed before the populations of the sea birds are regarded to become threatened (*Table 12*).

7 Impact assessment of gillnet fishery for seabirds

In this chapter the impact assessment of gillnet fishery for common guillemot, razorbill and norther gannet is carried out. At first, the method is described. Subsequently the different aspects playing a role in the assessment are dealt with. Finally, the impact is assessed by integration of the aspects.

7.1 Method for impact assessment

The conflict analysis consists of the evaluation of the fishing impact on the seabirds (common guillemots, razorbills and northern gannets). Unfortunately, the bycatch of seabirds in gillnets set in the proposed Natura 2000-site Brown Ridge is not recorded and no exhaustive data exist on the interaction between fishers and seabirds. To evaluate the fishing impact on the bird populations several aspects must be accounted:

- Do the fishery and birds overlap spatially?
  - In the proposed Natura 2000-site Brown Ridge (geographically)
  - In the water column (vertically)
- Do the fishery and birds overlap temporally?
- What is the risk for a diving bird to be caught in a gillnet?
- Do all gillnet types share the same risks?

7.2 Spatial overlap

The spatial overlap is studied for two dimensions: surface area and water column. Both are relevant for the assessment of the potential exposure.

<u>Surface area</u>

There is a potential spatial overlap between gillnet fishery (see *Figure 3*, *Figure 4*, *Figure 5*, *Figure 9*) and sea bird distribution (see *Figure 16* to Figure) in the Brown Ridge. Precise predictions about differences among sub areas within the Brown Ridge concerning the extent of overlap cannot be made. There is also due to the considerable difference between fishery intensity and seabird density in the spatial scale. For fishery intensity maps the grid size is large, namely either 1/16 ICES rectangle or an entire ICES rectangle. For seabird density maps the grid size is small with a resolution of 2 x 2 km and seabirds numbers per km^2 per species. General predictions can be made, and this is carried out for the five geographical options for the Brown Ridge based on the spatial density maps derived in the present study. There is a high uncertainty because locations of fishing and birds presence can vary.

<u>Water column and diving depth</u>

The gillnet gears stand on the sea floor. The sea floor depth of the Brown Ridge varies between 16 and 50 m (average 32 m). The diving depth of common guillemots and razorbills has not been investigated in the Brown Ridge or adjacent areas of comparable depth. From the literature it is known that razorbills often seem to prefer to make shallow dives (Ouwehand *et al.*, 2004; Shoji *et al.*, 2015), but they have also been recorded at depths of 120 m (Piatt & Nettleship, 1985) and 140 m (Jury, 1988). Guillemots can dive very deep. Common guillemots in the northwest Atlantic were recorded to dive often below 50 m with maximum depth of 152 m (Hedd *et al.*, 2009) and even 180 m (Piatt &

Nettleship, 1985). Diving depth is likely related to local diet: birds feeding on demersal fish need to dive down to the bottom while birds feeding on pelagic prey can feed higher in the water column.

The diving depths of the northern gannet has been recorded by Brierley & Fernandes (2001) and amounts to an average diving depth of 19,7 meter (SD 5 7.5, range 8,0 to 34,0 m). This means that a considerable part of the Brown Ridge seafloor is within reach for northern gannets. However northern gannets typically feed on pelagic prey and do not dive down to the seafloor but instead chase their prey in the upper and middle water column range. Therefore, the risk of entanglement in gillnet standing on the seafloor of the Brown Ridge is assessed to be very low for northern gannets and much lower than for common guillemots and razorbills when foraging in the same marine area. Although entanglements of northern gannets in fishing gear on the Dutch coast have been reported (Camphuysen, 1994).

Another way to derive information on the expected diving depth of sea birds is to study the presence of important prey fish species. The winter diet of common guillemots is varied, and a significant portion of their prey spectrum consists of demersal fish like sandeels *(Ammodytes sp.)* as found by in the southern North Sea in winter time (Ouwehand *et al.*, 2004). Therefore, the significance of sandeels in the Brown Ridge area may be high for common guillemots, because the depth is no limitation.

Razorbills, on the other hand, forage on smaller fishes (Ouwehand *et al.*, 2004). Observations at sea, in the Brown Ridge area, have indicated that razorbills do so by making shallow dives, often working together to push prey fish concentrations towards the water surface (M. Leopold, pers. comm.).

Geelhoed *et al.* (2014) investigated the densities of common guillemots and razorbills and the depth distribution of fish in the Brown Ridge area. They found very low densities of biomass of potential prey fish deeper than 13 meters. However, these low fish densities were measured in only one winter, the weather was bad and so the bird density was relatively low, and it may be an underestimate of the potential conflicts. Therefore, conclusions cannot be drawn from this study.

From the information described above, it can be expected that razorbills and northern gannets mostly forage well away from the bottom in the Brown Ridge area. If this would be the case (always), there would be either no risk or a small risk for razorbills and northern gannets being caught by gillnets in the Brown Ridge area. On the other hand, common guillemots probably often dive to the seafloor of the Brown Ridge area in case of foraging on sandeels and other demersal fish (Leopold & Camphuysen 1992; Ouwehand *et al.*, 2004) where they are exposed to gillnets. Also, in the FIMPAS project (ICES, 2011) the same interpretation was made with respect to guillemots and set gillnets in the Frisian Front.
From the literature it is known that most seabird bycatch occurs in depths of less than 20 m (Stempniewicz, 1994 In: Žydelis *et al.*, 2013). Bellebaum *et al.* (2013) also found that the probability of bycatch decreased with increasing water depth. However, both razorbills and guillemots have been caught in bottom-set gillnets, over a large range of water depths, for both species exceeding 100 m (Piatt & Nettleship 1985), so all probably depends on the foraging strategies used by these birds, while present in the Brown Ridge area.

7.3 Temporal overlap

Spatial data of common guillemot and razorbill densities are available for November (years 2014 until 2016) and January and February (2015 until 2017). For both the Dutch- and German gillnet fleet, information on the spatial and temporal distribution of the fishing effort is available that can be used to calculate the overlap between fishing activities and bird presence.

The available data on fishing effort show that only sole- and cod fishery is relevant as fishery targeting seabass does not take place in November, January and February, see chapter 2. In the months that birds are recorded, fishing effort is relative low, see *Figure 24* and *Figure 25*. Finally, there is only fishing effort recorded in the southern part of the Brown Ridge area that is located in ICES rectangle 33F3 in those months.

For the German fleet only sole fishery takes place, see chapter 2. When looking at this fishery activity in more detail it can be seen that there is only some limited activity in February and in the Brown Ridge area located inside 33F3 ICES rectangle, see *Figure 26*.

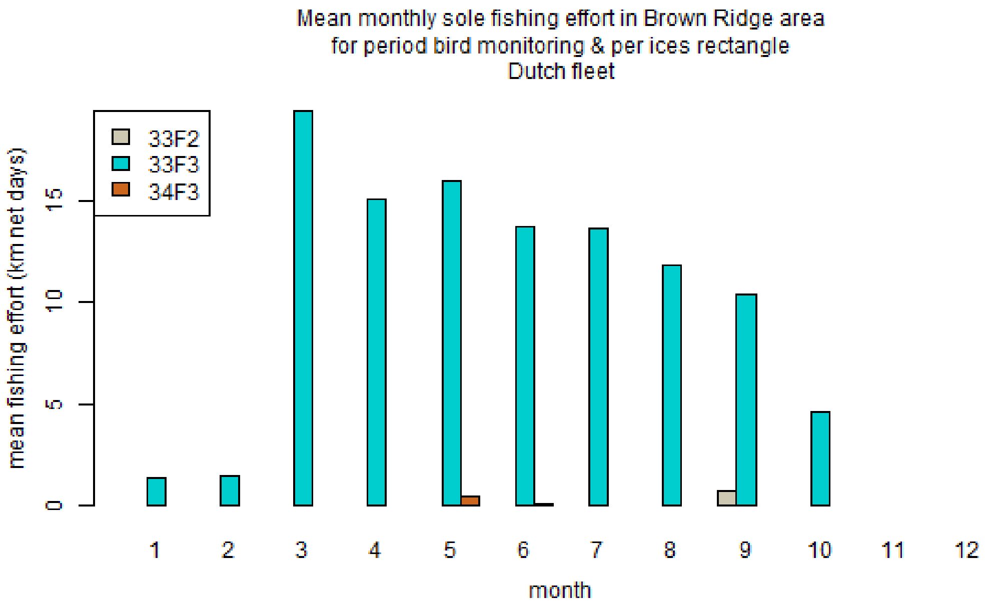


Figure 24 Mean monthly sole gillnet fishery effort by the Dutch fleet in the Brown Ridge in ICES rectangles

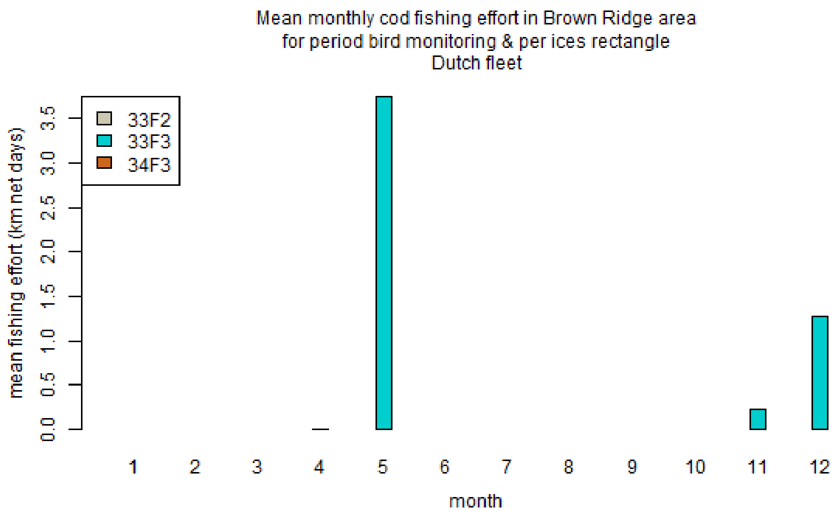


Figure 25 Mean monthly cod gillnet fishery effort by the Dutch fleet in the Brown Ridge in ICES rectangles

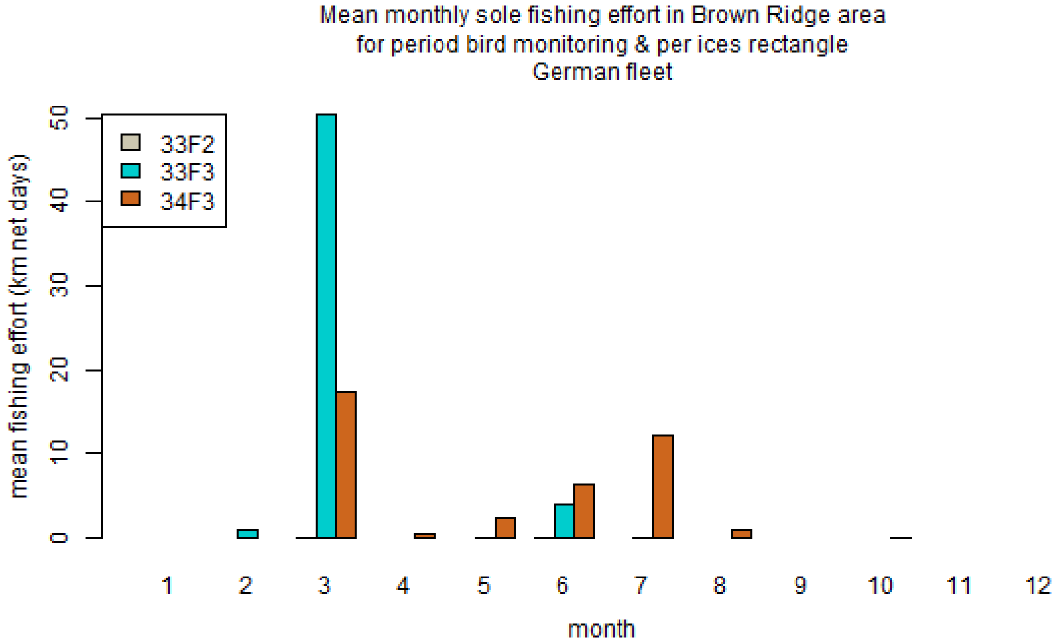


Figure 26 Mean monthly sole gillnet fishery effort by the German fleet in the Brown Ridge in ICES rectangles

There is little temporal overlap between gillnet fishery intensity (see Figure 3, Figure 4, Figure 5, Figure 9, Figure 24, Figure 25, Figure 26) and sea bird distribution (see *Figure 16*, *Figure 17*) in the Brown Ridge in the months August, November, January and February (*Figure 27* to *Figure 32*). In general, the intensity of seabass and sole fishery is much higher in the summer half year than in the winter half year, whereas the abundance of common guillemot and razorbill is opposite with high numbers in the winter half year and low number is the summer half year. Cod fishery is carried out in only three months in the year (May, November, December) with a potential high overlap in November and December, however, the presence of the birds was only recorded in four months, with November as the only month with a temporal overlap. This produces a fragmentary picture. For all three gillnet fishery types the temporal overlap analysis is hampered by the limited availability of bird abundance data. Inclusion of bird counts all months of the period October to May is of importance for improvement.

In ICES rectangles 34F3 and 33F2 there is no (proof for) exposure as there is no fishery activity in the months with bird monitoring data. When overlaying the relevant Dutch and German fishery activities in ICES rectangle 33F3 over bird presence in the same ICES rectangle the Brown Ridge variants can be compared to each other. In Figure 27 to Figure 32 it can be seen that for both the Dutch and German fleet the Brown Ridge variant A1-3 (with the largest surface area located in ICES rectangle 33F3) leads to the highest overlap in use while variant B1 (with the lowest surface area in ICES rectangle 33F3) leads to the lowest overlap in use. The overlap between seabirds and gillnet fishery in the five Brown Ridge variants decreases in the order: A1-3, A1-1 and A1-2, A2, B1. It can be concluded that less spatial overlap of the birds with the gillnet fishery can be expected in case the Brown Ridge optional areas are less situated in the southern part (33F3). In the previous years (2012 and 2013) the gillnet fishery intensity in ICES rectangle 33F3 was also higher than the one in 34F3. Although it should be noted that these data are based on a relatively short period.

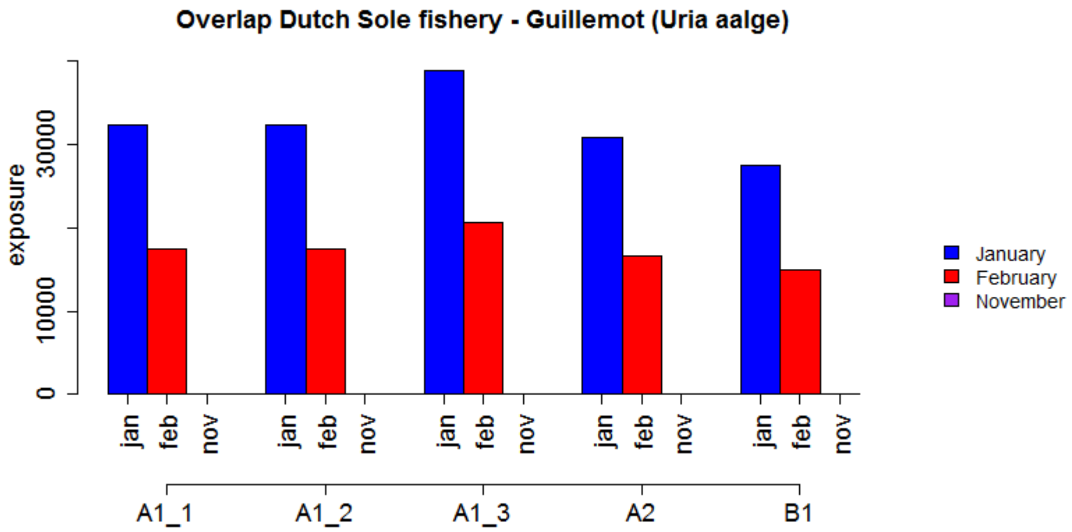


*Figure 27 Overlap of Dutch gillnet fishery on sole and common guillemots on the Brown Ridge in the months January, February and November as average of the seasons 2014/2015, 2015/2016, 2016/2017. Overlap is expressed as exposure in km net days * number of birds*

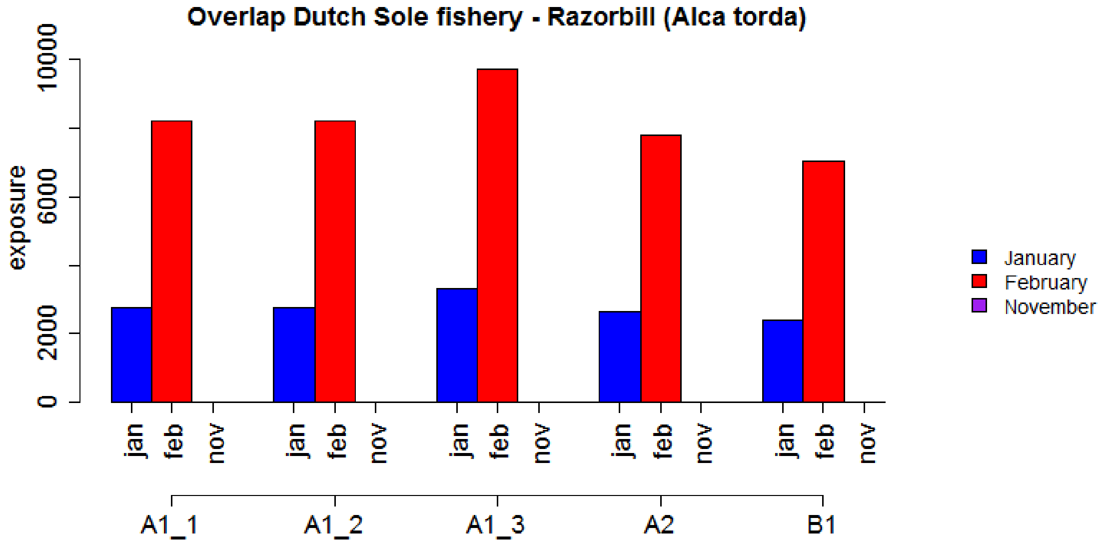


*Figure 28 Overlap of Dutch gillnet fishery on sole and razorbills on the Brown Ridge in the months January, February and November as average of the seasons 2014/2015, 2015/2016, 2016/2017. Overlap is expressed as exposure in km net days * number of birds*

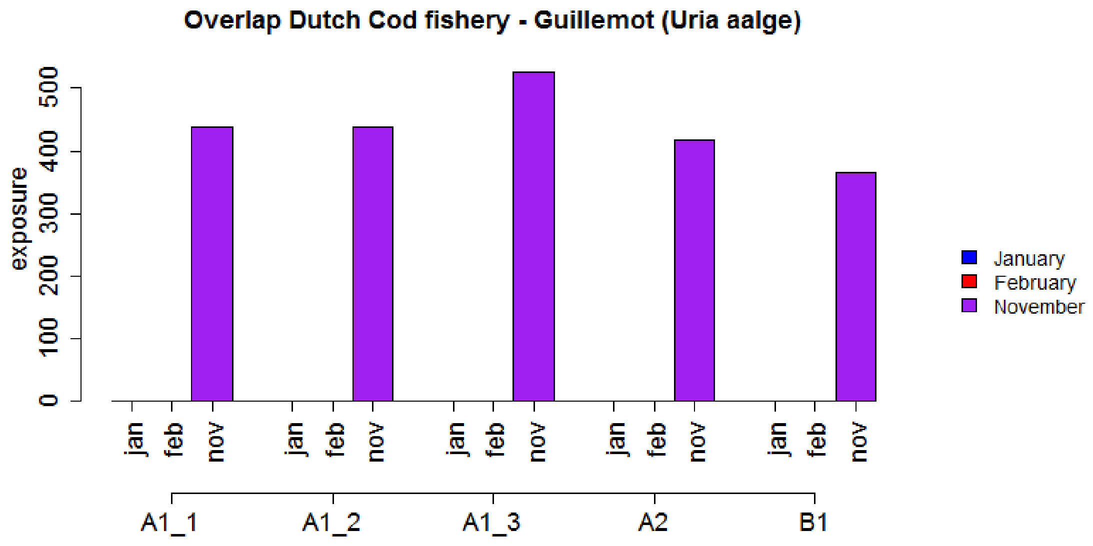


*Figure 29 Overlap of Dutch gillnet fishery on cod and common guillemots on the Brown Ridge in the months January, February and November as average of the seasons 2014/2015, 2015/2016, 2016/2017. Overlap is expressed as exposure in km net days * number of birds*

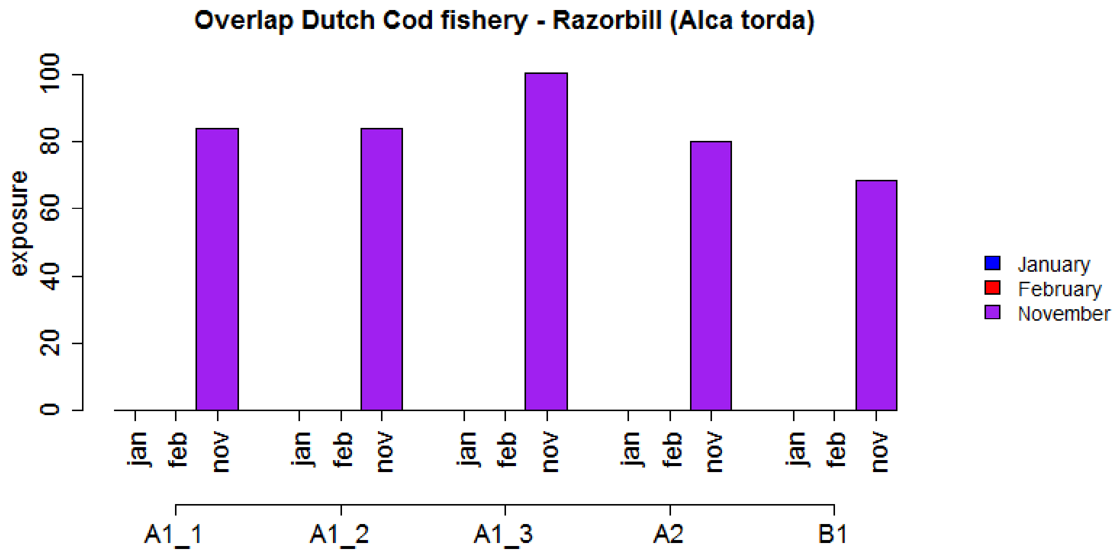


*Figure 30 Overlap of Dutch gillnet fishery on cod and razorbills on the Brown Ridge in the months January, February and November as average of the seasons 2014/2015, 2015/2016, 2016/2017. Overlap is expressed as exposure in km net days * number of birds*

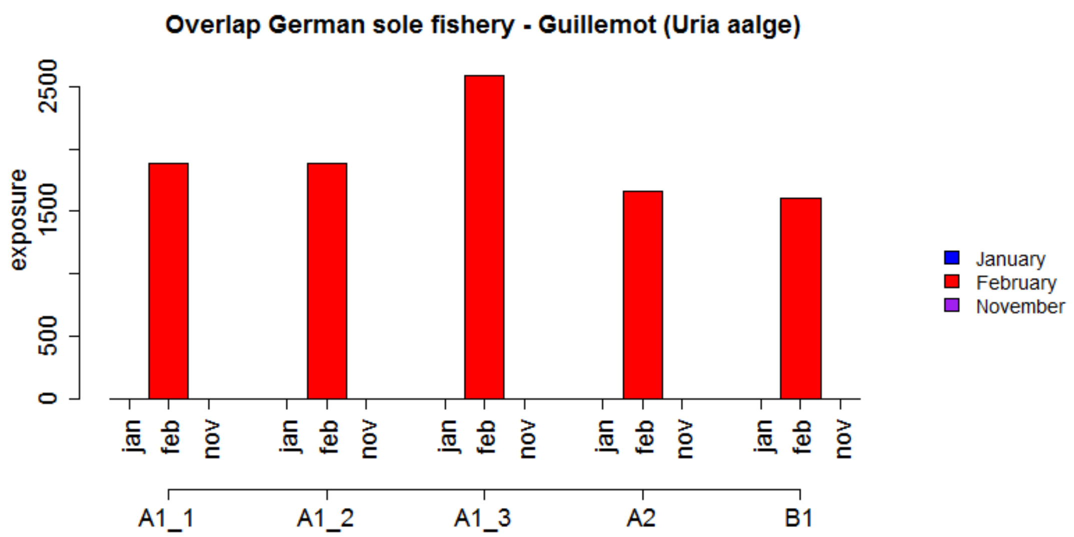


*Figure 31 Overlap of German gillnet fishery on sole and common guillemots on the Brown Ridge in the months January, February and November as average of the seasons 2014/2015, 2015/2016, 2016/2017. Overlap is expressed as exposure in km net days * number of birds*

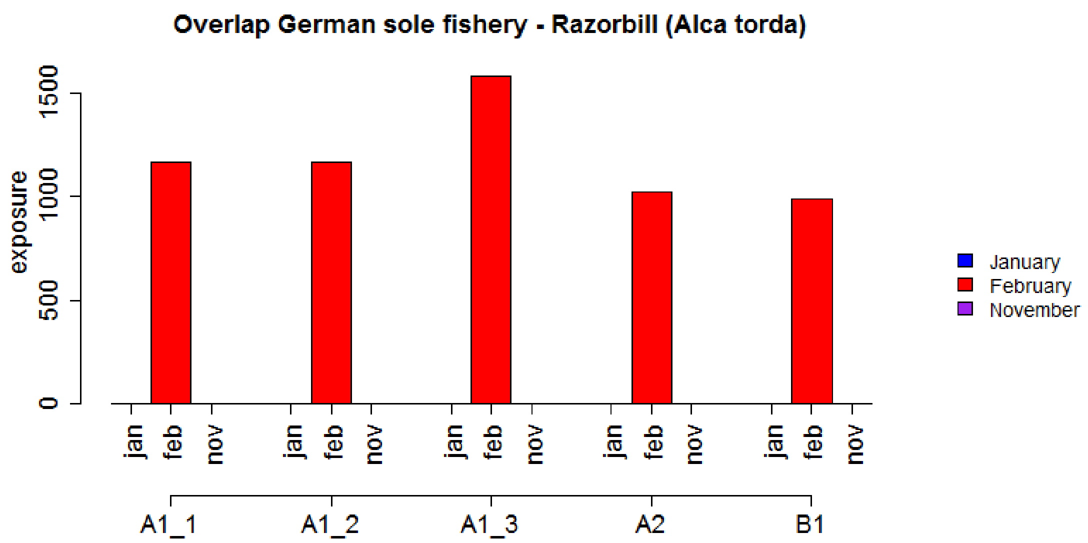


*Figure 32 Overlap of German gillnet fishery on sole and razorbills on the Brown Ridge in the months January, February and November as average of the seasons 2014/2015, 2015/2016, 2016/2017. Overlap is expressed as exposure in km net days * number of birds*

It is clear that the risk assessment is seriously hampered by the absence of data for seabird abundance in 8 of the 12 months. In fact, the average fishery effort in the four months when bird were counted (January, February, August, November) covered a small part of the effort during a complete year, amounting to 0% for seabass fishery, 21% for sole fishery and 13% for cod fishery.. The previous study by Jongbloed et al. (2015) used seabird density data that were developed by Leopold *et al.* (2014). The underlying data has been taken from the ESAS and MWTL databases for the years 1991 up to 2013 and have been processed to show a seasonal average distribution. Seasons are six two-monthly periods starting with 1= Aug-Sep, 2= Oct-Nov, 3= Dec-Jan, 4= Feb-Mar, 5= Apr-May and 6= Jun-Jul. In case it is chosen to apply the extrapolation in the present study than the density values of August could be applied to September, the ones of November to October, the ones for January to December and the one for February to March. In that way eight months of the year (August up to March) could be covered, representing the most important period for the selected seabird species in the Brown Ridge. In that case it can be expected that the highest bycatch risk would occur in some months (March, October, December) for which no MWTL-airplane monitoring data for seabirds are available for the period 2014 to 2017. In more detail:

- In seabass fishery the highest risks for all three seabird species occurred in October, March and September due to a relatively high fishery intensity in combination with seabird numbers extrapolated from adjacent months (respectively November, February, August).
- In sole fishery the highest risks for common guillemot and razorbill occurred especially in March due to a relatively high fishery intensity in combination with high seabird numbers extrapolated from adjacent month (February).
- In cod fishery the highest risks for all three seabird species occurred especially in December due to a relatively high fishery intensity in combination with high seabird numbers extrapolated from adjacent month (November).

7.4 Bycatch risk

It would be very helpful for the impact analysis to have quantitative data for the actual numbers of individual seabird found entangled in gillnets in the Brown Ridge area, over the year. The bycatch probability could then be expressed in number of mortal birds per km net length per year. However, this kind of data is not available. As already described in chapter 5 many factors influencing the bycatch probability are involved making modelling bycatch probability very complicated. In addition, the bycatch chance will probably differ for each combination of diving bird species and gillnet type. Therefore, monitoring of bycatch seems an obvious approach.

7.5 Difference between gillnet types

In the FIMPAS projects (ICES, 2011) a literature review was carried out to reveal differences among gillnet types with respect to the risk of seabird bycatch. A basis for differences was not found. However, there is a lack of knowledge on this subject (Žydelis *et al.*, 2013). Bellebaum *et al.* (2013) studied seabird bycatch in coastal set net fisheries in the eastern part of the German Baltic Sea. When accounting for season and location, differences in bycatch probability between fishing métiers were weak and disappeared when fishing effort was included in the model. In other words: any type of gillnet is likely to catch diving seabirds, if these are present at the time of fishing, and forage near the sea floor. It is obvious that there is a difference in bycatch risk between the three gillnet categories studied in this report, although this risk cannot be quantified. The gear design of gillnet for seabass, sole and cod differs with respect to mesh size, net height, depth set, twine type and lead line. These gear design factors are demonstrated to be correlated with bycatch rate (Northridge et al., 2017; Zydelis et al., 2013).

7.6 Integration

The impact of gillnet fishery on seabirds results from integration of the factors described above. The Brown Ridge is deeper than coastal waters which reduces the risk significantly of sea birds being caught by gillnets standing on the sea floor (as compared to Dutch coastal waters). From the scarce information on diet and diving behaviour (during daylight only), razorbills and northern gannets would seem to be mainly shallow divers in the Brown Ridge area, which would reduce their risk of being by-caught significantly. Common guillemots however dive deeper. Although the true bycatch risk is unknown, probably the risk is considerably higher for common guillemots than for razorbills and northern gannets. Data on bird abundance during the year are only available for four months, whereas data on gillnet fishery effort are available for all year. This hampers the analysis of the temporal overlap and thereby the possible bycatch risk. Based on the four months August, November, January and February, the month August provides the greatest risk of encounter for common guillemot and northern gannet due to the relatively high fishery effort. Seabass gillnet fishery did not occur in these four months and cod gillnet fishery only occurred in November and was low. Therefore, bycatch risk of seabirds in seabass and cod gillnet fishery on the Brown Ridge was absent or negligible in the period 2014 to 2017. In addition, gillnet fishery carried out by the Dutch fleet is not expected at distances greater than 20 miles from the coast and at the very low cod stock level in the southern North Sea. In contrast the intensity of the Dutch sole gillnet fishery may still be substantial, although this could not be elucidated from the available fishery activity information. Therefore, the actual magnitude of the problem is unknown, monitoring the bycatch of diving seabirds in set gillnets should be a first step in the process and an alternative to temporal closure of the Brown Ridge.

The conclusion for the impact on common guillemots in the present study is in line with the ones from the FIMPAS project (ICES, 2010, 2011). In the FIMPAS project an impact assessment was carried out for gillnet fisheries in the Frisian Front. In the workshops, a fishing gear impact matrix for the conservation objectives was composed. A high impact level was indicated for the impact of gillnets on common guillemots. High impact levels was defined as "direct disturbance, the continuity of the species is in danger". The judgement is based on majority opinions of the stakeholders (industry, scientists, NGO's) (ICES, 2011).

8 Draft measures

The conclusion of the impact assessment (chapter 7) was that despite major knowledge gaps due to the low gillnet fishery intensity, limited temporal overlap and the seabird diving behaviour no measures might be necessary for the razorbill and the northern gannet, whereas measures may be necessary for the common guillemot for precautionary reasons. The bycatch of a single common guillemot, razorbill or northern gannet is already critical in case the Ornis criterion for extra mortality is chosen (chapter 5).

In case monitoring of bycatch of common guillemots, razorbills and northern gannets demonstrates absence of bycatch it can be concluded that measures will not be necessary. In contrast, substantial bycatch of these species will urge the need for effective measures. Anticipating on the outcome, we can provide the general ideas existing on optional mitigation measures for bycatch (Žydelis *et al.*, 2013):

- Spatial-temporal closures
- Visual alerts (visibility of gillnet)
- Acoustic alerts (pingers)
- Restrictions on fishing depth
- Change of fishing gear

The most feasible options are spatial and temporal regulation of fishing effort and gear substitution. A ban on gillnetting in Californian waters at depths below 90 meters has nearly eliminated formerly high bycatch of common guillemots (Carretta & Chivers, 2004 In: Žydelis *et al.*, 2013). Increasing visibility of nets also seems promising but not for birds diving at night. Further research on mitigation measures is required (Žydelis *et al.*, 2013).

In FIMPAS project (ICES, 2011) an agreement was reached with respect to mitigation measures for the impact of gillnet fishery on common guillemots in the Frisian Front: a ban on gillnetting in the Frisian Front from 1ste June to 30th November. This measure was considered to be sufficient to contribute to the achievement of the conservation objectives in that particular situation, where common guillemot densities are highest in a relatively short, post-breeding (summer) season. A monitoring programme for seabird numbers and seabird bycatch will be needed in a 6 years assessment. A VMS obligation for all vessels is required. It should be noted that, next to the site-specific ecological characteristics, there is a difference between Frisian Front and Brown Ridge in the timing of the presence of common guillemots and razorbills. The decision on a total ban on gillnet fishing in the Frisian Front from June-November was based on the precautionary principle. It should be noticed that the distribution of common guillemots differs between Frisian Front and Brown Ridge, which will lead to a different period for closures for the Brown Ridge. In the FIMPAS projects (ICES, 2011) it was concluded that there seems to be no necessity that the management regime for gillnet fisheries in the Frisian Front should account for differences among gillnet types, based on a literature review.

Bellebaum *et al.* (2013) recommended specific measures to reduce bycatch risk in the German coastal fisheries using effort reductions and replacement of set nets with alternative gear.

Specific for the present study on seabird bycatch in the Brown Ridge area it is difficult to predict the effectiveness of measures due to the absence of information on the bycatch risk without mitigation measures. It is plausible that temporal closure is a feasible and effective measure in the period when the highest density of common guillemot occurs. This is a half-year period running from October to March (see Figure 23). The absolute effort and economic value of seabass, as well as cod gillnet fishery in the Brown Ridge is very low (see Figure 3, Figure 5, **Fout! Verwijzingsbron niet gevonden. Fout! Verwijzingsbron niet gevonden.**). Measures with respect to these fishery types do not seem to be necessary.

Still, measures like a closure of the fishery will impact that fishery and there is, as yet very little evidence (pro or contra) for the magnitude of the bycatch problem. Therefore, there would seem to be every reason to measure the actual amount of bycatch in the Brown Ridge. In this light it is promising that the monitoring of all protected species, including birds, is now part of the data Collection Framework under the Common Fisheries Policy since January 2017 (EU Dec 2016/1251). However, it seems that member States of the European Union have not yet (fully) implemented the monitoring and the on board observer effort is strongly biased to trawl fisheries while incidental by-catch for birds and mammals are known to occur more often in set nets (ICES, 2019a; ICES 2019b). In the future it is recommended to shift the observer effort from trawls towards set nets.

9 Knowledge gaps

This study revealed that some important knowledge gaps exist. A major part of the Dutch gillnet fishery is carried by small boats without VMS for which the exact fishery locations are not known. This hampers the determination of differences among the five optional geographical variants for the Brown Ridge in the gillnet fishery effort. Due to the low detail level of gillnet locations the risk assessment analysis can only calculate differences between the five optional areas with high uncertainty.

The influence of net position (vertical or sloping) and mesh size of sole gillnets on bycatch chance of diving birds is unknown. These characteristics may differ between the fishing grounds like Baltic Sea and some locations in the North Sea for which bycatch was recorded.

Spatial distribution of the gillnet fishery activity of Danish fishing fleet in the Dutch waters has not been provided. This type of information is important because in the period 2012–2016 the effort and economic revenue of the Danish gillnet fleet in the Brown Ridge appeared to be higher than the one of the Dutch and the German gillnet fleets.

Monitoring of seabird distribution over the Brown Ridge area in the period 2014 to 2017 took place in four months of the year, namely part of the months in the mold (August), late autumn (November) and winter period (January, February). These are important periods for the seabirds in the Brown Ridge, however the months in which no monitoring of seabirds was carried out are also important to monitor in order to improve the impact assessment. In addition, the bycatch risk of seabirds in gillnets in the remaining periods of the year (spring and summer) when bird density is relatively low, cannot be assessed but may not be negligible. This applies to the sole gillnet fishery with a relatively high intensity in the spring and summer.

The estimation of the economic value of the fisheries contains large uncertainties. There are several small Dutch gillnet fishery ships (i.e. ships without VMS activity) active in the ICES rectangles that include the Brown Ridge (33F3 and 34F3) and the number for the Brown Ridge itself are unknown but may be small or even zero due to the large steaming distance from the Dutch coast to the Brown Ridge area. In the calculations the assignment of the effort of these small ships to the Brown Ridge is based on the surface area of the Brown Ridge relative to ICES rectangles 33F3 and 34F3. This is probably an overestimation. Therefore, the estimated values can only be crude estimates. For Dutch data, the coverage of data for passive gears is not as good as for other fisheries. There are many small vessels in the gillnet fisheries that do not carry VMS and tend to catch lower volumes not necessarily reported in logbooks because there is no obligation to report fish volumes less than 50kg. The value of the revenues from the Brown Ridge for the Dutch gillnet fishery is much lower compared to the revenues of the Danish gillnet fishery. This is an important point that should be investigated in future research, for example by insisting data on VMS activity for small vessels or with a survey among fishermen.

There are many important knowledge gaps in seabird bycatch in gillnet fisheries in general (Žydelis *et al.*, 2013) which hamper the impact assessment for the Brown Ridge. The WGBYC of ICES aims to improve this but indicates that still much more data and insight is needed. An example of a recently initiated study is EASME/EMFF/2015/04: “Study on mitigation measures to minimise seabird bycatch in gillnet fisheries.” The status of this study is unknown to us. We were not able to find a report.

The major knowledge gap is the insight in the occurrence of bycatch of common guillemots, razorbills and northern gannets in gillnets in North Sea areas like the Brown Ridge, which are of intermediate depth. The most effective way to gain this insight is by monitoring bycatch carried out by the fishers, in combination with independent researchers. It is recommended to start with monitoring the bycatch of common guillemots by sole gillnet fisheries in the Brown Ridge in the critical period of the year (October–May). Although the attention will be focussed on common guillemots, in this monitoring other sea bird species like the razorbill and northern gannet among the bycatch victims should be registered as well and does not require more effort.

Electronic monitoring of fishery activity, locations and bycatch in fisheries was proved to be more accurate than VMS (Van Helmond et al., 2019). Application of a remote electronic monitoring system produced provided useful results for small scale fisheries like gillnet fisheries in relatively small areas (Oesterwind & Zimmermann, 2013a, 2013b). Therefore, this application could also be interesting for gillnet fishery in the Brown Ridge area.

Bycaught auks, especially in offshore locations, provide a unique opportunity for stomach content analysis. If dead birds can be made available for such studies, more can be learnt about their ecology in the Brown Ridge area. This knowledge can be used to improve the risk assessment of bycatch of common guillemots and razorbills in gillnets in the Brown Ridge.

The distribution and density of sandeels in the Brown Ridge area is poorly known, especially in the winter half year. In case sandeels are relatively abundant in the area it can be expected that common guillemots are attracted to dive deep, raising the risk to get entangled in gillnets. Sandeels are monitored in the DCF fishery surveys (IBTS, BTS, sandeel dredge survey) but this does not provide information of the small scale distribution on the Brown Ridge (HAWG, 2019).

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11 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 C008/20
Project Number: 4318100293

The scientific quality of this report has been peer reviewed by the a colleague scientist and the head of the department of Wageningen Marine Research.

Approved: Bram Couperus
Researcher

Signature:

Date: 29 January 2020

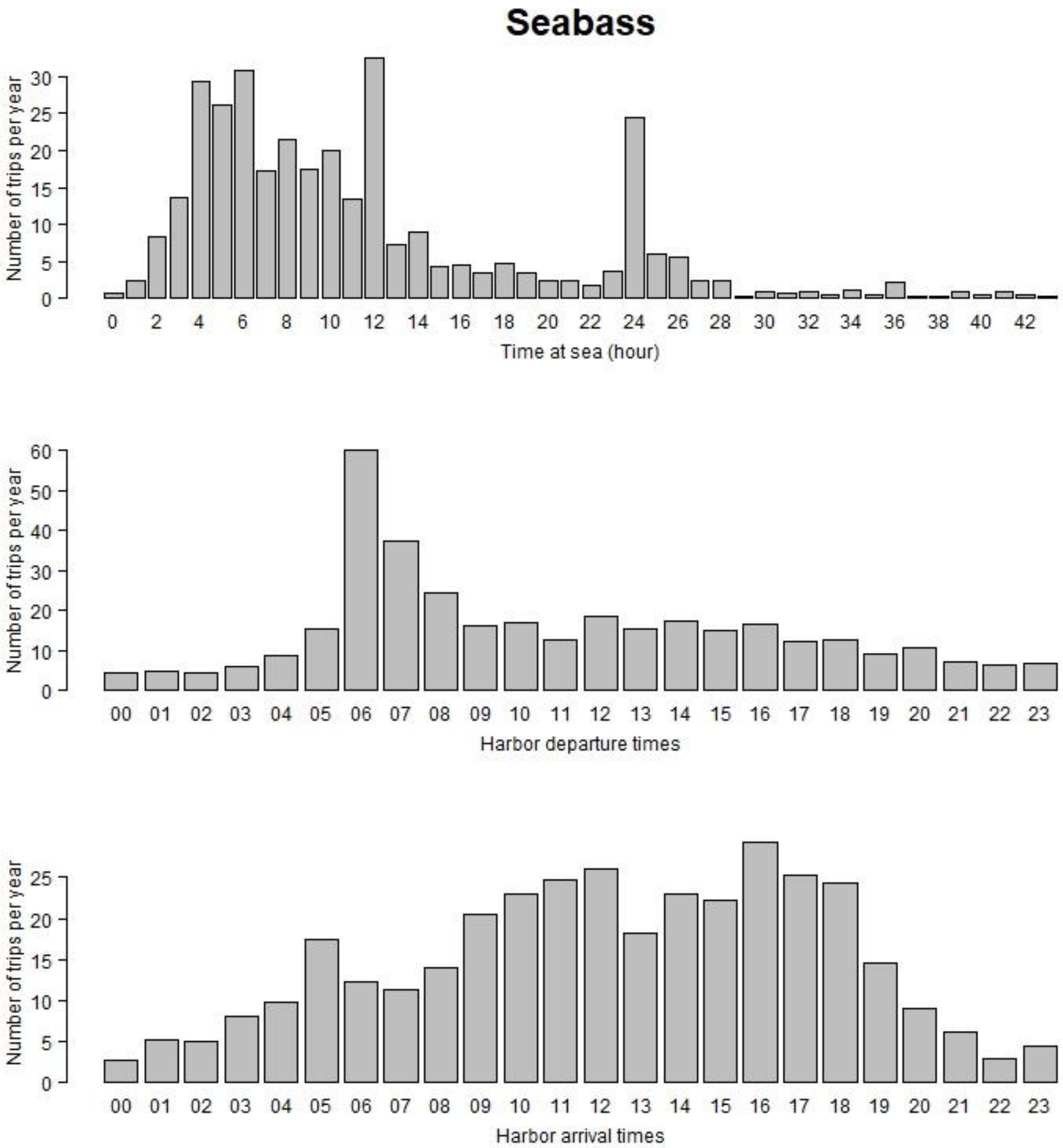
Approved: Jakob Asjes
Manager integration

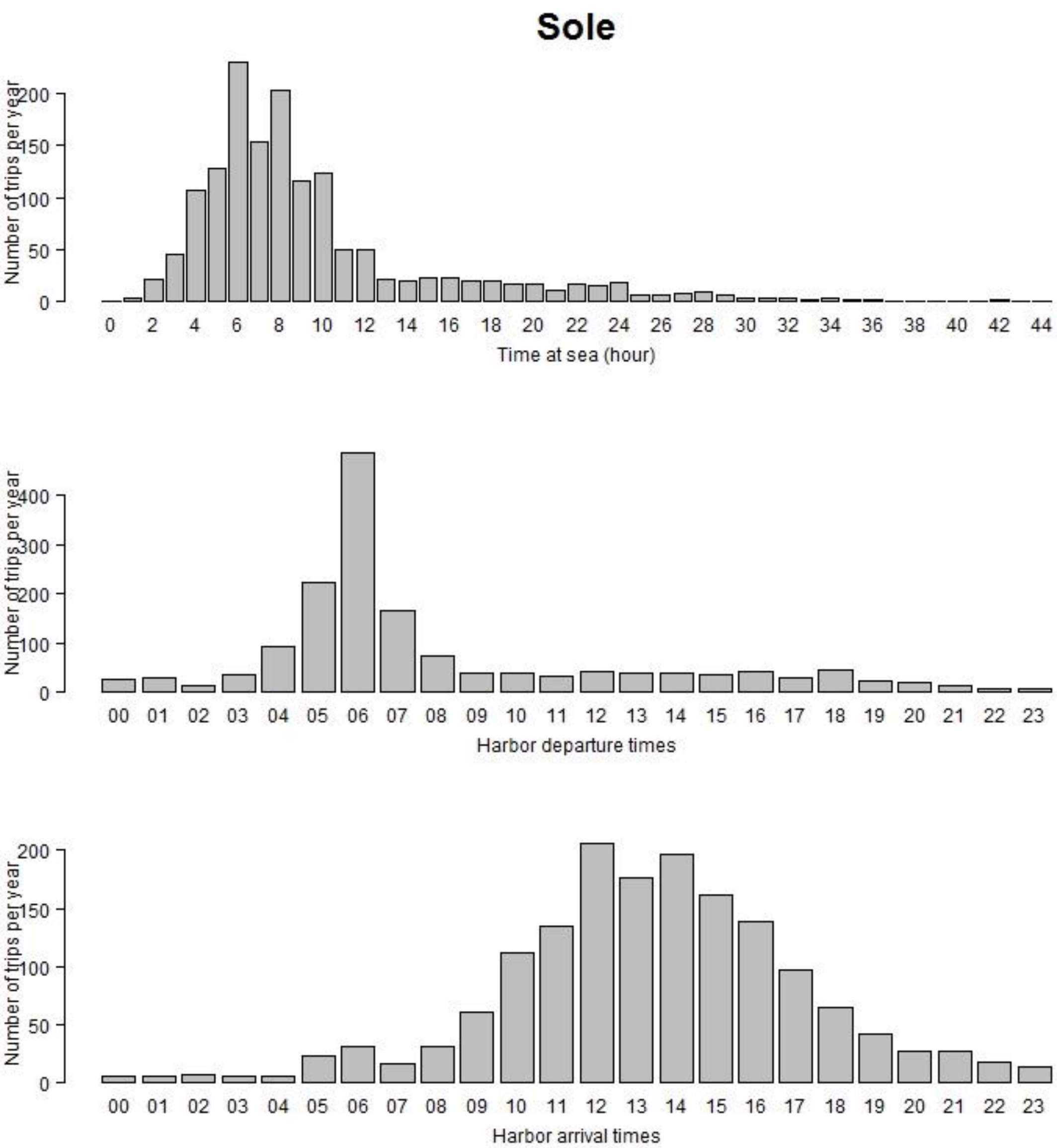
Signature:

Date: 29 January 2020

Annex 1 Duration of fishing trips and net set times

Duration of fishing trips




Sole
Number of trips per year
0 50 100 150 200
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
Time at sea (hour)
Number of trips per year
0 100 200 300 400
00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Harbor departure times
Number of trips per year
0 50 100 150 200
00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Harbor arrival times

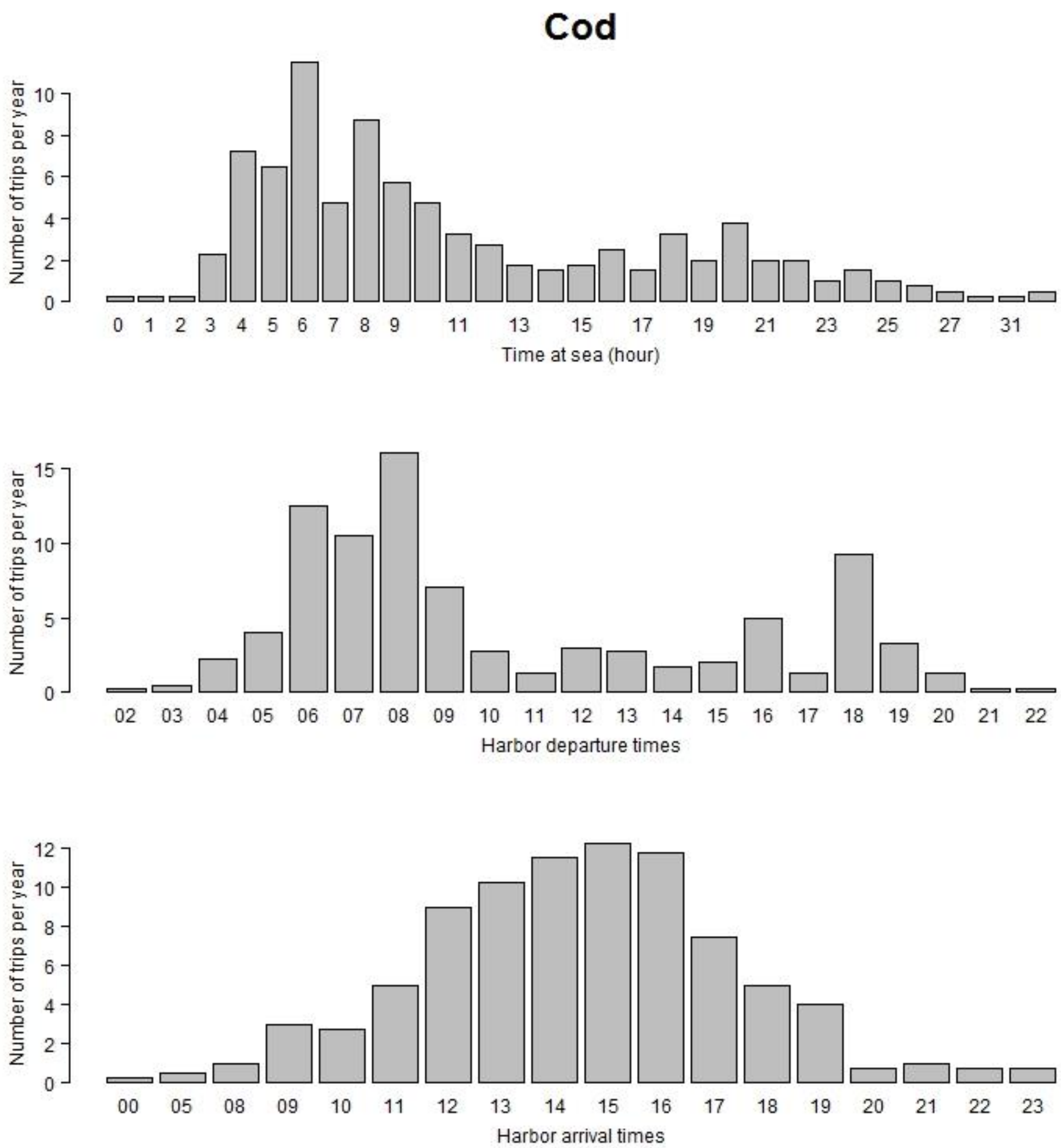


Figure 33 Mean number of trips per year (period 2014 until 2017) and duration of time at sea (out of the harbour), departure time and arrival time of gillnetters targeting Seabass; Sole and Cod

Net set times of fishing trips

A number of rules are formulated to estimate the net set times of fishing trips categories a, b and c (see Jongbloed *et al.* 2013 for details). The rules are summarized in *Table 14*.

Table 14 Formulas for estimation of net set times for gillnet fisheries

VMS-vessels	Non-VMS vessels	
	Beach / night fishers	(multiple) Day fishers
(DTA-DTD)x20/24	(DTD2-DTD1)x20/24	(DTA-DTD)x20/24

DTA and DTD are date-times of arrival at - and departure from the harbour in the same logbook records.
DTD2 and DTD1 are date-times of departure from the harbour on two successive logbook records.

Additional conditions of the night fishery differ for the categories:

Category a) Seabass:
A vessel leaves the harbour in the evening after 20:00 hours to set the nets and leaves the next morning before 8:00 hours to haul the nets

Category b) Sole:
1) Vessels leaving the harbour between 3:00 and 10:00 with an additional departure from the harbour within 27 hours earlier
2) Vessels leaving the harbour between 10:00 and 22:00 with an additional departure from the harbour within 10 to 27 hours earlier

Category c) Cod:
1) Vessels leaving the harbour between 4:00 and 10:00 with an additional departure from the harbour within 27 hours earlier
2) Vessels leaving the harbour between 11:00 and 21:00 with an additional departure from the harbour within 10 to 27 hours earlier

Since gillnet set-time (days) as an effort indicator may be biased because of differences in lengths of the gillnets (km) set, km-net-days are used as an measure of gillnet fishing intensity in this study

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