Hornsea Project Four

Compensation measures for FFC SPA: Gannet Bycatch Reduction: Ecological Evidence

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Table of Contents

List of Tables

List of Figures

Glossary

Term	Definition
Development Consent Order (DCO)	An order made under the Planning Act 2008 granting development consent for one or more Nationally Significant Infrastructure Projects (NSIP).
Environmental Impact Assessment (EIA)	A statutory process by which certain planned projects must be assessed before a formal decision to proceed can be made. It involves the collection and consideration of environmental information, which fulfils the assessment requirements of the EIA Directive and EIA Regulations, including the publication of an Environmental Impact Assessment (EIA) Report.
Grey Literature	Information that is not produced by commercial publishers. It includes research reports, working papers, conference proceedings, theses, preprints, white papers, and reports produced by government departments, academics, business, and industry.
Hornsea Project Four Offshore Wind Farm	The term covers all elements of the project (i.e., both the offshore and onshore). Hornsea Four infrastructure will include offshore generating stations (wind turbines), electrical export cables to landfall, and connection to the electricity transmission network. Hereafter referred to as Hornsea Four.
Landfall	The generic term applied to the entire landfall area between Mean Low Water Spring (MLWS) tide and the Transition Joint Bay (TJB) inclusive of all construction works, including the offshore and onshore ECC, intertidal working area and landfall compound. Where the offshore cables come ashore east of Fraisthorpe.
National Grid Electricity Transmission (NGET) substation	The grid connection location for Hornsea Four.
Orsted Hornsea Project Four Ltd.	The Applicant for the proposed Hornsea Project Four Offshore Wind Farm Development Consent Order (DCO).

Acronyms

Term	Definition
AEoI	Adverse Effect on Integrity
DCO	Development Consent Order
ECC	Export Cable Corridor
EIA	Environmental Impact Assessment
FFC	Flamborough and Filey Coast
ICES	International Council for the Exploration of the Sea
MLWS	Mean Low Water Springs
MMO	Marine Management Organisation
NGET	National Grid Electricity Transmission
RIAA	Report to Inform Appropriate Assessment
SPA	Special Protection Area
UK BMP	United Kingdom Bycatch Monitoring Program
WTGs	Wind Turbine Generators

1 Summary

1.1 Background

1.1.1.1 Orsted Hornsea Project Four Limited (hereafter the 'Applicant') is proposing to develop Hornsea Project Four Offshore Wind Farm (hereafter 'Hornsea Four'). This document has been prepared to support the identification of compensatory measures for Hornsea Four and its potential impacts on gannet, *Morus bassanus*, providing an update to the evidence submitted within **B2.8.1. Compensation measures for FFC SPA: Bycatch Reduction: Ecological Evidence (APP-194)**, which was submitted as part of the DCO application.

1.1.1.2 The reduction in bycatch to benefit gannet is one compensation measure being proposed by the Applicant to compensate for potential impacts on gannet and is the focus of this report (see **B2.6 RP Volume B2 Chapter 6 Compensation measures for FFC SPA Overview (APP-183)** which sets out the suite of compensation measures for Hornsea Four). Seabird bycatch in the UK has been acknowledged by governmental and non-governmental organisations as a threat to seabird populations and work is already being undertaken by organisations to investigate it. Specifically, the UK Seabird Plan of Action (PoA)[1]) outlines work to be completed in understanding the level of bycatch by UK fishing vessels. In addition to this, the Defra funded Clean Catch UK is an initiative that was developed to work with fishermen to further understand potential bycatch levels and how bycatch can be reduced. Moreover, work is being undertaken by RSPB and BirdLife International to trial seabird bycatch reduction methods. The Applicant is also currently undertaking a bycatch reduction technology selection phase focused on trialling a bycatch reduction technique on auks (guillemot and razorbill) in static gillnet fisheries.

1.1.1.3 The purpose of this report is to provide evidence for the use bycatch reduction techniques as a compensation measure for gannet. This report provides evidence of gannet bycatch in the UK, identifies areas of high bycatch risk, as well as identifying potential techniques to reduce gannet bycatch rates.

1.1.1.4 The scale of compensation required for the annual predicted mortality of gannet from FFC SPA due to displacement and collision from Hornsea Four is presented in the Hornsea Four RIAA (**B2.2 Report to Inform Appropriate Assessment Part 1 (APP-167)**, submitted as part of the DCO application).

1.1.1.5 A potential plan for execution of the gannet bycatch compensation measure was submitted as part of the DCO application within the Gannet, Guillemot and Razorbill Compensation Plan (**B2.8 FFC SPA: Gannet, Guillemot and Razorbill Compensation Plan (APP-193)**[2]) (submitted September 2021). Should this compensation measure be taken forward, further details on the precise delivery methodology for the measure would also be provided in a Gannet Implementation and Monitoring Plan for Bycatch. The implementation and monitoring plan would be submitted to the Secretary of State for approval (in consultation with the MMO and Natural England) at least one year prior to the commencement of any

[1] UK Seabird Plan of Action (PoA) – ME6024. Available at: http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=20461

[2] Please note that gannet has been separated from kittiwake in the compensation documents to reflect the position on AEoI and that compensation are now considered necessary for kittiwake, as set out in **G1.5 Kittiwake AEoI Conclusion (AS-023)**, whereas for gannet the Applicant remains confident there would be no AEoI alone or in combination and the compensatory measures for gannet remain "without prejudice" measures (see **G1.50 Compensation measures for FFC SPA: Derogation and Compensation Update Position Statement**).

wind turbine. An outline of the implementation and monitoring plan was presented by the Applicant within the Gannet, Guillemot and Razorbill Implementation and Monitoring Plan (GGRIMP) (**B2.8.7 Outline Gannet, Guillemot and Razorbill Compensation Implementation and Monitoring Plan (APP-200)**) which was also submitted with the DCO application (noting that a gannet alone version will be submitted at Deadline 5).

1.1.1.6 This report discusses the following;

- An introduction to seabird bycatch and fisheries;
- Identification of longline fishing effort in the UK;
- Identification of midwater trawl fishing effort in the UK;
- Results of a bycatch risk mapping exercise identifying potential "high risk zones" of gannet bycatch;
- A review of potential longline and midwater trawl bycatch reduction measures, and identification of short-listed techniques to reduce gannet bycatch in the UK; and
- Bycatch reduction as an effective compensation measure (an analysis of the scale of bycatch reduction to be an effective compensation measure).

1.1.1.7 In addition, there are three accompanying appendices:

- 1) GIS mapping of gannet at sea distributions per month;
- 2) An in-depth analysis of the potential longline bycatch reduction methods; and
- 3) An in-depth analysis of the potential midwater trawl bycatch reduction methods.

1.2 Key Findings

1.2.1.1 This document has identified that gannet are highly vulnerable to bycatch in gears when they are on/near the surface, including during deployment and hauling of nets (Bradbury *et al.,* 2017). In the UK, Northridge *et al.* (2020) estimated gannet bycatch to be within the hundreds per year (2016/2017):

- 220 (2016)/241 (2017) by longline fisheries;
- 22 (2016)/19 (2017) by <10 m static gillnet fisheries; and
- 36 (2016)/31 (2018) by >10 m static gillnet fisheries.

1.2.1.2 Northridge *et al.* (2020) did not identify midwater trawls as a bycatch risk for gannet, however Danish fishers contacted during fisheries consultation as part of the Hornsea Four fisheries consultation process stated that they observe many gannet diving into trawl nets whilst they are being hauled[3]. Due to the small-scale coverage of the UK BMP (<5% midwater trawl effort), there is potential that bycatch may not have been recorded in full.

1.2.1.3 Fishing effort for both longline and midwater trawl vessels identified the highest fishing effort within ICES rectangle IVa and VIa, with 45% and 24% of the UK longline fishing effort and 33% and 37% of the UK midwater trawl fishing effort respectively. Both longline and midwater trawl effort is therefore concentrated in Scottish waters, therefore Scotland is most likely to have the highest bycatch occurrences within the UK fishing fleet. Nevertheless, as foreign vessels also fish within UK waters, there is potential for fishing effort hotspots to also occur elsewhere. For example, the Gran Sol fishery has been identified (both

[3] Stated during a telephone conversation between Danish fishers and Orsted fishery liaisons. Waiting on written comments.

within the literature and communications with bycatch experts) as a high risk of bycatch from longline fishing for seabirds including gannet.

1.2.1.4 Bycatch risk mapping identified the highest potential gannet bycatch from UK fisheries to be within Scottish waters for both longline and midwater trawl fisheries. For longline, this was located offshore off the north coast of Scotland, whereas for midwater trawl fisheries the highest risk locations were near to the coast around the gannet colonies. Both longline and midwater trawl bycatch risk from UK fisheries was highest over the breeding season, most likely due to UK gannets migrating south for the non-breeding season.

1.2.1.5 Potential bycatch reduction techniques have been identified for longline and trawl fisheries with positive results from species with similar foraging ecology to gannet. Therefore, there is the potential for bycatch reduction techniques to greatly reduce the bycatch of gannet in UK-based fisheries. The short-listed techniques are:

- Longline:
    - Lumo leads (line weighting);
    - Side setting with bird scaring lines; and
    - Hook shielding (e.g., Hookpod/ Smart Tuna Hook).
- Midwater Trawl:
    - Tori-lines; and
    - Cones.

1.2.1.6 There is limited evidence on the techniques which may reduce gannet bycatch in net entanglement in midwater trawl fisheries and therefore no net entanglement bycatch reduction techniques were short-listed.

1.2.1.7 Due to the evidence collated within this review, the Applicant will focus on longline bycatch reduction. The most promising technique identified for longline bycatch reduction is the Hookpod (hook shielding), with evidence showing reduction of seabird bycatch by 95% in longline fisheries (see **Appendix B** for evidence supporting measure). The Hookpod covers the baited hook until it reaches a certain depth and can therefore be set beyond the depth range for diving gannet. Hook shielding is independent of seabird behavioural responses as it removes the risk factor (the hook) and therefore the bycatch risk for the majority of seabird species. This allows evidence of mitigation success using such techniques from other seabird species, such as albatross, to act as proxy for gannet.

1.2.1.8 If required, the Applicant is confident of the deployment of a bycatch reduction technique as a compensation measure, as previous bycatch reduction research (i.e. using Hookpods) shows a significant reduction in seabird bycatch which has been tested and such techniques have been up taken by the fishing industry. Moreover, the Applicant is currently progressing a bycatch reduction selection phase for guillemot and razorbill in operational static net fisheries. Through this, the Applicant has created strong ties with the fishing industry as well as with FishTek Marine (the company who has also developed two of the short-listed technologies for longline fisheries: Lumo leads and the Hookpod).

2 Introduction

2.1 Project Background

2.1.1.1 Hornsea Four will be located approximately 69 km offshore of the East Riding of Yorkshire in the Southern North Sea and will be the fourth project to be developed in the former Hornsea Zone. Hornsea Four will include both offshore and onshore infrastructure including an offshore generating station (wind farm) including up to 180 wind turbine generators (WTGs), export cables to landfall, and connection to the National Grid Electricity Transmission (NGET) network at Creyke Beck. Detailed information on the project design can be found in **Volume A1, Chapter 1: Project Description**, with detailed information on the site selection process and consideration of alternatives described in **Volume A1, Chapter 3: Site Selection and Consideration of Alternatives** (submitted as part of the DCO application).

2.2 Document Purpose

2.2.1.1 Ecological evidence for bycatch reduction as a compensation measure for gannet, guillemot, and razorbill was proposed by the Applicant in September 2021 (**B2.8.1. Compensation measures for FFC SPA: Bycatch Reduction: Ecological Evidence**). The report focused on guillemot and razorbill bycatch in gillnet fisheries. This document provides an update outlining the evidence of gannet bycatch in longline and midwater trawl fisheries, and a review of potential bycatch reduction techniques.

2.3 Gannet Overview

2.3.1.1 Northern gannet are the largest species of the *Sulidae* family, which contains gannets and boobies. Currently the global population of gannet is increasing (BirdLife International, 2018), and in the UK, it is estimated that there are currently 220,000 breeding gannet pairs, (RSPB, 2021) which equates to approximately 60-70% of the global population (Wildlife Trust, 2021). Gannets are monotypic (no races/subspecies of *Morus bassanus*) and therefore all gannet within the UK are part of the Northern Atlantic biogeographic population (Robinson, 2005).

2.3.1.2 Gannet breed on coastal cliffs around the north of the UK where there is suitable habitat. In the UK, there are 21 colonies (gannetries), mainly on offshore islands and stacks, two on mainland cliffs (Bempton Cliffs and Troup Head) (JNCC, 2021; RSPB 2021). Gannet create compact nest "cups" typically 30-60 cm in height (made from seaweed, plants, earth, and debris from the sea). They lay only one egg per breeding season, which they incubate for 42-46 days (Cramp and Simmons, 1997; Nelson, 2005).

2.3.1.3 Gannet plunge dive from heights of 30 m, in pursuit of small fish and can dive to depths of up to 20 m (mean dive depth ~5 m), and sometimes can feed from the surface (JNCC, 2021; Wildlife Trust, 2021; Garthe *et al.,* 2007). Additionally, they also feed from fishing discards from fishing vessels (JNCC, 2021). During the breeding season, FFC SPA gannet tend to dive for herring, mackerel, and sand eels in waters relatively close to the Bempton colony (Hamer *et al.,* 2000). During the breeding season, the mean foraging range for gannet is 120.4 km (mean maximum is 315.2 km) and the maximum recorded is 709 km (Woodward *et al.*, 2019).

2.3.1.4 FFC SPA is located on the east coast of England and supports the only mainland breeding colony of gannet in the UK (Natural England, 2020), supporting over 13,000 breeding pairs of gannet (JNCC, 2021). At FFC SPA the number of breeding pairs of gannet has increased by 240% between 2003 and 2017, compared to 34% increase overall in the total UK breeding gannet pairs[4] (JNCC 2021). The FFC SPA supports 2.6% of the biogeographical population (Natural England, 2020). Gannet are highly philopatric and often return to the same breeding colony (Nelson, 2005). Gannet are also monogamous and breed with the same partner year after year. Outside of the breeding season, gannet migrate south from their breeding colonies, and can travel to locations as far as west Africa (Furness *et al.*, 2018). Colonies on the west coast of the UK travel south through the North Sea and English Channel past Spain and Portugal to West Africa (Kubetzki *et al.*, 2009; Fort *et al.*, 2012; Furness *et al.*, 2018).

3 Methods

3.1 Literature Review

3.1.1.1 A literature review was undertaken to determine the key fishing gears that bycatch gannet in the UK, estimate current bycatch numbers, and explore bycatch reduction techniques. Sources included, but were not limited to, scientific journals, government reports and grey literature.

3.2 Data Search

3.2.1.1 Relevant data was identified by searching for available databases and a literature search. Specific databases and organisations are listed throughout the document at relevant locations.

4 Seabird Bycatch

4.1 Introduction to Gannet Bycatch

4.1.1.1 Bycatch is the incidental capture of non-target species in fisheries and can present a significant pressure on seabird populations (Miles *et al.*, 2020). Within recent decades, many seabird populations have declined, largely due to commercial fisheries (direct competition and bycatch) (Croxall *et al.,* 2012). Gannet are particularly vulnerable to bycatch as they are attracted to fishing vessels and often feed on discarded fish scraps (JNCC, 2021). Boats actively fishing may therefore draw birds from some distance, which may in turn be at risk of bycatch. Furthermore, gannets are plunge divers, observing prey from well above the water's surface. They therefore are unlikely to see certain fishing gear before their dive.

4.1.1.2 Gannet vulnerability to bycatch was further assessed through Bradbury *et al.* (2017) risk assessment model, which aimed to identify species most likely to be caught as bycatch. Within this assessment, gannet were within the top ten (out of 53) seabird species for surface, pelagic, and benthic fishing gear, for the species sensitivity index score – the top species for surface fishing gear (**Table 1**). This suggests that bycatch disproportionately affects gannet, particularly in surface gears. As mentioned above, gannets are plunge diving species, most of their dives are relatively shallow, but can be up to 72 feet (22 m). Originally, it was thought

[4] Between 2003 and 2015.

that only surface and pelagic fishing gears would result in bycatch of seabirds due to the overlap in diving range with fishing depth. However, it has since been identified that shallow diving species are susceptible to be caught in deep set gear as the gear is being deployed/hauled (Bradbury *et al.*, 2017) with evidence of gannet being bycaught in trawls during the hauling process as gannet dive into the net to retrieve the fish (*per. comms*[5].).

Table 1: Seabird sensitivity index (SSI) score for gannet. Rank is compared to other assessed UK seabirds: 1 is the highest SSI score (most vulnerable to bycatch). Total of 53 seabirds compared, total rank 61 (some seabirds ranked for breeding and winter). Data extracted from Bradbury *et al.* (2017).

Gear	SSI Score	Rank
Surface	96	1
Pelagic	58	7
Benthic	58	10

4.1.1.3 The Report of the Workshop to Review and Advise on Seabird Bycatch (ICES, 2013) reviewed evidence on bycatch and identified the following fishing gears as likely (or known) to incidentally catch gannet:

- Trammel nets and set gillnets;
- Set longlines;
- Purse seines;
- Bottom otter trawls; and
- Pelagic trawls.

4.1.1.4 Within UK fisheries, Northridge *et al.* (2020) identified longline fishing as the highest risk to gannet bycatch, with hundreds of gannet being bycaught per year (2016 = 220, 2017 = 241). Static gillnetting was also identified as a threat, however on a smaller scale, with (2016 = 117, 2017 = 102) being bycaught per year. It is noted that when gannet bycatch was extrapolated separately for <10 m and >10 m static net vessels, the total bycatch estimate was 58 and 50 (2016 and 2017 respectively), therefore lower than the estimated bycatch when all static net vessel sizes are extrapolated together. It is uncertain which bycatch estimate is the most accurate (117/102 vs 58/50). Northridge *et al.* (2020) did not identify midwater trawls as a bycatch risk for gannet, however Danish fishers contacted during fisheries consultation as part of the Project stated that they observe many gannet diving into trawl nets whilst they are being hauled[6]. Due to the small-scale coverage of the UK BMP (<5% midwater trawl effort), there is potential that the bycatch may not have been recorded in full. Longline and midwater trawl fisheries are therefore the two chosen fishing methods to be assessed within this review. Static nets were not reviewed further due to the lower bycatch risk and uncertainty in bycatch estimates.

4.2 Scale of Impact

4.2.1.1 Gannet were observed to be caught within longline fisheries, in estimates of hundreds per year (2016 = 220, 2017 = 241; Northridge *et al.,* 2020). The ICES divisions IVa (4.a.) and VIa

[5] Stated during a telephone conversation between Danish fishers and Orsted fishery liaisons. Waiting on written comments.
[6] Stated during a telephone conversation between Danish fishers and Orsted fishery liaisons. Waiting on written comments.

(6.a.) were identified as the most important areas for longline fishery bycatch (2016 = 130; 2017 = 159) (Northridge *et al.*, 2020). Both divisions are within Scotland. ICES divisions VIIb (7.b.), VIIc (7.c.), VIIj (7.j.) were also identified as important regions of gannet longline bycatch (2016 = 91; 2017 = 80). These regions are located off the southwest coast of the UK. (See **Figure 4** in **Section 5** for exact locations of these ICES regions). The locations of the remaining bycatch were not stated within the analysis.

4.2.1.2 The scale of midwater trawl bycatch has not been quantified as the evidence received was anecdotal. There were therefore no specific bycatch rates provided for midwater trawls.

4.3 Introduction to Fishing Methods

4.3.1.1 This evidence review focuses on two fishing methods due to evidence collated (both quantitative and anecdotal evidence (**paragraph 4.1.1.4**)):

- Longline – evidenced widely in the literature and identified as the highest bycatch risk for gannet in UK fisheries; and
- Midwater trawl – identified in the literature and anecdotal evidence from Danish fishers.

4.3.1.2 The following sections give a brief introduction to the fishing methods.

4.3.2 Longline

4.3.2.1 Longlining is a fishing practice whereby a longline, or main line, trails behind a boat with baited hooks attached at regular intervals (potentially miles long depending on the fishery) (**Figure 1**). A longline can be set at different depths depending on target catch species, namely pelagic or demersal.

4.3.2.2 Seabirds are vulnerable to longlining during the setting and hauling process where hooks are within foraging range from the surface as diving seabirds will attempt to take bait from baited hooks. It has been estimated that hundreds of thousands of seabirds are killed globally each year in longline fisheries (320,000; Anderson *et al.,* 2011).

4.3.3 Trawling

4.3.3.1 Trawling is a common fishing technique used worldwide due to its efficiency in capturing large numbers of fish. Trawl nets are designed to be towed by a boat through the water column, although there are several trawling methods, they fall into two categories (**Figure 2** and **Figure 3**):

- 1) demersal (bottom) trawling; and
- 2) pelagic (midwater) trawling.

4.3.3.2 Both techniques use a cone or funnel-shaped body with a wide opening to catch fish or crustaceans and a narrow, closed end (known as the cod-end) that holds the catch. Both bottom and midwater trawls use otterboards/ trawl doors to keep the mouth of the net open. They differ by targeting different sections of the water column (near the sea floor/ in the water column) (**Figure 2** and **Figure 3**).

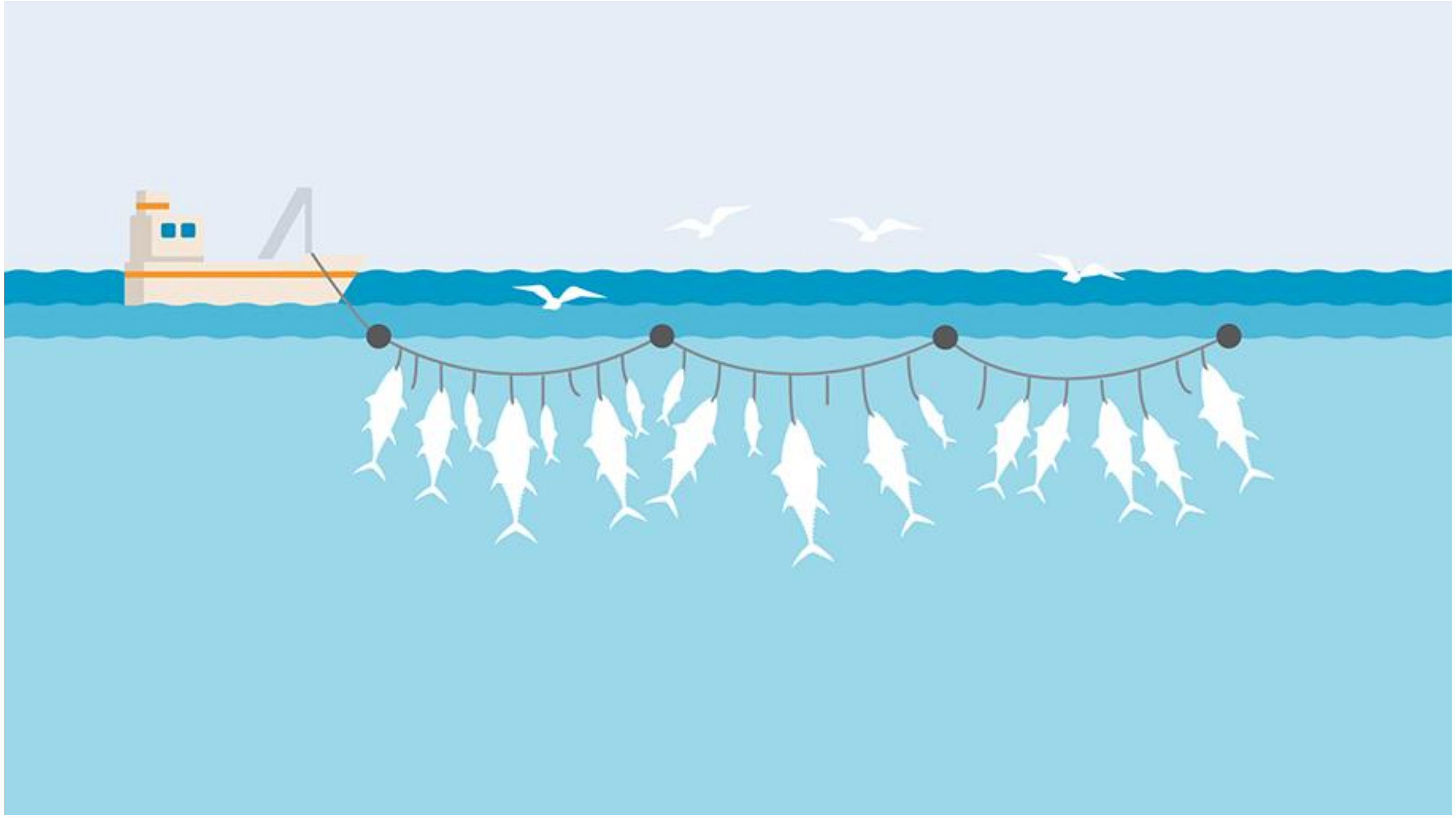


Figure 1: Longline fishing diagram (taken from the Marine Stewardship Council[7]).

[7] Available at: https://www.msc.org/what-we-are-doing/our-approach/fishing-methods-and-gear-types/longlines

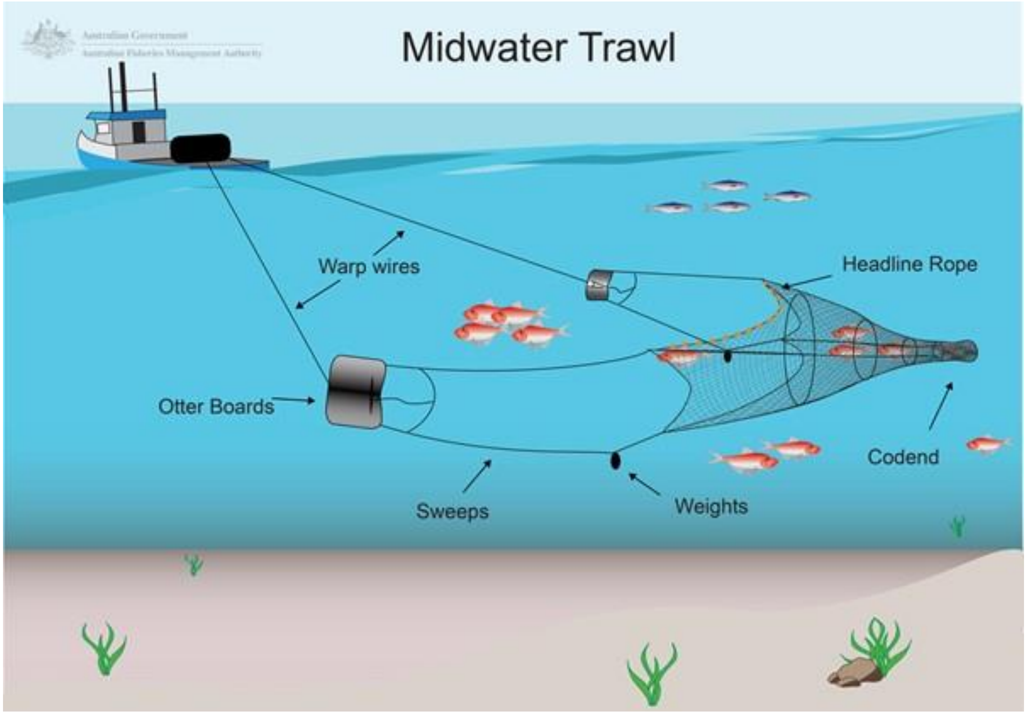


Figure 2: Pelagic (midwater) trawl diagram (taken from the Australian Fisheries Management Authority[8]).

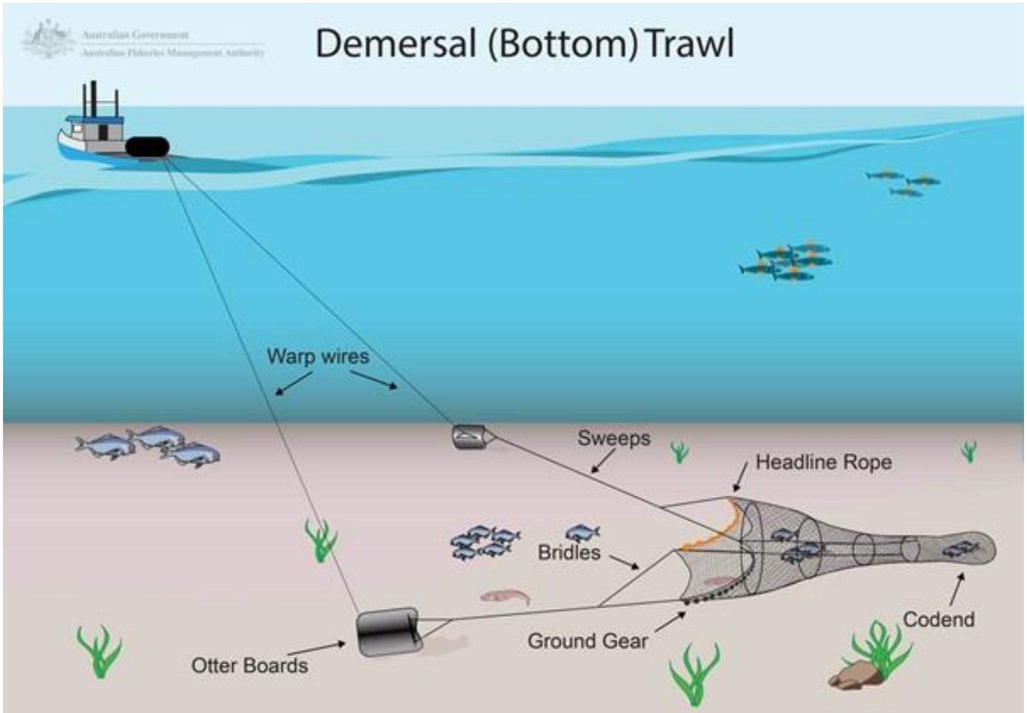


Figure 3: Demersal (bottom) trawl diagram. (taken from the Australian Fisheries Management Authority[9]).

[8] Available at: https://www.afma.gov.au/fisheries-management/methods-and-gear/trawling
[9] Available at: https://www.afma.gov.au/fisheries-management/methods-and-gear/trawling

4.3.3.3 Trawling results in bycaught of several taxa, including cetaceans, pinnipeds, and seabirds, with trawling and tropical shrimp trawling accounting for 55% and 27% of all global discarded bycatch, respectively (Davies *et al.,* 2009; Eayrs, 2007). Seabird bycatch often occurs in trawl fisheries due to the attraction of birds to potential foraging opportunities i.e., discarded waste such as offal, fish heads and tails, or other non-commercial catch (Pierre *et al.,* 2010).

4.3.3.4 Seabirds are particularly vulnerable to larger mesh sizes of some trawl nets, particularly pelagic (120-800mm) (ACAP, 2016). Seabirds dive into the net entrance and then drown when shooting (launching) the net or are killed/ injured when the net is hauled onto the vessel. However, seabirds are also vulnerable to smaller mesh sizes (R. Wells from Parker, 2017). Seabirds may also be incidentally killed by warp strike, where birds collide with trawl warps, netsonde or paravane cables. If the warp hits the wing of a bird, it wraps around and the drag created by the forward motion of the vessel pulls the bird underwater, causing the bird to drown (BirdLife International and the ACAP, 2015).

5 UK Fishing Effort

5.1 Introduction

5.1.1.1 To understand the potential locations of high bycatch risk, it is important to understand fishing effort (both spatially and temporally). This section therefore explores the UK longline and midwater trawl fishing effort from 2015 to 2018 (noting that 2018 was the most recent data available) to identify hotspots and trends. This fishing effort data is used within the bycatch risk mapping in **Section 5.4**.

5.2 Methods

5.2.1 Fishing Effort

5.2.1.1 The UK fishing fleet at sea is evaluated annually by the Marine Management Organisation (MMO) to assess the fleet, landings, effort, and trade, and subsequently incorporated into the UK Sea Fisheries Annual Statistics dataset managed by the MMO. Longline and midwater trawl data was obtained for 2015 to 2018 (noting that 2018 was the most recent data available) and analysed by Brown and May Marine Consultants[10].

5.2.1.2 Fishing effort (days fished) for both longline and midwater trawl vessels were compared between ICES divisions and ICES rectangles (**Figure 4**). ICES rectangles were the smallest scale available to monitor fishing effort by location and thus were used to map UK fishing effort in ArcGIS (Desktop 10.5.1).

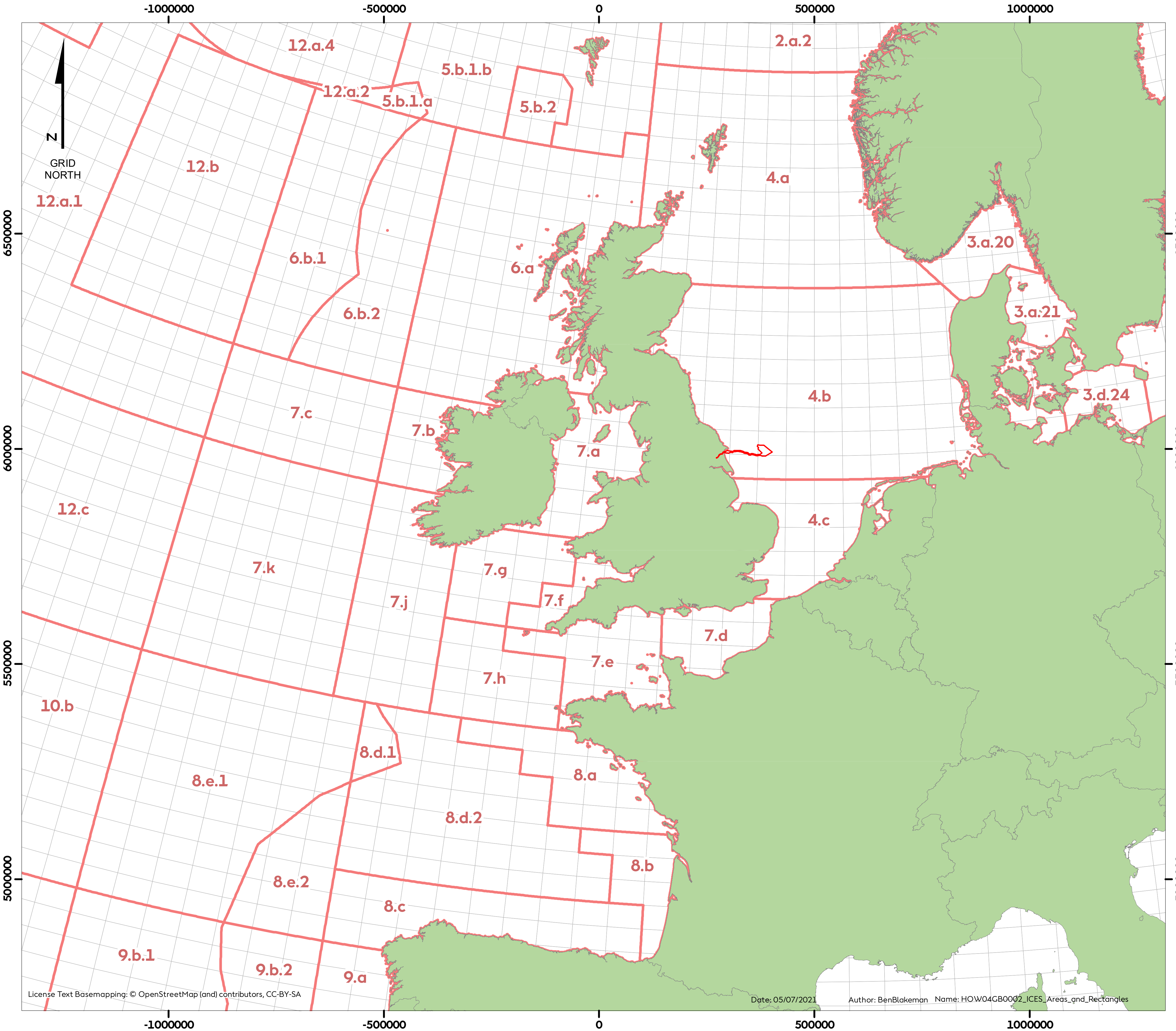
5.3 Results

5.3.1.1 Fishing effort per ICES division for longline and midwater trawl UK fisheries is presented in **Table 2**. Midwater trawl fishing vessels represent a higher level in fishing effort compared to longline in days fishing (over double). "Hotspots" for both fishing types occur in IVa and VIa (Scotland).

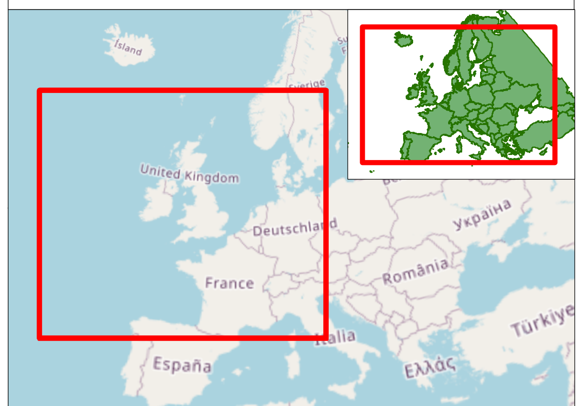
[10] Original data from the Marine Management Organisation (https://www.gov.uk/government/collections/uk-sea-fisheries-annual-statistics). Extracted by gear type (longline/ midwater trawl), and fishing effort (days at sea) identified.

Hornsea Four

Figure 4
ICES Areas and
ICES Statistical Rectangles



Order Limits
ICES Areas
ICES Statistical Rectangles



Coordinate system: ETRS 1989 UTM Zone 31N
Scale@A3: 1:8,500,000

0 200 400 Kilometres

0 100 200 Nautical Miles

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ICES Areas and
Statistical Rectangles
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Created by: BPHB
Checked by: FC
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5.3.1.2 At a smaller scale (ICES rectangles) for longlines, fishing effort is concentrated offshore, mainly off the north coast of Scotland and the east coast of the Shetland Islands (Figure 5). For midwater trawlers, fishing effort is concentrated closer to the coast than further out at sea (Figure 6).

Table 2: Fishing effort in days for longline and midwater trawl UK fisheries in 2018. The divisions in bold represent the highest fishing effort locations. Data extracted from MMO and handled by Brown and May Marine.

ICES Division	Longline	Midwater Trawl
IIa (2.a.2)	-	41
IVa (4.a)	3,229	5,051
IVb (4.b)	24	1962
IVc (4.c)	233	78
IXa (9.a)	6	-
Vb (5.b)	1	-
VIa (6.a)	1,680	5,684
VIb (6.b.1/6. b.2)	-	79
VIIa (7.a)	43	683
VIIb (7.b)	46	10
VIIc (7.c)	71	67
VIId (7.d)	122	130
VIIe (7.e)	29	1,400
VIIf (7.f)	32	60
VIIg (7.g)	6	58
VIIh (7.h)	11	138
VIIj (7.j)	537	60
VIIk (7.k)	2	-
VIIIa (8.a)	87	4
VIIIb (8.b)	18	2
VIIIc (8.c)	32	-
VIIId (8.d.1/8. d.2)	71	1
NULL[11]	844	-
TOTAL	7,124	15,508

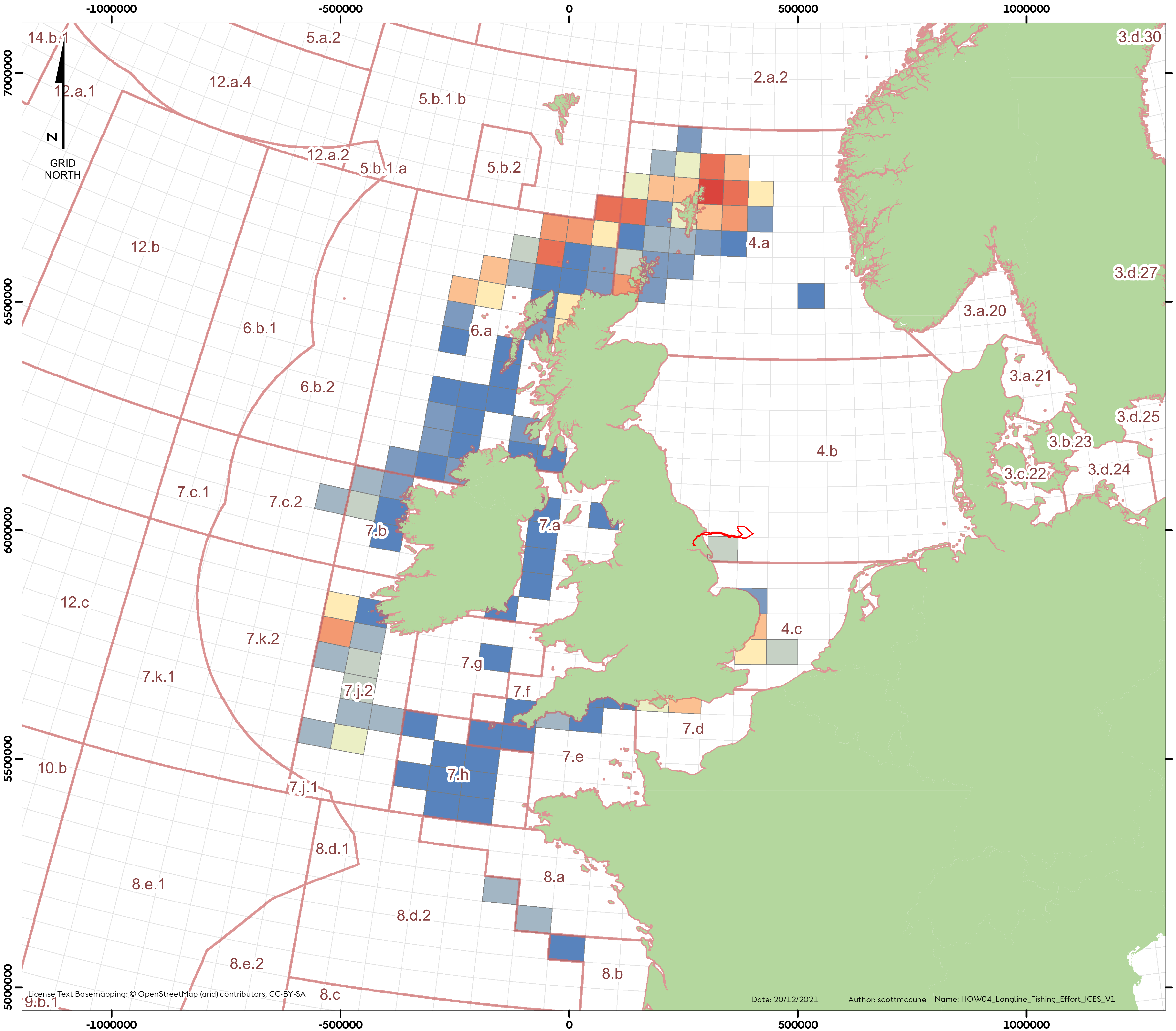
5.3.1.3 Fishing effort for both gear types varied annually (Figure 7 and Figure 8):

- Longline fishing effort doubled between 2015 to 2018 (3,410 to 7,124); whereas
- Midwater trawl effort decreased nearly by half (26,716 to 15,508).

5.3.1.4 Fishing effort for both gear types also varied throughout the year (Figure 9 and Figure 10):

- Longline fishing effort ranged from 357 to 969 days at sea. Fishing effort increased from September over winter, peaking in July; whereas
- Midwater trawl effort fluctuated steadily through the year (ranged between 867 to 1,589), with the highest effort months occurring June to August and lowest effort occurring in December.

[11] No ICES division specified.



Hornsea Four

Figure 5
Longline Fishing Effort

- Order Limits
- ICES Areas

ICES Statistical Rectangles:

Longline Fishing Effort (Days Fished):

- 1.00000000 - 3.00000000
- 3.00000001 - 9.00000000
- 9.00000001 - 19.0000000
- 19.0000001 - 31.0000000
- 31.0000001 - 45.0000000
- 45.0000001 - 69.0000000
- 69.0000001 - 142.000000
- 142.000001 - 222.000000
- 222.000001 - 446.000000
- 446.000001 - 882.000000

Coordinate system: WGS 1984 UTM Zone 31N
Scale@A3: 1:8,000,000

0 160 320 Kilometres

0 75 150 Nautical Miles

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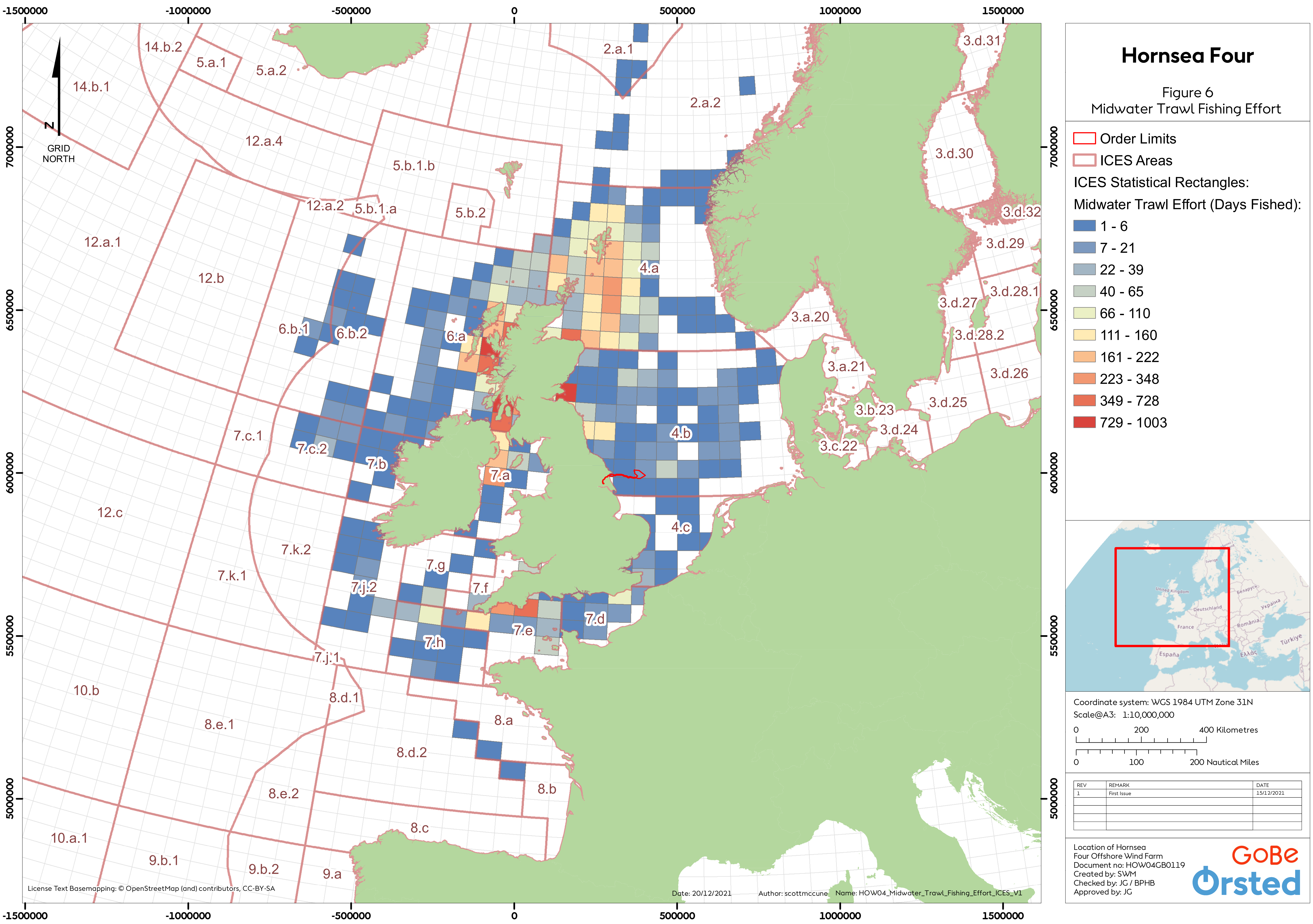
Hornsea Four
Figure 6
Midwater Trawl Fishing Effort
Order Limits
ICES Areas
ICES Statistical Rectangles:
Midwater Trawl Effort (Days Fished):
1 - 6
7 - 21
22 - 39
40 - 65
66 - 110
111 - 160
161 - 222
223 - 348
349 - 728
729 - 1003
Coordinate system: WGS 1984 UTM Zone 31N
Scale@A3: 1:10,000,000
0 200 400 Kilometres
0 100 200 Nautical Miles
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Date: 20/12/2021
Author: scottmccune
Name: HOW04_Midwater_Trawl_Fishing_Effort_ICES_V1
2.a.1
2.a.2
3.d.31
3.d.30
3.d.32
3.d.29
3.d.28.1
3.d.27
3.d.28.2
3.d.26
3.d.25
3.d.24
3.b.23
3.c.22
3.a.20
3.a.21
4.a
4.b
4.c
14.b.2
14.b.1
5.a.1
5.a.2
12.a.4
5.b.1.b
12.a.2
5.b.1.a
5.b.2
12.a.1
12.b
6.b.1
6.b.2
6.a
7.c.1
7.c.2
7.b
7.a
12.c
7.k.2
7.k.1
7.g
7.j.2
7.f
7.e
7.d
7.h
7.j.1
10.b
8.d.1
8.a
8.e.1
8.d.2
8.b
8.e.2
8.c
10.a.1
9.b.1
9.b.2
9.a

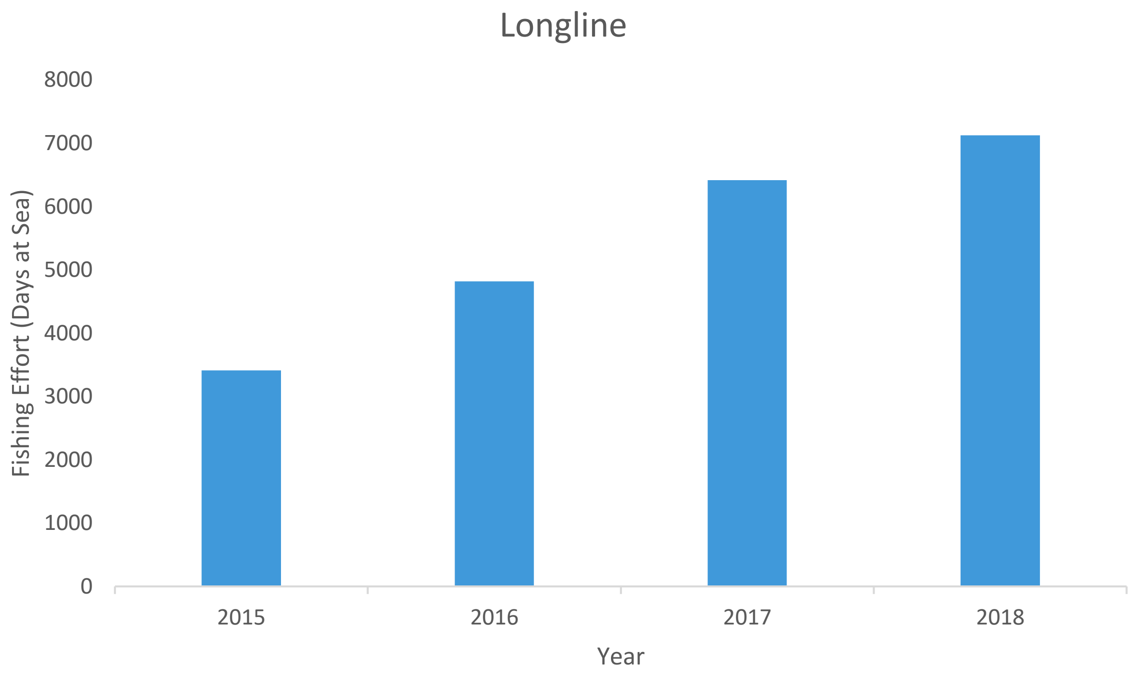


Figure 7: Fishing effort (days at sea) for longline vessels by ICES division from 2015 to 2018. Data extracted from MMO and handled by Brown and May Marine.

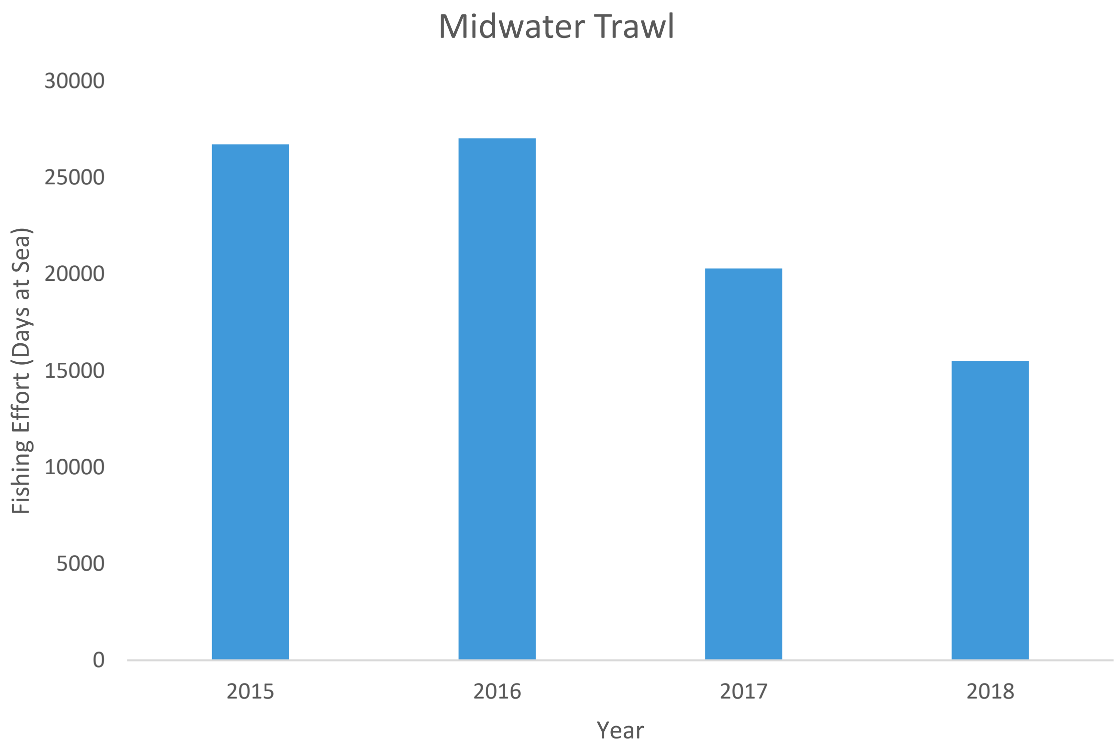


Figure 8: Fishing effort (days at sea) for midwater trawl vessels by ICES division from 2015 to 2018. Data extracted from MMO and handled by Brown and May Marine.

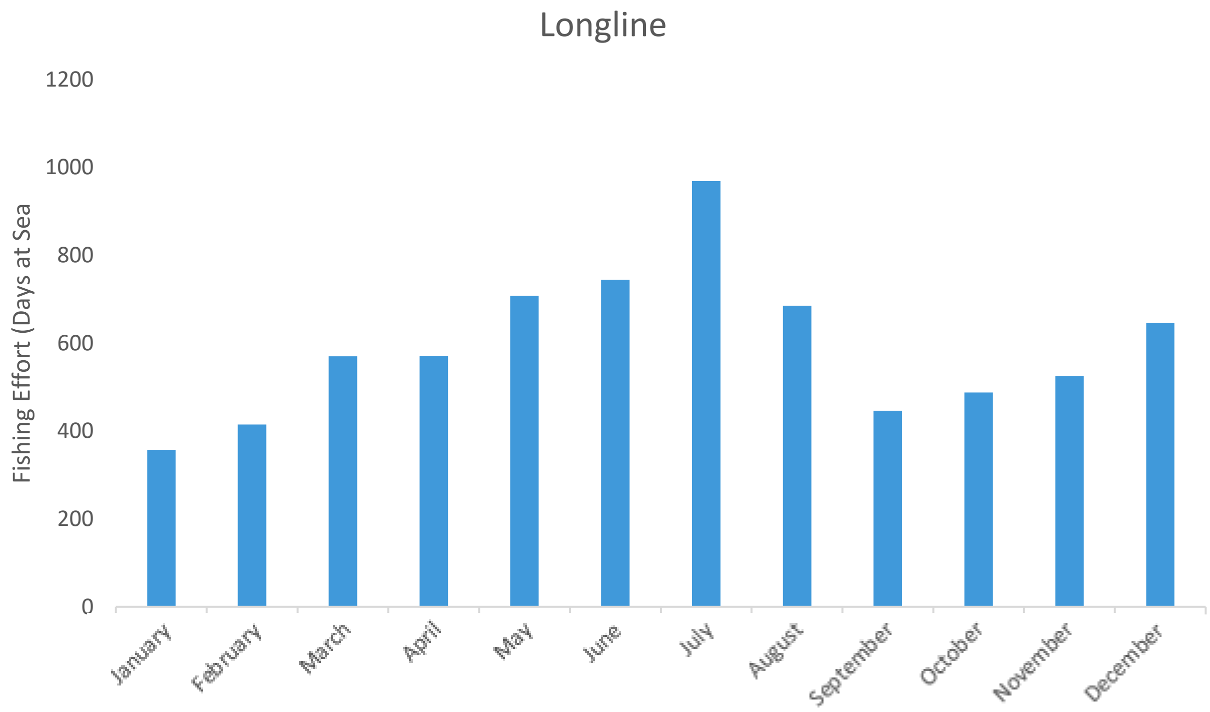


Figure 9: Total days fishing using longlines by month in the UK during 2018. Data extracted from MMO and handled by Brown and May Marine.

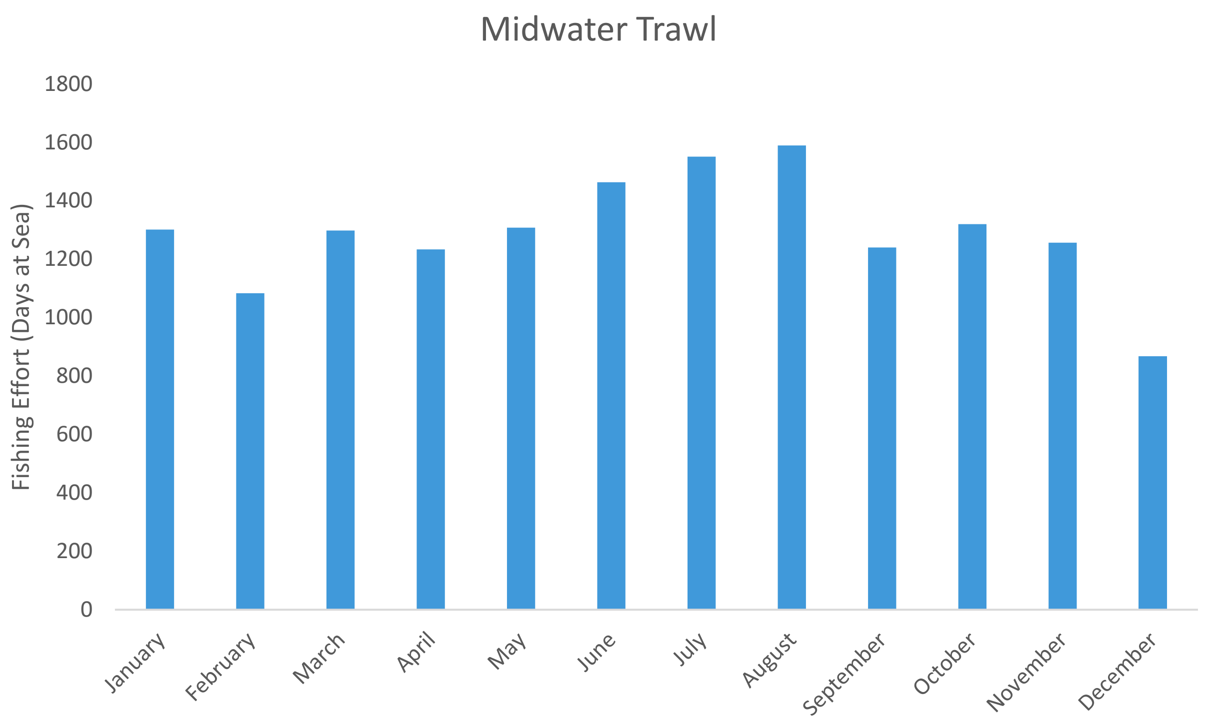


Figure 10: Total days fishing using midwater trawlers by month in the UK during 2018. Data extracted from MMO and handled by Brown and May Marine.

5.4 Discussion

5.4.1.1 UK longline fishing effort has increased steadily from 2015, reaching over 7,000 days at sea by 2018. The highest fishing effort occurred in ICES rectangle IVa, followed by VIa, with 45% and 24% of the UK fishing effort respectively.

5.4.1.2 UK midwater trawl fishing effort has decreased from 2015, reducing to around 15,500 days at sea by 2018. Similarly to longline fishing, the highest fishing effort occurred in ICES rectangles IVa and VIa, with 33% and 37% of the UK fishing effort respectively.

5.4.1.3 Both longline and midwater trawl effort is concentrated in Scottish waters, therefore Scotland is most likely to present the highest bycatch occurrences within the UK fishing fleet. Within England, highest effort is located on the south coast and southeast coast. Foreign vessels also fish within UK waters, there is potential for fishing effort hotspots to also occur elsewhere.

5.4.1.4 Although fishing effort varies throughout the year, the impact will vary depending on the densities of gannet within the locations per month. This has been evaluated below in **Section 5.4**.

6 Foreign Fleet Fishing Effort

6.1 Introduction

6.1.1.1 The above analysis solely refers to the UK fishing fleet. As a result, fishing by foreign vessels in UK waters (or beyond but within species migratory routes) will contribute to impacts at UK colonies. The following section summarises information identified through literature, as well as communications with relevant personnel, that may aid in identifying important fisheries regarding bycatch of gannet from UK colonies.

6.2 Longline

6.2.1.1 Longlining is a global fishing practice, with seabird bycatch occurring in various fisheries from various nationality fleets (Anderson *et al.,* 2011). The rate of bycatch differs between the locations due to a variety of factors, including but not limited to, sink rate of hooks, bird species present (and density of birds present), as well as gear/ setting (BirdLife International *pers. comm.*; Bradbury et al., 2017; Belda and Sanchez, 2003).

6.2.1.2 To identify the level of foreign fleet longline fishing effort within UK waters, Brown and May Marine used VMS data to map effort through density/value in **Figure 11**, **Figure 12**, **Figure 13** and **Figure 14**. The figures indicate that Spanish and French fleet are likely to have the greatest overlap with gannet from FFC SPA during migration (**Appendix A**; Furness *et al.,* 2018).

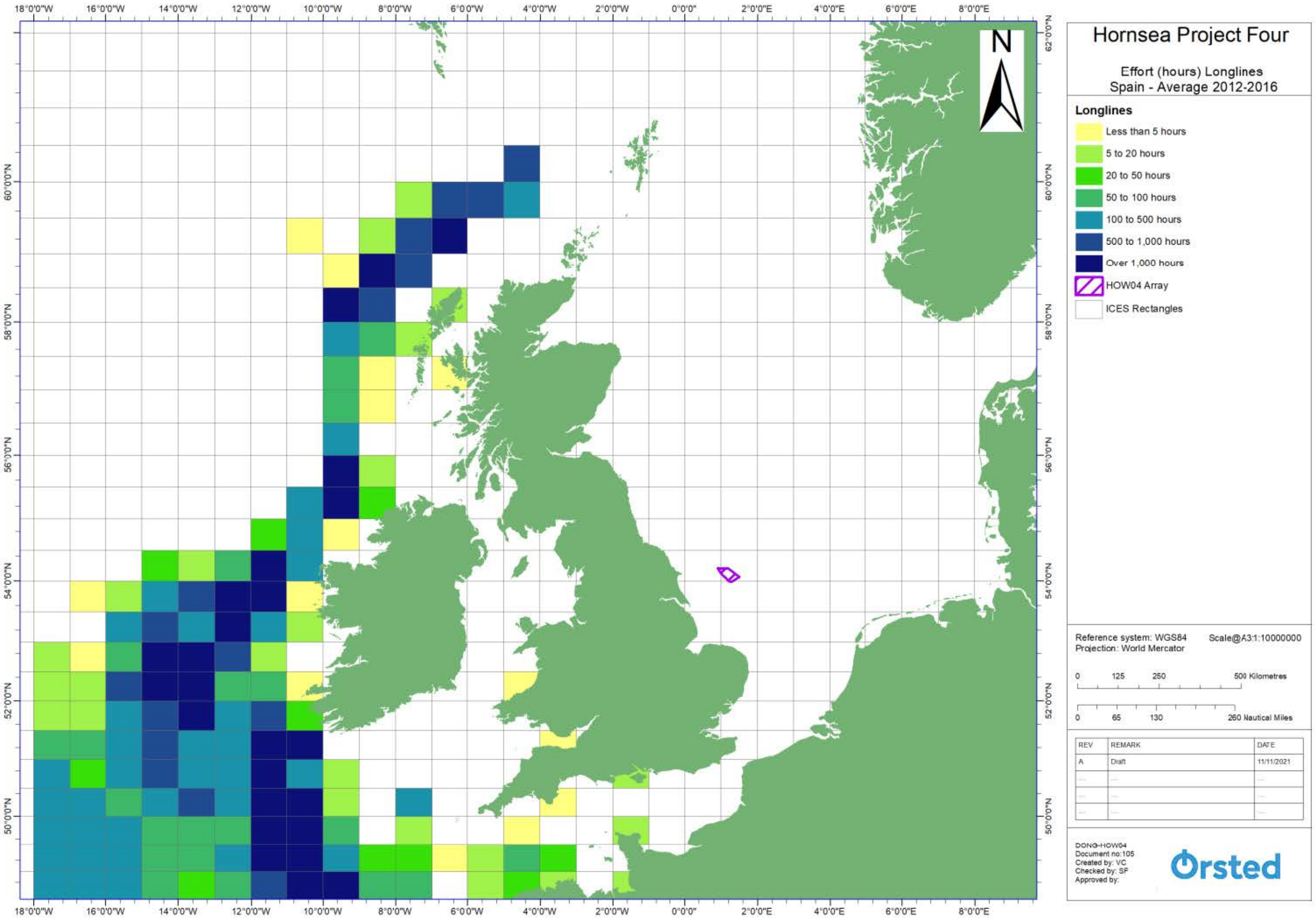


Figure 11: Effort (hours fished) using Longlines – Spain, average 2012-2016. Figure produced by Brown and May Marine.

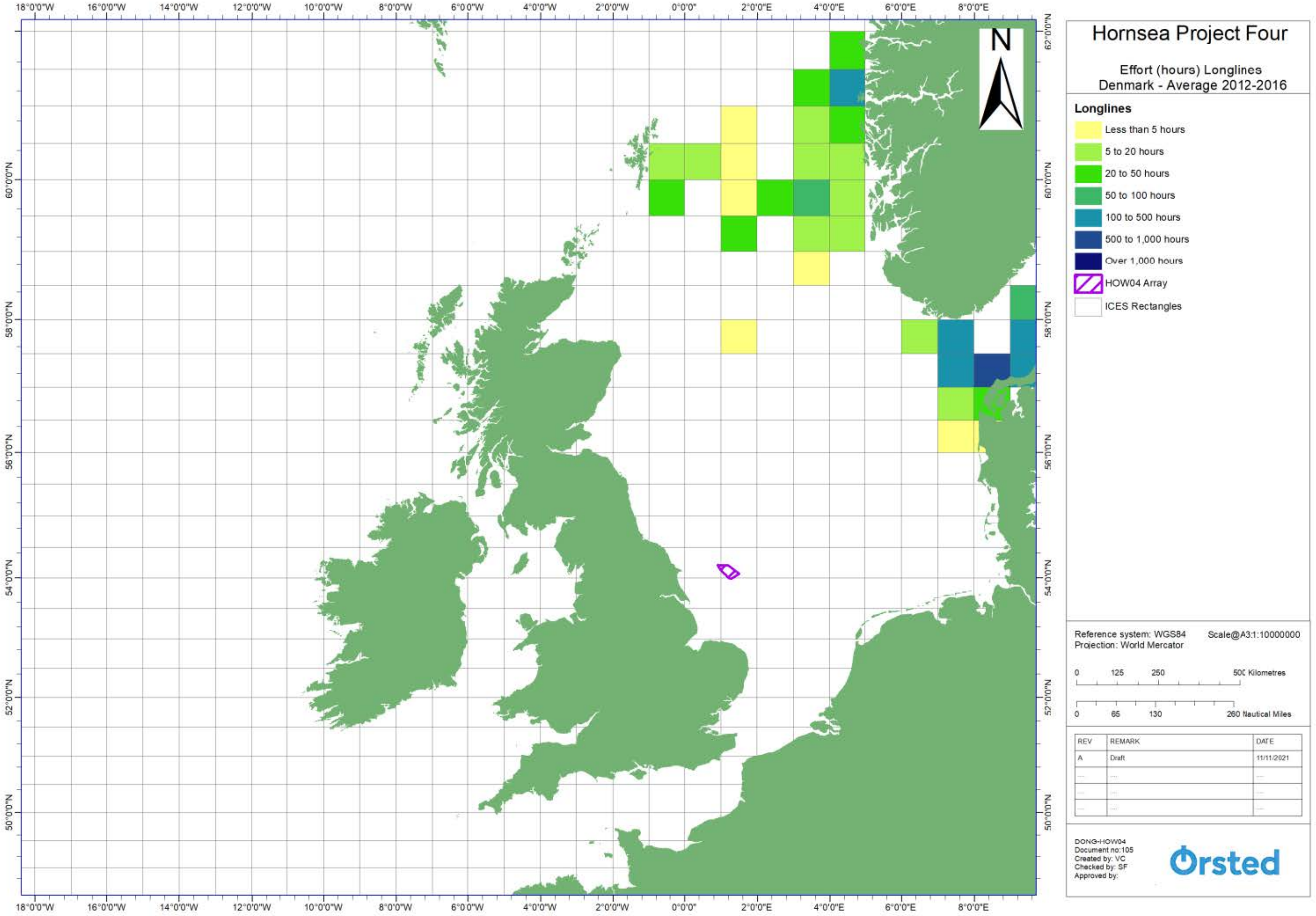


Figure 12: Effort (hours fished) using Longlines – Denmark, average 2012-2016. Figure produced by Brown and May Marine.

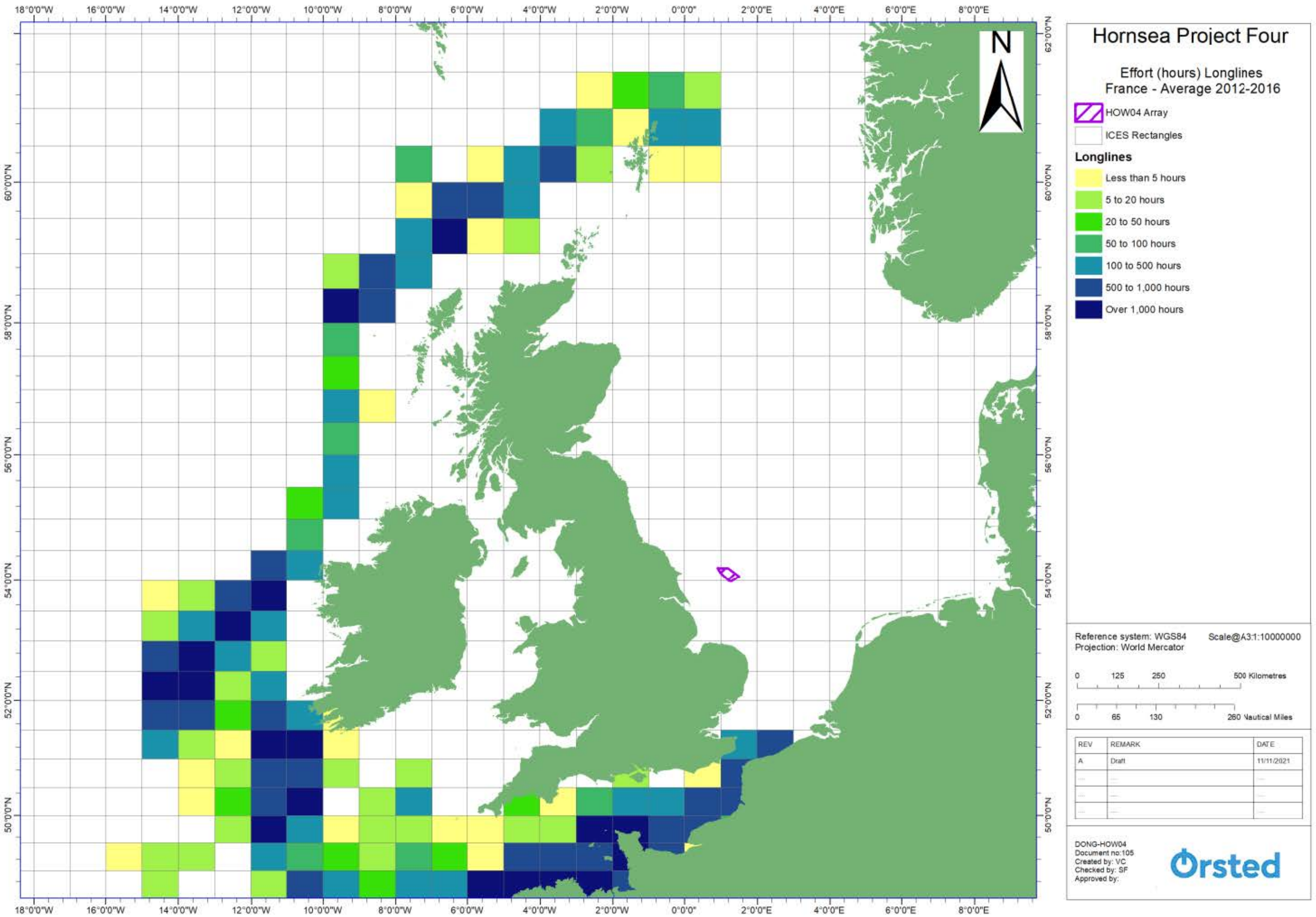


Figure 13: Effort (hours fished) using Longlines – France, average 2012-2016. Figure produced by Brown and May Marine.

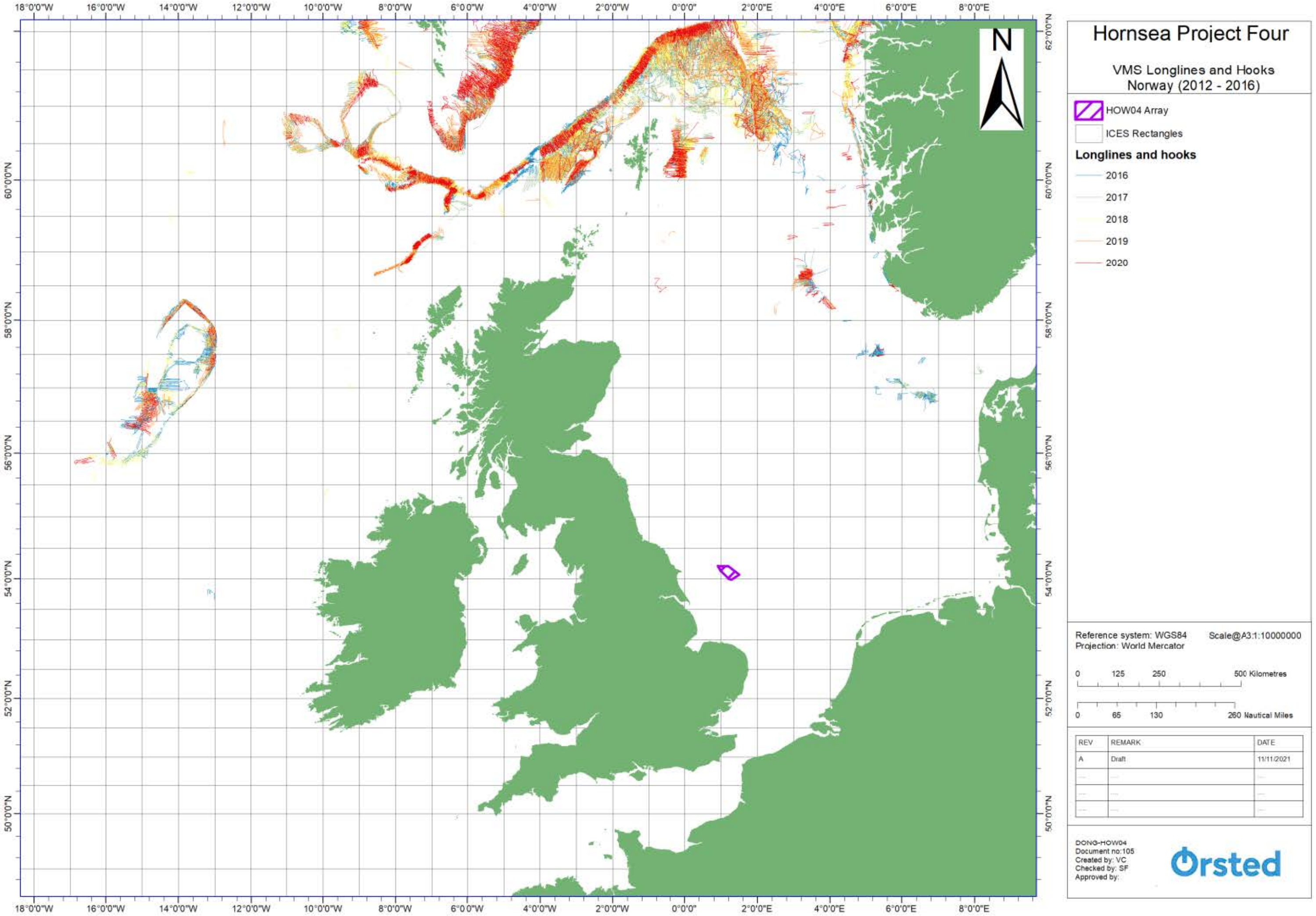


Figure 14: Effort (hours fished) using Longlines – Norway, average 2012-2016. Figure produced by Brown and May Marine.

6.2.1.3 The Gran Sol fishery (a fishing ground located west of the UK in the Atlantic Ocean, occupied mostly by Spanish fleet (**Figure 11**)), has been identified as a location of extremely high seabird bycatch (Anderson *et al.*, 2011; BirdLife International *pers. comm.*). Observations within the Gran Sol longline fishing fleet recorded 48 to 141 birds bycaught on each fishing trip[12] (bycatch rate of 1.008 birds per 1000 hooks (Anderson *et al.,* 2011)). The main species recorded included gannet, however the specific numbers bycaught of each species have not been published. ICES (2008) estimated annual seabird bycatch by longline vessels, and estimated gannet bycatch in ICES region VIII (south west of the UK, an area which has potential overlap with the Gran Sol fishery) as moderate to high.

6.2.1.4 It should also be noted that gannet bycatch was estimated at 4,500 in the ICES region VI (north west of the UK) and greater than 3,000 in the ICES region IX (west of Portugal). However, a recent publication (Araújo *et al.,* 2022), estimated the gannet bycatch within the Portuguese continental waters (ICES division IXa - smaller scale than ICES region IX) of between 779–4629 gannet bycaught per year within this singular fishery (total of 39 longline fisher licenses). Therefore, there is potential that gannet bycatch is higher than previously estimated.

6.2.1.5 Gannet from FFC SPA are likely to encounter all of these bycatch "hotspots" during migration (clockwise migration around Britain and Ireland (Furness *et al.,* 2018)). Reducing bycatch within these locations would therefore likely provide positive impacts for the gannet colony at FFC SPA.

6.3 Midwater Trawl

6.3.1.1 During fisheries consultation carried out by Orsted, Danish trawl fishers operating within the North Sea stated that gannet are bycaught in trawls during hauling as gannet dive into the net to retrieve fish (*per. comms*[13].), despite Northridge *et al*. (2020) not identifying midwater trawling as a high bycatch risk to gannet.

6.3.1.2 To identify the level of foreign fleet trawl fishing effort within the North Sea, Brown and May Marine used VMS data to map effort through density/value in **Figure 15**, **Figure 16**, and **Figure 17**. The figures indicate that there are foreign fleet trawlers in the vicinity of the FFC SPA, within the foraging range of gannet and could therefore have potential for high bycatch of gannet in this area.

6.3.1.3 Nevertheless, as the evidence is anecdotal and no specific bycatch rates were recorded, it is not possible to estimate the level of bycatch within the North Sea from foreign fishing fleet.

7 Bycatch Risk Mapping

7.1 Introduction

7.1.1.1 To understand high bycatch "risk zones", a bycatch risk assessment of UK waters has been undertaken by GoBe Consultants Ltd on behalf of the Applicant to understand the areas where the highest densities of gannet encounter longline and midwater trawl fishing gear (and therefore inferring bycatch risk). This section solely focuses on the relationship between seabird density and fishing effort and will allow the targeted approach of bycatch reduction technology if deemed necessary by the Regulator.

[12] https://www.acap.aq/latest-news/2289-not-just-a-southern-problem-seabird-mortality-from-longlining-in-the-north-atlantic/
[13] Stated during a telephone conversation between Danish fishers and Orsted fishery liaisons.

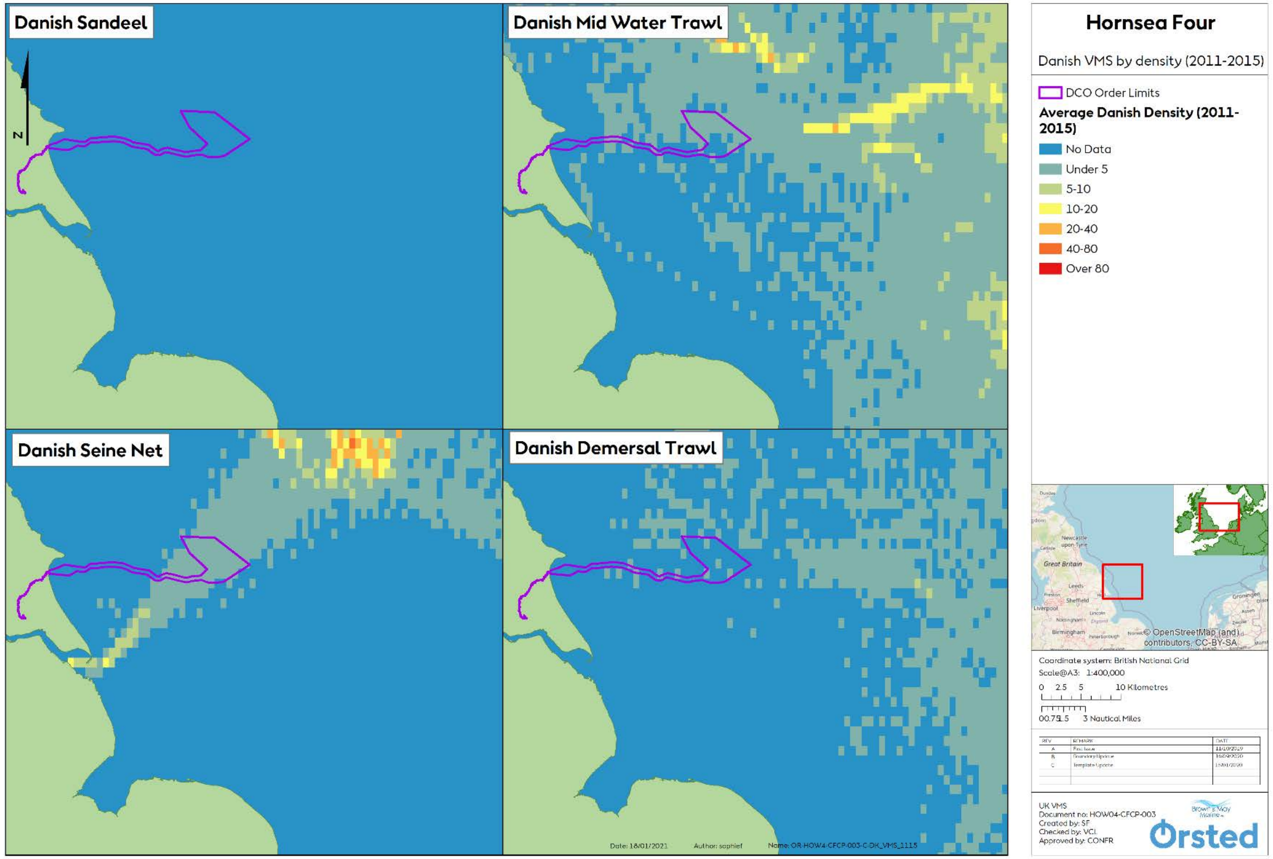


Figure 15: Average Danish VMS by density (2011-2015) for the sandeel (top left), midwater trawl (top right), seine net (bottom left), and demersal trawl (bottom right) fisheries. Figure produced by Brown and May Marine.

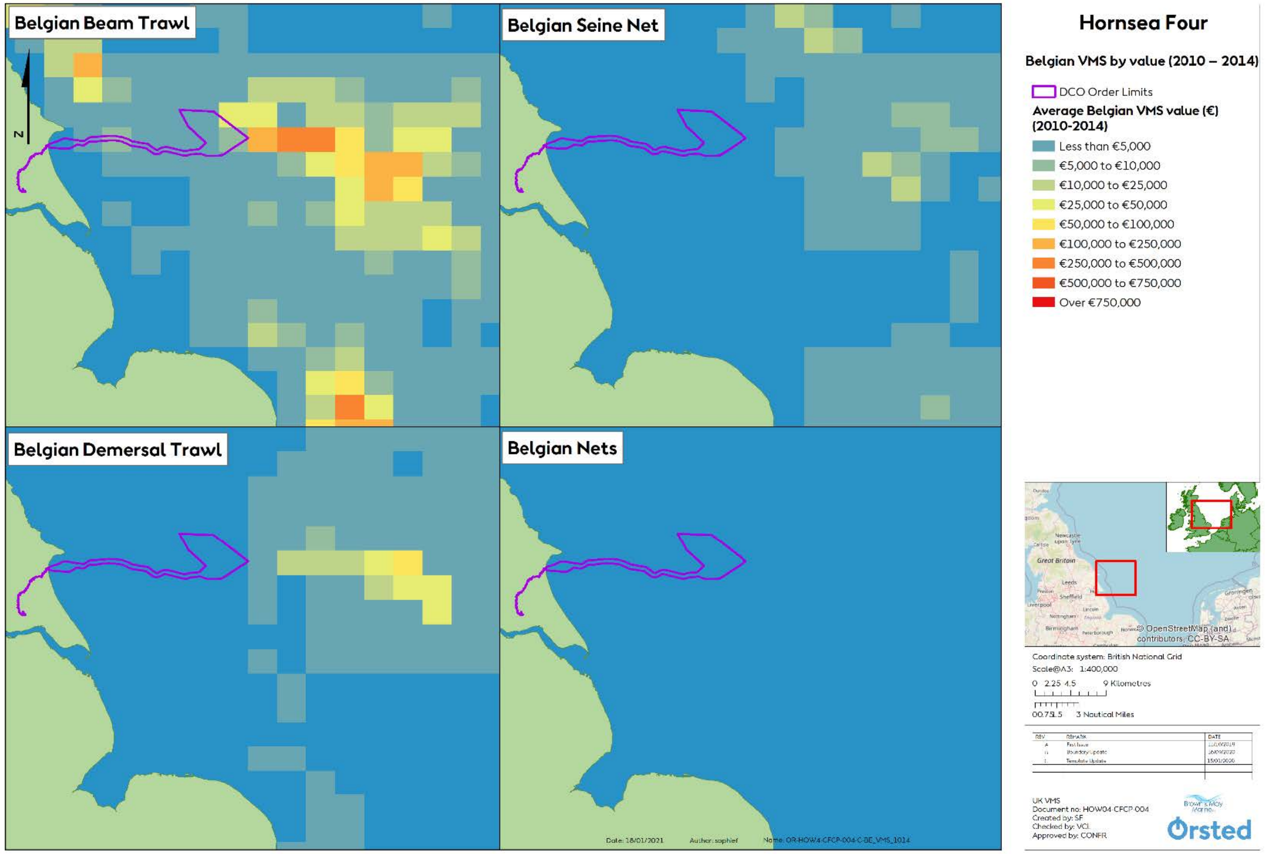


Figure 16: Average Belgian VMS by value (2010-2014) for the beam trawl (top left), seine net (top right), demersal trawl (bottom left), and net (bottom right) fisheries. Figure produced by Brown and May Marine.

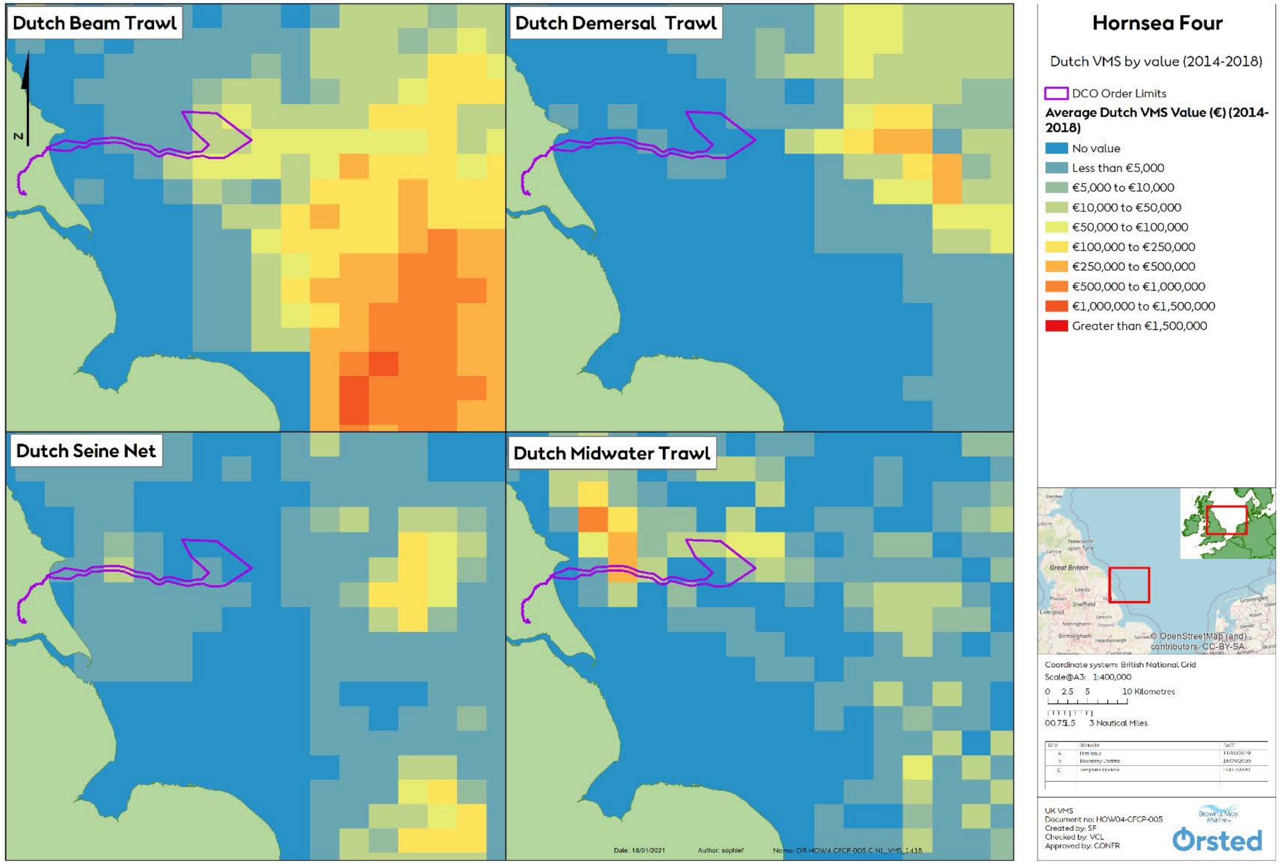


Figure 17: Average Dutch VMS by value (2014-2018) for the beam trawl (top left), demersal trawl (top right), seine net (bottom left), and midwater trawl (bottom right) fisheries. Figure produced by Brown and May Marine.

7.2 Methods

7.2.1 Seabird Distribution

7.2.1.1 Monthly distribution densities of gannet were mapped in ArcGIS (Desktop 10.5.1) (**Appendix A**). Seabird density was aggregated by Waggitt *et al.* (2019) per month at a 10 km resolution. As the smallest scale for fishing effort was ICES rectangles the seabird density data was also extracted by ICES rectangles (1 degree longitude, 0.5 degrees latitude) (**Figure 4**). The average density per rectangle was used.

7.2.2 Bycatch Risk

7.2.2.1 Bycatch risk was estimated by comparing seabird density (**Section 7.2.1**) and fishing effort (**Section 5**) per ICES rectangle per month using **Equation 1** (adapted from Bradbury *et al.* (2017)). The natural logarithm (+1 to avoid undefined values) was taken to transform each density into an order of magnitude to smooth out smaller discrepancies in counts, but still allowed large-scale patterns to be highlighted. Bycatch was then mapped in ArcGIS (Desktop 10.5.1) to identify high bycatch risk locations.

Equation 1: Bycatch risk calculated with the natural logarithm of seabird density (+1) and fishing effort.

$$Bycatch\ risk = ln\ (seabird\ density + 1) \times fishing\ effort$$

7.3 Results

7.3.1 Seabird Distribution

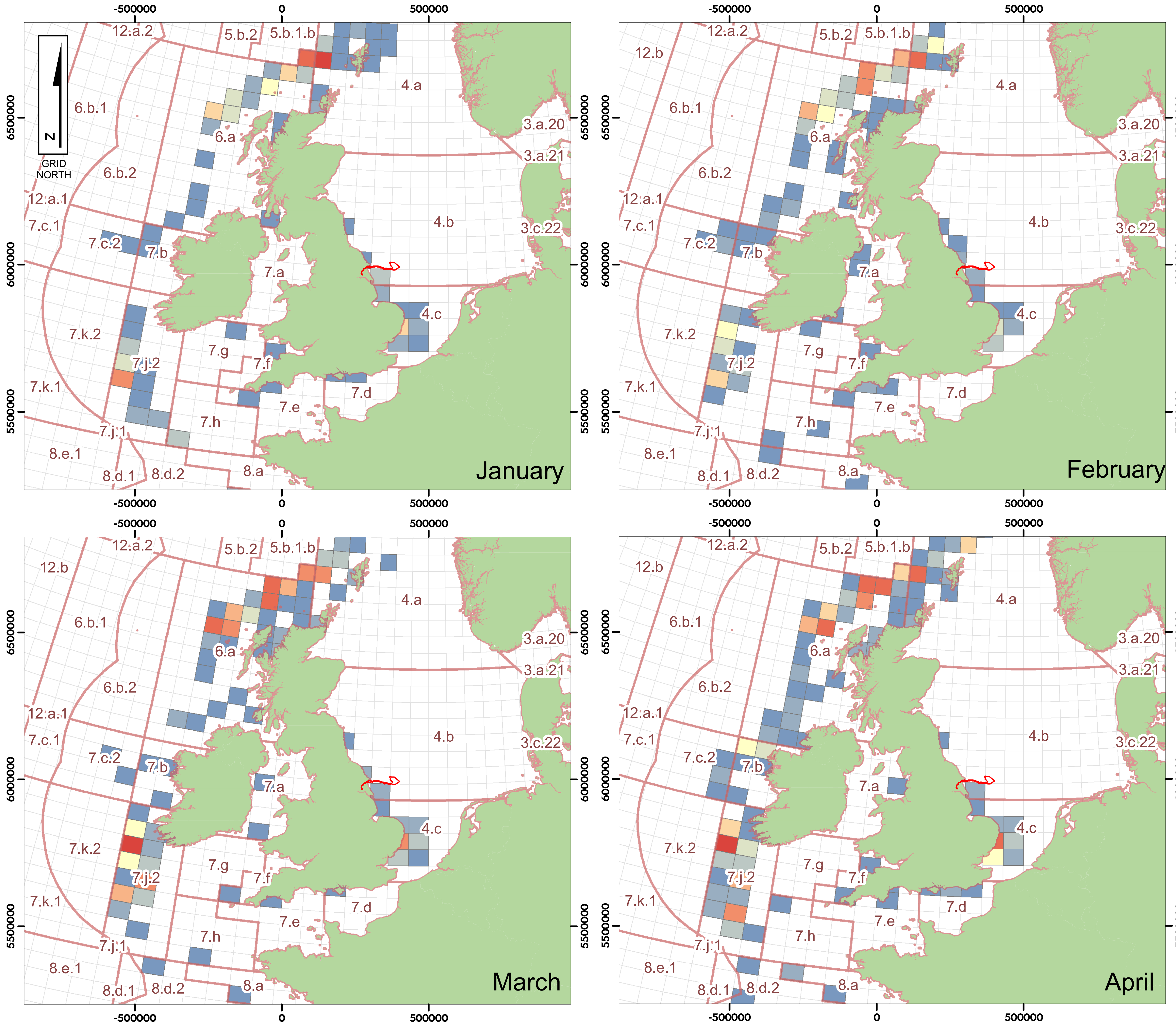
7.3.1.1 Monthly distribution densities of gannet were mapped around the UK (data derived from vessel and aerial survey data from 1980 to 2018 (Waggitt *et al.*, 2019); **Appendix A**). Overall, gannet distributions were highest at sea off the west coast of the UK, with highest concentrations of gannet within the North Sea through June to October (peaking in September).

7.3.1.2 Gannet distributions were highest around colonies from April to August, which represents the breeding season. The highest spread of gannet in UK waters occurs during September, during the beginning of their migration south.

7.3.2 Bycatch Risk

7.3.2.1 The risk of seabirds being caught in fishing gear increases with the density of fishing effort and individuals. The risk for gannet to longline and midwater trawl fishing effort (UK fleet only) has been mapped below (longline: **Figure 18**, **Figure 19**, **Figure 20**; midwater trawl: **Figure 21**, **Figure 22**, **Figure 23**). The highest bycatch risk for both longline and midwater trawlers is in Scottish waters, further offshore (north) for longlines and close to shore (on both the east and west coast) for midwater trawlers.

7.3.2.2 Overall longline bycatch risk is highest during the breeding season from May to August. Midwater trawl bycatch risk is also highest over similar months, however, is extended from March to October.



Hornsea Four

Figure 18
Gannet Longline Bycatch Risk

Order Limits
ICES Areas

ICES Statistical Rectangles:

Gannet Longline Bycatch Risk:

- 1
- 2 - 10
- 11 - 25
- 26 - 50
- 51 - 75
- 76 - 100
- 101 - 125
- 126 - 150
- 151 - 200
- 201 - 500
- 501 - 800

Coordinate system: WGS 1984 UTM Zone 31N
Scale@A3: 1:12,000,000

0 240 480 Kilometres
0 120 240 Nautical Miles

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Date: 21/12/2021 Author: scottmccune Name: HOW04_Gannet_Longline_Bycatch_ICES_JAN_to_APR_V1

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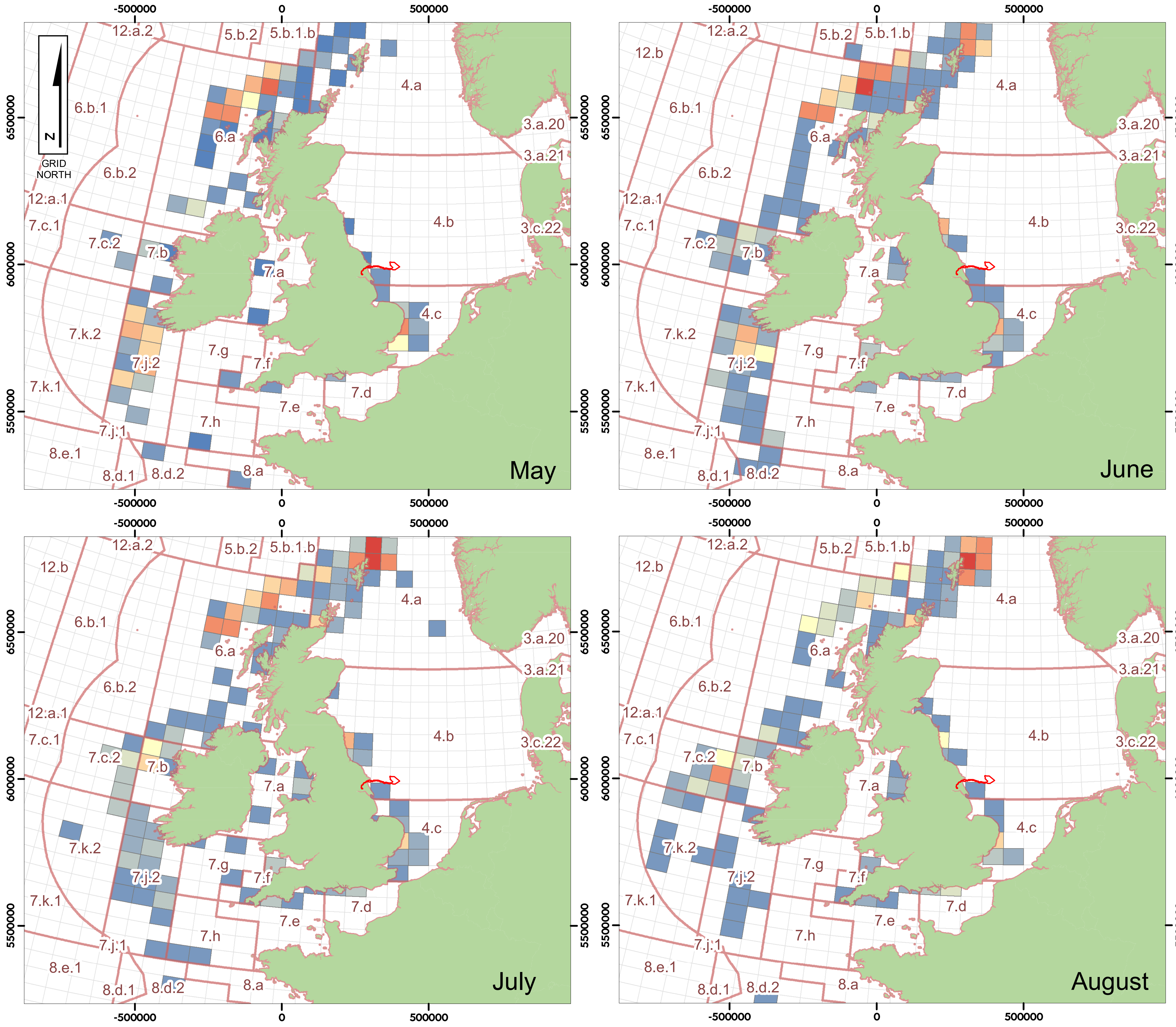
Figure 19
Gannet Longline Bycatch Risk



Order Limits
ICES Areas
ICES Statistical Rectangles:
Gannet Longline Bycatch Risk:

- 1
- 1 - 10
- 10 - 25
- 25 - 50
- 50 - 75
- 75 - 100
- 100 - 150
- 150 - 200
- 200 - 500
- 500 - 900
- 900 - 1250

Coordinate system: WGS 1984 UTM Zone 31N
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0 240 480 Kilometres
0 120 240 Nautical Miles

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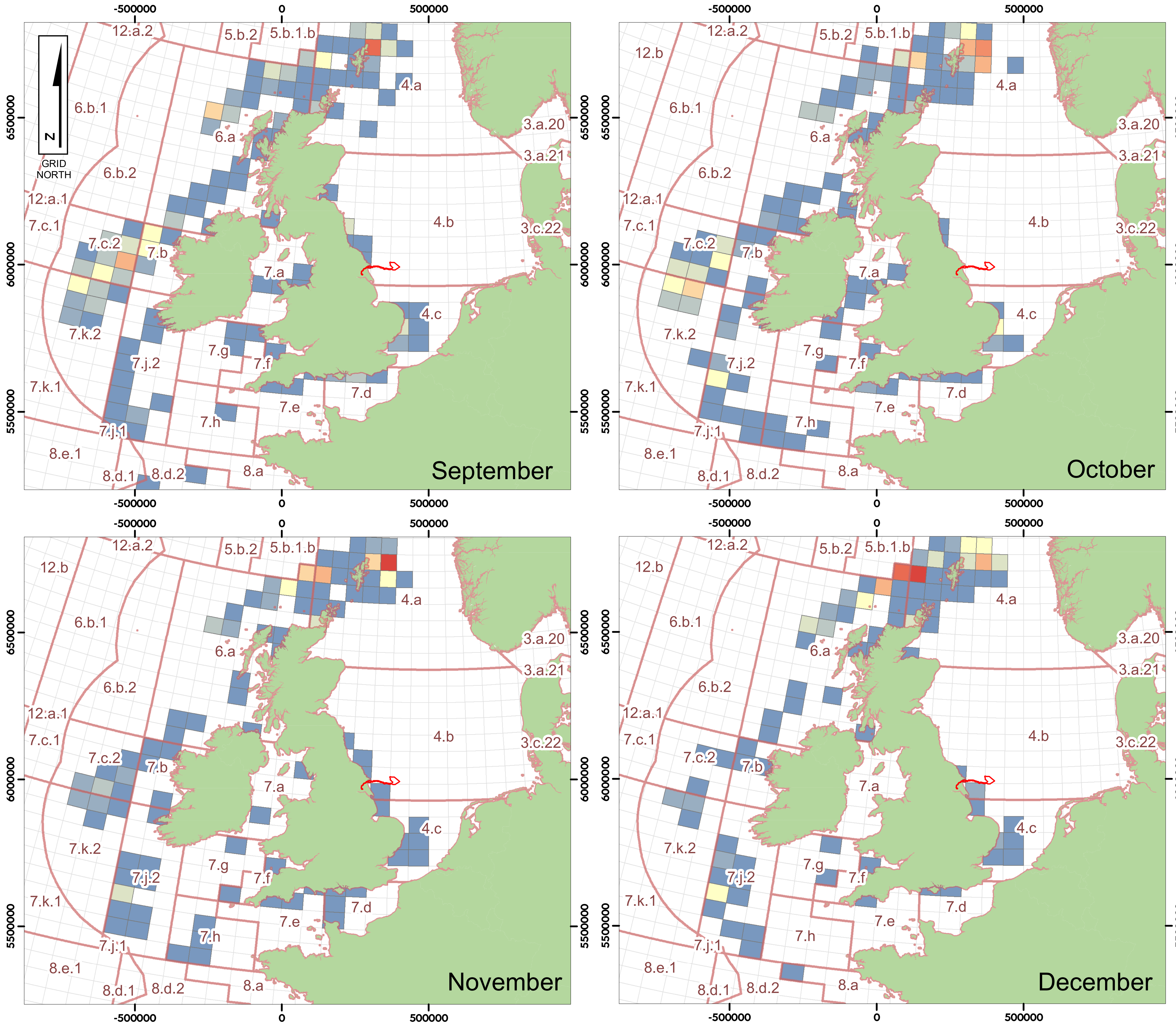
Figure 20
Gannet Longline Bycatch Risk



- Order Limits
- ICES Areas

ICES Statistical Rectangles:

Gannet Longline Bycatch Risk:

- 1
- 2 - 25
- 26 - 50
- 51 - 75
- 76 - 100
- 101 - 150
- 151 - 200
- 201 - 400
- 401 - 600
- 601 - 800
- 801 - 1050

Coordinate system: WGS 1984 UTM Zone 31N
Scale@A3: 1:12,000,000

0 240 480 Kilometres

0 120 240 Nautical Miles

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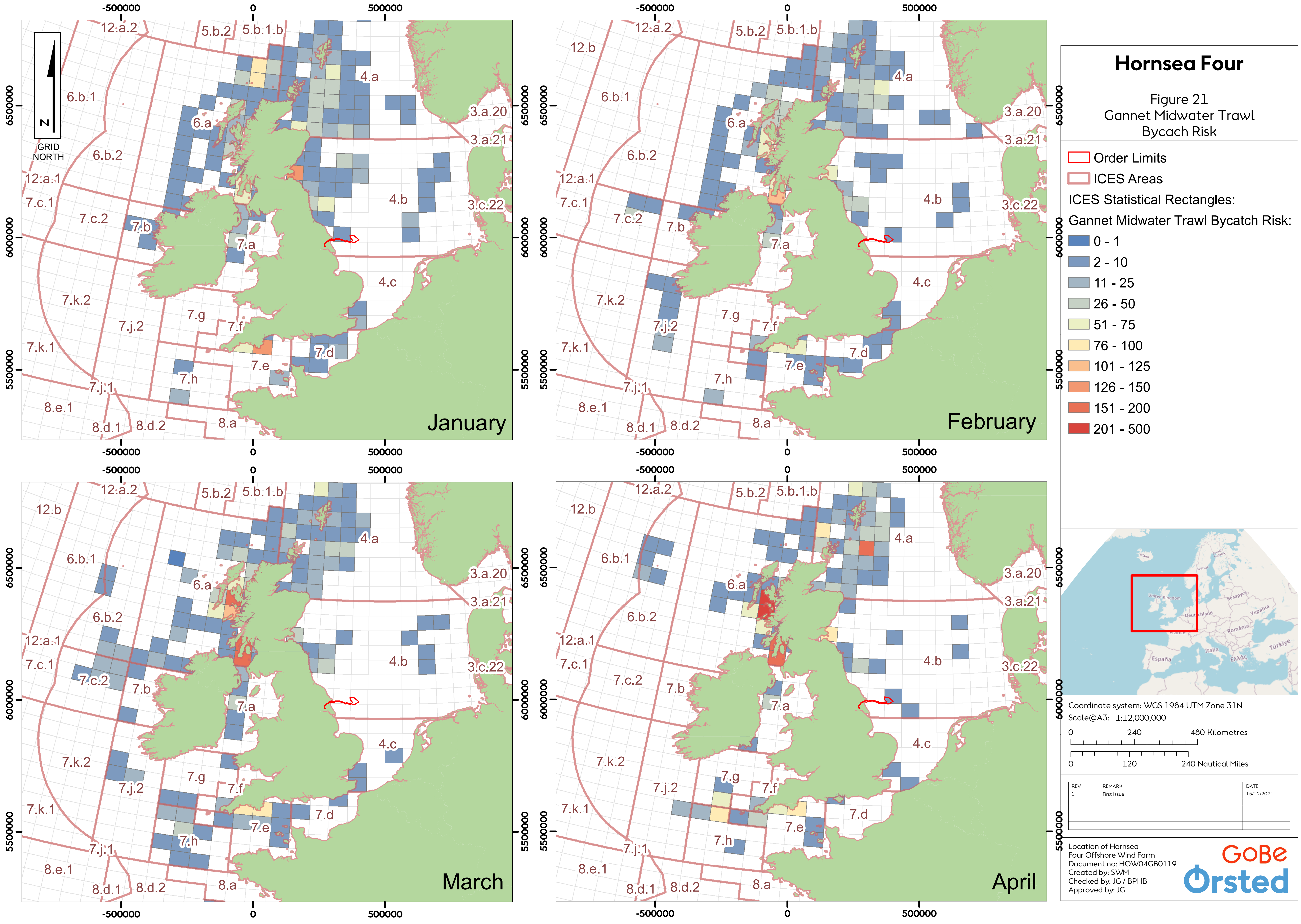
Hornsea Four
Figure 21
Gannet Midwater Trawl
Bycach Risk
Order Limits
ICES Areas
ICES Statistical Rectangles:
Gannet Midwater Trawl Bycatch Risk:
0 - 1
2 - 10
11 - 25
26 - 50
51 - 75
76 - 100
101 - 125
126 - 150
151 - 200
201 - 500
January
February
March
April
Coordinate system: WGS 1984 UTM Zone 31N
Scale@A3: 1:12,000,000
0
240
480 Kilometres
0
120
240 Nautical Miles
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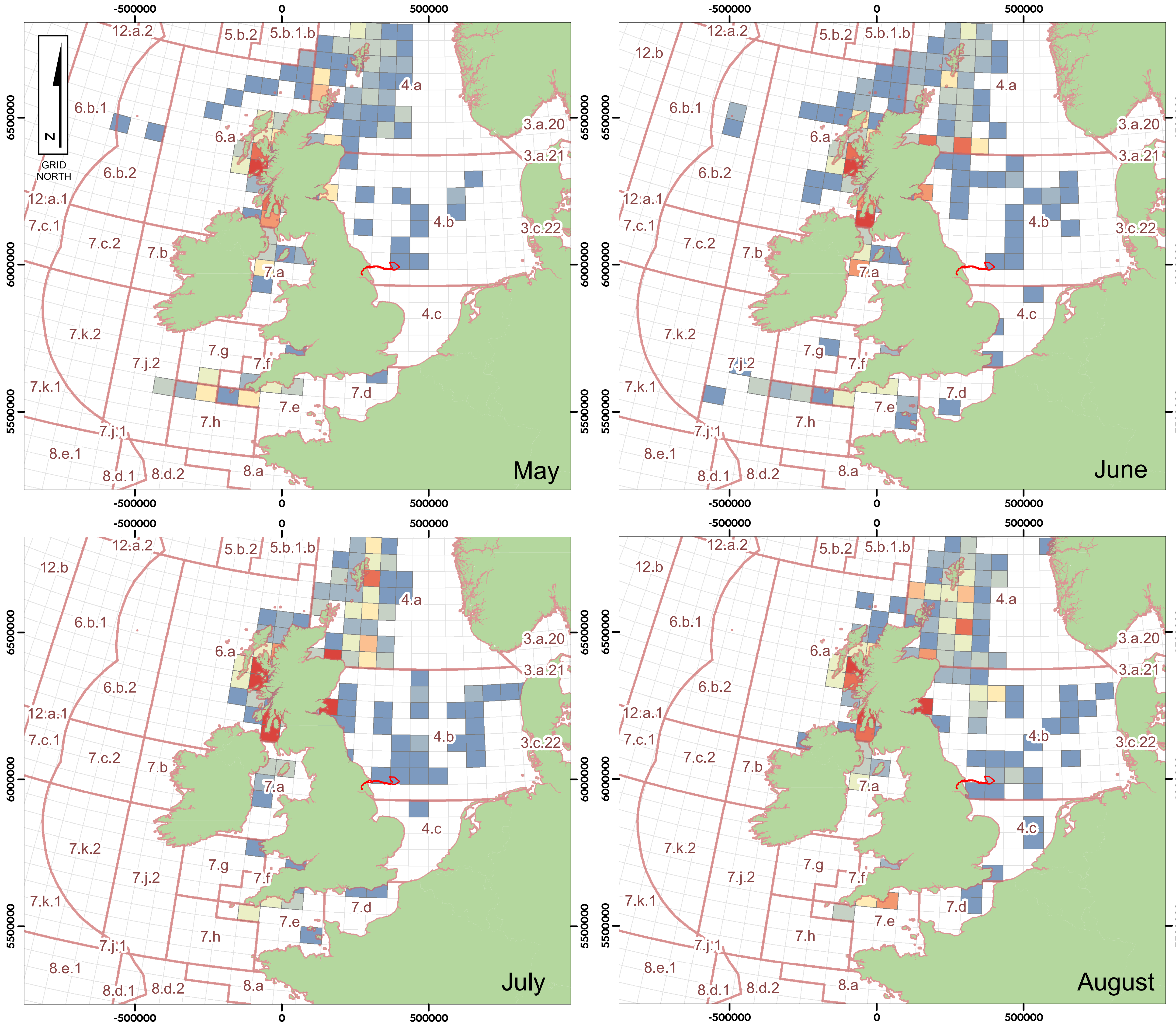

Hornsea Four

Figure 22
Gannet Midwater Trawl
Fishing Effort

Order Limits
ICES Areas

ICES Statistical Rectangles:

Gannet Midwater Trawl Bycatch Risk:

- 0 - 1
- 2 - 10
- 11 - 25
- 26 - 50
- 51 - 75
- 76 - 100
- 101 - 125
- 126 - 150
- 151 - 200
- 201 - 500

Coordinate system: WGS 1984 UTM Zone 31N
Scale@A3: 1:12,000,000

0 240 480 Kilometres

0 120 240 Nautical Miles

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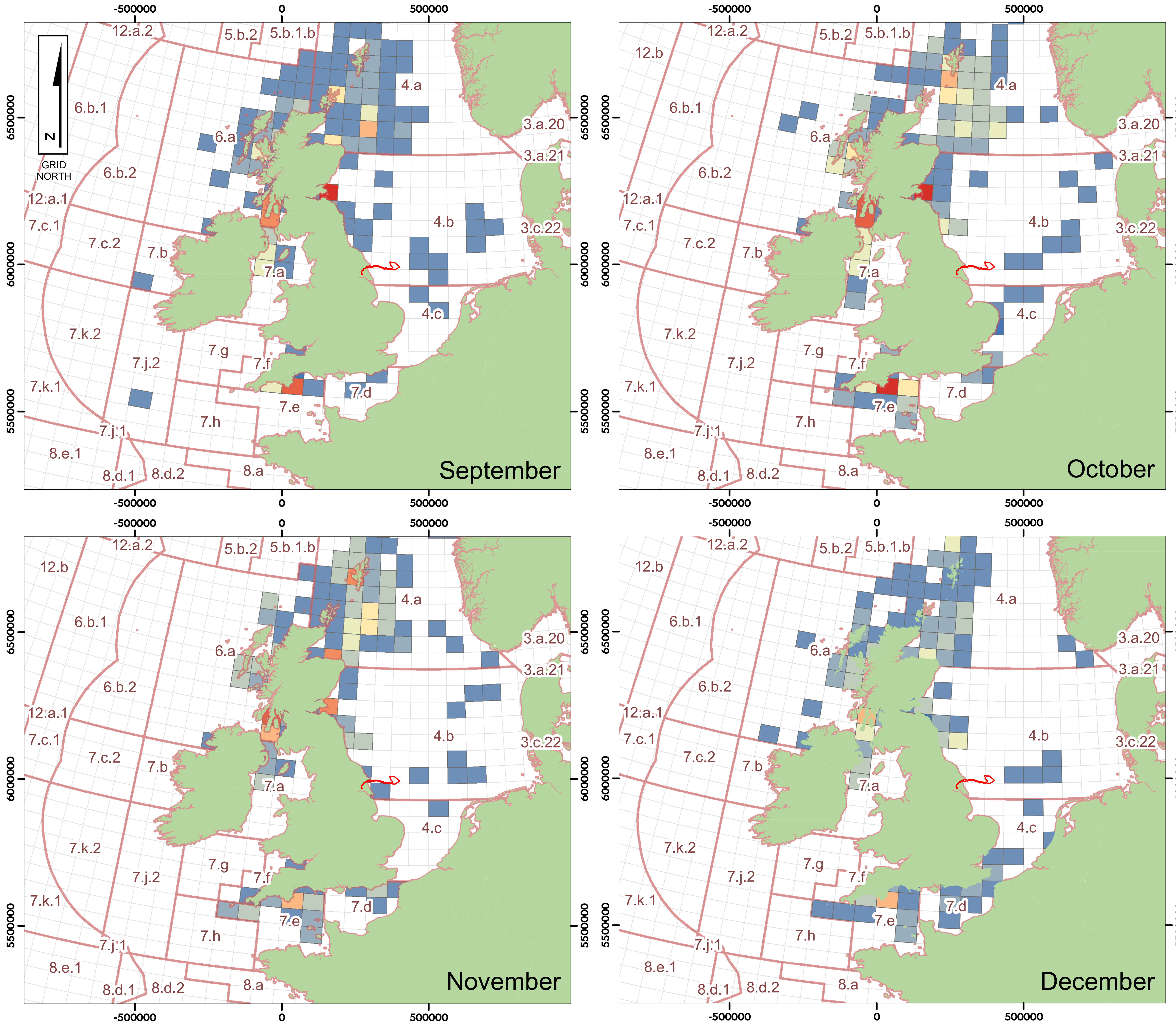

Hornsea Four

Figure 23
Gannet Midwater Trawl Bycatch Risk

Order Limits
ICES Areas
ICES Statistical Rectangles
Gannet Midwater Trawl Bycatch Risk:
- 0 - 1
- 2 - 25
- 26 - 50
- 51 - 75
- 76 - 100
- 101 - 125
- 126 - 150
- 151 - 200
- 201 - 250
- 251 - 500

Coordinate system: WGS 1984 UTM Zone 31N
Scale@A3: 1:12,000,000
0 240 480 Kilometres
0 120 240 Nautical Miles

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7.5 Discussion

7.5.1.1 By taking into consideration seabird distribution density combined with UK fishing effort, estimates for highest bycatch risk zones were created. For both longline and midwater trawlers, risk zones from UK fishing fleet were within Scottish waters, further offshore in longline fisheries and around the breeding colonies for midwater trawlers.

7.5.1.2 As identified in the bycatch risk mapping, bycatch risk was identified to be highest in the UK during the breeding season. However, this related solely to UK fleet in UK waters. Therefore, there is potential for bycatch risk elsewhere during other periods from non-UK vessels (see **Section 6.2**). For example, post-breeding migrations through longline fishing grounds in the Gran Sol fishery.

8 Bycatch Reduction Techniques Review

8.1 Introduction

8.1.1.1 This section provides an overview of the evidence base of potential bycatch reduction methods that may be used for gannet in longline and midwater trawl fisheries. The review has tackled several key components, as follows:

- Key criteria for successful bycatch reduction;
- Identification of potential seabird bycatch reduction methods for longlines and midwater trawlers;
- Overview of the potential for the long-listed methods to be successful at reducing gannet bycatch; and
- Short-list of methods most suitable to use for reducing gannet bycatch.

8.1.1.2 Accompanying documents (**Appendix B** and **Appendix C**) contain:

- Quantification of success for each bycatch reduction method, including examples of previous trials and experiments and their impacts on bycatch and target catch rates.

8.2 Success of Bycatch Reduction Techniques

8.2.1 Outline of key success criteria

8.2.1.1 To design an effective bycatch reduction program, it is necessary to understand the life history of target and non-target species, their interactions with fish and fishing gear, the effects of spatial and temporal shifts in fishing effort, the socio-economic impacts to the fishery and the incentives of fishery participants (O'Keefe *et al.*, 2012).

8.2.1.2 Therefore, in order for any bycatch reduction technique to be deemed successful it is necessary to fulfil at least the following set of criteria (O'Keefe *et al.*, 2012):

- Reduce identified bycatch or discards;
- Does not negatively affect target catch rate;
- Does not increase the bycatch of other vulnerable species;
- Does not lead to spatial or temporal displacement of bycatch;
- Does not negatively impact the ecosystem; and
- Is economically viable for a fishery.

8.2.2 Previous successful bycatch reduction scheme

8.2.2.1 For bycatch reduction to be successful, uptake by the fishing industry is important. The Applicant is confident in the compliance of fisheries using the suggested bycatch reduction technique due to a positive response of fishers to take part in the bycatch reduction scheme (~80% of fishers who responded to the questionnaire expressed interest to take part in future pilot studies (see **Section 8** in **B2.8.1 Compensation measures for FFC SPA: Bycatch Reduction: Ecological Evidence**). Moreover, the Applicant has 10 vessels currently participating in the bycatch reduction selection phase, testing the effectiveness of bycatch reduction techniques on guillemot and razorbill. In addition to this, previous bycatch reduction schemes have resulted in fishers using bycatch reduction techniques (without forced implementation). Below is a case study on a previous seabird bycatch reduction technique.

8.2.2.2 In Namibia, the hake fishery is the most important fishery for the country. Previously, the majority of hake were caught by trawl, however in 1991 demersal longlining began. Namibia, historically, had the highest levels of seabird bycatch globally and in 2010 an estimated 20,567 birds were killed in the hake demersal longline fishery alone. Over four years, BirdLife International's Albatross Task Force worked alongside the Namibian Nature Foundation to monitor numbers of birds being killed and to test potential bycatch reduction strategies (Da Rocha *et al.*, 2021).

8.2.2.3 The use of bird-scaring lines reduced bycatch from 0.57 birds/1000 hooks to 0.04 and no albatross were caught when using this bycatch reduction device (Da Rocha *et al.*, 2021). Prior to 2015, Namibian fishers started voluntarily using the bird-scaring lines on their boats. A total of 15% of the trawl fleet and 25% of the demersal longline vessels voluntarily took up the use of this technique (BirdLife International, 2014), prior to the introduction of regulations requiring their use in November 2015.

8.2.2.4 The use of bycatch reduction methods without regulations suggests that a percentage of fishers are willing to take part in reducing seabird bycatch, therefore there will more than likely be uptake of the Applicant's bycatch reduction technique in the UK fishing fleet.

8.3 Bycatch Reduction Technology Review

8.3.1 Introduction

8.3.1.1 There are currently a low number of studies that assess the impacts of bycatch reduction techniques specifically on gannet. A long-list of potential bycatch reduction techniques for gannet in longline and midwater trawl fisheries has therefore been compiled to identify any suitable bycatch reduction techniques. Gannets are plunge diving species alongside boobies, some pelicans, tropicbirds, terns and some shearwaters and petrels (American Bird Conservancy, 2016) and therefore trials on these species may be used as an indication of the behaviour that may be exhibited by gannet. Moreover, specific gannet foraging behaviour can be used to identify whether a technique would be successful (e.g., gannet dive to a depth of 20 m, therefore a technique that excludes bycatch up to 20 m would be successful for gannet).

8.3.2 Longline

8.3.2.1 In general, long-line bycatch reduction technologies use one or more of five methods to mitigate the incidental mortality of seabirds (Parker, 2017):

- 1) Reduction in the window of time seabirds can access baited hooks;

- 2) Scare birds away from risk areas when lines are set or hauled;
- 3) Reduce attraction for seabirds to the risk area;
- 4) Make baits 'cryptic' so seabirds cannot see the bait (and therefore not take it); and
- 5) Apply spatial or temporal restrictions to fishing areas.

Long-list

8.3.2.2 **Table 3** presents a long-list of potential longline fisheries bycatch reduction methods for seabirds discussed in Parker (2017), and other potential technologies identified through a literature search.

Table 3: Potential bycatch reduction methods in longline fisheries.

Thematic Category	Bycatch Reduction Ideas
Sinking Rate	Weighted lines
	Sliding leads
	Bait thaw status
	Hooking position
	Side-setting
Hauling Rate	Branchline hauler
Deterrent	Bird scaring lines
	Fish oil deterrents
	Water cannons
Stealth Gear	Hook shielding
	Dyed bait
	Underwater bait setter
Offal Management	Discard ban
Operational fishing measures	Fisheries closures (area/ seasonal)
	Gear-switching/ restrictions

8.3.2.3 A literature review of the long-listed bycatch reduction measures (**Table 3**) was carried out to identify the effectiveness of the techniques on reducing gannet bycatch. However, it must be noted that not all methods have been tested on gannet, therefore this report collates all available information to best inform potential bycatch reduction solutions by using similarities in foraging behaviour to draw comparisons where appropriate. No operational fishing measures were evaluated due to the potential for these methods to negatively impact target catch. No bycatch reduction technique will be short-listed that has negative impacts on fisheries.

8.3.2.4 **Table 4** evaluates the success of each bycatch reduction study from **Table 3** using the criteria stated in **Section 8.2.1** (O'Keefe *et al.*, 2012) (noting not all columns have been able to be assessed for each case study as not each column was assessed within the studies). A tick was given if the criteria was met and a cross if not (only if addressed within the study). A dash has been used when not incorporated within the study or no evidence was found. See **Appendix B** for a more in-depth evaluation of each bycatch reduction method.

Table 4: Evaluation of bycatch reduction technique studies conducted on longlines. Evaluation criteria include Reduced Bycatch (bycatch of the study-specific species was reduced), No Effect on Target Catch (catch of fisheries target species was not reduced or negatively affected), No Effect on Other Non-Target (bycatch did not increase on other species), No Effort Impacts (no negative impacts resulting from a spatial or temporal shift in fishing effort). ✓ = evaluation criteria met, X = evaluation criteria not met and - = evaluation criteria not assessed in the study, or no results found.

BYCATCH REDUCTION PROGRAM	Study target bycatch	Reduced Bycatch	No Effect on Target Catch	No Effect on Non-Target	No Effort Impacts
Increasing Sink Rate					
Weighted Lines					
Melvin *et al.*, 2011a	White-chinned petrels, yellow-nosed and black-browed albatrosses, and cape gannet	✓	✓ Weighting long-line branchlines did not affect the catch rates of target fish (Gianuca *et al.*, 2013; Parker, 2017)	✓ Weighting long-line branchlines did not affect the catch rates of non-target catch (Parker, 2017)	-
Jiménez *et al.*, 2013; Robertson *et al.*, 2013	Mixture of seabird species, specific species not mentioned	✓			-
Sliding Leads					
N.A. – studies testing safety but not effectiveness against bycatch	-	-	-	-	-
LumoLeads (FishTek Marine Ltd); Claudino dos Santos *et al.* 2016	Black browed albatross, white chinned petrels, and great shearwaters	✓	✓ There was no difference in the catch rates of target species among treatments	✓ Studies to date have not shown an increase in the bycatch of other taxa (Parker, 2017)	-
Bait Thaw Status					
Klaer and Polacheck, 1998	Mixture of seabird species, specific species not mentioned	✓	-	-	-
Brothers *et al.*, 1995; Robertson *et al.*, 2010 – studies testing	-	**X** (conflicting results on sink rate)	-	-	-

BYCATCH REDUCTION PROGRAM	Study target bycatch	Reduced Bycatch	No Effect on Target Catch	No Effect on Non-Target	No Effort Impacts
sink rate but not bycatch					
Side-setting					
Gilman *et al.*, 2007; Gilman *et al.*, 2016	Laysan and black-footed albatross	✓ Combined with bird curtain	-	-	-
Increasing Haul Rate					
Branchline Hauler					
-	-	-	-	-	-
Deterrents					
Bird scaring lines					
Melvin *et al.*, 2014	Albatross and petrels	✓	May increase target catch rates as they reduce seabird attacks on baits (reducing bait loss during setting) (Lokkeborg 2011)	Seabird mortality from entanglement with bird scaring lines has been recorded – rare event (Parker, 2017)	
Løkkeborg and Robertson, 2002;	Northern fulmars	✓			-
Domingo *et al.* 2011	Mixture of seabird species, specific species not mentioned	✓			
Fish oil deterrents					
Pierre and Norden, 2006	Flesh-footed shearwaters, Buller's shearwaters, and black petrels	✓	No evidence was found in the small number of studies indicating impacts on catch rates (Parker, 2017)	No evidence was found in the small number of studies indicating an impact on other taxa. However, the use of shark oil could potentially encourage sharks to be targeted purely for oil extraction (Parker, 2017)	-
Water cannons					
Kiyota *et al.* 2001	Mixture of seabird species, specific species not mentioned	✓ however, impacted by strong winds (less effective)	-	-	-

BYCATCH REDUCTION PROGRAM	Study target bycatch	Reduced Bycatch	No Effect on Target Catch	No Effect on Non-Target	No Effort Impacts
Stealth Gear					
Hook Shielding					
Hookpod (FishTek Marine Ltd); Barrington 2016a; Sullivan *et al.*, 2017	Albatross and petrels	✓	✓ No reduction in catch rates identified (Parker, 2017)	✓ No evidence of effects on catch rates of non-target taxa (Parker, 2017)	-
Smart Tuna Hook; Baker and Candy, 2014; Barrington *et al.*, 2016b	Mixture of seabird species, specific species not mentioned	✓			-
Underwater bait setter					
Robertson *et al.* 2015; Robertson *pers. Comm.* In Parker, 2017	Albatrosses and petrels	✓	✓ No reduction in catch rates identified (Parker, 2017)	✓ No evidence of effects on catch rates of non-target taxa (Parker, 2017)	-
Dyed bait					
Boggs, 2001;	Black-footed and Laysan albatrosses	✓	Broader research needs to be conducted to ensure that blue-dyed bait does not reduce catch rates (Parker, 2017)	✓ No evidence of effects on catch rates of non-target taxa (Parker, 2017)	-
Cocking *et al.* 2008	Mixture of seabird species – majority wedge-tailed shearwaters (and other procellariform seabirds	✓ (with squid but not with fish)			
Offal Management					
Discard Ban					
Clark *et al.*, 2020	Gannet	✓ (no gannet increasing foraging at fishing vessels)	-	-	-

Short-list

8.3.2.5 A short-list of potential methods for reducing gannet bycatch in longline fisheries has been produced in **Table 5**.. From an initial assessment, the Hookpod (hook shielding device) has been identified as the technique with the highest potential to reduce gannet bycatch, due to removing the baited hook from being available to gannet during setting (until a depth greater than gannet can dive).

Table 5: Short-listed bycatch reduction methods in longline fisheries.

Short-list	Explanation
Lumo Leads (weighted line)	The Lumo lead has been developed by FishTek Marine and reduced seabird bycatch by adding weight to the baited hooks, thereby reducing the time available for birds to access baited hooks (Parker, 2017). Lumo leads are safer to use than general line weighting as they reduce the occurrence of flybacks (when a weight flies back toward the vessel because of line breakages, therefore endangering crew members onboard). Trials have identified Lumo leads to have an increased sink rate as well as being successful at reducing seabird bycatch (Pierre *et al*. 2015; Claudino dos Santos *et al*. 2016 respectively). The trials did not evaluate bycatch rates for gannet, instead focused on albatross, petrels, and shearwaters. Nevertheless, as the gear increases the sink rate of the baited hook, the baited hook will surpass 20m quicker (maximum foraging depth for gannet). The opportunity for gannet to come into contact with the baited hook is decreased, therefore reducing potential for bycatch.
Side setting with bird scaring lines	Side-setting is the process of deploying baited hooks from the side of the vessel instead of the stern of the vessel (traditional deployment). This technique aims to reduce seabird interactions with baited hooks as seabirds tend to forage behind vessels, avoiding foraging at the sides. By the time hooks have reached the stern of the vessel due to drag, they will be below the reach of diving seabirds, therefore reducing the potential for bycatch (Parker, 2017; CleanCatchUK, 2021). Moreover, as the baited hooks would not be deployed into the propeller wash (which may slow the sink rate of baited hooks), this rate would be increased (CleanCatchUK, 2021). Bird-scaring lines deter birds from entering the area where baited hooks are sinking, effectively acting as a 'protective curtain' (visual and physical barrier) (Parker, 2017; AFMA 2015). As birds are visual foragers, the brightly coloured objects distract birds and reduce interaction with hooks. Combing both techniques together have been trialled in various studies (Gilman et al., 2007; Gilman *et al.,* 2016). Using both techniques together have demonstrated significant reductions in bycatch and therefore has high potential to reduce gannet bycatch in UK longline fisheries. The trials did not evaluate bycatch rates for gannet, instead focused on albatross, (Laysan and black-footed). Nevertheless, the technique reduces the number of gannet in the vicinity of the baited hook whilst it is at/ near the surface. The opportunity for gannet to come into contact with the baited hook is decreased, therefore reducing potential for bycatch.
Hook shielding	Hook shielding acts as a bycatch reduction technique through guarding the barb of the hook. The hook is therefore not accessible to seabirds therefore the bird cannot be bycaught. The shield around the hook automatically retracts at a set depth when it is deeper than the diving depth of the seabird (20 m for gannet).

Short-list	Explanation
	There are currently two highly developed technologies which use hook shielding: (1) Smart Tuna Hook; and (2) Hookpod. ACAP Seabird Bycatch Working Group (SBWG) recommend the 'Hookpod' as a stand-alone best practice seabird bycatch reduction device in surface long-line fisheries, indicating that the Hookpod has achieved the six ACAP Seabird Bycatch Mitigation (reduction) Criteria (Parker, 2017). The trials did not evaluate bycatch rates for gannet, instead focused on albatross and petrels. Nevertheless, there is high potential for this technique to work for gannet when assessing the ecological diving behaviour of gannet. For example, when using the Hookpod, the depth that the pod opens can be set to 20 m, therefore out of range for diving gannet to be bycaught on the baited hooks (as gannet dive to a depth of 20 m, see Section 2.3).

8.3.3 Midwater Trawl

8.3.3.1 In general trawl bycatch reduction technologies use one or more of three methods to mitigate the incidental mortality of seabirds (Parker, 2017):

- 1) Scare birds away from risk areas where they are vulnerable to bycatch/ warp strike;
- 2) Reduce time net is at the surface; and
- 3) Reduce attraction for seabirds to the area.

Long-list

8.3.3.2 Table 6 presents a long-list of potential midwater trawl fisheries bycatch reduction methods for seabirds discussed in Parker (2017), and other potential technologies identified through a literature search.

Table 6: Potential bycatch reduction methods in midwater trawl fisheries.

Thematic Category	Bycatch Reduction Ideas
Deterrent	Bafflers
	Warp Scarers
	Tori-lines
	Cones
Reduce Net Time at Surface	Net Restrictor
	Net Binding
	Net Weighting
Offal Management	Discard Ban
	Net Cleaning
Operational Fishing Measures	Fisheries closures (area/ seasonal)
	Gear-switching/ restrictions

8.3.3.3 A literature review of the long-listed bycatch reduction measures (Table 6) was carried out to identify the effectiveness of the techniques on reducing gannet bycatch. However, it must be noted that not all methods have been tested on gannet, therefore this report collates all available information to best inform potential bycatch reduction solutions. No operational fishing measures were evaluated due to the potential for these methods to negatively impact target catch. No bycatch reduction technique will be short-listed that has negative impacts on fisheries.

8.3.3.4 **Table 7** evaluates the success of each bycatch reduction study from **Table 6** using the criteria stated in **Section 8.2.1** (O'Keefe *et al.*, 2012) (noting not all columns have been able to be assessed for each case study as not each column was assessed within the studies). A tick was given if the criteria was met and a cross if not (only if addressed within the study). A dash has been used when not incorporated within the study or no evidence was found. See **Appendix C** for a more in-depth evaluation of each bycatch reduction method.

Table 7: Evaluation of bycatch reduction technique studies conducted on midwater trawl fisheries. Evaluation criteria include Reduced Bycatch (bycatch of the study-specific species was reduced), No Effect on Target Catch (catch of fisheries target species was not reduced or negatively affected), No Effect on Other Non-Target (bycatch did not increase on other species), No Effort Impacts (no negative impacts resulting from a spatial or temporal shift in fishing effort). ✓ = evaluation criteria met, X = evaluation criteria not met and - = evaluation criteria not assessed in the study, or no results found.

BYCATCH REDUCTION PROGRAM	Study target bycatch	Cause of mortality	Reduced Mortality	No Effect on Target Catch	No Effect on Non-Target	No Effort Impacts
Deterrents						
Bafflers						
Sullivan *et al.*, 2006; Middleton and Abraham, 2007	Large bird species: Albatross and giant petrels	Warp Strike	✓ (less effective than warp scarers and tori-lines)	No effect of bafflers on target catch has been identified (Parker, 2017)	No effect of bafflers on non-target catch has been identified (Parker, 2017)	-
Bull, 2007	Mixture of seabird species, specific species not mentioned	Warp Strike	**X**			-
Middleton and Abraham, 2007	Small bird species	Warp Strike	X Not statistically significant			-
Warp Scarers						
Sullivan *et al.*, 2006; Middleton and Abraham, 2007	Large bird species: Albatross and giant petrels	Warp Strike	✓	No effect of warp-scarers on target catch has	No effect of warp-scarers on non-target catch has been	-

BYCATCH REDUCTION PROGRAM	Study target bycatch	Cause of mortality	Reduced Mortality	No Effect on Target Catch	No Effect on Non-Target	No Effort Impacts
Middleton and Abraham, 2007	Small bird species	Warp Strike	✓ 'Marginally significant'	been identified (Parker, 2017)	identified (Parker, 2017)	-
Pierre *et al.*, 2014	Mixture of seabird species, specific species not mentioned	Warp Strike	X			-
Tori-Lines						
Sullivan *et al.*, 2006; Middleton and Abraham, 2007; Maree *et al.*, 2014	Large bird species: Albatross and giant petrels	Warp Strike	✓	No effect of tori-lines on target catch has been identified (Parker, 2017)	Seabird mortality from entanglement with bird scaring lines has been recorded – rare event (Parker, 2017)	-
Middleton and Abraham, 2007	Small bird species	Warp Strike	✓			-
Melvin *et al.*, 2011b	Mixture of seabird species, specific species not mentioned	Warp Strike	✓			-
Cones						
Gonzalez-Zevallos *et al.*, 2007	Mixture of seabird species, mostly the Kelp gull and the Black-browed albatross	Warp Strike	✓	No effect of cones on target catch has been identified (Parker, 2017)	No effect of cones on non-target catch has been identified (Parker, 2017)	-
Reduce net time at surface						
Net Restrictor						
- Further evidence required (Parker, 2017)	-	Net Entanglement	-	-	-	-

BYCATCH REDUCTION PROGRAM	**Study target bycatch**	**Cause of mortality**	**Reduced Mortality**	**No Effect on Target Catch**	**No Effect on Non-Target**	**No Effort Impacts**
Net Binding						
Sullivan *et al* 2010 in ACAP 2016	Mixture of seabird species, specific species not mentioned	Net Entanglement	✓	-	✓ No effect of net-binding on non-target catch has been reported (Parker, 2017)	-
Cleal *et al.,* 2009	Mixture of seabird species, specific species not mentioned	Net Entanglement	-	X binding did not always break, so could not catch fish		-
Net Weighting						
Hooper *et al.* 2003;	Mixture of seabird species, specific species not mentioned	Net Entanglement	- Increases sinking rate but no testing of changes to bycatch	✓ No effect of net-weighting on target catch has been reported (Parker, 2017)	✓ No effect of net-weighting on non-target catch has been reported (Parker, 2017)	-
Offal Management						
Discard Ban						
Clark *et al.,* 2020	Gannet	Net Entanglement and Warp Strike	✓ (no gannet increasing foraging at fishing vessels)	-	-	-
Net Cleaning						
Hooper *et al.* 2003 – anecdotal, not formally tested	Mixture of seabird species, specific species not mentioned	Net Entanglement	✓(Anecdotal from sightings)	✓ No effect of net cleaning on target catch has been reported (Parker, 2017)	✓ No effect of net cleaning on non-target catch has been reported (Parker, 2017)	X Potential for lost fishing opportunities due to time spent cleaning the net (Parker, 2017)

Short-list

8.3.3.5 A short-list of potential methods for reducing gannet bycatch in midwater trawl fisheries has been produced in **Table 8**. There is limited evidence on the techniques which may reduce gannet bycatch in net entanglement. Net entanglement has been identified by Danish fishers as a bycatch risk for gannet. However, with the current available evidence, no net entanglement bycatch reduction techniques have been short-listed.

Table 8: Short-listed bycatch reduction methods in midwater trawl fisheries.

Short-list	Explanation
Tori-lines	Tori-lines are designed to prevent birds from entering the area at the rear of the vessel where they are at risk of warp strike. Tori-lines are fixed to the stern and towed parallel to the outside of each warp cables, forming a protective curtain to stop birds entering the area they are at risk of warp strike (Parker, 2017). Testing of tori-lines in a variety of studies have identified tori-lines to be successful at reducing warp strike by greater than 73% (Sullivan *et al.* 2006; Melvin *et al*. 2011b; Maree *et al*. 2014). Moreover, Sullivan *et al.* (2006) identified tori-lines as performing better than bird other deterrents (bafflers or warp scarers). Tori-lines have been tested on a variety of different species (both large and small bird species; Middleton and Abraham, 2007), and has been identified as being successful at deterring all species evaluated. Although the specific species have not been mentioned in the study, it is likely that the results are transferable to gannet. As deterrents do not rely on foraging behaviours to be successful (e.g., diving depths), as long as birds are kept away from the warp cable then the number of warp strike deaths will be reduced.
Cones	The cone bycatch reduction device consists of a tapered cylindrical object that is attached to the warp cable at the warp-water interface (Parker, 2017). It is designed to deter birds, preventing birds from becoming entangled and drowned on warp cables. Trials have shown a significant reduction in warp-strike when using cones as a deterrent (89% reduction; Gonzalez-Zevallos *et al.* 2007). A variety of different bird species were successfully deterred by cones, however, gannet were not specifically stated. Nevertheless, it is likely that the results are transferable to gannet. As deterrents do not rely on foraging behaviours to be successful (e.g., diving depths), as long as birds are kept away from the warp cable then the number of warp strike deaths will be reduced.

8.4 Conclusions

8.4.1.1 There are some promising techniques available that have the potential to reduce gannet bycatch in longline and midwater trawl fisheries. The short-listed techniques are:

- Longline:
  - Lumo leads (increased sink rate);
  - Side-setting with bird scaring lines (deterrent); and
  - Hook shielding.
- Midwater trawl:
  - Tori-lines (deterrent); and

- Cones (deterrent).

8.4.1.2 Although these techniques have not been tested on gannet themselves, there is high potential for these techniques to work by understanding gannet behaviour. In particular, as gannet can forage up to a depth of 20m, it is important to ensure these techniques make baited hooks unavailable until the hook reached 20m. This can be achieved when using the Hookpod[14] (hook shielding) as the depth that the Hookpod opens can be set to 20m, therefore out of range for diving gannet.

8.4.1.3 Further fisheries consultations and discussions with the developers of the reduction technologies would be required prior to implementation. This has been discussed in **Section 10: Next Steps**. The most promising technique identified is the Hookpod (evidence shows reduction of seabird bycatch by 95% in longline fisheries), which therefore will be the focus within the next stages of the development of gannet bycatch reduction techniques as compensation.

9 Summary of Key Findings

9.1.1.1 This document has identified that gannet are highly vulnerable to bycatch in gears when they are on/ near the surface, including during deployment and hauling and hauling of nets (Bradbury *et al.,* 2017). In the UK, Northridge *et al.* (2020) estimated gannet bycatch to be within the hundreds per year (2016/2017):

- 220 (2016)/241 (2017) by longline fisheries;
- 22 (2016)/19 (2017) by <10 m static gillnet fisheries; and
- 36 (2016)/31 (2018) by >10 m static gillnet fisheries.

9.1.1.2 Additionally, Danish fishers contacted during fisheries consultation as part of the Project stated that they observe many gannet diving into trawl nets whilst they are being hauled[15]. Due to the small-scale coverage of the UK BMP (<5% midwater trawl effort), there is potential that the bycatch may have been missed. Midwater trawlers and longline fisheries were therefore identified as the most important fisheries regarding gannet bycatch.

9.1.1.3 Fishing effort for both longline and midwater trawl vessels identified the highest fishing effort within ICES rectangle Iva and Via, with 45% and 24% of the UK longline fishing effort and 33% and 37% of the UK midwater trawl fishing effort respectively. Both longline and midwater trawl effort is therefore concentrated in Scottish waters, therefore Scotland is most likely to the highest bycatch occurrences within the UK fishing fleet. Within England, highest effort is located on the south coast and southeast coast. Nevertheless, as foreign vessels also fish within UK waters, there is potential for fishing effort hotspots to also occur elsewhere. For example, the Gran Sol fishery has been identified (both within the literature and communications with bycatch experts) as a high risk of bycatch from longline fishing for seabirds including gannet.

9.1.1.4 Bycatch risk mapping identified the highest potential gannet bycatch in UK fisheries to be within Scottish waters for both longline and midwater trawl fisheries. For longline this was located offshore off the north coast of Scotland, whereas for midwater trawl fisheries the highest risk locations were near to the coast around the gannet colonies. Both longline and

[14] https://www.hookpod.com/en/
[15] Stated during a telephone conversation between Danish fishers and Orsted fishery liaisons. Waiting on written comments.

midwater trawl bycatch risk from UK fisheries was highest over the breeding season, most likely due to UK gannets migrating south for the non-breeding season.

9.1.1.5 Potential bycatch reduction techniques were identified for both longline and trawl fisheries with positive results from species with similar foraging ecology to gannet. Therefore, there is the potential for bycatch reduction techniques to greatly reduce the bycatch of gannet in UK-based fisheries. The short-listed techniques are:

- Longline:
  - Lumo leads (line weighting);
  - Side setting with bird scaring lines; and
  - Hook shielding (e.g., Hookpod/ Smart Tuna Hook)
- Midwater Trawl:
  - Tori-lines; and
  - Cones.

9.1.1.6 There is limited evidence on the techniques which may reduce gannet bycatch in net entanglement in midwater trawl fisheries. Net entanglement has been identified by Danish fishers as a bycatch risk for gannet. However, with the current available evidence, no net entanglement bycatch reduction techniques were short-listed.

9.1.1.7 Due to the evidence collated within this review, the Applicant will focus on longline bycatch reduction (due to midwater trawl bycatch reduction technique review not identifying a successful technique for net entangle, which was identified as the bycatch issue within the anecdotal evidence from Danish fishers). The most promising technique identified for longline bycatch reduction is the Hookpod (hook shielding), evidence shows reduction of seabird bycatch by 95% in longline fisheries. The Hookpod makes baited hooks unavailable until the hook reaches 20m (the depth that the Hookpod opens can be set to 20m), and is therefore out of range for diving gannet.

9.1.1.8 If required, the Applicant is confident of the deployment of a bycatch reduction technique due to the evidence presented in support of certain reduction technologies and as previous bycatch reduction techniques have been up taken by the fishing industry. Moreover, the Applicant is currently progressing a bycatch reduction selection phase for guillemot and razorbill in operational static net fisheries. Through this, the Applicant has created strong ties with the fishing industry as well as with FishTek Marine (the company who has also developed two of the short-listed technologies: Lumo leads and the Hookpod).

10 Next Steps

10.1.1.1 To continue to progress the bycatch reduction workstream for gannet (if deemed necessary by the Secretary of State), the Applicant will continue discussions on the level of gannet bycatch and potential reduction techniques within UK waters and within the migratory pathway of gannet (specifically in relation to longline bycatch). This will include, but is not limited to:

- Continuing conversations with bycatch experts (such as BirdLife International, the JNCC and other parties including academia) to identify fisheries with high gannet bycatch and potential mitigation solutions;
- Consulting with the National Federation of Fisherman's Organisations to identify bycatch risk areas and potential bycatch reduction delivery partners;

- Undertake fisher consultation with UK and foreign vessels using a questionnaire approach (noting the Applicant has translated the questionnaires to relevant language to increase accessibility); and
- Consider undertaking a bycatch technology selection phase in an active longline fishery or proceed to implementation should it be deemed necessary.

11 References

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Appendix A GIS Mapping

1 Methods

1.1.1.1 Monthly densities of gannet have been estimated at a 10 km resolution by Waggitt *et al.*, (2019). 2.68 million km of aerial and vessel survey data were collected from 1980 to 2018. The data was then collated and standardised to account for variations in survey techniques. Variations were first estimated using detection function models then adjustments were made to account for these. Biases that may cause variations have been summarised in **Table A 1**.

Table A 1: Biases derived from survey sampling (Waggitt *et al.*, 2019).

Bias	Description
Perception Bias	Undetected animals due to observer's visibility being compromised e.g., high sea state.
Availability Bias	Undetected animals due to animals being out of sight e.g., diving.
Response Bias	Animals' reaction to the presence of the platform. Can increase or decrease the likelihood of sightings depending on the animal's response e.g., disturbed by the platform (decrease) or approach the platform (increase).

1.1.1.2 Waggitt *et al.* (2019) modelled the sightings against environmental characteristics (annual temperature, annual temperature variance, depth, fronts, regional temperature, seabed roughness) as well as the proximity to land, proximity to the breeding colony and the point of the breeding cycle. Relationships between these factors were identified and used to estimate the seabird densities at monthly scales around the UK.

2 Results

2.1.1.1 Monthly distribution densities of gannet been mapped around the UK (**Figure A 1**; **Figure A 2**; **Figure A 3**). Overall, gannet distributions were highest at sea off the west coast of the UK, with highest concentrations of gannet within the North Sea through June to October (peaking in September).

2.1.1.2 Gannet distributions were highest around colonies from April to August, which represents the breeding season. The highest spread of gannet in UK waters occurs during September, during the beginning of their migration south.

3 References

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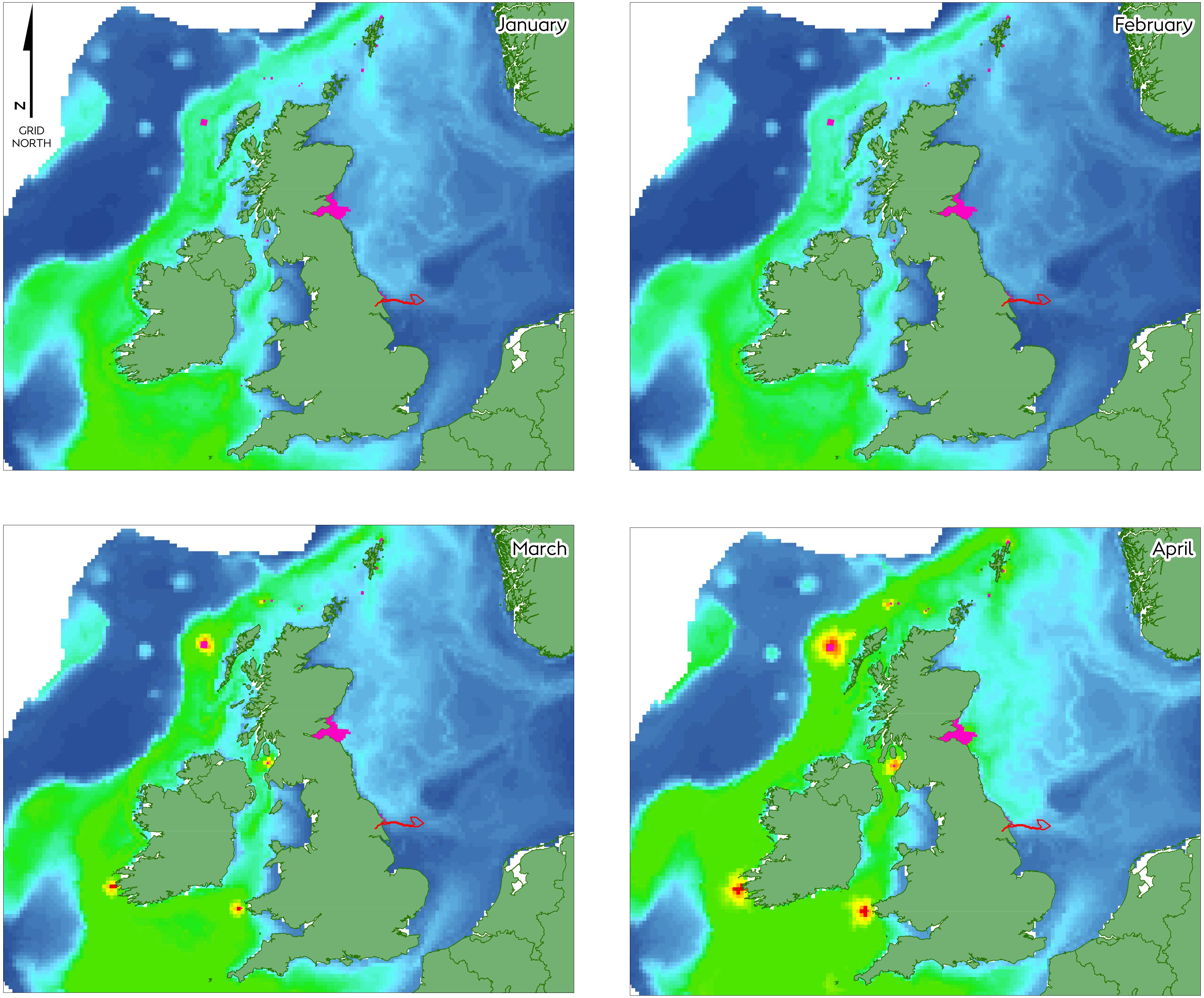


Hornsea Four

Figure A1
Waggitt et al., 2019
Gannet Densities (January-April)

Order Limits

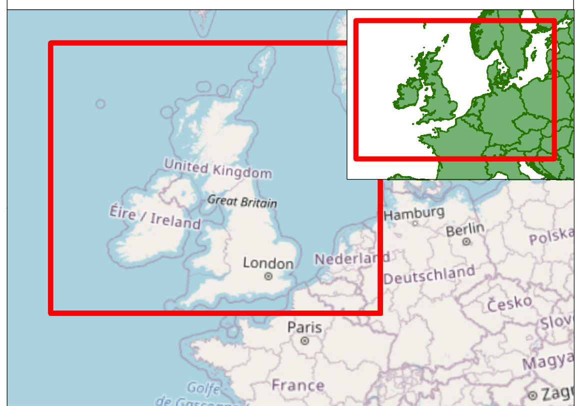
Gannet

High : 1.65

Low : 0

Special Protection Areas

Spatial variation in predicted densities (birds per km) of seabird species, per month, in the North-East Atlantic. Values are provided at 10km resolution (Waggitt et al 2019).



Coordinate system: ETRS 1989 UTM Zone 31N
Scale@A3: 1:10,000,000

0 80 160 320 Kilometres

0 80 160 Nautical Miles

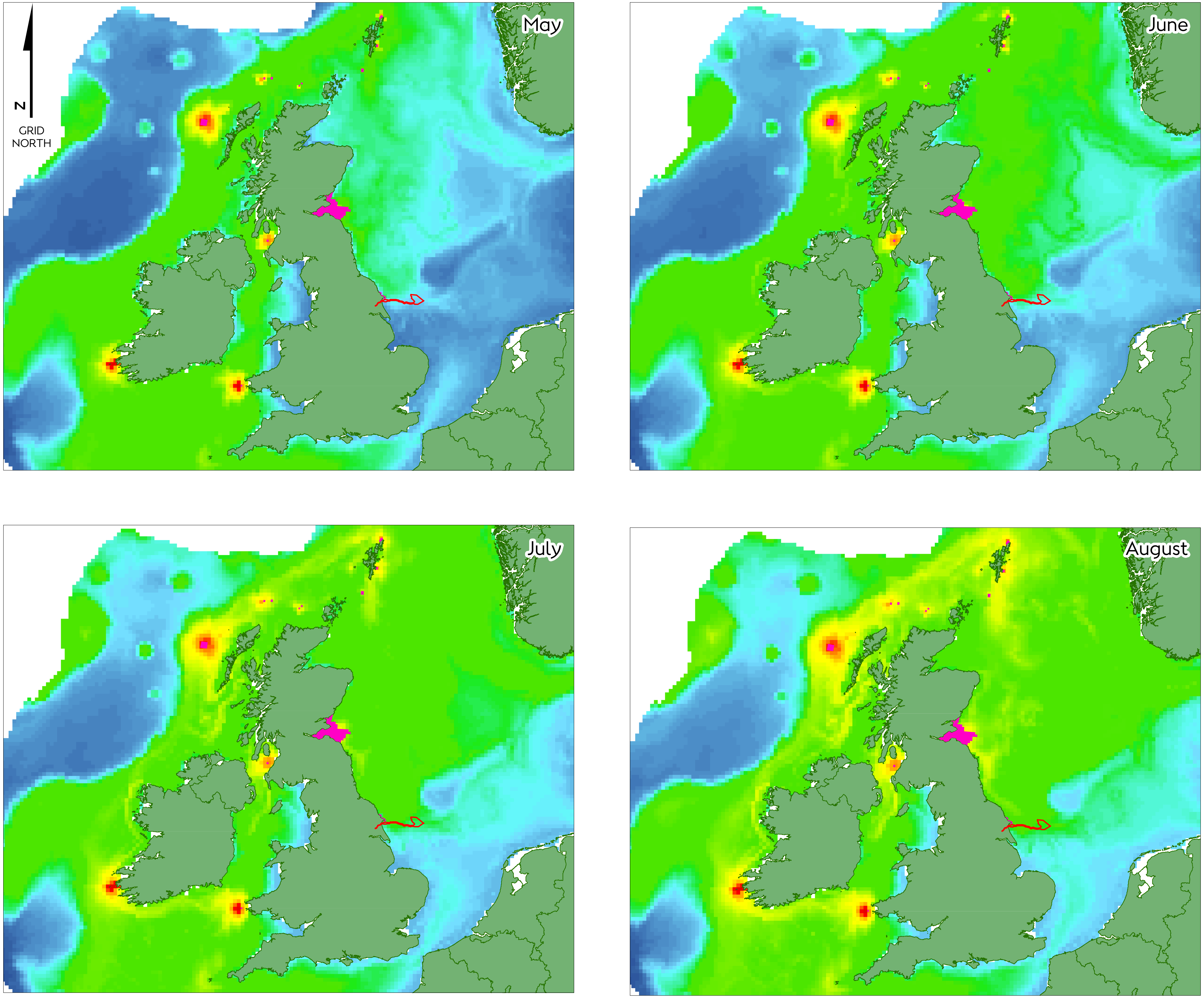
REV	REMARK	DATE
...	First Issue	16/11/2021

Waggitt et al., 2019
Gannet Densities
Document no: HOW04GB0025
Created by: BPHB
Checked by: FC
Approved by: NS

GoBe
Ørsted

Date: 23/11/2021

Author: scottmccune Name: HOW04GB0025_MERP_Gannet_Jan_April_v2



Hornsea Four

Figure A2
Waggitt et al., 2019
Gannet Densities (May-August)

Order Limits

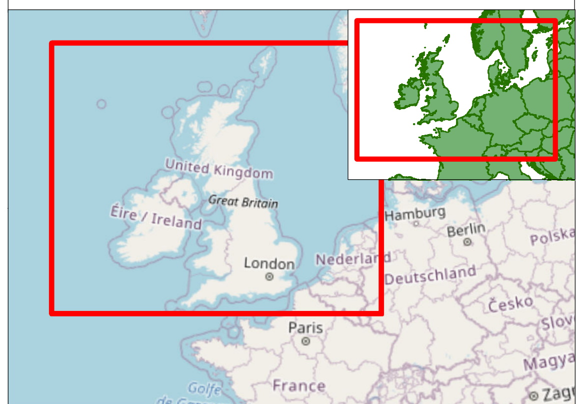
Gannet

High : 1.65

Low : 0

SPAs with Gannet Presence

Spatial variation in predicted densities (birds per km) of seabird species, per month, in the North-East Atlantic. Values are provided at 10km resolution (Waggitt et al 2019).



Coordinate system: ETRS 1989 UTM Zone 31N
Scale@A3: 1:10,000,000

0 80 160 320 Kilometres

0 80 160 Nautical Miles

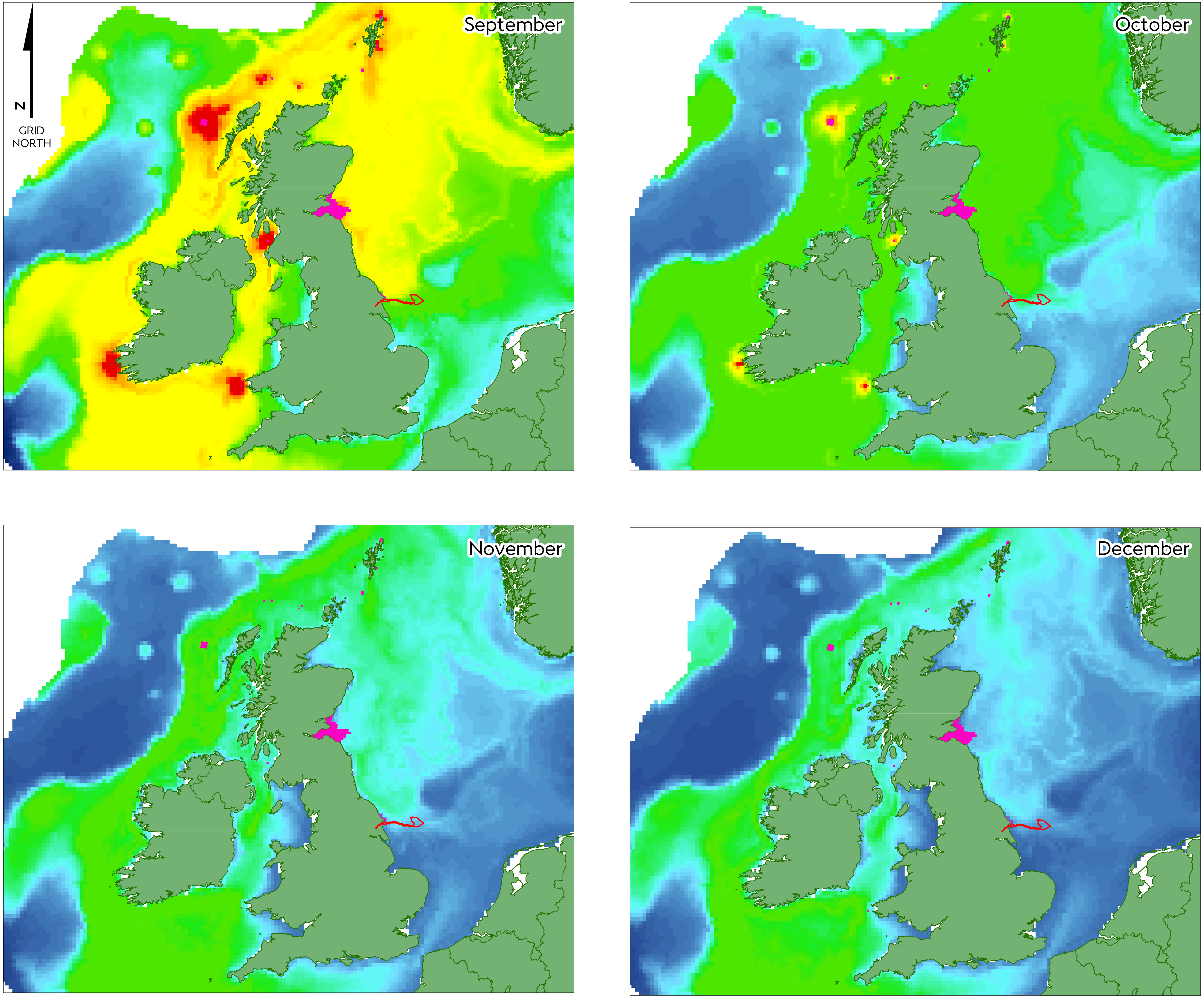
REV	REMARK	DATE
...	First Issue	16/11/2021

Waggitt et al., 2019
Gannet Densities
Document no: HOW04GB0026
Created by: BPHB
Checked by: FC
Approved by: NS

GoBe
Ørsted

Date: 23/11/2021

Author: scottmccune Name: HOW04GB0026_MERP_Gannet_May_August_v2



Hornsea Four

Figure A3
Waggitt et al., 2019
Gannet Densities (Sept-December)

Order Limits

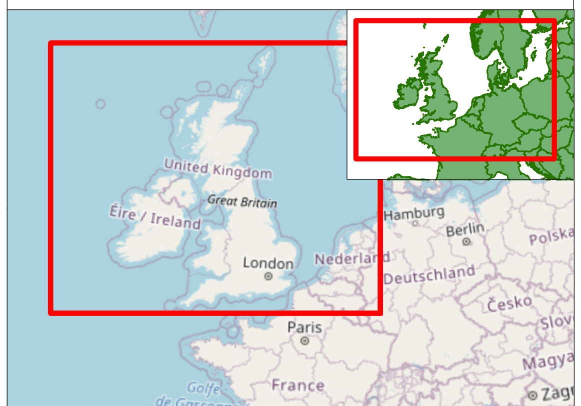
Gannet

High : 1.65

Low : 0

SPAs with Gannet Presence

Spatial variation in predicted densities (birds per km) of seabird species, per month, in the North-East Atlantic. Values are provided at 10km resolution (Waggitt et al 2019).



Coordinate system: ETRS 1989 UTM Zone 31N
Scale@A3: 1:10,000,000

0 80 160 320 Kilometres

0 80 160 Nautical Miles

REV	REMARK	DATE
...	First Issue	16/11/2021

Waggitt et al., 2019
Gannet Densities
Document no: HOW04GB0027
Created by: BPHB
Checked by: FC
Approved by: NS

GoBe
Ørsted

Date: 23/11/2021 Author: scottmccune Name: HOW04GB0027_MERP_Gannet_Sept_December_v2

Appendix B Gannet longline bycatch reduction review

1 Introduction

1.1.1.1 The Applicant has identified longline fisheries as a potentially major cause of gannet bycatch in the UK (see **G1.42 Compensation measures for FFC SPA: Gannet Bycatch Reduction: Ecological Evidence**). To successfully reduce bycatch numbers and act as compensation, a successful technique to reduce bycatch needs to be identified. Within the **Compensation measures for FFC SPA: Gannet Bycatch Reduction: Ecological Evidence (APP-194)** report (**Section 7.5**), an overview of the long-listed longline bycatch reduction techniques was listed, however, was not listed in depth to be concise. The purpose of this appendix is to explore the evidence base available for potential gannet bycatch reduction methods in the UK in detail (long-list - **Table B 1**). This document also quantifies the success of each method including examples of previous trials and experiments and their impacts on bycatch and target catch rates.

2 Long-list of bycatch reduction methods

2.1.1.1 **Table B 1** presents a long-list of potential long-line fisheries bycatch methods for seabirds discussed in Parker (2017), and other potential technologies identified through a literature search. No operational fishing measures were evaluated due to the potential for these methods to negatively impact target catch. No bycatch reduction technique will be short-listed that has negative impacts on fisheries.

Table B 1: Long-list of longline bycatch reduction techniques.

Thematic Category	Bycatch Reduction Ideas
Sinking Rate	Weighted lines
	Sliding leads
	Bait thaw status
	Hooking position
	Side-setting
Hauling Rate	Branchline hauler
Deterrent	Bird scaring lines
	Fish oil deterrents
	Water cannons
Stealth Gear	Hook shielding
	Dyed bait
	Underwater bait setter
Offal Management	Discard ban
Operational fishing measures	Fisheries closures (area/ seasonal)
	Gear-switching/ restrictions

3 Sink rate

3.1 Introduction

3.1.1.1 Seabirds are at most risk of bycatch on baited hooks between the time the hooks are deployed behind a vessel and when they sink beyond the diving ranges of seabirds (Parker, 2017). By increasing the sink rate of baited hooks in longline fisheries, the less time is available for foraging seabirds to come into contact with the hook. Therefore, increasing the sink rate reduces the chance of birds becoming bycaught.

3.2 Weighted lines

3.2.1 Bycatch reduction method and how it works

3.2.1.1 Adding weight to the branch lines (snoods) increases the sink rate of baited hooks, thereby reducing the time available for birds to access baited hooks (Parker, 2017). The position which the weight is placed impacts the time is takes for the hook to sink, with weights closest to the hook resulting in the fastest sink rates (Parker, 2017). The recommended weights are:

- 40 g (or greater) at the hook;
- 60 g (or greater) attached within 1 m of the hook;
- 80 g (or greater) attached within 2 m of the hook; and
- Not recommended to attach at a greater distance (Barrington *et al.* 2016; Parker, 2017).

3.2.1.2 It is recommended that weighted lines are used in conjunction with other bycatch reduction techniques (e.g., bird-scaring lines **Section 5.2**) to ensure that the hook has reached a great enough depth to not be a risk to seabirds (when the baited hook passes the extent of the additional method).

3.2.2 Success from trials to date

3.2.2.1 Numerous experimental studies have tested various degrees of line-weighting against standard fishing practices in surface long-line fisheries and have shown line weighting to successfully increase sinking time and therefore reduce seabird bycatch (Boggs 2001; Melvin *et al.* 2010) (Parker, 2017). Line weighting is therefore widely used and accepted as an effective measure to reduce incidental catch of seabirds in demersal and pelagic longline fisheries and is a recommended best practice by the Agreement for Conservation of Albatrosses and Petrels (ACAP) (CleanCatchUK, 2021).

3.2.2.2 Nevertheless, 'flybacks' can occur, which is when a weight flies back toward the vessel because of line breakages, therefore endangering crew members onboard (CleanCatchUK, 2021).

3.2.3 Conclusion

3.2.3.1 Although weighted lines have been successful in reducing seabird bycatch, due to the potential health and safety concerns from this technique, weighted lines have not been short-listed.

3.3 Sliding Leads (Safe Leads[16])

3.3.1 Bycatch reduction method and how it works

3.3.1.1 Sliding leads (developed by FishTek Marine)reduce bycatch in a similar way to weighted lines (see **Section 3.2**). However, there is an added safety feature to reduce flybacks, therefore making them safer. In the event of a line breaking under tension, sliding leads are designed

[16] Sliding Leads were previously called Safe Leads. The name was changed to better describe their function (Parker, 2017).

to slide away from the crew, dampening the energy of the recoiling hook and reducing the likelihood of its flying back towards the vessel and causing injury (CleanCatchUK, 2021).

3.3.2 Success from trials to date

3.3.2.1 Trials have identified sliding leads to be much safer than line weighting (Sullivan *et al*. 2012; Pierre *et al.,* 2015), however, there have been no trials identified within the literature search identifying sliding leads effectiveness at reducing seabird bycatch. As it is a similar technique to weighted lines, it is likely that sliding leads will have a similar success rate, however this has yet to be evaluated.

3.4 Lumo Leads

3.4.1.1 Lumo leads (created by FishTek Marine), were developed as an advancement to sliding leads to include a luminescent feature within the weight.

3.4.1.2 Trials have identified Lumo leads to have an increased sink rate as well as being successful at reducing seabird bycatch (Pierre *et al.* 2015; Claudino dos Santos *et al.* 2016 respectively).

3.4.2 Conclusion

3.4.2.1 Sliding and Lumo leads are a safer option for fishers for increasing sink rate in longline fisheries. Although both developments have the potential to reduce seabird bycatch by increasing the sink rate, only Lumo leads have been short-listed due to the lack of evidence for seabird bycatch reduction in sliding leads.

3.5 Bait Thaw Status

3.5.1 Bycatch reduction method and how it works

3.5.1.1 Thawed bait can aid in increasing the sink rate due to the decreased buoyancy of thawed bait vs frozen bait, therefore reducing the time available in the foraging depths of seabirds (Parker, 2017).

3.5.2 Success from trials to date

3.5.2.1 There is conflicting evidence surrounding the bait thaw status as an effective bycatch reduction technique (Parker, 2017). Although Klaer and Polacheck (1998) identified significantly lower bycatch rates using thawed bait in Japanese longline fishing vessels (Australia), studies assessing the sink rate of bait (frozen/ thawed) showed that the sink rate was impacted by species, size, and the state of the swim bladder, with a latter study identifying negligible differences in sink rate (Brothers *et al.,* 1995; Robertson *et al.,* 2010b respectively).

3.5.2.2 Due to the conflicting evidence, and limited studies within fisheries, the use of thawed bait as a bycatch reduction technique needs further assessment.

3.5.3 Conclusion

3.5.3.1 Although thawed bait can potentially aid in reducing bycatch, due to the conflicting evidence and uncertainty, thawed bait has not been short-listed.

3.6 Side-setting

3.6.1 Bycatch reduction method and how it works

3.6.1.1 Side-setting is the process of deploying baited hooks from the side of the vessel instead of the stern of the vessel (traditional deployment) (**Figure B 1**). This technique aims to reduce seabird interactions with baited hooks as seabirds tend to forage behind vessels, avoiding foraging at the sides. By the time hooks have reached the stern of the vessel due to drag, they will be below the reach of diving seabirds, therefore reducing the potential for bycatch (Parker, 2017; CleanCatchUK, 2021). Moreover, as the baited hooks would not be deployed into the propeller wash (which may slow the sink rate of baited hooks), this rate would be increased (CleanCatchUK, 2021).

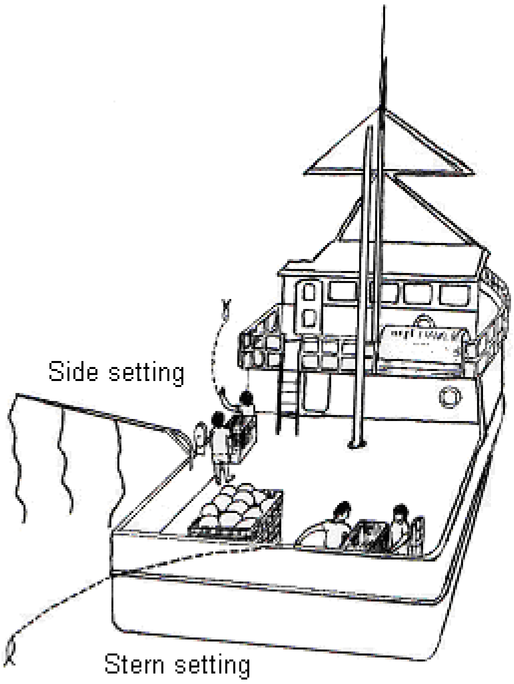


Figure B 1: Side-setting for longline fishing (Gilman, 2004).

3.6.2 Success from trials to date

3.6.2.1 Gilman *et al.* (2016) tested the effectiveness of side setting on Pacific albatross and identified a significant reduction in bycatch. However, 89% of the vessels using side-setting also used a bird curtain, therefore the results cannot be isolated to side-setting impacts. The results showed a significant reduction in bycatch, which is consistent with other trials (Gilman *et al.,* 2007; Gilman *et al.,* 2008 (side-setting combined with bird curtain)).

3.6.3 Conclusion

3.6.3.1 Side-setting has the potential to be a successful bycatch reduction technique, however, the evidence is based on side-setting with a bird curtain therefore side-setting on its own cannot be identified as a successful bycatch reduction technique on its own. Nevertheless, side-setting is short-listed (combined with using a bird curtain) due to success of the trials using both techniques together to date.

3.7 Summary

3.7.1.1 Increasing the sink rate has the potential to significantly reduce gannet bycatch in longline fisheries as less time is available for gannet to encounter the baited hooks (gannet have a maximum dive depth of 20 m). Only two of the four potential methods have been short-listed: (1) Lumo leads (sliding leads), and (2) side settings (combined with bird-scaring lines). The other methods were not shortlisted due to conflictions in evidence on success, and health and safety concerns.

4 Haul Rate

4.1 Introduction

4.1.1.1 Seabirds attempt to take retained bait from hooks during the hauling process when hooks are close to the surface (BirdLife International and ACAP, 2014). Therefore, increasing the haul rate will reduce the time available for seabirds to interact with the hooks.

4.2 Branchline Hauler

4.2.1 Bycatch reduction method and how it works

4.2.1.1 During hauling, each longline (branchline) is hauled individually near to the surface (BirdLife International and ACAP, 2014). At this time, birds will attempt to snatch retained bait. The branchline hauler is a mechanical device which can accelerate the hauling process making it more difficult for birds to catch bait (CleanCatchUk, 2021).

4.2.2 Success from trials to date

4.2.2.1 Currently, there are insufficient data to support branchline haulers in reducing seabird bycatch (CleanCatchUK, 2021).

4.2.3 Conclusion

4.2.3.1 Due to the limited testing of the branchline hauler, it has not been short-listed and therefore not progressed further.

4.3 Summary

4.3.1.1 Although increasing the haul rate of longlines has the potential to reduce gannet bycatch, no technology has been identified through a literature search that has been significantly trialled and tested. Therefore no technique is short-listed.

5 Deterrents

5.1 Introduction

5.1.1.1 Deterrents are used to discourage birds from entering an area where they may potentially be bycaught. For longlines, this is the area directly behind the boat where the lines are being set but the hooks have yet to sink to a depth out of range of foraging.

5.2 Bird Scaring Lines

5.2.1 Bycatch reduction method and how it works

5.2.1.1 A bird scaring line (also known as bird scaring streamers or tori-lines) is an aerial line that is fixed to the stern and towed behind a vessel (**Figure B 2**). A drogue is fitted to the end of the line and sits in the water creating drag. Between the drogue and the stern, brightly coloured streamers are attached. These streamers move in the wind which deters birds from entering the area where baited hooks are sinking, effectively acting as a 'protective curtain' (visual and physical barrier) (Parker, 2017; AFMA, 2015). Birds are visual foragers so brightly coloured objects distract birds and reduce interaction with hooks.

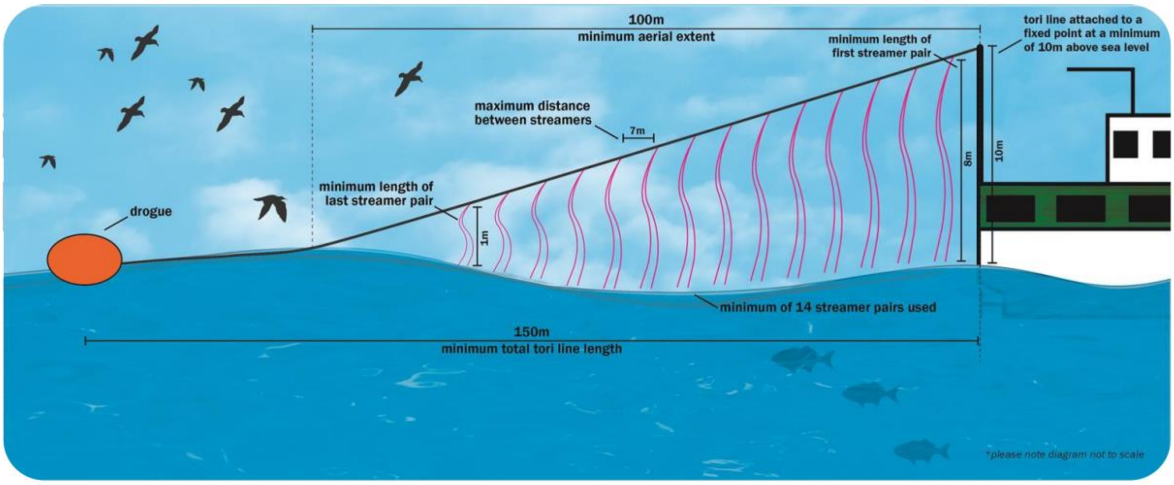


Figure B 2: Bird-scaring line for longline fisheries (AFMA, 2015).

Bait casting machines

5.2.1.2 Bait casting machines can be used in conjunction with bird scaring lines. Bait casting machines deploy baited hooks, saving the requirement of individual hooks needing to be cast by hand (Parker, 2017). This enables the lines to be accurately placed within the bird scaring lines therefore potentially making them more efficient (Parker, 2017).

5.2.2 Success from trials to date

5.2.2.1 There are a range studies outlining the success of bird-scaring lines (see Løkkeborg and Robertson 2002; Bull, 2009; Domingo *et al.,* 2011; Løkkeborg, 2011; Melvin *et al.,* 2014; Da Rocha *et al.,* 2021 for further details). A recent example of success is the use of bird-scaring lines is in the Nambian fishery, where seabird bycatch was reduced by 98.4% since 2015 (Da Rocha *et al.,* 2021). As a result of the demonstrated success of the bird-scaring lines, they are considered best practice by ACAP, when used in conjunction with night-setting and line weighting (Parker, 2017).

5.2.3 Conclusion

5.2.3.1 As stated in Section 3.6, bird scaring lines have been short-listed with side-setting. This is due to the success of both techniques being used together. This decision is strengthened by the results from the trials of bird scaring lines on their own, with the recommendation from ACAP to use them in conjunction with other techniques.

5.3 Fish oil deterrents

5.3.1 Bycatch reduction method and how it works

5.3.1.1 There have been observations of seabirds avoiding water with an oil slick at the surface, therefore dripping fish or shark liver oil from a vessels stern is a possible method to reduce seabirds attending a vessel, and thus reduce incidental bycatch (Parker, 2017).

5.3.2 Success from trials to date

5.3.2.1 There has been limited testing on the use of fish oil as a deterrent to seabirds (Parker, 2017). A study by Pierre and Norden (2006) recorded a reduction in flesh-footed shearwater, Buller's shearwaters, and black petrels when small quantities of shark oil are introduced into the water. Nevertheless, another study on albatrosses and petrels did not find any significant differences in the number of birds attending the vessel (Norden and Pierre, 2007). The evidence for the success of this technique is therefore conflicting.

5.3.3 Conclusion

5.3.3.1 Despite the potential positive effects from using fish/ shark oil as a bycatch reduction technique, there is conflicting evidence. There are no refined specifications or performance standards, and it can potentially be impractical in certain sea conditions (Parker, 2017). The oil may also potentially negatively impact seabird feathers (Parker, 2017). Fish oil has therefore not been short-listed.

5.4 Water Cannons

5.4.1 Bycatch reduction method and how it works

5.4.1.1 Discharging water at high pressure from water cannons during gear setting/ hauling, could prevent or reduce seabirds from entering the area where the hooks are available to seabirds, thereby reducing incidental bycatch (Parker, 2017).

5.4.2 Success from trials to date

5.4.2.1 Evidence from Kiyota *et al.* (2001) showed birds to avoid the area where there were water cannons, therefore successfully deterring the birds and reducing bycatch. However, the water jet was hampered by weather conditions, with cross winds reducing the area covered by the water cannon. The winds could also blow the water back onto the vessel causing potential safety concerns for the fishers.

5.4.3 Conclusion

5.4.3.1 The use of water cannons as a potential bycatch reduction technique has not been short-listed due to the potential health and safety risks with the water being blown back onto the deck.

5.5 Summary

5.5.1.1 Out of all the deterrents identified, only bird scaring lines have been short-listing (as a joint technique with side-setting). This is due to much of the conflicting evidence for other techniques and potential for negative impacts.

6 Stealth gear

6.1 Introduction

6.1.1.1 Stealth gear has the potential for reducing bycatch via removing the potential to be caught (hook shielding) or hiding the bait from the seabirds. Both types of these techniques have the potential to be successful through removing the threat physically, or visually (gannet are visual predators, therefore if they cannot see the prey they will not attempt to take it).

6.2 Hook Shielding

6.2.1 Bycatch reduction method and how it works

6.2.1.1 Hook shielding acts as a bycatch reduction technique through guarding the barb of the hook. The hook is therefore not accessible to seabirds therefore the bird cannot be bycaught. The shield around the hook automatically retracts at a set depth/ after a set time therefore retracting when it is deeper than the diving depth of the seabird. There are two developed technologies which use hook shielding (**Figure B 3**):

- (1) Smart Tuna Hook; and
- (2) Hookpod[17]

Figure B 3: Hook shielding devices: Smart Tuna Hook (left), and Hookpod (right).

6.2.2 Success from trials to date

6.2.2.1 Both Smart Tuna Hook and Hookpod are widely accepted techniques. Trials of the Hookpod have identified significant reductions in bycatch by around 95% (Sullivan *et al.* in Barrington 2016b). With trials of the Smart Tuna Hook reducing seabird bycatch by 81.8% to 91.4%.

6.2.3 Conclusion

6.2.3.1 Hook shielding as a device to reduce bycatch has been short-listed as a technique to potentially reduce gannet bycatch. Gannet dive to a depth of 20 m, therefore setting the retraction depth to > 20 m has the potentially to significantly reduce gannet bycatch. This has been identified through successful trials of both techniques.

[17] Hookpod – FishTek Marine Ltd https://www.hookpod.com/en/

6.3 Dyed bait

6.3.1 Bycatch reduction method and how it works

6.3.1.1 Gannet are visual predators which identify prey from the air, and only dive to catch prey when prey is identified. By camouflaging bait (normally blue) is thought it will be less obvious to seabirds, therefore, if seabirds cannot see the bait, they will be less likely to attempt to take it and therefore less likely to be bycaught on the baited hooks (Parker, 2017).

6.3.2 Success from trials to date

6.3.2.1 Trails have shown that blue-dyed bait (particularly squid) can aid in reducing seabird bycatch in longline fisheries. Research in Hawaii found that dyeing squid bait blue reduced attacks during setting by black-footed and Laysan by 95% and 94% respectively (Boggs 2001). Moreover, an Australian study identified a 68% reduction (Cocking *et al.* 2008). However, studies of dyed fish are less successful than that of dyed squid and would therefore only work within fisheries where squid is the chosen bait.

6.3.3 Conclusion

6.3.3.1 Dyed bait is a bycatch reduction technique for longline fisheries using squid bait. Due to the success in the trials, dyed bait has been short-listed, however, further information is required on the bait used by UK longline fisheries. If it is found that squid are not used within the UK longline fishing industry, then dyed bait will not be progressed further.

6.4 Underwater bait setter

6.4.1 Bycatch reduction method and how it works

6.4.1.1 Lines are set underwater by the underwater bait setter to eliminate the visual cue of available food whilst reducing the time baited hooks are available to birds, therefore reducing bycatch (Parker, 2017). There are various designs, including deploying through a "sling-shot" of the capsule (with the baited hook), or a chute that deploys the baited hooks (**Figure B 4**; CleanCatchUK, 2021).

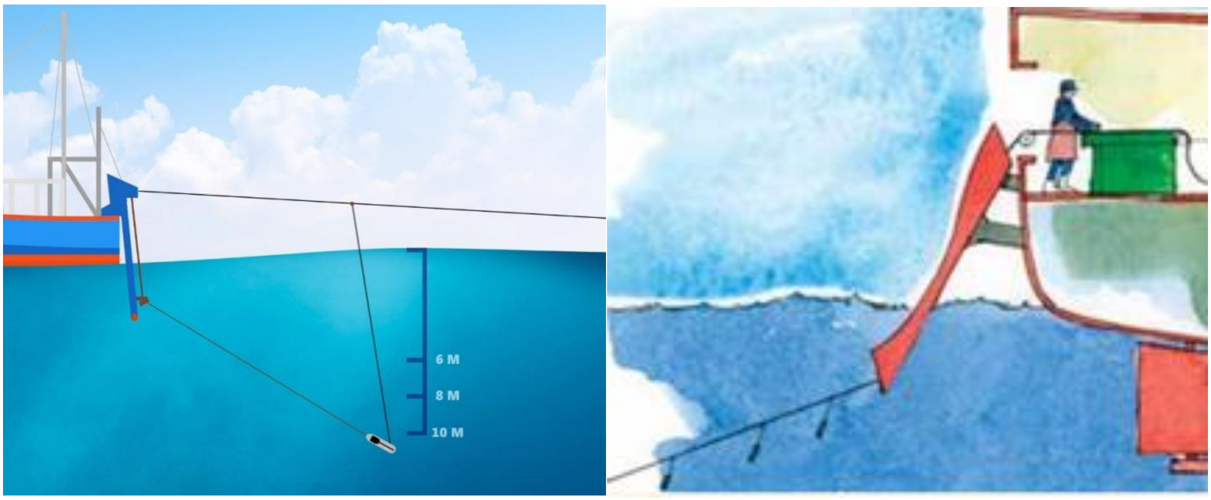


Figure B 4: Underwater Bait Setter. "Sling-shot design" (left) and the chute design (right) (Deepwater Group, 2020; CleanCatchUK, 2021).

6.4.2 Success from trials to date

6.4.2.1 The underwater bait setter has not been experimentally compared to current best practice bycatch reduction techniques for surface longline fishing or to fishing with no reduction technique with the exception of a limited trial (Parker, 2017). Observations showed constant attack rates of birds at the baited hooks occurred until the underwater bait setter was used, then seabird attendance and hook attack rates were eliminated (G. Robertson *pers. comm.* in Parker, 2017).

6.4.3 Conclusion

6.4.3.1 Due to the limited evidence and testing (despite successful observations) from trials, the underwater bait setter has not been short-listed as a potential bycatch reduction technique.

6.5 Summary

6.5.1.1 Only hook shielding has been short-listed as a potential bycatch reduction technique due to having the most substantial evidence for being successful. Although the underwater bait setter has the potential to be a successful bycatch reduction technique, further testing is required.

7 Offal / Discard Management

7.1 Introduction

7.1.1.1 Seabirds are attracted to vessels due to potential foraging opportunities from discards within the vicinity of the vessel. Discard and offal management in longline fisheries is therefore the safe offloading of waste materials away from hooked lines. Although the offal itself is not attached to the hooks, and therefore does not pose a direct threat, it does attract seabirds, causing them to feed in close proximity to hooked lines making them more vulnerable to foraging on the baited hooks.

7.2 Discard Ban

7.2.1 Bycatch reduction method and how it works

7.2.1.1 Discard bans aim to reduce seabird-fishery interactions, thereby reducing the potential for bycatch as there are less seabirds within the vicinity.

7.2.2 Success from trials to date

7.2.2.1 Gannet fishery interactions were assessed in fisheries were discarding is banned in Clark *et al.* (2020). Gannet usually are attracted to vessels, however, within the area of the discard ban gannet were more likely to continue traveling rather than approach the vessel to forage (Clark *et al.,* 2020). Without gannet foraging near the vessels, they are not in proximity to be caught.

7.2.2.2 However, prey availability near colonies was identified as high due to the short foraging trips. It was therefore probable that the high prey availability also contributed to the lack of vessel attendance.

7.2.3 Conclusion

7.2.3.1 When encountering vessels, gannets rarely foraged but instead were more likely to continue travelling (Clark *et al.,* 2020). Nevertheless, further information is needed on how discard bans may impact gannet foraging behaviour and whether success is linked to prey availability near to the breeding colonies. Discard bans were therefore not short-listed.

7.3 Summary

7.3.1.1 Although there is evidence for discard bans to significantly reduce vessel attendance (therefore reducing the potential for bycatch), discard ban as a potential for a bycatch reduction technique has not been short-listed. This is through uncertainty as for whether a discard ban within a set location would be successful depending on prey availability.

8 Overall Summary

8.1.1.1 Three techniques from the review of longline bycatch reduction techniques have been short-listed:

- Lumo Leads (weighted line);
- Side setting with bird scaring lines; and
- Hook shielding.

8.1.1.2 Further fisheries consultations and discussions with the technique developers is required prior to implementation. The most promising technique identified is the Hookpod (evidence shows reduction of seabird bycatch by 95% in longline fisheries), which therefore will be the focus within the next stages of the development of gannet bycatch reduction techniques as compensation.

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Appendix C Gannet trawl bycatch reduction review

1 Introduction

1.1.1.1 The Applicant has identified midwater trawl fisheries as a potentially major cause of gannet bycatch in the UK (see **G1.42 Compensation measures for FFC SPA: Gannet Bycatch Reduction: Ecological Evidence**). In order to successfully reduce bycatch numbers and act as compensation, a successful technique to reduce bycatch needs to be identified. Within the **Compensation measures for FFC SPA: Gannet Bycatch Reduction: Ecological Evidence (APP-194)** report (**Section 7.5**), an overview of the long-listed midwater trawl bycatch reduction techniques was listed, however, was not listed in depth in order to be concise. The purpose of this appendix is to explore the evidence base available for potential gannet bycatch reduction methods in the UK in detail (long-list -**Table C 1**). This document also quantifies the success of each method including examples of previous trials and experiments and their impacts on bycatch and target catch rates.

1.1.1.2 There are currently few studies that assess the impacts of bycatch reduction techniques specifically on gannet. A long-list of potential bycatch reduction techniques for gannet in longline and midwater trawl fisheries has therefore been compiled to identify where any suitable bycatch reduction techniques. Gannets are plunge diving species alongside boobies, some pelicans, tropicbirds, terns and some shearwaters and petrels (American Bird Conservancy, 2016) and therefore trials on these species may be used as an indication of the behaviour that may be exhibited by gannet. Moreover, specific gannet foraging behaviour can be used to identify whether a technique would be successful (e.g., gannet dive to a depth of 20m, therefore a technique that excludes bycatch up to 20 m would be successful for gannet).

1.1.1.3 Two significant bycatch problems are caused by trawl fisheries (BirdLife International and ACAP, 2015a):

- (1) net entanglement; and
- (2) collisions with cables (warp strike).

1.1.1.4 This review will focus on bycatch reduction technologies for both causes of bycatch.

2 Long-list of bycatch reduction methods

2.1.1.1 **Table C 1** presents a long-list of potential midwater trawl fisheries bycatch methods for seabirds discussed in Parker (2017), and other potential technologies identified through a literature search. No operational fishing measures were evaluated due to the potential for these methods to negatively impact target catch. No bycatch reduction technique will be short-listed that has negative impacts on fisheries.

Table C 1: Long-list of potential midwater trawl gannet bycatch reduction techniques.

Thematic Category	Bycatch Reduction Ideas
Deterrent	Bafflers
	Warp Scarers
	Tori-lines
	Cones
Reduce Net Time at Surface	Net Restrictor
	Net Binding
	Net Weighting

Thematic Category	Bycatch Reduction Ideas
Offal Management	Discard Ban
	Net Cleaning
Operational Fishing Measures	Fisheries closures (area/ seasonal)
	Gear-switching/ restrictions

3 Deterrent

3.1 Introduction

3.1.1.1 Deterrents are used to discourage birds from entering an area where they may potentially be bycaught. For trawlers, this is largely the stern through bycatch in nets or warp strike (predominantly those which tow the net) (BirdLife International and ACAP, 2015a). There are multiple technologies which can be used to deter seabirds (bafflers, warp scarers, tori-lines, and cones), each have been evaluated and reviewed below.

3.2 Bafflers

3.2.1 Bycatch reduction method and how it works

3.2.1.1 Seabirds can become entangled, or struck by, warp lines (warp strike) when foraging on discards from trawlers (Parker, 2017). The bird baffler was developed as part of an Australian Government funded project conducted by the Southeast Trawl Fishing Industry Association (SETFIA)[18], to find ways to further decrease interactions between fishing gear and seabirds (AFMA, 2021). There are a variety of baffler designs (**Figure C 1**), but generally consist of two "booms" extending from the stern of the vessel, and two arms extending from the side of the vessel (Parker, 2017). Ropes are attached to the booms and arms to aid in deterring birds from entering the warp strike risk area.

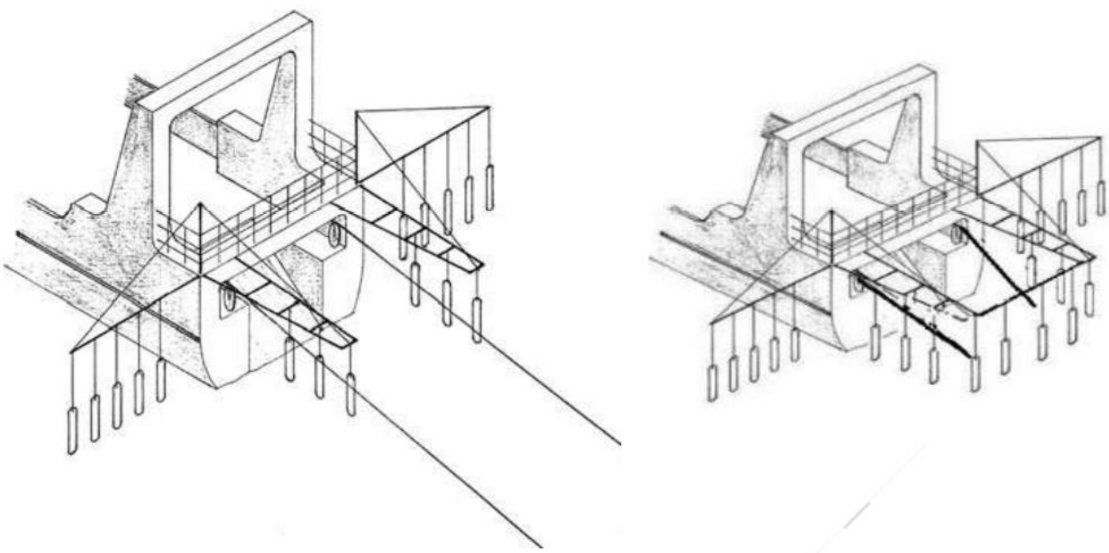

Figure C 1: Two types of bafflers: Brady Baffler (left), and Burka Baffler (right). Figure derived from Parker (2017).

3.2.1.2 There have been a variety of results from studies trialling the use of bird bafflers. Studies by Sullivan *et al.*, (2006) and Middleton and Abraham (2007) both found a statistically

[18] https://setfia.org.au/

significant decrease of warp strike of large seabirds by 35 to 90% (albatross and giant petrels). However, both studies tested other deterrents (warp scarers and tori-lines) and found that bafflers were the least effective.

3.2.1.3 There have also been studies that have shown bird bafflers do not significantly reduce warp strike, particularly with smaller bird species (Bull, 2007; Middleton and Abraham, 2007).

3.2.2 Conclusion

3.2.2.1 Due to the mixed results of the effectiveness of bafflers as deterrents, and the lower effectiveness compared to other deterrents, bafflers have not been short-listed as a potential technique to reduce gannet bycatch in trawlers.

3.3 Warp Scarers

3.3.1 Bycatch reduction method and how it works

3.3.1.1 Similar to bafflers (**Section 3.2**) warp scarers are designed to prevent birds from entering the area at the rear of the vessel where they are at risk of warp strike. Warp scarers are streamers or reflective tape that are attached directly to the warp cable, therefore aiming to deter seabirds from entering the area beneath the warp cables (Parker, 2017; **Figure C 2**). Warp scarers cannot be left on the warp cable throughout fishing, so is deployed after shooting the net, and retrieved prior to hauling (Parker, 2017).

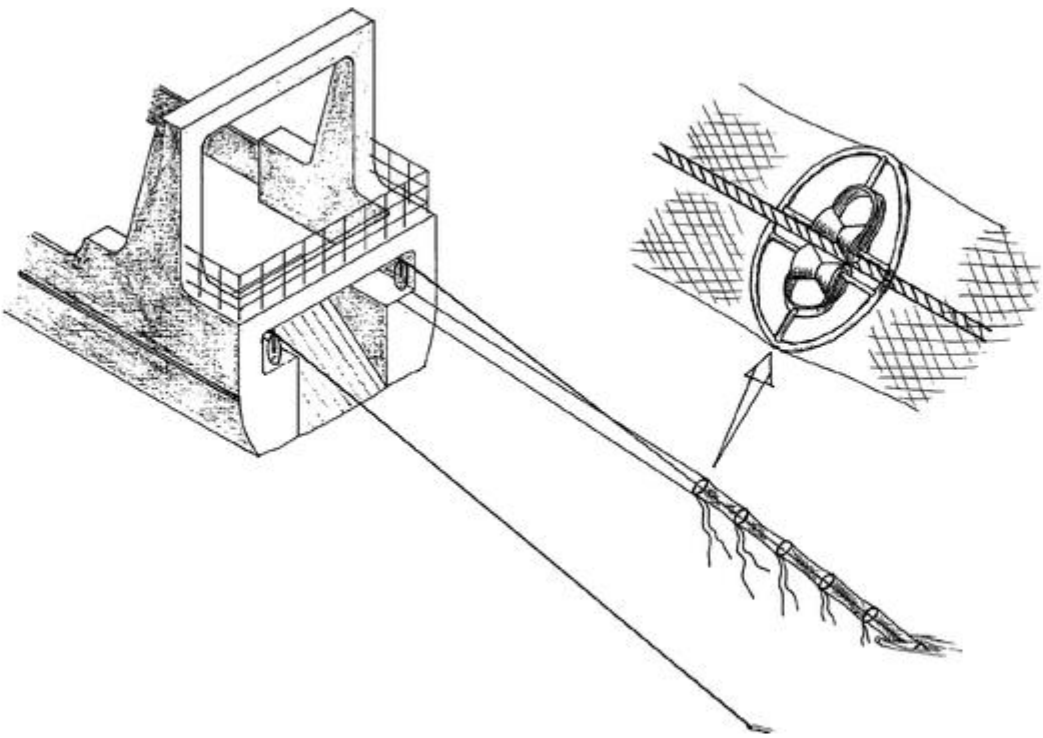

Figure C 2: Warp scarers attached to the warp cable (Sullivan *et al.*, 2006).

3.3.2 Success from trials to date

3.3.2.1 Similar to bafflers, there have been mixed results of success. A significant reduction in the number of large bird strikes on the warps, and a marginally significant reduction on smaller birds was identified in Middleton and Abraham (2007). Whereas Pierre *et al.* (2014) identified no significant reduction in bird strike when using warp scarers. Nevertheless, in trials that tested multiple technologies, warp scarers were identified as less significant than tori-lines (Sullivan *et al.,* 2006; Middleton and Abraham, 2007).

3.3.2.2 Additionally, there was concern for crew safety was expressed during trials when deploying and retrieving the warp scarer, and as it was difficult to manage (Sullivan *et al.* 2006).

3.3.3 Conclusion

3.3.3.1 Due to health and safety concerns, along with the lower effectiveness compared to other deterrents (tori-lines), bafflers have not been short-listed as a potential technique to reduce gannet bycatch in trawlers.

3.4 Tori-Lines

3.4.1 Bycatch reduction method and how it works

3.4.1.1 Similar to bafflers (**Section 3.2**) and warp scarers (**Section 3.3**), tori-lines are designed to prevent birds from entering the area at the rear of the vessel where they are at risk of warp strike. Tori-lines are fixed to the stern and towed parallel to the outside of each warp cables, forming a protective curtain to stop birds entering the area they are at risk of warp strike (Parker, 2017) (**Figure C 3**).

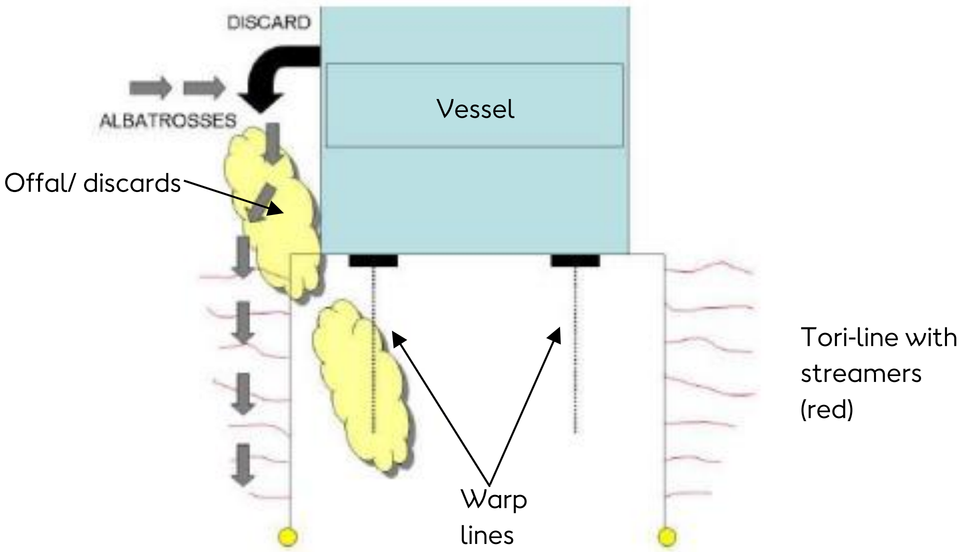

Figure C 3: Tori-lines towed behind a fishing vessel. Grey arrows represent movement of seabirds avoiding the warp lines. Figure adapted from Parker (2017).

3.4.2 Success from trials to date

3.4.2.1 Testing of tori-lines in a variety of studies have identified tori-lines to be successful at reducing warp strike by greater than 73% (Sullivan *et al.* 2006; Melvin *et al.* 2011; Maree *et* *al.* 2014). Moreover, Sullivan *et al.* (2006) identified tori-lines as performing better than bird bafflers or warp scarers (**Sections 3.2** and **3.3** respectively).

3.4.3 Conclusion

3.4.3.1 Tori-lines have been successful in a variety of trials, whilst also being identified as more successful than other deterrents. Tori-lines have therefore been short-listed for further evaluation as a bycatch reduction technique for gannet in midwater trawls.

3.5 Cones

3.5.1 Bycatch reduction method and how it works

3.5.1.1 The cone bycatch reduction device consists of a tapered cylindrical object that is attached to the warp cable at the warp-water interface (Parker, 2017). It is designed to deter birds, preventing birds from becoming entangled and drowned on warp cables.

3.5.2 Success from trials to date

3.5.2.1 Testing of cones as a bycatch reduction technique have shown a significant reduction (89% reduction) in warp-strike when using cones as a deterrent (Gonzalez-Zevallos *et al.* 2007). It is noted that cones are already in use in a small number of New Zealand trawl fisheries (Parker, 2017).

3.5.3 Conclusion

3.5.3.1 Cones have been short-listed as a potential bycatch reduction technique due to the success of the trials to date and current use in trawl fisheries.

3.6 Summary

3.6.1.1 Out of the deterrents identified for mid-water trawlers, tori-lines and cones were the most effective methods identified with the greatest significant results. Therefore, they have both been short-listed for further evaluation. Bafflers and warp scarers were not short-listed due to not being as successful as tori-lines.

4 Reduce Net Time and Surface

4.1 Introduction

4.1.1.1 Net entanglement occurs when trawl nets are at, or close to, the surface during shooting and hauling as seabirds attempt to take fish straight from the net (BirdLife International and ACAP, 2015a). As birds dive into the net to retrieve the fish, they can become entangled and drowned/ crushed (BirdLife International and ACAP, 2015a). By reducing the net time at the surface, this limits the opportunity for birds to scavenge on fish within the nets and therefore reduce the potential bycatch.

4.1.1.2 It is noted that entanglement has been stated to be a larger problem in pelagic fisheries compared to demersal trawl fisheries due to larger net and mesh sizes used in pelagic fisheries (BirdLife International and ACAP, 2015b). As midwater (pelagic) trawls are the focus of this review, these techniques are likely going to be important for reducing bycatch in these fisheries.

4.2 Net Restrictors

4.2.1 Bycatch reduction method and how it works

4.2.1.1 Net restrictors prevent the mouth of the net from opening widely during shooting and hauling thereby reducing the potential for seabirds to dive into the net (reducing the potential for bycatch) (Parker, 2017).

4.2.2 Success from trials to date

4.2.2.1 BirdLife International and ACAP (2015a) state that there is insufficient support for the efficacy of net-restrictors as at-sea testing is required to determine if captures in the centre net are reduced.

4.2.3 Conclusion

4.2.3.1 Due to the lack of support from BirdLife International and ACAP (2015a), net restrictors have not been short-listed as a potential bycatch reduction technique.

4.3 Net Binding

4.3.1 Bycatch reduction method and how it works

4.3.1.1 In fisheries with a met size of 150 to 800mm, net binding can be used to prevent the net opening at the surface. The string has a set breakage strength, therefore inducing the net to open underwater (BirdLife International and ACAP, 2015b). This technique therefore reduces bycatch and drowning from net shooting but not from hauling.

4.3.2 Success from trials

4.3.2.1 There have been successful trials identifying net binding as an effective bycatch reduction technique (Sullivan, 2010 submitted in ACAP, 2016). However, there have been instances of the binding not breaking, therefore the net did not open, and fishers did not get their catch (one in five trial trawls) (Cleal *et al.,* 2009).

4.3.3 Conclusion

4.3.3.1 Although net binding can be successful in reduction bycatch, due to the potential impact of fishers catches (if the binding does not break), the technique has not been short-listed. The Applicant does not support techniques that may impact fisher catches.

4.4 Net Weighting

4.4.1 Bycatch reduction method and how it works

4.4.1.1 Adding weight to the belly of the net increases the rate and angle at which the net sinks during shooting and increases the angle it ascends at during hauling (BirdLife International and ACAP, 2015b). An increased sink rate will reduce the time available for seabirds to interact with the net, therefore reducing the potential to be bycaught.

4.4.2 Success from trials

4.4.2.1 The sink rate of nets has been studied, however the impact of the sink rate has not been evaluated for actual changes in bycatch rates (Parker, 2017).

4.4.3 Conclusion

4.4.3.1 Although there is potential for sink rate to impact bycatch rates, there is a lack of sufficient evidence in bycatch reduction rates. Net weighting has therefore not been short-listed as a potential bycatch reduction technique.

4.5 Summary

4.5.1.1 All of the techniques for reducing the net time on the surface have not been short-listed due to lack of evidence/ potential negative impacts of catch. However, further research is still needed into techniques which may reduce gannet bycatch in net entanglement as net entanglement has been identified by Danish fishers as a bycatch risk for gannet.

5 Offal Management

5.1 Introduction

5.1.1.1 Seabirds are attracted to trawl vessels/ nets due to potential foraging opportunities from discards within the vicinity of the vessel. Discard and offal management is therefore the safe offloading of waste materials away from hauling operations to reduce proximity to the nets and therefore the potential for bycatch.

5.2 Discard Ban

5.2.1 Bycatch reduction method and how it works

5.2.1.1 Discard bans aim to reduce seabird-fishery interactions, thereby reducing the potential for bycatch as there are less seabirds within the vicinity.

5.2.2 Success from trials to date

5.2.2.1 Gannet fishery interactions were assessed in fisheries were discarding is banned in Clark *et al.* (2020). Gannet usually are attracted to vessels, however, within the area of the discard ban gannet were more likely to continue traveling rather than approach the vessel to forage (Clark *et al.,* 2020). Without gannet foraging near the vessels, they are not in proximity to be caught.

5.2.2.2 However, prey availability near colonies was identified as high due to the short foraging trips. It was therefore probable that the high prey availability also contributed to the lack of vessel attendance.

5.2.3 Conclusion

5.2.3.1 When encountering vessels, gannets rarely foraged but instead were more likely to continue travelling (Clark *et al.,* 2020). Nevertheless, further information is needed on how discard bans may impact gannet foraging behaviour and whether success is linked to prey availability near to the breeding colonies. Discard bans were therefore not short-listed.

5.3 Net Cleaning

5.3.1 Bycatch reduction method and how it works

5.3.1.1 Without net cleaning, fish/ squid get stuck within the netting and present a foraging opportunity for seabirds (Parker, 2017). When seabirds forage within the net, they can get caught and therefore drown during net shooting/ killed during hauling (Parker, 2017).

5.3.2 Success from trials to date

5.3.2.1 The success of net cleaning as a bycatch reduction technique has not been quantified and is therefore supported by observation only (Hooper *et al.,* 2003; Parker, 2017). The anecdotal evidence suggests fewer birds attend the net after cleaning, however, this has not specifically been tested (Hooper *et al.,* 2003).

5.3.3 Conclusion

5.3.3.1 Due to lack of evidence (only anecdotal), net cleaning has not been short-listed as a potential bycatch reduction technique. Moreover, net cleaning may decrease the time available for fishing as the net must be cleaned in between each shoot, therefore reducing the catch for fishers. Techniques with negative impacts to fishers will not be short-listed.

5.4 Summary

5.4.1.1 Although there is evidence for reduction in bycatch, neither a discard ban or net cleaning have been short-listed as potential bycatch reduction techniques due to lack of evidence (discard ban - potentially impacted by prey availability; net cleaning – evidence is anecdotal and negative impacts on fishers (net cleaning)).

6 Overall Summary

6.1.1.1 Two techniques from the review of midwater trawl bycatch reduction techniques have been short-listed:

- Tori-lines; and
- Cones.

6.1.1.2 There is limited evidence on the techniques which may reduce gannet bycatch in net entanglement. Net entanglement has been identified by Danish fishers as a bycatch risk for gannet. However, with the current available evidence, no net entanglement bycatch reduction techniques have been short-listed.

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