Improving Understanding of Seabird Bycatch in Scottish Longline Fisheries and Exploring Potential Solutions

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Executive Summary

Seabird bycatch of several species, but predominately northern fulmar, has been recorded by fisheries observers working in the UK offshore longline fishery that targets hake in United Kingdom and European Union waters from the Celtic Sea to the northern North Sea. Previous mortality estimates for the fishery (Northridge et al. 2020), using data collected from 2010 – 2018, indicated that total seabird bycatch in the UK offshore longline fishery might be in the region of several thousand individuals per year, but low sampling levels meant that confidence intervals around the estimates were wide and there were significant caveats related to potential biases in the data used in the analyses.

Because of the significant uncertainties associated with those initial estimates, the Scottish Government funded work to improve knowledge and understanding of bycatch in the fishery through new data analyses and discourse with industry. A comprehensive literature review was also undertaken to describe potential risk factors that might influence the levels of northern fulmar bycatch in similar northern hemisphere fisheries and to identify possible mitigation approaches that could be tested to help reduce bycatch in the fishery.

No clear bycatch risk factors for northern fulmar were identified from a review of large-scale modelling studies which highlights the complexity of the interactions between this species and longline fishing activity. Similarly, statistical modelling undertaken during this project, based on a much smaller bycatch dataset from the UK, also found no obvious operational or environmental factors that were associated with elevated bycatch levels.

From a review of bycatch mitigation journal papers and reports, some initial candidate measures for potential testing, with industry collaboration, have been identified. Some well-known mitigation approaches such as bird scaring lines, offal management routines and line weighting approaches have been used successfully in other parts of the world to reduce seabird bycatch and will be worth considering. Other interesting but less widely documented approaches, including the use of swivel hooks, have also shown potential for reducing northern fulmar bycatch and could also be tested for efficacy in the hake fishery if this was considered a suitable approach by industry.

Analysis of the available sampling data from 2010 to 2021 identified spatial and temporal biases in the existing dataset, with some obvious gaps in sampling coverage within the range of the fishery and intra-annually. To partially address the

influence of these biases in mortality estimates, we developed a new and more refined analytical approach using statistical models and included additional data collected from 2018 – 2021 to produce updated mortality estimates for the fishery.

The modelled mortality estimates for northern fulmar in the longline fishery range from 1,000 to 2,000 individuals annually over the last two decades. The latest estimates are considerably lower and more reliable than the previous estimates of about 4,500 mortalities per annum produced for 2016 and 2017. Modelled estimates for northern gannet were produced and indicate annual mortality of 50 to 150 individuals which is also lower than the previous estimates of 100 to 400 per year. New estimates were also produced for great shearwater and great skua and indicate likely annual bycatch mortality of 10-20 individuals for each species. Based on the available data, there appears to have been an upward trend in seabird bycatch in the fishery since 2000 that is driven by increasing UK longline fishing effort over that period.

We developed and implemented a system for at-sea collection and shore-side storage and transport of whole bycaught seabird specimens. During the project fifty-seven seabird samples were obtained and will be used to supplement existing biological datasets to inform population studies. The data from these (and future) samples will provide unique insights into seabird ecology and the impacts of fishing activity on affected populations.

Observer notes and the results of a questionnaire survey conducted under this project have highlighted the fact that seabird bycatch rates are highest in summer and in the more northern part of the fisheries range. Bycatch rates may also be affected by the behaviour of the birds, by the time of day the lines are set and by the prevailing weather conditions. Skippers have expressed willingness to test further mitigation measures.

This project has significantly improved our understanding of seabird bycatch in the UK's largest longline fishery. The latest mortality estimates indicate that bycatch levels are not as high as initially thought. Data modelling within this project and elsewhere, and the insights from the fisheries observer who has carried out all the data collection in the fishery over the last decade, suggests that there is a complex ecological relationship between the fishing vessels activity and seabird behaviour that sometimes leads to individuals being caught. Continued monitoring in the fishery will incrementally improve our current understanding of the issue and will help further refine future mortality estimates. However, given the desire of some sections of the longline industry to reduce bycatch levels, and the identification of some initial candidate mitigation measures, trials could be conducted in collaboration with industry to assess which approaches are practical and effective, while background monitoring continues to further inform our understanding of bycatch in the fishery. This dual approach will provide additional data to help frame this issue in the appropriate context, while simultaneously helping the longline industry achieve their aims in relation to seabird bycatch and would satisfy the UK and Scottish Governments environmental obligations and ambitions.

Introduction

The Scottish Government is committed to providing a clean, healthy, safe, productive and biologically diverse marine environment that meets the long-term needs of people and nature by managing Scottish waters sustainably to protect biological diversity and to ensure that marine ecosystems continue to provide economic, social and wider benefits for people, industry and society. The Marine Scotland 2018-2019 Programme for Government committed to identify actions to address the significant declines in seabird populations through a new Scottish Seabird Conservation Strategy (SSCS). The developing SSCS highlights the vulnerability of seabird species to a range of human pressures, including incidental bycatch in fisheries. Consequently, estimating bycatch levels and understanding the possible effects of bycatch mortality on seabird populations (and reducing it where necessary) forms a fundamental element in supporting the Scottish Government's long-term environmental ambitions.

Under the UK Fisheries Act (2020), the ecosystem objective calls for any incidental catches of sensitive species to be minimised and, where possible, eliminated. Sensitive species are defined under the Act and includes those species listed under Annex II or IV of Directive 92/43/EEC ('The Habitats Directive'), any other species of animal or plant, other than a species of fish, whose habitat, distribution, population size or population condition is adversely affected by pressures arising from fishing or other human activities, and any species of bird.

Scotland's Fisheries Management Strategy (2020-2030) also includes an 'International Commitment' to monitor and reduce incidental bycatch, including bycatch of marine mammals and birds. The Strategy also embraces an ecosystem-based approach to fisheries, with a focus on *"conservation of vulnerable and protected species, for example, by limiting unwanted bycatch and encouraging proper handling practices when returning protected species to the sea".* Furthermore, and of relevance to this project, the Strategy calls for management decisions which make the most of fishers' knowledge: *"We want to listen to our fishers and the experience and knowledge they have about the marine environment, using this knowledge to add to the richness of our overall understanding".*

In 2020, data collected by onboard observers from the UK Bycatch Monitoring Programme (BMP) were used to produce the first broadscale UK seabird bycatch estimates for net, midwater trawl and longline fisheries (Northridge et al. 2020). This work highlighted a few fisheries where bycatch rates of seabirds appeared to be relatively high, though the results were highly caveated regarding the small sample sizes from some fisheries metiers and the likelihood that sampling data may be biased for a variety of reasons, including uneven spatial and seasonal coverage. One of the fisheries that appeared to have relatively high bycatch rates was the UK offshore longline fishery that mainly targets European hake (Merluccius merluccius) primarily along the continental shelf break in ICES Subareas 4,6,7. The fishery is currently prosecuted by about 14 UK registered vessels, as well as vessels from some EU member states.

Using available data collected between 2010 and 2018 it was initially estimated that bycatch in the UK offshore longline fishery was likely to be in the region of 4,500 seabirds per year (Northridge et al. 2020). However, confidence intervals around the estimates were wide and the estimates were based on a small sample size of just 14 sampled trips. Furthermore, there may be biases in the data as the sampled trips were spread out over a nine-year period and therefore might not have been representative of the fleet activity in the two years (2016 and 2017) for which the estimates were produced. Most of the recorded bycatch in the fishery was of northern fulmar (Fulmarus glacialis), a species which has shown a shallow decline in numbers at nesting sites in Scotland since the mid-1990s. Although the drivers of this decline are not known in detail, they are thought most likely to be due to a decline in the North Sea whitefish industry and a corresponding reduction in the amount of offal discharged from fishing vessels, which provides an important food source for this species (JNCC 2020).

Following the publication of the Northridge et al. (2020) report, the fishery came under increased attention from some conservation groups. However, well before those preliminary estimates were published, one of the two main industry bodies that represent vessels in the UK longline fleet had already expressed a wish to explore mitigation measures in the fishery to reduce seabird bycatch, and informal discussions about possible mitigation approaches had already begun.

To improve understanding of bycatch in the fishery following the publication of the Northridge et al. (2020) report, and to inform future discussions and possible actions related to bycatch and its potential mitigation in the fishery, the Scottish Government funded this project which specifically focussed on the hake longline fishery and included a broad range of objectives that were addressed using qualitative and quantitative approaches. New data analyses were undertaken, and possible bycatch mitigation approaches were explored by collating relevant information from the wider literature and through discourse with industry and other researchers working on seabird bycatch in similar fisheries.

The report is divided into six sections covering the main project objectives.

The first section provides a literature review of relevant studies on fulmar bycatch and mitigation globally, with the aims of identifying risk factors that may be associated with fulmar bycatch and describing seabird bycatch mitigation measures that have been tested or are used in other demersal longline fisheries around the world.

Using data collected in the UK longline fishery between 2010 and 2021, the second section explores what factors may be linked to seabird bycatch rates in the fishery through statistical modelling approaches to try and identify when, where and in what circumstances seabird bycatch is most likely to occur in the fishery. An assessment of the spatial and temporal sampling coverage was also undertaken to explore the representativeness of existing sampling data.

The third section provides updated bycatch estimates for the longline fishery using additional observer data that has doubled the number of observed hauls since the Northridge et al. (2020) estimates were produced.

The fourth section describes efforts to recover bycaught seabirds from the fishery for later necropsy.

The fifth section summarises the detailed notes collected by the observer during data collection activities in the fishery, and describes work carried out to gain a better understanding of bycatch in the fishery, and the drivers for and willingness to address bycatch directly from skippers involved in the fishery.

The final section draws together the findings in a general discussion on the strengths and weaknesses of the data, highlights improvements in data collection/analysis and indicates some initial candidate mitigation measures for testing based on the literature review, existing sampling data and direct input from vessel skippers.

It should be noted that the work has been constrained by the global Covid-19 pandemic which has resulted in less onboard sampling than projected and limited potential for face-to-face engagement with skippers in Spain. Thus, some parts of the planned work have been constrained and these are described in the report.

Section 1: A literature review of northern fulmar bycatch rates, bycatch risk factors and potential mitigation approaches relevant to UK demersal longline fisheries.

1.1 Introduction

The northern fulmar is an abundant and widely distributed seabird of the taxonomic family Procellariidae. There are three recognised subspecies: Fulmarus glacialis glacialis breeds in the high Arctic regions of the North Atlantic, Fulmarus glacialis audubonii breeds in the boreal North Atlantic and Fulmarus glacialis rodgersii breeds in the Pacific Arctic (Edwards 2015). Northern fulmars mature between 6 to 10 years old and regularly attain 30 years of age, with some ringed specimens estimated at over 40 years old (Fransson 2017). The species is thought to be monogamous and returns to the same nesting site annually (Hatch and Nettleship 1998).

In the North Atlantic, the breeding season occurs between May and September and during that period adult birds tend to forage relatively close to the nesting site, with a mean foraging distance of 60km reported in Norway by Weimerskirch et al. (2001) but much longer foraging trips can also occur (Edwards et al. 2013). Thaxter et al. (2012) also provided estimates of fulmar foraging ranges based on data from Greenland, Norway and the United Kingdom with a mean of 47.5km and a mean maximum of 400km across the studies considered. Northern fulmar breeding distribution has changed dramatically in the North Atlantic over the last few centuries. Prior to the mid-18th century, breeding occurred in just a few locations in Iceland and St Kilda in the Western Isles of Scotland (Lloyd et al. 2010). The breeding range then began to expand around the coast of Iceland and to the Faeroe Islands, and a second colony also formed in Scotland on the Shetland Isles. More recently breeding colonies have become established in many countries of Northwest Europe and the species has also spread west across the Atlantic and now breeds along the east coast of Canada.

Outside the breeding season the northern fulmar is a truly oceanic seabird and spends all its time at sea, but the species does not appear to have a well-defined migratory route like some other seabird species (Mallory 2008; Edwards et al. 2013). This wide-ranging behaviour is highlighted by the movements of a GPS tagged individual that spent part of its time in waters around Scotland, the Faeroes and the Norwegian Sea, and part of its time further west to the mid-Atlantic ridge, Newfoundland and the Labrador Strait (Edwards et al. 2013). There were relatively few GPS positions recorded between those two general areas which indicated relatively quick transits between the Mid-Atlantic Ridge (and further west) and Northwest European waters.

Fulmars have a well-developed olfactory system (Wenzel 1986; Fangel et al. 2015) which they use to locate food sources (Nevitt 2008), such as aggregations of copepods in the open ocean (Edwards et al. 2013). They may also use this ability to locate fishing vessels at sea and often forage on discards and offal (Garthe & Hüppop 1994).

Through the 20th century northern fulmar abundance increased quite rapidly and this has been suggested to be related to whaling activity and increasing trawl effort (Fisher 1966), which led to enhanced foraging opportunities. Studies of fulmar diet suggest that some populations feed predominantly on zooplankton, sandeels or other fishery-independent sources of food but at some colonies a high proportion of the diet may be discards or offal (Hudson & Furness 1988; Ojowski et al. 2001).

The global (all subspecies) northern fulmar population was estimated at about seven million breeding pairs, or twenty million individuals including immature non-breeders (Birdlife International 2021). The European breeding population (which does not include Northwest Atlantic birds) was estimated at about seven million individuals (Birdlife 2015). The UK population was estimated to be about 500,000 breeding pairs during the period 1998 to 2002 (Seabird 2000), which represents a 3% decline in abundance from the previous census that was carried out from 1985 to 1988. However, there is evidence of a steeper decline since 2000. The latest available estimates for 2019, which are based on a sample of colonies rather than a census as was used previously, indicated reductions in the region of 37% since the index began in 1986 (JNCC 2020).

The IUCN Red List (IUCN 2021) currently classifies northern fulmar as “Least Concern” and the overall population trend is considered to be increasing. Similarly, Partners in Flight, a network of over 150 organisations involved in science and policy development, rates the species a 9 out of 20 on the North American Continental Concern Score, indicating a species of low conservation concern. Birds of Conservation Concern 4 which relates to the population status of birds in the UK, Channel Islands and Isle of Man (BoCC4 2015) currently classifies northern fulmar as “Amber”, so the species is of some, but not critical, conservation concern. However, northern fulmar has recently been reclassified as “Endangered” on the European Red List (Birdlife International 2015) as the population trend across much of the region is decreasing.

Reduced catch rates and discarding by EU fishing fleets since the late 1990s may have had a significant impact on the foraging success of several scavenging seabird populations in European waters (Bicknell et al. 2013) and declines in the abundance of the North Atlantic fulmar population since the 1980’s are considered to be at least partially related to reduced foraging opportunities around fishing boats and may represent a re-adjustment to more natural population levels following a period of elevated abundance related to fisheries byproducts (JNCC 2020). It seems likley that trends in fulmar abundance in the North Atlantic over the last century are intricately linked to levels of fishing activity, evolving fishing practises and fisheries management measures.

Preliminary mortality estimates (Northridge et al. 2020) based on limited observer data indicated that northern fulmar bycatch in some UK fishery sectors (nets, midwater trawls and longlines) is likely to be about 5,000 individuals per annum. It is not clear which breeding populations bycaught birds originate from. Most of the estimated UK mortality appears to occur in the offshore longline fishery that targets European hake in waters to the north and northwest of Scotland, with lower-level bycatch estimated to occur in the same fishery when it operates to the west and south of Ireland. Some bycatch mortality also occurs in static net fisheries (Northridge et al. 2020).

This review was compiled for two main purposes. Firstly, to draw together available information on fulmar bycatch rates and risk factors from other demersal longline fisheries in the northern hemisphere to help contextualise and inform our understanding of fulmar bycatch in UK fisheries, and secondly, to provide a summary of potential bycatch mitigation measures that may be of use to industry and Government to help reduce bycatch in the longline fishery in practical, economic and implementable ways.

1.2 Methods

We used academic bibliographic databases (e.g., Biosis, Web of Science); Google Scholar and contract or working group/workshop reports to identify published studies that estimated fulmar bycatch rates or described seabird bycatch mitigation measures that have been tested in demersal longline fisheries. In addition to specific research articles that typically cover a single fishery or mitigation approach, several global reviews of mitigation measures for longline fisheries are also available (Bull 2007; Løkkeborg 2011; Parker 2017). We also directly contacted scientists working on fulmar bycatch in other countries to obtain information from unpublished or ongoing work.

From published work in peer-reviewed journals, Biosis and Web of Science yielded a only a few tens of relevant papers using the search terms “fulmar”, “longline” and “bycatch”. Google Scholar yielded 910 results using the same search terms. We briefly reviewed all of these by scanning titles and abstracts, and initially identified about 200 papers that seemed at least partially relevant. More detailed review of these 200 papers and various reports resulted in a final set of about 90 publications of specific relevance to fulmar bycatch rates and potentially useful mitigation approaches for large scale demersal longlining operations.

1.3 Overview of fulmar bycatch & risk factors from other northern hemisphere longline fisheries

Largely because of their habit of following fishing vessels that are provisioning them with offal, fulmars are vulnerable to becoming caught in some kinds of fishing gear, notably on hooks in longline fisheries where they may attempt to take the bait from hooks as the lines are being set or hauled. Fulmar bycatch on longlines has been reported in many fisheries around the world. Northern fulmars are known to be caught on longlines in Alaska, Canada, Norway, Iceland, and the Faroes as well as in other European longline fisheries. There are relatively few recent estimates of bycatch in most of these fisheries.

Bycatch rates are usually measured in terms of the number of birds per 1000 hooks (Kriegr and Eich 2021). Melvin et al. (2019) showed that fulmar bycatch in Alaskan longline fisheries has declined substantially since the introduction of voluntary mitigation measures in 2002. Prior to 2002, fulmar bycatch rates averaged 0.051 birds per thousand hooks. After the adoption of streamer lines in 2002, the rate fell to 0.01 birds per thousand hooks, a five-fold reduction. The fishery targeted 4 species: sablefish (Anoplopoma fimbria), Pacific halibut (Hippoglossus stenolepis), Pacific cod (Gadus macrocephalus) and Greenland turbot (Reinhardtius hippoglossoides). Halibut was and remains the largest of these Alaskan fisheries.

Recent bycatch mortality estimates for northern fulmar in the Alaskan longline fishery (Krieger and Eich 2021) have fallen to an average of 3067 individuals per year between 2011 and 2020, compared with an average of over 10,000 per year between 1993 and 1999 (Melvin et al. 2001). This decline in mortality is partly due to the introduction of voluntary mitigation measures but also reflects the fact that many vessels switched from using longlines to pots in the sablefish fishery. Annual bycatch of northern fulmar in all Alaskan fisheries (of which 86% are in longline fisheries) was recently estimated at 0.25% of the population of 1.4 million birds and is considered low (Krieger and Eich 2021).

In the Western North Atlantic, Ellis et al. (2013) used observer data from 2002-2006 to estimate annual bycatch of seabirds in the pelagic and demersal longline fisheries in Atlantic Canada. Approximately 230 fulmars were estimated killed annually in these fisheries. Observer data have been collected in the region since 2001, but it seems they have not been fully analysed to date.

In the Eastern North Atlantic, Dunn & Steel (2001) suggested that the Norwegian offshore auto-lining fleet might take around 10,000 seabirds (mostly fulmars) per year, based on mean observed bycatch rates in their study, with no spatial stratification. They point out that there were over 9000 mostly small vessels engaged in some form of longlining in Norway, and so suggested that bird bycatches could have been around 20,000 birds per year in Norway in total, but with a rider that the total *“may easily run to 50,000 to 100,000”* per year when using more extreme Bycatch Per Unit Effort (BCPUE) figures. They also suggested, based simply on the numbers of vessels operating in Iceland and the Faroes, that the figure of 50,000 to

100,000 would be a conservative estimate for the entire ‘Nordic’ fleet. These speculative estimates have entered the literature more widely.

Anderson et al. (2011) using upper limits for bycatch estimates cited as being from Dunn and Steel (2001) suggested that as many as 140,000 birds per year could be taken in the combined longline fleets of Norway, Iceland and the Faroes. The authors point out that the estimates are from old studies of bycatch per unit effort in the 1980s and 1990s, against which they used more recent estimates of effort.

Fangel et al. (2015) suggested that the Norwegian bycatch of fulmars in the two coastal longline fisheries was around 3300 in the cod and haddock fishery and around 1500 in the Greenland halibut fishery in 2009, based on interview surveys. However, a later study of the Greenland halibut longline fishery alone involving a larger sample of 426 trips involving both interview data and observer data yielded an estimate of around 310 fulmars in total over the years 2012–2014 (Fangel et al. 2017), or about 100 per year. The reasons for the large differences in these estimates are unclear, but very different BCPUE figures were reported in the two studies, and the discrepancy underlines the difficulties in extrapolating from relatively small samples and when bycatches can be highly clumped. As the author’s state: *“few yet sometimes extreme bycatch events are … highly influential in controlling the bycatch estimates”.*

A small study involving observations of 103 fishing operations from 14 trips in the UK offshore hake longline fishery yielded provisional mortality estimates for fulmar of about 4,500 (95% CI 2200-9100) individuals per year (Northridge et al. 2020), but the authors stressed that the data were too limited (and likely had significant biases) to put much trust in. Estimates of fulmar bycatch in other European longline fisheries are generally lacking.

A summary of available northern fulmar bycatch estimates in longline fisheries is provided in Table 1.

Table 1: Summary of northern fulmar bycatch estimates from other longline fisheries.

Authors	Reference years	Nation	Target species	Region	Approximate annual totals	Type of estimate
Melvin et al. 2001	1993-1999	Alaska USA	Halibut, sablefish, cod	Bering Sea & Aleutian Islands	9000	Observed BCPUE
Melvin et al. 2001	1993-1999	Alaska USA	Halibut, sablefish, cod	Gulf of Alaska	1000	Observed BCPUE

Krieger and Eich 2021	2011-2020	Alaska USA	Halibut, sablefish, cod	All Alaska	3000	Observed BCPUE
Ellis et al. 2007	2002-2006	Canada	Pelagic & demersal	Maritime Provinces	230	Observed BCPUE
Dunn and Steel 2001	1997-1998	Norway	Demersal species	Offshore	10,000	Observed BCPUE
Dunn and Steel 2001	1997-1998	Norway	Demersal species	Inshore	10,000	Speculative
Dunn and Steel 2001	1997-1998	Nordic fleets	Demersal species	Combined	50,000-100,000	Speculative
Anderson et al. 2011	2007	Norway	Demersal species	Combined	6500 (up to 110,000)	Observed BCPUE (& updated effort)
Anderson et al. 2011	2007	Iceland	Demersal species	Combined	7000 (up to 20,000)	Speculative
Anderson et al. 2011	1997-1998	Faroes	Demersal species	Combined	3000 (up to 10,000)	Speculative
Fangel et al. 2015	2009	Norway	Cod/Haddock	Inshore	3300	Interviews - reported trip totals
Fangel et al. 2015	2009	Norway	Greenland Halibut	Inshore	1500	Interviews - reported trip totals
Fangel et al. 2017	2012-2014	Norway	Greenland Halibut	Inshore	100	Interviews and observed BCPUE
Northridge et al. 2020	2010-2018	UK	Hake	Offshore	2200-9100	Observed BCPUE

Bycatch rates, expressed as numbers of birds per thousand hooks are highly variable even within the studies listed above. Dunn and Steel (2001) tabulated recorded fulmar bycatch rates in Norwegian longline fisheries, which varied by two orders or magnitude from 0.01 to 1.75 in different studies. In Canada reported bycatch rates of fulmars appear to be at the lower end of published ranges: although data in Hedd et al. (2016) are not broken down explicitly by seabird species, in fisheries where fulmars dominate the bycatch, recorded seabird bycatch rates range from 0.008 (Atlantic cod) to 0.076 (Greenland halibut) birds per thousand hooks. Fangel et al. 2017 reported bycatch rates in the Greenland Halibut fishery in Norway of 0.294 birds per thousand hooks in 2009 and 0.045 in 2012-14 in the same fishery. Melvin et al. (2019) provide figures of 0.0513 birds per thousand hooks before mitigation and 0.0097 afterwards.

Rates are clearly highly variable between studies and indeed between years and between trips. This makes it challenging and risky to extrapolate from small sample sizes and may also hinder the accuracy of bycatch predictions.

Melvin et al. (2001) noted extreme inter-annual variation in seabird bycatch by species in Alaska. Seabird bycatch rates were 74% lower in 2000 compared with 1999 in the sablefish longline fishery and 93% lower in the cod longline fishery, driven by changes in seabird behaviour and distribution.

Various authors have explored the fishery related factors that may be associated with this extreme variability in bycatch rates. Melvin et al. (2019) explored several statistical modelling approaches, and found both year and area were important factors, as well as depth, season, total number of hooks and target fish catch per unit effort. The use of streamers and weighted lines in the Alaskan fisheries was associated with a significant reduction in bycatch or all species. Fulmars, however, were recorded bycaught at significant higher rates (by 40%) at night. Dietrich et al. (2009) applied a variety of multivariate models to the extensive observer data set from Alaska and found that 'vessel' was the single highest contributor to model deviance in 11 or 13 models, explaining 21-25% of deviance. Other fishery related variables rarely contributed more than 10% to explained deviance.

Fangel et al. (2017) used a generalized linear mixed model (GLMM) framework to examine potential drivers in the bycatch of fulmars in the Norwegian inshore Greenland halibut longline fishery. Contrary to the work of Melvin et al. (2019), they found no convincing effect of the use of bird scaring lines on bycatch rates but did note a very significant effect of hook type on bycatch rates. They noted that much of the variation in their bycatch data appears to be random and remains unexplained by any of the measured variables. They conclude that *“the bycatch in general is difficult to predict from the spatio-temporal, environmental and other mitigation variables included in our analysis, which suggests that incidental bycatch of fulmars in the Greenland halibut fishery is more random than systematic.”*

Against this backdrop of conflicting and generally inconsistent analyses of factors potentially driving fulmar bycatch in longline fisheries, a more pragmatic approach may be to examine what mitigation measures have worked for this and other seabird species in longline fisheries.

1.4 Description of mitigation measures tested and/or used in demersal longline fisheries

Potential options for seabird bycatch mitigation in demersal longline fisheries from the main review papers by Bull (2006), Lokkeburg (2008), Parker (2017) and ACAP (2019) and from a specific study by Fangel (2017) which described a method not covered by the reviews are presented in Table 2. A description of each tabulated method is then provided in the subsequent text. For clarity and based partially on the work of Lokkeborg (2008), we categorised the selected measures into vessel-based, gear-based and non-technical mitigation approaches. Within each of these broad categories we grouped measures with similar mitigation characteristics, such as deterrence, vessel modification and so on, to allow easier conceptualisation of the form and practical considerations of each mitigation approach.

Category	General Approach	Specific Approach	Specific Element	Parker 2017	Bull 2006	Lokkeburg	Fangel 2017	ACAP 2019
Vessel-Based	Deterrence	Deterrence during line setting	Bird scaring lines	Y	Y	Y		Recommended
			Water cannon			Y		
			Lasers					Not Recom
			Acoustics			Y		
			Olfactory					
		Deterrence during hauling	Bird exclusion devices	Y	Y	Y		
	Vessel modification	Equipment installation	Underwater line setters	Y	Y	Y		
			Line shooter	Y	Y	Y		Not recomm
		Structural modification	Moon pool	Y				
	Operational	Vessel operations	Night setting		Y	Y		Recommended
		Crew operations	Offal management	Y	Y			Recommended

Category	General Approach	Specific Approach	Specific Element	Parker 2017	Bull 2006	Lokkeburg	Fangel 2017	ACAP 2019
Gear based	Reduced attraction/ opportunity	Sink rates	External line weighting	Y	Y	Y		Recommended
			Integrated weights	Y				
			Branch line weighting					Recommended
		Bait	Thawed bait	Y		Y		Not recomm
	Reduced 'hookability'	Hook	Size and shape modifications			Y		Not recomme
			Swivel hooks				Y	
			Hook shields					Recommended
Non-technical	Input and output measures	Input measures	Effort management		Y	Y		Recommended
		Output measures	Bycatch thresholds					

Table 2: Seabird bycatch mitigation measures most relevant to demersal longline fisheries.

1.4.1 Vessel-based Approaches

Vessel-based mitigation measures include changes to the fishing operations, structural modifications or equipment deployed from the vessel to keep seabirds away from the gear as it is set or hauled. To date the most widely used category of vessel-based mitigation measures in longline fisheries has been physical deterrents deployed during line setting.

Bird-scaring lines (BSL), also known as streamer lines or tori lines, were first developed on Japanese longliners working in the Southern Ocean (Brothers 1999) and are single or multiple lines that are connected to a high point on the vessel and are typically deployed over the stern during line setting operations and are retrieved back onto the vessel after the lines are fully deployed. BSLs have a main rope/s that contain multiple streamers which form a protective barrier over the longline that is designed to deter foraging birds from the vicinity of the baited hooks as the gear is set. The streamers are typically of decreasing length further from the vessel to reduce handling problems that can occur if they entangle the longline. The BSL should be sufficiently long that it extends well beyond the point where the longlines enter the water because baited hooks often remain in foraging range of birds until they have sunk several metres below the surface (ACAP 2016). Numerous studies have shown that the use of single or multiple BSLs significantly reduced seabird bycatch rates in various demersal longline fisheries (Melvin et al. 2001; Lokkeburg & Robertson 2002; Lokkeborg 2003; Paterson et al. 2017) while in another study no clear effect on bycatch rates was found when using a BSL (Fangel et al. 2017). Goad & Debski (2017) also report problems associated with BSLs entangling the longline during setting. BSLs can be tensioned by the deployment of a rope or buoy at the outer end (Goad & Debski 2017; Parker 2017) and this may help maintain the BSL vertically or near vertically above the longline in side-winds, extend its effective range and reduce the likelihood of the BSL becoming entangled with the gear.

The use of **water cannons** to deter birds from longline vessels during line setting operations was investigated by Kiyota et al. (2001). They used a 30-Kilowatt electric centrifugal pump and reported that the range of the cannon was not sufficient to be particularly effective and that changes in wind direction would further limit its efficacy.

Laser systems have been used to deter birds from fish farms, airports, dairy and other agricultural settings and properties since at least the turn of the millenium (Blackwell et al. 2002; Glahn & Dorr 2000). A marinised version aimed at minimising seabird longline interactions was developed by the Dutch Company Savewave and marketed by Mustad in 2014. The device aims a green laser over the water around the longline as it is being set, and this circle of light (and beam in some conditions) can have a deterrent effect on scavenging seabirds. This device also comes with an optional acoustic deterrent package so that simultaneous acoustic and visual deterrents can be broadcast. A trial by Melvin et al. (2016) concluded that seabirds showed little detectable response to the laser during daylight hours but at night fulmars showed a transient and localized response. No more recent trials appear to have been undertaken (ACAP 2019b). Concerns have also been raised that it may damage seabird eyesight (ACAP 2016), but the evidence for this is not conclusive (Melvin et al. 2016).

Acoustic deterrents are used widely in the terrestrial environment (Gilsdorf et al. 2002), particularly agricultural settings. Gas cannons have been tested is some longline fisheries, but the general perception is that seabirds quickly habituate to the noise and there is little evidence for a long term effective acoustic deterrent for seabirds (Parker 2017).

Although listed in several reviews, there is little empirical evidence for **olfactory based solutions**. Two studies (Pierre & Norden 2006; Norden & Pierre 2007) from New Zealand suggested that some species of seabirds can be deterred by the use of shark liver oil during fishing operations. Parker (2017) refers to a study in Alaska, where the authors noted that after fish oil deployment behind a trawler the shearwaters departed the area completely. Olfactory approaches do not appear to have been tested or trialled elsewhere and ACAP (2019a) states that there is no evidence of effectiveness in pelagic longline fisheries.

All the methods described above are designed to deter birds from the vicinity of the hooks during standard line setting operations. An alternative approach is to deploy the line and hooks below the surface, so the baited hooks are outside typical foraging depths more quickly.

An **underwater line setter** was developed and marketed by Mustad, and efficacy tests have been reported by Løkkeborg (1998) and Ryan & Watkins (2002). Although the device showed promise, several problems were encountered. The line setting tube was attached to the transom of the vessel which can rise and fall significantly as the vessel pitches in large waves or swells and the seaward end of the device was frequently lifted out of the water making the baited hooks more visible and available to birds near the boat. Other potential problems included the fact that some of the bird species where the trials were conducted can dive up to 10m below the surface and a line setter extending that deep is impracticable and could cause structural damage in heavy weather. Parker (2017) highlights an example of a longliner in New Zealand that experienced stress on the vessel’s transom due to the presence of a setting tube. In a similar vein, another type of underwater line setter, the Kellian line setter, was conceived by a New Zealand fisherman and has undergone several incremental developments over the last decade (Baker et al. 2016). The basic design involves towing a device just off the stern of the vessel at a depth of 4 to 7m, which the line and hooks pass under increasing the line deployment angle - meaning the hooks are more quickly out of foraging range of most surface feeding seabird species. Trials of the latest version (KLS4.4) also showed promise but some issues with gear deployment and damage and loss of baits was reported. According to Baker et al. (2016), further work is required to address these issues. Despite being conceptually appealing and showing some potential as a mitigation approach, underwater line setters have not proven practicable and are therefore not yet used widely in commercial longline operations.

Another vessel-based approach to increasing the speed baited hooks pass through the foraging zone of surface feeding seabirds is related to mainline tension. Longlines are normally set behind a moving vessel meaning the mainline is under tension so hooks do not sink as quickly as they would if they were dropped into the water on an un-tensioned line.

Hydraulic line shooters reduce or remove tension on the mainline by deploying it more quickly than the vessel is moving (Parker 2017). Studies of the efficacy of line shooting devices on seabird bycatch rates are limited and results are also equivocal. Lokkeborg & Robertson (2002) found that lines set with a line shooter had higher seabird bycatch rates than the same lines set with a BSL, and Robertson (2008) found that sink rates of weighted mainlines were the same whether a line shooter was used or not. As with underwater line setting approaches, line shooters seem a reasonable idea but there is little conclusive evidence that they provide a suitable approach for reducing bycatch in demersal longline fisheries.

Most seabird mortality in demersal longline fisheries appears to occur during line setting operations as birds get caught on baited hooks and are dragged below the surface by the weight of the gear. However, some bycatch also occurs during line hauling and may lead to mortality and injury and some attempts have been made to reduce this interaction.

Bird Exclusion Devices (BEDs), such as brickle curtains, are designed for use when longlines are hauled and provide a barrier of ropes and floats around the area where the lines exit the water to reduce access to baited hooks as they resurface. BED systems were first developed in the mid-1990s in the Patagonian toothfish (Dissostichus eleginoides) fishery in the South Atlantic (Reid et al.2010). Initial trials reported a 97% reduction in interactions during hauling (Snell 2008). Other studies have shown signs that birds may habituate to the device (Sullivan 2004) and the potential for the system to interfere with line hauling operations in heavy weather has also been highlighted (Parker 2017) which might limit the systems utility in high latitude offshore fisheries.

Moon pools involve a vertical tunnel built through the vessels hull that open into a small pool inside the vessel and are often found in drilling ships and scientific research vessels. The basic design has been used in auto-longline vessels in Iceland, Norway, Denmark and the USA (Parker 2017) primarily to provide a safer working environment for the crew compared to open deck vessels. In the context of seabird bycatch, the use of a moon pool would shield the hooks from foraging birds during hauling but would not reduce bycatch that occurs during line setting as lines are usually hauled through the moon pool but are typically set over the stern of the vessel in the traditional manner. Some fisheries also shoot lines through the moon pool. There do not appear to be any direct studies on the effects of moon pools on seabird bycatch rates (Parker 2017).

In addition to more technical bycatch reduction approaches as described above, several studies have assessed how vessel operational changes might affect bycatch rates. Most seabird species forage primarily by sight (though olfaction is known to be used by at least some bird taxa) so in general bycatch rates tend to be lower when lines are set in darkness (Weimerskirch et al. 2000), and **night setting** is recommended as best practise by ACAP and some national authorities including New Zealand. However, night-setting at high latitudes during summer months is almost impossible when there is little darkness. Furthermore, some seabirds are able to forage effectively in bright moonlight, while others may use the light from deck lights to aid foraging. Conclusive evidence that night setting is a useful measure to prevent fulmar bycatch is lacking and Melvin et al. (2019) concluded that for most seabird species bycatch rates in Alaskan demersal longline fisheries were lower at night, but northern fulmars were the exception and were caught at higher rates (+ 40.4%) at night.

It is widely recognised that the main reason seabirds are attracted to fishing boats is the enhanced foraging opportunities provided by the disposal of discards and offal (Weimerskirch et al. 2000). Several national authorities (e.g., New Zealand) have developed standards making **offal management** a key part of any mitigation strategy by ensuring offal is not discharged at the same time as lines are being set or that offal disposal during hauling operations is carried out on the opposite side of the vessel. Offal retention (for subsequent disposal when not setting or hauling is occurring) is recommended by ACAP (2019), but it has been highlighted that there may be logistical, or safety constraints associated with the temporary storage of all offal onboard (Bull 2006).

1.4.2 Gear-based Approaches

A factor known to influence seabird bycatch rates in longline fisheries is the speed at which the baited hooks sink through the upper part of the water column during line setting operations (Bull 2006; Lokkeburg 2008; Parker 2017; ACAP 2019). ACAP (2014) produced guidance on minimum line sink rates of 0.3 m/s required to reduce opportunities for surface and near surface feeding species to access baits. Increasing line sink rates above 0.3 m/s is suggested as part of a suite of complementary measures which are used concurrently, and it is not recommended as a standalone approach to bycatch mitigation.

Under commercial conditions sink rates are likely to vary due to factors such as prevailing sea state, effects of upwellings caused by a vessels propellor, buoying effects of bycaught birds and variable materials, shapes and sizes of the weights used (ACAP 2014). In general, research into the effects of line sink rates has either focused on recording line sink rates directly, or by assessing changes in bycatch rates under different weighting configurations (Bull 2006).

Robertson (2000, in Bull 2006) assessed sink rates under different external **line weighting** regimes by placing 6.5kg weights at various spacings (30m, 50m, 70m, 100m, 140m and 200m) in the demersal longline fishery for Patagonian toothfish near the Falkland Islands. As might be expected, overall sink rates decreased as spacing between weights increased. The sink rate in the top part of the water column was highest with weight spacings of 30m and 50m. Sink rates through the water column did not vary much when weights were spaced 70m or above. A study investigating different weighting regimes (4.25kg, 8.50kg and 12.75kg at 40m spacings) in the Patagonian toothfish fishery around South Georgia found a significant reduction in seabird bycatch rates when 8.50kg rates were used compared to 4.25kg weights, but no additional reduction was achieved by using 12.75kg weights (Agnew et al. 2000, Bull 2006).

Melvin et al. (2001) assessed the effects of adding weights to demersal longlines in fisheries targeting Pacific cod (Gadus macrocephalus) in the Bering Sea and sablefish (Anoplopoma fimbria) in the Gulf of Alaska where northern fulmar are the most frequently bycaught seabird species. In the first year of the study the addition of 10lb (4.5kg) weights every 90m in the cod fishery and 0.5lb (0.25kg) weights every 11m in the sablefish fishery reduced overall seabird bycatch rates by 76% and 37% respectively. However, in trials the following year when the same weighting regimes were compared against bycatch reduction rates associated with the use of paired BSLs no significant reduction was seen. Marked differences in seabird abundance, bait attack rates and bycatch rates were seen between the two years and the authors concluded that extreme inter-annual variation in rare event phenomena such as seabird bycatch has important implications for fisheries management, and that adequate evaluation of seabird bycatch deterrents via observer programs will require multi-year data sets.

The use of **integrated weighting in mainlines** was tested in a demersal longline fishery in New Zealand (Robertson et al. 2004; Robertson et al. 2006). A comparison between lines with integral weighting of 50g/m and standard unweighted lines produced significant reductions of 95%-98% in bycatch rates of white-chinned petrels (Procellaria aequinoctialis) and 60%-100% reductions for sooty shearwaters (Ardenna grisea). Commercial catch rates were not affected.

In trials in the Alaskan demersal longline fishery targeting cod in the Bering Sea, three experimental mitigation treatments (integral line weighting, integral weighting with BSLs and unweighted lines with BSLs) were compared with a control of no mitigation (Dietrich et al. 2008). Integrated weighting reduced bycatch rates of surface feeding species (northern fulmar and Larus spp.) by 91% to 98% and a diving seabird, the short-tailed shearwater (Puffinus tenuirostris) by 80% to 87%. It was also estimated that integral weighted lines reduced the distance behind the vessel that birds had access to baits by almost 50% when compared to non-weighted lines.

Robertson et al. (2004) recorded link sink rates of unweighted lines and weighted lines made from two materials – silver line and polyester. Tests were carried out from two chartered vessels and no differences in sink rates were found between vessels, but statistically significant differences were observed between line types. The weighted polyester line sank fastest (mean 0.272 m/s), followed by the weighted silver line (0.239 m/s) and the unweighted line (0.109 m/s). However similar sink rates to the weighted lines were achieved by attaching external weights to unweighted lines. In contrast to the findings of Roberson et al. (2004), Pierre et al. (2013, in Parker 2017) found that line weighting configurations and corresponding sink rates varied greatly between vessels operating under normal commercial conditions, which suggests that there could be significant inter-vessel variation in bycatch rates in some fisheries.

The pros and cons of line weighting (external and integral) approaches for reducing seabird bycatch were summarised by Bull (2006) and Parker (2017) and those of relevance to demersal fisheries are tabulated in Table 3.

Table 3: Pros and cons of line weighting approaches for seabird bycatch mitigation (Adapted from Bull (2006) and Parker (2017)).

Pros	**Cons**
There is evidence that optimal line weighting configurations do reduce seabird bycatch.	There are concerns for crew health and safety associated with the use of extra or heavier external weights.
Reduced bycatch and attack rates associated with optimal weighting configurations will lead to less bait loss and may therefore translate into improved target catch rates.	Use of lead weights (integral or external) increases the risk of this potentially harmful compound accumulating in the marine environment.
Integral weighted lines are safe for crew to use.	Adding extra weights increases crew workload.
Integral weight lines have a uniform sink profile which eliminates lofting associated with external weighted lines (ACAP, 2016).	Integral weight lines are typically used with auto-lining systems so may not be suitable for all vessel configurations.
Appropriate weighting can maintain hooks at the correct depths so may improve target catch rates.	The use of appropriate external weighting regimes can only be checked through at-sea inspections.
Catch rates of target species were not reduced using integral weighted lines.	Integral weight lines may lead to higher catches of unwanted fish and elasmobranchs because the main line sits on the seabed.
The use of integral weighted lines can be checked in port inspections.	Increased gear costs.

Branch line weighting approaches to bycatch mitigation are normally associated with pelagic longline fisheries where snood lengths are much longer than in demersal fisheries, and so additional weighting will sink the bait more rapidly out of the range of surface feeding birds and keep it below the normal foraging range of diving seabirds. To date there seems to be little research done on branch line weighting in demersal fisheries where snood lengths are short, and baits may be quite close to the seabed when actively fishing so could become snagged if additional weights are added. However, a new longline configuration was developed in 2005 in Chile to try and reduce cetacean depredation in a demersal fishery (Moreno et al. 2007), that is conceptually similar to a branch line weighting approach. The system has been termed the “Chilean longline” and consists of a mainline off which hang weighted branch lines of 15m long at approximately 40m spacings. From each of these branch lines are multiple snoods with baited hooks. One of the inadvertent but positive side effects of using this system was that seabird bycatch was eliminated during the three-year trials of the system (Moreno et al. 2007). The observed bycatch reduction was considered to be entirely associated with the very high initial sink rate that occurs because each branch lines has individual weights of 4kg-10kg.

Investigations into the potential bycatch reduction effect of using **thawed rather than frozen baits** have largely focused on pelagic fisheries but may have relevance to demersal fisheries. Parker (2017) provided a short summary of work that has been conducted in this area. Two studies (Brothers et al. 1999; Klaer and Polacheck 1998) indicated that thawed baits sink faster, one tested actual sink rates (they also found that swim bladder state affected sink rates) and the other compared seabird bycatch rates from thawed and frozen baits and assumed because rates were lower with thawed baits that sink rates must therefore be higher. However, when Robertson et al. (2010) tested thawed versus frozen bait sink rates they found only a negligible effect and concluded that there would be no significant reduction of seabird bycatch rates with thawed baits. Some issues associated with the use of thawed baits highlighted in Parker (2017) are that: baits may not be fully thawed before deployment, there is a lack of evidence of efficacy of this approach across bait types; thawed baits may detach from hooks more easily and bait thawing requires a specific part of the vessel to be set aside for this task.

Li et al. (2012) developed generalised linear models to examine the effects of **different hook sizes and shapes** from longline data collected under the US National Marine Fisheries Service (NMFS) Pelagic Observer Programme in Atlantic waters. Four combinations of hook shape and size (8/0 J-hook; 9/0 J-hook, 16/0 circle hook; 18/0 circle hook) were used in the sampled hauls. Results indicated that combinations of hook type and size significantly influenced the probability of catching seabirds. The 8/0 J-hook (the smallest of the four types) was associated with the highest bycatch probability. Both sizes of circle hook had the lowest bycatch probability, but the authors state that results may be confounded by other factors such as bait type, location, season and target species and the relatively low number of recorded seabird bycatches in the analysed dataset. Similarly, a study of the variables affecting seabird bycatch (including black-browed albatross (Diomedea melanophris), white-chinned petrel (Procellaria aequinoctialis) and southern giant petrel (Macronectes giganteus)) by Argentinian and Chilean vessels targeting

Patagonian toothfish found that hook size was an important source of variation in bycatch rates (Moreno et al. 1996). A significant inverse relationship between hook size and bycatch rate was found.

A study by Fangel et al. (2017) analysed three years of data from a small-vessel demersal longline fishery for Greenland halibut (Reinhardtius hippoglossoides) in coastal water of northern Norway. Most of the seabird bycatch in the fishery is of northern fulmar. Using statistical models to explore the data, they found no significant trends related to environmental, spatial or temporal factors that could explain the variation in bycatch rates. However, they did find that trips where non-swivel hooks were used had bycatch rates about 100 times higher (mean= 0.760, SE =0.160) than trips which used swivel hooks (mean 0.008, SE 0.002). Another interesting finding was that about two-thirds of the bycaught birds were adults, and that males dominated (71.1%). Beck et al. (2020) also reported a strong sex bias in fulmar longline bycatch in Alaska, where 66% of bycaught fulmars were male. The Fangel et al. (2017) study did not determine the reason for the lower rates associated with the use of swivel hooks but the authors suggest it might be related to the bait behaving less predictably in the water on a swivel hook, the swivel hooks might have a lower hooking efficiency for fulmar (or surface feeding seabirds in general), or the swivel hooks may sink more rapidly because they weigh 6g compared to 2g for the non-swivel hook. Fangel et al. (2017) comment that given the apparently significant reductions associated with the use of swivel hooks observed in this fishery, further research should be undertaken in other fisheries to assess if this finding applies elsewhere.

Much of the research into hook related approaches to seabird bycatch mitigation has focussed on the efficacy of what are generically termed **hook shields**. The basic premise of hook shields is that a weighted plastic or metal case/capsule covers the hook point and barb during line setting but then releases the hook at a predetermined depth below the likely foraging range of surface feeding or diving birds. To date, most of the investigations into the utility of hook shielding devices have focussed on pelagic longline fisheries with generally positive results (Sullivan et al. 2017, Goad et al. 2017 (in Debski et al. 2018), Jusseit 2010). However, given the significant operational differences between pelagic and large scale demersal longline fisheries it is not clear if hook shields have a useful role to play in bycatch mitigation in demersal longline fisheries.

1.4.3 Non-technical approaches

Non-technical approaches to bycatch mitigation are often classified as either regulatory (top-down) or voluntary (bottom-up) and may involve the development and implementation of input measures (also known as process standards) which aim to control or alter the fishing activity in some way or output measures (also known as performance standards) which aim to control the result of that fishing activity (Morrison, 2004; Squires et al. 2021). Non-technical approaches can be used in isolation or in combination with technical approaches such as those described in the previous sections.

Input measures typically involve management regimes that place restrictions on the level of fishing effort (such as restricting gear dimensions or the number of days vessels are permitted to fish) or by managing the spatio-temporal distribution of effort.

Input measures that reduce effort levels could be successful at reducing bycatch if there is a clear and predictable relationship between effort and bycatch levels, but that relationship is not always straightforward for taxa such as seabirds that are mobile, wide-ranging and exhibit relatively rare but often clumped patterns of bycatch (Baerum et al. 2019; Northridge et al. 2020). Simple effort reduction approaches would almost certainly reduce commercial catches so could significantly affect the economic viability of the fishery and adequately describing those economic consequences is beyond the scope of this review.

However, an increasingly widely advocated input measure for conservation purposes are **spatio-temporal closures**, which have been introduced in some parts of the world specifically to reduce bycatch of various highly mobile taxa, but generally with mixed results.

Croxhall (2008) describes the development of albatross bycatch mitigation measures in the Patagonian toothfish longline fishery in the Southern Ocean from the 1990's to the early 2000's. Most of the mitigation measures employed were technical approaches (BSLs, line weighting, offal management) but a seven-month closed season was introduced around South Georgia in 1995, which was subsequently extended to nine months a few years later. No closure was introduced in the Southern Indian Ocean fishery, but the same technical approaches were used. Croxall (2008) reports that equivalent bycatch reduction in the Indian Ocean fishery took longer to achieve than in the South Atlantic fishery, suggesting this is at least partly because of the absence of the closed area in the Indian Ocean example.

Spatio-temporal closures have also been considered for a range of other mobile and widely distributed species. Murray et al. (2001) assessed the effectiveness of a large scale but short-term (1 month) closure off New England (U.S.A.) to reduce harbour porpoise (Phocoena phocoena) bycatch using at-sea observer data to compare bycatch rates before, during and after the closure and concluded that the measure was ineffective because of spatio-temporal variation in patterns of bycatch rates and the effects of displaced fishing effort. Grantham et al. (2008) evaluated the cost/benefit of three different closure approaches for reducing seabird, shark and turtle bycatch in a longline fishery in South Africa and found that temporary, rather than permanent or seasonal closures, were the most effective at reducing bycatch and minimising costs to industry. Using computer simulations Smith et al. (2021) found that only dynamic (as opposed to static) spatio-temporal closures had the potential to reduce bycatch of the highly mobile leatherback turtle (Dermochelys coriacea) in pelagic longline fisheries, and that relatively high levels of observer coverage of 20% was the minimum required to provide an evidence base for implementing effective closures. Pinn (2018) reviewed the evidence for the conservation benefits of Marine Protected Areas (MPAs) for cetaceans. This review concluded that in most cases MPAs failed to achieve conservation goals because of changes in the spatial distribution of populations for which the protected area was designated, a lack of enforcement or management measures within the MPA and the need for additional measures beyond the MPA boundary. O'Keefe et al. (2014) evaluated the effectiveness of a variety of commercial and non-commercial species bycatch mitigation approaches, including spatio-temporal closures, by a meta-analysis of the results of multiple studies. They found that many of the closures considered did not successfully reduce bycatch, and in some cases created new bycatch issues due to the unforeseen effects of fishing effort displacement. Those closures that successfully reduced bycatch were well designed, typically involved industry input, were economically viable, involved a suite of measures and gave due consideration to possible unintended consequences (O'Keefe et al. 2014).

The use of **output measures** involves the development of some predefined acceptable bycatch level or required bycatch reduction but the actual means of achieving such a standard is not necessarily prescriptive (Squires et al. 2021) but would be implemented in terms of a bycatch quota or allowance. The use of output measures in relation to bycatch has typically involved the development of a bycatch threshold (or limit or target). Thresholds can either be heuristic, such as the ASCOBANS 1.7% of population abundance human induced mortality rate for harbour porpoise (Scheidat et al. 2013) or explicitly designed based on the biological characteristics of a specific population, such as Potential Biological Removal (PBR) which is used under the USA Marine Mammal Protection Act (Punt et al. 2020) and has been proposed for use for seabirds by OSPAR and HELCOM. Bycatch thresholds can be highly sensitive to the input values used in the calculations and so important pre-conditions for the effective use of thresholds are 1. the existence of clear and agreed management or conservation objectives and 2. robustly defined assessment units. In practical terms implementing output measure-based approaches would require the distribution of a bycatch "quota" across vessels and fisheries to ensure that bycatch levels were within the accepted thresholds.

1.5 Discussion

Previous studies have not revealed any clear and consistent risk factors associated with fulmar bycatch among longline fisheries. Studies in Alaska found that fulmar behaviour and distribution can change sharply year to year, and statistical models suggested that among various fishery related factors, vessel identity did most to explain observed variation in bycatch. Setting at night also increased fulmar bycatch in Alaska substantially. In Norway, the use of swivel hooks was associated with much lower fulmar bycatch rates, but no other fishery related factor stood out as being important. Nevertheless, the numerous technical approaches to reducing seabird bycatch in longline fisheries that have been trialled around the world and summarised above provide a basis for identifying plausible approaches to addressing this issue in relation to fulmars in UK waters.

The technical mitigation approaches reviewed above have met with varying degrees of success, highlighting the point made by Melvin et al. (2019) and many others that *"conservation measures should be fishery specific".* The issue is complicated by the fact that birds are highly mobile and subject to behavioural changes that affect how likely they are to get caught.

The majority of seabird bycatch in longline fisheries involves capture on a baited hook which occurs during line setting or less frequently during hauling operations if the bait is still in place. There are occasional reports of birds becoming tangled in snood lines (Moreno 1996), but this appears to constitute a much lower risk. This has led to an emphasis on the development of longline mitigation approaches that either deter birds from the vicinity of the hooks as lines are set, or through methods to ensure that lines are quickly out of the foraging depth range of the species in question.

Bird-scaring lines (BSLs) have been tested successfully in numerous fisheries and are currently legally required in some longline fisheries, including in the USA, Brazil and Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) waters. The specifications for the BSLs in these fisheries are described within the relevant regulations and are fishery specific but have some common attributes that aim to maximise bycatch reduction rates through requirements for line attachment heights, line length and streamer length etc. The recommended configurations are also designed to minimise operational problems that can occur, such as BSLs tangling with the longlines during line setting and so reduce time/cost implications for industry which can help encourage uptake and/or compliance. By reducing bycatch levels and bait loss, the use of BSLs may also increase fish catch rates which would be attractive to industry.

Discussions with industry, and observer data, indicate that BSLs are already being used on a voluntary basis by at least some of the vessels in the UK offshore longline fleet, but that problems with entangling the longlines are quite regularly experienced, and the BSLs do not appear to be very effective in some weather conditions. A logical next step might be to test the designs of BSLs that are already used successfully in other similar fisheries to evaluate if they are appropriate for use in the UK fishery.

Other deterrent approaches such as water cannons, lasers, acoustic deterrents and olfactory deterrents appear to be less promising and there is little evidence to support the testing or use of these mitigation approaches in the UK offshore longline fishery.

Several approaches have been developed to try and ensure that baited hooks are deployed below the foraging range of surface feeding birds. Various versions of underwater line setters have been tested and although the underlying principle is logical, most attempts have encountered a variety of problems including the lower end of the device lifting out of the water in heavy weather (which is prevalent in

Scottish waters) making the baits available to birds (Løkkeborg 1998; Ryan & Watkins 2002), to more serious issues of structural damage to vessels (Parker 2017). The consensus appears to be that although conceptually appealing, the development of underwater line setters requires significant future work to make sure they are effective and safe in all sea conditions. At present they do not provide a realistic option for mitigation in the UK fishery.

Line shooters that reduce tension on the mainline by deploying it more quickly than the vessel is moving allowing the hooks to sink more rapidly is an alternative approach, but there is little evidence that the approach significantly reduces bycatch rates or is suitable for large scale demersal longline fisheries. Studies into the use of thawed rather than frozen baits as a means of increasing hook sink rates have produced contrasting results (Brothers et al. 1999; Klaer and Polacheck 1998; Robertson et al. 2010) and there is little evidence that this is a suitable approach for reducing bycatch in a large-scale demersal fishery.

Altering the longline weighting configuration to increase line sink rates, either through changes to the external weights or the use of integral weighted lines, has been shown to reduce seabird bycatch in some fisheries (Agnew et al. 2000; Robertson et al., 2004; Bull 2006; Robertson et al. 2006; Dietrich et al. 2008). However, Melvin et al. (2001) had mixed results in line weighting trials spanning two years and concluded that high inter-annual variation in seabird abundance, bait attack rates and bycatch rates meant that proper evaluations of the effects of line sink rates should be conducted over multi-year periods. ACAP (2014) currently recommend a line sink rate of over 0.3m/s to reduce foraging opportunities for surface/near surface feeders but do not recommend line sink rates as a standalone approach to bycatch mitigation, because under commercial conditions sink rates can vary for a variety of reasons. A short study to quantify line sink rates (Rouxel 2020) was carried out on a single vessel from the UK offshore longline fleet and found that sink rates varied widely depending on the section of the gear, with sections nearer floats sinking more slowly than sections nearer the weights as would be expected. Most of the recorded sink rates were below ACAP guidance, but the study was limited in its scope and these finding may not apply across the fleet and in different conditions. The study does highlight some potential for increasing line sink rates to reduce bycatch in the fishery, but this would require fleet wide assessment of current sink rates and subsequent simulation and significant field testing of modified weighting regimes or complete gear redesigns, and this approach does not appear to be favoured by industry at this time (pers. comm. M. Hermida).

Surprisingly, given that the hook is so prominent in the occurrence of bycatch, there have been relatively few studies investigating how hook designs may influence bycatch rates, and ACAP (2016) did not recommend hook design approaches to mitigation simply because they are insufficiently researched. Perhaps one of the reasons for the lack of studies to date is that the hooks are also of fundamental importance to target species catch rates, so it is possible that there is less inclination to test modifications to that element of the gear. However, there are two interesting findings in relation to the effects of hook size and type in demersal longline fisheries. In the fishery for Patagonian toothfish a significant inverse relationship was found between hook size and seabird bycatch rates (Moreno et al. 1996) and in a Norwegian fishery for Greenland halibut a 95% reduction in fulmar bycatch rates was reported with the use of swivel circle hooks compared to the J hook design that was used as standard in the fishery (Fangel et al. 2017). The exact reason behind the large reduction associated with the use of swivel hooks was not fully determined in the study, and further funding was not secured to extend the work (pers. comm. K. Baerum), however this seems an approach potentially worthy of closer examination in the UK fishery.

Other hook related approaches involve changing the hook colour, altering the hook position in the bait and shielding the hook point during line setting, but as with bait related approaches, most of the research into the effects of these hook modifications have been undertaken in pelagic longline fisheries and the findings do not appear relevant to large scale demersal longline fisheries.

Adapting the operational behaviour of fishing vessels is another approach that has been investigated in relation to seabird bycatch. Night setting is recommended as best practise by ACAP and the New Zealand fisheries management authority. However, work by Melvin et al. (2019) found that for most seabird species bycatch rates associated with night setting were lower, but this did not apply to northern fulmar which showed significantly higher bycatch rates (+40%) in night set operations. This certainly calls into question the relevance of the ACAP recommendation in relation to the UK fishery, where fulmar appear to constitute over 95% of the total seabird bycatch. If the findings of Melvin et al. (2019) are transferable to the UK situation, then a requirement for night setting would likely increase overall bycatch in the fishery. Night setting approaches are also hampered by the shorter night-time period from spring to autumn in high latitude fisheries, such as the longline fishery off Scotland.

A second commonly proposed operational approach is offal and discard management. Seabirds are attracted to fishing boats because they provide a reliable source of food. Daily operational patterns in the UK longline fishery tend to involve a long period of hauling lines and processing the catch, during which offal and discards are disposed of, and then a shorter period of line setting during which most fatal bycatch occurs. This means there is not a clear temporal overlap between offal and discard disposal and the period of highest bycatch mortality risk. However, some bycatch does occur during line retrieval, and this might be reduced by altering where or when the offal/discards are disposed. For example, this might be achieved by routing disposal chutes to exit through the opposite side of the vessel from where hauling occurs, or by keeping offal/discards aboard and disposing of them when lines are no being set or retrieved. Disposing of offal away from the hauling area seems logical and would be possible to implement without major disruption if the deck layout of the vessel was suitable. There may be logistical, or safety issues associated with keeping offal/discards on board for later disposal, as highlighted by Bull (2006), and these would need to be considered carefully before such an offal/discard management approach was implemented in the fishery. This approach might help break the behavioural link between fishing operations and food resource that some birds have clearly learned. However, it is worth considering if the approach of retaining offal/discards on board could in fact increase bycatch rates, if birds began to forage at higher density and more aggressively around the line hauling/setting operations because the previous steady supply of offal/discards had been removed. Sherley et al. (2019) estimated that reductions in fisheries discards in the North Sea between 1990 and 2010 may have led to a 39% reduction in the number of scavenging seabirds that this resource could support. Clearly, some thought should also be given to how changes in offal/discard management might affect the foraging success of those birds that have learnt to feed around longline fishing vessels and what the population impacts of reducing that foraging opportunity might be.

Some bycatch occurs in the UK fishery during line retrieval and in most cases the birds are released alive but will have some level of injury and post release mortality rates are not known. Some measures such as bird-exclusion devices are designed to keep birds away from the line hauling area but the results in terms of bycatch reduction are somewhat conflicting, with some studies reporting reduced interactions (Snell 2008) and others indicating that birds habituate to the presence of the device (Sullivan 2004). Some operational problems where the device tangles with the lines as they are hauled have also been reported (Parker 2017), particularly during use in heavy weather and this would likely constitute a significant safety issue of the vessel and crew. Given that most fatal seabird interactions with the UK fishery are associated with line setting operations the utility of bird-exclusion devices to significantly reduce bycatch mortality is probably limited.

The use of input measures to reduce seabird bycatch would require a significant management effort to firstly define clear species-specific management/conservation objectives, then detailed quantitative assessments using robust data to evaluate how those objectives might best be achieved and this should include a proper consideration of unintended consequences, and an economic impact assessment to understand the financial impacts on industry and possible changes in food supply to society. Output measure approaches would also require the defining of clear management objectives and the setting of bycatch thresholds, but perhaps the most difficult issue is to determine and agree how action to reduce levels to below agreed thresholds (assuming bycatch levels exceed the threshold) would be distributed across the vessels, fisheries and nations that contribute to the known mortality of what are typically highly mobile species with trans-national distributions.

Section 2: Statistical analysis of existing data

2.1 The data

Data used in this analysis were collected by onboard observers and were recorded on a haul-by-haul basis. The data covered a wide range of operational, environmental and catch data including, inter alia, the number of hooks set, line length, soak time, haul start/end times, date and position. The number of bycaught seabirds was recorded by species as the line was retrieved. Bycatch also occurred as the line was retrieved but these specimens were unhooked and are generally released alive. Live bycatch typically appears to form a small part of the total bycatch (circa 6%) but is highly variable and on some observed trips live bycatch exceeded the levels of dead bycatch. Only bycaught birds recorded as "dead" have been used in this analysis.

Most observed hauls (74%) had zero bird bycatch mortalities, and 92% of hauls had three or less bycatches. Counts of bycaught fulmars were highly over-dispersed with a variance to mean ratio of 6.99. Although fulmars accounted for most of the birds recorded, there were also ten northern gannet (Morus bassanus), two great shearwater (Ardenna gravis) and one great skua (Stercorarius skua) mortalities recorded.

The preliminary bycatch estimates for the longline fishery produced by Northridge .et al.(2020) were based on 14 trips sampled between 2010 and 2018. Sampling in the fishery continued after 2018, and by June 2021 observers under the BMP had undertaken a further four trips. Revised preliminary estimates were produced in summer 2021 incorporating all the data collected from 2010 to June 2021 using a similar analytical approach to Northridge et al.(2020). These updated estimates are presented in Section 3. A further five trips were also sampled between August and November 2021, increasing the total number of observed hauls from 103 in 2018 to 201 by the end of 2021, effectively doubling the amount of available data since the Northridge et al.(2020) report. The full 201 haul dataset was subsequently (late 2021) used to produce estimates for four species: northern fulmar, northern gannet, great skua and great shearwater using a modelling approach, rather than the ratio-based approach used in the earlier preliminary and revised preliminary estimates. Modelled estimates are provided in Section 3.

An important initial objective in our analysis was to examine how representative of the wider fleet activity the sampling data were. It is likely that the sample dataset contains significant biases, as hauls are not sampled in a truly random manner across the fleet, and haul observations are constrained by the fact that an observer must remain on the same vessel for the full duration of a trip.

The mean number of hauls per trip was 8.7 (95% confidence interval: 6.9 – 10.7). When hauls were considered within trip there was no evidence for any temporal clumping of the data (from a runs test on the per haul bycatch) for any of the bird species observed bycaught.

2.2 Are sampling data representative of fleet activity?

The UK offshore longline fleet undertakes approximately 500 trips per year. Annual sampling coverage in the longline fishery has been limited and largely carried out on a sporadic and opportunistic basis since 2010. By the end of 2021 a total of 23 trips and 201 hauls had been observed, meaning sampling coverage was typically less than 0.5% of total effort (in trips) per year. Total sampling effort in the fishery over the last decade equates to about 5% of the annual UK fishing effort in a typical year. According to official fishing effort statistics the UK longline fleet consisted of approximately 40 vessels since 2010 but this is misleading. Some vessels involved in the fishery have changed over the years and vessels may also change ownership and names, but usually there are about 10 to 15 vessels actively operating in any one year. Sampling trips have been undertaken on six different vessels between one and five times each. The selection of sampled vessels is essentially opportunistic and is based on the willingness of skippers and owners to carry observers. All sampled vessels so far are members of one of the two main industry representative organisations involved in the fishery.

Making robust comparisons between low level sampling effort and overall fleet fishing effort for this fishery is not straightforward because the distribution of fishing effort is variable and relatively unpredictable within and between years. As an initial overall comparison Figure 1 shows the distribution of fishing effort by the UK offshore longline fleet (defined here as vessels over 20m in length targeting hake and to a much lesser extent ling (Molva molva) over the period 2000 to 2019 and sampling effort over the period 2010 to 2021. Yellow circles denote fishing effort by the fleet (in days at sea by ICES rectangle), while black triangles denote the sampled haul locations. Fleet effort has been mainly concentrated along the continental shelf edge especially North of Scotland. Sampled hauls are mainly north of Scotland, but also west and south of Ireland. Depth contours of the coastlines, 200m, 500m and 1000m isobaths are also show for context.

In general, there is reasonable agreement between the distribution of sampling and fleet fishing effort but given the low coverage levels it is expected that there would be some areas that are not particularly well represented. Sampling appears to have been relatively over-emphasised in the more northerly region and relatively under-emphasised between about 53^{o} N (Northwest Ireland) and 58^{o} N (West Scotland) and at around 51^{o} N (Southwest Ireland).

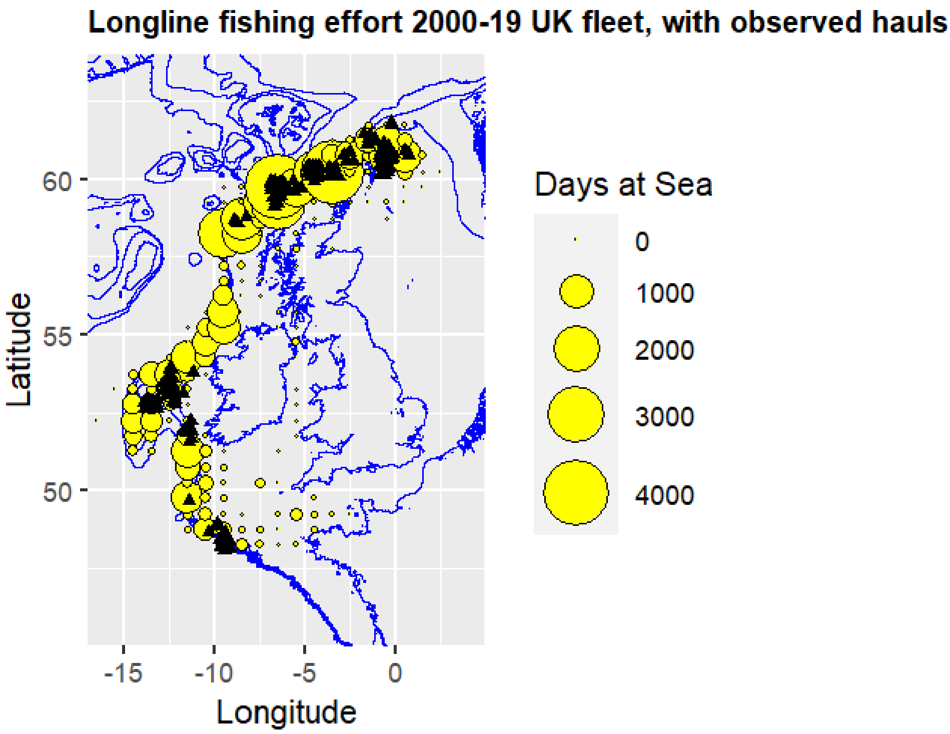

Figure 1: Spatial co-occurrence of 2000 - 2019 fleet fishing effort (yellow dots indicate fishing effort days at sea per ICES rectangle) and sampling effort since 2010 (dark triangles indicate individual hauls).

The relationship between fleet effort and observer sampling effort is demonstrated more clearly by examining the difference between the proportions of sampling to fishing effort along a latitudinal axis over the period 2010 to 2019. Figure 2 shows how the proportions of sampling, by half a degree of latitude (equivalent to the latitudinal dimension of an ICES rectangle) corresponds to the distribution of fishing effort. Values close to the 0% Y- axis indicate that the proportion of sampling is close to the proportion of fishing effort at that latitude. Values strongly negative indicate proportionally less sampling effort than fishing effort, while values with strongly positive values indicate proportionally more sampling effort than fishing effort.

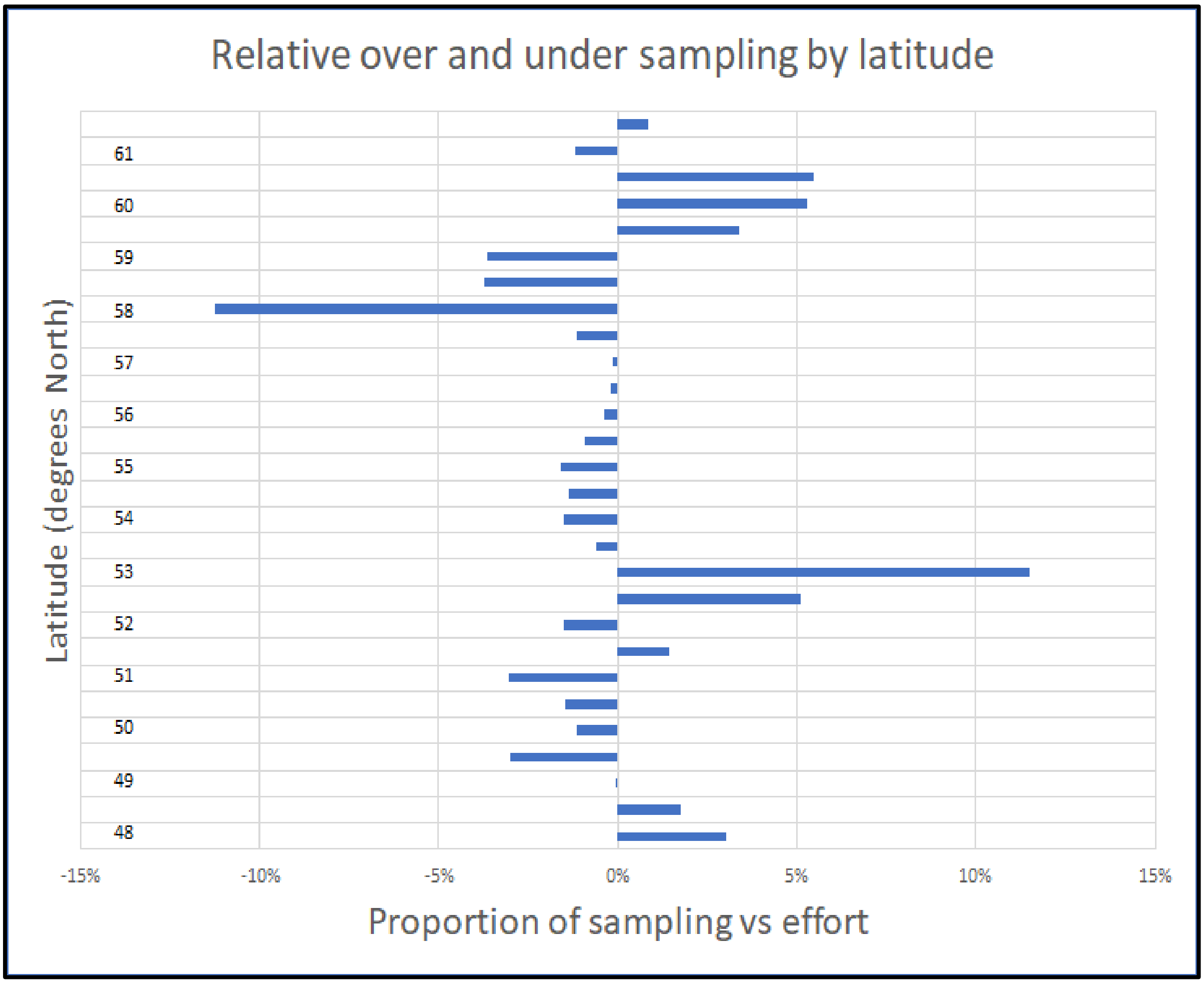

Figure 2: Relative under and over sampling of the longline fleet by latitude (negative values indicate areas with lower proportional sampling, positive values indicate higher proportional sampling).

Figure 2 indicates that there is some systematic spatial bias in the sampling data through relative over-sampling at higher latitudes (60º – 62º N, roughly the latitude of the Shetland Isles) and at some mid latitudes (clustered around 53º N, roughly the latitude of west Ireland) but relative under-sampling between 54º and 59º N (roughly northwest Ireland to the Scottish Western Isles). In part at least, this is explained by the fact that only about 200 hauls have been sampled, and hauls are autocorrelated within trips, meaning that sampling tended to occur in clustered regions within the full range of the fishery. Only by increasing sampling coverage levels and by specifically targeting sampling into specific areas would sampling ensure better representation across a wider range of latitudes. However, planning sampling in a fishery that ranges unpredictably over an area from the northern Bay of Biscay to the northern North Sea is challenging. Vessels tend to move fishing grounds within and between years to follow the concentrations of their target species, and potentially for other operational reasons. This means that it is difficult to focus sampling effort precisely on specific locations within the full fishery range in a way that would ensure more representative sampling distribution.

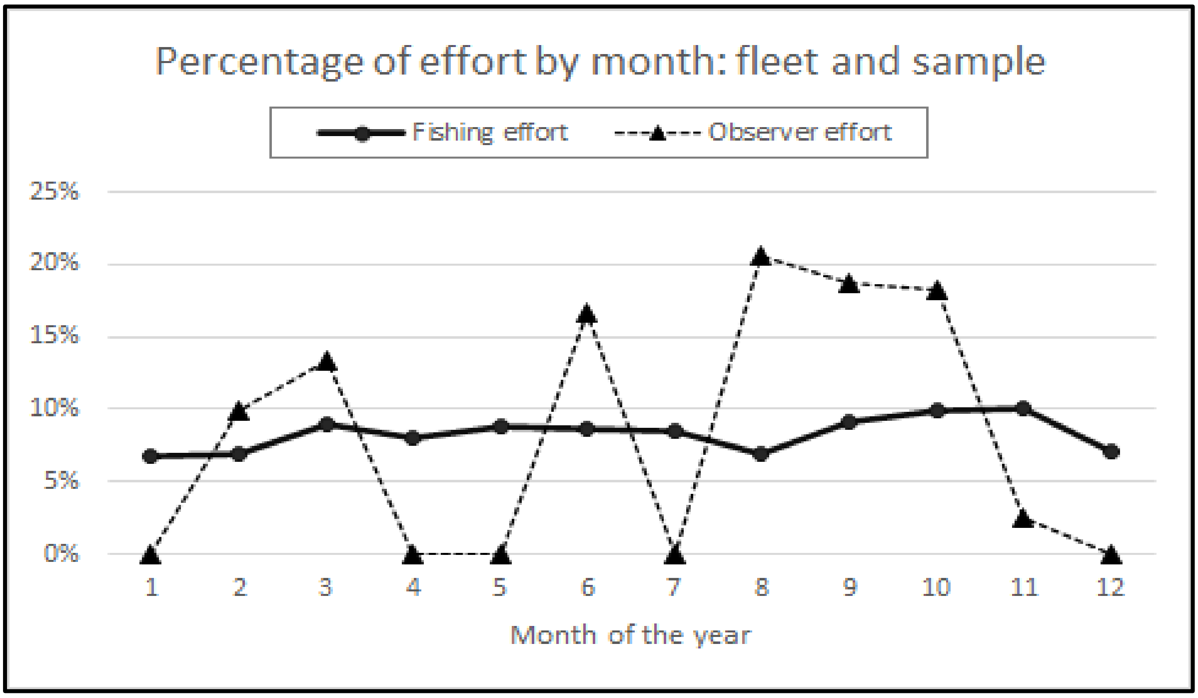

Figure 3: Fleet fishing effort and sampling effort: average % of total (2010 to 2019) by month.

Ideally, intra-annual sampling levels would reasonably reflect fishing effort levels across the year. Figure 3 shows how observer sampling effort (orange line) was distributed by month, compared with fleet effort (blue line) by month over the ten-year period (2010 to 2019). Monthly fishing effort is more stable than monthly sampling effort and sampling does not closely represent the pattern of intra-annual fleet effort. Sampling levels were higher in the summer and early autumn months, and clear gaps are evident in December-January, April-May and July.

2.3 Modelling covariates

The data were analysed in a regression framework with the variation in bycatch per haul considered as a function of a variety of input variables. Because of the features of the data, namely the distributional properties and most especially the infrequency of bycatch, two distinct regression methods were considered: Generalized Additive Mixed Models (GAMMs, Wood 2017) and zero-inflated models. Neither approach was perfect for this data but the results from both analyses are presented. Geographic and vessel-based variables were considered.

The data analysed consisted of individual hauls (n = 201) as the primary sampling unit. Hauls are undertaken on specific trips by a specific vessel, which in turn exhibit some degree of geographic clustering within ICES rectangles. Trips were also often spread over more than one (but usually adjacent) ICES rectangle. Some vessels consistently used fewer hooks per day than others (Figure 4). In statistical terms this is described as: hauls nested within trips and trips nested within vessels. Observed bycatch events are statistically quite rare implying a non-normal distribution of the data.

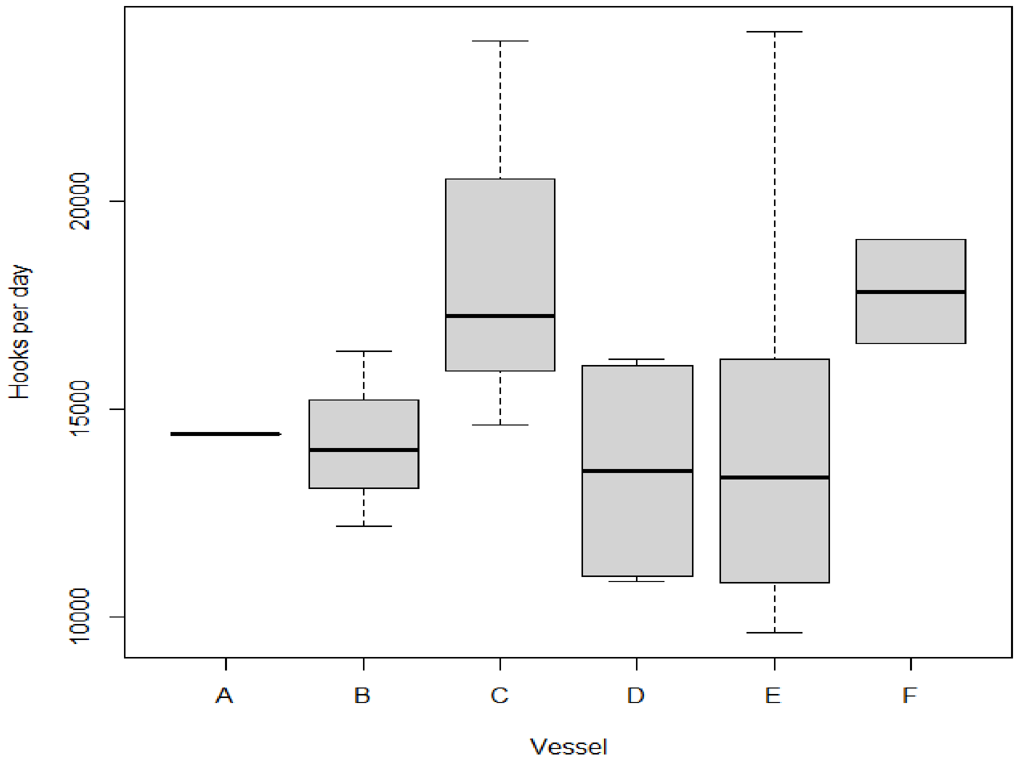

Figure 4: Boxplots of the number of hooks used per fishing day by vessel. Extremes are minimums and maximums.

Given the data constraints (i.e., many zeros and a hierarchical data structure) the data were initially modelled in two ways. First as GAMMs, assuming a quasi-Poisson or negative-binomial distribution of the error to account for the potential correlation in the data and its hierarchical nature. Secondly, zero-inflated models were also considered using the R library pscl (Jackman 2020). In this case Poisson and negative binomial errors were considered. Model simple presence-absence using a binomial error structure was considered but because one output was estimates of total bycatch this was not feasible.

The dependent variable was the number of birds (of the relevant species) per haul. Sampling effort could be classified either by the number of hooks or total line length. Here we used the number of hooks as it was more directly related to the risk of bycatch.

Other available variables of potential influence on bycatch were Sea state, Day of year, Target species, Year, Latitude and Shot time measured as absolute time of day (Shottime) and as a proportion of the night length to account for light effects on bycatch, (Proptime). In addition, there were the broader effects of ICES Rectangle, Vessel and Trip.

Model selection was backwards using a $P<0.05$ inclusion criterion albeit with some modifications. P-value selection is more conservative than using the Akaike Information Criterion (AIC). P-values produce several scores per model and simple ranked model result tabulations, as often presented with AIC estimations, are not particularly informative using P-value based selection, so the model scores are not presented here.

The variables ICES rectangle, vessel and trip were all associated so it was difficult to tease these effects apart. The models were fitted first without these variables, then they were incorporated in the model and backwards model selection recommenced. Models with more than one of these variables produced unreliable fits. So ultimately trip alone was considered in the final models. However, it should be strongly stressed that Vessel, Trip and ICES rectangle are highly confounded in the dataset.

Models were fitted for northern fulmar and northern gannet, as only these two species had sufficiently high bycatch records to warrant an exploratory modelling approach.

2.3.1 Haul models for fulmars

Results are given for model selection undertaken on the two types of models: a GAMM with Trip as a random effect, and a zero inflated Poisson error model with Trip considered as a fixed effect. Both models are not quite ideal. The GAMM is less than ideal because there appears to be a residual structure in the error and the zero-inflated model is less than ideal because it cannot consider trip as a random effect at the cost of a few degrees of freedom and some correlation with the other variables. There was no evidence for unexplained temporal correlation in the residuals after the models had been fitted (see also Section 3.1).

GAMMs

The final model after model selection on the data considered as a GAMM is as follows.

$$E[n_{ij}] = e^{\alpha + b_j + s(\ln(Hooks_i)) + s(Latitude_i)}$$

where n_{ij} represents the count in the ith datum, b_j is the effect associated with Trip factor j where Trip is a random effect (i.e., b_j is drawn from $N(0, \sigma_b^2)$) and Hooks and Latitude were covariates considered initially as thin plate spline smooths. A quasi-Poisson error structure was assumed with a log-link function.

The smooth of hooks collapsed down to a linear effect i.e.

$$E[n_{ij}] = e^{\alpha + b_j + \ln(\text{Hooks}_i) + s(\text{Latitude}_i)}$$

which makes logical sense if bycatch is simply proportional to the fishing effort as might be expected.

Figure 5 illustrates the Hooks effect from this latter model, which concludes that the effect of Hooks while detectable is negligible. Figure 6 shows the Latitude effect from this latter model which shows that more fulmars are caught at higher latitudes.

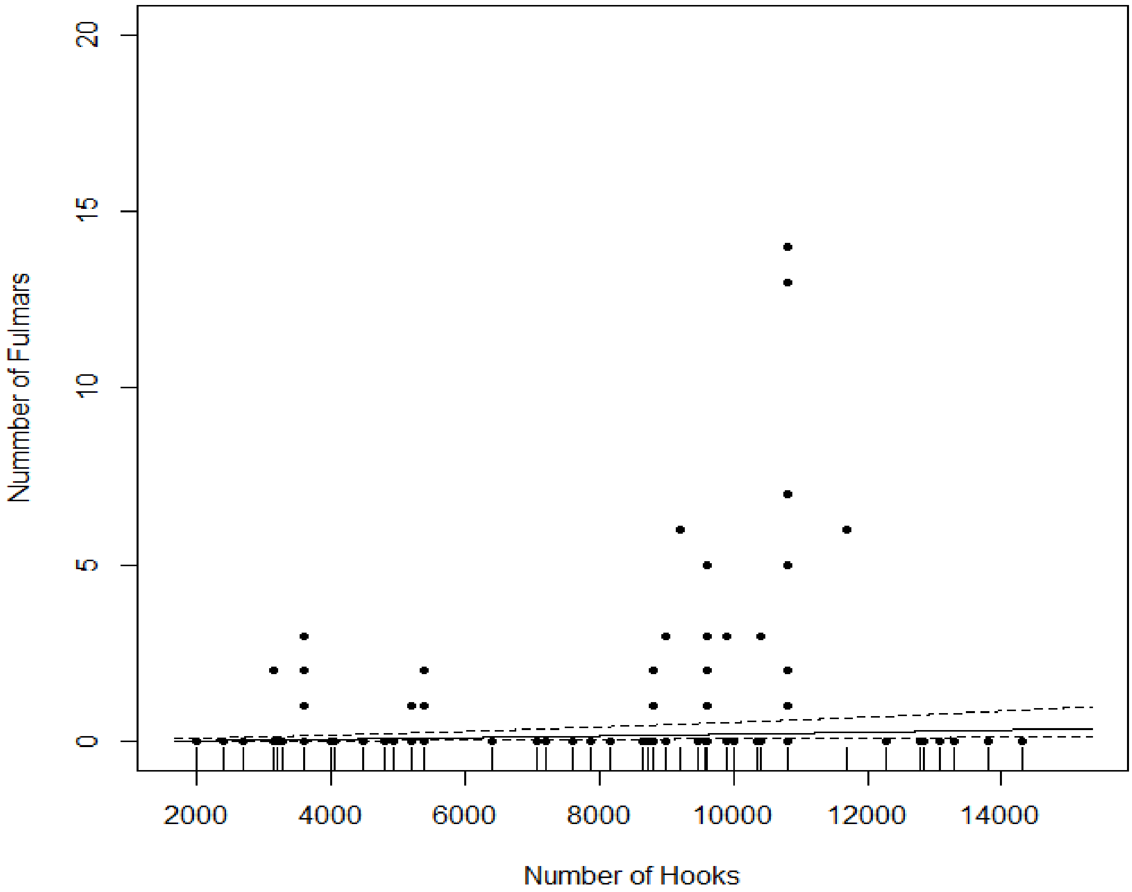

Figure 5: Bycatch of fulmars by number of hooks per line assuming Lat. 57.4° (the mean latitude from the sample). Solid line: point estimate, dashed lines: 2.5% and 97.5% bound on confidence interval. Points: actual points for data (N.B. the points are associated with other latitudes).

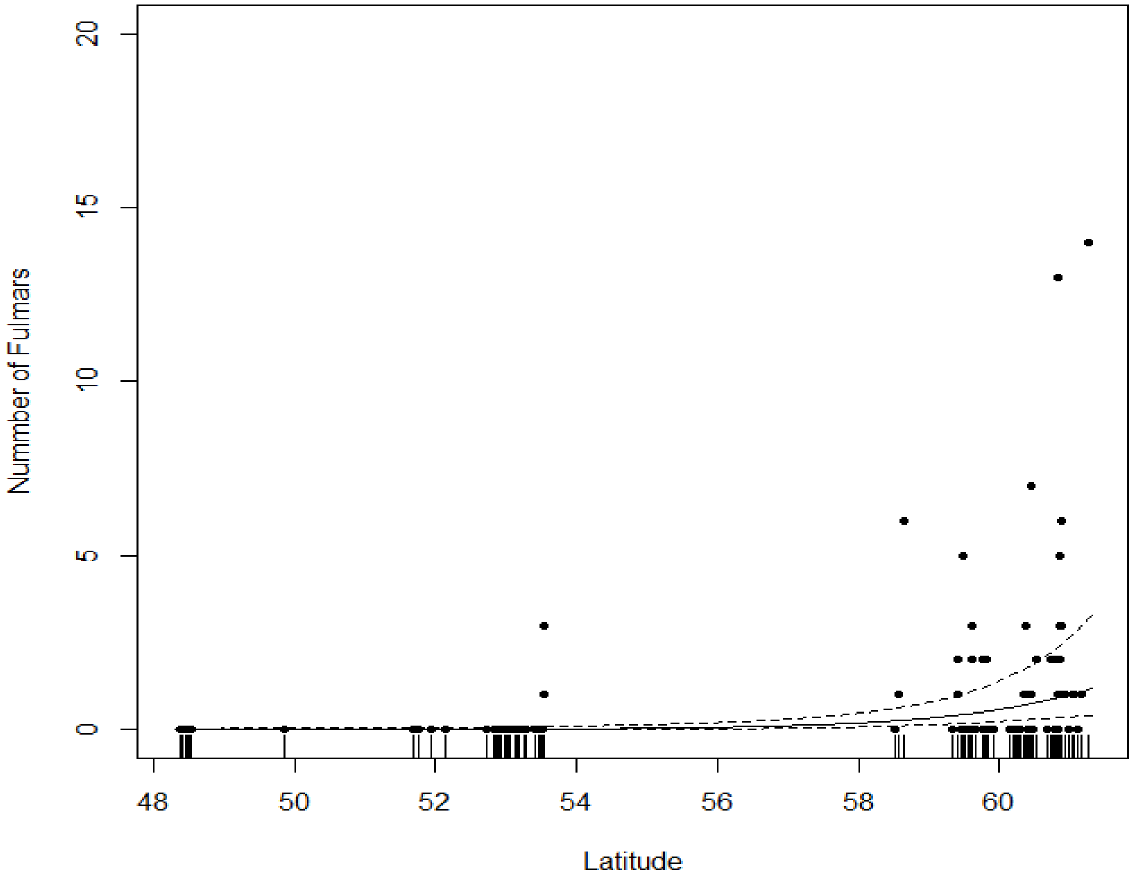

Figure 6: Predicted bycatch of fulmars by latitude per line assuming a line of 7200 hooks (the overall mean of hooks per haul). Solid line: point estimate, dashed lines: 2.5% and 97.5% bound on confidence interval. Points: actual points for data (N.B. the points are associated with other hook values rather than just 7200).

Zero-inflated models

Models with an assumed negative binomial error in the non-zero component were rejected by virtue of diagnostic plots and a boundary likelihood ratio test (after Hilbe, 2011). No fittable model involving Trip was found using backwards selection so forward selection with Trip was commenced based on the reduced set of variables found by the initial backwards selection. The best model here, consisted of Trip in the probability component (considered as a fixed factor) and number of ln (hooks) as a linear function in the count component of the model (Figure 5). The error was considered Poisson.

The count component was

$$\mathrm{E}[\mathrm{n_i}] = \mathrm{e}^{\ln(\mathrm{Hooks_i})}$$

The probability component is of form

$$p_j = \frac{e^{a_j}}{1 + e^{a_j}}$$

with α as the coefficient associated with every fixed level j of Trip.

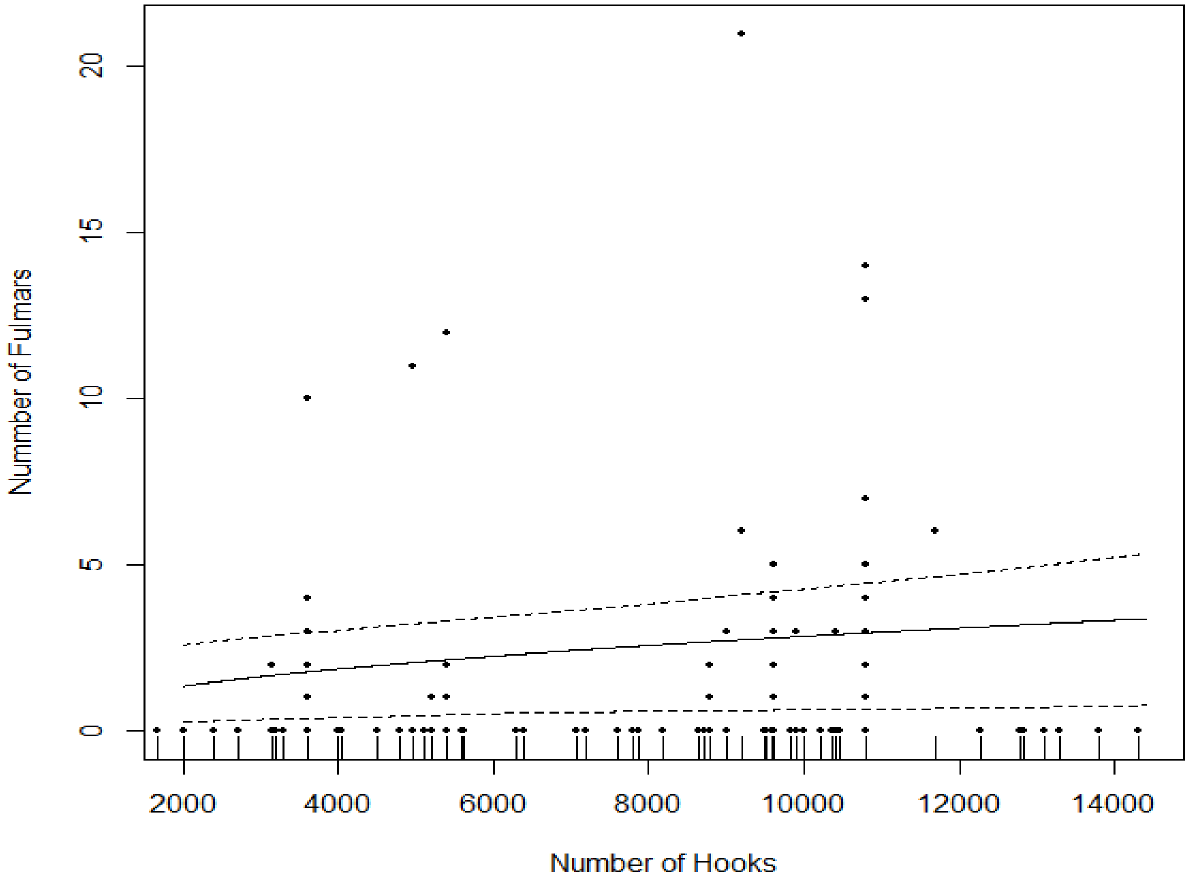

Figure 7: Predicted bycatch of fulmars from the zero-inflated model by number of hooks per line assuming trip 12 and day of year 215. Solid line: point estimate, dashed lines: 2.5% and 97.5% bound on confidence interval. Points: actual points for data (N.B. the points are associated with other trips than just trip 12 and other days than just 215).

No model that captured any effects on northern gannet bycatch could be found.

After considering the merits of the different models, the GAMM was used for estimating bycatch as these models seemed to be more robust.

Section 3: Estimating bycatch using sampling data

Ratio-based and model-based approaches were used to produce new bycatch estimates for northern fulmar. The model-based approach was also used to produce new estimates for great skua, great shearwater and northern gannet. The production of these new estimates is described below.

3.1 Revised ratio-based estimates

Preliminary estimates of bycatch in the longline fishery (Northridge et al.2020) indicated annual bycatch of about 4,500 northern fulmars, with confidence intervals running from two thousand to nine thousand. These initial estimates were derived from a very small sample size of 102 observed hauls from 14 trips undertaken between 2010 and 2018.

Revised estimates produced under this project for northern fulmar were generated using a larger dataset (an additional 63 hauls collected during 2018 and 2019) and a bootstrap by trip approach, rather than bootstrap by haul, as was done by Northridge et al.(2020). The revised approach also used fishing effort data from 2000 to 2019, rather than the two years fishing effort data (2016 and 2017) used in the Northridge et al.(2020) estimates. This new approach produced mortality estimates with wider confidence intervals than Northridge et al.(2020).

Over the 20-year period the revised estimates were produced for, estimated northern fulmar bycatch in the longline fishery ranged from about 1000 individuals per year to around 4000 individuals per year, and associated confidence intervals ranged from a few hundred individuals to close to ten thousand individuals per year (Figure 8). The revised estimates for the calendar years 2016 and 2017 specifically (as highlighted in Figure 8), of about 4000 fulmars per year are fairly similar to the preliminary estimates produced by Northridge et al.(2020) but the confidence intervals are wider.

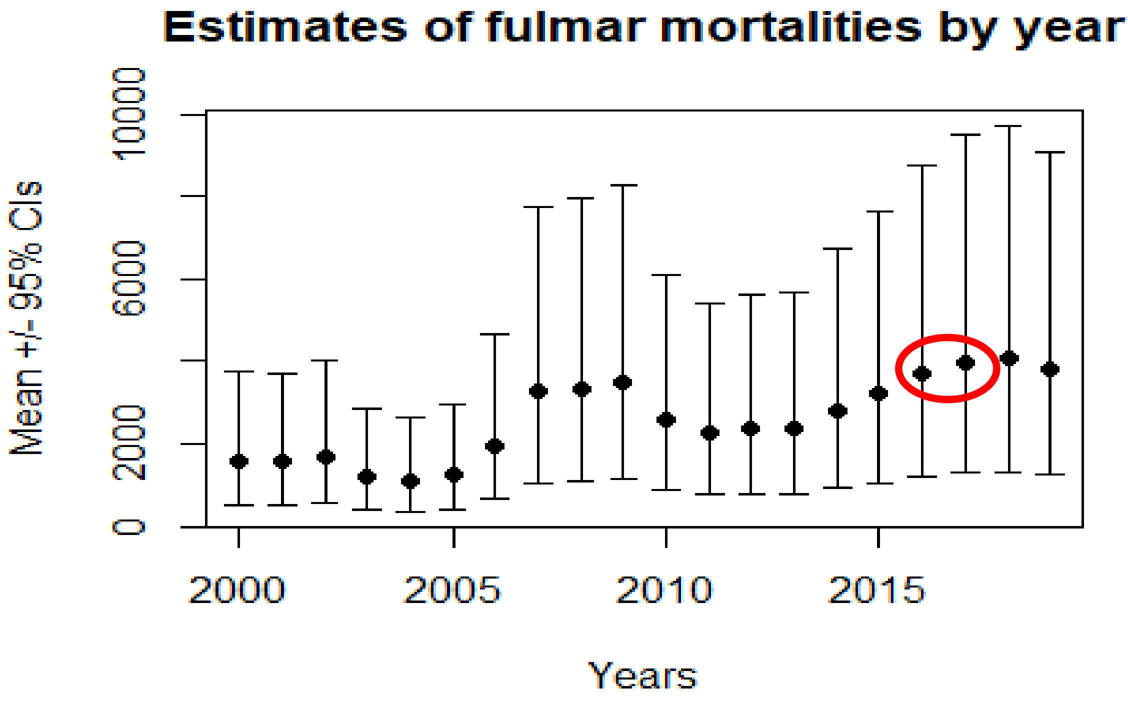

Figure 8: Revised ratio-based estimates for northern fulmar generated using a bootstrap by trip method on 165 observed hauls to July 2021. Calendar years 2016 and 2017 are indicated by the red circle.

3.2 Modelled bycatch estimates

With additional observer data collected up to October 2021, a more detailed model driven approach to estimating bycatch mortality was also developed and is described below. In addition to northern fulmar, the modelling approach has enabled bycatch estimates to be produced for great skua, great shearwater and northern gannet, which were observed bycaught in small numbers.

3.2.1 Methods

To produce estimates of bycatch across the entire longline fleet, the observed bycatch data were considered along with an estimate of the number of hauls per day at sea derived from the observed trips (n=23), which we assume are representative of the number of hauls per day in the wider fleet. In addition to the observed data, UK fleet effort summaries were used since 2000 to estimate fishing effort (days at sea) by ICES rectangle and year. There was a positive relationship between the number of hauls and trip length in the observer data (Figure 9), however this was not incorporated into the estimation, but instead the observed mean number of hauls per day was used to estimate the fleet effort in that metric.

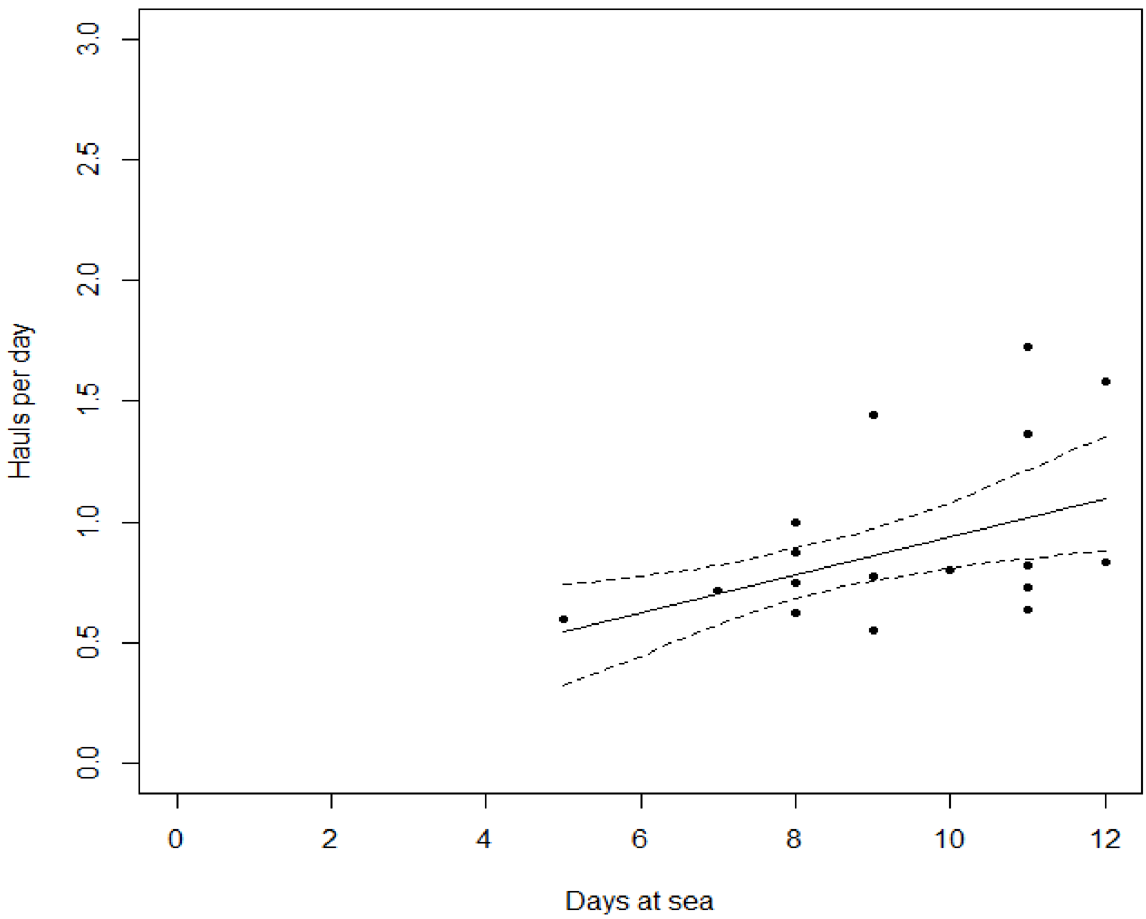

Figure 9: Hauls per day by trip length from the 23 sampled trips. Solid line: best fit line. Dashed lines: 2.5% and 97.5% confidence intervals generated from a non-parametric bootstrap on trips.

With the mean observed bycatch per ICES rectangle by month, mean observed bycatch by month alone, mean observed bycatch by ICES rectangle alone and overall (across all rectangles and months) estimated, the estimation procedure was as follows:

For each year of effort,

1. the relevant ICES rectangles were considered in turn.
2. the number of hauls by the fleet was estimated from the number of days per rectangle.
3. the number of bird catches for that ICES rectangle for that month was calculated given the number of hauls. If haul data for that ICES rectangle were not available, then the bycatch was taken for the mean of that month in the data. If month was not available, then bycatch per haul was estimated from the mean of the ICES rectangle over the surveyed trips and if neither month nor ICES square were available, overall bycatch per haul was

considered. However, in the case of fulmars if data was missing mean bycatch per haul were taken from the predictions for the relevant latitude from the GAMM model.

4. Sum bycatch for each relevant ICES rectangle in question
5. Sum for year in question.

To obtain uncertainty around the estimates, the whole process was then repeated 1000 times as a non-parametric bootstrap, resampling with replacement the hauls per day data and the bycatch per haul data. Non-parametric bootstrap estimates were also obtained for the GAMM model by latitude predictions.

The method assumes no year effect except as mediated through changes in fishing effort which is justifiable given that a year effect was not found in the haul analysis.

3.2.2 Results

According to official fishing effort statistics, overall effort in the UK longline fleet has increased over the last two decades (Figure 10). The time series of bycatch estimates for fulmar, northern skua, great shearwater and northern gannet are given in Figures 11 to14. In every case there is an increase in bycatch over time which, under this analytical approach, is driven by the generally increasing trend in effort in the fishery.

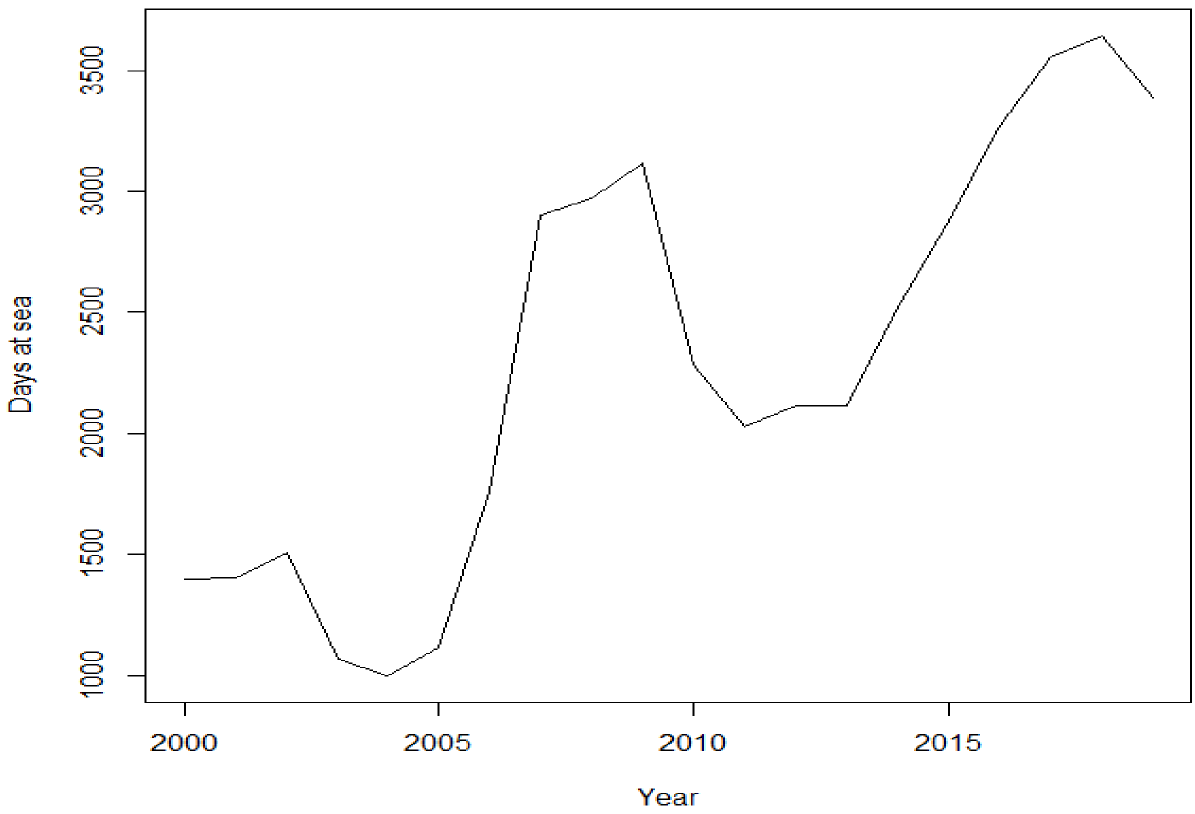

Figure 10: Annual effort (days at sea) in the UK offshore longline fleet.

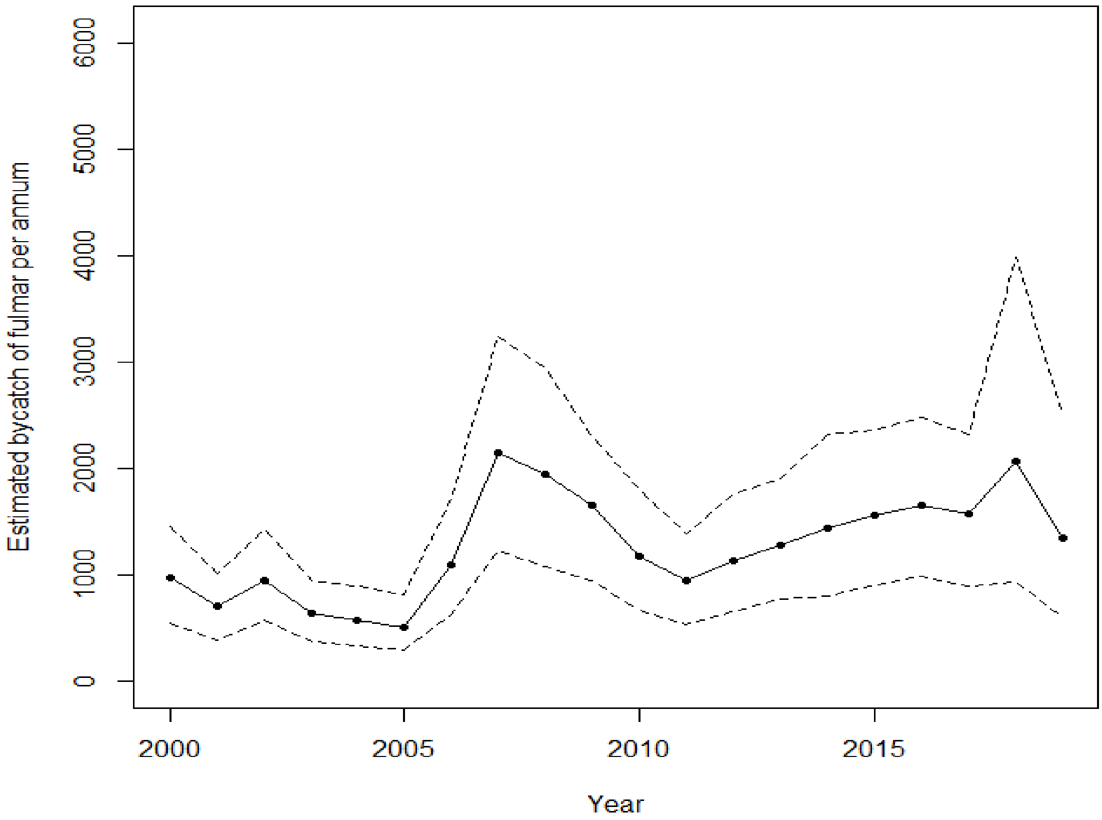

Figure 11: Estimated annual bycatch mortality of northern fulmar. Solid line = point estimate, dashed lines: 2.5% and 97.5% confidence interval.

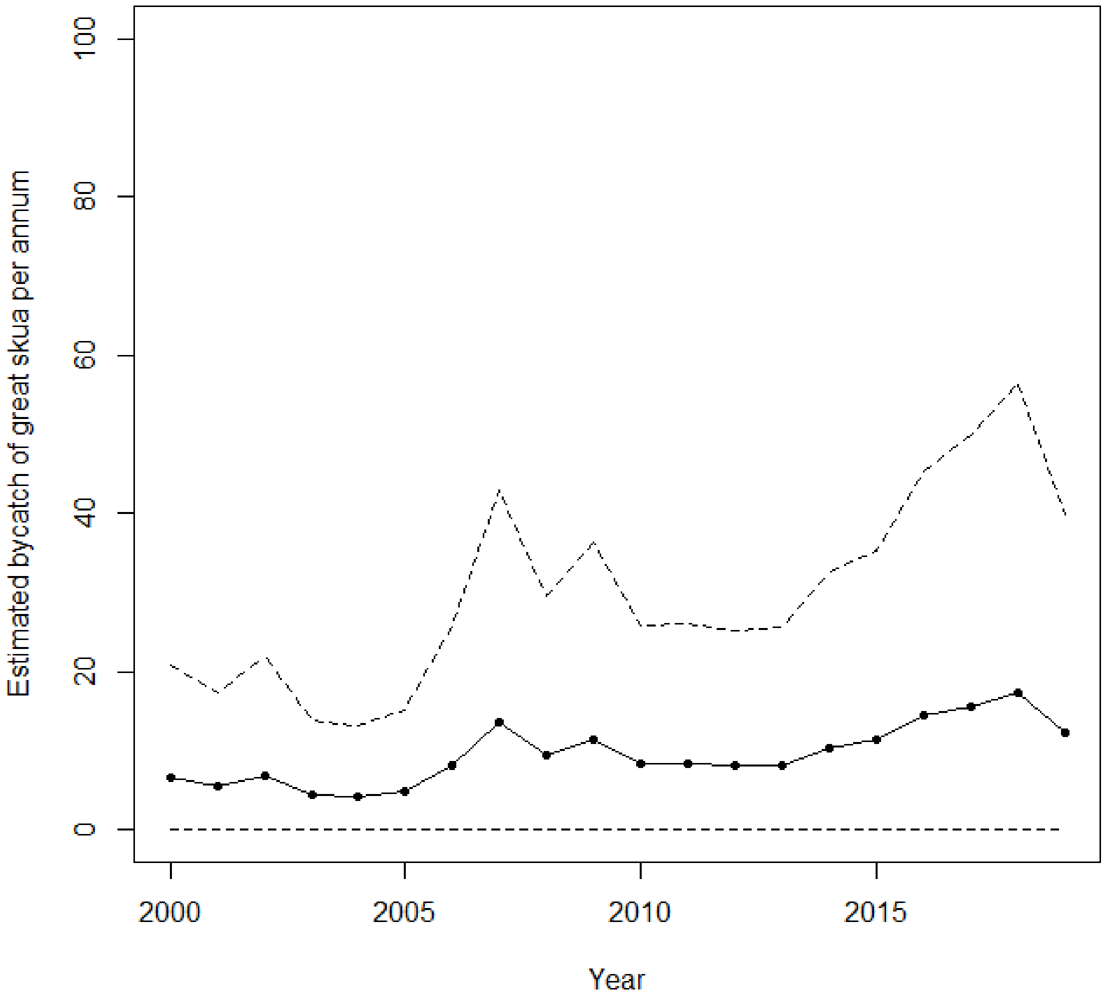

Figure 12: Estimates of annual bycatch mortality of great skua. Solid line = point estimate, dashed lines: 2.5% and 97.5% confidence interval.

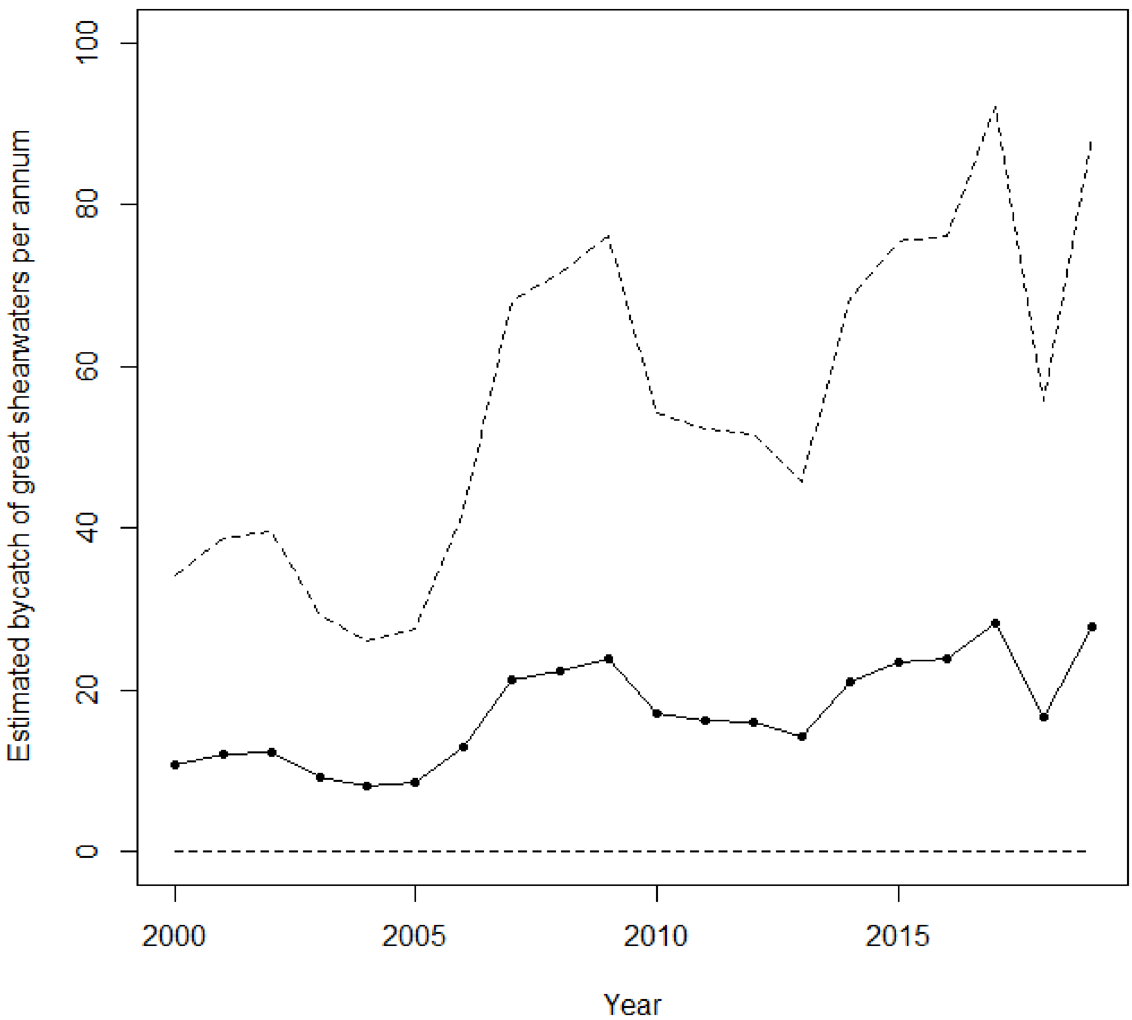

Figure 13: Estimates of annual bycatch mortality of great shearwater. Solid line = point estimate, dashed lines: 2.5% and 97.5% confidence interval.

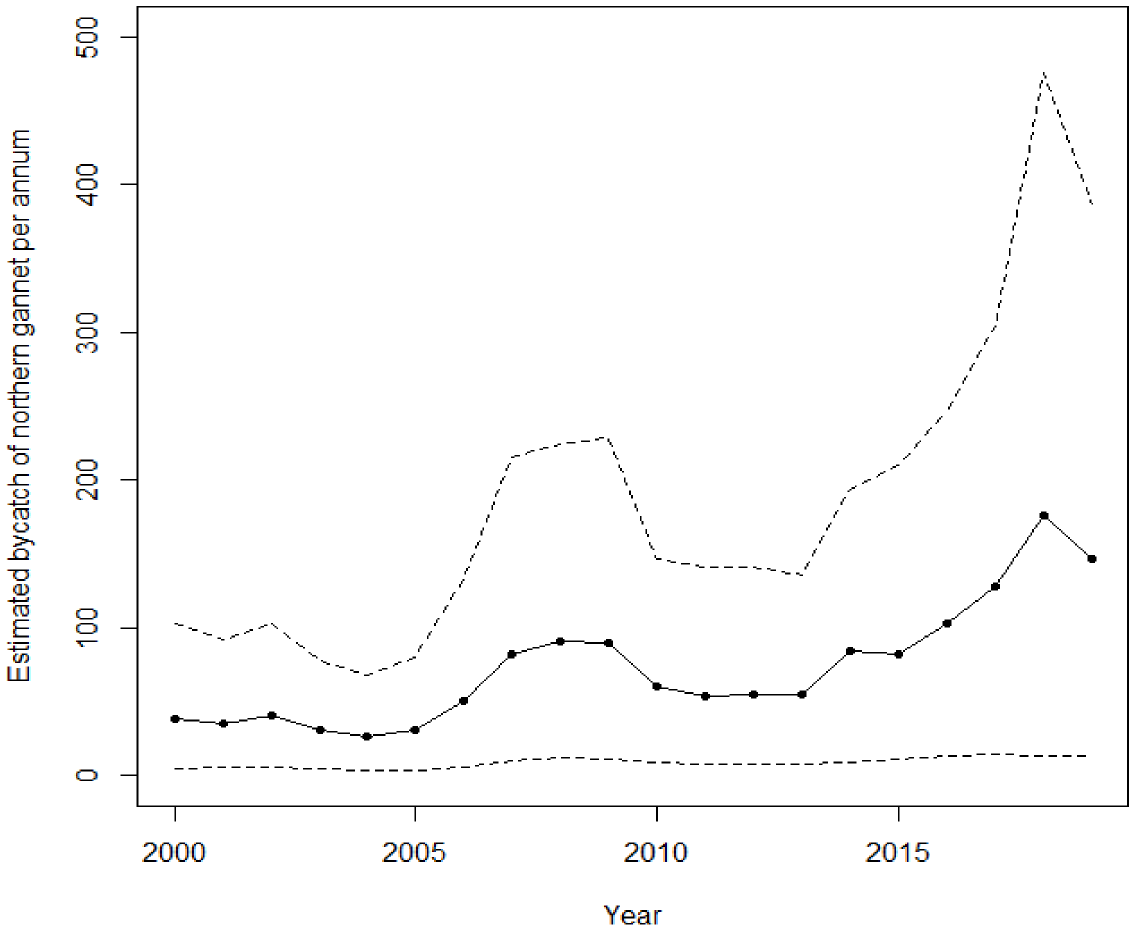

Figure 14: Estimates of annual bycatch mortality of northern gannet. Solid line = point estimate, dashed lines: 2.5% and 97.5% of confidence interval.

Overall, these results suggest that:

1. Bycatch of seabirds in the fishery may have increased over the last two decades due to an increase in fishing effort.
2. Bycatch of great shearwaters and great skuas is less than one hundred individuals of each species per year, and most likely between ten and twenty individuals per year.
3. Bycatch of northern gannets is less than four hundred individuals per year and most likley about one hundred individuals per year.
4. Bycatch of northern fulmars is probably 1000-2000 individuals per year and in the most recent year (2019) is close to 1000, though confidence intervals remain wide and range from about five hundred to four thousand individuals per year.

3.3 Discussion

The apparent changes in fulmar bycatch estimates from those initially provided by Northridge et al.(2020), evident in the updated estimates described in Section 3.1 and Figure 8, and then in the most recent estimates produced using a modelling approach presented in Section 3.2 are a consequence of more refined spatial and temporal stratification, an increase in overall data availability, and – in the case of estimates generated using a modelling approach – improved estimation methodologies. These changes improved the reliability of the latest mortality estimates which are lower (and have wider confidence limits) than those produced by Northridge et al.(2020).

However, based on the findings from Section 2.2, the data on which these latest estimates are based are likely to be biased (as demonstrated in Figures 2 & 3) and are from just 201 sampled hauls across 23 trips spanning over a decade. By comparison, Melvin et al.(2019) used data from over 90,000 haul observations to examine seabird bycatch in Alaskan waters and Fangel et al.(2017) used data collected from 426 trips. Consequently, it is important that these latest results for the UK offshore longline fishery are viewed rationally and in the context of the underlying biases and low data levels.

Section 4: Collection of whole seabird samples

To support follow-on analyses into the demographic composition, breeding status and colony affinity of seabirds, whole dead bycaught specimens, were collected, safely stored on-board and returned to shore in collaboration with industry representatives.

Processes in relation to the storage and transport of bycaught seabird samples were discussed with the Marine Scotland Licensing Operations Team (MS-LOT) prior to the work starting to ensure that the planned activities complied with all legal requirements, including those contained in the Conservation of Offshore Marine Habitats and Species Regulations 2017.

To ensure that suitable storage facilities were available in relevant ports, Marine Scotland Compliance agreed to provide use of existing freezers in Lerwick and Ullapool. Additionally, a further small chest freezer was purchased and installed in the Marine Scotland Directorate office in Scrabster.

A concise sample collection and storage protocol was developed based, where relevant, on the guidance in Uhart et al.(2020). The protocol included instructions for observers on how to handle, bag, label and store the samples onboard the vessel to minimise damage and sample contamination.

At-sea sampling during 2020 and 2021 was severely impacted by Government restrictions on travel and social mixing resulting from the Covid-19 pandemic. Consequently, an observer did not join a longline vessel until August 2021, which was much later than anticipated, and the trip was only permitted following the development and implementation of a detailed and vessel specific Covid risk management plan that was designed to minimise the risk of cross contamination between the observer and crew. In addition to their normal data collection duties the observer was asked to collect as many dead seabird samples as possible, with a specific focus on northern fulmars but if bycatch rates were low then other species could also be retained.

During five trips totalling 46 days at sea between August and October 2021, four seabird bycatches occurred (two northern gannets and two great shearwaters). One of the shearwaters was released alive, so three whole specimen samples were obtained and stored in a freezer onboard the vessel. No fulmar bycatch occurred during the trips when the observer was aboard, so arrangements were made with the vessels skipper for one of the crew to continue collecting samples during subsequent trips. Sampling equipment and instructions were left on board and regular contact was maintained with the vessel. During two further trips seven seabird samples were collected by the crew; six fulmars and one gull (species yet to be determined). These samples were stored with the initial three samples on board the vessel and then all ten samples were transferred to the freezer in Scrabster. The samples were then transferred to the Marine Laboratory at Aberdeen by a member of the Marine Scotland catch sampling team, before being transferred to a freezer at the University of St Andrews.

During observer trips in May/June 2022 a further 47 fulmar samples were collected and were subsequently transferred to freezers ashore.

Basic details of the samples are provided in Table 4.

Table 4: Basic information on whole bycaught seabird samples collected during the project.

Species	Number	ICES Subarea
Northern gannet	2	7
Great shearwater	1	7
Northern fulmar	17	4
Northern fulmar	36	6
Gull (spp TBD)	1	4
Total	57	

Initial basic morphometric examinations of the seabird samples were planned under the project but due to time constraints stemming from the fact that most of samples were obtained late in the project, this was not achieved. Full examinations will take place in due course in collaboration with relevant seabird experts.

This sample collection exercise will continue post-project as it provides a unique source of material for biological and population studies relevant to understanding the full impacts of fisheries bycatch.

Section 5: Exploration of potential mitigation strategies with Industry

5.1 Introduction

The purpose of this section of the project was two-fold: firstly, to collate and summarise the detailed trip notes collected by the onboard observer who has undertaken the data collection in the fishery for over ten years and secondly, to obtain the views and knowledge of skippers on bycatch in a more formal way than had been done previously. Initially we planned to hold a small workshop or series of meetings with skippers, but due to restrictions from the Covid-19 pandemic that was not achieved and as an alternative we developed a questionnaire (see Annex 1) that was circulated to skippers in the fleet to complete. The results of both elements are described below.

5.2 Summary of observer notes

In addition to gathering data on sensitive species bycatch rates, observers working under the UK Bycatch Monitoring Programme often collect supplementary information on fishing operations, animal behaviour around vessels, summaries of discussions with skippers and provide other insights into possible reasons for observed bycatch rates. Although these may be considered anecdotal in nature, they provide useful information for contextualising and understanding the factors that may lead to bycatch events occurring.

As a first step we collated the observer notes and insights formed across 23 trips in the fishery into a short informal report. The notes are based on first-hand observational experience and in-depth discussions during sea trips with skippers and crews from several vessels in the UK longline fleet. A summary of this information is provided below.

Vessels in the UK offshore longline fleet set about 150 line units per day. Each line unit has about 80 hooks normally with frozen pilchard or herring as bait. Hooks are attached to the main line on 1m snoods, which are spaced 2.5 meters apart with alternating 2kg weights and small floats approximately every 20 hooks. This characteristic is what gives rise to the name “piedra bola” (“stone float”) by which this longline configuration is commonly known. Figure 15 provides a schematic of a section of longline.

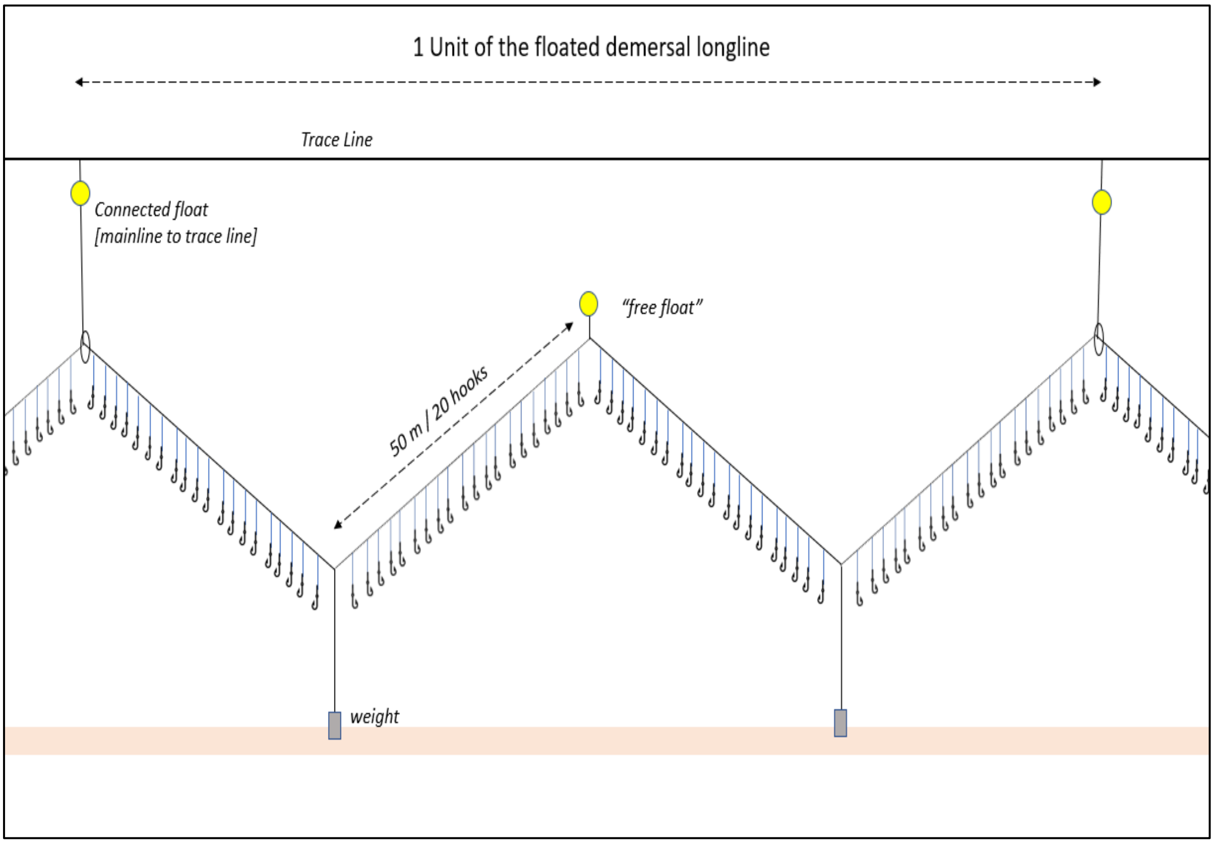

Figure 15: A schematic of 1 unit of the "piedra bola" or floated demersal longline. Image reproduced here courtesy of Y. Rouxel, Birdlife International.

Depending on the seabed conditions and the depth at which the target species (mainly hake, and occasionally ling) are more abundant, different configurations of weights and floats may be used. Lines are clustered into sections called "claros" which contain five units of about 400 hooks, with heavier weights (25 kg) in between each claro. Lines are normally set in one single continuous operation and typically follow the optimal depth contour. However, if there are several vessels in an area and full line setting is not possible, the longline can be split into two or three shorter sections that are set and hauled independently. These shorter sections are normally deployed fairly close together.

When the vessel reaches the area where the lines will be set, the skipper will normally wait until it is dark before deploying them. The line setting process can take several hours. After the lines have been deployed, line retrieval normally starts in the late morning and the hauling operation will last for around twelve or thirteen hours, during which time the crew will process the catch and prepare the lines to be set again. When all the lines are on board (sometimes after midnight), the vessel often moves for one or two hours to the position where the lines will be deployed again, and line setting normally starts between 3am and 5am. This daily routine continues until the vessel is ready to land the catch and is normally only interrupted by severe weather conditions.

It has been observed several times that bycatch sometimes occurs in clusters and the skipper's insight might explain this. Some skippers are of the view that when seabird bycatch occurs it makes the lines less effective, as bycaught birds tangle the line and don't allow it to sink as it should. Furthermore, a bycaught bird will generally keep the other adjacent baits at the surface for longer which can lead to bycatch of other birds in the same section of line.

Based on discussions with skippers, to try and avoid bycatch, most of the vessels (in the UK fleet) set their longlines at night when skippers feel seabirds are less active, and some vessels use home-made scarers (which consists of a rope with some coloured ribbons hanging from it) as deterrents during line setting. Scarers can help prevent bycatch, but they also cause problems if they tangle with the fishing line. This happens more frequently in bad weather conditions and can lead to the line breaking which causes significant delays in line setting and retrieving operations.

Some bycatch occurs during line setting, and all birds that are securely hooked at that point in the fishing operation will drown prior to line retrieval. Birds are also caught during line hauling and most of these are released alive. These birds are generally hooked in their beak or wing. Most attempts by seabirds to grab baits during line hauling do not lead to birds getting hooked and often they manage to take the bait successfully.

From general observer observations several factors appear to influence the bycatch rates:

- **Time of year** - bycatch rates appear to be lower in winter, spring and late autumn, and higher in summer and early autumn.
- **Location** - bycatch rates appear to be lower to the south and west of Ireland and to the west of Scotland, but higher to the north of Scotland.
- **Performance of the scarer -** sometimes in side-winds the scarer is blown away from the line as it is being set and this appears to be associated with higher bycatch rates than when the scarer is vertically above the lines.
- **Timing of line setting -** Lines that are set across the dawn period appear to have higher bycatch rates. One skipper commented that sometimes on bright moonlit nights, bycatch can also occur even if the full line is set during darkness.
- **Behavior of the birds** - there are always birds around the vessel during line setting and hauling but sometimes they do not appear to be interested in the bait. However, at other times they are much more eager and aggressive which leads to more seabirds getting caught. This behavioral observation may partially explain the highly variable bycatch rates observed in the fishery.

During discussions with skippers some questioned whether certain birds have become more reliant on foraging around the fishing fleet than others. Skippers had also noticed that sometimes the birds are calmer and less interested in the baits, while at other times they are more determined to grab them. Some skippers wondered if this changing behaviour is related to the abundance of other food, or to the fish catch rates and how much offal and discards are available during the day. The observer concludes that there seems to be a complicated ecological relationship between the birds, the vessels and bycatch levels.

5.3 Discussions with industry on bycatch and bycatch mitigation

The intention at the outset of the project was to hold one or more informal meetings or small workshops with skippers from the fishery to obtain their views on bycatch and bycatch mitigation in the fishery. Initial discussions took place with industry representatives to that effect early in 2021. However, due to travel restrictions and various other uncertainties related to the Covid-19 pandemic, and because most of the skippers are at sea for large parts of the year and are rarely all ashore at the same time, it was determined that a group meeting or workshop would not be feasible in the project timescales. Consequently, other possible routes for directly obtaining skippers input were discussed and resulted in the development of a questionnaire that could be circulated throughout the fleet.

A first draft of the questionnaire was completed by the skipper of a vessel while our observer was aboard in autumn 2021. Several significant adjustments were made to the draft, based on the skipper’s feedback and some further consideration by the project team. A final draft was submitted to the University of St Andrews Ethics Committee in December 2021 and received ethical approval shortly afterwards. As part of the ethics requirement, a participants information sheet was also provided to all participants along with the questionnaire. The questionnaire and information sheet are provided in full in Annex 1.

The final questionnaire was sent to the main industry representatives in early 2022, and responses from the skippers (and in one case also the chief mate) of four vessels (approximately 30% of the UK fleet) were received. Responses are summarised below.

5.3.1 Summary of the skippers’ responses

Fisher experience: All respondents have significant experience in the hake longline fishery. Three skippers have over ten years’ experience, and one skipper and the chief mate of one of the vessels have five to ten years’ experience. Collectively, the respondents have at least 40 years of first-hand experience as skippers in the fishery.

Fishing effort: Overall, most of the fishing effort of the four vessels occurs in 4a. However, there are some differences in where and when the vessels fish. One vessel works all year in ICES Division 4a (Northern North Sea). The three other vessels split their time between 4a and 6ab (West of Scotland) and one of those vessels also spends limited time working in 7cbkj (West/Southwest of Ireland).

Estimated bycatch: The skippers were asked to provide estimates of their annual seabird bycatch. Estimates of bycatch resulting in mortality ranged from 1-5 to 80 birds per year. Estimates of live bycatch (caught during line hauling) ranged from 10 to over 200 birds per year. There was some variation in the skippers' views regarding bycatch trends: one skipper felt bycatch levels were generally increasing, another felt levels were decreasing, and two skippers and the chief mate of one vessel felt bycatch levels were stable.

Factors affecting bycatch: All respondents felt that fishing area and season had an influence on bycatch levels. In Division 4a, four respondents indicated that bycatch is highest in quarter 3 (July - September) and one respondent indicated highest bycatch in quarter 2 (April - June). In 6ab, two respondents indicated that bycatch was highest in quarter 2 and two indicated it was highest in quarter 3.

The reason for the higher bycatch in quarters 2 and 3 is considered by all respondents to be related to the increased hours of daylight during the summer months. One respondent noted that this is particularly significant at the more northerly part of the fisheries range around latitude 60^{o} N. Another respondent indicated that the light levels are important in 6ab when bycatch is higher if lines are shot across the dawn period, but that the same does not appear to happen in 4a when there is almost no darkness during the middle of summer, so the full lines are normally shot in daylight. One respondent indicated that there is more bycatch and less fish catch when lines are set in daylight and when closer to land.

The skippers were asked if they had noticed any other patterns in bycatch. Two respondents indicated that there appear to be less birds around their vessels if there are trawlers working nearby. One respondent indicated that fulmars are more abundant close to land, and in better weather.

Bycatch mitigation: All respondents have a variety of measures in place to try to reduce bycatch levels. All vessels use bird scaring lines routinely. Three vessels set the lines at night as much as possible, and two of those indicated that they also turn off the external deck lights while line setting at night. Three vessels dispose of offal at night after line hauling. One vessel disposes of offal from the opposite side of the vessel to where the lines are hauled. One vessel also prepares bait under cover and never outside on deck.

The skippers were asked if there were other ways it might be possible to reduce bycatch. The respondents suggested the following potential solutions: the use of acoustic deterrents to keep birds away from the vessels, spraying water to keep birds away from the line hauling area, use of a kite simulating a bird of prey to keep birds away from the vessel. Two respondents did not provide any suggestions but said that in their opinion the practices they currently use do reduce bycatch, although they are willing to considering alternative options.

The skippers were asked for their opinion of the efficacy of five different approaches that have been suggested as possible ways of reducing bycatch in other fisheries:

1. **Reduce deck lighting during line setting.**
   All respondents agreed that reducing deck lighting during line setting is a suitable approach for seabird bycatch mitigation in the hake fishery.

2. **Bird scaring lines during line setting.**
   All respondents agreed that the use of bird scaring lines during line setting is a suitable approach for seabird bycatch mitigation in the hake fishery.

3. **Increase line sink rates.**
   Three respondents think that increasing line sink rates is unsuitable for the hake fishery because of health and safety concerns for crew members if weights were increased, possible effects on the behaviour of the fishing gear and fish catch rates with altered weighting regimes and because current weightings are dependent on the line setting system and weighting regimes are sometimes changed to suit working in different areas. One respondent indicated that their current weighting regime has evolved and is appropriate for the fishery. One respondent felt that changing line sink rates would have no influence on bycatch levels. Only one respondent felt that increasing line sink rates would reduce bycatch levels.

4. **Change where discards and offal exit the vessel.**
   Four respondents felt that changing where discards and offal exit the vessel would help reduce bycatch. One of these respondents also suggested that it is better to dispose of all offal/discards after sunset. One respondent felt it would not make any difference as birds caught during line hauling are always released alive.

5. **Keep birds away from the line hauling area.**
   All respondents agreed that keeping birds away from the line hauling area is a good idea. One respondent suggested using acoustics, and another suggested using a water cannon or spray.

Finally, skippers were asked for other comments or personal thoughts about the fishery, the seabirds, seabird bycatch and its possible mitigation. One respondent said that the birds benefit a lot from their fishing activity and that the birds deliberately associate with the vessels, but that they will continue to look for new ways to reduce bycatch and if appropriate ways are identified they will put them into practice. Another respondent said they will continue to work to learn new forms of deterrence and will put them into practice, with the aim of helping the birds and their own fishing operations. Another respondent highlighted that increasing line weightings will increase the workload, which is already large, but asked about possible funding avenues to help automate the longline operations and to re-route offal disposal chutes to the opposite side of the vessel, which would help reduce bycatch. All respondents indicated that they would be prepared to test their own, or other, ideas to reduce bycatch.

Section 6: General Discussion

The work undertaken during this project has improved our overall understanding of the complexities of bycatch in the hake longline fishery and has highlighted useful improvements to data collection procedures and sampling designs which will continue to enhance our knowledge of the factors that lead to bycatch in the fishery and its possible effects on affected seabird populations.

Factors influencing bycatch rates: The modelling exercise to explore what environmental or operational factors might influence bycatch rates was largely inconclusive, though this is not surprising given the limited amount of data on which the analysis was based. Analyses of much larger datasets in Alaska (Melvin et al.2019) and Norway (Fangel et al.2017) also failed to find clear links between northern fulmar bycatch rates and specific operational or behavioural factors, which alongside the current analysis, the notes collated by the observer (that consolidated his and some skipper's observations and insights) and the questionnaire responses from skippers, serves to highlight the complexity and high variability of seabird, and particularly northern fulmar, bycatch in the hake fishery and is in line with the general findings from other similar northern hemisphere demersal longline fisheries.

Bycatch estimates: Based on the analytical approach used, which was largely determined by the limited amount of data available, overall bycatch in the fishery is estimated to have increased over the last two decades as total fishing effort in the fishery increased over that period. However, the latest modelled estimates produced within this project are considerably lower than the preliminary estimates presented in Northridge et al.(2020). The modelling approach undertaken within this project was a more sophisticated analysis that considered potential seasonality in bycatch rates (which was not incorporated in the preliminary estimates) and used additional data collected since 2018 that almost doubled the available data. Therefore, the modelled estimates presented here are considered to be more reliable than the Northridge et al.(2020) estimates, and should supersede the earlier estimates in future discussions about the possible impact of the hake fishery on seabird populations. Nevertheless, the data from which these latest estimates are derived are likely to be spatially and temporally biased and overall data levels remain low, so uncertainty around the true level of bycatch in the fishery remains high. Further data collection efforts, and where possible designed to address existing biases, will help to improve the accuracy of future estimates. Sampling levels in the fishery are currently quite low and may be insufficient to elucidate inter-annual trends in bycatch rates, but there is no obvious signal in the data of changes in rates over the last decade, and information provided by skippers through the questionnaires does not suggest any clear trend either, so it is likely that the increase in overall mortality is driven by an increase in the number of vessels participating in the fishery rather than operational or behavioural changes that may have increased underlying bycatch rates.

Seabird samples: One of the major gaps in the current understanding of the potential population level implications of bycatch is a lack of information about the population affinity of affected birds. Baetscher et al.(2022) used genetic stock identification techniques to assign bycaught northern fulmars to regional breeding colonies based on over one thousand sampled individuals and found large differences in the susceptibility of different colonies to bycatch that was driven mainly by differences in the summer foraging areas used by different colonies. This research has shown that with close industry collaboration it is possible to collect whole bycaught individuals from the hake fishery and return them to shore within existing monitoring efforts. If sufficient samples are obtained, and funds are available for genetic analysis, a similar approach could be attempted in the UK which would be an important step in understanding the possible population level impacts of the fishery. Whole bycaught samples also provide a unique source of biological material for studies into the biology, population dynamics and feeding ecology of seabirds so have significant scientific, conservation and management value. Consequently, we recommend that this data collection exercise continues going forward.

Data collection: To further improve understanding of bycatch in the longline fishery several improvements to data collection protocols have already been implemented and will assist in understanding how (1) bird density and behaviour, (2) the use of mitigation measures and (3) other operational and environmental factors, may influence the likelihood of bycatch occurring. Consideration of how future sampling coverage might be increased, and how improvements to the spatio-temporal distribution of sampling might be achieved, will be required to address the sampling biases that this work has highlighted. This will require continued open discussions between industry, scientific institutions and Government, and a commitment to continued funding for data collection activities in the fishery.

Potential mitigation approaches: The literature review, questionnaire responses from skippers and the summary of the observers' notes all provide important and insightful information on the types of mitigation approaches that might be suitable for testing in the fishery. Industry has already made voluntary efforts towards reducing seabird bycatch in the fishery, but some bycatch still occurs. Given industry's desire to reduce bycatch to improve fish catch rates and for reputational and environmental reasons, further efforts will be required to develop new, or fine tune existing, mitigation practises, and these should be tested within controlled trials to properly test their efficacy. Based on the skipper questionnaire responses, the most favourable routes for achieving bycatch reduction are related to: (1) the use of bird scaring lines, (2) offal management approaches, (3) night setting (including turning off deck lights) and, (4) the deterrence of birds from the line hauling area. Alterations to the line weighting configuration do not appear to be widely acceptable due to vessel and crew health and safety concerns, operational considerations and potential but unknown impacts on fish catch rates. However, a short research project undertaken on a single vessel in the hake longline fishery by Rouxel et al.(2022) found that the line sink rates on some parts of the gear were well below ACAP recommended standards and indicated that baited hooks might be within the foraging depth range of near surface feeding species beyond the typical range of bird scaring lines. The results from Rouxel et al.(2022) may not be representative of sink rates throughout the fleet and there are clearly industry concerns and reservations about altering line weighting configurations in the fishery, however, the results do highlight some potential for altering line sink rates as a bycatch mitigation approach. The skippers' questionnaires also produced some potential mitigation solutions including the use of water cannons/spray or acoustics to keep birds from the line hauling areas and bird of prey kites to keep seabirds from the general vicinity of the vessel. Industry led suggestions such as these are worth serious consideration.

The literature review provides a comprehensive compilation of bycatch mitigation options that have been tested in demersal longline fisheries elsewhere in the world. This broadens the selection of candidate mitigation approaches that industry may be willing to trial or may even inspire new ideas to help reduce seabird bycatch.

Some of the approaches described in the review, such as swivel hooks, appear to show potential as possible mitigation approaches for the fishery and could be tested. Others, such as underwater line setters, have encountered technical problems during development and testing but nonetheless already appear to be of possible interest to industry (pers. comm. M. Hermida (Hooktone Ltd)).

This project has highlighted a range of mitigation approaches from a variety of sources that are of potential relevance to the hake fishery, but key to ensuring the successful mitigation of seabird bycatch is that industry is properly engaged and central to any decisions that are taken about which candidate approaches should be tested in the fishery.

Next steps: The UK Government and devolved administrations are committed to reducing bycatch in UK fisheries through a range of UK legislative drivers, including the UK Marine Strategy and the Fisheries Act 2020. Within these instruments the main underlying principle is one of managing human activities to ensure the long-term sustainability of the ecosystems on which those activities depend. This provides an important basis for contextualising the need for addressing bycatch in particular situations. Demonstrable population level impacts would require action to reduce bycatch levels to within appropriate thresholds. In situations where population level impacts are not occuring or are unclear, there is a requirements to minimise, and where possible, eliminate bycatch under the Fisheries Act 2020, and this can be addressed by incrementally reducing bycatch levels, assuming that is achievable within the context of maintaining a productive, safe and profitable fishing industry.

Some sections of the UK offshore longline fishery have been engaging openly and constructively with the scientific community on the issue of seabird bycatch for well over a decade and are keen to reduce bycatch levels in the fishery (pers. comm. M. Hermida (Hooktone Ltd)). Northern fulmar (and other species at lower levels) bycatch is known to occur in the fishery, but it is not clear to what degree bycatch mortality in the fishery is a factor in the apparent population declines of northern fulmar in the Northeast Atlantic over the last 30 years. In fact, the perceived positive relationship between fulmar abundance and fishing activity levels and practises over the last century (Camphuysen and Garthe 1997; JNCC 2020) means it is likely that the species population status has benefitted more than suffered from commercial fishing operations historically, and recent declines are considered to be more likely associated with declines in commercial catch levels and changes in discarding practices that have reduced foraging opportunities for many scavenging seabirds (JNCC 2020).

However, given an industry sector that are engaged, interested and potentially willing to adapt their fishing practises to minimise bycatch levels, there is a strong argument for exploring and testing mitigation options that are proposed by, or at the very least acceptable to industry from the outset. This will help ensure that mitigation measures, if they are proven to be effective, are more likely to be adopted in the fishery on a routine basis. At the same time, continued monitoring in the fishery will further improve knowledge of the factors influencing bycatch rates and the possible population impacts of the fishery. This dual approach should fulfil the objectives of incrementally reducing bycatch levels whilst maintaining a profitable, productive and safe fishery while simultaneously improving assessments of the overall impact of the fishery in a way that meets industry needs and Governments environmental ambitions.

Section 7: Conclusions

The latest bycatch estimates for the fishery provided in this report are considerably lower and more reliable than the preliminary estimates produced by Northridge et al.(2020) but uncertainty around the estimates remains high and identified spatio-temporal biases in the sampling data may also affect their accuracy.

Despite the limited data used in the exploratory analyses within this project, when viewed against the findings from other similar fisheries, it indicates that the factors influencing bycatch rates in the hake fishery are multiple and complex. Consequently, there isn't a single element of the fishing operation that can be focussed on as a basis for developing new mitigation approaches, nor is there an existing mitigation approach that is both acceptable to industry and which would guarantee the elimination of bycatch in the fishery.

Given the lack of a single clear and demonstrated mitigation approach that is suitable for the fishery, top-down regulatory approaches are unlikely to achieve much positive mitigation effect and may simply jeopardise the good relationship that has developed between industry, scientists and Government. A collaborative approach will more likely lead to tangible reductions in bycatch in the longer-term.

The UK and Scottish Government's commitments to reducing seabird bycatch are clear, and the growing collaborative approach between this fishery sector and our scientific team is very positive and means that with further work it should be possible to develop and test mitigation approaches that are acceptable to industry and therefore have potential to be widely adopted in the fishery.

Clearly more data collection is needed to elucidate the factors influencing bycatch, and to improve the reliability of estimates and the biological/population implications of bycatch in the fishery. However, given industry's desire to reduce bycatch there is no reason why general background data collection should not continue while mitigation trials are conducted concurrently. This would have the simultaneous effect of increasing knowledge of the impacts of the fishery whilst working towards suitable approaches for reducing that impact.

Our next steps in this work will be to work with industry to develop and implement trials of potential mitigation measures based on the literature review presented above and considering the skipper's views on which approaches are most likely to be successful and practical. The choice of approach will be developed collaboratively but will be guided by industry.

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Annex 1: Seabird bycatch questionnaire

We have developed this short questionnaire to obtain your views about and knowledge of seabird bycatch in the UK offshore longline fishery. From data collected by our observer over the last decade we know that bycatch sometimes happens, but levels seem to vary a lot in different areas and seasons.

As vessel skippers you have more direct experience of the fishery than anyone, so we would like to ask about your understanding of where and when seabird bycatch is most likely to occur, what the most important factors might be that lead to bycatch happening or not, whether you would like to try and reduce seabird bycatch on your vessel and what sorts of solutions or approaches you think would be most effective at reducing bycatch.

Hemos desarrollado este breve cuestionario para recoger y plasmar vuestro punto de vista y vuestra experiencia en lo relativo a las capturas accidentales de aves marinas en aguas del Gran Sol/Escocia.

A partir de los datos recogidos por nuestros observadores a lo largo de los 10 últimos años sabemos que las capturas accidentales ocurren con elevada variabilidad, tomando valores prácticamente nulos a unas pocas aves por día y barco, según la época del año y la zona en la que se trabaje.

Como capitanes de pesca , entendemos que vosotros tendreis una idea bastante aproximada acerca bajo qué condiciones y con qué frecuencia ocurren las capturas accidentales, y de qué soluciones o enfoques podrían ser más efectivos y realizables para reducir las capturas accidentales de aguas marinas.

1) How many years have you been a skipper in the hake longline fishery? Cuántos años has sido capitán de pesca en barcos de palangre de fondo?

0-5	**5-10**	**10+**

2) How many days you normally fish a year in each area and season? Cuántos días trabajas en cada zona a lo largo del año?

	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
4a (Northern North Sea)				
6a,b (W Scotland, Rockall)				
7c,b,k,j (W, SW Ireland)				
7a,g,h (Irish, Celtic Sea)				
8 (Biscay)				

3) Approximately how many seabirds do you normally catch each year? Aproximadamente, cuántas aves marinas se capturan accidentalmente cada año?

Dead/ muertas	
Alive / vivas	

4) Have you noticed any changes in seabird bycatch levels since you have worked in this fishery? Has notado si la frecuencia de estas capturas han cambiado a lo largo de los últimos años?

Increasing / Aumenta	**Decreasing / Disminuye**	**Same / Sin cambios**

5) Do you think that the fishing area and season has an influence on bycatch levels? Piensas que la época del año y la zona en la que se trabaja afecta a las capturas accidentales de aves marinas?

Yes / Si	**No / No**

6) If bycatch levels change between areas and seasons, please enter approximately how many seabirds you normally catch in each area / season combination. Si consideras que la tasa de capturas depende de la época del año y del mar en cuestión, completa el cuadro estimando la tasa de capturas?

	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
4a (Northern North Sea)				
6a,b (W Scotland, Rockall)				
7c,b,k,j (W, SW Ireland)				
7a,g,h (Irish, Celtic Sea)				
8 (Biscay)				

7) If bycatch levels are different between areas and seasons, why do you think that is? Por qué crees que los niveles de capturas accidentales varían a lo largo del año y en distintas zonas?

8) Have you noticed any other patterns in bycatch levels? Has notado otros patrones que expliquen la variación de los niveles de capturas accidentales?:

9) Are you already trying to reduce seabird bycatch levels on your vessel? Estáis intentando reducir las tasas de capturas accidentales en vuestro buque?

Yes / Si	**No / No**

10) How do you try to reduce bycatch levels? Cómo intentais reducir las tasas de capturas accidentales en vuestro buque?

11) Do you do this all the time or only sometimes? Son éstas prácticas habituales o eventuales?

Always / Habituales	Sometimes / Eventuales

12) If you do it sometimes but not always, why is that? Si son eventuales, a qué se debe?

13) Are there any other ways you think it might be possible to reduce bycatch levels? Existen otras formas con las que consideres que podeis reducir los niveles de capturas accidentales de aves marinas?

14) These ideas have been suggested as possible ways of reducing bycatch in other longline fisheries, do you think they would help in the hake fishery? Las siguientes ideas han sido sugeridas para reducir capturas accidentales en otras pesquerías de palangre de fondo; consideras que podrían ser practicables para la flota palangrera del Gran Sol?

Reduce deck lighting during line setting **/** Apagar las luces al largar	

Bird scaring devices deployed during line setting / Utilizar lineas espantapájaros mientras se larga	
Increase how quickly the lines/hooks sink / Procurar aumentar la velocidad a la que se hunden las lineas	
Change where discards and offal exit the vessel / Echar vísceras y descartes por el lado opuesto al que se vira	
Keep birds away from the line hauling area / Mantener a los pájaros alejados de la linea mientras se vira (de algún modo)	

15) Would you be prepared to test any of your own or other ideas to reduce bycatch? Estarías dispuesto a probar alguna de éstas u otras ideas para reducir las tasas de capturas accidentales?

Yes / Si	**No / No**

16) Would you be prepared to take an observer to sea to: Estarias dispuesto a llevar observadores a bordo para:

a) Collect data to assess seabird bycatch levels? Recoger datos relativos a las capturas accidentals?

Yes / Si	**No / No**

b) To help you test ways to try and reduce bycatch? Ayudar en el testeo de medidas para reducir las capturas accidentals?

Yes / Si	**No / No**

17) Have you any other comments or personal thoughts about the fishery, the seabirds, seabird bycatch and its possible mitigation? Tienes algún otro comentario que hacer acerca de la pesquería, de las aves marinas, de sus capturas accidentales y de la posible mitigación de las mismas?

18) If you are happy for one of the project team to contact you directly to talk in more detail about the project, please provide your phone number here. Si no tiene inconveniente en que uno de los miembros del equipo del proyecto se comunique con usted directamente para hablar con más detalles sobre el proyecto, déjenos aquí su número de teléfono.

Telephone / Telefono:

University of St Andrews
St Andrews, Fife, KY16 9AJ, Scotland

Annex 2: Participant Information Sheet

Participant Information

University of St Andrews

Improving understanding of seabird bycatch in Scottish longline fisheries and exploring potential solutions

Al Kingston, Juan Pablo Forti Buratti, Simon Northridge

What is the study about?

We invite you to participate in a research project about improving understanding of seabird bycatch in UK longline fisheries. The UK and Scottish Governments have a long-term policy ambition to reduce bycatch levels of non-commercial species as much as practically possible to minimise the effects of fishing activity on the wider environment, to help ensure the long-term sustainability of UK fisheries. As part of a project for Marine Scotland we have developed a questionnaire to obtain your views about, and knowledge of, seabird bycatch and how it might be reduced in the UK hake longline fishery.

Sobre qué trata el estudio?

Le invitamos a participar en en un proyecto de investigación cuyo objeto es mejorar nuestra comprensión de las capturas accidentales de aves en las pesquerías de palangre de fondo del Reino Unido. Tanto el gobierno de Escocia como el del Reino Unido tienen el objetivo de reducir las capturas accidentales de especies no comerciales para minimizar el impacto de la pesca sobre el ambiente, contribuyendo a asegurar la sustenibilidad a largo plazo de sus pesquerías. Como parte de este proyecto, elaborado para Marine Scotland, hemos diseñado este cuestionario para obtener una visión clara y detallada de vuestros puntos de vista y vuestro conocimiento acerca de las capturas accidentales de aves marinas en el palangre de fondo y su minimización.

Why have you been invited to take part?

You have been asked to take part in this questionnaire because you are a skipper of a fishing vessel that operates in the UK hake longline fishery. You have more first-hand experience and knowledge of seabird bycatch on your vessel than anyone else. As an individual, and a collective group of skippers, you will be able to provide unique insights into where and when bycatch is most likely to occur, what factors are associated with high and/or low bycatch levels and the practicalities of potentially altering your fishing practices to help reduce bycatch levels. This information will help inform the UK Governments understanding about the most appropriate way to try and reduce seabird bycatch in your fishery.

Por qué ha sido invitado a participar?

Usted ha sido invitado a participar en esta encuesta porque es un capitán de pesca de la flota que faena con palangre de fondo en aguas del Reino Unido. Usted tiene una experiencia y conocimientos mayores acerca de las capturas accidentales de aves marinas que cualquier otro a bordo de su buque, por lo que tanto usted como sus colegas, serán capaces de proveer valiosa información acerca de bajo qué circunstancias las capturas accidentales son más o menos frecuentes, y en qué manera es posible reducirlas de forma efectiva. Con esta información, los gobiernos implicados estarán en mejores condiciones de tomar buenas decisiones encaminadas a la reducción de las capturas accidentales.

Do I have to take part?

This information sheet has been written to help you decide if you would like to take part. **It is up to you and you alone whether you wish to take part.** If you do decide to take part you will be free to withdraw at any time without providing a reason, and with no negative consequences.

Estoy obligado a participar?

En absoluto. Este documento informativo ha sido escrito para ayudarle a usted a decidir si desea o no participar, **lo cual es una decisión enteramente suya**. Si por algún motivo, habiendo decidido participar prefiere no seguir participando, es completamente libre de hacerlo , sin ningún tipo de consecuencias negativos.

What would I be required to do?

You will be asked to complete a questionnaire with 18 questions. Some are simple questions that will be very quick to answer, some questions are more detailed and may take longer, but we anticipate that it will take less than 1 hour to complete. A project team member may also contact you by telephone after you have completed the questionnaire to clarify any points or to ask for further detail on specific questions.

Que se espera que haga?

Se le pedirá que complete un cuestionario de 18 preguntas. Algunas serán sencillas, en otras se le pedirá respuestas más detalladas que le requerirán un poco más de tiempo. Puede que le lleve media hora terminarla, en ningún caso más de una hora. Es posible que después de haber realizado la encuesta, algún miembro del proyecto se ponga en contacto con usted para aclarar alguna cuestión si fuera necesario.

Are there any risks associated with taking part?

Completing the questionnaire will take up some of your time and so may cause some inconvenience. The purpose of the questionnaire is to access information that might be considered “sensitive”. There is a risk that if this information became widely available to outside groups with an interest in the topic that they might try to criticise or even interfere in some way with your fishing operations. However, there is also a reverse risk of not completing the questionnaire that if the administration decide it is necessary to try and reduce seabird bycatch that your individual and collective thoughts and ideas may not be properly considered in discussions about how that might best be achieved.

We will mitigate these risks by ensuring that any information you provide is anonymised and only presented in the final report as a collective opinion, so that individual participants cannot be identified. We will report the findings of this questionnaire in an accurate way without prejudice. We will ensure that the information you provide is presented in a suitably prominent way so that it given due consideration in future discussions on the topic.

Existe algún riesgo asociado al hecho de partcipar?

Entedemos que al participar usted está invirtiendo parte de su tiempo, lo cual puede entenderse como un perjuicio, aunque esperamos que no le suponga mayor inconveniente. No obstante, siendo la finalidad de este custionario obtener cierta información sensible, existe el riesgo de que si la información llega a ser disponible a grupos ajenos al proyecto, éstos puedan criticar o incluso interferir con las operaciones pesqueras. Por otro lado, también existe un riesgo asociado al hecho de no participar, ya que en ese caso las administraciones no dispondrán de información suficiente para elaborar medidas que se ajusten a las necesidades y capacidades del sector.

Por nuestra parte, nos comprometemos a mantener el anonimato de los participantes. En nuestro informe se verán reflejadas vuestras opiniones como un colectivo, no de forma individual, manteniendo la imparcialidad y la claridad necesaria para que sean tenidas en cuenta en el futuro.

Are there any benefits associated with taking part?

The main benefit with taking part is that your voice as an individual, and as a collective group, will be formally considered within the larger project. Too often the thoughts and ideas of fishermen are overlooked in the fisheries management system and this questionnaire provides a direct route for you to contribute to the future direction of fisheries research and management in the UK. By completing the questionnaire, you may also begin to think about seabird bycatch more often during your normal fishing operations and so may be able to provide increasingly useful insights about how it may be possible to reduce it.

Que beneficios hay asociados al hecho de participar?

El beneficio principal es que la voz de todos y cada uno de los capitanes de pesca será escuchada y tenida en consideración en el conetxto de un proyecto mayor. Con demasiada frecuencia el conocimiento y las ideas de los capitanes de pesca es desoído, y con este cuestionario queremos proveeros de un canal para que contribuyais en la dirección que tomen la gestión e investigación pesqueras.

Por otro lado, esperamos que el propio hecho de realizar la encuesta, contribuya a que vuestra idea del problema sea más clara y por lo tanto, podais tener ideas simples y realizables para reducirla aún más.

Informed consent

It is important that you can give your informed consent before taking part in this study and you will have the opportunity to ask any questions in relation to the research before you provide your consent.

Consentimiento informado

Es importante que usted otorgue su consentimiento informado antes de comenzar la encuesta, teniendo en ese proceso la oportunidad de formular cualquier pregunta relacionada con el proyecto antes de decidir participar.

Who is funding the research?

This research is being funded by the Scottish Government.

Quién patrocina esa investigación?

Esta investigación está siendo subvencionada por el gobierno de Escocia.

What information about me or recordings of me ('my data') will you be collecting?

We will be circulating a questionnaire to you either directly by email or via your industry representatives. The questionnaire will ask for your name and telephone number (where appropriate), vessel name and some information about the length of your experience in the fishery. We will not ask for any other personal details.

Qué información acerca de mi o de mis datos se recogerá?

Este cuestionario circulará vía e-mail o a través de algún representante de la industria. Solo necesitaremos tu nombre y número de teléfono, nombre del buque y años de experiencia en el caladero.

How will my data be securely stored, who will have access to it?

The information you provide will be stored in a **PSEUDONYMISED** form, which means that your data will be edited so that you are referred to by a unique reference such as a code number or different name, and the original data will remain accessible only to core project personnel. Your data will be stored securely at the University of St Andrews, and only core project personnel will be able to access it. There will be a 'key' document, which will link your unique reference to your real identity. The key will be kept in a different secure file at the University of St Andrews and only core project personnel will have access to it and be able to reconnect your data to you. All personal data will be destroyed after the project is finished.

Cómo serán almacenados mis datos y quienes tendrán acceso a ellos?

Los cuestionarios serán almacenados bajo **PSEUDONIMO**, y los archivos originales sólo serán accesibles para las personas directamente responsables del proyecto. Los datos serán almacenados en la Universidad de St Andrews, y de forma separada se almacenará el documento clave en el que se relacionen los pseudónimos con las identidades reales de los partcipantes en la encuesta. Una vez termine el proyecto, los datos personales de los participantes serán eliminados.

How will my data be used, and in what form will it be shared further?

Your research data will be analysed as part of the research study. The information you provide will be presented collectively, in a report to Marine Scotland, along with the information provided by all other respondents. The report will be published so the contents will be available to wider society but information you provide will be **ANONYMISED** meaning that no-one could use any reasonably available means to specifically identify you from the data.

It is expected that the project to which this research relates will be finalised in March 2022.

Cómo serán usados mis datos, y cómo serán publicados?

Los datos que usted proveerá serán analizados como parte del programa de investigación, y serán presentados colectivamente en un informe remitido a Marine Scotland, junto la información aportada por otros participantes. Este informe será publicado, pero la información será **ANÓNIMA**, de modo que no será posible relacionarla con usted ni con otro participante. Está previsto que la finalización del informe ocurra en Marzo de 2022.

Where can I find out about the results of the study?

A full project report, including a section on the questionnaire results, will be published by Marine Scotland and we will circulate the report to all participating skippers and relevant industry representatives.

Dónde puedo encontrar los resultados del estudio?

Un informe completo acerca de este proyecto de investigación, incluidos los resultados del cuestionario, será publicado por Marine Scotland y remitido los capitanes de pesca que hayan participado, así como a los representantes de la industria involucrados.

When will my data be destroyed?

Any personal data you provide will be destroyed when the final project report is published.

Cuando serán destruidos mis datos?

Todo dato personal que usted haya aportado será destruido tan pronto el informe sea publicado.

International data transfers – Personal data

Your data will be stored and processed at The University of St Andrews. No matter their physical location, researchers are required to store and make use of personal data as if they were in the UK; University requirements and the provisions of the data protection law apply at all times.

Transferencia internacional de datos – Datos personales

Sus datos serán almacenados y procesados en la Universidad de St Andrews. Independientemente de su localización física, los investigadores deberán almacenar y tratar los datos como si éstos estuvieran en el Reino Unido, siguiendo en todo momento los estándares de la Universidad y las leyes de protección de datos del Reino Unido.

Will my participation be confidential?

Yes, your participation will only be known to the core project team members listed at the top of this form.

Será mi participación confidencial?

Si, su participación solo será conocida por los responsables directos del proyecto, listados al final de este document

Use of your personal data for research and data protection rights

The University of St Andrews (the 'Data Controller') is bound by the UK 2018 Data Protection Act and the General Data Protection Regulation (GDPR), which require a lawful basis for all processing of personal data (in this case it is the 'performance of a task carried out in the public interest' – namely, for research purposes) and an additional lawful basis for processing personal data containing special characteristics (in this case it is 'public interest research'). You have a range of rights under data protection legislation. For more information on data protection legislation and your rights visit https://www.st-andrews.ac.uk/terms/data-protection/rights/. For any queries, email dataprot@st-andrews.ac.uk.

You will be able to withdraw your data before 05/02/21.

Uso de sus datos personales para investigación y derechos de protección de datos

La Universidad de St Andrews, que ejerce como 'controlador de datos', está sujeta al acta del año 2018 referida a la protección de datos del Reino Unido y al GDPR, 'General Data Protection Regulation'. Ambos documentos constituyen el soporte legal para el manejo de datos personales, en este caso, bajo el epígrafe 'realización de una tarea de investigación para el interés público'. Para más información , visite el sitio web https://www.st-andrews.ac.uk/terms/data-protection/rights/ o remita sus dadas a la direción de correo electrónico dataprot@st-andrews.ac.uk .

Ethical Approvals

This research proposal has been scrutinised and subsequently granted ethical approval by the University of St Andrews Teaching and Research Ethics Committee.

Aprobación ética

Esta investigación ha sido analizada y consecuentemente garantizada su aprobación ética por el comité de enseñanza y ética en la investigación de la Universidad de St Andrews.

What should I do if I have concerns about this study?

In the first instance, you are encouraged to raise your concerns with the researcher. However, if you do not feel comfortable doing so, then you should contact the School of Biology Ethics Contact (contact details below). A full outline of the procedures governed by the University Teaching and Research Ethics Committee is available at https://www.st-andrews.ac.uk/research/integrity-ethics/humans/ethical-guidance/complaints/.

Qué debo hacer si tengo alguna objeción o preocupación respecto de este estudio?

En primera instancia, se le recomendará elevar sus preocupaciones al investigador en cargo del proyecto. Si por algún motivo usted no se sientiera cómodo de esta forma, podrá contactar con el School of Biology Ethics Contact (ver detalles del contacto más abajo). Un listado completo de los procedimientos estipulados por el comité de enseñanza y ética en la investigación de la Universidad de St Andrews está disponible en: https://www.st-andrews.ac.uk/research/integrity-ethics/humans/ethical-guidance/complaints/ .

Contact details

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