SMRU Contribution to the DefineIt Final Report

Task 3.2.2: The susceptibility of sensitive species through analysis of their distribution and the overlap with relevant fishing effort distribution.

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ABSTRACT

The population sizes and estimates of sustainable take limits for the most numerous species of seabird and marine mammal have been collated for the North Sea. All available bycatch rate data have also been compiled to provide a quantitative overview of the vulnerability of each species to each gear type for which observer data are available. Certain species and gear combinations occur much more frequently than others. Specifically harbour porpoises, seals and guillemots are frequently recorded in static nets, while longline fisheries have relatively high rates of bycatch for fulmars and kittiwakes. The data collated are not necessarily representative of all North Sea fisheries, and sampling biases are noted. Nevertheless, when the observed bycatch rates are compared with a crude index of overall fishing effort for static nets, it is possible to see which species are most likely and least likely to be subject to unsustainable levels of annual removal.

Using distribution data from a long term sightings database, together with STECF data on the spatial distribution of fishing effort within the North Sea, it has also been possible to explore the susceptibility of several species to bycatch in specific gear types. A method of calculating and displaying risk of bycatch is developed, and 25 maps of species distribution (summer and winter for bird species) are presented as guides to where further monitoring and / or mitigation measures might best be focused.

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1. Introduction

The bycatch of many sensitive species is still poorly documented in most European Fisheries. This is especially true of species that are of limited or no commercial value such as mammals and birds, and also some of the rarer fish, which are not included under the Data Collection Framework. Although the Habitats Directive requires European Member States to monitor the incidental killing of cetaceans and a few fish species[1] (sturgeons and houting), few member states have addressed this obligation. Instead cetacean bycatch monitoring has been developed under Council Regulation 812/2004, which stipulates bycatch monitoring of cetaceans in certain fisheries. However, the monitoring of cetacean bycatch in the North Sea as mandated by Reg 812/2004 is limited to monitoring of pelagic trawl fisheries which are now thought to have generally very low rates of cetacean bycatch in the North Sea, while gillnet fisheries, which are thought to have the most frequent interactions, are not specified as being in need of further monitoring under regulation 812/2004. This is probably because at the time the regulation was drafted there had already been some dedicated monitoring of gillnet fisheries in the North Sea and some mitigation measures had been put in place, both nationally (Denmark) and under the Regulation, where certain fisheries have been required to use acoustic deterrent devices to limit cetacean bycatch. Nevertheless, implementation of the mandatory use of pingers has been slow, and the regulation only applies in this regard to vessel over 12m in length, whereas the vast majority of gillnet vessels in the North Sea fall under this length cut-off. Consequently bycatches have continued and only very limited monitoring has been undertaken in the past decade. To date, there has been no overview or compilation of the available data on cetacean bycatch rates in the North Sea, though a number of reviews have compiled existing estimates from a range of sources. There has been no estimate of seal bycatch for the North Sea, though observational data do exist.

The bycatch of seabirds is even less well known than that of mammals in the North Sea. Žydelis et al. (2009) reviewed bird bycatch reports from the North Sea and found just three dedicated bycatch studies of seabirds in the North Sea, though two of these were actually in Dutch lakes (IJsselmeer and Markermeer) and the third focused only on salmon bag-nets in coastal Scotland, an extremely limited fishery in the North Sea Context. A fourth study used telephone interviews to estimate bycatch rates of birds in coastal fisheries of Sweden, providing an annual estimate of around 3000 bird mortalities for the Swedish west coast (Kattegat and Skagerrak).

Observations of bycatch rates are of interest from a behavioural perspective, but are of limited further value unless it is possible to scale up those observations to a large scale, for example for all fisheries of a certain type in the marine ecosystem that the bycaught species inhabits. For this to be possible, detailed information on fishing effort, and often distribution, are required. These are usually only available at a crude level of detail that will not enable any precise estimate of bycatch to be made. Nevertheless, even crude effort data may allow some assessment of the likely threat level to be made, while fleet effort distribution data when combined with vulnerable species distribution data, can provide a map of most sensitive areas that may require further investigation.

[1] "Member States shall establish a system to monitor the incidental capture and killing of the animal species listed in Annex IV (a)." Paragraph 4 of Article 12 of Council Directive 92/43/EEC of 21 May 1992 on the Conservation of Natural Habitats and of Wild Fauna and Flora (OJ L 206, 22.7.1992, p. 7)

Assessing the scale of bycatch of protected species is only part of the task that is required. For any known bycatch rates to be useful, some assessment of their likely significance at the population level is also required. It is therefore necessary to have population abundance estimates of the species concerned, to have an indication of what level of bycatch (for example as a proportion of total abundance) is deemed to be unsustainable or otherwise unacceptable.

In this report we have compiled data from various bycatch observer schemes in the North Sea to provide a first overview of the bycatch rates of seabirds and mammals in North Sea fisheries. One of the reasons why no comprehensive overview of the bycatch of protected species has been made for the North Sea is that bycatch rates are highly variable among fisheries, and the most relevant fisheries themselves are poorly documented. It is therefore difficult to provide an accurate or a precise overall estimate of bycatch for any species for the North Sea. However, a more modest aim of investigating which fisheries bycatch has been reported in, which fisheries have not been reported to have bycatch, and where the likely highest risk to protected species populations may lie, is more tractable.

This report is presented in two overall sections. In the first we review available data on the abundance and bycatch rates of birds and of mammals in the North Sea, providing estimates of bycatch rates by fishery where feasible, and we compare these rates and abundance estimates with our best estimates of sustainable limits to bycatch and estimates of total fishing effort, in order to highlight which fisheries and species are most likely to be of concern.

In the second section we review the available information on the distribution of seabirds and mammals and compare these distributions with available information on fishing effort distribution in order to map out areas of highest risk.

2. Quantifying the scale of bycatch impact: species sensitivities

2.1 Abundance estimates

For mammals and birds, the concept of providing a single abundance estimate for an open-ended area like the North Sea is challenging. Most sea birds and mammals are liable to travel considerable distances, so that a substantial part of the overall population may move in and out of an area like the North Sea. Nevertheless for management and conservation purposes assumptions are made on the distribution of animals through the year in order to obtain approximate abundance estimates that can be applied to the whole Sea, while recognising that the boundaries to the area are anthropic and porous as far as the animals are concerned.

Seals

Two species of seal regularly inhabit and breed in the North Sea, the grey seal (*Halichoerus grypus*) and the harbour or common seal (*Phoca vitulina*). Major breeding sites for the grey seal exist at Donna Nook, the Farne Islands and Fast Castle in England, and at the Isle of May and in Orkney in Scotland. The common seal has major breeding colonies and haul out sites in the Wash and in the Wadden Sea, and further North in Orkney and Shetland, with some smaller haul out and breeding sites along the intervening British North Sea coast.

Grey seal numbers are estimated based on counts of white-coated pups during the breeding season and a population model that links pup numbers to adult population size. Most, but not all, pupping sites are surveyed every year in the UK. The latest pup count for UK North sea colonies was 20,312 in Orkney and 8,314 among the colonies from Blakeney Point in Norfolk to the Firth of Forth in Scotland(Sea Mammal Research Unit, 2011). These pup counts suggest a predicted population of 64,600 animals (CI 51,500-83,800), but some smaller pupping sites are not included in this estimate. Among UK sites these include Shetland and the Northern Scottish mainland, where pup production is estimated at around 3,300 and the Wadden Sea where around 400 pups are produced annually(Sea Mammal Research Unit, 2011). Assuming a similar ratio of pups to adults among these colonies, the expected total population size for adult grey seals associated with all North Sea breeding sites is therefore just over 73,000 (73,034: CI 58,223-94,740).

With regard to harbour seals, counts are made at UK summer moulting season haul out sites, when it is estimated that around 72% (CI 54% to 88%) of the population is available for counting at low tide at any one time(Sea Mammal Research Unit, 2011). Haulout counts on British North Sea coasts indicated around 11,500 harbour seals hauled out on UK coasts, equivalent to around 16,000 animals in total (approximate CI of 13,000 to 21,300)(Sea Mammal Research Unit, 2011). Counts in the Wadden Sea in recent years total around 18,000, with another 1,050 in the Lijmfjorden in Denmark (Sea Mammal Research Unit, 2011). Assuming a similar ratio of hauled out to total population in the Wadden Sea and Denmark as in Britain would suggest that the total North Sea population is around 42,430 (approximate CI of 34,400-56,600). A further 11,700 harbour seals have been counted in recent years in the Kattegat and Skagerrak , which if the same figure of 72% hauled out is assumed, would suggest another 16,250 (approx. CI 13,300 – 21,700) harbour seals in that region.

Cetaceans

Several species of cetacean frequent the North Sea. The most numerous is the harbour porpoise (*Phocoena phocoena*), while minke whales (*Balaenoptera acutorostrata*) and white-beaked dolphins (*Lagenorhynchus albirostris*) are the next most numerous. At least one semi-resident population of Bottlenose dolphins (*Tursiops truncatus*) inhabits the coastal waters of North east Scotland for much of the year, while less frequent visitors to the North Sea include Atlantic white-sided dolphins (*Lagenorhynchus acutus*), short-beaked common dolphins (*Delphinus delphis*), humpback whales (*Megaptera novaeangliae*), killer whales (*Orcinus orca*), long-finned pilot whales (*Globicephala melas*) and Risso's dolphins (Grampus griseus)(Reid, Evans, & Northridge, 2003).

There have been two area-wide abundance estimates made for cetaceans in the North Sea, known as SCANS (Hammond et al., 2002) and SCANS II (Anonymous, 2006) that were conducted in 1994 and 2005 respectively. Although only providing two snapshots of cetacean densities at an eleven year interval, these estimates provide the best indication of the numbers of cetaceans likely to be present in the North Sea. For the purposes of this report we have used the more recent estimates generated during the SCANS-II survey, which are tabulated below. Note that the SCANS-II survey blocks do not coincide exactly with ICES subdivisions IVa-c, or with IIIa ,b (see Figure 1 for SCANS-II survey blocks).

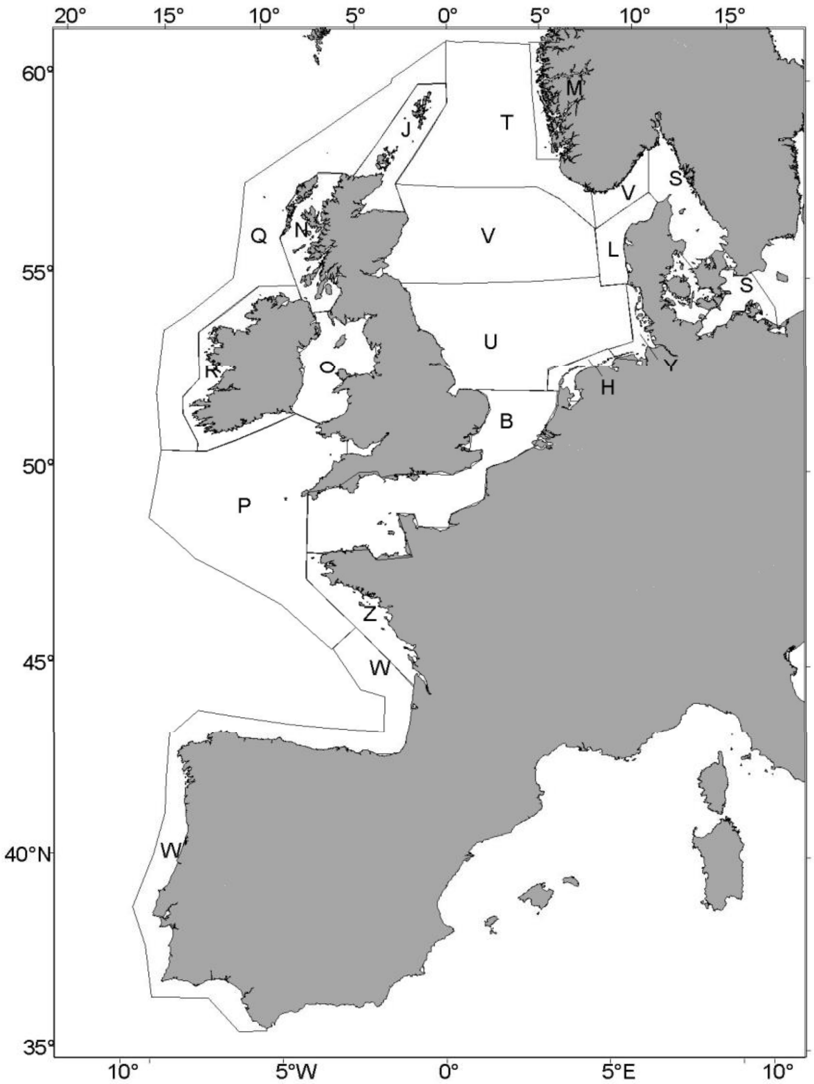


Figure 1: map of the SCANS-II survey blocks

Abundance estimates were only available from the SCANS-II survey for four species in the North Sea: harbour porpoises, white-beaked dolphins, minke whales and bottlenose dolphins.

Table 1: Cetacean abundance and density estimates by SCANS-II strata (rows in italics by aerial survey, others by ship survey)

A. Harbour Porpoises			
SCANS-II Survey Block	**Conventional line Transect Abundance Estimate**	**CV**	**Estimated Animal density**
T - Northern North Sea	23766	0.33	0.177
J – Northern Isles	*10254*	*0.36*	*0.274*
M - Norwegian coast	*3948*	*0.38*	*0.305*
V – Central North Sea	47131	0.37	0.294
L – West Jutland	*11575*	*0.43*	*0.555*
U – Southern North Sea	88143	0.23	0.562
H – Frisian Islands	*3891*	*0.45*	*0.355*
Y – German Islands	*1473*	*0.47*	*0.125*
B - Southern North Sea & Channel	*40927*	*0.38*	*0.331*
North sea and Channel total:	**231108**		

B. White beaked dolphins				***Unidentified Lagenorhynchus sp.***		
SCANS-II Survey Block	**Conventional line Transect Abundance Estimate**	**CV**	**Estimated Animal density**	**Conventional line Transect Abundance Estimate**	**CV**	**Estimated Animal density**
T - Northern North Sea	1525	0.56	0.011	12627	0.8	0.094
J - Northern Isles	*682*	*0.86*	*0.0182*	-	-	-
V – Central North Sea	7862	0.37	0.049	6460	0.35	0.04
U – Southern North Sea	493	0.48	0.003	405	1	0.003
Total North Sea Abundance	**10562**			**19492**		
Possible total white-beaked dolphins?	30054					

C. Minke whales			
SCANS-II Survey Block	**Conventional line Transect Abundance Estimate**	**CV**	**Estimated Animal density**
T - Northern North Sea	1738	0.52	0.013
J - Northern Isles	*835*	*1.02*	*0.0223*
V – Central North Sea	4449	0.45	0.028
U – Southern North Sea	3519	0.68	0.022
B - Southern North Sea & Channel	*1202*	*0.96*	*0.0097*
Total North Sea	**11743**		

D. Bottlenose dolphins			
SCANS-II Survey Block	**Conventional line Transect Abundance Estimate**	**CV**	**Estimated Animal density**
V – Central North Sea	123	4.83	0.08
J - Northern Isles	412	0.86	0.011
North Sea Total	**535**		

Birds

Abundance estimates for birds are difficult for a small area like the North Sea, as many species show large annual fluctuations between winter and the late spring or summer breeding season. We have collated a number of estimates from several sources and these are tabulated below. The data sources and additional details are provided in the following section where levels of sustainable take are considered.

Table 2: Compiled estimates of bird abundance for those species deemed likely most vulnerable to bycatch: North Sea

Common Name	Species	Population Estimate	Low Estimate (breeding)
Red and Black throated divers	*Gavia stellata/arctica*	48000	48000
Cormorant	*Phalacrocorax carbo*	14000	6700
Shag	*Phalacrocorax aristotelis*	60000	21400
Fulmar	*Fulmaris glacialis*	1148000	589000
Gannet	*Morus bassanus*	286000	90000
Great Skua	*Catharacta skua*	16800	1000
Common Gull	*Larus canus*	176000	140000
Herring Gull	*Larus argentatus*	918000	174000
Great Black-backed Gull	*Larus marinus*	300000	50000
Kittiwake	*Rissa tridactyla*	830000	323000
Sandwich Tern	*Sterna sandvicensis*	100000	34000
Common Tern	*Sterna hirundo*	130000	4000
Guillemot	*Uria aalge*	1700000	680000
Razorbill	*Alca torda*	313000	183000
Black Guillemot	*Cephus grylle*	24050	24050
Little Auk	*Alle alle*	853000	180000
Puffin	*Fratercula arctica*	226000	63000
Common Eider	*Somateria mollissima*	304000	100000
Common Scoter	*Melanitta nigra*	570000	525000
Little Gull	*Larus minutus*	5400	5400
Long-tailed duck	*Clangula hyemalis*	47000	47000

2.2 Sustainable levels of removal

There are no agreed methods for estimating levels of incidental kill for protected or vulnerable marine species in Europe that can be considered consistent with conservation goals. A rule-of-thumb has been adopted by North Sea member states that takes in excess of 1.7% of the best estimate of population size are considered unsustainable for small cetaceans. A widely used alternative measure(Wade, 1998) is the Potential Biological Removal (PBR) that has been adopted in the USA for the conservation and management of marine mammals, which allows limits to incidental take to be calculated from two or three simple metrics. More recently the same approach has been used to set unacceptable take limits for seabird bycatch. We have used the PBR and the 1.7% approach below when considering not only marine mammals but also seabirds.

Seabirds share many life-history traits with marine mammal species such as low fecundity, delayed maturity and high rates of survival which make it possible to apply the PBR framework to many seabird species. Several studies have already been used and adapted the PBR concept to look at bird species and populations (e.g. Dillingham & Fletcher 2008, Zydelis et al. 2009, Tuck 2011, Watts 2010, Poot et al. 2011) and we have adopted a similar approach for this study.

Potential biological removal represents a threshold of additional annual mortality above which a population can be expected to reach and maintain its ‘optimum sustainable population’ (OSP) (Wade 1998). For any given population, PBR can be calculated from three parameters. A minimum abundance estimate is taken to be the lower 20^{th} percentile of the central or point abundance estimate. This can be derived from the Coefficient of variation or CV of the abundance estimate. The second is an estimate of R_{max} – the population’s reproductive potential, which is the highest rate of reproduction practically possible for a population under ideal conditions or where population density is very low compared to the carrying capacity. Finally a recovery factor is used to ensure that the probability of severely depleted populations being reduced to extinction is minimised. The recovery factor can range from 0.1 for severely depleted populations to 1.0 for those very close to their carrying capacity. Wade (1998) showed that a default value of 0.5 where the population status is unknown is a safe value to use in many situations. The PBR is then defined as:

$$PBR = N_{min}\, 1/2\, R_{MAX}\, F_R$$

For marine mammals abundance estimates, Wade (1998) used the lower 20^{th} percentile of a log-normal distribution to calculate N_{min}:

$$N_{\min} = \frac{N}{\exp(z\sqrt{\ln(1+CV(N)^2})}$$

where N is the abundance estimate, and z is the standard normal variate, which is 1.96 for the 2.5 percentile and 0.842 for the 20^{th} percentile.

For seabird abundance estimates, Dillingham & Fletcher (2008) used a Taylor series approximation to estimate N_{min} by;

$$N_{min} = \widehat{N} \exp(Z_p \, CV_{\widehat{N}})$$

Where Z_p is the *p*th standard normal variate ($p = 0.2$ for the lower bound of a 60% CI). This approximation is valid for $CV_N < 0.6$, and reasonable up to $CV_N = 1$.

Although most marine mammal abundance estimates are calculated and published with an associated CV, in practice, a coefficient of variation ($CV_{\widehat{N}}$) is very rarely described in the literature for seabird population estimates. In order to estimate a population minimum, $CV_{\widehat{N}}$ was therefore assumed by Dillingham and Fletcher (2009) based on the certainty and apparent precision of the population estimates reported. Dillingham & Fletcher (2008) assumed $CV_{\widehat{N}} = 0.5$ where estimates were imprecise and we have followed their example and used 0.5 as a default value. Where multiple sources tend to agree at similar population estimates suggestive of some precision, this has been reduced to $CV_{\widehat{N}} = 0.2$ or 0.3, and where the source has described the estimate as a population minimum, we have used $CV_{\widehat{N}} = 0.1$.

For many sea bird species multiple population estimates were available in the literature, often varying very significantly. Exact methodological details were often lacking, which made comparisons difficult or impossible. We therefore calculated two different PBR values based on an upper and lower population estimate. A population minimum was calculated for each, with the default value of $CV_{\widehat{N}} = 0.5$ applied to all of the upper population estimates.

We set a default value of $F_R = 0.5$, following Dillingham & Fletcher (2008) and Zydelis et al (2009) for seabirds and following Wade (1998) for sea mammals. This assumes a stable population and would require adjustment if the population were thought to be in decline, or where the annual mortality was close to reaching the PBR limit.

Values of Rmax are difficult to estimate, and it is usual to assume a value of 0.04 for small cetaceans and 0.12 for pinnipeds (Wade 1998). For seabirds, Niel & Lebreton (2005) developed a method for estimating R_{MAX} as a simple function of generation time.

$$R_{MAX} = \lambda_{max} - 1$$

Optimal generation time (T_{op}) can be calculated as below using only: 'a' age at first reproduction, and 's' adult survival probability.

$$T_{op} \approx 1 / (\lambda_{max} - 1)$$

Where maximum annual growth rate (λ_{max}) is calculated by;

$$\lambda_{max} = ((sa - s + a + 1) + \mathrm{sqrt}((s - sa - a - 1)^2 - 4sa^2)) / 2a$$

Whereas our assumptions for the marine mammals are fairly standard and easily understood, those for seabirds require some elaboration:

2.2.1 Assumptions and Data Sources for estimating PBR parameters for Seabirds:

Black and red throated divers

The population estimate used below is for the wintering population and comes from Skov et al 1995. No lower estimate is available so the CV has been left at 0.5 for both PBR estimates. Adult survival estimate is the lower of the two species, from Hemmingsson & Eriksson 2002. Age at first reproduction comes from BTO Birdfacts and Poot et al. 2011.

Cormorant

Population estimate is for the wintering population and comes from Skov et al 1995 and Skov et al 2007. Lower estimate is for the breeding population of the N Sea and also comes from Skov et al 1995. No measure of certainty available for the lower estimate, so CV has been left at 0.5. Adult survival estimate is from Krementz, Sauer & Nichols (1989) in Garthe and Huppop (2004). Age at first reproduction comes from Frederiksen & Bregnballe (2001).

Shag

Population estimate is for average yearly number and comes from Skov et al 1995. Lower estimate is from Wetlands International (2006) referenced by Poot et al. (2011). As this figure is quoted as the minimum population size in Scotland, CV has been set at 0.1. Adult survival estimate is from Potts et al. (1990). Age at first reproduction comes from Russel (1999), quoted in Poot et al. (2011).

Fulmar

Population estimate is from ICES WGSAM data (2010). Lower estimate is the lowest seasonal figure from the same data set. Other estimates in the literature for the N Sea breeding population are greater by 31000 individuals, from Skov et al (1995) and Dunnet et al (1990), so CV has been set to 0.2. Adult survival estimate and age at first reproduction are both from Russel (1999), quoted in Poot et al (2011).

Gannet

Population estimate is the average yearly value from ICES WGSAM data (2010). Lower estimate is from Skov et al. (1995). All other recent estimates in the literature for the N Sea breeding population are significantly greater, so CV has been set to 0.2. Adult survival estimate is taken from Russel (1999), quoted in Poot et al (2011). Age at first reproduction is halfway between figures quoted by Poot et al. (2011), and Nelson (1973).

Great Skua

Population estimate is from Skov et al. (1995), and only refers to the breeding population of Orkney and Shetland. Lower estimate is from Skov et al. (2007), representing the wintering population in the N Sea. As this figure is much lower than the other source suggests, CV has been set at 0.1. Adult survival estimate is from Skov et al (2007), from del Hoyo et al (1992). Age at first reproduction comes from Klomp & Furness (1992) and BTO Birdfacts.

Common Gull

Population estimate is from Skov et al (2007). Lower population estimate is from Skov et al (1995). Dunnet et al (1990) estimate a breeding population above that which we have taken as our low estimate, so the CV has been reduced to 0.3. Adult survival is from Glutz von Blotzheim & Bauer (1982), quoted in Garthe & Huppop (2004). Age at first reproduction comes from BTO Birdfacts, via Poot et al (2011).

Herring Gull

Population estimate is from Skov et al (2007). Lower population estimate is the lowest seasonal abundance taken from the ICES WGSAM data (2010). Thi figure is well below all other estimates available in the literature (e.g. Dunnet et al 1990, Skov et al 1995) so the CV has been reduced to 0.1. Adult survival is from Glutz von Blotzheim & Bauer (1982), quoted in Garthe & Huppop (2004). Age at first reproduction comes from BTO Birdfacts and Maclean (1986).

Great Black-Backed Gull

Population estimate is the wintering population size from Skov et al (2007) and Skov et al (1995). Lower population estimate is the breeding population size from Skov et al (1995). All other population estimates a significantly greater (e.g. ICES WGSAM data 2010 and Poot et al 2011) so the CV has been reduced to 0.3. Adult survival and age at first reproduction both come from Wernham et al (2002), cited in Poot et al (2011).

Kittiwake

Population estimate is from Skov et al (1995). Lower population estimate the lowest value from ICES WGSAM data (2010). All other estimates of the breeding population are far above this figure (Skov et al 1995 and Dunnet et al 1990) so the CV has been reduced to 0.1. Adult survival is from Harris et al (2000). Age at first reproduction comes Russel (1999), via Poot et al (2011).

Sandwich Tern

Population estimate is from Skov et al (1995). Lower population estimate is also from Skov et al (1995) and represents the breeding season. The only other available population estimate is from Poot et al (2011), but only includes the Dutch population, so the CV has been left at 0.5. Adult survival is from Garthe & Huppop (2004). Age at first reproduction comes from BTO Birdfacts, via Poot et al (2011).

Common Tern

Population estimate is from Skov et al (1995). Lower population estimate is from Skov et al (1995), representing the birds which remain in the region through the summer. Dunnet et al (1990) estimate a breeding population nearly thirty times greater than that which we have taken as our low estimate, so the CV has been reduced to 0.1. Adult survival is from del Hoyo et al (1996) quoted in Garthe and Huppop (2004). Age at first reproduction is from Becker and Wendeln (1997).

Guillemot

Population estimate is from Skov et al (1995), based on Tasker et al. 1987, Lloyd et al. (1991) and Webb et al. (1995). Lower population estimate is from Dunnet et al (1990). All other available estimates are well above this figure (ICES WGSAM data and Skov et al 2007), so the CV has been reduced to 0.1. Adult survival is from Birkhead & Hudson (1977). Age at first reproduction comes from BTO Birdfacts and Birkhead & Hudson (1977).

Razorbill

Population estimate is the highest value from the ICES WGSAM data (2010). Lower population estimate is from Skov et al (1995), based on Tasker et al. (1987). The consensus of recent studies is at least this lower estimate (Skov et al 2007 and Mitchell et al 2004), but the CV has been left at 0.5 to incorporate uncertainty from Dunnet et al (1990), whose breeding population estimate was much lower. Adult survival is from Chapdelaine (1997). Age at first reproduction comes from BTO Birdfacts and Lavers et al. (2008).

Black Guillemot

The only available population estimate for the study region is from Skov et al (1995).Since no lower population estimate is available, CV has been left at 0.5. Adult survival is from Frederiksen & Petersen (1999). Age at first reproduction comes from BTO Birdfacts.

Little Auk

Population estimate is from Skov et al (2007). Lower population estimate is from Skov et al (1995). Since no lower population estimate is available, CV has been left at 0.5. Adult survival is calculated from figures quoted in Harding et al. (2011). Age at first reproduction comes from the Animal Diversity web page.

Puffin

Population estimate is from Skov et al (1995). Lower population estimate is from ICES WGSAM data (2010). Since this lower estimate is well below all other available estimates (Skov et al 2007, Dunnet et al 1990 and Birdlife International 2004), CV has been reduced to 0.1. Adult survival is from Harris et al. (2000). Age at first reproduction comes from BTO Birdfacts website.

Common Eider

Population estimate is from Poot et al (2011), who cite Wetlands International (2006). Lower population estimate is from Skov et al (1995). Skov et al say the population is “at least”, this figure, so CV has been reduced to 0.1. Adult survival is from Descamps et al. (2011), cited on the BTO Birdfacts web page. Age at first reproduction comes from BTO Birdfacts website.

Common Scoter

Population estimate is from Skov et al (2007). Lower population estimate is from Skov et al (1995). Since this is the only lower estimate available CV has been left at 0.5. Adult survival is from Krementz et al. (1989). Age at first reproduction comes from Poot et al. (2011).

Little Gull

Population estimate is from Skov et al (2007). No lower population estimate is available, so CV has been left at 0.5. Adult survival is from Garthe & Huppop (2004). Age at first reproduction comes from Poot et al. (2011).

Long-Tailed Duck

Population estimate is from Skov et al (2007). This is the only estimate available in the literature, so CV has been left at 0.5. Adult survival is from Schamber et al. (2009). Age at first reproduction comes from Petersen & Ellarson (1978).

2.2.2 Tabulated sustainable take levels

Figures below in Tables 3 and 4 for birds and mammals respectively provide some guidelines for what may be considered a maximum acceptable level of take. For several species of birds there are large differences in the estimated sustainable take levels depending on whether summer or winter abundance levels are considered. Ideally it would be possible to estimate bycatch by season, but detailed fishing effort data are not available on a seasonal basis. Nevertheless the take limits tabulated above provide a yardstick against which to compare estimates of bycatch rate (per unit effort) and estimates of total effort to identify those species for which we can be fairly sure bycatch rates are <u>unlikely</u> to exceed sustainable levels, and in contrast those where there is some reason to believe annual removals <u>may be</u> close to or may exceed sustainable levels. Identifying the latter species helps to pin down those species most vulnerable to fishing pressures. In section 2.3 we consider what is known about the bycatch per unit effort for these species.

Table 3: Possible sustainable take levels for Sea Birds

Common Name	Population Estimate	Low Estimate (breeding)	Adult Survival Estimate	Age at first reproduction	CV on population estimate	CV on low population estimate	F	N min upper	N min lower	PBR upper	PBR lower
R&B divers	48000	48000	0.84	2	0.5	0.5	0.5	31513	31513	1935	1935
Cormorant	14000	6700	0.84	3	0.5	0.5	0.5	9191	4399	422	202
Shag	60000	21400	0.83	3	0.5	0.1	0.5	39391	19673	1852	925
Fulmar	1148000	589000	0.924	8	0.5	0.2	0.5	753679	497752	13139	8677
Gannet	286000	90000	0.901	4.5	0.5	0.2	0.5	187763	76057	5386	2182
Great Skua	16800	1000	0.9	7	0.5	0.1	0.5	11029	919	232	19
Common Gull	176000	140000	0.8	3	0.5	0.3	0.5	115547	108761	5777	5438
Herring Gull	918000	174000	0.93	4	0.5	0.1	0.5	602680	159955	16365	4343
GBB Gull	300000	50000	0.835	4	0.5	0.1	0.5	196954	45964	7408	1729
Kittiwake	830000	323000	0.882	5	0.5	0.1	0.5	544907	296928	15463	8426
Sandwich Tern	100000	34000	0.88	3	0.5	0.5	0.5	65651	22321	2691	915
Common Tern	130000	4000	0.875	3	0.5	0.1	0.5	85347	3677	3556	153
Guillemot	1700000	680000	0.915	5	0.5	0.1	0.5	1116075	625112	28110	15744
Razorbill	313000	183000	0.9	4	0.5	0.5	0.5	205489	120142	6422	3754
Black Guillemot	24050	24050	0.87	4	0.5	0.5	0.5	15789	15789	545	545
Little Auk	853000	180000	0.7655	3	0.5	0.5	0.5	560007	118173	29700	6267
Puffin	226000	63000	0.916	5	0.5	0.1	0.5	148372	57915	3720	1452
Common Eider	304000	100000	0.82	3	0.5	0.1	0.5	199580	91928	9589	4417
Common Scoter	570000	525000	0.773	3	0.5	0.5	0.5	374213	344670	19611	18063
Little Gull	5400	5400	0.8	2.5	0.5	0.5	0.5	3545	3545	203	203
Long-tailed duck	47000	47000	0.74	2	0.5	0.5	0.5	30856	30856	2325	2325

Table 4: Possible sustainable take levels for Marine Mammals

SCANS-II Survey Block and Species	N	CV	N_{min}	PBR	1.7% limit
Harbour Porpoises					
T - Northern North Sea	23,766	0.33	18,130	181	404
J – Northern Isles	10,254	*0.36*	7,643	76	174
M - Norwegian coast	3,948	*0.38*	2,898	29	67
V – Central North Sea	47,131	0.37	34,860	349	801
L – West Jutland	11,575	*0.43*	8,183	82	197
U – Southern North Sea	88,143	0.23	72,805	728	1498
H – Frisian Islands	3,891	*0.45*	2,710	27	66
Y – German Islands	1,473	*0.47*	1,011	10	25
B - Southern North Sea & Channel	40,927	*0.38*	30,041	300	696
TOTALS:	231,108		178,280	1,783	3,929
White-beaked dolphins					
T - Northern North Sea	1525	0.56	982	10	26
J - Northern Isles	*682*	*0.86*	364	4	12
V – Central North Sea	7862	0.37	5,815	58	134
U – Southern North Sea	493	0.48	336	3	8
TOTALS:	10,562		7,498	75	180
"Uncertain *Lagenorhynchus* species" [2]					
T - Northern North Sea	12627	0.8	6,984	70	215
V – Central North Sea	6460	0.35	4,852	49	110
U – Southern North Sea	405	1	201	2	7
TOTALS:	19,492		12,037	120	331
TOTALS for **all *Lagenorhynchus* species**	30,054		19,535	195	511
Minke whales					
T - Northern North Sea	1738	0.52	1,151	12	30
J - Northern Isles	*835*	*1.02*	410	4	14
V – Central North Sea	4449	0.45	3,099	31	76
U – Southern North Sea	3519	0.68	2,094	21	60
B - Southern North Sea & Channel	*1202*	*0.96*	609	6	20
TOTALS:	11,743		7,363	74	200
Bottlenose dolphins					
V – Central North Sea	123	4.83	27	0	2
J - Northern Isles	412	0.86	220	2	7
TOTALS:	535		248	2	9
Harbour Seal - All North Sea	16,250	0.5	10,917	328	276
Grey Seal - All North Sea	73,034	0.5	49,067	1472	1242
Both seal species	89,284		59,984	1,800	1,518

[2] Many sightings could not be distinguished between white-sided and white-beaked dolphins. The latter are more common in the North Sea than the former.

2.3 Bycatch rates from observer data

In this section we have summarised information that was available to us relating to the bycatch rates of birds and mammals in the North Sea and and adjacent areas in selected fisheries. The main data sources are the protected species bycatch monitoring scheme carried out in the UK since 1996, the English discard scheme run by CEFAS and the Danish discard studies conducted during the 1990s that were also charged with estimating porpoise bycatch rates.

Bycatch monitoring schemes report bycatch rates in a variety of units. Typically the number of animals (cetaceans, seals or birds) is presented in terms of animals per fishing operation, or animals per trip, per day or per tonne of target fish landed. Sometimes more detailed effort data is provided as the denominator of the rates presented, such as animals per km.hour of static net fished. The diversity of metrics used makes it difficult to compare results between all the surveys. A more significant problem is that fact that it is usually impossible to get a good overview of the overall fleet effort from all countries impacting a given species in a given European sea area which means that raising observed levels to total catch levels (animals per year) is usually very hard or impossible.

Discard sampling schemes should in theory provide a useful basis for exploring the rates of bycatch of protected species. Unfortunately, protected species monitoring is non-mandatory under the Data Collection Framework, and while some countries have adopted a policy of recording any bycatches of protected or vulnerable species in their discard sampling protocols, the degree to which this is actually implemented, and the time frame over which such a protocol has been maintained, is usually unclear. Nevertheless, existing programmes such as those in the UK and Denmark mentioned above provide some information on observed bycatch rates, but also, where no bycatches of a particular species have been observed, they can also provide an upper limit on the likely bycatch rate assuming bycatch events are binomially distributed, if the number of observed fishing operations without bycatch is known.

Table 5: Numbers of seabirds reported bycaught in 24.228 observed hauls by UK (1996-2011) and Danish (1992-1994) observers. Numbers of hauls were estimated from other data supplied in Vinther (1994) - days at sea and bycatch per km.hour. Rates presented as birds per 1000 fishing operations. 95% UCL assuming binomial distribution of bird catches.

CEFAS OBSERVATIONS	SPECIES	Hauls Obs.	No. reported	Bycatch rate No / K.haul	95% UCL on rate
Beam Trawl	Gannet	6558	1	0.2	0.8
Gillnet	Fulmar	1006	12	11.9	20.7
Gillnet	Gannet	1006	1	1.0	5.5
Gillnet	Guillemot	1006	5	5.0	11.6
Long Lines	Fulmar	123	8	65.0	124.1
Nephrops trawl	Gannet	845	1	1.2	6.6
Trammel net	Petrel	349	1	2.9	15.9
	TOTAL	**8,881**	29	3.3	4.7

SMRU OBSERVATIONS					
Drift net	Guillemot	93	4	43.0	106.5
Gill net (not tramm. or tangl)	Guillemot	675	6	8.9	19.2
Gill net (unspecified)	Cormorant	8198	17	2.1	3.3
Gill net (unspecified)	Gannet	8198	2	0.2	0.9
Gill net (unspecified)	Guillemot	8198	127	15.5	18.4
Gill net (unspecified)	Herring Gull	8198	1	0.1	0.7
Midwater pair trawl	Cormorant	1493	1	0.7	3.7
Midwater pair trawl	Guillemot	1493	25	16.7	24.6
Midwater pair trawl	Razorbill	1493	3	2.0	5.9
Midwater trawl	Cormorant	441	1	2.3	12.6
Tangle net	Cormorant	2276	6	2.6	5.7
Tangle net	Gannet	2276	2	0.9	3.2
Tangle net	Guillemot	2276	10	4.4	8.1
Tangle net	Herring Gull	2276	1	0.4	2.4
Trammel net	Cormorant	847	1	1.2	6.6
Wreck net	Gannet	421	1	2.4	13.2
LongLine	Fulmar	811	7	8.6	17.7
LongLine	Kittiwake	811	1	1.2	6.9
	TOTAL	**14,444**	216	15.0	17.1
DTU OBSERVATIONS					
Turbot tangle nets	Guillemots	95	5	52.6	118.6
Turbot tangle nets	Fulmars	95	2	21.1	74.0
Cod gillnets	Guillemots	808	17	21.0	33.5
	TOTAL	**903**	24	26.6	39.3

Table 6: Summary of observations on porpoise bycatches from European Observer schemes around the North Sea

Area	Year(s)	Season	Set net Fishery for:	Trips	Days	Hauls	T target	Km	Km.hrs	Porpoises	Per trip	Per day	Per Haul	Per Tonne	Per km	Per 10000 km.hour
NO: N. Sea	2006		Monk				11.95			14				1.17		
NO: N. Sea	2007		Monk				22.41			13				0.58		
NO: N. Sea	2008		Monk				9.72			8				0.82		
NO: N. Sea	**2007-2009**		**Monk**				**44.08**			**35**				**0.79**		
NO: N. Sea	2006		Cod				16.79			14				0.83		
NO: N. Sea	2007		Cod				10.33			13				1.26		
NO: N. Sea	2008		Cod				7.40			8				1.08		
NO: N. Sea	**2007-2009**		**Cod**				**34.52**			**35**				**1.01**		
NO: All coast	2005		Cod/Monk			21652	31.94			5			0.0004	0.16		
SW: Skag	1995	Mar-May	Cod/poll		95	250			3438	11		0.116	0.044			32.0
SW: Skag	1996	Spring	Cod/poll		74	195			1981	0		0.000	0.000			0.0
SW: Skag	1996	Autumn	Cod/poll		20	101			257	1		0.050	0.010			38.9
SW: Skag	1997	Winter	Cod/poll		30	97			407	0		0.000	0.000			0.0
SW: Skag	**1996-1997**	**All**	**Cod/poll**		**219**	**643**			**6083**	**12**		**0.055**	**0.019**			**19.7**
SW: Skag	1996	Spring	Cod/poll		37	113			2371	1		0.027	0.009			4.2
SW: Skag	1996	Autumn	Cod/poll		63	64			916	2		0.032	0.031			21.8
SW: Skag	1997	Winter	Cod/poll		17	107			1509	0		0.000	0.000			0.0
SW: Skag	**1996-1997**	**All**	**Cod/poll**		**336**	**927**			**10879**	**15**		**0.045**	**0.016**			**13.8**
DK: Katt	1992-	Jan-Mar	Cod	2	2	2	0.05	2		0	0.00	0.000	0.000	0	0	

	1998															
DK: Katt	1992-1998	Oct-Dec	Cod	7	8	7	0.47	10		0	0.00	0.000	0.000	0	0	
DK: Katt	**1992-1998**	**All**	**Cod**	**9**	**11**	**9**	**0.52**	**12**		**0**	**0.00**	**0.000**	**0.000**	**0**	**0**	
DK: Katt	1992-1998	Jan-Mar	Mixed	10	12	10	0.04	29		0	0.00	0.000	0.000	0	0	
DK: Katt	1992-1998	Apr-Jun	Mixed	25	30	27	2.69	84		1	0.04	0.033	0.037	0.371	0.0119	
DK: Katt	1992-1998	Jul-Sep	Mixed	11	13	11	0.97	32		0	0.00	0.000	0.000	0	0	
DK: Katt	1992-1998	Oct-Dec	Mixed	8	10	8	1.18	25		0	0.00	0.000	0.000	0	0	
DK: Katt	**1992-1998**	**All**	**Mixed**	**54**	**66**	**56**	**4.88**	**170**		**1**	**0.02**	**0.015**	**0.018**	**0.205**	**0.0059**	
DK: Katt	1992-1998	Jan-Mar	Lumpfish	7	8	9	1.81	29		2	0.29	0.252	0.222	1.106	0.0690	
DK: Katt	1992-1998	Apr-Jun	Lumpfish	3	3	3	0.86	7		3	1.00	0.926	1.000	3.488	0.4286	
DK: Katt	**1992-1998**	**All**	**Lumpfish**	**10**	**11**	**12**	**2.67**	**36**		**5**	**0.50**	**0.447**	**0.417**	**1.873**	**0.1389**	
DK: N Sea	1993-2000	Jan-Mar	Cod	18	44	280	68.50	356		36	2.00	0.824	0.129	0.526	0.1011	
DK: N Sea	1993-2000	Apr-Jun	Cod	14	38	215	49.40	243		5	0.36	0.130	0.023	0.101	0.0206	
DK: N Sea	1993-2000	Jul-Sep	Cod	58	172	681	188.30	1175		86	1.48	0.499	0.126	0.457	0.0732	
DK: N Sea	1993-2000	Oct-Dec	Cod	28	61	393	144.10	887		22	0.79	0.363	0.056	0.153	0.0248	
DK: N Sea	**1993-2000**	**All**	**Cod**	**118**	**315**	**1569**	**450.30**	**2661**		**149**	**1.26**	**0.473**	**0.095**	**0.331**	**0.0560**	
DK: N Sea	1997	Mar-Sep	Hake	2	5	32	3.10	122		4	2.00	0.836	0.125	1.290	0.032	

															8	
DK: N Sea	1994-2000	Jan-Mar	Plaice	9	47	61	61.60	498		21	2.33	0.444	0.344	0.341	0.0422	
DK: N Sea	1994-2000	Apr-Jun	Plaice	12	21	33	8.50	157		0	0.00	0.000	0.000	0	0	
DK: N Sea	1994-2000	Jul-Dec	Plaice	3	4	3	0.20	7		0	0.00	0.000	0.000	0	0	
DK: N Sea	**1994-2000**	**All**	**Plaice**	**24**	**73**	**97**	**70.30**	**662**		**21**	**0.88**	**0.288**	**0.216**	**0.299**	**0.0317**	
DK: N Sea	1992-2000	Jan-Dec	Sole	22	52	68	8.20	875		0	0.00	0.000	0.000	0	0.0000	
DK: N Sea	1992-2000	Mar-Jun	Turbot	13	64	110	24.40	945		78	6.00	1.221	0.709	3.197	0.0825	
DK: N Sea	1992-2000	Jul-Sep	Turbot	5	28	41	6.20	301		77	15.40	2.772	1.878	12.419	0.2558	
DK: N Sea	1992-2000	**All**	**Turbot**	**18**	**92**	**151**	**30.60**	**1246**		**155**	**8.61**	**1.691**	**1.026**	**5.065**	**0.1244**	
UK: N Sea	1996-2011	**All**	**Bass**	**87**	**92**	**393**	**2.46**	**275**	**708**	**8**	**0.09**	**0.087**	**0.020**	**3.256**	**0.0291**	**113.0**
UK: N Sea	1996-2011	**All**	**Cod**	**428**	**601**	**3342**	**215.15**	**1404**	**23059**	**25**	**0.06**	**0.042**	**0.007**	**0.116**	**0.0178**	**10.8**
UK: N Sea	1996-2011	**All**	**Dogfish**	**1**	**8**	**18**	**3.00**	**16**	**364**	**0**	**0.00**	**0.000**	**0.000**	**0.000**	**0.0000**	**0.0**
UK: N Sea	1996-2011	**All**	**Sole**	**156**	**170**	**713**	**7.68**	**352**	**5508**	**5**	**0.03**	**0.029**	**0.007**	**0.651**	**0.0142**	**9.1**
UK: N Sea	1996-2011	**All**	**Herring**	**7**	**7**	**16**	**1.36**	**7**	**19**	**0**	**0.00**	**0.000**	**0.000**	**0**	**0.0000**	**0.0**
UK: N Sea	1996-2011	**All**	**Mixed**	**3**	**3**	**7**	**1.36**	**4**	**10086**	**0**	**0.00**	**0.000**	**0.000**	**0**	**0.0000**	**0.0**
UK: N Sea	1996-2011	**All**	**Monkfish**	**8**	**50**	**160**	**3.33**	**612**	**28236**	**0**	**0.00**	**0.000**	**0.000**	**0**	**0.0000**	**0.0**
UK: N Sea	1996-	**All**	**Mullet**	**2**	**2**	**5**	**0.22**	**5**	**27**	**0**	**0.00**	**0.000**	**0.000**	**0**	**0.000**	**0.0**

	2011														**0**	
UK: N Sea	1996-2011	**All**	**Salmonids**	**81**	**87**	**209**	**2.53**	**82**	**422**	**2**	**0.02**	**0.023**	**0.010**	**0.791**	**0.024 3**	**47.3**
UK: N Sea	1996-2011	**All**	**Skate**	**182**	**215**	**1076**	**10.02**	**508**	**1843 2**	**39**	**0.21**	**0.181**	**0.036**	**3.891**	**0.076 8**	**21.2**
UK: N Sea	1996-2011	**All**	**Turbot**	**15**	**25**	**120**	**0.24**	**60**	**1874**	**4**	**0.27**	**0.160**	**0.033**	**16.36 1**	**0.066 3**	**21.3**
UK: N Sea	**1996-2011**	**All**	**All Species**	**970**	**1260**	**6059**	**247.35**	**332 5**	8873 6	**83**	**0.09**	**0.066**	**0.014**	**0.336**	**0.025 0**	9.4
OVERALL				**1227**	**2221**	**21652**	**928**	**9109**	**99615**	**529**	**0.341**	**0.185**	**0.02**	**0.534**	**0.051**	**9.838**

For porpoises, bycatch rates have been expressed in terms of several denominators, with positive bycatch per 10,000 km hours of fishing effort values ranging from about 4 to 113. Porpoises per km.hour should represent a standardised metric assuming there is a linear relationship between both net length and soak time and bycatch probability for a porpoise, though this is by no means certain.

The most commonly reported metrics are bycatch per haul and bycatch per day. Values for porpoises in and around the North Sea over a numerous static gear types range from 0 to 1.69 porpoises per day, and 0 to 1.02 porpoises per haul. In reality, the only fishing effort metric that is likely to be available at the fleet level, for the purposes of raising such bycatch estimates to annual totals for the North Sea, is likely to be the days at sea. The median value for porpoise bycatch per day at sea from Table 6 is 0.036 when seasonal and annual distinctions are ignored (that is – just considering the bycatch by fishery) – or one porpoise per 28 days fished. The mean value is 0.172 or 1 porpoise per 5.8 days fished. The latter is likely to be biased through sampling having been focused on a few fisheries where bycatch was thought to be high (e.g. the turbot fishery) but which do not make a major contribution to the overall set net fishing effort in the region.

It is clear that gillnet and tanglenet fisheries are most often involved in porpoise bycatches, but other gear types are also known to take porpoises less frequently (Northridge 1991). Lunneryd, Königson, & Sjöberg (2004) report that around 30% of reported porpoise bycatches were from trawls during a telephone survey of fishermen on the Swedish west coast, while the rest were from a variety of static nets. Overall porpoises appear most vulnerable to static nets with some gear types (cod wreck nets and turbot nets for example) having a higher bycatch rate than others.

Information on bycatches of other marine mammals is much less detailed. Bycatches of baleen whales (minkes and humpback whales) in The North Sea have been reported due to entanglement in creel (lobster pot) ropes and/or gillnet ropes (Northridge et al., 2010). There are some sporadic accounts of *Lagenorhynchus* bycatch in some fisheries (Vinther 1995, Northridge 1991), but insufficient data to provide any estimates of bycatch rates.

Seals are caught in both static and mobile gears in the North Sea not infrequently (Northridge 1991). The UK protected species observer programme has recorded 134 seals caught in the North Sea since 1996. Until recently observers were not trained to distinguish between the two species so it is not feasible to break the observed seal bycatch rates down to species level. There are few other data with which to compare catch rates across gear types to assess gear specific vulnerability, but Lunneryd, Königson, & Sjöberg (2004) found that seals were reported in a wide variety of gear types, both static and mobile, during telephone surveys with Swedish fishermen. Table 7 summarises seal bycatch rates by gear type, in terms of seals per haul and per day at sea, based on the UK observer data alone.

Table 7: Records of seal bycatch in UK North Sea fisheries by gear type

GEAR TYPE	Seals	Hauls	Days at sea	Seals/haul* 100	Seals/day * 100
Light otter trawl	0	5	3	0	0
Midwater trawl	2	105	163	1.9	1.2
Midwater pair trawl	48	100	78	48	61.5
Ring net	0	3	1	0	0
Drift net	1	51	20	2.0	5
Set net (unspecified)	83	5510	1128	1.5	7.4
Gill net	0	45	14	0	0
Trammel net	0	185	50	0	0
Tangle net	0	8	2	0	0
Stake net	0	4	4	0	0
Danish gill net	0	7	1	0	0
Wreck net	0	3	1	0	0
Drift Trammel	0	286	69	0	0
TOTALS	134	6312	1534		

The data summarised in Tables 5-7 demonstrate the relative vulnerability of different bird and mammal species to specific gear types. Clearly the data for porpoises are more detailed, particularly with respect to static nets, than are the data for other species, or indeed for mobile gears. In theory it would be simple to use such data to extrapolate figures for total bycatch for the North Sea, but there are two significant impediments to such a conclusion. The first is that, as Table 6 demonstrates, bycatch rates are very variable within the general category of static nets, and also between years and seasons. Taking average bycatch rates for an overall gear type can be misleading, especially when particular fisheries may have been targeted for sampling which also have relatively high porpoise bycatch rates. The second more fundament reason is that detailed fishing effort data are very hard to pull together across the 8 nations that regularly fish in the North Sea. This is addressed further in 2.4

2.4 Fishing effort and likely scale of bycatch for the North Sea

Collating fishing effort data from several different EU countries is notoriously difficult, even though each member state of the EU maintains the same system of EU logbooks. Logbooks, however, only apply to the over 10m section of the fleet, whereas the vast majority of boats using static nets throughout the EU are under-10m. Collating effort on this sector therefore relies on a varied set of national data collection protocols. Furthermore, even among the logbook data, differences in national diligence result in differences in the availability of certain data items. Several of the logbook data entries relating to effort are non-mandatory and therefore unavailable in some meber states, and some items are also interpreted differently in different countries. The collation and maintenance of fleet effort records remains the responsibility of individual member states, and any EU level collation relies upon a Commission data call.

Previous data calls for combining effort data were available in two formats for the present project. The STECF-SGMOS Effort Management WG (Anon., 2011) has collated and evaluated effort and catch data for fisheries with the purpose of reviewing fisheries regulated through effort management. The publicly available dataset from that group includes annual fishing effort (hours fished) by ICES rectangles (1.0 x 0.5^{o}) by country, vessel size (<10m, 10-15 m, > 15 m) and fishing technique/gear group for the EU member states. Total effort figures are available as kW-days per country, and by regulation area, are also available from the WG. Norwegian data are currently not available.

KW-days are calculated by multiplying the days fished by the registered power in KW for each vessel and summing over particular strata. However, "STECF-EWG considers that the use of fishing days (or kW*days) to manage effort of static gears such as gillnets and longlines is a very poor approximation of the effective effort" Anon (2011). This clear from an examination of the registered power of UK vessels using gillnets, where there is a poor relationship between power and vessel length. This is because gillnet vessels may include old trawler that still have powerful engines, but which are not needed to tow anything, alongside much lower powered purpose built gillnet boats. Clearly, from Section 2.3 above, gillnets are the primary gear type of interest in determining the susceptibility of protected taxa to fishing.

A second publicly available dataset is available from STECF (http://stecf.jrc.ec.europa.eu/data-reports), in which effort data are presented as hours fished by ICES rectangles (1.0 x 0.5^{o}) by country, vessel size (<10m, 10-15 m, > 15 m) and fishing technique/gear group for the EU member states. Again data from Norway are not available. These data are also hard to interpret for gillnets as, unlike trawls, gillnets continue to fish when boats are back in port, and EU logbook data do not allow any assessment of soak-time for static gear by individual net or by vessel. It is not obvious how 'hours fished' is calculated for gillnet fishing effort. For the UK, however, "it was not possible to provide trawled hours data. This is because hours trawled is not a mandatory field in the fishers' logbooks and is therefore not necessarily completed. Instead, the data used to provide nominal effort ... is held on a statistical rectangle basis by UK. This (sic) data was simply multiplied by 24 to get a measure of fishing effort expressed in hours" (Anon 2008). It is not clear whether or not the same approach was used by other member states in providing hours fished data for gillnets.

For gillnets alone, there is a third source of data, from an ICES workshop that examined the functioning of Regulation 812/2004 on cetacean bycatch in some detail (ICES 2010). Workshop participants from all member states that fish in the North Sea provided gillnet effort data in terms of the number of days at sea, extracted from national databases for the workshop. There were no days at sea data available for Norway, but Norwegian landings were available for gillnet vessels, and using the lowest landings per day at sea value from neighbouring countries, the workshop was able to make an approximation of the number of days at sea by the Norwegian gillnet fleet, though likely an over-estimate of effort. These data are reproduced in summary form below in Table 8, which also includes the equivalent 'hours fished' data from the STECF.

Table 8: Available effort data from two sources for static nets in the North Sea and Skagerrak

GILLNET FLEET ACTIVITY BY NATION			
	Days at sea	Tonnes landed	Hours fished
IV abc	From WKREV812 for 'latest year' (mainly 2009)		From STECF for 2010
Belgium	420	143	3048
Denmark	5760	7257	108579
France	2200	na	20201
Germany	1014	704	14237
Netherlands	3578	na	11469
Norway	[9011][3]	1801	na
Sweden	0	0	0
UK	5998	2185	158018
IIIa			
Denmark	5428	2880	13765
Sweden	950	223	15109
TOTALS	34359	15193	344426

There is a poor correlation between days at sea as reported to the ICES workshop and hours fished as reported to STECF. This underscores the problems of using compiled effort data from EU member states. As days at sea are recorded clearly in the EU logbook data, and as 'hours fished' seems to have been calculated in an ad hoc manner by each member state, the former statistic is probably more useful as an overall guide to the amount of effort by member state. On the other hand the days at sea data here are only available for large sea areas and not by ICES rectangle. The hours fished data were reported to STECF by rectangle, and despite their obvious shortcomings do at least provide some description of the spatial distribution of effort by gear type across the region.

We have therefore chosen to use the hours fished data supplied to STECF by ICES rectangle as a means of exploring the spatial overlap between vulnerable species and those fisheries to which they appear most vulnerable.

The days at sea data from ICES WKREV812 (Anon 2010) provide at least some crude yardstick as to the overall amount of gillnet effort in the North Sea- which we take to be around 35,000 days in 2009. No similar data could be located for midwater trawls or any other major gear category, but gillnets (or set nets) are clearly the gear type most frequently associated with bycatch records of both mammals and birds.

[3] Estimated from tonnes landed per day at sea in neighbouring countries.

3. Susceptibility to specific fisheries

3.1 Species and fisheries of most concern

In the preceding section we have compiled data on the abundance, likely sustainable take levels, bycatch rates and effort data (for gillnets) for the species of concern within the North Sea, and the Skagerrak when data were available. From these compilations a picture of species and gear specific vulnerability can be discerned, and furthermore, if some very crude assumptions are made, we can also suggest which species are most likely to be exposed to a conservation threat as a result of their vulnerability to specific gear types within the wider North Sea.

Table 9 provides a synthesis of preceding tables with the aim of identifying which species are most vulnerable to which gear types. We have used data from 5 through 7 to suggest possible overall bycatch rates (per haul) and used our own data and others' data as available to estimate the number of fishing operations (hauls) per day for broad gear categories as shown in the relevant column in Table 9 ("expected number of hauls per day"). In this way we can calculate an expected number of animals bycaught per day (actually per 1000 days).

In order to introduce some measure of uncertainty, we have also assumed a binomial distribution in bycatch per haul, and calculated the upper 95% confidence limit on the bycatch rate per haul. This has been translated into a UCL on the bycatch per day at sea.

We have data to suggest that recent (2008-2010) fishing effort levels for all set nets (gillnets, tangle nets and trammel nets) is around 35,000 days for the North Sea and Skagerrak (table 8), but we were unable to find similar reliable data on the total number of days at sea for midwater trawls, nephrops trawls, beam trawls or longlines. Therefore, using the data from table 8 we are able to suggest a possible annual level of take for birds and mammals in this region.

Finally we can compare that level of take with the sustainable limits (PBR or 1.7%) previously presented in Tables 3 and 4.

This enables us to compare the final four columns in Table 9 to identify species that appear to be most vulnerable to bycatch at the population level. Examining our estimates of bycatch rates in Table 9 (Catch per 100 days at sea – mean and UCL) provides another way of identifying vulnerability at the individual level (higher probability of capture for any individual animal). The absence of data relating to days at sea for some gear types – particularly for midwater trawls, constrains what we can say about some of the species concerned.

It must be stressed that the figures given in Table 9 are not a substitute for a rigorous bycatch estimate, nor should they be interpreted as such. There are many simplifications and assumptions that underlie these data, and which would make it dangerous to rely on such numbers as estimates of total bycatch in any fishery sector. They are intended as guides to the possible scale of bycatch, given all the underlying assumptions. Probably the most significant assumption is that by pooling observations from several countries and many fishery metiers we can arrive at an overall average bycatch rate. This is clearly unrealistic, as even a casual inspection of Table 6 should reveal.

Table 9: Overview of possible bycatch rates per 1000 days at sea with potential scale of bycatch in the North Sea, and sustainable limits, by species and by gear type. Note that North Sea Effort as days at sea was only available for set nets.Table 10: Overview of possible bycatch rates per 1000 days at sea with potential scale of bycatch in the North Sea, and sustainable limits, by species, and by ear type. Note that total North Sea effort as days at sea was only available for set nets.

Bycatch species or group	General gear type	Observations			Catch rate per 1000 days at sea		Assumed total fleet days in North Sea	Possible catch level per year (but see text for caveats)		Sustainable take limits	
		No of hauls observed	No of bycaught individuals	Expected No of hauls per day	Mean	95% UCL		Assuming mean catch rate	Assuming 95% UCL rate	Lower estimate of PBR	Higher estimate of PBR
Cormorant	All set nets	11321	24	3.2	6.78	10.09	35000	237	353	422	202
	All midwater trawl	1934	2	1.2	1.24	4.48	NA	NA	NA		
Fulmar	LongLine	934	15	1.3	20.88	[34.26]	NA	NA	NA		
	All Set nets	1101	14	3.2	40.69	67.98	35000	1424	2379	13139	8677
Gannet	Nephrops trawl	845	1	2.1	2.49	13.81	NA	NA	NA		
	Beam Trawl	6558	1	6.6	1.01	5.61	NA	NA	NA		
	All set nets	11901	6	3.2	1.61	3.51	35000	56	123	5386	2182
Guillemot	All midwater trawl	1493	25	1.2	20.09	29.54	NA	NA	NA		
	All set nets	13151	174	3.2	42.34	49.07	35000	1482	1717	28110	15744
Herring Gull	All set nets	10474	2	3.2	0.61	2.21	35000	21	77	16365	4343
Kittiwake	LongLine	811	1	1.3	1.60	8.91	NA	NA	NA	15463	8426
Petrel	All set nets	349	1	3.2	9.17	50.75	35000	321	1776	na	na
Razorbill	All midwater trawl	1493	3	1.2	2.41	7.03	NA	NA	NA	6422	3754
										PBR	1.7%
Porpoise	All set nets	21652	446	3.2	65.92	72.25	35000	2307	2529	1783	3929
Seal (2 spp).	All midwater trawl	205	50	1.2	292.68	[370.31]	NA	NA	NA		
	All set nets	6099	84	3.2	44.07	54.48	35000	1543	1907	1800	1518

Reported bycatch rates are highly variable between fisheries even among set net fisheries, between seasons and between years. By pooling such data we assume that the sampling is representative of the whole fleet, which is very unlikely. Certain fisheries may have been targeted for sampling precisely because they have high bycatch rates, and these can then bias the overall rate if a stratified approach to bycatch estimation is not taken. The same argument applies to our estimates of the number of hauls per day; these can be highly variable and a stratified approach to bycatch estimation would need to be adopted in a formal bycatch estimation. We have also assumed that bycatch events are binomially distributed, and while experience suggests this is a reasonable assumption for porpoise bycatch and for the bycatch of some birds in some fisheries, there are examples where bycatches are highly clumped with several or many animals recorded from a single haul. This is true of seals in midwater trawls and of fulmars in longline hauls. It would therefore be unwise to read too much into these examples.

Despite these shortcomings and caveats, Table 9 provides a useful overview and a basis for focusing further work – by identifying those fisheries and species combinations that might require further investigation or even mitigation strategies. It could also be taken to suggest some species / gear combinations that are *probably* not too great a concern on the basis of current data. It also allows us to focus on the spatial overlap between those species and fisheries about which we might be most concerned: by highlighting the key vulnerabilities, we can go on to explore the level of susceptibility for each species by comparing its distribution with that of the most relevant fishery. We have undertaken this in section 3.2 and 3.3.

Comparing the values of possible bycatch levels with those indicating sustainable levels in Table 9 would suggest that the bycatch of cormorants, porpoises and seals in set net fisheries (marked yellow in Table 9) should be worth examining in more detail, whereas at first sight, bycatches of herring gulls, fulmars and even guillemots in set net fisheries seem less likely to be of conservation concern (marked green in Table 9). Of course this should not be taken as proof that conservation risk is high for the first three groups and low for the latter group; it simply suggests that this might help focus further work.

The lack of any overall effort levels for longlining (*inter alia*) precludes any such preliminary judgements about fulmars in that gear type.

3.2 Susceptibility- examining spatial overlap

We have used data on fishing effort that are publicly available through STECF to examine the distribution of fishing effort by gear type throughout the North Sea. We have used hours fished as the metric most likely to provide an overview of those areas where effort is most and least intense. The data were available for several years, and by ICES rectangle, and we have chosen to use the latest available year, 2010, and have plotted effort by ICES rectangle scaled by the sea surface area of each rectangle. Because ICES rectangles sometimes overlie land, using the number of hours fished without adjusting for the spatial area available for fishing within each rectangle could suggest a lower level of interaction with a vulnerable species than should actually be the case. We have therefore used hours fished per km^2 as the derived statistic of interest here and have calculated that for each ICES rectangle.

We have used sightings data collected by the Seabirds at Sea Team over several decades (1979 to 2006) to provide indices of seabird and cetacean density. These have been calculated as the number of individuals by species seen per km travelled at sea, by ICES rectangle. Because data are relatively sparse in any one year, we have pooled all years in the expectation that the average distribution does not vary too much from the most recent years' distribution. Clearly this is an assumption that should require further exploration, and we present results here more as an exploration of a methodology than a finalised assessment of spatial overlap.

Seal distribution maps have been prepared at the Sea Mammal Research Unit based on telemetry data collected over many years that have been used to model habitat use for both grey and common seals throughout the North Sea (Esther Jones, unpublished data).

For seabirds there are often large differences in both the number and distribution of birds within the North Sea on a seasonal basis. We have tried to address this by plotting distribution (summer vs winter) for each of the bird species concerned. Unfortunately seasonal distribution of fishing effort was not available for the STECF publicly available dataset, so we have assumed that fishing effort distribution does not vary over the year.

In order to compare the distribution of animals and fishing effort we have developed an index of co-occurrence to represent the degree of overlap – or perhaps the degree of risk of entanglement of capture. This is high where animal density and fishing effort are both intense, but low when either fishing effort or animal density is low. It is zero where animal sightings rates are zero or fishing effort is zero, and adopts a value of 1 in areas with average sightings rates and average effort. Expressing animal sightings rates as S (animals per km) and fishing effort as E (hours fished per km^2), a cell by cell co-occurrence index (CoI) can be calculated as:

$$CoI_i = \frac{S_i}{\hat{S}} * \frac{E_i}{\hat{E}}$$

for each cell (i) where $\hat{S}$ is the overall mean sightings rate and $\hat{E}$ the overall mean effort value.

Cells with values of greater than 1 represent areas of greater than average overlap or coincidence and those with values of less than 1 have a lower level of overlap or risk of entanglement or bycatch. Visually, one can represent the value of CoI for each cell as a graphic symbol (circle) whose area is proportional to the value of CoI. This provides an easy way to visualise those areas where overlap between the species and fishery of interest is greatest.

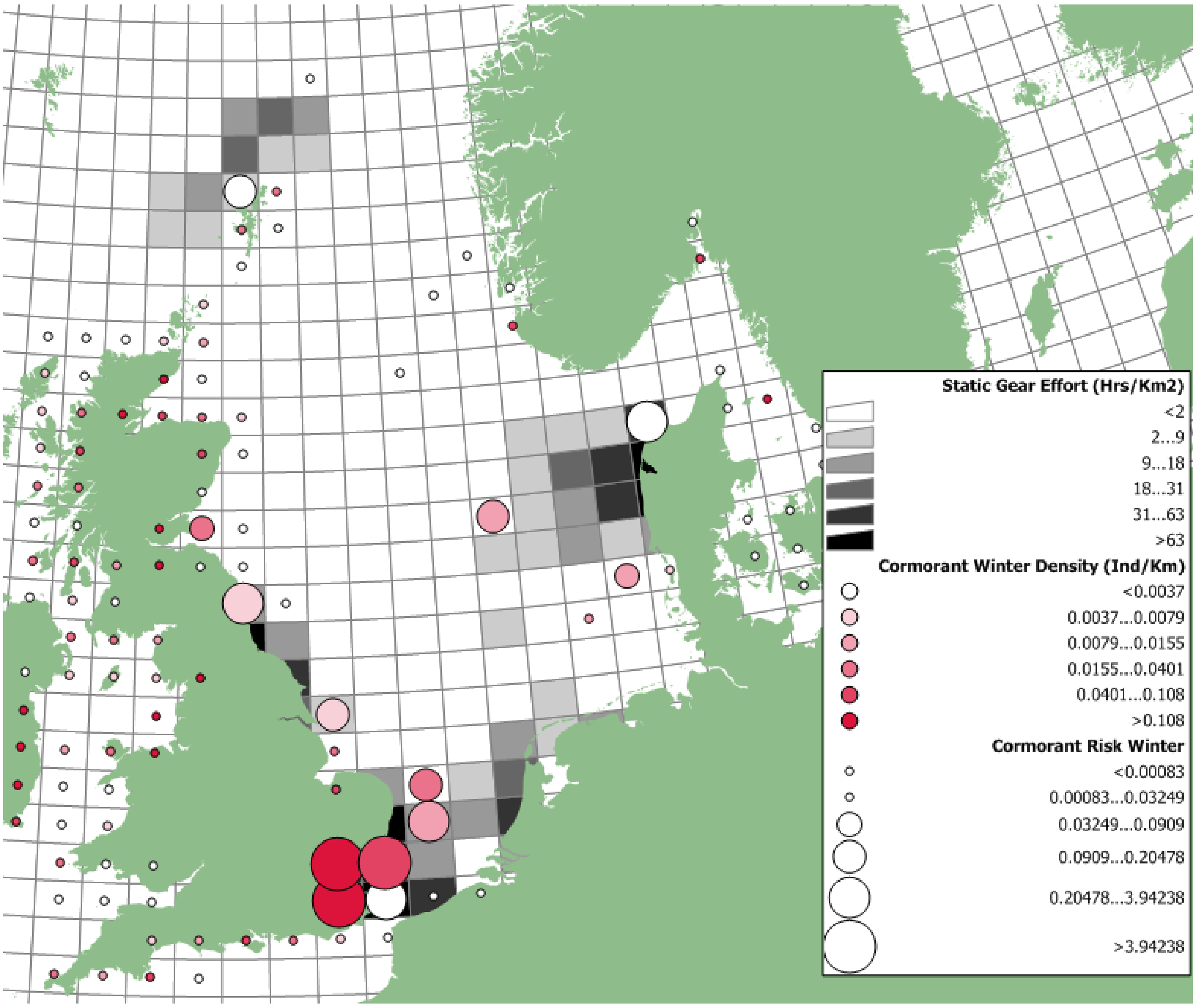
We have calculated the sightings rates, effort level and co-occurrence index as described above for all the species and fisheries of concern. We have mapped 15 species / gear type combinations (Table 11). These were mainly based on the observed bycatch rates by gear type (table 10 and 5-7), but we have also included white-beaked dolphins and minke whales, where records of bycatch in pelagic trawls and static gear respectively have been reported, but for which no observer based records of bycatch rate are available. In these instances, where bycatch is suspected but not well documented, maps of co-occurrence can help to delimit areas of likely interaction, which may then help focus observer scheme efforts.

Table 11: Species / fishery pairs for which distributions have been plotted.

Species of concern	Set nets	Midwater / pelagic trawls	Longlines
Cormorant	*	*	
Fulmar	*		*
Gannet	*		
Guillemot	*	*	
Herring Gull	*		
Kittiwake			*
Razorbill		*	
Harbour porpoise	*		
Minke whale	*		
Seal - grey	*		
Seal -common	*		
White-beaked dolphin		*	

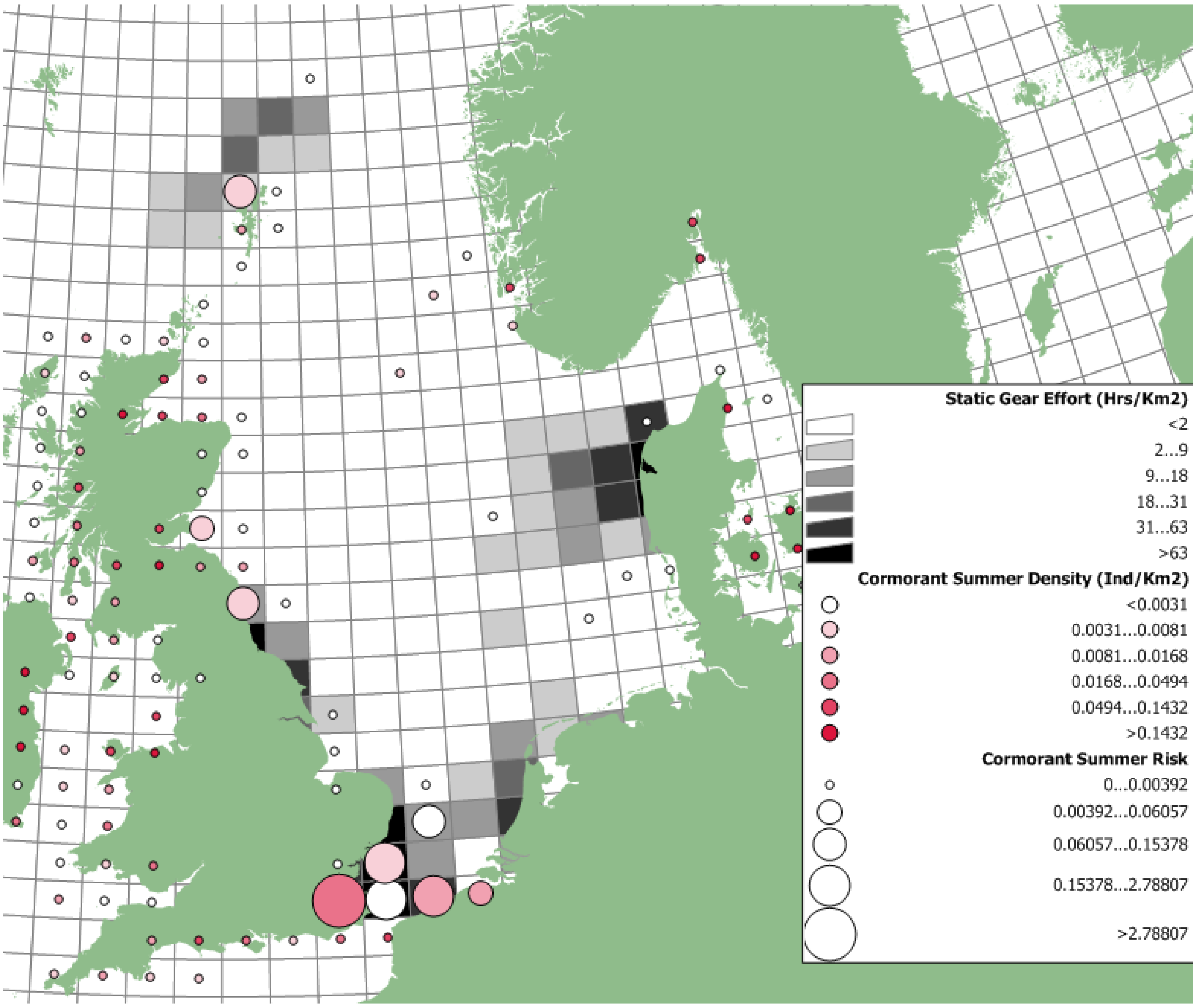
In each of the maps below, fishing effort is expressed as hours fished per km^2 for each ICES rectangle. Areas of highest fishing effort for this gear type are represented by ICES rectangles shaded darkest (see key on each map). Bird density (individuals sighted per km travelled) is expressed on a coloured scale in the circles; circle colours of a darker red indicate greater densities (see key on each map). Circle size reflects the Co-occurrence Index which can also be thought of as risk of a bycatch event occurring, assuming that risk is proportional to animal density and fishing effort level.

Figure 2: Cormorants and static gear – winter distribution of cormorants; co-occurrence index.



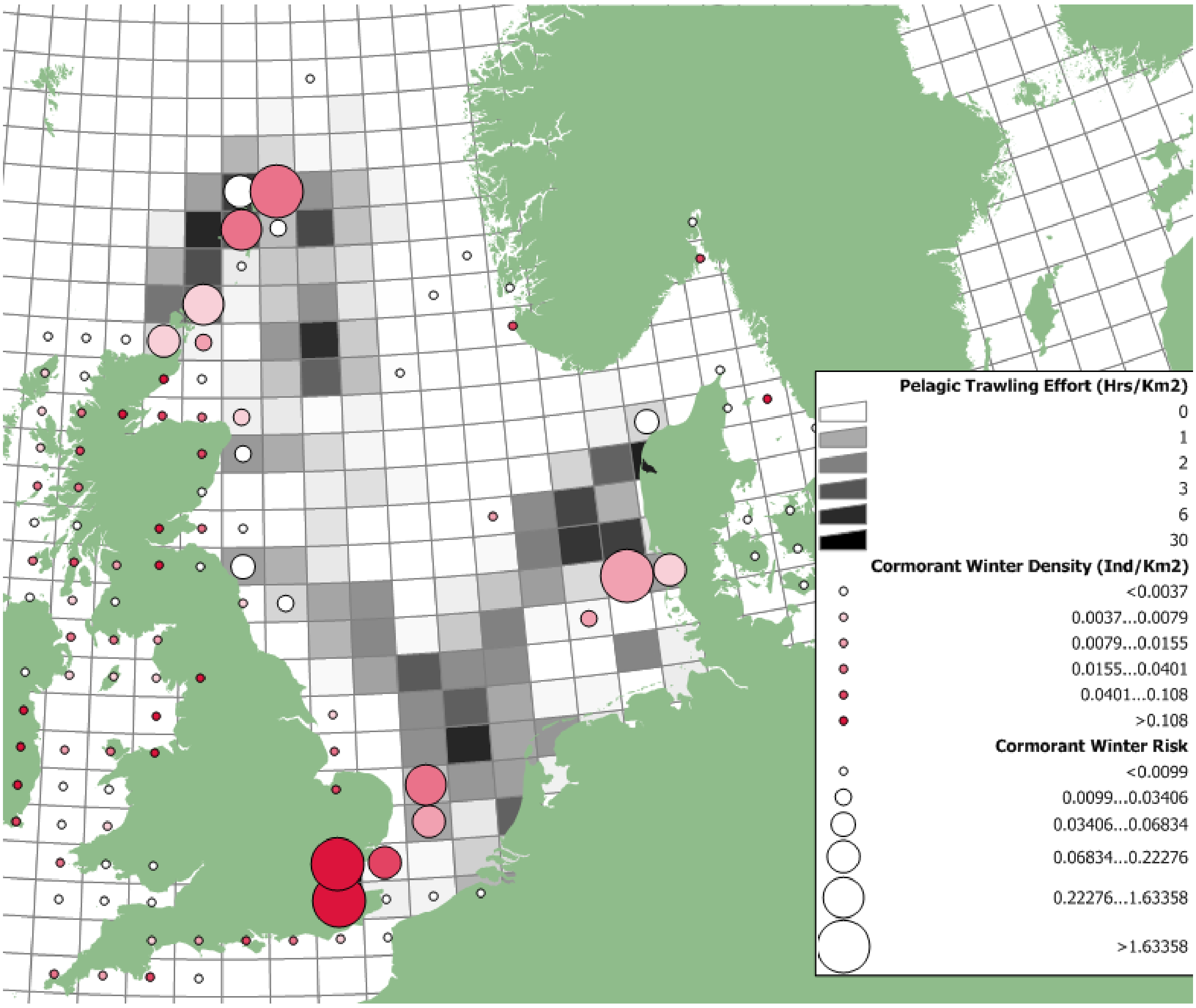
In this map, the Thames estuary area appears to be the area with the greatest co-occurrence of cormorants and set net fishing gear during the winter months. This is also the area with some of the highest cormorant sightings rates. High sightings rates of cormorants in Shetland and parts of Northeast Scotland are not matched by any significant set net fishing effort levels.

Figure 3: Cormorants and static gear – summer distribution of cormorants; co-occurrence index.



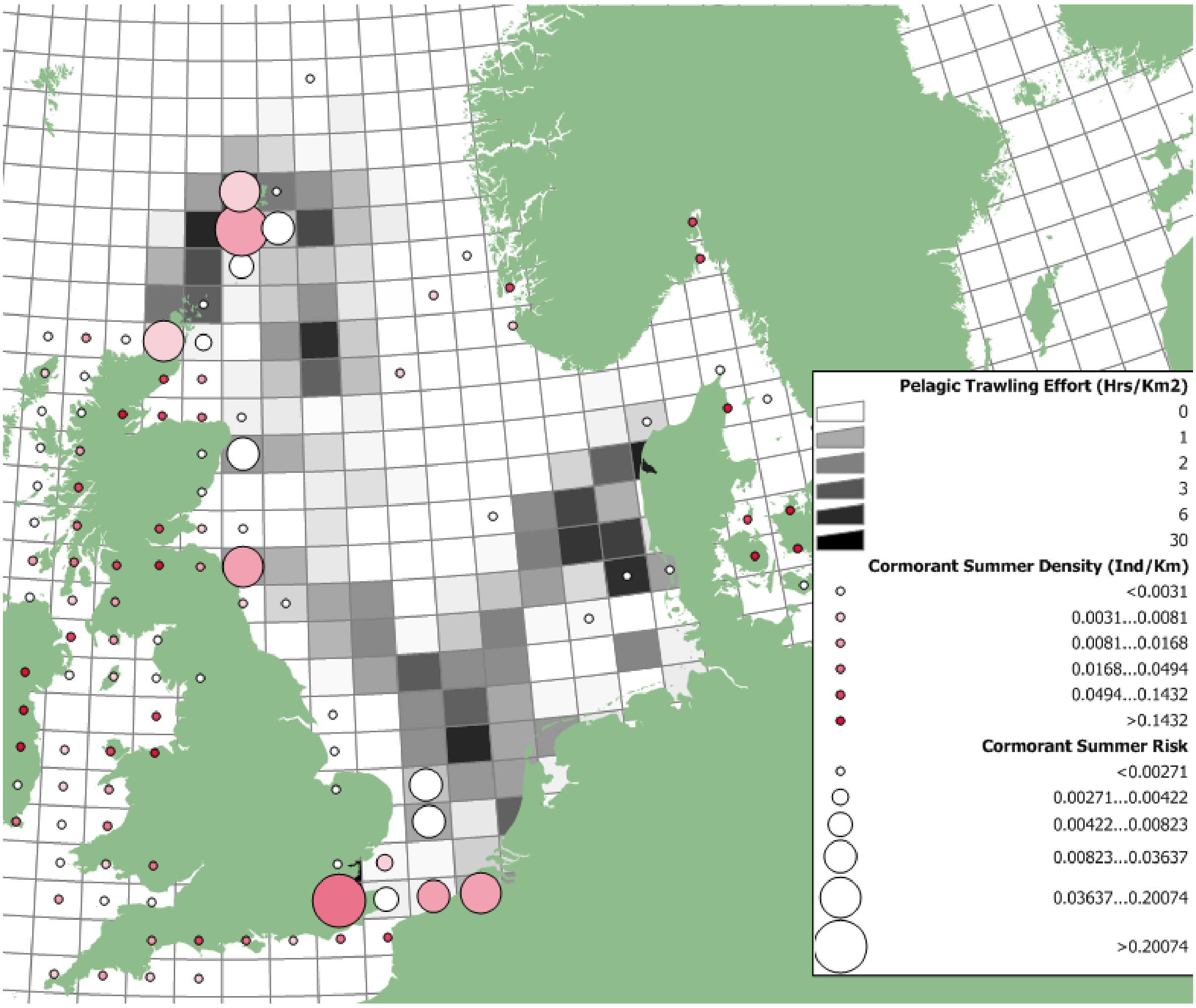
In this map the south-western North Sea (southern edge of IVc) is the area with highest levels of co-occurrence for cormorants and set nets in the summer. Other areas of high gillnet effort have relatively low levels of cormorant sightings rates.

Figure 3 Cormorants and pelagic trawls - winter distribution of cormorants; co-occurrence index



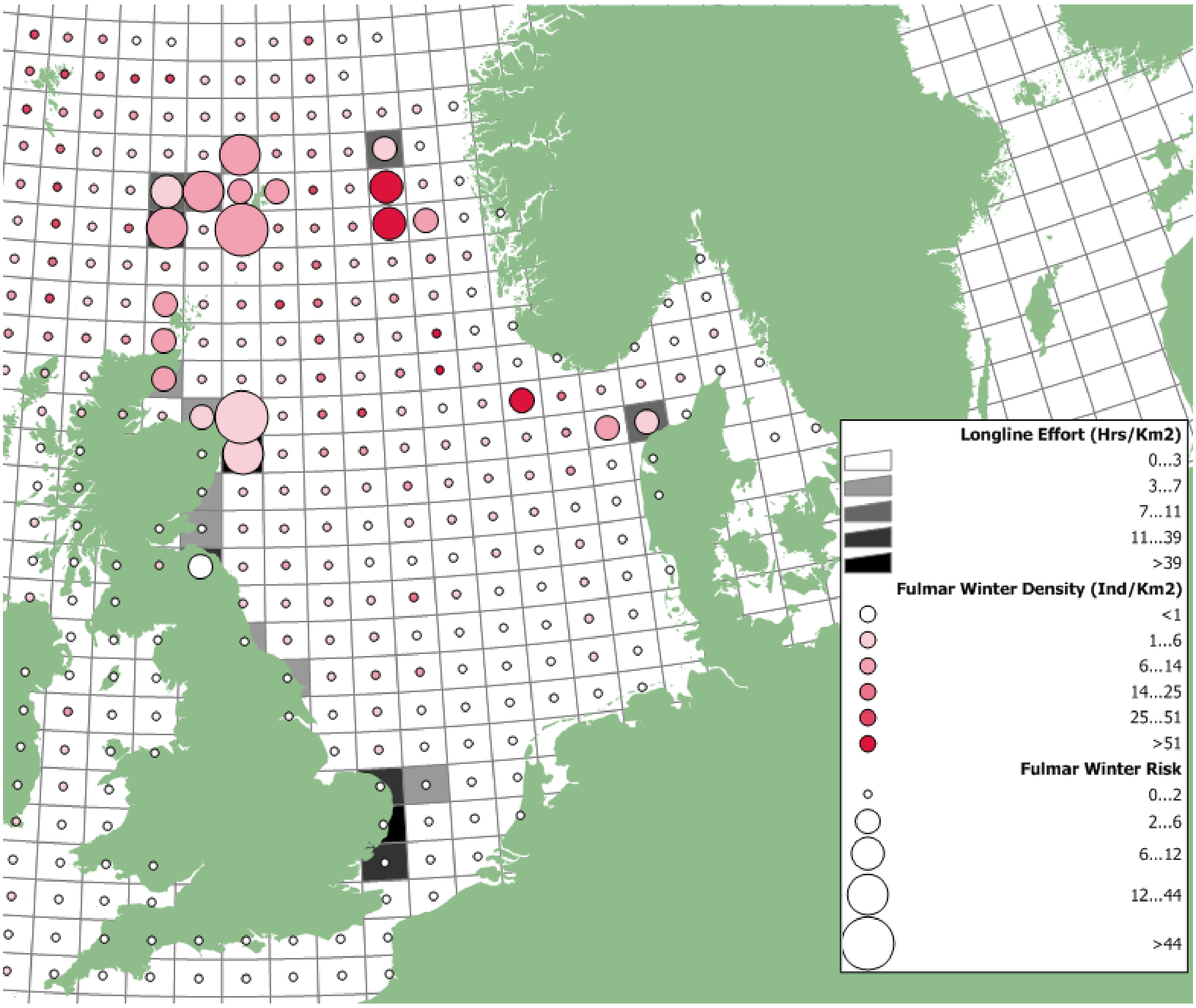
Highest levels of co-occurrence are in the Thames estuary, around Shetland and around the Horns reef area off Denmark. High levels of cormorant sighting around northeast Scotland are not matched by any significant levels of pelagic trawl effort in the same cells.

Figure 4 Cormorants and pelagic trawls - summer distribution of cormorants; co-occurrence index



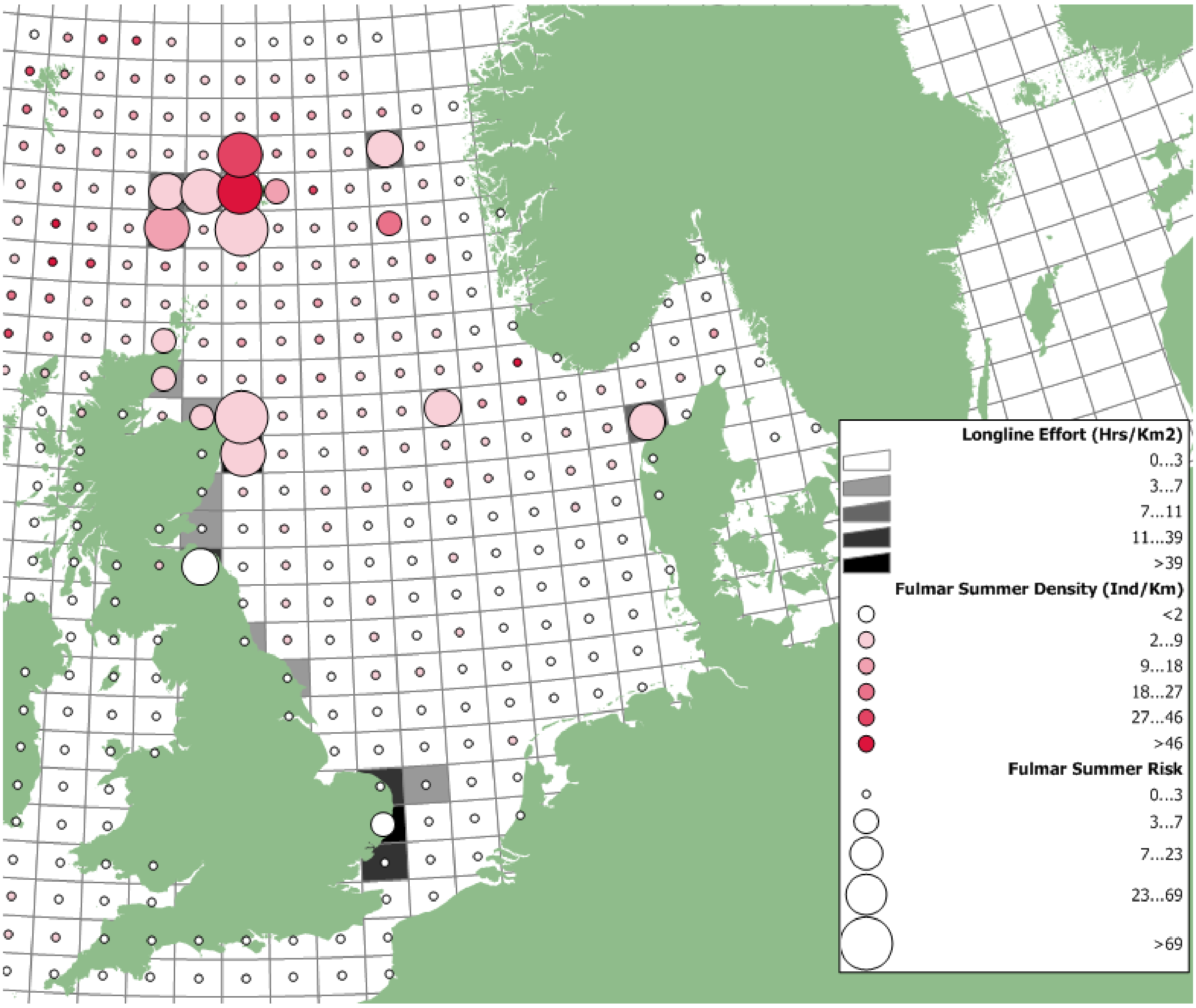
Again, highest levels of co-occurrence are in the southern North Sea (Thames estuary/Akkaert Bank) and in parts of Shetland, but also off northeast England.

Figure 5: Fulmars and longline effort – winter distribution of fulmars; co-occurrence index



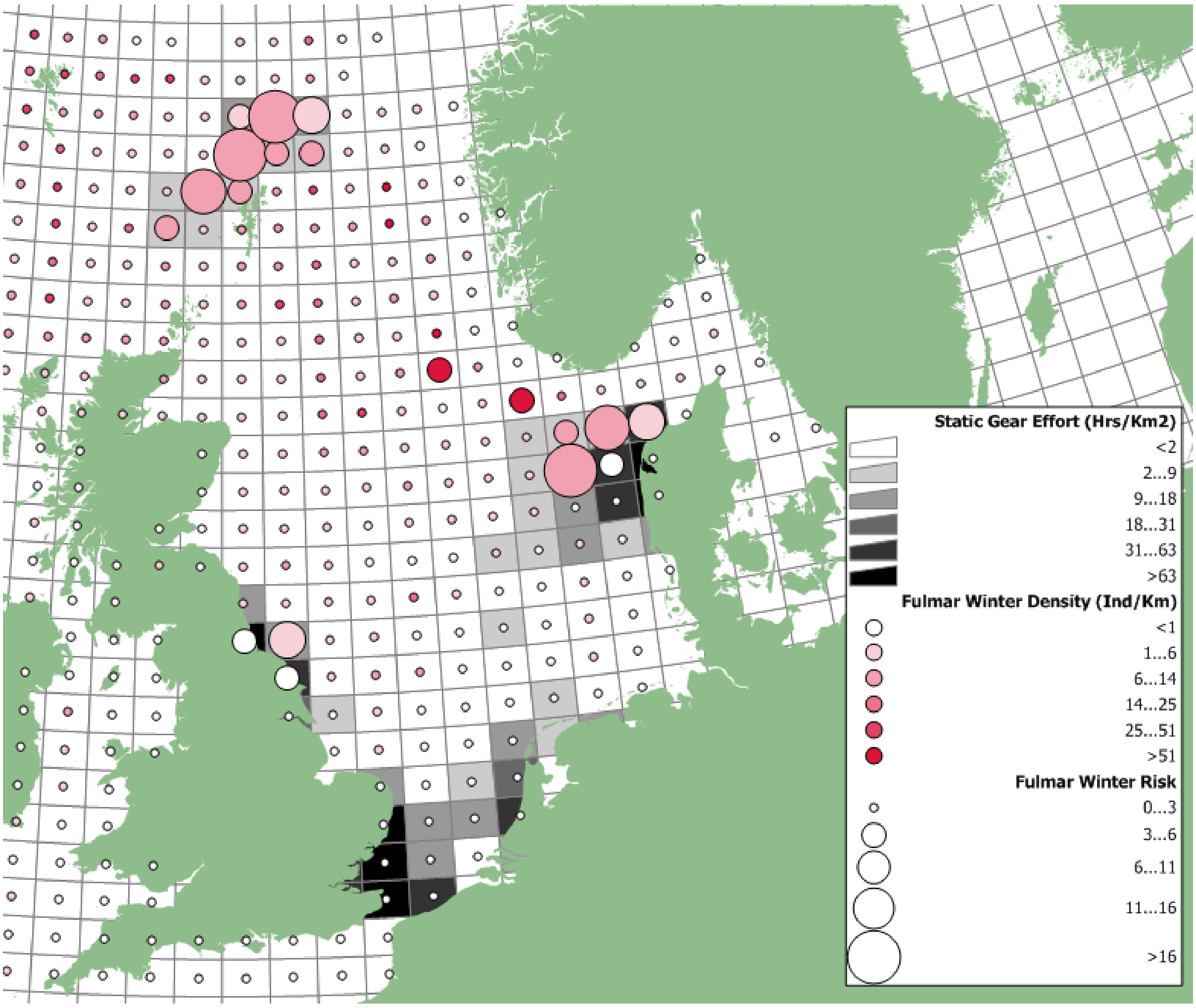
The greatest areas of overlap between longliners and fulmars during the winter are in area IVa and the Aberdeenshire coast, and around Shetland.

Figure 6: Fulmars and longline effort – summer distribution of fulmars; co-occurrence index



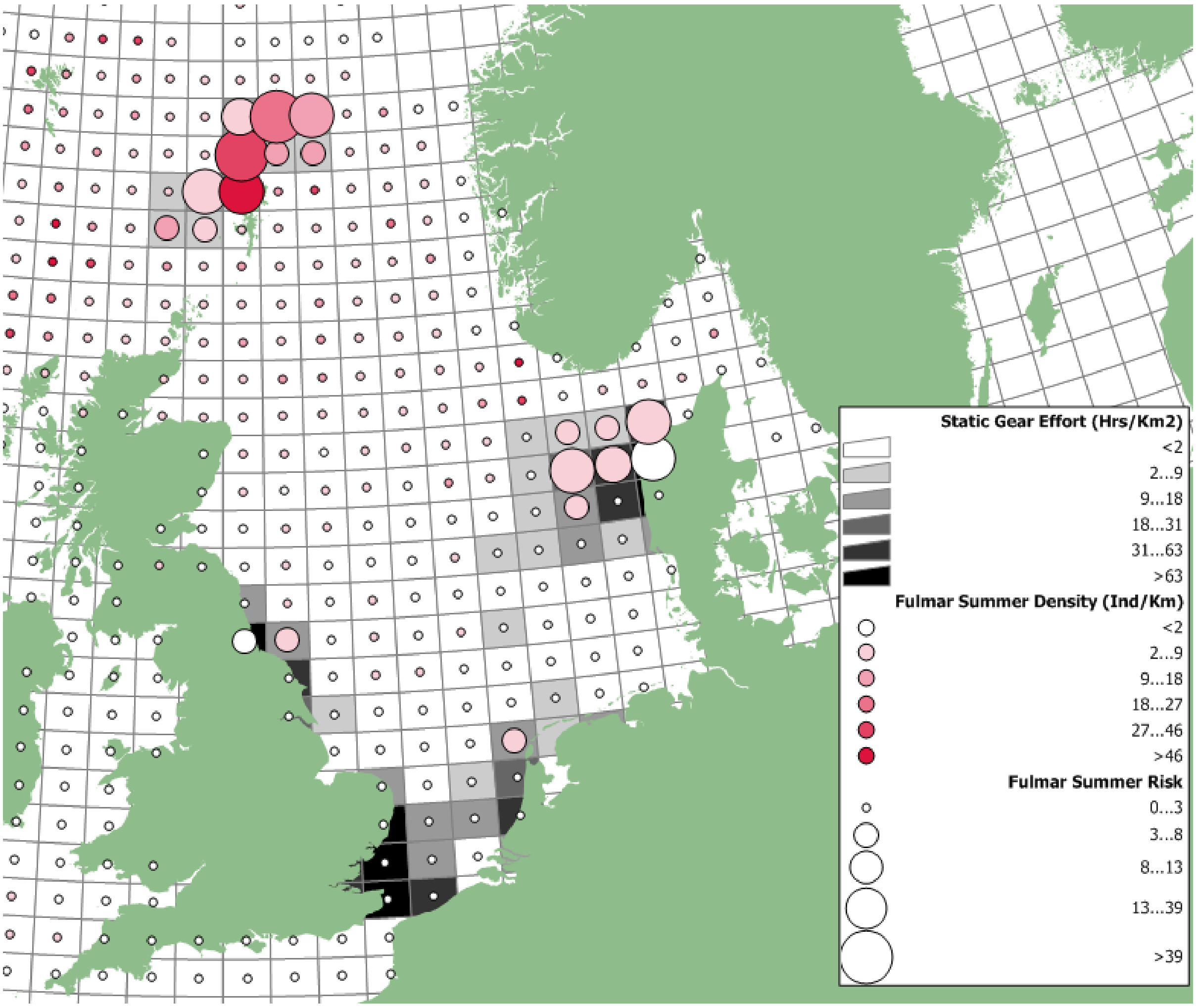
Areas of overlap between longliners and summer fulmars are very similar to those for the winter distribution.

Figure 7: Fulmars and static net effort – winter distribution of fulmars; co-occurrence index



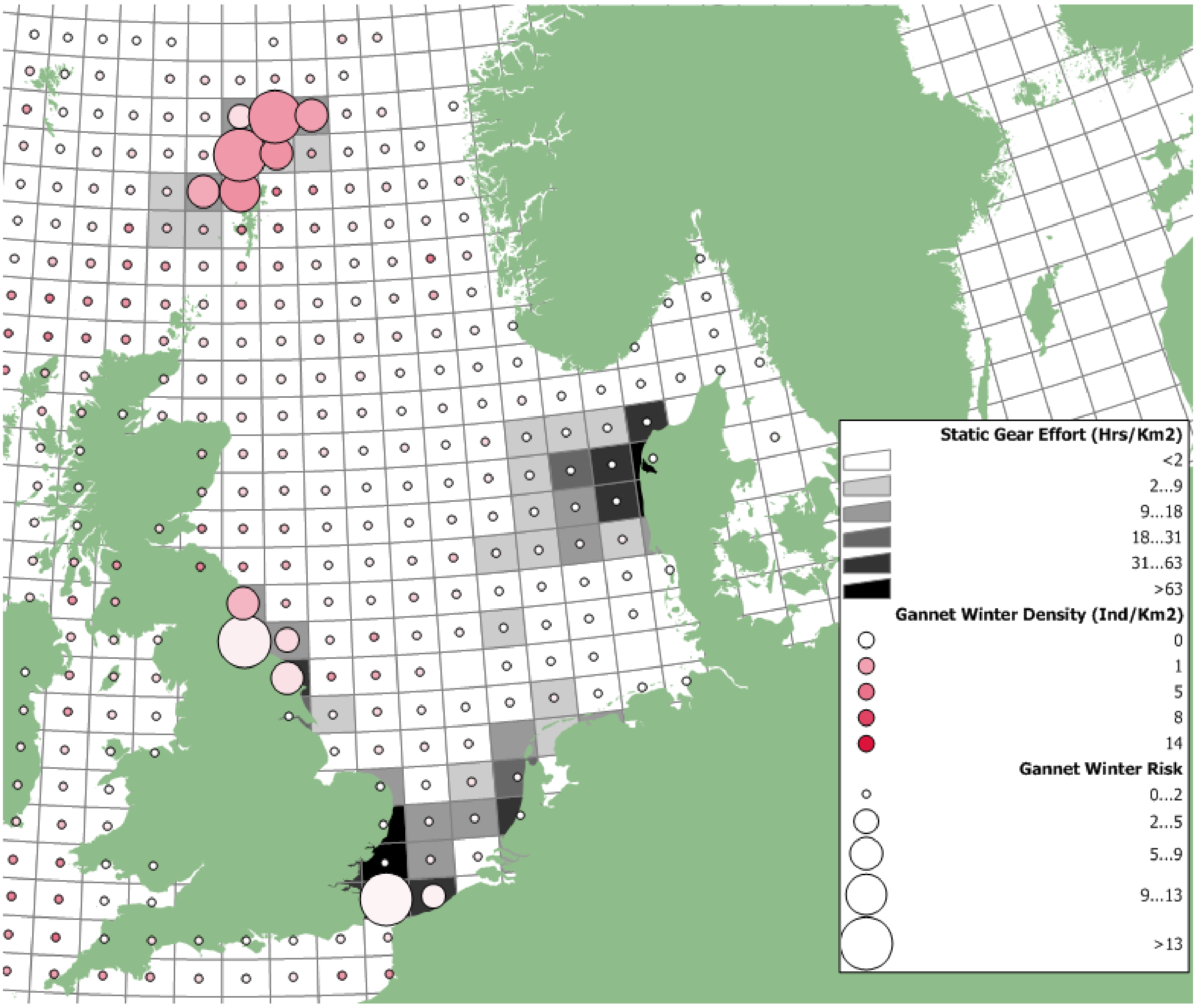
Static gear overlap with winter fulmar distribution is greatest around Shetland and on the turbot and Little Fisher Banks off Denmark.

Figure 8: Fulmars and static net effort – summer distribution of fulmars; co-occurrence index



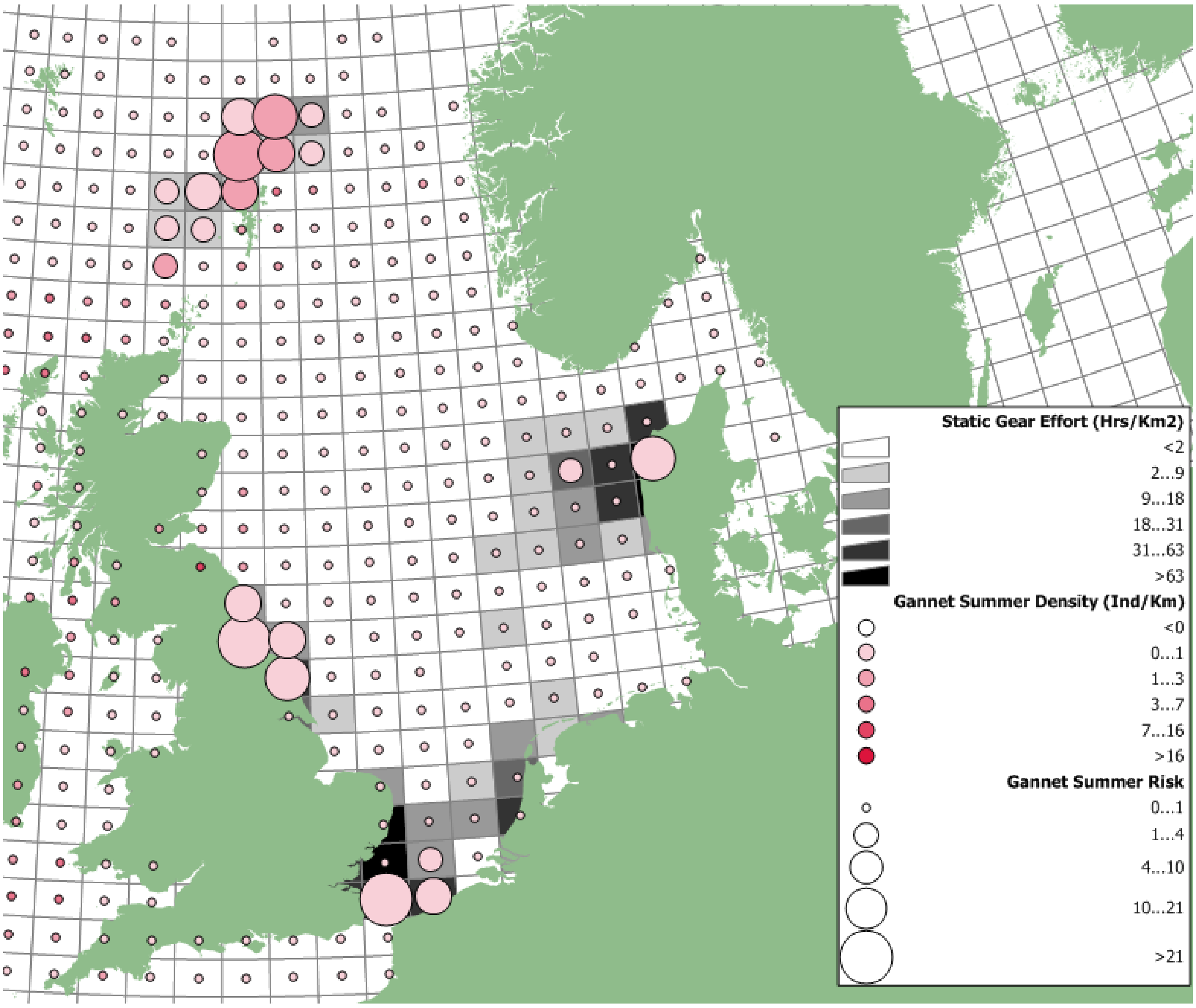
Greatest areas of overlap between set nets and fulmars in the summer are again similar to those for set nets in the winter – around Shetland and off northeast Denmark.

Figure 9: Gannets and static net effort – winter distribution of gannets; co-occurrence index



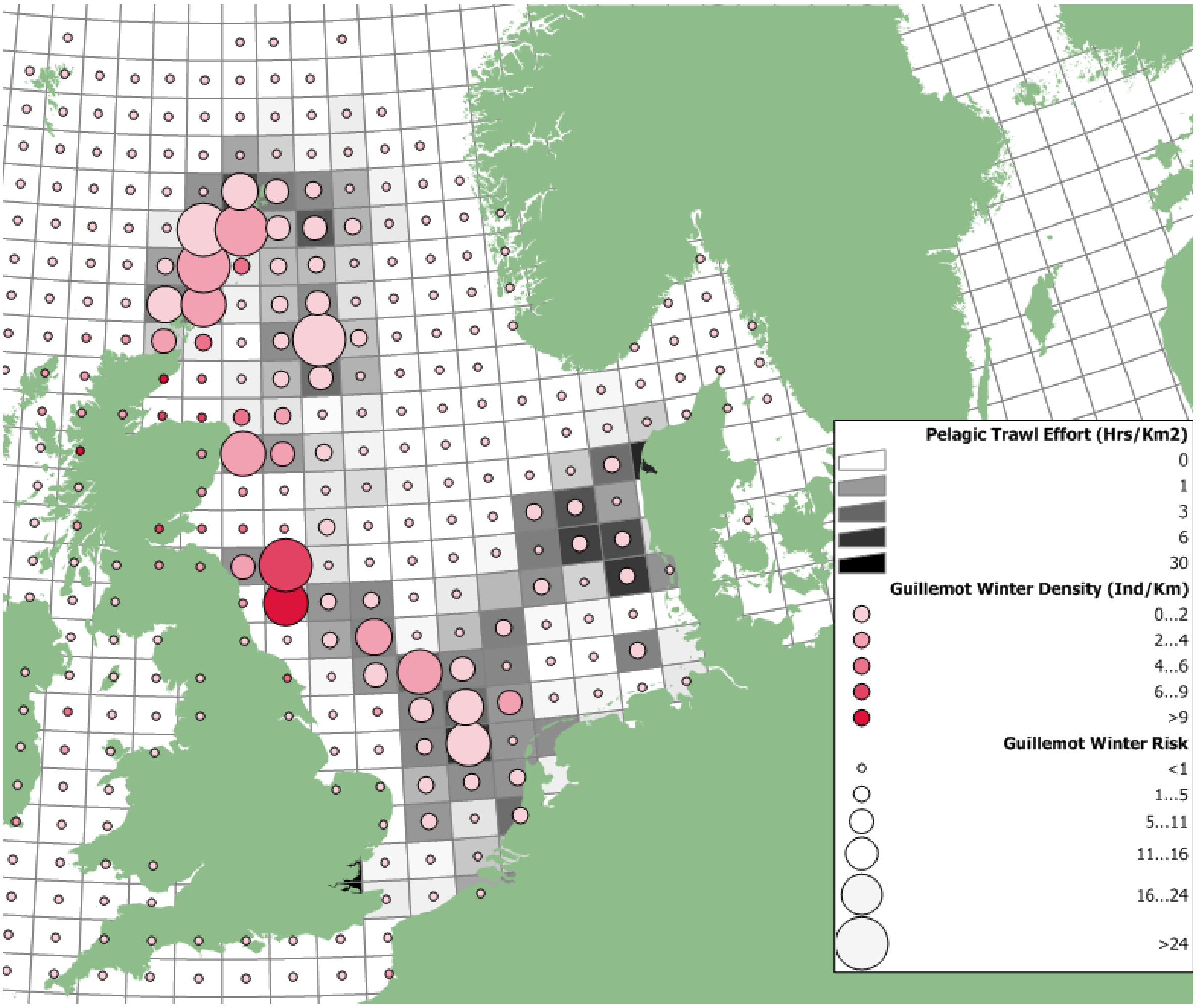
For fixed nets and the winter density of gannets, the co-incidence index highlights Shetland, the northeast of England and the extreme southern edge of the North Sea as being the areas of highest risk of bycatch.

Figure 10 – Gannets and static net effort – summer distribution of gannets; co-occurrence index



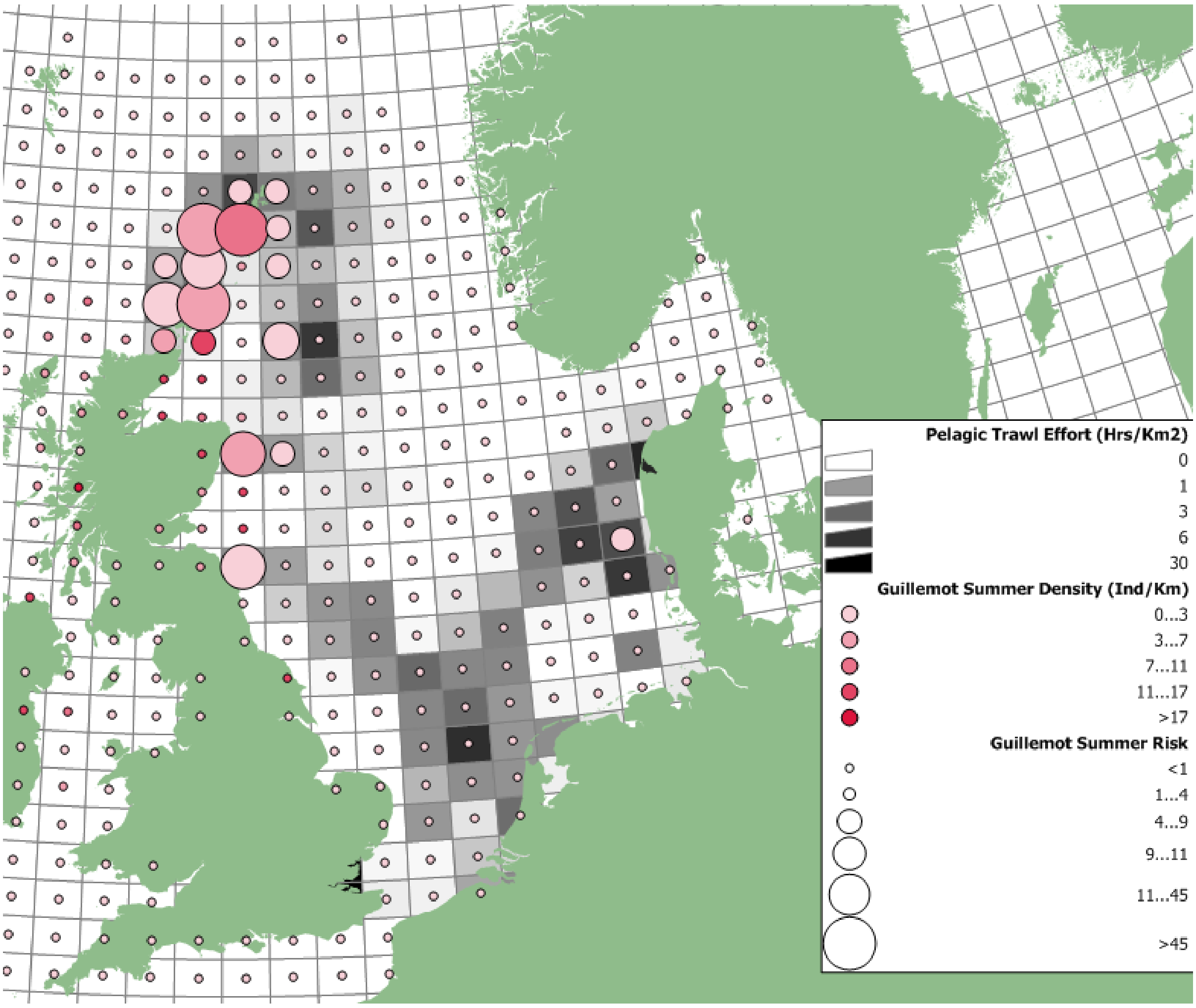
The areas of greatest overlap for summer gannet distribution is almost identical to that in the winter, except that there is during the summer a greater risk of bycatch predicted in northwestern Jutland.

Figure 11: Guillemots and pelagic trawl effort – winter distribution of guillemots; co-occurrence index



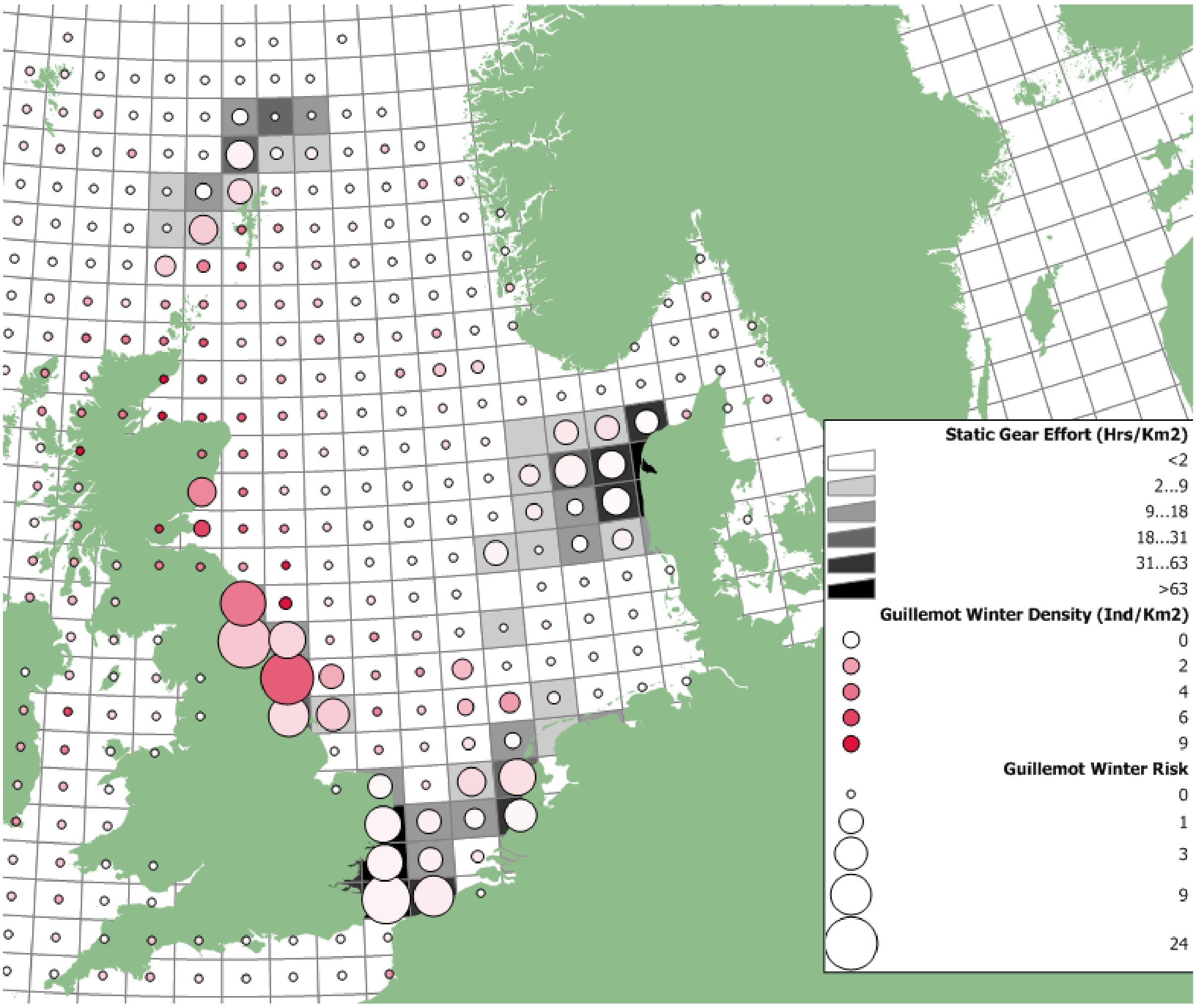
The risk of pelagic trawl bycatch for guillemots in the winter is elevated throughout a wide sweep of the western/central North Sea, but generally speaking not close inshore. Shetland, Orkney and the Fladen Ground are also highlighted.

Figure 12: Guillemots and pelagic trawl effort – summer distribution of guillemots; co-occurrence index



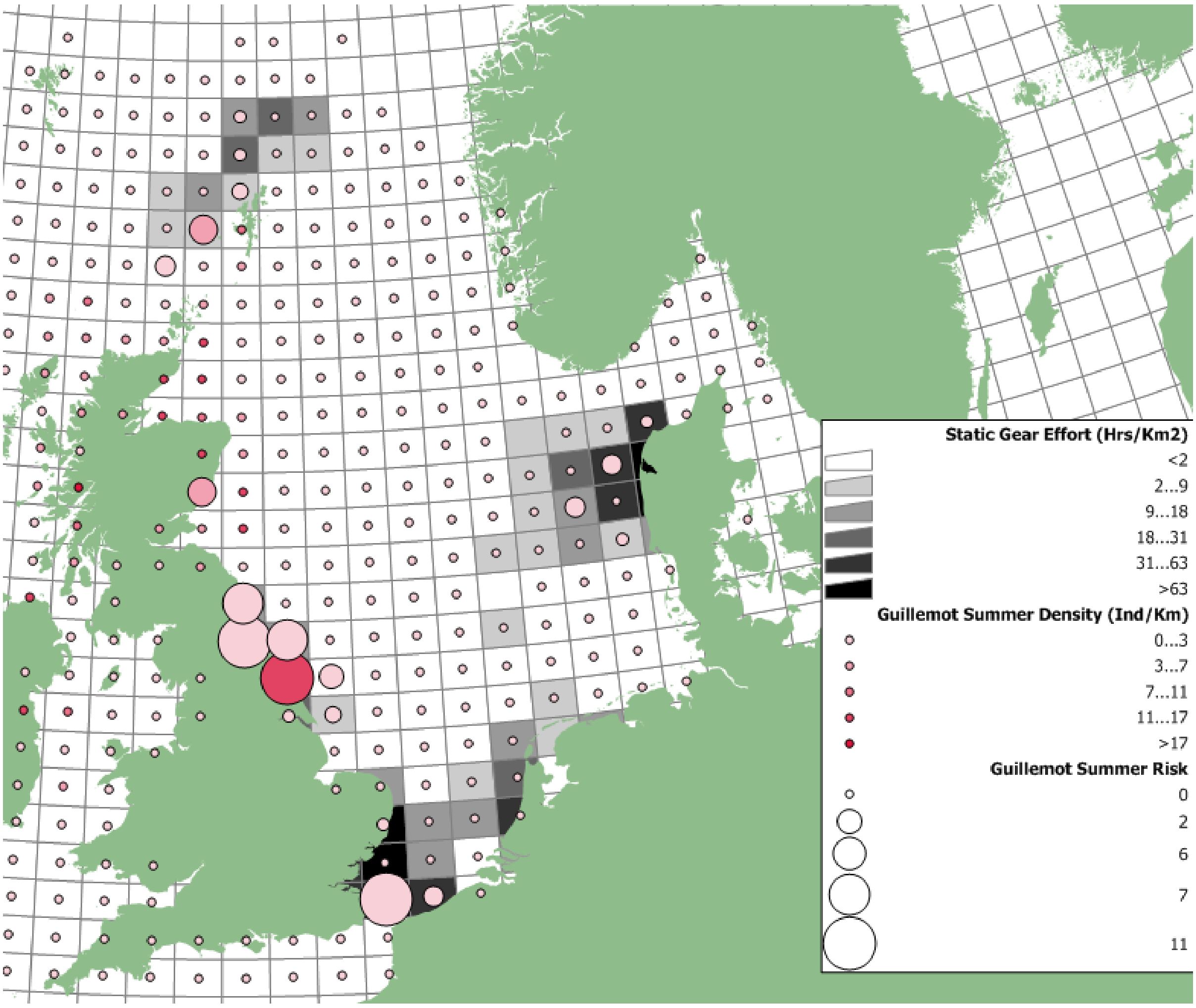
The summer distribution of guillemots focuses risk of bycatch in the northerly areas that were highlighted during the winter, notably around Shetland and Orkney. The degree of co-occurrence is predicted to decrease in most of the central and southern North Sea during the summer when compared with the winter.

Figure 13 Guillemots and static net effort – winter distribution of guillemots; co-occurrence index



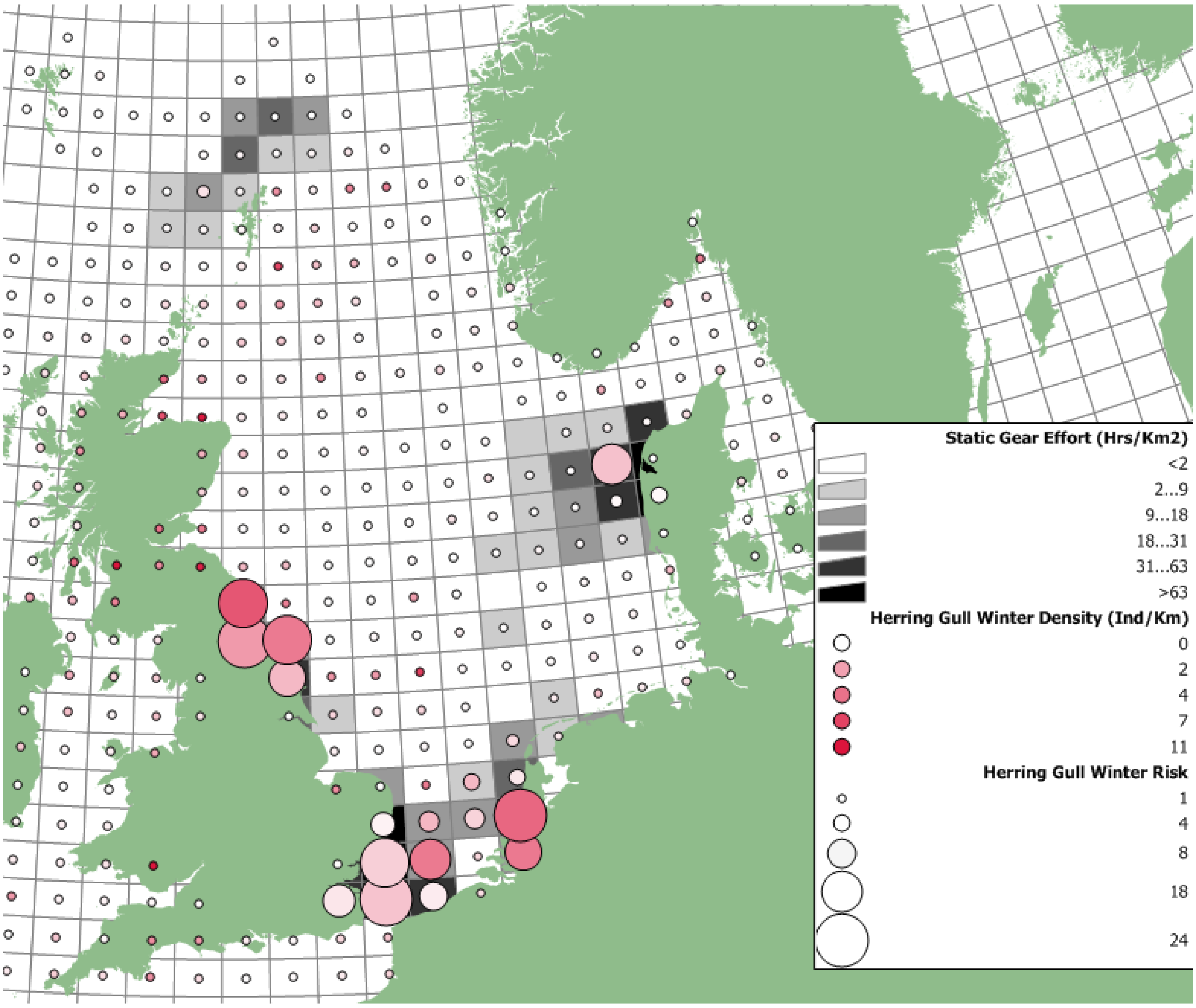
The winter risk of bycatch for guillemots appears to be highest in the coastal waters of the southern bight of the North Sea, and along the northeast coast of England. Some elevated levels of co-occurrence are also predicted off west Jutland.

Figure 14: Guillemots and static net effort – winter distribution of guillemots; co-occurrence index



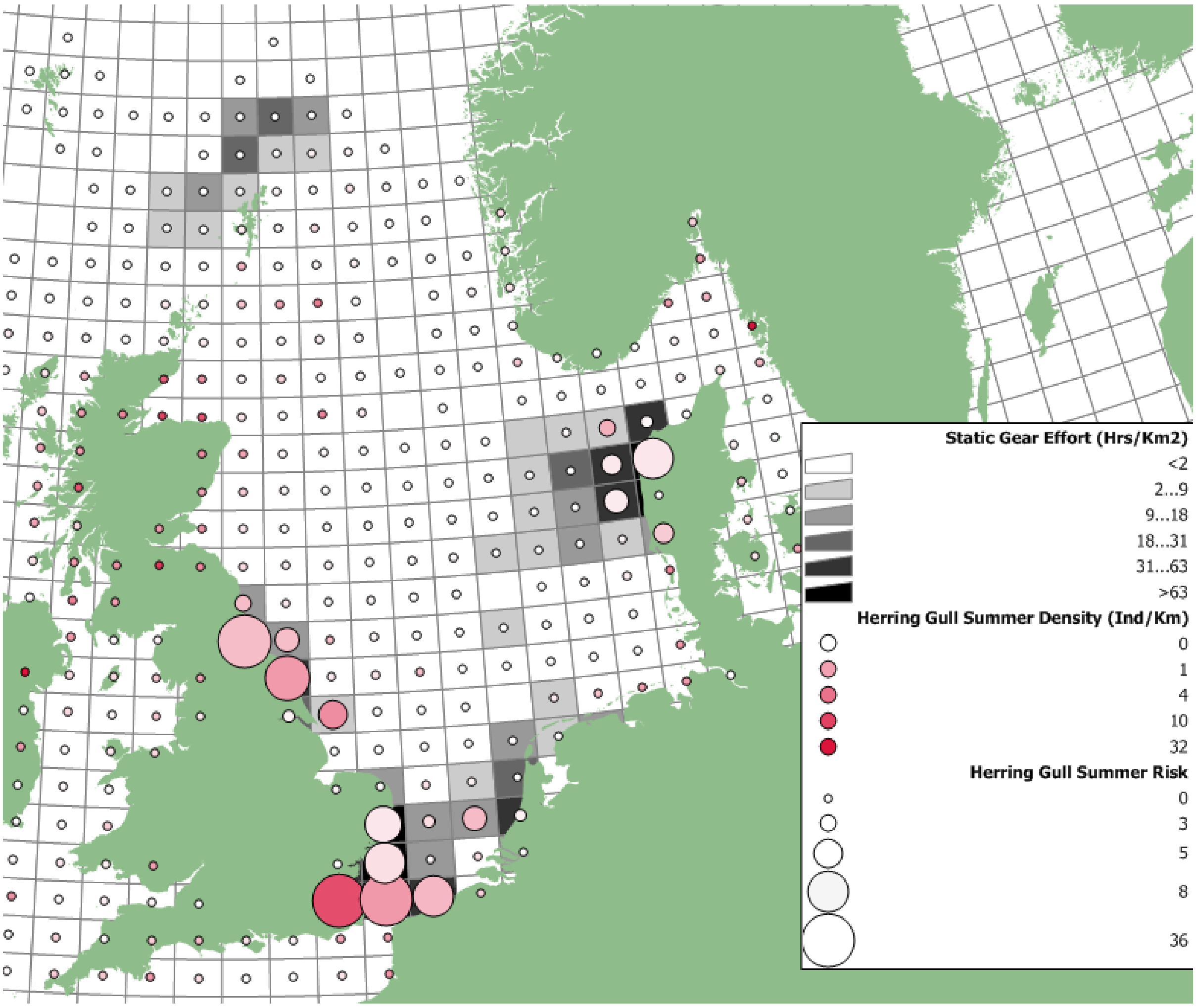
Co-occurrence of static nets and guillemots during the summer is highlighted mainly off the northeast coast of England, with some elevated levels west of Shetland, west of Jutland and off the Kent coast.

Figure 15: Herring gulls and static net effort – winter distribution of herring gulls; co-occurrence index



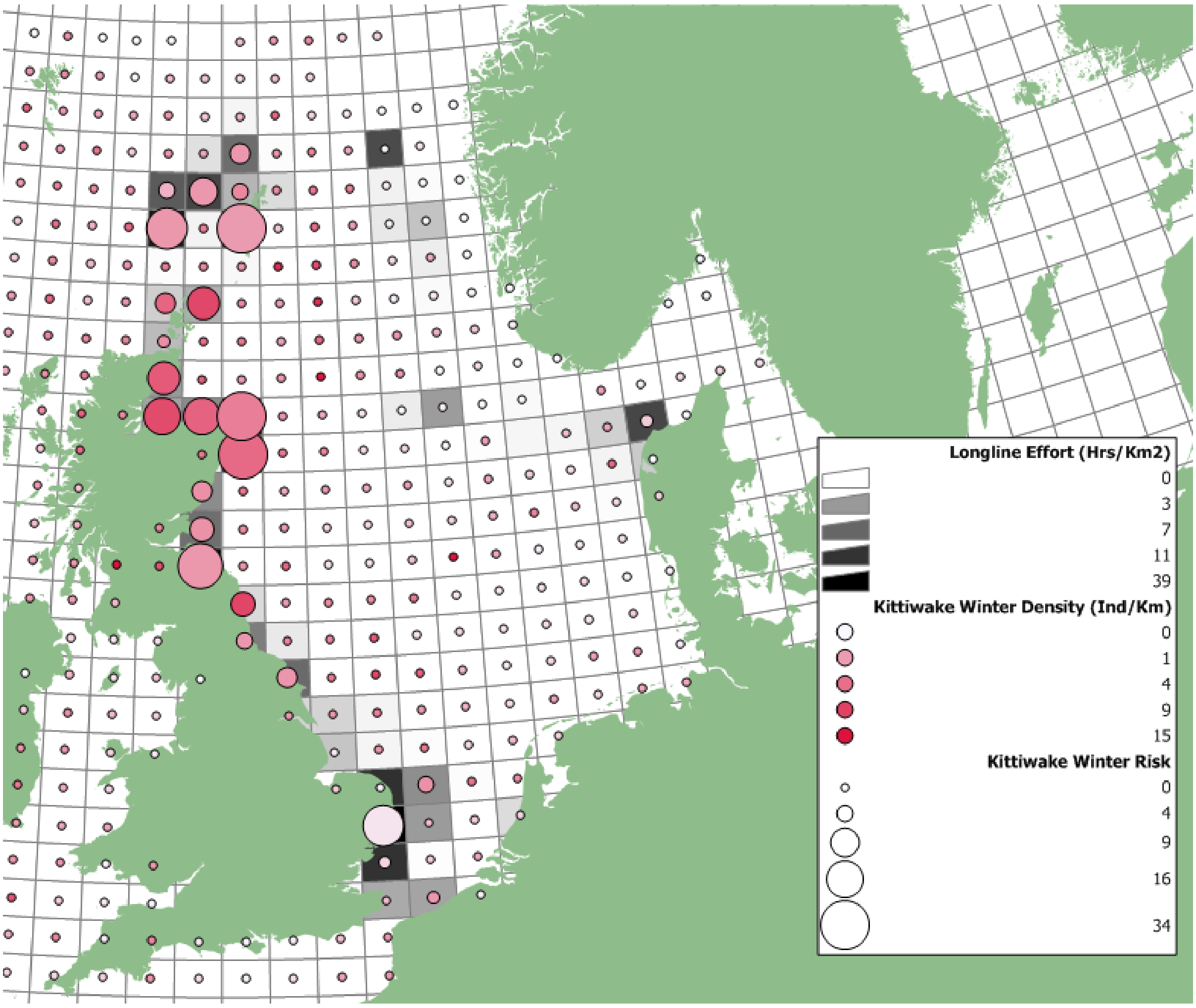
Highest areas of overlap for static gear and herring gulls during the winter are in coastal waters of the southern Bight of the north sea (Kent, Essex and the Netherlands), coastal waters of Northeastern England and on the Jutland Bank.

Figure 16: Herring gulls and static net effort – summer distribution of herring gulls; co-occurrence index



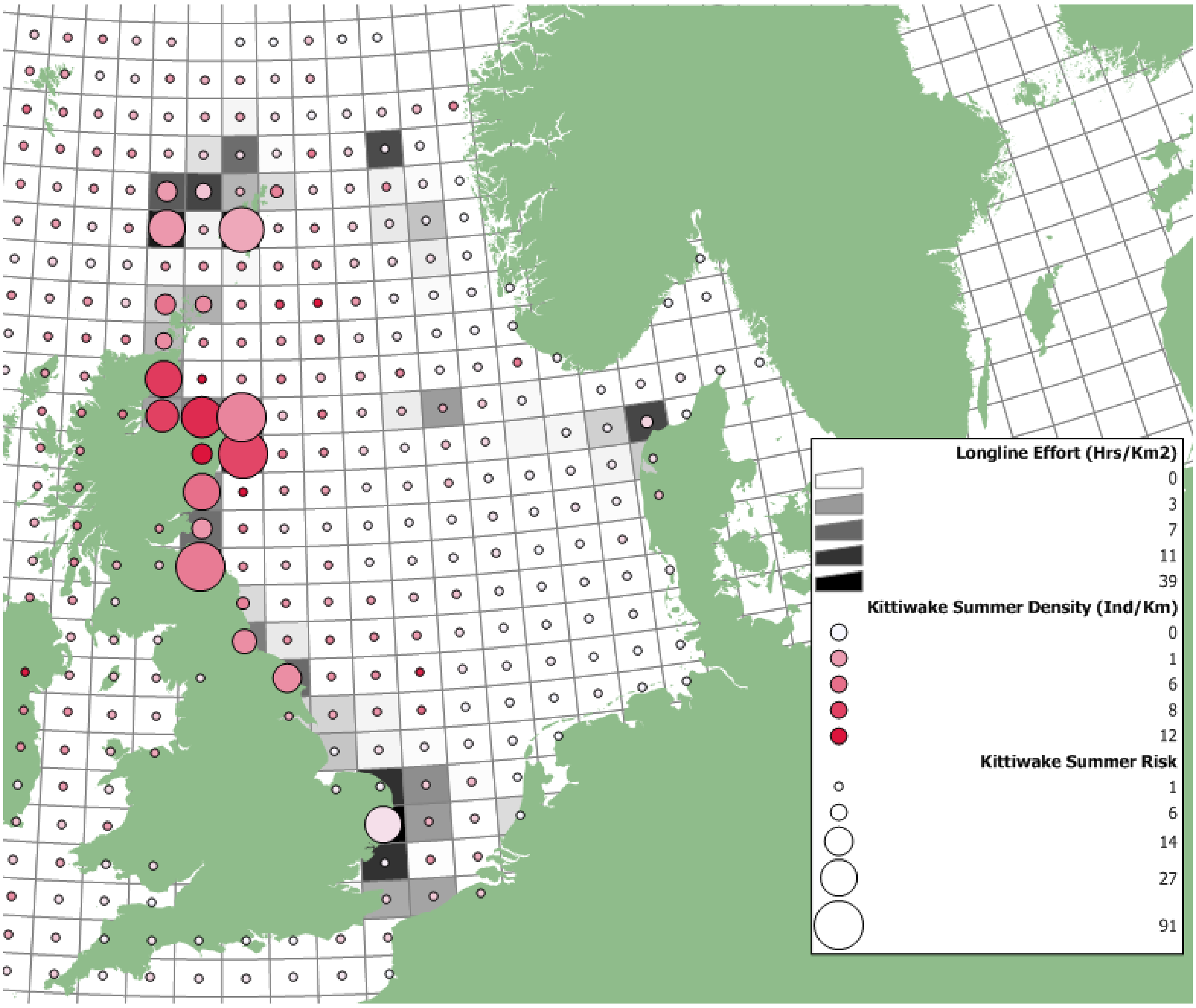
There is little change between the winter and summer areas of co-occurrence for herring gulls and static gear – though the areas of major overlap have shrunk slightly in the western coast of the North Sea and expanded slightly off the Jutland coast.

Figure 17: Kittiwake and longline effort – winter distribution of kittiwake; co-occurrence index



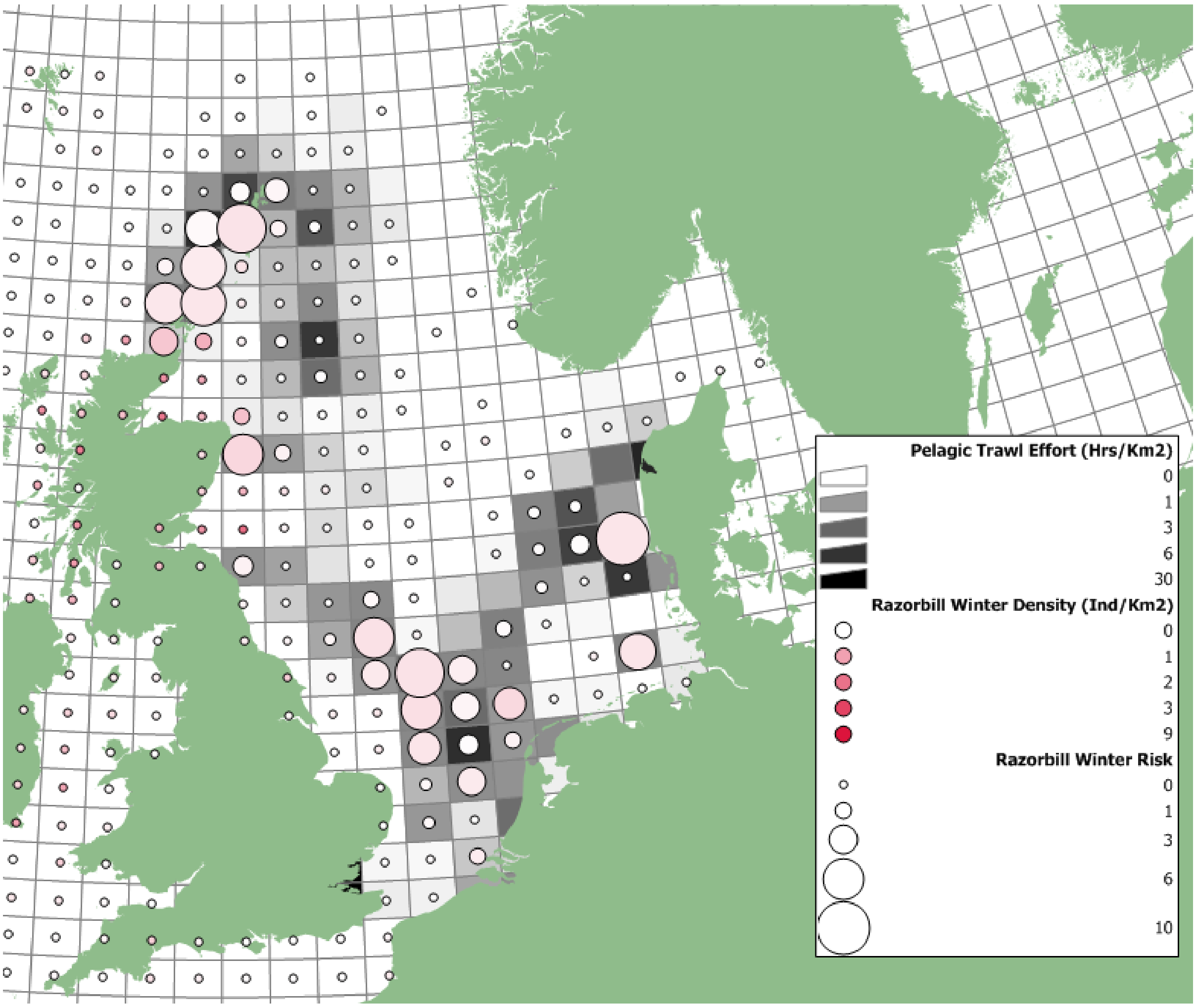
The predicted areas of greatest co-occurrence for longliners and kittiwakes during winter are mainly in the northeast of Scotland and around Shetland and Orkney, and the Suffolk coats in England. This is mainly a reflection of the limited distribution of longline fishing.

Figure 18: kittiwakes and longline effort – summer distribution of kittiwakes; co-occurrence index



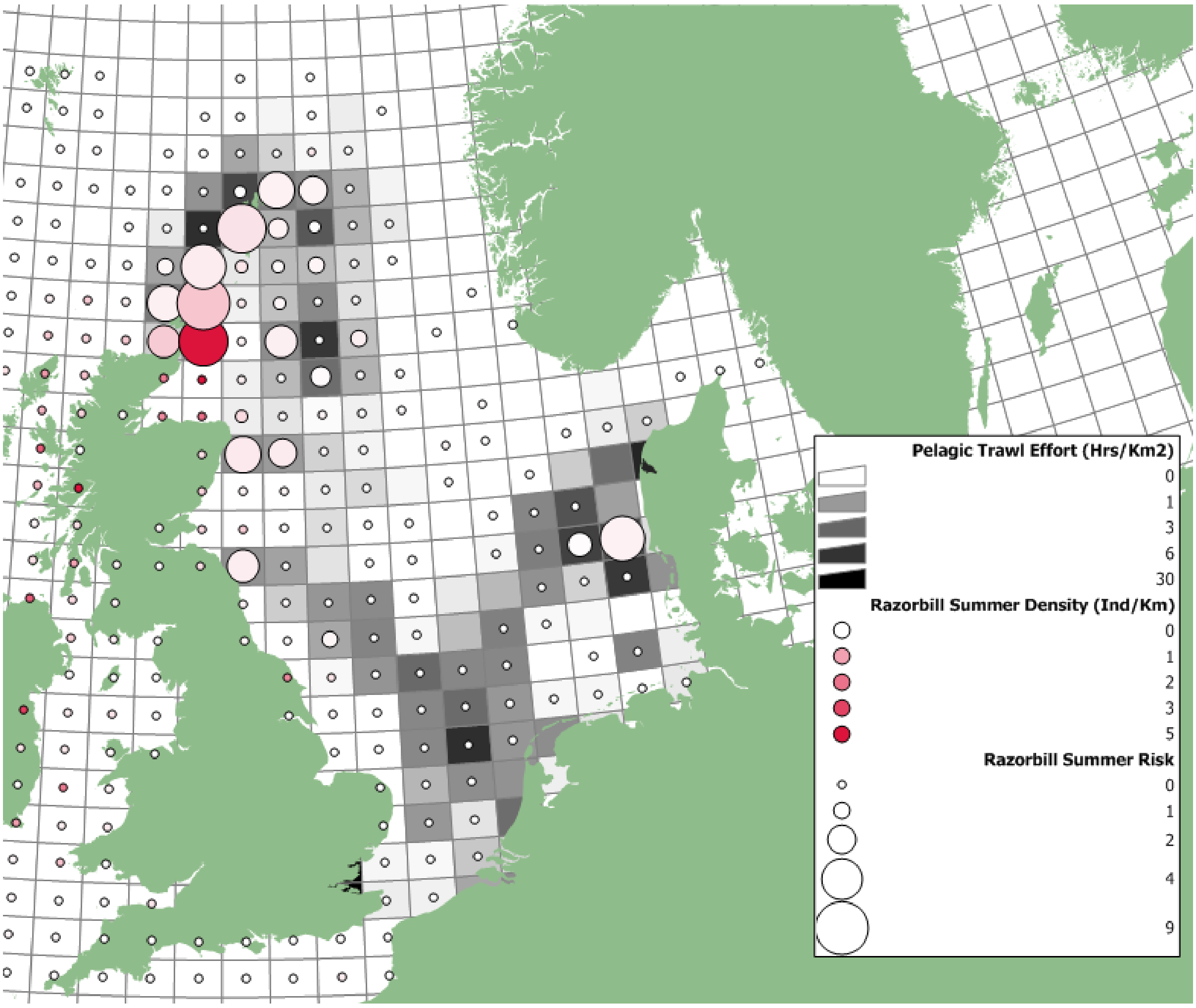
The predicted areas of co-occurrence are almost identical for the summer distribution of kittiwakes.

Figure 19: Razorbills and pelagic trawl effort – winter distribution of razorbills; co-occurrence index



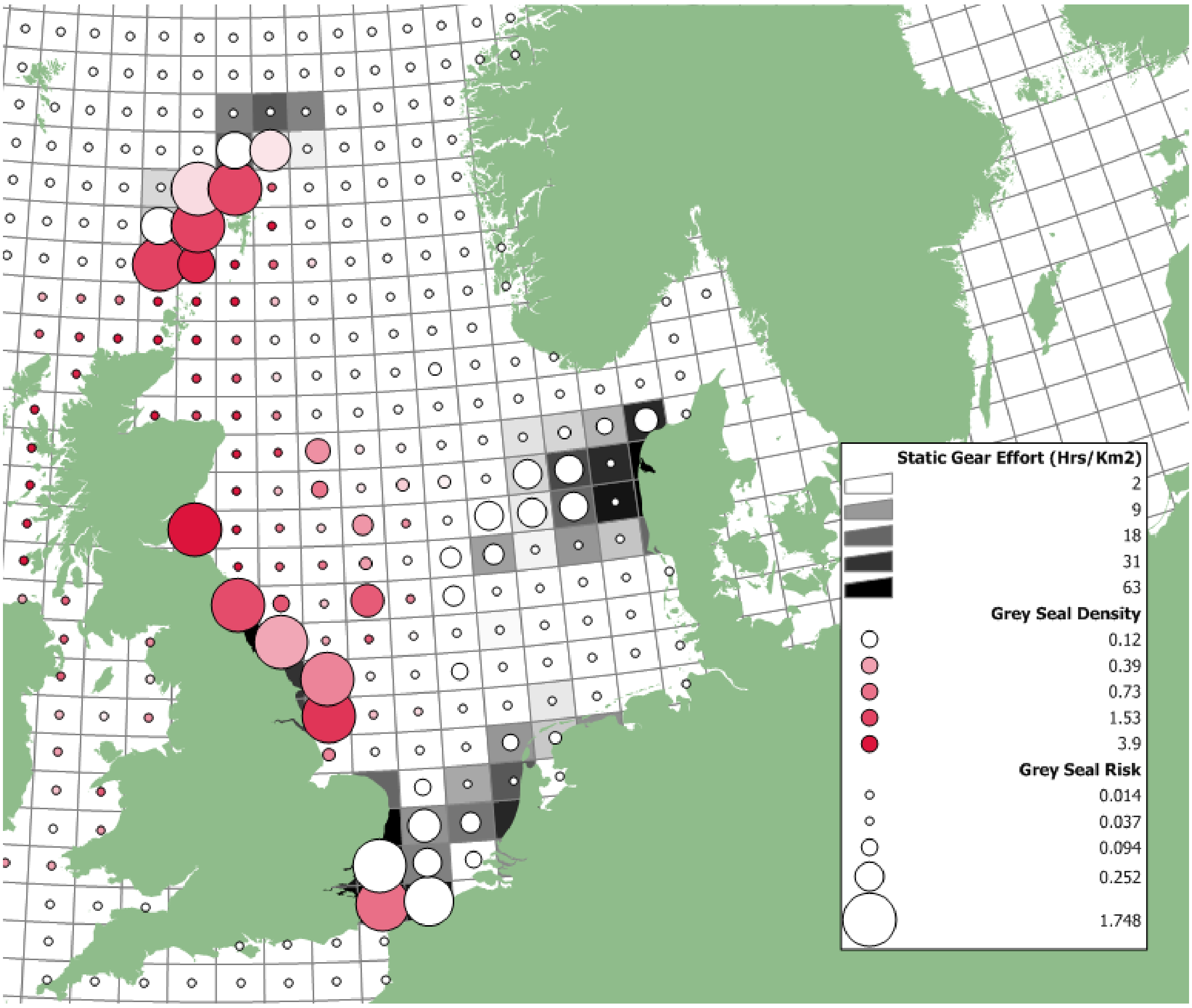
During the winter season, there are two larger and two smaller areas where razorbills might be most expected to overlap with pelagic trawlers. These are firstly around Shetland and Orkney and then in the southern Central North Sea around the Dogger bank. Lesser hotspots are predicted off Aberdeenshire and off west Jutland.

Figure 20: Razorbills and pelagic trawl effort – summer distribution of razorbills; co-occurrence index



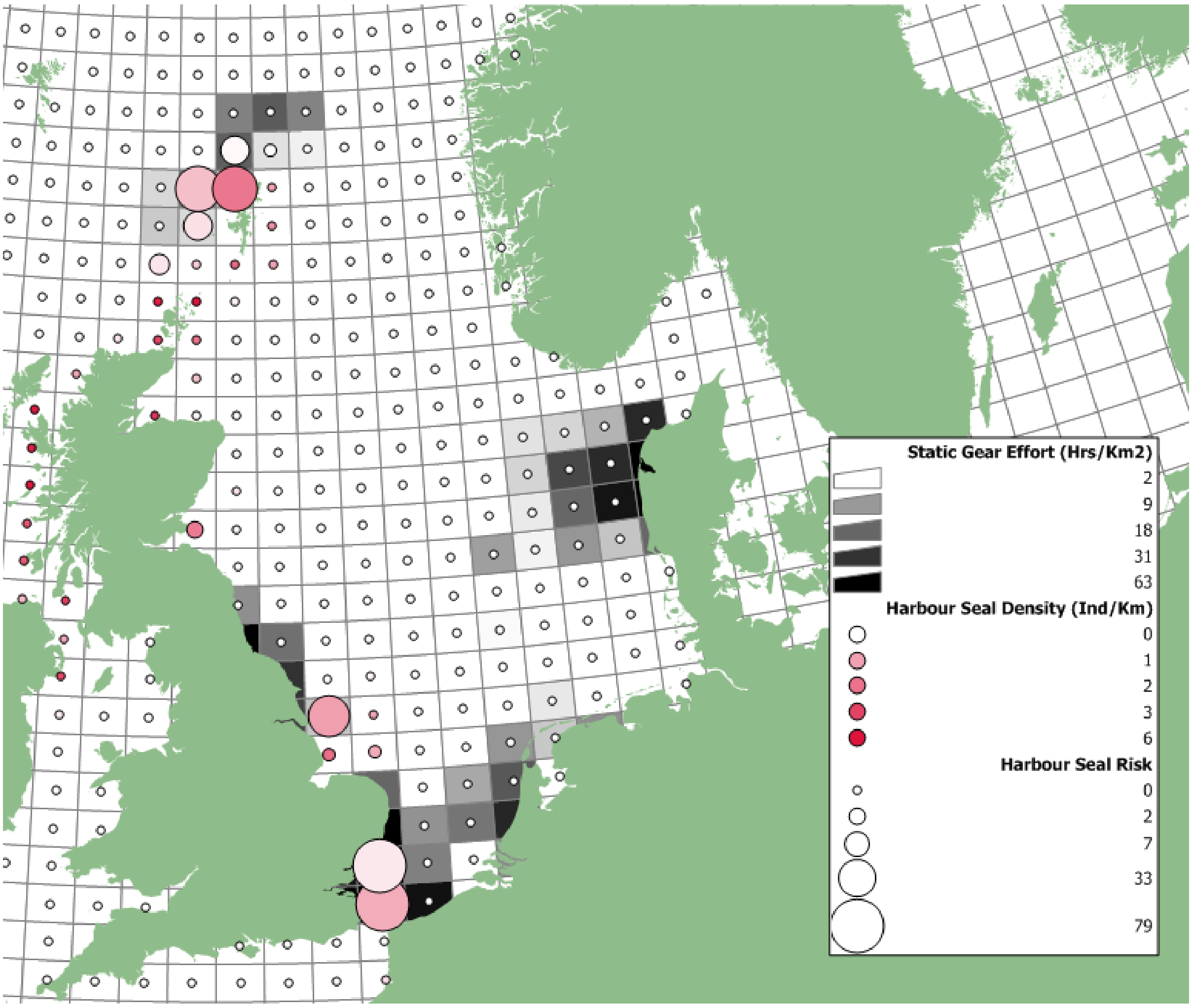
The summer co-occurrence of razorbills with pelagic trawl effort is mainly focused around Orkney and Shetland. A few other areas off northeast Scotland, northeast England and Jutland are predicted.

Figure 21: Grey seals and static net effort; co-occurrence index



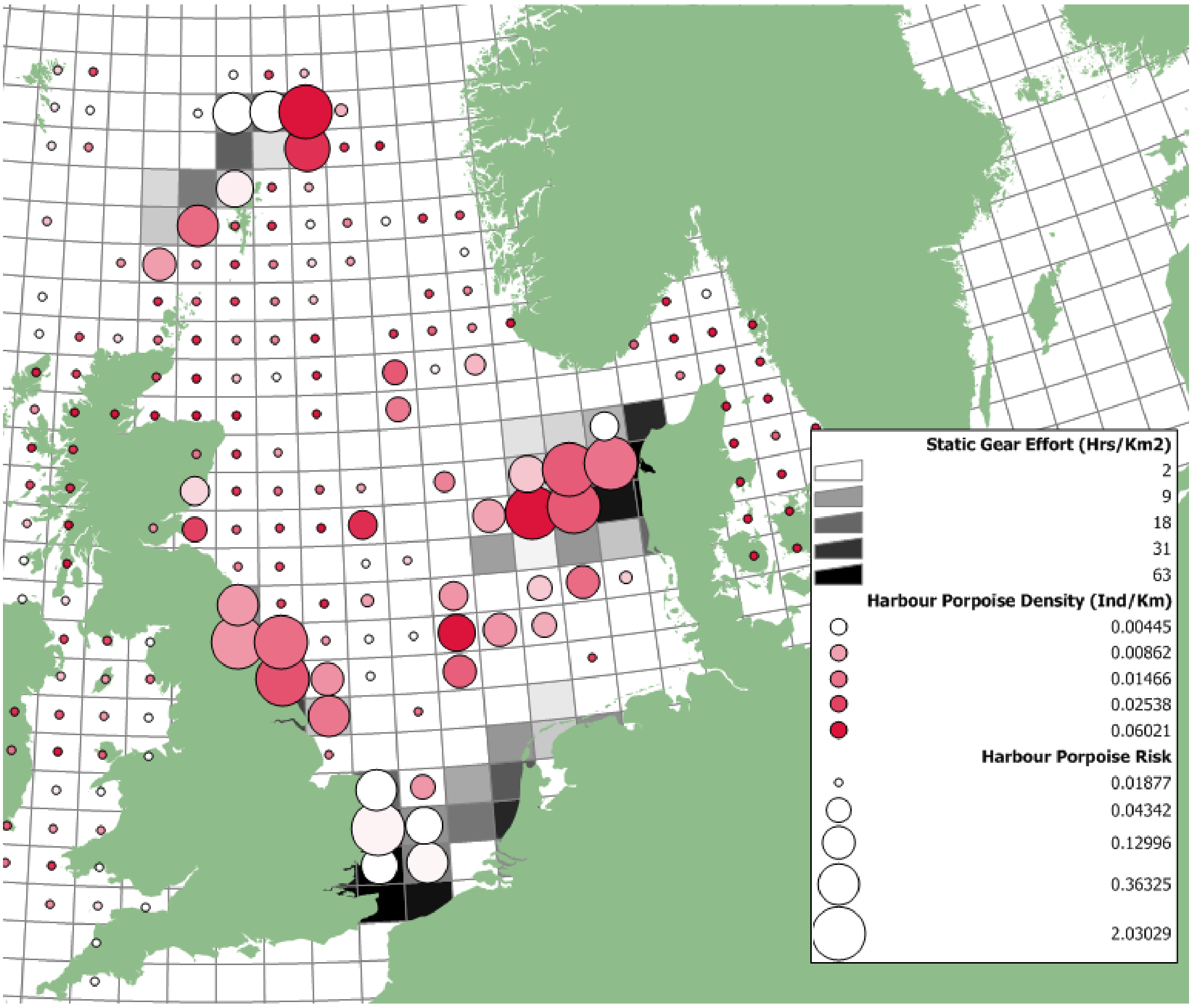
Greatest areas of co-occurrence – or risk of entanglement, between grey seals and static nets are along the east coast of England, in the extreme southern corner of the North Sea, around Orkney and Shetland and also over a dispersed area of the central North Sea.

Figure 22: Common seals and static net effort; co-occurrence index



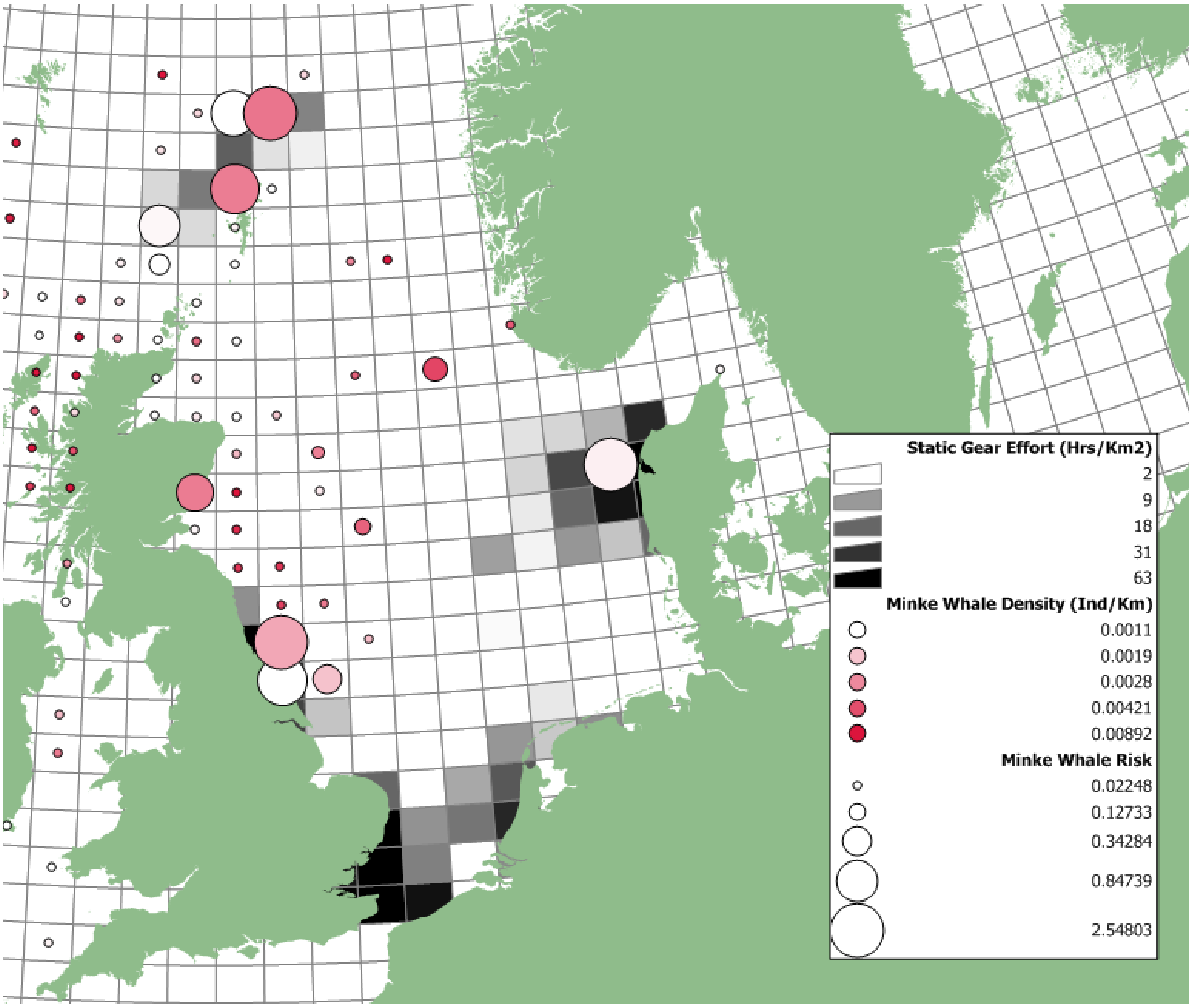
In contrast to the grey seal areas of co-occurrence with Static nets, common or harbour seal co-occurrence is predicted in a few focused areas: northwest of Shetland, around the Thames estuary, and around the Humber estuary.

Figure 23: Harbour porpoises and static net effort; co-occurrence index



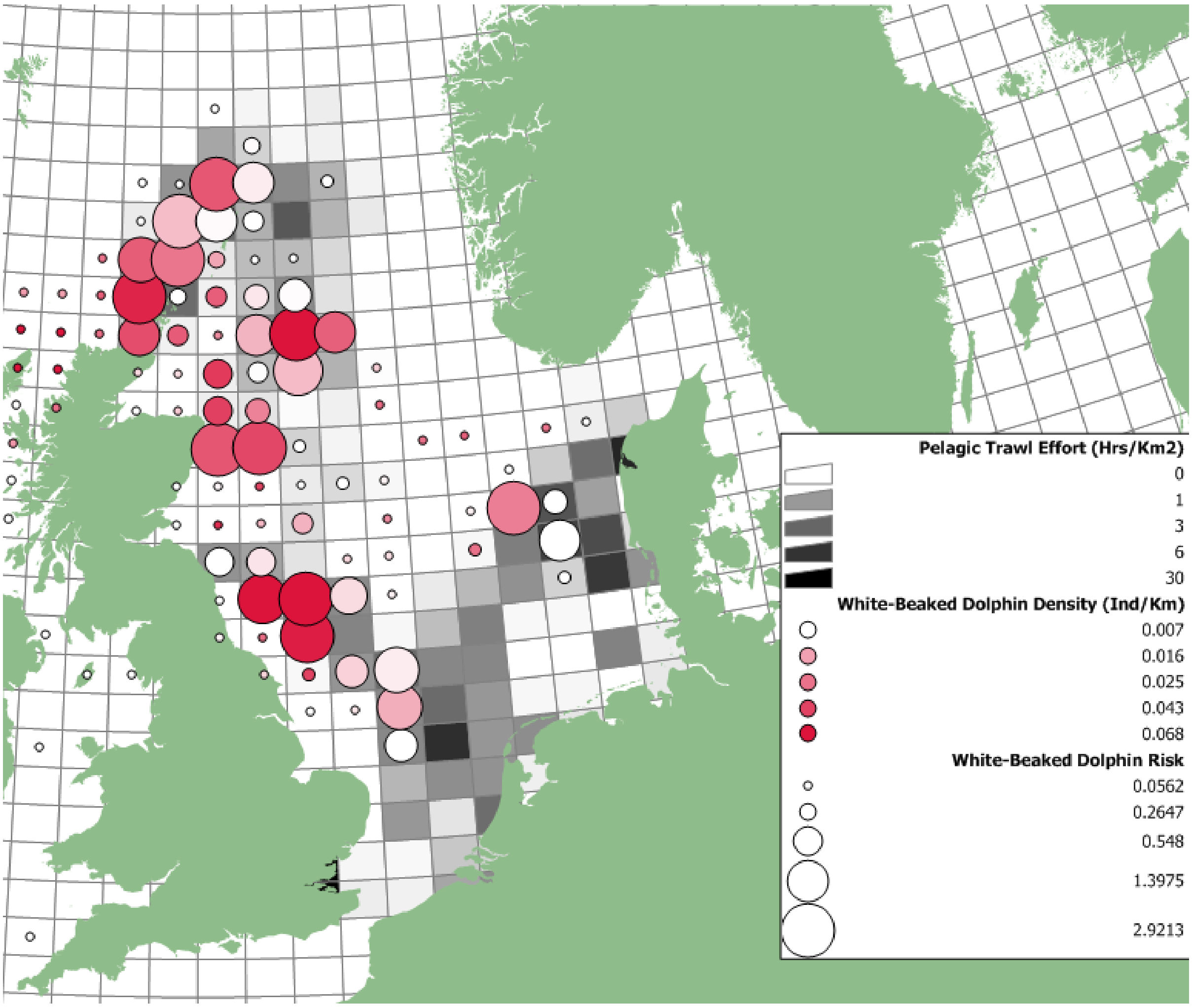
The areas with the predicted highest co-occurrence between porpoises and set nets are off the Yorkshire and Tyneside coasts of England, in the central/eastern North Sea west of Jutland, north of west of Shetland and off the coast of East Anglia.

Figure 24: Minke whales and static net effort; co-occurrence index



Minke whales are most likely to co-occur with set nets in areas north of Shetland, off the Angus coast in East Scotland, off the west coast of Jutland and around ™he Yorkshire coats of England. Another useful comparison would be with creel or lobster pot fishing effort, although we have not plotted such a map. Minke whales are typically caught not in the fishing gear itself, but in the mooring ropes and interconnecting ropes associated with static gear. Creel fisheries are densely distributed in parts of the western and Northern North sea where minke whales are most frequently sighted.

Figure 25: White-beaked dolphins and pelagic trawl effort; co-occurrence index



The co-occurrence of white-beaked dolphins and pelagic trawl fisheries is predicted to be highest over a broad swathe of the western and northern part of the North Sea, from Shetland to the Aberdeenshire coast, and also off the coast of England from the Dogger bank to the Farne Deeps, as well as in a more restricted area due west of Jutland.

4. Conclusions and Discussion.

We have collated abundance estimates, estimates of sustainable take levels, and bycatch rates for vulnerable seabird and mammal species inhabiting the North Sea for the first time. Through tabulating these data we are able to provide a quantitative assessment of the vulnerability of several of these species to particular gear types.

The highest observed bycatch rate (per day) appears to be for seals in mid-water trawl fisheries (table 9); this figure should be treated with great caution as it is based on a few incidents in one restricted area over a decade ago, and almost certainly gives and unrepresentative view of the bycatch rate of seals in this type of fishery for the North Sea as whole. Porpoise bycatch rates in static nets are the next highest observed rate, and these are based on a very large sample size from many different gear types. Some bias is also probable here, however, as some of the sampling was focused on particular fisheries with a known high bycatch rate of porpoises. Again it may not be safe to assume the figures presented here are truly representative of fisheries in the North Sea overall. Ignoring those few examples where a single individual has been reported from a relatively small sample of a particular gear type, other relatively high bycatch rates have been observed for fulmars in longline fisheries, for fulmars in set nets fisheries (though mainly from Danish samples – possibly in areas where fulmars are most at risk see figures 7 & 8), for guillemots in set nets and mid-water trawls and for seals in static nets. It is clear from this that some species are more vulnerable than others to bycatch in specific gears.

A distinction is to be made between the level of individual vulnerability to a particular gear type and the extent to which that same gear type may make the population vulnerable from a conservation perspective. It is clear that guillemots for example have a relatively high rate of bycatch in several gill or tangle net fisheries, yet the observed rates when compared with current fishing effort levels and with guillemot abundance and their presumed sustainable take limits, do not immediately suggest that the population may be at risk.

We were unable to compile reliable and useful estimates of total fishing effort (days at sea) for all fishing methods, as it is clear that the metrics used for fleet effort regulation (Kw.days or hour fished) are not a reliable index of fishing effort for static gear, nor are bycatch statistics available in terms of these metrics, making any extrapolation impossible to the North Sea level. Nevertheless we did obtain data for gillnet fishing effort (days at sea) for the whole North Sea, which suggests that around 35,000 days at sea are expended in gillnet fishing effort. This level of effort suggests that cormorants, seals and porpoises all might be subject to levels of bycatch that are of concern from a conservation perspective (may exceed PBR levels) – though there are many assumptions in this conclusion and a more detailed stratified analysis would be advisable. We are unable to conclude anything about the levels of bycatch in pelagic trawl, longline or other fisheries in the absence of reliable effort data.

Available effort data do at least provide a means of exploring how spatial fishing patterns may interact with the distribution of vulnerable species. Figures 2-26 demonstrate a specifc means of showing the level of co-occurrence of the distribution of vulnerable species and fisheries which catch them. These maps could be refined if effort data were available on a seasonal basis. The chief advantage of such maps is to isolate areas where bycatch numbers are likely to be highest, and thereby either help to develop sampling plans for bycatch monitoring, or indeed to develop bycatch mitigation strategies that are spatially explicit.

Further work will be needed to:

- Improve estimates of sustainable take levels
- Collate fishery effort data in a more useful manner
- Model observed bycatch rates in a more detailed way to determine which factors are most important in determining bycatch rates of particular species in particular gear types
- Generate more precise and more accurate estimates of bycatch by species
- Further develop distribution maps for the species concerned.

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