Revive our Seas: The case for stronger regulation of sandeel fisheries in UK waters

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Executive summary

The sandeel is a small shoaling fish critical to the healthy functioning of marine food webs in UK waters, including some of our most threatened seabirds. The kittiwake – which is particularly sandeel-dependent – has seen its UK numbers fall by half since the 1960s, with diminishing availability of prey during the breeding season thought to be mainly responsible.

It has become clear that sea warming is driving sandeel decline. But there is also evidence the international North Sea sandeel fishery is a contributory factor and is affecting the resilience of seabird populations to chronic climatic shifts in their food resources.

The industrial sandeel fishery is one of the largest in the North Sea, providing raw material used in the production of fish meal and fish oil for agricultural and aquaculture feeds. However, we identify three serious flaws in the current management of the fishery.

1. The sandeel fishery is permitted to operate within the foraging range of red-listed species like kittiwake and puffin breeding at internationally important - and legally protected -seabird colonies on the UK coast.

2. The current approach to setting maximum annual catch levels aims to protect the sandeel stock itself, but not the wildlife that depends on it. Even fishing in accordance with the scientific advice can lead to depletion of sandeel stocks to levels likely have a negative impact on top predators like seabirds.

3. Scientific advice on catch levels within sandeel management areas takes no account of zones that are closed by law to sandeel fishing, thus fishing effort is concentrated into a smaller area, potentially leading to overfishing and localised depletion of sandeel.

Given the mounting scale of different threats to seabird populations, particularly offshore wind energy development, this report addresses the question: *What fisheries management measures for sandeel could increase resilience of seabird populations to climate change and the other threats they now face*?

We make the case that the introduction of stronger curbs on the commercial fishery for sandeels in UK waters and beyond is required to achieve national and international targets for the recovery of seabird populations. The UK's status as an independent coastal State plus new legal powers provide a context, which for the first time in several decades enables the consideration of strengthening the management of the sandeel fishery in UK waters for the benefit of seabirds and other wildlife.

We propose that stronger regulation of the industrial sandeel fishery requires:

1. Area closures:
    a. The whole of the UK EEZ (our preferred approach);

    or, as a minimum

    b. Both the Dogger Bank and the Scottish part of the EEZ

2. Improving the scientific advice on sandeel catches for the whole North Sea to:
    a. Incorporate the concept of 'set-aside' of sandeel biomass for seabirds and other wildlife in the process of advising on annual catch limits for the North Sea sandeel fishery.

    and

    b. Adjust catch limits downward to take account of zones where fishing for sandeel is not permitted, thus preventing the concentration of fishing effort into an area of sea far smaller than for which advice was given.

2 should be undertaken as a priority across the North Sea and irrespective of any UK initiatives to create new areas closed to sandeel fishing. All measures must be underpinned by cooperation between UK administrations and other interested parties, as well as comprehensive monitoring, both of sandeels and breeding sandeel-dependent seabird populations.

The proposals presented here are not definitive, exhaustive or mutually exclusive but are intended to open a dialogue on both the need and the choices for change, noting that a combination of area closures and improved scientific advice is both possible and desirable.

Each intervention has its own merits on environmental, economic and social grounds but we have not carried out a detailed cost-benefit analysis at this stage. However, it stands to reason that the greatest benefits for a variety of UK breeding seabirds (and other top predators, notably marine mammals and commercial fish like cod) would come from putting an end to the sandeel fishery across the greatest possible area of sea adjacent to the UK coast.

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Cover Image: Chris Gomersall (rspb-images.com)

1. Evidence for seabird declines linked to reduced sandeel availability

The lesser sandeel (*Ammodytes marinus*, hereafter 'sandeel') is a low-trophic-level, lipid-rich 'forage' fish which plays a key role in the food web between primary productivity (plankton) and top predators, especially piscivorous fish (e.g. mackerel, whiting and Atlantic salmon), marine mammals and seabirds. As the dominant prey of many seabird species in the breeding season, the sandeel is pivotal to sustaining their populations in the UK and wider North Atlantic.

The evidence is compelling that declining availability of sandeel is adversely affecting the breeding productivity of certain seabird species. Whereas climate change is held primarily responsible for the adverse impact on sandeels[1], commercial fishing for sandeel can exacerbate the problem[2], invoking the argument for a precautionary approach to the fishery.

The OSPAR Intermediate Assessment (2017)[3] concluded that '*In the Greater North Sea and Celtic Seas, all seabird species that frequently failed to raise young feed on small fish in surface waters. Widespread breeding failure in seabird species feeding in deeper waters or at the seabed was far less frequent. This difference could be linked to the availability of small forage fish species at the surface (e.g. lesser sandeel and sprat) that are typical prey for various surface feeding species (e.g. black-legged kittiwake).'…..'Prey availability is likely to be driven by ecosystem specific changes, possibly initiated by commercial fisheries (past and present) in combination with climate change.'*

This link between prey availability and breeding performance is echoed by the finding that the UK Marine Strategy *Target on Marine Bird Population Condition*[4] has not been met in the Greater North Sea where 35% of seabird species, especially 'surface feeders' on small fish, have recently experienced frequent, widespread breeding failures. The assessment notes that '*Reduced availability of small fish, on which the seabirds feed, has been largely responsible for declines in seabird breeding abundance and the frequent, widespread breeding failures in some species*' and that this reduction '*could be a result of climate change or due to past and present fisheries*.'

Most research has focussed on the black-legged kittiwake (hereafter 'kittiwake') as a species particularly highly dependent on sandeel for self-maintenance and raising young [5] [6]. Like other surface feeders (notably terns), the kittiwake is especially vulnerable to sandeel depletion, unlike deep divers (e.g. auks, gannets) which can access more prey options. Several studies have shown that the breeding success and adult survival of North Sea kittiwakes are strongly affected by sandeel stock biomass[7] [8] and/or the presence of a sandeel fishery nearby[9]. According to ICES[10], '*Local depletion of sandeel aggregations at a distance less than 100 km[11] from seabird colonies may affect some species of birds, especially black-legged kittiwake and sandwich tern, whereas the more mobile marine mammals and fish are likely to be less vulnerable to local sandeel depletion*'.

Over time, reduced sandeel biomass has been linked to population declines of UK seabirds, e.g. the UK kittiwake population has halved since the late 1960s[12]. The Seabird Monitoring Programme (SMP)-derived kittiwake index shows that breeding abundance of the species in Scotland in 2018 was 69% below the 1986 baseline[13]. A reduction in the availability of sandeels in the Northern Isles is highlighted by NatureScot as having contributed to declines in populations of kittiwake, terns and Arctic skua[14].

These declines translate, in turn, into escalating threat status at population level, both nationally and internationally. As NatureScot points out, the declining sandeel dependent species are all either red listed (shag, Arctic skua, puffin, kittiwake) or amber listed (Arctic tern) as UK Birds of Conservation Concern[15]. In 2008, kittiwake was added to the OSPAR list of Threatened and/or Declining Species[16] and in 2017, the species was assessed by the IUCN Red-List of Threatened Species as Vulnerable to global extinction [17], as is Atlantic puffin[18], another highly sandeel-dependent seabird.

The continuing poor performance of kittiwake is highlighted by its productivity at one of our most intensively monitored colonies, the Flamborough and Filey Coast Special Protection Area (SPA), which includes RSPBs Bempton Cliffs Nature Reserve. Collectively this is the UK's biggest mainland seabird assemblage and England's largest kittiwake colony, serving as a potential hub source of recruitment to more depleted colonies elsewhere. The 2019 monitoring report for the SPA[19] shows overall deterioration of kittiwake productivity in the last ten years, with fewer than 0.6 chicks fledged per pair in the four years 2016-2019 (Fig 1):

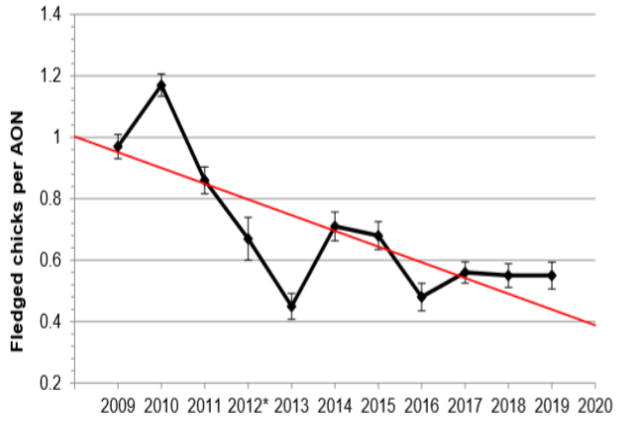

Fig 1

Kittiwake productivity (fledged chicks per AON = apparently occupied nest), 2009-2019.

Points show mean of plot results ± SE. (See Lloyd *et al.* 2019 (footnote 20) for further details.)

Frederiksen *et al.* (2004; see footnote 9, above) notes that on the Isle of May, eastern Scotland, where kittiwake populations also suffered serious decline, chick production of 1.17 chicks per pair would be required to stabilise population trends.

2. Drivers of reduced sandeel biomass and availability

Scientific evidence is mounting that sea warming is responsible for disrupting the food web and reducing sandeel recruitment in the North Sea[20] [21] [22], and that this is a key factor in the decline of seabird populations and their productivity.

However, the additive impact of commercial sandeel fishing is also acknowledged[23] [24]. Cook *et al.* (2014)[25], using data for 1986-2010 from the North Sea region, demonstrated that breeding productivity indicators for a number of seabird species including kittiwake showed consistent negative relationships with fisheries pressure, represented by the proportion of the sandeel population harvested; in short, breeding failure was higher in years when more of the

biomass was fished. Lynam *et al*. (2017)[26] states that 'As fishing mortality of sprat and sandeel is reduced, the average breeding success of seabirds should increase'. Carroll *et al*. (2017)[27] found a strong correlation between kittiwake productivity on the Yorkshire coast and fishing mortality of sandeel on the Dogger Bank whereby higher breeding success of the birds was associated with lower fishing mortality (F) of 1-year old fish two years previously. While the mechanism behind this lagged effect is unknown (though credible explanations are explored in the paper), the authors concluded that '*Even without clear mechanisms, the result adds weight to the evidence… that sandeel fisheries can affect kittiwake food availability and, therefore, productivity*.' They concluded that '*In light of worsening environmental conditions and declining sandeel and kittiwake populations, careful consideration should be given to the requirements of sandeel-dependent predators when making fishery management decisions.'*

In this context, the hindcast analysis of the Dogger Bank sandeel stock by Lindegren *et al* (2018)[28] to assess the consequence of high fishing mortality is relevant. The authors estimated that current sandeel spawning stock biomass (SSB) on the Dogger Bank would have been about twice as large, had fishing mortality been maintained at 0.4 rather than at the levels of 0.8 to 1.2 experienced between 1999 and 2009.

This conclusion is reinforced by a report[29], which addresses the deteriorating status of the sandeel stock in the central and southern North Sea, including Dogger Bank, in relation to the conservation objectives of German Marine Protected Areas (MPAs). The report notes that in sandeel management area SA 1r (see Fig 2, below) the Spawning Stock Biomass (SSB) has repeatedly fallen below B_{pa}[30] since 2004, the authors attributing the poor condition of the stock mainly to high fishing pressure. According to ICES[31], SSB was at or below B_{lim}[27] from 2004 to 2007 and again in 2014. Since 2008, SSB has been above B_{lim} but below B_{pa} in 2008, 2010, 2013 and 2015. See February 2021 ICES advice[32] for the most complete time series of these stock parameters.

ICES attributes declining SSB in recent years partly to the sandeels' lower than expected weight-at-age, noting that '*The mean weight-at-age has decreased in the last three decades, with the lowest on record being observed for ages 3 and 4, and the second lowest for age 1, in 2019. Reasons remain unknown*.' However, it has been suggested elsewhere that availability and quality of food (*Calanus* copepods) is a factor in the observed long-term reduction in growth rate of the early maturation stages of North Sea sandeels[33].

The German study concludes that the sandeel fishery in German Natura 2000 sites seriously jeopardizes the likelihood of achieving the conservation objectives of the Habitats- and the Birds Directives as well as the environmental targets of the MSFD: '*The bad condition of the sandeel stocks in the central and southern North Sea shows that the main targets of the CFP (implementation of a sustainable, ecosystem-friendly use of the marine resources and exploitation according to the MSY principle) and the MSFD (species and biotope types are in a good environmental status) have been missed so far*.'

Note that on 9 May 2019 (and effective from 9 June 2019) the Marine Stewardship Council (MSC) suspended certification of the sandeel in management areas SA 1r and 2r owing to the 'depleted' stock falling below safe biological limits and thus below score 60 against MSC Principle 1.1.1.

3. North Sea sandeel fishery management

3.1 Sandeel fishing grounds

Sandeel fishing in UK waters is currently confined to the North Sea. Historically, there was a small fishery, targeted by local Scottish boats only, off north-west Scotland (ICES Area 6.A) but the fishery no longer operates (landings have been close to zero since 2001 and zero since 2008) and ICES no longer advises on fishing opportunities for this stock[34].

Once they settle as adults, sandeels are largely resident and rarely disperse more than 30km from their 'home' ground.[35] Consequently sandeel aggregations are relatively isolated from one another, the North Sea 'stock' comprising seven distinct, more-or-less reproductively isolated sub-populations, each exhibiting different population dynamics[36]. A decline in the sandeel stock in several areas in recent years, concurrent with a marked change in distribution, has increased concerns about local depletion. Since 2010, ICES has addressed this concern by dividing the Greater North Sea (including Skaggerak and Kattegat) into seven sandeel management areas (SAs) of which five (1r, 2r, 3r, 4 and 6) are currently fished[37] (Fig 2). The western half of SA 1r lies within the UK EEZ, SA 4 entirely so (for map showing SAs and boundaries of national EEZs see Fig 1.1.1.1a in ICES 2016[38]). See Wright *et al.* (2019)[39] for analysis and definition of the stock structure justifying these multiple assessment areas for management according to their differing productivity and population dynamics.

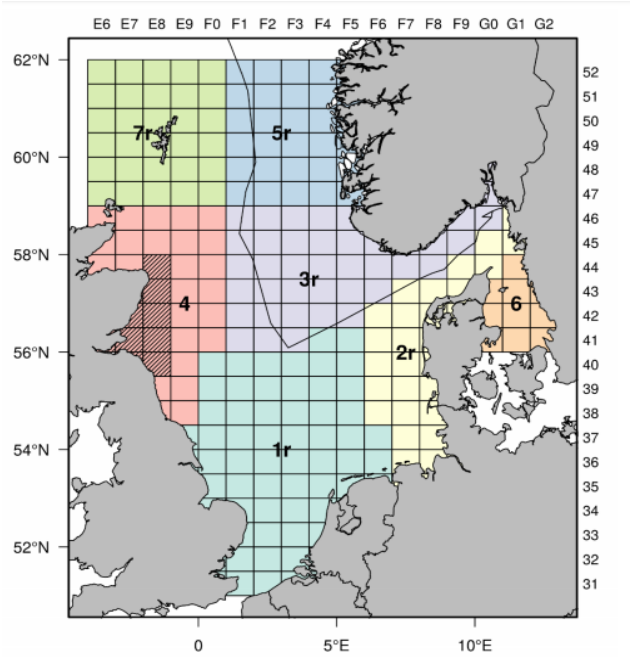

Fig 2

North Sea sandeel assessment and management areas (SAs).

Also shown are (a) the closed area (hatched) within SA 4 (see section 3.3, below); (b) border of the Norwegian EEZ.

Source:

https://www.ices.dk/sites/pub/Publication%20Reports/Advice/2019/2019/san.sa.1r.pdf

Among North Sea countries, Denmark is by far the biggest contributor to the sandeel landings. Up to 2002, Danish landings represented on average 73% of the total, rising to 83% between 2002 and 2009, followed by Norway, with Sweden and Scotland each having very small quotas (See Annex 12 in ICES HAWG Report 2014[40]), in Scotland's case for monitoring purposes only. Norway's sandeel allocation in EU waters is typically ca 20,000 tonnes as a swap for EU access to Norwegian whitefish, and the Norwegian fleet is said to take all its quota from the Dogger Bank (H. Lund (Danmarks Fiskeriforening), *pers. comm.,* 2014). In any year, Norwegian vessels are understood to make only one or two fishing trips

(each of 5 or fewer days) to the Dogger Bank, starting in April, usually catching all their annual quota by mid-May[41].

Under the Common Fisheries Policy (CFP), the North Sea sandeel fishery is strictly seasonal, being restricted to 1st Apr – 31st July[42], although it usually finishes towards the end of June by which time national quotas have been taken. In any case the seasonal nature of the fishery is dictated by the timing of the sandeel's overwintering fasting period in order to avoid predation, fish older than age 1 burying themselves in the seabed sediment from typically August until April the following year, emerging only to spawn in January[43].

The UK EEZ is a major focus of sandeel fishing effort, especially SA 1r. Sandeel landings averaged over 2009-2020 from the North Sea's seven management areas show that by far the largest proportion (55%) came from SA 1r (see **Annex**, below). Moreover, within SA 1r, the primary focus of effort is the Dogger Bank (**Fig 3**), the largest (17,600km2) sandbank in the central-southern North Sea – topographically a plateau with a relatively dynamic shallow top flanked by more stable slopes.

Fig 3

Satellite image of the North Sea with the Dogger Bank outlined in red.

Source:

https://commons.wikimedia.org/wiki/File:Doggerbank.jpg

Situated in the UK part of the Dogger Bank (**Figs 4** and **5**) is also the Dogger Bank Special Area of Conservation (SAC) designated to protect Habitat H1110 ('Sandbanks which are slightly covered by seawater all the time') currently assessed as '*unfavourable*'. The conservation objectives aim to restore the qualifying feature to '*favourable condition*'[44]. The management measures needed to achieve the conservation objectives include reduction of pressure on the benthic habitat from bottom-contacting fishing gear. Sandeels are listed as species component of the 'characteristic communities' of the Dogger Bank SAC[45], playing an important role in nutrient provision.

UK Government proposals to use new post-Brexit legal powers to prohibit all bottom towed fishing across the whole UK portion of the site were put to consultation in February 2021[46]. This would see the prohibition on demersal and semi-pelagic trawls, demersal seines and dredges throughout the SAC (plus a small buffer area around the SAC), bringing an end to targeted sandeel fishing in the area. Based on scientific advice from JNCC the MMO concludes that '*demersal trawls (including semi-pelagic) and demersal seines are not*

compatible with the conservation objectives of the site and the removal of sandeels may result in an adverse effect on site integrity via this pressure.'[47]

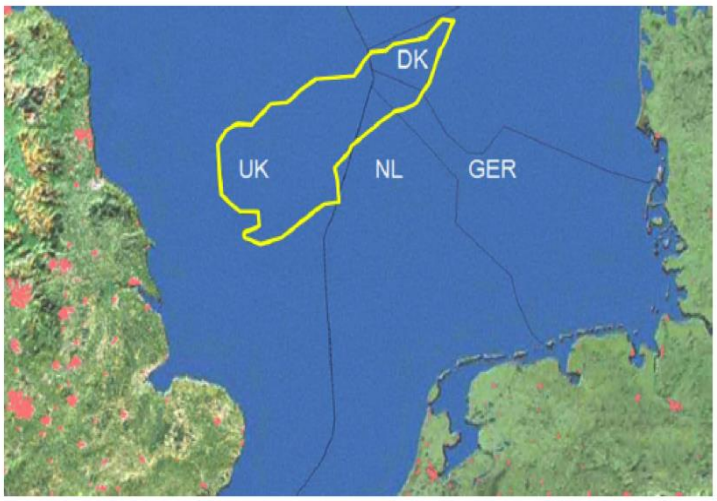

Fig 4

Location of the Dogger Bank relative to the EEZ boundaries of the UK, Netherlands (NL), Germany (GER) and Denmark (DK).

Source:

https://www.msp-platform.eu/practices/international-fisheries-management-plan-dogger-bank

Sandeels are known to favour the Dogger Bank's perimeter slopes, generating a high Catch Per Unit Effort (CPUE), and accordingly the western extremity of the Dogger Bank in the UK EEZ is of major importance for the fishery. Fig 5 demonstrates how maximum Danish sandeel fishing effort concentrates on these western UK slopes. Note that much of the most intense level of this effort occurs outside the UK's SAC boundary and closer to the Yorkshire coast, thus well within the foraging range of breeding kittiwakes and other seabirds. Although the spatial pattern in Fig 5 derives from 2007-09 data, this prime sandeel area of UK waters continues to be particularly targeted. As stated in an assessment[48] of the Danish sandeel fishery in relation to planned windfarm development on the UK part of the Dogger Bank, '*The fishermen consulted considered that the western edge of the Dogger Bank was amongst the most important fishing grounds particularly in water depths ranging from 28m to 48m.*'

The high importance and economic value of the area to Denmark for sandeel catches were emphasised by Danish fishing industry members of the North Sea Advisory Council (NSAC) and influential in discussions about formulating spatial restrictions on bottom trawling in the Dogger Bank Natura 2000 areas (E. Dunn (ex-chair NSAC Dogger Bank focus group), *pers. comm.*). At the conclusion of the process for submitting (June 2019) a Joint Recommendation[49] of the North Sea Member States to the European Commission on fisheries management measures, the proposed closed areas represented ca. 17% of Danish fishing effort (heavily dominated by sandeel) and 15% of Danish landings. In effect, therefore, the proposed measures – even when eventually implemented – will exert little constraint on Danish trawling for sandeel on the Dogger Bank.

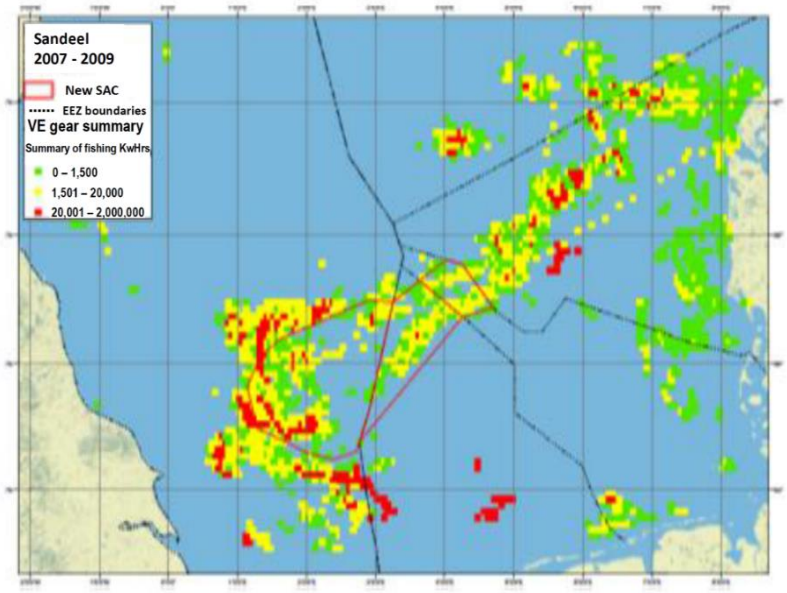

Fig 5

'Heat map' of effort distribution (KWhrs) for Danish sandeel trawls, 2007-2009, with red depicting the highest effort.

The dark dotted lines are EEZ boundaries; the red lines are the Dogger Bank SAC boundaries of (L to R) UK, Netherlands and Germany.

Source: Data processed and provided by DTU Aqua, based on data from the Danish Fisheries Agency.

It is challenging to determine exactly what proportion of the Danish landings (none of which are into UK ports) derives from the UK part of the Dogger Bank. Based on landings data from those ICES rectangles that intersect with the Dogger Bank SAC the Marine Management Organisation (MMO) estimates that sandeel landings by non-UK vessels from the Dogger Bank SAC was approximately 155,800 tonnes between 2014 and 2018.[50] This equates to approximately 24% of total sandeel landings by any country in SA 1r over the same period (652,733 tonnes).

3.2 Fishing grounds and kittiwake distribution

Fig 6 shows the distribution of North Sea sandeel fishing grounds in relation to the location of kittiwake colonies, including England's largest located in the Flamborough and Filey Coast SPA, and the colonies along the east coast of Scotland, the largest of which is at St Abb's Head.

Fig 6

Locations of sandeel fishing grounds (orange) and coastal kittiwake colonies (green dots) (by size); the two largest in, respectively, Scotland and England are arrowed.

Also delineated are:

- the 2 key sandeel management areas SA 1r and SA 4
- sandeel MPAs
- closed areas off E Scotland/NE England, and around Shetland

Adapted from map in:

http://www.mccip.org.uk/media/1818/mccip-sandeels-and-their-availability-as-prey.pdf

[*NB: As shown, map is 'Fig 2' in original MCCIP caption.*]

For nearly a decade the RSPB has been tracking the foraging pattern of tagged kittiwakes from the Flamborough and Filey Coast SPA which includes RSPBs Bempton Cliffs Nature Reserve, collectively the UK's biggest mainland seabird colony and England's largest kittiwake colony. The research demonstrates that the sandeel-rich western flank of the Dogger Bank is part of the birds' foraging area, albeit at the limit of their foraging range. From early RSPB data (Fig 7) the pattern of relatively straight (purple and yellow) tracks *en route* to the Dogger Bank is indicative of birds making a beeline for a destination and not dallying to search and forage, the latter searching activity being typified by the more 'scribbled', meandering and turning-back trajectory of tracks once the Dogger Bank is reached. This suggests that sandeels may be relatively scarce between the mainland and the Dogger Bank, which in turn highlights the importance of the latter as a target food source.

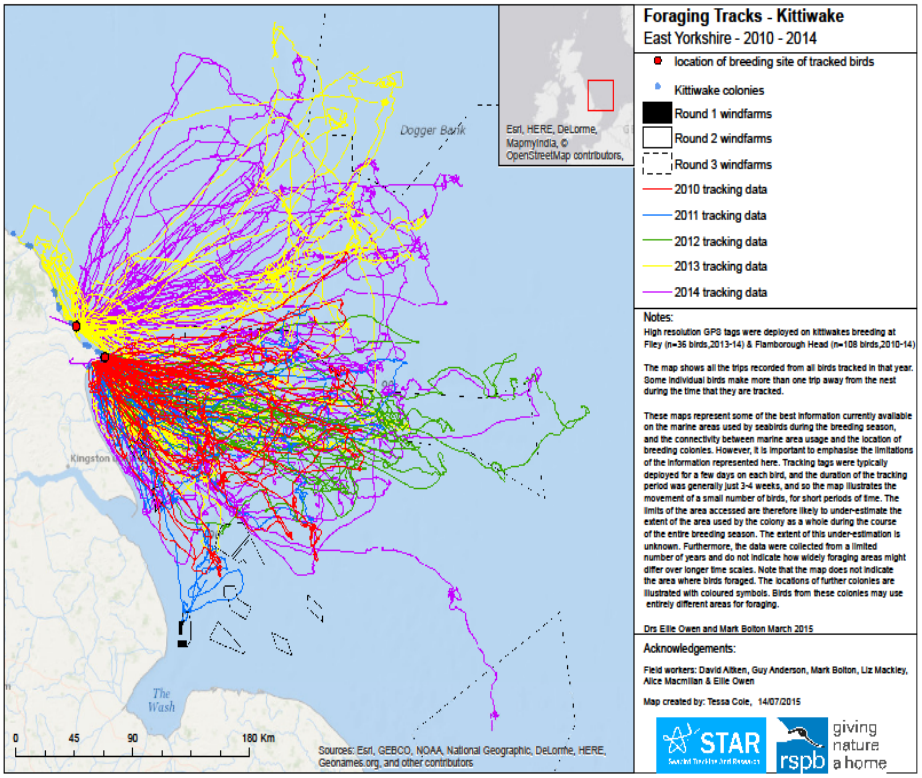

Fig 7

Foraging tracks of breeding kittiwakes (2010-2014) showing use of Dogger Bank (top right) from the upper Flamborough and Filey Coast SPA. The dotted line on Dogger Bank delineates the Round 3 zone for windfarms.

Source: RSPB STAR (Seabird Tracking and Research) project.

Subsequent kittiwake tracking in the context of offshore windfarm development (**Fig 8**) confirms this continuing utilisation of Dogger Bank, albeit the 2017 data show a much stronger SE axis of foraging effort from the Flamborough and Filey Coast. Such annual variation is not unexpected, given the fluctuating nature of the prey population.

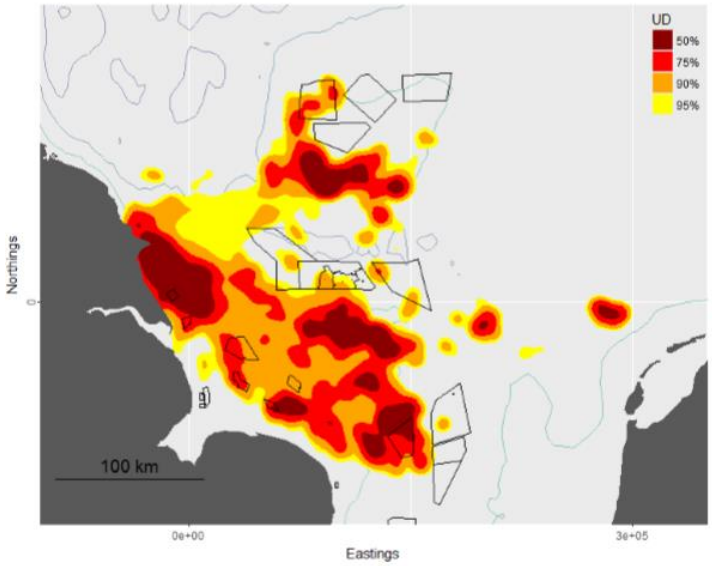

Fig 8

Utilization distributions of kittiwakes tracked at Flamborough and Filey Coast in the 2017 breeding season (N=168 trips from 18 birds). 50%, 75%, 90% and 95% contours are shown (see scale bar), also bathymetric contours (pale blue), and outlines (pale grey) of all proposed, planned or active windfarm zones.

Source: https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010080/EN010080-001300-D2_HOW03_Appendix%207_Wischnewski%20et%20al_2017.pdf

3.3 Establishment of a closed area

In the late 1990s, in response to concerns about declining seabird productivity, in particular of kittiwakes on the east coast of Scotland, the UK Government called for a moratorium on sandeel fishing adjacent to seabird colonies along the North Sea coast[51]. Acknowledging evidence of '*a measurable, negative effect of the fishery on the sandeel stock (local depletion)… which coincided with a reduction in breeding success of seabirds, especially kittiwakes*', ICES advised to use '*the criterion of kittiwake breeding success falling below 0.5 fledged chicks per well-built nest for three successive seasons as the threshold to close sandeel fisheries in areas important for foraging by the kittiwake colonies being monitored*'[52]. This criterion was the trigger to close an area of ca 21,000sq km[53] to sandeel fishing off East Scotland/NE England (**Fig 9**, below), a restriction which has been maintained continuously ever since and post EU withdrawal has been retained under UK legislation (see pp 153-154 in Regulation (EU) 2019/1241[54] which specifies also that '*Fisheries for scientific investigation shall be allowed in order to monitor the sandeel stock in the area and the effects of the closure.*'). While this was a welcome step at the time, it was taken in a reactive way based on evidence of an existing problem. This is a less desirable approach to fisheries management than one which seeks to avoid such problems arising by incorporating an ecosystem-based approach to management in the first place (see section **8,** below). Aware of the potential for displaced fishing effort following area closure, ICES (2000) also advised that measures be taken to ensure that concentrations of fishing effort on sandeel did not build up elsewhere in the North Sea.

ICES further proposed that such a closure should stay in place until kittiwake breeding success exceeded 0.7 fledged chicks per well-built nest, and on this basis OSPAR subsequently proposed an Ecological Quality Objective[55]. However, the ICES thresholds for triggering, respectively, closure and re-opening of an area did not receive legal underpinning as the European Commission did not accept kittiwake breeding success as a suitable index for re-opening the closed area and no alternative criteria have since been put forward [56].

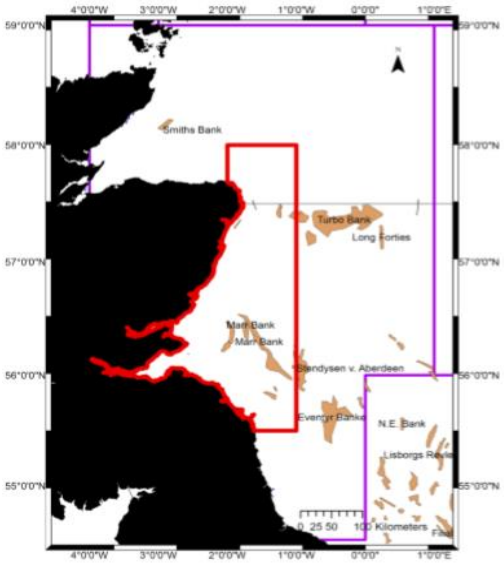

Fig 9

The closed area (outlined red) to sandeel fishing off E Scotland/NE England.

The closure lies within SA 4 (outlined purple). Sandeel fishing banks are shown orange. The southern limit (55^0 30') of the closure is just south of the Farne Islands (Northumberland).

Source:

ICES WKSand 2016 Report: http://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/acom/2016/WKSAND/WKSAND_2016.pdf)

Numbers of guillemots, razorbills, puffins and kittiwakes recorded at sea in the east Scotland study area (see Fig. 1 in Daunt *et al.*, 2008[57]) appeared to increase with closure of the fishery, and then subsequently to decline again as local sandeel abundance declined. However, only the breeding performance of kittiwakes at the Isle of May appeared related to variation in local sandeel abundance[46 58]. In their abstract, Daunt *et al.* concluded: '*Our results suggest that fishery closure can have a beneficial impact on top predators sensitive to variation in the abundance of the target species, although environmental conditions before and after closure are also likely to be critically important*.'

The most recent (2007) STECF evaluation of closed areas[59] likewise pointed to the short-term recovery, following the area closure, of both sandeel abundance and the most sandeel-dependent seabird species: '*The closure partially met the goal to improve sandeel availability for a dependent predator (kittiwakes). Following the closure there appears to have been an improvement in the age one and older sandeel abundance until around 2003. Environmental changes have since caused dramatic declines in sandeel size and seabird breeding productivity in 2004 and 2006-07.*' However, importantly the STECF evaluation recommended that '*the current poor state of sandeels in the closed area would not be helped with re-opening at this time. Catches did increase immediately outside the closed area beyond the level recommended by ICES in some years*.'

3.4 Setting fishery catch limits

ICES advice to inform the setting of annual catch limits (Total Allowable Catches = TACs) of most commercially exploited fish stocks in the North Sea is currently based primarily upon the outputs of a combination of models, including multispecies models (primarily Stochastic Multi-Species model: SMS) and various single-species models. SMS models the trophic interactions between and dynamics of various fish stocks and includes, as part of each stock's natural mortality, the consumption of those stocks by various 'external predators' such as seabirds and marine mammals (the dynamics of which are not explicitly modelled and are effectively treated as an 'external fleet'). SMS generates estimates of the natural mortality of each age/size class within a defined stock of each species and over a defined time period. These values are used as input to single species stock models which, given those levels of natural mortality, estimate the levels of fishing mortality that would be consistent with the size of the stock meeting or exceeding various stock-specific reference points.

In the case of short-lived species, such as sandeel, recruitment is highly variable and biomass can fluctuate markedly between years. Because of the few age groups in the population, the future size of a stock is very sensitive to, and determined by, the incoming recruitment. A precautionary approach is therefore applied to ensure that the spawning stock biomass (SSB) is above levels at which recruitment is likely to be impaired. The aim is to ensure that the probability of the stock being below this lower limit (i.e. $B_{lim)}$ in any single year is no more than 5%[60].

In summary, the primary goal of this approach is to ensure that the level of fishing mortality associated with the permitted TAC is such that the SSB of sandeel (and other forage fish stocks) is very likely to be sufficient to enable successful recruitment in the subsequent year. Sustainability of the fish stock, and thereby the fishery, is the primary goal and it is

assumed that the current levels of predation by top predators will be maintained if the stock is fished at a level that is at or below the fishing mortality target appropriate for the stock.

However, section 8.1 (below) addresses the limitations of this approach in failing to include a reference point specifically to ensure that, post-fishing harvest, there are enough sandeels to meet seabirds' requirements.

4. Policy context

A strong suite of drivers, across the spectrum from international treaties and conventions to national policy targets, has a bearing on the UK's obligation and powers to address the negative impacts of commercial sandeel fishing on seabird populations:

4.1 UK-EU Trade and Cooperation Agreement & International Law

The EU-UK Trade and Cooperation Agreement (TCA)[61] establishes the objectives and principles under which the UK and the EU will cooperate on the management of fisheries. An adjustment period ending on 30 Jun 2026 maintains mutual access to each other's waters and a phased transfer of quota shares. The share of North Sea sandeels is maintained throughout at c.97% EU and 3% UK. After the adjustment period negotiations on access and share of stocks will be on an annual basis, although multi-annual agreements are also possible.

The agreement preserves the regulatory autonomy of each party as independent coastal State under the United Nations Convention on the Law of the Sea (UNCLOS), and each party can introduce measures in its own waters for environmental sustainability as long as these apply equally to all vessels and are based on the best available scientific advice.

As an independent coastal State, in line with UNCLOS Article 61(1) on the 'Conservation of Living Resources', the UK is able to determine the allowable catch of the living resources in its EEZ. Article 61(2) notes that in doing so the coastal State '*shall ensure through proper conservation and management measures that the maintenance of the living resources in the EEZ is not endangered by over-exploitation*.' It is also relevant that UNCLOS Article 61(4) notes that (emphasis added here by our underlining): '*In taking such measures* [defined in Art 6.3 as 'to maintain or restore populations of harvested species at levels which can produce the maximum sustainable yield, as qualified by relevant environmental and economic factors'] *the coastal State shall take into consideration the effects on species associated with or dependent upon harvested species with a view to maintaining or restoring populations of such associated or dependent species above levels at which their reproduction may become seriously threatened.'*

There is no current commercial UK interest in fishing for sandeels (Shetland's inshore sandeel fishery having ceased in 2003[62] following chronic local stock decline). However, UNCLOS Article 62 specifies that when the coastal State '*does not have the capacity to harvest the entire allowable catch'* it shall give other States access to the '*surplus of the allowable catch*' and take into account, inter alia, '*the need to minimize economic dislocation in States whose nationals have habitually fished in the zone or which have made substantial efforts in research and identification of stocks'*. Of relevance here is that as noted above, under Article 61(1), the entire allowable catch shall be determined by the coastal State and presumably, given the sentiment expressed in Article 61(4), should be set so as to ensure that the reproduction of associated or dependent species (such as seabirds) should not be seriously threatened. The issue for discussion with other coastal States would then be whether the UK fleet has the "capacity" to harvest that entire allowable catch and if not, through agreements or other arrangements, give other States access only to the surplus defined by that pre-determined allowable catch.

UNCLOS Articles 61 and 62 are therefore of significance for potential future UK arrangements with the EU, as well as other coastal States (e.g. Norway) engaged to a much lesser extent in the North Sea sandeel fishery.

4.2 OSPAR Convention

With UK's withdrawal from the EU, the OSPAR Convention committed to 'Protecting and conserving the North-East Atlantic and its Resources' arguably assumes greater significance as a regional policy framework for the UK, just as it is for other non-EU Parties (Norway, Iceland). Relevant OSPAR indicators in the context of the sandeel fishery are:

Recovery in the Population Abundance of Sensitive Fish Species[63]

D1 Biological Diversity

D1.2 Population Size

Marine Bird Breeding Success/Failure[64]

D1 Biological Diversity

D1.3 Population Condition

Reflecting on the assessment that more than 25% of the surface feeders (e.g. kittiwake) in the Greater North Sea had experienced widespread breeding failure every year since 2007, the conclusions of the OSPAR Intermediate Assessment (2017) (see also section 1, above) drew attention to linkage with '*the availability of small forage fish species at the surface (e.g. lesser sandeel and sprat)*'. It is also noteworthy here that the OSPAR List of Threatened and/or Declining Species and Habitats includes kittiwake, the Background Document[65] for which points to the potential threat of an 'industrial sandeel fishery' to prey availability.

While the OSPAR Convention allows for the cooperation of Contracting Parties across most human activities that might adversely affect the marine environment in the North-East Atlantic, programmes or measures cannot be adopted under OSPAR in relation to fisheries management.

4.3 EU Nature Directives & UK Regulations

Although now outside of the EU, all four UK administrations have made commitments to maintain (or exceed) standards of protection for the environment derived from EU law. Domestic regulations across the UK ensure that all the requirements set out in the EU Birds and Habitats Directives continue to apply. Activity considered to be in potential conflict with achieving the conservation objectives of a Natura 2000 network site (Special Protection Area (SPA) or Special Area of Conservation (SAC) established under the Birds and Habitats Directives) must be managed. For example, marine SPAs selected to protect foraging areas for seabirds must be managed in order to *inter alia* maintain (or recover) the habitats and food resources required to ensure the qualifying birds meet favourable condition.[66] Thus, the removal or avoidance of fisheries pressure that could lead to a reduction in prey availability would be an appropriate management response to achieve this objective.

Moreover, if future policies by UK administrations regarding sandeel fisheries in UK waters – including granting and/or licensing access by foreign vessels – are considered to constitute a

plan or project, then that plan should be subject to Habitats Regulation Appraisal and should consider not just impacts of the fishery within protected marine sites but also off-site impacts on coastal SPAs for breeding seabirds.

As detailed above in 3.1 above, through its proposals to manage fisheries activity in the Dogger Bank SAC and three other offshore sites, the UK Government has already signalled its intention to uphold the legal requirement to manage activity in order to meet the conservation objectives of protected areas.

4.4 25 Year Environment Plan (YEP) for England and UK-wide Marine Strategy

The 25 YEP[67] sets out the UK Government's long-term approach to protecting and enhancing the environment in England and seeks to establish the country as '*the leading global champion of a greener, healthier, more sustainable future for the next generation'*. The plan '*calls for an approach to agriculture, forestry, land use and fishing that puts the environment first*' and the development of '*a fishing policy that ensures seas return to health and fish stocks are replenished*.

The 25 YEP also puts considerable store on aiming for MSY in fisheries but simply achieving conventional MSY levels for low trophic level forage (forage) fish species such as sandeel will not deliver the necessary wider ecosystem benefits for seabirds and marine mammals. This deficiency has been highlighted by much research, e.g. Smith et al. (2011)[68] which argues that significantly lower exploitation rates are needed for such fish.

According to the 25 YEP, '*An ecosystem approach to fisheries management will account for, and seek to minimise, impacts on non-commercial species and the marine environment generally, including through technical conservation measures*.' Such an ecosystem-based approach is a requirement of the UK-wide Marine Strategy Regulations 2010[69], which transpose the requirements of the EU Marine Strategy Framework Directive[70] into domestic law.

The regulations require the introduction of measures to achieve or maintain Good Environmental Status (GES) of UK seas by 2020. The 2019 updated assessment of the state of UK's seas[71] found that of the 15 descriptors or ecosystem components used to assess GES only 4 had fully met the target. Birds – for which the high-level objective for GES is '*The abundance and demography of marine bird species indicate healthy populations that are not significantly affected by human activities*' – were not only found to have failed to achieve GES but were assessed as moving away from target. Thus, there is a renewed imperative on governments to introduce measures that will halt and reverse this trend.

4.5 UK Fisheries Act 2020 & Scotland's Fisheries Management Strategy 2020-30

The UK Fisheries Act 2020 introduces a range of new powers, which provide UK administrations with the novel ability to manage fisheries outside of the CFP framework. [72]

Several elements of the Act are particularly relevant to enabling the management of the fishery for sandeels and other forage fish in UK waters to be strengthened, notably the Fisheries Objectives on sustainability, the precautionary and ecosystems-based approaches, scientific evidence and climate change.

The Act also amends the Marine and Coastal Access Act 2009 to grant the MMO byelaw-making powers relating to, *inter alia*, prohibiting or restricting fishing in offshore English

waters, in order to conserve marine flora or fauna or habitats. This new mechanism creates the opportunity to introduce restrictions on fishing activity to meet the conservation objectives of protected sites, such as has recently been proposed for the UK part of the Dogger Bank SAC[73]. The Act also provides equivalent powers to Scottish and Welsh Ministers.

Scotland's Fisheries Management Strategy 2020-2030 provides promising signals for action to strengthen sandeel fishing in Scottish waters. Action 11 of a 12 point action plan states: '*We will to work with our stakeholders to deliver an ecosystem-based approach to management, including considering additional protections for spawning and juvenile congregation areas and restricting fishing activity or prohibiting fishing for species which are integral components of the marine food web, such as sandeels*.'[74]

4.6 Seabird Conservation Strategies

The parallel Seabird Conservation Strategies under development in England and Scotland both aim to protect seabird populations and help them recover by identifying practical actions to mitigate the current and emerging pressures on populations. These offer an important and timely framework for identifying and incorporating specific active interventions to restrict sandeel fishing for the benefit of seabirds, alongside other measures to mitigate other threats, such as invasive species and fisheries bycatch

5. Sandeel fishery closure options

What potential actions might UK administrations introduce to restrict sandeel fishing in the light of exit from the EU and the new legislative framework?

5.1 Spatial closure: background

Given that climate change is likely to be the key driver of decline in sandeel biomass, and that mitigating climate change – while not ultimately intractable – is likely to be a very long term human challenge, the question arises, as posed by Wright et al. 2018[75], *'What management measures for sandeels could also increase resilience to climate change*?' The authors suggest: '*As the main anthropogenic pressure on sandeels is fisheries, the main additional measures that could help maintain sufficient numbers for predators are through fisheries management, including closures*.'

Furness *et al.* (2013)[76] advocated closing UK waters to fisheries for sandeels (and sprats) in order to restore the dwindling productivity of kittiwake and several other seabirds dependent on these prey species. This measure was identified to be the most cost-effective, evidence-based management option for more seabird species than any other measure considered in the report. The authors cite evidence that '*the depletion of sandeel stocks has been the single most influential factor reducing productivity of kittiwakes at colonies in the British Isles*'. The authors also note that '*Closure of sandeel fisheries in UK waters would have little direct cost for British fishermen, since the fishery is almost entirely carried out by the Danish fishing fleet*', and that such closure would align the UK with the USA where legislation against the commencement of new forage fisheries has been passed on the Pacific coast[77] to protect seabirds and the wider marine ecosystem. Similar legislation is currently tabled for US Atlantic coast fisheries[78] [79].

In UK waters, the existing 'sandeel box' (3.3 and Fig 9, above) sets an important precedent for this management response. It's worth noting, however, that owing to the discrete nature of any given sandeel aggregation (see 3.1, above), the benefits from this northern closure do not flow to areas of the North Sea, such as the Dogger Bank area (ca 250km south).

Norway also includes area closures in its sandeel management regime which differs from the EU's. In its part of the North Sea, Norway closes an area to fishing in any year unless the abundance of sandeel is relatively high (biomass estimated from the acoustic survey). There is no strict definition of 'high abundance' but no area has been opened when the biomass estimate has been less than 20,000 tonnes.[80]

In summary, closing areas of the sea to sandeel fishing has an established track record as a management tool in the kit of technical measures and, as the evidence in section 3.3 shows, can benefit seabirds that are sensitive to the availability of the target species. The next question concerns the potential spatial scale and location of deployment in UK waters. Our proposed options are to close the UK EEZ to commercial sandeel fishing, or failing this to close the part of the Dogger Bank and the Scottish zone of the EEZ to commercial sandeel fishing.

5.1.1 Close the UK EEZ to sandeel fishing (preferred option)

Brexit, the UK-EU Trade and Cooperation Agreement, the status of the UK as an independent coastal State and new Fisheries Act powers (4.5, above) provide a new legal

context which enable consideration of closing the entire UK EEZ to the existing and any potentially new sandeel fishery in order to improve the survival and productivity of kittiwake and other sandeel dependent seabirds.

While this is the RSPB's preferred option, we do not underestimate the challenge of taking unilateral action on such a scale, given the political negotiations with the EU (in the case of sandeels especially Denmark) and other coastal States and that such agreements will likely include reciprocal access arrangements beyond the current adjustment period set by the EU-UK TCA (noting that between 2012 and 2016 UK vessels landed on average 7,000 tonnes of fish with a value of £10m from Danish waters[81]).

Nevertheless, a valid scientific case can be made for action by the UK in its own waters (noting that the respective devolved governments of the UK would need to agree on such an approach). While we have not carried out detailed cost-benefit analysis of management options, it is self-evident that the greatest potential for significant conservation gains for a variety of UK breeding seabirds would come from putting an end to sandeel fishing across the greatest possible area of sea adjacent to the UK coast.

In regard to taking such wider spatial closures, it is also relevant that, as noted in 5.1.2 (below), just closing the UK part of the Dogger Bank SAC alone would still leave active some of the most intense Danish fishing effort for sandeel operating in the UK EEZ, and even closer to the Yorkshire seabird colonies than the Dogger Bank itself. Indeed, closing the Dogger Bank SAC alone might displace significant effort into this area and risk exacerbating the problem, especially as the current scientific advice on maximum catches takes no account of closed areas (see 6.2).

The case that just closing part of the Dogger Bank may not yield the maximum benefit for seabirds compared with a more extensive closure is arguably strengthened by the inter-annual variation in offshore foraging dispersion by kittiwakes from Flamborough and Filey Coast SPA (see Figs 8 and 9), encompassing areas well outside the Dogger Bank.

The UK is a special case in terms of the size and status of its internationally important, sandeel-dependent seabird populations at risk from sandeel fisheries. The seabird populations of other North Sea countries, at least those in the EU, pale into insignificance compared with the numbers breeding on the North Sea coast of England and Scotland. This confers on the UK a special responsibility to take appropriately ambitious measures to protect its EEZ as the most accessible and critically important area for sustaining our breeding seabird populations.

5.1.2 Close the Dogger Bank part of the UK EEZ to sandeel fishing

As demonstrated in 3.1 (above), the Dogger Bank is the focus of major Danish sandeel fishing effort. Sandeel management area SA 1r yields 55% of all landings from the North Sea, of which by far the most comes from the UK part of the Dogger Bank. Clearly, therefore, closure of the UK part of the Dogger Bank would effectively eliminate the bulk of sandeel fishing from at least the English part of the UK's EEZ, and could be perceived as more politically tractable than closing the entire UK EEZ to sandeel fishing. As a consequence of exit from the EU, the UK part of the Dogger Bank, most of which is designated as a Natura 2000 site (SAC), could be closed to sandeel fishing under new UK Fisheries Act powers (see 4.5, above).

However, closing the Dogger Bank SAC alone to sandeel fishing (as has been proposed by an MMO byelaw) would halt only a relatively small proportion of the sandeel fishing effort, since the majority of the most intense effort is currently exerted outside (to the west, north and south) of the SAC boundary (Fig 5), often significantly closer than the Dogger Bank to the affected seabird colonies on the Yorkshire coast. Moreover, pressure in this area may be intensified as a result of displacement of fishing effort from within the SAC. Thus, in this option we would advocate closure of sandeel fishing across the entire proportion of the Dogger Bank that lies within the UK EEZ (see Fig 4, above).

5.1.3 Close the Scottish part of the UK EEZ to sandeel fishing

During the early 1990s a sandeel fishery developed off the Firth of Forth in the area now called SA 4. The landings from this fishery peaked at over 100,000t in 1993 and then subsequently declined. The Outer Firth of Forth area is important for breeding kittiwakes and other seabirds, and the removal of such large quantities of sandeels within their foraging range soon became a matter of major concern, leading to the establishment of the closed area or 'box' from 2000 onwards (see 3.3, above). All commercial fishing was excluded although a very small annual quota continued to be allocated for scientific stock monitoring purposes[82].

Although the bulk of Danish sandeel fishing effort is concentrated on the productive central and eastern areas of the North Sea, vessels continue to fish at a low level in SA 4 outside the closed area, not least to maintain their track record and fishing opportunities in the area. Catches (from ICES 2020[83]) over recent years (2009-2019), shown in column 5 of the table in the Annex (below), differ markedly between years, reflecting variable fishing effort and typically wide annual fluctuations in sandeel recruitment. For example, owing to the 2018 year class being the second lowest on record for SA 4, ICES[84] advised a zero TAC in 2019; however, in order to obtain samples to assess the status of the stock in 2020, ICES also advised a monitoring TAC not exceeding 5000 tonnes. This monitoring then revealed that the incoming 2019 year-class was well above the average recruitment and among the highest in the time series. Accordingly, ICES (2020) advised a relatively substantial upper catch limit in 2020 of 39,611 tonnes.

While we have focussed here on the closed area, it is worth noting that it does not serve the needs of all the sandeel-dependant seabird populations on the east coast of Scotland. Sandeels are a priority marine feature in terms of conservation in Scotland's seas and appropriate for spatial management. Accordingly, the Scottish MPA network includes a small number of sites (Turbot Bank, North-West Orkney, North-East Lewis and Mousa to Boddam nature conservation MPAs) designated to protect sandeel larvae as sources of wider recruitment, and yet-to-be-implemented management proposals prohibit a targeted sandeel fishery within site boundaries. Furthermore, a newly designated suite of marine SPAs in Scottish waters could trigger regulation of fishing for sandeel (and herring/sprat) within or around the sites. Although no SPAs lie within areas currently targeted by the sandeel fishery, management advice on the Outer Firth of Forth and St Andrews Bay Complex SPA recommends that the overlapping sandeel box is retained to ensure conservation objectives are met. While these additional sites are welcome, further spatial measures – beyond the sandeel box – are likely to be required to comprehensively protect the sandeel foraging grounds of Scotland's east coast seabird assemblage.

In summary, the closed area in SA 4 and the bespoke sandeel MPAs, while necessary, are arguably not sufficient at a time when kittiwakes and other seabirds breeding along the

whole of Scotland's east coast face mounting pressure from food web disruption and offshore renewable energy development. Serious consideration should therefore be given to excluding the relatively small, and exclusively Danish, sandeel fishery from not just SA 4 but from the entire Scottish zone of the UK EEZ.

5.1.4 Spatial closure options: concluding reflections

Notwithstanding the RSPB's preferred option to close the UK EEZ to sandeel fishing, the proposals presented above are neither definitive nor exhaustive but intended to open a dialogue on both the need and the choices for change. Other potential spatial closures include an extension – especially southward – of the existing 'sandeel box' (an option not explored here) or a precautionary closure/presumption against the opening of a targeted sandeel fishery inside UK territorial waters (0-12nm), an area within which there is currently no such commercial fishing for sandeel. The latter could be implemented along with closure of the Dogger Bank, should closure of the entire EEZ prove intractable.

This reinforces the point that the options presented here are not mutually exclusive, e.g. failing closure of the UK EEZ to sandeel fishing, the UK part of the Dogger Bank and the Scottish zone should be subject to simultaneous closure. An argument in favour of this combination is that, were the Dogger Bank to be closed to sandeel fishing, this could potentially displace significant fishing effort into the Scottish zone, to the possible detriment of the latter.

6. Beyond closed areas

Section 5, above, addresses a range of policy options available to UK administrations for restricting sandeel fishing within various parts or the entire UK EEZ. These options, however, do not deal with ensuring sufficient sandeel availability to seabirds in areas beyond any closed areas. Were the UK to take restrictive measures in just part (e.g. Dogger Bank) of its EEZ, it would, in the light of potential displacement of effort, still be desirable to ensure a sustainable biomass of sandeels for seabirds and other dependent predators across the entirety of the EEZ. Even if the UK were to take restrictive measures across all its EEZ it would, for the same reason, still be desirable to ensure a sustainable biomass of sandeels for seabirds and other dependent predators across the wider North Sea ecosystem beyond the UK EEZ. In other words, a necessary measure additional to any spatial restriction is to put in place an approach to setting of allowable catches in any remaining areas open to the fishery (either inside or outside the UK EEZ) that ensures a high likelihood that sufficient sandeel stocks will remain to support successful seabird reproduction.

The following proposals, while primarily addressed at the approach to scientific advice by ICES, require support from UK administrations to effect the desired change.

6.1 Sandeel biomass 'set-aside' for the birds

If the UK were to close part or all its EEZ to sandeel fishing, this might displace commercial sandeel fishing effort to other areas of the North Sea, with potentially negative impacts on ecosystems. To mitigate this, consideration should be given to ensuring that, in setting commercial catch limits, sufficient biomass is left for the seabirds and other Endangered Threatened and Protected (ETP) species at a wider spatial level, namely the Greater North Sea. This challenge falls primarily to ICES (with OSPAR support as appropriate, e.g. JWGBIRD[85]) as the agency responsible for ensuring sufficient sandeel escapement for this purpose when setting its advice on catch limits for the commercial fishery.

Even were the UK not to implement any new spatial closure, there is still a *prima facie* case for creating this biomass 'set-aside', based on the following critique, developed by Natural England with the support of RSPB and Cefas, of the modelling approach currently used by ICES for advising on the setting annual catch limits for sandeel.

As noted in the Report of the 2016 Benchmark Workshop on Sandeel (WKSand 2016), '*Due to their importance in North Sea food webs, ICES has advised that management should ensure that sandeel abundance be maintained high enough to provide food for a variety of predator species*.' But the question arises whether ICES' methodology actually delivers sufficient safeguard. As described in 3.4 (above), ICES apply multi-species models and single-species models to formulate advice on annual TACs. The estimated consumption of fish stocks by top predators is included in the multi-species models that yield estimates of the natural mortality of individual stocks and is therefore factored into the single-species models used to derive TACs for sandeels and other forage fish.

However, this methodology takes no account of the scaling factor or 'ecological multiplier' (EM) that must inevitably exist between the consumption of sandeels by seabirds and other predators i.e. their *physiological* requirements) and the abundance of prey that must be available to them in order to find the (often small) fraction of the stock they actually consume (i.e. their *ecological* requirements). The reference points used to limit TACs of forage fish in the North Sea may therefore often result in stock levels below those required by some seabird species such as kittiwake to breed successfully.

Highlighting the sensitivity of kittiwake and other surface-feeding seabirds to sandeel availability, Wright *et al.* (2018)[86] confirms this aspect of the modelling, observing that '… *ICES advice does not explicitly consider the food requirements of predators in estimating a TAC and fisheries may locally deplete sandeel aggregations within these stock areas*.' Wright *et al*. (2018) therefore proposes that consideration be given to '*setting aside a component of the stock biomass to avoid adverse effects on dependent predators like seabirds*.' In an important, and relatively long-established study which addressed interactions between birds and their marine food resources, Goss-Custard *et al.* (2004)[87] established the existence of threshold shellfish biomass levels required to sustain the overwinter survival of certain species of wading birds. This work set a precedent, leading to widespread incorporation of the birds' ecological requirements as a reference point in inshore shellfisheries management in the UK.

This set-aside factor has also long been acknowledged academically as an issue in offshore fisheries but has never translated into setting operational catch limits in fisheries management. Cury *et al.* (2011)[88] presented a meta-analysis of a global time-series of seabird productivity and low-trophic level prey stock assessment data. Like the study of Goss-Custard *et al*., Cury *et al*. revealed non-linear relationships between the birds' key demographic rates (productivity in this case) and the biomass of their key prey resource. The study found the threshold points in these relationships to occur when the prey stock was about one third of the maximum recorded, suggesting that a third of the peak long-term maximum stock size of forage fish should be left for birds each year to ensure that seabird populations remain stable.

However, 'one-third-for the birds' is a highly generic rule of thumb and close examination of the studies included in the review by Cury *et al.* shows differences between species in the steepness of the plotted relationships between seabird productivity and prey biomass, suggesting a degree of between-species variation in sensitivity to reduced prey abundance. Furness (2006)[89], for example, established that the abundance of the forage fish stock at this threshold point may be 10 - 100 times greater than the quantity of fish consumed by the predatory species. Furness concluded that it is entirely possible that the reference points currently used to set TACs of forage fish in the North Sea (which do not include a point defined by application of any 'ecological multiplier' to the seabirds' consumption of those fish) fall below the threshold biomass level required by some seabird species to minimise the likelihood of reproductive failure.

The challenge is therefore to derive estimates of the ecological multipliers (EMs) between the biomass of forage fish consumed by breeding seabird populations and the biomass of those fish stocks necessary to ensure a sufficient density and availability of fish within the birds' foraging ranges in order to secure high seabird breeding success. EMs allow estimates of the resource consumption by a population of consumers to be scaled-up to the biomass of resource that must be present (in the area they exploit) to ensure their well-being (high productivity and survival).

There is growing awareness of the need to address this challenge. Dickey-Collas (2014)[90] observed that while ICES advice suggests that forage fish in the North Sea are being sustainably managed, this management is completely single-species in nature and does not account for species interactions. A recent review[91] identifies this as a generic problem, highlighting that lack of reference points defining safe ecological limits for predators is a widespread, ongoing issue in fisheries management.

The need for such a tool is implicit in the draft US Forage Fisheries Conservation Act[92] (see also **5.1**, above) in which the amendments to Sec. 7 (Contents of Fisheries Management

Plans) include the following measure: *"(16) when setting annual catch limits for forage fish fisheries, assess, specify, and reduce such limits by the diet needs of fish species and other marine wildlife, such as marine mammals and birds, for which forage fish is a significant part of their diet."*

In summary, there is a clear need to translate ecological multipliers into reference points for defining safe ecological limits for seabirds in the process of setting TACs for North Sea sandeels (and other forage fish). Accordingly, we encourage the attention of ICES to the task of adjusting the stock assessment methodology, requiring a programme of work to:

1. Conduct the research and analysis necessary to derive the relevant ecological multiplier estimates for the sandeel-dependent North Sea seabird assemblage.
2. Translate those estimates into reference points to define safe ecological limits for the birds in the process of setting annual catch limits for sandeels.
3. Apply appropriate precautionary measures (e.g. an ecological multiplier derived for the most sensitive species - kittiwake) until such time as (1) and (2) are factored into the operational methodology for setting catch limits.

This work should be undertaken as a priority and irrespective of any UK initiatives to create new closed areas. The UK could take a lead role in promoting this initiative to ICES, tabling it in OSPAR as appropriate, and engendering the necessary cooperation and support of other interested parties.

6.2 Adjusting catch limits for the presence of closed areas.

Ever since the establishment twenty years ago of the closed area off E Scotland and NE England, amounting to approximately one-third of sandeel management area SA 4, there has been no mechanism in the assessment methodology for taking the existence of this sandeel box into account, with the result that advisory catch limits are routinely set as if *the whole* of SA 4 was open to the fishery. This operational disconnect results in the advised TACs being disproportionately large in comparison with the proportion of SA 4 that is open to the fishery.

ICES is aware of this loophole and addresses it by urging voluntary restraint on fishing effort in the part of SA 4 not closed to fishing. In 2017[93], for example, the advice that catches in SA 4 should be no more than 54,033 tonnes was caveated with: *'However, a closed area exists in this region and ICES advises to not take the full catch in the open banks as this will increase the risk of local depletion. ICES is not in a position to advise on the magnitude of the associated catch*.'

ICES again acknowledged this loophole in 2018[94]: '*The catch advice figures for 2017 and 2018 are much higher than the catches realized in recent years. While parts of the sandeel banks in Sandeel Area 4 (SA 4) are closed for fisheries (STECF, 2007), the assessment and reference points are based on the entire stock, i.e. including those sandeels that are distributed in the closed areas. An exchange of sandeels does take place between the closed and open banks in SA 4, but sandeel movement is limited*.'

A case study on sandeels included in Scotland's Marine Assessment 2020 notes that '*ICES takes no account of area closures when advising on TACs, so current advice on SA4 catches does not consider that around half of the sandeel habitat in the stock region is closed to fishing*.'[95]

This assessment anomaly is perverse, potentially inflating fishing effort in the part of SA 4 open to the fishery. The loophole encourages vessels to 'fish the line' of the closed area boundary, thereby posing an unnecessary risk to the closed area and the seabird

populations it was designed to protect. It is unsatisfactory and sets up to fail in that, in order to mitigate this risk, the onus is on the fishery to take less than its allotted quota.

Notwithstanding any other regulatory measures that might be taken in the Scottish zone of the EEZ (see 5.1.3) ICES is urged to find an appropriate adjustment to setting catch limits such that the existence of this and any future closed area is suitable accounted for.

7. Scientific monitoring

As concluded from an analysis of the impact of the East Scotland/NE England sandeel closure[96], '*It is critical that monitoring across a range of trophic levels continues, complemented by research to identify the functional relationships among oceanography, primary and secondary production, forage fish, top predators and fisheries. Only in this way will high-quality data on ecosystem function become available to management*.'

If the option were to be chosen to exclude sandeel fishing from all or part of the UK's EEZ, and/or if there was an adjustment in the stock assessment methodology to leave a greater proportion of the sandeel biomass for seabirds and other predators (see 6.1,), it would be important to monitor the effect and effectiveness of these measures. Indeed, this may be required under UNCLOS Article 63.2[97] and any future UK-EU agreement on fisheries.

The UK is currently allotted a small (and commercially unviable) sandeel quota of a generally 5000 tonnes for monitoring key demographic parameters, the most important use of which is to evaluate the effectiveness of the closed area off E Scotland/NE England. But most of the monitoring of sandeels in UK waters is by sampling the catches of commercial fishing vessels (mainly Danish) and this facility and the knowledge it yields would be diminished or lost depending on the extent of any new closure within UK waters.

In that event, therefore, the UK administrations should commit to continue monitoring the sandeel stock to inform the efficacy of closure on seabird populations. This should be part of the UK monitoring programme, with catches for monitoring purposes used to inform the UK Marine Strategy objectives set for D1, D4 birds and D1, D4 fish.

A complementary need is enhanced monitoring of breeding seabird populations. Sampling effort under the UK Seabird Monitoring Programme (SMP)[98] is considered insufficient to deliver reliable abundance / productivity trend information for several sandeel-dependent seabird species[99] [100] [101] and it is therefore vital that governments commit to investing in a fit-for-purpose monitoring scheme.

8. Policy coordination

It is important for the UK and Scottish Governments to coordinate and align any new curbs on sandeel fishing in their respective waters, and this should be reflected in a Joint Fisheries Statement, Fisheries Management Plans as required by the UK Fisheries Act, and in the programme of measures under the UK Marine Strategy.

Cooperation and collaboration will be needed not only across the UK but also with other European countries with a direct management interest in the sandeel fishery, mediated as necessary through ICES, OSPAR and other relevant fora.

As Fig 8 (above) illustrates, sandeel-rich sandbanks are attractive not only to seabirds but also as suitable substrate for wind turbine arrays. In addition to the arrays shown in Fig 8, the Offshore Wind Leasing Round 4, recently announced by The Crown Estate, includes options for developers to propose further developments across the entirety of the UK part of the Dogger Bank.[102] Such concentrated overlap also occurs elsewhere, e.g. the Outer Firth of Forth. In considering spatial measures to regulate sandeel fishing, therefore, it will be essential for UK administrations to consider cumulative and in-combination impacts on seabirds in relation to the deployment of offshore wind farm development. The major and rapid escalation of offshore wind farms, and their potential negative impacts on seabird populations[103], is a new dimension threatening to further reduce the resilience of seabirds

already facing multiple other pressures. The UK's legally binding target of achieving 'net zero' greenhouse gas emissions by 2050 (and 2045 in Scotland), and the collateral damage that offshore development to that end may inflict on seabird populations, arguably make it all the more compelling to take a precautionary approach to minimising other established and arguably better evidence-based threats to seabirds, such as from sandeel fishing, while also addressing cumulative and in-combination impacts from all offshore human activity.

9. Conclusions and recommendations

Seabirds are in trouble with frequent and widespread breeding failures observed in recent years. Surface feeding species that are highly dependent on sandeels are faring the worst. The operation of an industrial fishery for sandeels in the North Sea is highly likely to be making an already bad situation for seabirds worse. To have any hope of success in halting and reversing downward trends, governments must collectively act with urgency to build resilience in seabird populations to current and future human induced pressure.

The key recommendations of this report are to:

4. Restrict commercial sandeel fishing in UK waters by further spatial closure. Preferably the whole UK EEZ but failing this both the Dogger Bank and the Scottish zone as a minimum.
5. Improve the scientific advice on annual catch limits (TACs) for sandeel to a) account for the needs of seabirds and the wider North Sea ecosystem, and b) adjust for the presence of existing and future zones of sea where fishing for sandeel is prohibited.

The UK Government's 2018 White Paper '*Sustainable fisheries for future generations*'[104], the then Secretary of State for Environment, Food and Rural Affairs declared:

'*As an independent coastal state for the first time in over 40 years, access to UK waters will be on our terms, under our control and for the benefit of UK fishermen. Today we are setting out our plans to promote a more competitive, profitable and sustainable fishing industry across the whole of the UK and setting a gold standard for sustainable fishing around the world*.'

Similarly, the Scottish Government has stated its aim to be a '*world-leading fishing nation'*, pledging to take an ecosystem-based approach to management, including the consideration of restricting or prohibiting fishing for key species such as sandeel.

There will never be a more opportune time for UK administrations to translate this rhetoric into reality. We urge the curbing of the commercial fishery for sandeels as an exemplar of these pledges on global leadership and a practical demonstration of the commitment to deliver an ecosystem approach to fisheries management.

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Annex

Sandeel catches (tonnes landed) and advised Total Allowable Catches (TAC) in 2009-2021 for the seven management areas (SAs) in the Greater North Sea (using data from *ICES advice on sandeel (Ammodytes sp.) fishing opportunities, catch and effort, published 25 Feb 2021 in Report of the ICES Advisory Committee*).

See Fig 2, above, for locations of management areas (NB: inter-annual comparisons for management areas are complicated by alteration of some area boundaries in 2016).

In each year/area cell, the TAC is shown in italics below the catch, except in 2009 and 2010 when the TAC was set for the whole of the Greater North Sea, i.e. not differentiated by management area. Shaded cells indicate where reported catches were >10% above the advised TAC.

	Sandeel Management Area						
Year	1r	2r	3r[1]	4[2]	5r[3]	6	7r[4]
2009	309591 -	36709 -	6362 -	0 -	0	260 (no advice)	0
2010	300892 -	51635 -	61243 -	275 -	0	132 (no advice)	0
2011	319656 (*320000*)	24897 (*34000*)	92452 (*100000*)	272 (*10000*)	0	481 (*42*)	0
2012	46116 (*23000*)	12552 (*5000*)	40134 (*47000*)	2585 (*5000*)	0	211 (*42*)	0
2013	214981 (*225000*)	47847 (*18000*)	9844 (*60000*)	5225 (*4000*)	0	90 (*336*)	0
2014	98732 (*57000*)	65084 (*5000*)	95464 (*230000*)	4414 (*5000*)	0	79 (*219*)	0
2015	164770 (*133000*)	37899 (*29000*)	104631 (*290000*)	4392 (*5000*)	0	199 (*219*)	0
2016	15264 (*16000*)	9569 (*5000*)	44076 (*103000*)	6232 (*6000*)	0	123 (*219*)	0
2017	242069 (*255956*)	141314 (*175941*)	115642 (*120000*)	18474 (*54043*)	0	0 (*175*)	0
2018	131898 (*134461*)	20240 (*5000*)	74933 (*78669*)	42298 (*59345*)	0	0 (*175*)	0
2019	*86723* *(91916)*	5151 (*5000*)	136901 (*135689*)	6666 (*5000*)	0	96 (*175*)	0
2020	105928 *(113987)*	73921 (*62658*)	247646 (*155072*)	19707 (*39611*)	0	177 (*175*)	0
2021	(*5464*)	(*5000*)	(*161335*)	(*77512*)	(*0*)	(*140*)	0
Average annual catch '09- '20	169718	43901	85777	9212	0	154	0
% of total catch from all areas	55	14.2	27.8	3	0	0.05	0

Superscripts:

1) TAC shown is for combined EU and Norwegian zones.

2) In years 2012, 2014, 2015 and 2019, no commercial fishery, rather monitoring TAC only. ICES advice was that catches for monitoring purposes should not exceed 5000t.

3) Zero catch advised due to absence of scientific assessment.

4) Zero catch advised due to absence of scientific assessment (no commercial sandeel fishery since 2003).

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