Hornsea Project Three
Offshore Wind Farm

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Response to the Secretary of State's Minded to Approve Letter
Appendix 3: Supporting Evidence for Kittiwake Prey Resource

Date: September 2020

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Offshore Wind Farm

Ørsted

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Author	Ørsted, Howell Marine Consulting & GoBe Consultants		
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Ørsted

5 Howick Place,

London, SW1P 1WG

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Acronyms

Acronyms	Description
AIS	Automatic Identification System
BEIS	Department for Business, Energy and Industrial Strategy
CFP	Common Fisheries Policy
DFPO	Danish Fishermen Producers Organization
DPPO	Danish Pelagic Producers Organization
Defra	Department for Environment, Food and Rural Affairs
DCO	Development Consent Order
DGENV	Directorate-General for Environment
EC	European Commission
EMS	European Marine Sites
EU	European Union
FQA	Fixed Quota Allocation
F	Fishing mortality
FFC SPA	Flamborough and Filey Coast Special Protection Area
FLOWW	Fishing Liaison with Offshore Wind and Wet Renewables Group
FMSY	Fishing mortality consistent with achieving Maximum Sustainable Yield
HRA	Habitats Regulations Assessment
ICES	International Council for the Exploration of the Sea
ITQ	Individual Transferable Quota
IUCN	International Union for Conservation of Nature
JNCC	JNCC Joint Nature Conservation Committee
KCP	Kittiwake Compensation Plan
MCAA	Marine and Coastal Access Act 2009
MMO	Marine Management Organisation
MoU	Memorandum of Understanding
MPA	Marine Protected Area
MSFD	Marine Strategy Framework Directive

Acronyms	Description
MSY	Maximum Sustainable Yield
Nm	Nautical mile
NE	Natural England
OWSMRF	Offshore Wind Strategic Monitoring Research Forum
RSPB	Royal Society for the Protection of Birds
SST	Sea Surface Temperature
SoS	Secretary of State
SNH	Scottish Natural Heritage
SNCB	Statutory Nature Conservation Bodies
SSB	Spawning Stock Biomass
SPA	Special Protection Area
TAC	Total Allowable Catch
UNCLOS	UN Convention on the Law of the Sea
VMS	Vessel Monitoring System

1. Background and purpose

1.1 On the 1st July 2020, the Secretary of State ("SoS") for Business, Energy and Industrial Strategy (BEIS) published his Habitats Regulations Assessment ("HRA") in respect of the Development Consent Order (DCO) and Deemed Marine Licences for the Hornsea Three offshore wind farm alongside a "Minded to Approve" letter. The SoS could not rule out an adverse effect on integrity beyond reasonable scientific doubt in relation to in-combination collision impacts on black-legged kittiwake, a qualifying feature of the Flamborough and Filey Coast Special Protection Area (FFC SPA).

1.2 The SoS has requested a Kittiwake Compensation Plan (KCP) which gives confidence that any compensatory measures proposed will be sufficient to offset the impact to the kittiwake feature of the FFC SPA and thereby maintain the coherence of the network of Special Protection Areas (SPA) designated, at least in part, for kittiwake.

1.3 Natural England has previously advised that the management of fisheries to increase the availability of prey to black-legged kittiwake be explored as a primary compensation measure, in the examination of Norfolk Boreas, Natural England state "the compensation measure mostly likely to increase the FFC SPA productivity i.e fisheries management measures has not been taken forward by Norfolk Boreas" (REP14-065 of the Norfolk Boreas Examination. R17.1.4 Flamborough and Filey Coast SPA).

1.4 This report presents the available evidence on the prey availability dynamics for kittiwake and the legal, practical and ecological feasibility of delivering prey resource management as compensation under Article 6(4) of the Habitats Directive. This cumulates in a determination that Ørsted Hornsea Project Three (UK) Limited, as the Applicant for the DCO for Hornsea Three, is not able to provide the rational basis required by the SoS to conclude that increasing prey availability as a compensation measure can be secured or delivered. The report therefore presents a preferred prey availability proposal, which is outside the scope/definition of compensation under Article 6(4), for consideration by Natural England as the statutory conservation adviser to the SoS with respect to designated sites. The proposed approach intends to support government-led, ecosystem-based management of marine resources as a means to restore the protected kittiwake population.

2. The structure of this report

2.1 This report is structured in as follows:

- Part 1 (Section 3) provides a review of the available evidence on the feeding strategy of black-legged kittiwake, relationships between the availability of prey and kittiwake productivity, and identifies relevant evidence gaps in understanding the viability of prey resource management as a compensation measure for the Applicant;
- Part 2 (Section 4) explores the feasibility of delivery mechanisms available to the Applicant to increase the availability of prey via fisheries management as a means of primary compensation for kittiwake; and
- Part 3 (Section 5) outlines a proposal in relation to prey availability that is grounded in an ecosystem-based approach to managing prey stock.

3. Part 1 – Evidence review

Introduction to Part 1

3.1 This section of the report considers the evidence linking kittiwake productivity to the availability of prey and identifies gaps in knowledge. This section provides:

- a review of the role of forage fish species in the North Sea;
- an evidence review of kittiwake feeding strategy;
- an evidence review of prey dynamics, including interactions with commercial sandeel fisheries;
- an overview of sandeel fishery management; and
- a summary of relevant evidence gaps.

Forage fish and their predators

3.2 Forage fish are planktivorous pelagic species (e.g. sandeel, sprat, herring) that are often the pathway for converting plankton production into food available to higher trophic levels (Alder *et al*., 2008). Sandeel is thought to be the most important prey forage fish in the North Sea (Engelhard *et al*., 2014). Seabirds are most dependent on forage fish, but predators also include piscivorous fish and marine mammals. Food web interactions are convoluted and forage fish may compete for food leading to potentially complex interactions. Predators such as kittiwake will compete for forage fish leading to possible effects of one predator on other predators. In particular, the North Sea "offers a wider portfolio of interacting species whose productivity oscillates in response to both the environment and each other's dynamics" (Engelhard *et al*., 2014).

3.3 Of the forage fish in the North Sea, all feed on plankton, are short-lived, mature at 1 or 2 years, and only live for 3 to 5 years (Petitgas, 2010). Due to this high turnover, and with changes in climate and the composition of the North Sea plankton community over the last 100 years, there have been substantial changes in forage fish productivity as a result of changes in prey plankton composition and availability (Beaugrand, 2004; Leterme *et al*., 2005). With a relative reduction in fishing pressure in the North Sea in recent years, studies have shown that populations of pelagic fish may now be regulated through bottom-up mechanisms (Kenny *et al*., 2009; Fauchald *et al*., 2011). There is no consensus on this though, as Mackinson *et al*. (2009) concluded that populations of both pelagic and demersal fish are still largely shaped by fisheries.

3.4 Predators that consume forage fish in the North Sea include piscivorous fish, seabirds, and marine mammals and a range of studies have shown that availability of forage fish can exert bottom-up control on these predators (e.g. Cury *et al*., 2011; Smith *et al*., 2011). These bottom-up effects are clearest where a predator is a specialist relying on the availability of the particular forage fish. For kittiwake, this may only apply during the breeding season where a shortage of appropriately sized prey may result in breeding failures due to high chick mortality (Wanless *et al*., 1998; Frederiksen *et al*., 2004).

3.5 Sandeel are the most important forage fish species in the North Sea and, in addition to kittiwake, sandeel are a key component in the diet of certain other seabirds (Sandwich tern, European shag, great skua, Atlantic puffin, common guillemot, razorbill, northern gannet), piscivorous fish (whiting, horse mackerel, grey gurnard, haddock, mackerel), and marine mammals (minke whale, harbour seal, and grey seal) (Harris and Wanless, 1991; BWPi, 2004; Mendel *et al*., 2008; ICES, 2011; Engelhard *et al*., 2014). Many of these species are afforded protection under the Habitats or Birds Directives[1] due to their conservation status.

3.6 Even where a predator's diet does contain a range of prey species, their fitness can be strongly influenced by one prey type if this is of high calorific value (Wanless *et al*., 2005). Sandeel is one such high energy prey (Hislop *et al*., 1991) that appears to be linked to improved body condition of fish predators (whiting, grey gurnard, and weever) and grey seals (Engelhard *et al*., 2013a, b).

3.7 Although at the scale of the North Sea, no one predator species exerts significant top-down control over forage fish, predators can have substantial impact at local scales. On the Dogger Bank, whiting, grey gurnard, and weever aggregate to high density patches of sandeel, where they can be responsible for >80% of sandeel predation (Engelhard *et al*., 2008); likewise, whiting and haddock aggregate to high sandeel concentrations off the Scottish coast where they cause significant predation (Temming *et al*., 2004).

3.8 The significance of sandeel as a forage fish highlights the need for an ecosystem-based approach to any fisheries management due to complex trophic interactions, demonstrates how sensitive multiple kittiwake prey interactions are to climatic regulation, and highlights the importance of top-down control by a relatively small number of fish species including saithe, whiting, mackerel, and horse mackerel (ICES, 2011). For example, the Shetland sandeel stock is thought to have declined since 2000 due to impacts of predation by an increasing stock of adult herring.

Summary
• Forage fish are planktivorous pelagic species that are often the pathway for converting zooplankton production into food available to higher trophic levels • Sandeel is thought to be the most important prey forage fish in the North Sea and is evidently the most important in the diet of seabirds and seals. • In addition to kittiwake, sandeel are a key component in the diet of other seabirds (Sandwich tern, European shag, great skua, Atlantic puffin, common guillemot, razorbill, northern gannet), piscivorous fish (whiting, horse mackerel, grey gurnard, haddock, mackerel), and marine mammals (minke whale, harbour seal, and grey seal). Many of these species are afforded protection under the Habitats or Birds Directives due to their conservation status. • At local scales, predators can have significant top-down control over forage fish populations. • With a relative reduction in fishing pressure in the North Sea in recent years, some believe that populations of pelagic fish may now be regulated through bottom-up mechanisms.

[1] https://www.gov.uk/government/publications/protected-marine-species

Kittiwake feeding strategy

3.9 The black-legged kittiwake *(Rissa tridactyla)* is a coastal breeding bird found in the North Pacific, North Atlantic and Arctic. It is a small gull species and the only one that is predominantly cliff-nesting, where it forms large, dense colonies on sheer sea cliffs during the summer breeding period (Hatch *et al*., 2009). Outside of this breeding period, kittiwake are found almost exclusively at sea.

3.10 Kittiwake are listed as vulnerable on the International Union for Conservation of Nature (IUCN) red list in recognition of the fact that the species is estimated to have declined globally by around 40% since the 1970s. Climate change and industrial fishing resulting in changes to the main prey species of kittiwake are thought to be the main contributing factors (Frederiksen *et al*., 2004, Nikolaeva *et al*., 2006).

3.11 Kittiwake feed primarily on fish in open water, but over their geographic range their diet is variable and also includes marine invertebrates such as shellfish, squid, and shrimps (del Hoyo *et al*. 1992-2006). At UK North Sea colonies, kittiwakes feed mainly on sandeels while breeding, although other fish species, such as sprat, and young herring, may replace them in areas where sandeel are uncommon (e.g. Bull *et al*., 2004; Coulson, 2011; Lauria *et al*., 2012). Reliance on sandeel varies with region and season and the diet of kittiwake populations from the coast of eastern England can comprise up to 60% sandeel (Furness and Tasker, 2000). The FFC SPA, which protects the largest kittiwake colony in the UK, is located in this coastal region.

3.12 Sandeel are small eel-like fish that swim in large shoals and are an abundant and important component of food webs in the North Atlantic, linking zooplankton with many fish, seabird and mammal species. Though there are five species of sandeel found in the North Sea, the lesser (or Raitt's) sandeel, *Ammodytes marinus*, is the most abundant and comprises over 90% of sandeel fishery catches. Sandeel bury into sandy sediment overnight and over the winter months (Wright *et al*., 2000). Whilst overwintering, sandeel emerge between December and February to spawn their demersal eggs onto sand. Larvae then hatch between February and April and are transported by currents for 7-10 weeks (Wright and Bailey, 1996; Régnier *et al*., 2017). Evidence from tag-recapture studies and research surveys suggests that sandeel do not move far once settled (Kunzlik *et al*., 1986, Wright *et al*., 1998). Due to the relatively short period that larvae drift and the dependency of later life-stages on specific areas of sand, several distinct sandeel stocks are now recognised within the North Sea (ICES, 2017) and this is reflected in the regional variation in breeding success of several seabird species (Frederiksen *et al*., 2005). Older sandeel are active in the water column until early summer, emerging from sand during daylight hours to feed.

3.13 Significantly, the size of sandeel targeted by kittiwake changes throughout the year. Breeding adult kittiwake eat sandeels aged one year and older during April/May but shift to smaller juvenile sandeels for themselves and their young in June/July (Harris and Wanless, 1997, Lewis *et al*., 2001, Daunt *et al*., 2008). As kittiwake are obligate sea surface feeders (i.e. they are only able to capture prey within the top metre of the sea surface), sandeels are therefore only available as prey for a relatively short period of time.

3.14 Kittiwakes may not be able to utilise sandeel fully if there is a mismatch in the timing of sandeel availability and when breeding kittiwakes require peak energy. Sandeel larval growth is highly dependent on matching the onset of spring copepod production. The timing of the spring plankton blooms dictates the timing and emergence of zooplankton and therefore their sandeel predators. Poor synchrony between the peak in larval hatch times and sandeel prey availability can severely impact growth and survivorship leading to low sandeel recruitment (Wright and Bailey, 1996, Régnier *et al*., 2017), which impacts feeding opportunities for kittiwake at the sea surface (Scott *et al*., 2006, Carroll *et al*., 2015). On Foula, Shetland, low availability of young sandeel negatively affected adult kittiwake survival (Oro and Furness, 2002), which indicates that young-of-the-year sandeels may play an important role for adult kittiwakes in replenishing body reserves following breeding while older sandeels tend to remain buried in the sand in early summer and have thus become unavailable to kittiwakes (Ruffino *et al*., 2020). What this demonstrates is that healthy levels of multiple sandeel year classes are important for kittiwake to survive and breed successfully.

3.15 Climate change is also having an influence on sandeel within the North Sea. Warmer seas delay the sandeel spawning time and are expected to also delay hatch times (Wright *et al*., 2017a). At the same time, warming also leads to an earlier onset of spring plankton blooms. This can lead to a mismatch between peak sandeel hatch times and prey availability and will adversely affect sandeel growth and survivorship leading to low recruitment (Wright & Bailey, 1996; Régnier *et al*. 2017). This is further complicated by the effect of climate change on local environmental conditions such as changing ocean currents and a possible shift in composition of copepod species.

Summary
• Kittiwake are surface feeders, feeding primarily on fish in open water, but they have a variable diet over their geographic range. • At FFC SPA, sandeel is the principal prey species for kittiwake, particularly during the breeding season. • Breeding adult kittiwake eat 1+ group sandeel in April/May and shift to smaller 0 group sandeels (fish hatched in the current year) for themselves and their young in June/July. As such, multiple healthy year classes of sandeel are important for kittiwake. • Kittiwake are only able to feed on sandeel when they emerge from the sediment between April to November, with a peak in dietary composition in June/July corresponding to the appearance of shoals of 0 group sandeels near the surface. • Kittiwake cannot utilise sandeel fully if there is a disparity in the timing of sandeel availability and when breeding kittiwakes require peak energy. Climate change has increased the likelihood of a misalignment due to a change in the time of the spring plankton bloom and hence sandeel emergence.

3.16 Sandeels are the target of what has been the largest single-species fishery in the North Sea over recent decades. There is evidence that the sandeel fishery has contributed to depletion of sandeel biomass in the North Sea (Lindegren *et al*. 2018) (discussed further in Section 3.29 below). Breeding, breeding success and survival rate of kittiwake are considered to be strongly influenced by sandeel stock size and thus by commercial fisheries on sandeels (Furness and Tasker 2000, Lewis *et al*. 2001, Oro and Furness 2002, Mitchell *et al*. 2004, Frederiksen *et al*. 2004).

3.17 Aebischer and Coulson (1990) reported at North Shields, United Kingdom, a mean kittiwake survival rate of 0.8 but with variation from 0.85 in 1954-1965 to only 0.65 in 1982-85. They suggested that the decrease in survival in the 1980s might most likely be due to changes in abundance of small pelagic fish including sandeel on which the kittiwakes depend. Oro and Furness (2002) showed that kittiwake breeding adult annual survival rates at a colony in Shetland varied between 0.98 and 0.53 (with a mean of 0.8), with a strong effect of sandeel abundance and a weak influence of great skua breeding success. Frederiksen *et al*. (2004) analysed environmental factors affecting survival rates of breeding adult kittiwakes at the Isle of May colony. They found that survival rate varied between 0.98 in 1986-87 and 0.82 in 1998-99, with 35 to 52% of the annual variation in survival rate being explained by the presence or absence of a commercial fishery for sandeels in the area and sea surface temperature (SST). Kittiwake survival was lower when there was a sandeel fishery and when SST was higher. This is consistent with the fishery depleting the North Sea sandeel stock, and with sandeel recruitment decreasing with higher SST (Arnott and Ruxton 2002). On average, kittiwake adult survival rate was reduced by about 0.05 during the period when a commercial fishery for sandeels was active in the area. The results presented by Frederiksen *et al*. (2004) are closely consistent with those of Oro and Furness (2002), but for kittiwake breeding in different regions, associated with different sandeel stocks, and with different commercial fisheries.

3.18 There is evidence that a reduction in the abundance of sandeels can cause a reduction in the breeding success and survival of kittiwakes, and that large reductions in sandeel abundance result in breeding failure of kittiwakes and population decline (Furness and Tasker 2000, Oro and Furness 2002, Frederiksen *et al*. 2004, Furness 2007, Carroll *et al*. 2017). Kittiwake breeding success, and breeding numbers, crashed in Shetland after the collapse of the Shetland sandeel stock (Furness and Tasker 2000). Kittiwake breeding success has also been affected at the Isle of May, off east Scotland, when the sandeel stock in that area (which is distinct from the sandeel stocks at Shetland or in the southern North Sea; Frederiksen *et al*. 2005; ICES 2019) was heavily fished (Frederiksen *et al*. 2004).

3.19 Frederiksen *et al*. (2004) also showed that breeding success of kittiwakes at the Isle of May (part of Forth Islands SPA) was on average 0.5 chicks per pair lower during years when sandeel fishing occurred in the area than it was in years with no sandeel fishing. Furthermore, on the Isle of May and across the Shetland isles, kittiwake breeding success was found to be related to abundance and availability of both juvenile and sandeels aged one and older (e.g. Daunt *et al*. 2008; Poloczanska *et al*. 2004; Rindorf *et al*. 2000). As a result of the persistent low breeding success of kittiwakes a decision was taken to close an area to sandeel fishery (the NW North Sea sandeel box off the east coast of Scotland) (see Section 3.26).

3.20 Kittiwake lay one to three eggs with a mean clutch size[2] of 2.01 in the British Isles (Cramp and Simmons, 1977-1994, del Hoyo *et al*., 1992-2006). Productivity, the number of chicks produced pre nest, at the Flamborough & Filey Coast SPA has declined since the 1980s (JNCC, 2015). Breeding success of the Flamborough & Filey Coast kittiwake population was 1.2 chicks/pair in 1986-1990, but fell to 0.8 chicks/pair in 2010-2014, with that reduction largely being attributable to high fishing mortality of sandeels resulting in a reduction in sandeel abundance (Carroll *et al*., 2017). The relationship found by Carroll *et al*. (2017) for kittiwakes at Flamborough & Filey Coast SPA in relation to sandeel stock in ICES North Sea SA1 (Dogger Bank and neighbouring areas) is similar to that previously identified at Shetland (Furness and Tasker, 2000, Oro and Furness, 2002, Furness, 2007), and at the Isle of May (Frederiksen *et al*., 2004).

Summary
• Sandeels are the target of what has been the largest single-species fishery in the North Sea over recent decades and there is evidence that this has contributed to a decrease in sandeel biomass in the North Sea. • Breeding, breeding success and survival rate of kittiwake can be strongly influenced by sandeel stock size and thus by commercial fisheries on sandeels. • There is evidence of a negative relationship between kittiwake productivity and sandeel fishing mortality at Flamborough & Filey Coast SPA, Shetland, and the Isle of May.

Commercial fisheries interactions

3.21 The sandeel fishery is the largest single-species fishery (by weight) in the North Sea with historic landings of around a million tonnes per annum. The fishery started in the 1950s, reaching peak landings of around 1 million tonnes in the late 1990s, before declining to 100,000 to 400,000 tonnes per year since 2003 (Furness, 2002, ICES, 2015a). Landings have decreased primarily due to a reduction in the productivity of sandeel in the northern North Sea where recruitment has decreased to less than half the average of earlier years. Since the early 2000s the fishing fleet has declined in size, but in spite of this, sandeel stock biomass has declined and is often below stock reference points (ICES, 2015a). Despite the reduction in the fishery, landings of sandeel in 2009 were still higher than those for all demersal fish species combined (Engelhard *et al*., 2014).

3.22 ICES who advise the European Commission on the Total Allowable Catch (TAC) of sandeel, define the fishery as follows:

“Sandeels are taken by trawlers using small mesh gear. The fishery is seasonal, taking place mostly in the spring and summer. Most of the catch consists of Ammodytes marinus and there is little by-catch of protected species. The I-group constitutes the major part of the catches. The Dogger and Fisher Bank fisheries are the most important fishing grounds. The North Sea sandeel catches are taken almost exclusively by Denmark and Norway.”

[2] Clutch size refers to the number of eggs laid in a single brood by a nesting pair of birds

3.23 A spatial and temporal overlap exists between sandeel fisheries and kittiwake feeding grounds. The major sandeel fishing grounds are located approximately 100 km from the UK coast with some smaller grounds closer to the coast but still offshore (>12 nmi) (see Figure 3.1) (ICES 2007; Jensen *et al*., 2011; South *et al*., 2009) and so overlap with seabird foraging areas. The mean maximum foraging range for kittiwake is considered to be approximately 156 km, however GPS tracking studies have shown that kittiwakes from Flamborough and Filey Coast SPA also forage within the Dogger Bank area of the southern North Sea.

3.24 Sandeel fishing occurs in April to June and the fleet mainly target year one or older sandeels through use of a specific mesh size. Depending on the timing of the fishery relative to the timing of the switch in diet from year one or older sandeels to juvenile sandeels, fisheries may directly compete with breeding kittiwakes when energetic demands are high. As such, it is especially important to consider the sensitivity of the seabirds during the breeding season when considering potential impacts of the fishery. Furthermore, effects in subsequent years are also likely to accrue through the overall reduction in the abundance of older sandeels (Carrol *et al*., 2017), particularly where fishing reduces the spawning stock to the point where egg production limits the numbers of juvenile fish (Daunt *et al*., 2008).

3.25 In Shetland, sandeel stock biomass fell rapidly in the late 1980s during the period of a local industrial fishery for sandeels, and that fishery was closed in 1990. Breeding success of kittiwakes in Shetland in 1990 was 0.12 chicks per pair. In 1991, the first year of the sandeel fishery closure, sandeel recruitment was higher than it had been in any of the previous seven years during heavy fishing. Kittiwake productivity in 1991 was 0.57 chicks per pair, the highest at monitored Shetland colonies since 1986 (JNCC data and ICES sandeel stock data).

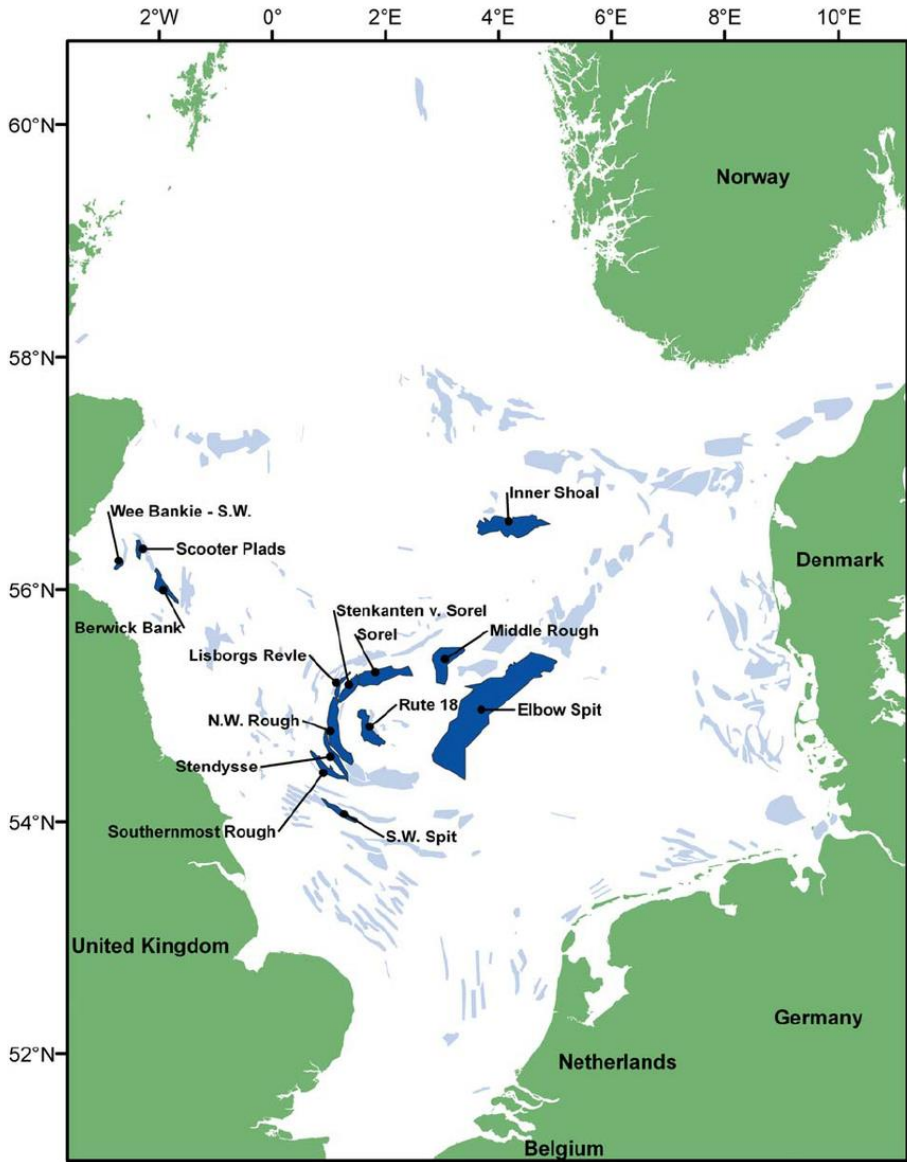

Figure 3.1 Location of sandeel habitat areas (areas with potentially high density of non-buried sandeel)

3.26 An area off the east coast of Scotland was closed to sandeel fishing from 2000 because kittiwake breeding success in the area had fallen to very low levels (European Commission (EC), 2000, Wright *et al*., 2002). Intensive fishing for sandeels for several years by the Danish industrial fleet[3] on the sand banks close to the east coast of Scotland was considered to be the main cause (Wright *et al*., 2002). The aim of this fishery closure was to allow sandeel stocks in the area to recover. The abundance of 0 and 1+ sandeel age classes increased markedly in 2000, the first year of fishery closure (Greenstreet *et al*., 2006). The large increase in 1+ group sandeel abundance in 2000 was likely to be the combined effects of a substantial decline in fishery removals of sandeels of this age group in 1999 and coincidental recruitment of a stronger 0 group cohort in 1999 compared with that in 1998 (Greenstreet *et al*., 2006, Daunt *et al*., 2008).

3.27 Frederiksen and Wanless (2006) reviewed the evidence that the sandeel closure increased productivity of kittiwakes and other seabirds. They found that the closure appeared to result in increased productivity of kittiwake within the study area compared with a control area outside the closure. Productivity of kittiwakes did not differ between fishery and non-fishery years outside the closure zone, but inside the zone breeding productivity was considerably lower during fishery years (the difference was 0.28 chicks per nest and statistically highly significant ($p<0.0001$). Daunt *et al*. (2008) and Frederiksen *et al*. (2008) also found an initial increase in kittiwake breeding success at colonies within the closed area compared to those outside, providing evidence for the mitigation of fishery impact by closing the fishery.

3.28 However, monitoring of seabird breeding performance in the area continued in 2004-5 and success was poor across all species in 2004 and all except kittiwakes in 2005 despite the continued closure of the fishery (Mavor *et al*., 2005, Parsons, 2005). It is now thought that closing the area to fishing has been insufficient to maintain high sandeel biomass in the area (Greenstreet *et al*., 2010). Recruitment of young sandeels at levels at least comparable to the long-term average is also critical and this is governed by natural processes. In the absence of continued high recruitment, natural sandeel mortality exceeds growth production and population biomass has declines. Greenstreet *et al*. (2010) concluded that:

"Closing industrial fisheries for short-lived, highly-productive species such as sandeels appears to provide no guarantee of ensuring high abundance of these species in the managed area. Thus, closed area management does not ensure that prey supplies to marine top predators remain at levels sufficient to support continuous strong reproductive performance. At best it ensures that anthropogenic activities, such as industrial fishing, are not directly responsible for predator population collapses."

[3] Off Scotland, small sandeel fisheries operate at Shetland and off the west coast. These fisheries are rather different in character to the large North Sea sandeel fishery. They are smaller in scale and restricted to small inshore grounds and managed nationally. The Shetland fishery was not thought to have had a significant effect on the availability of sandeels to seabirds. However, subsequent management of the fishery has explicitly recognised the importance of the Shetland sandeel population to seabirds.

3.29 As aforementioned, breeding success and productivity of kittiwake at the Flamborough and Filey Coast SPA has been found to correlate with sandeel abundance (Carroll *et al*., 2017). Lindegren *et al*. (2018) carried out a hindcast analysis of the Dogger Bank sandeel stock to assess the consequence of high fishing mortality. They estimated that sandeel spawning stock biomass would have been about double what it is now, if the fishery had maintained fishing mortality (F) at F=0.4 rather than at the levels of 0.8 to 1.2 as seen during 1999-2009. Their results suggest that in some years high fishing mortality of the sandeel stock has had an influence on the abundance of the sandeel.

3.30 At present, sandeel stock remains considerably below its long-term average and subject to a fishing mortality around F=0.6[4] (ICES, 2018). The spawning stock biomass (SSB) in SA1 was also at a dangerously low level of 67,711 tonnes in 2019, which is less than 10% of its highest historical level and is slightly below the limiting spawning stock biomass at which ICES should recommend closure of the fishery (B_{lim} of 110,000 tonnes SSB) because there is a serious risk of recruitment failure in this stock (ICES, 2019). Despite this the quota set for the Danish sandeel fishery, which is by far the main EU fishing nation for sandeel, has been set at 215,863 metric tons, double the quota in 2019 which was 106,387 metric tons. Furthermore, the stock assessment model used by ICES does not take full account of real-word variability and variance is therefore underestimated by the model. The result is that a Total Allowable Catch (TAC) may be set at a higher level than required to meet management objectives[5].

3.31 High fishing mortality has been found to be associated with reduced spawning stock biomass in each of the next two years, and lower kittiwake breeding success two years later (Carrol *et al*., 2017). It is possible that the lag may be due to the fishery focussing on year one and two sandeels and the ability of kittiwake to switch to juvenile sandeel, thus providing an initial buffer on impacts (Carrol *et al*., 2017). Further, as populations decline, sandeel distributions contract into core habitats (Wright *et al*., 2000). It is therefore possible that smaller sandeel aggregations closer to the coast could become depleted over time with this reduction in food availability leading to a lagged response on kittiwake populations. However, available data are currently insufficient to be able to determine possible mechanisms for the lagged response.

3.32 Closed areas are a management option for sedentary, short-lived species subject to a directed fishery (i.e. sandeel), because protected habitats support all age classes, and rapid recovery in species abundance is more likely (Gell and Roberts, 2003, Sale *et al*., 2005). Following closure of a sandeel fishery along the east coast of Scotland, there was an immediate increase in sandeel abundance (Greenstreet *et al*. 2006). This increase was most likely the result of improved survival of sandeels year one or older, previously the target of the fishery, combined with coincidental high levels of recruitment (Greenstreet *et al*. 2006).

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[4] A figure above the level tested in the scenario of Lindegren *et al.* (2018), and which their scenario modelling clearly demonstrates has a negative impact on sandeel abundance.

[5] Management metric equals <0.05 risk of spawning stock biomass being depleted below the reference point threshold at which fishing should be closed to save the stock from commercial extinction (ICES, 2017)

3.33 Cury *et al*. (2011) suggested that fisheries management should aim to keep food fish stocks such as sandeels above a threshold of one-third of their historical maximum biomass in order to achieve good productivity among dependent seabird populations. The southern North Sea sandeel stock has fallen far below that rule of thumb management objective. Daunt *et al*. (2008) suggest that fishery closures could have a beneficial impact on top predators that are sensitive to variation in abundance of target species, although environmental conditions before and after closure are likely to be highly important.

Summary
• The sandeel fishery has been the largest single-species fishery (by weight) in the North Sea with historic landings of around a million tonnes per annum. • The sandeel fishery is offshore (>12 nmi), seasonal, taking place mostly in the spring and summer, and may directly compete with breeding kittiwakes when energetic demands are high. • The SA1 sandeel population remains below precautionary limits and is regularly fished beyond the 'one third [of unfished biomass] for the birds' rule (Cury *et al*., 2011) and with age-1 fishing mortality (F) >0.5 (Carroll *et al*., 2017) • An area off the east coast of Scotland was closed to sandeel fishing from 2000 because kittiwake breeding success in the area had fallen to very low levels. • The success of the closure is difficult to evaluate as an initial increase in *kittiwake* breeding success can be partly attributed to coincidental high recruitment of sandeel as well as a decline in fishery removals. Subsequent monitoring has shown that a continued ban on sandeel fishing in the area has failed to maintain sandeel biomass at initial high levels. • Reducing fishing mortality in SA1 is unlikely to reverse widespread kittiwake declines due to sandeel recruitment variability, but some colonies in eastern England may benefit.

Sandeel fishery management

3.34 ICES is the sole scientific advisor for North Sea shared and/or international stocks that come under the Common Fisheries Policy (CFP), and CFP/Norwegian responsibilities. The legitimacy of this role is provided through a grant agreement with the EU and with Norway. ICES do not play a role in the enforcement, monitoring of fisheries or the management. ICES is also a science advisor to the EU Directorate-General for Environment (DGENV) on the Marine Strategy Framework Directive (MSFD). All ICES advice is aimed at providing advice under the ecosystem approach and the precautionary approach. ICES Maximum Sustainable Yield (MSY[6]) advice rule:

"The production in a fish stock can be highly variable. It is related to stock size (often expressed as spawning–stock biomass, SSB) and the size structure in the stock, which in turn depend also on the fishing mortality and fishing pattern.

Surplus production of a stock is the catch that can be harvested without changing the average production in the long term. For a given fishing pattern there is a level of fishing mortality that in the long term will generate the highest surplus production. This peak of the surplus production is the MSY, and the fishing mortality generating this peak is FMSY.

[6] In fisheries, MSY is defined as the maximum catch (in numbers or mass) that can be removed from a population over an indefinite period.

Fishing mortality is the only variable that can be directly controlled by fisheries management. Fisheries management cannot directly control the stock size, it can only influence it through the fishing mortality. Stock size is also subject to natural variability that on a year-to-year basis can overwhelm the influence of fishing. MSY is a long-term average. A management strategy that harvests variable yields in response to the natural variability in stock size will on average give yields closer to the long-term MSY than a strategy operating with the maximum constant yield that could be taken sustainably.

Due to the natural variability in stock size there may be situations where the spawning stock is so low that reproduction is at significant risk of being impaired. A precautionary approach implies that fisheries management in such situations should be more cautious. For stocks where quantitative information is available, a reference point B_{lim} *may be identified as the stock size below which there may be reduced recruitment. A precautionary safety margin incorporating the uncertainty in ICES stock estimates leads to a precautionary reference point* B_{pa}*, which is a biomass reference point designed have a low probability of being below* B_{lim}*. In most cases the safety margin is taken as a standard value, such that in most cases* $B_{pa} = B_{lim} \times 1.4$*. When the spawning stock size is estimated to be above* B_{pa}*, the probability of impaired recruitment is expected to be low.*

For short-lived species, the biomass can fluctuate wildly between years. A precautionary approach in this situation implies that a minimum stock size, $B_{escapement}$*, should remain in the sea every year after fishing. “*

3.35 Sandeel catches in EU waters are managed through seven area TACs which are set at the beginning of every year according to an escapement strategy Figure 3.2).

3.36 For short-lived stocks, such as sandeel, ICES consider their MSY approach to be “escapement fishing” where the fishery each year aims to reduce the stock size to a biomass consistent with having a specific, low probability of impairing recruitment and that is a sufficient resource for predators (Dickey-Collas *et al*., 2014; ICES 2015b). However, some fisheries scientists have disputed that management of this fishery contains any predator-focused reference point in the management process (Hill *et al*., 2020).

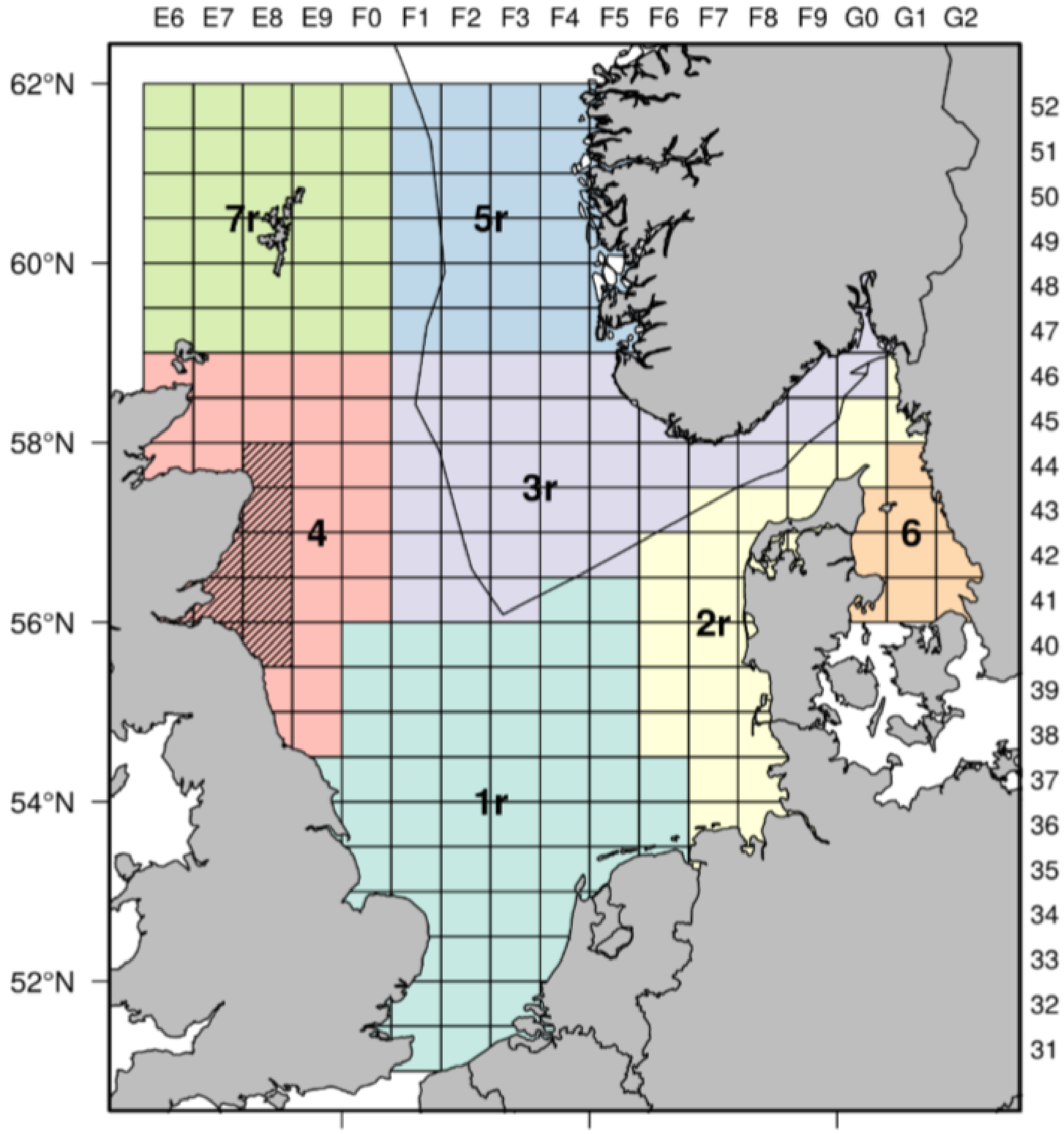

Figure 3.2 Sandeel in divisions 4.b–c, Sandeel Area 1r. Stock areas for the seven sandeel stocks. The border of the Norwegian Exclusive Economic Zone (EEZ) is also shown. The closed part of Sandeel Area 4 is shown with hatched markings.

3.37 For sandeel in SA1r corresponding to the southern North Sea, the spawning-stock biomass (SSB) was below B_{lim} and B_{pa} = MSY $B_{escapement}$ in 2019 and at the beginning of 2020 (Figure 3.3), indicating potentially impaired recruitment (Table 3.1)

3.38 In England, Natural England and the Joint Nature Conservation Committee (JNCC) are inshore and offshore statutory nature conservation bodies respectively and who advise authorities when fisheries may be having an impact on the feature of a marine protected area (MPA). Their statutory roles concerning fisheries are covered in more detail in Section 4.

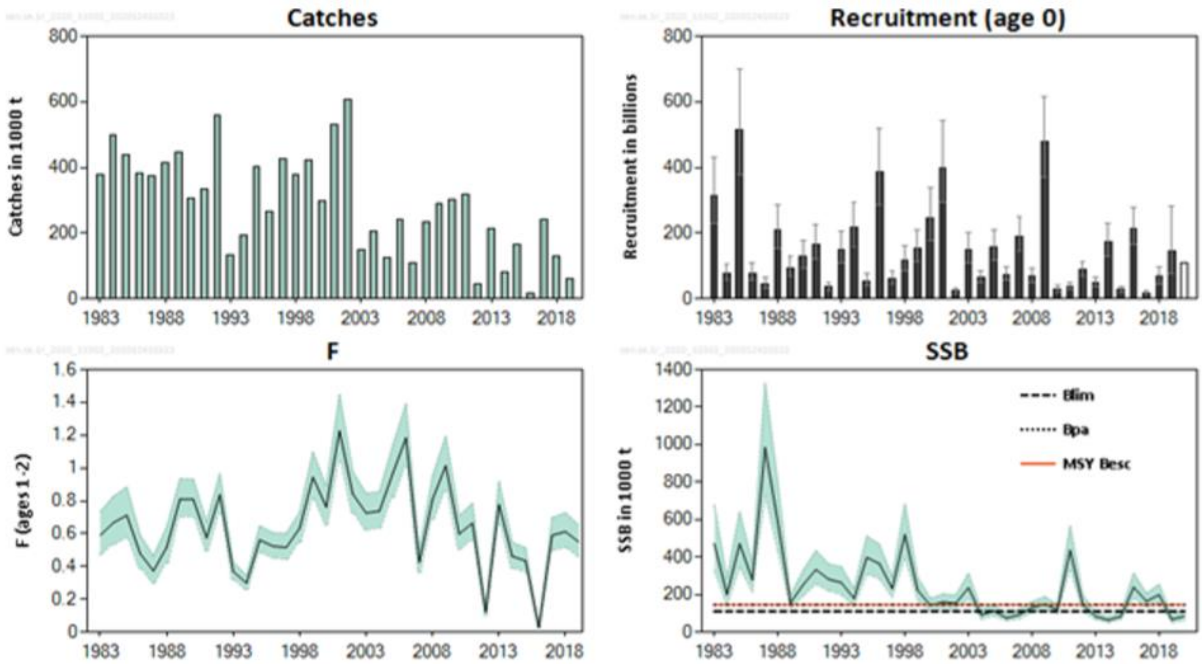

Figure 3.3 ICES Advice 2020 Sandeel in divisions 4.b-c, Sandeel Area 1r. Historical development of the stock from the summary of the stock assessment, with 90% confidence intervals. Assumed values are not shaded[7].

Table 3.1 ICES Advice 2020 Sandeel in divisions 4.b–c, Sandeel Area 1r. State of the stock and fishery relative to reference points.

		Fishing pressure				Stock size			
		2017	2018	2019			2018	2019	2020
Maximum sustainable yield	F_{MSY}	?	?	? Undefined		MSY $B_{escapement}$	✔	✖	✖ Below escapement
Precautionary approach	F_{pa},F_{lim}	?	?	? Undefined		B_{pa},B_{lim}	✔	✖	✖ Reduced reproductive capacity
Management plan	F_{MGT}	–	–	– Not applicable		B_{MGT}	–	–	– Not applicable

Summary

- ICES is the sole scientific advisor for North Sea shared and/or international stocks that come under the CFP, and CFP/Norwegian responsibilities
- For sandeel, the biomass can fluctuate wildly between years due to variable recruitment and a very short lifecycle. The ICES precautionary approach implies that a minimum stock size, Bescapement, should remain in the sea every year after fishing.
- Sandeel catches in EU waters are managed through seven area TACs which are set at the beginning of every year according to an escapement strategy. For Area 1r, corresponding to the southern North Sea, SSB was below Blim and Bpa = MSY Bescapement in 2019 and 2020, indicating potentially impaired recruitment.

[7] http://ices.dk/sites/pub/Publication%20Reports/Advice/2020/2020/san.sa.1r.pdf

Relationships between sandeel biomass and kittiwake at FFC SPA

3.39 The Applicant carried out statistical modelling to look at relationships between changes in sandeel spawning stock biomass (SSB) in the stock management area SA1 and the kittiwake population at FFC SPA (DMP Stats, 2020; Annex 1). Based upon advice from Natural England following the workshop on 11 August these followed the approach of Carroll *et al*. (2017). These results should be interpreted with caution as there are a number of major necessary assumptions and approximations underpinning these results (see Annex 1).

3.40 Rudimentary calculations were conducted based on Carroll *et al*. (2017) and the most recent SA1 stock assessments, providing estimates of the increases in chick numbers from increases in productivity (via probability of fledging). This productivity increase is expressed as a function of increased sandeel SSB and an implied decrease in fishing mortality (F).

3.41 Naïve calculations were conducted with approximated parameter uncertainty based on Carroll *et al*. (2017), providing estimated changes in chick numbers. These estimated approximately 175 to 237 additional chicks for an increase of 2% in SA1 sandeel SSB, equivalent to a 0.5% increase in kittiwake productivity or decrease of 4% in fishing mortality in the preceding year.

3.42 A series of Population Viability Analysis (PVA) style simulations were further run to estimate the effects of SSB changes on the population structure of the FFC SPA kittiwakes, in particular adult numbers, assuming a range of reduced mean fishing mortalities.

3.43 The smallest reduction in fishing mortality (<4% of 2018 levels) considered within these PVAs resulted in a median of 190 additional adults after five years, with 147 additional adults projected at the 2.5th percentile of simulations i.e. a nominal 95% lower confidence bound.

3.44 Sandeel SSB is hugely variable, driven by large variability in recruitment year-to-year, which in turn can be influenced by several environmental factors including Sea Surface Temperature (SST) and changes in local hydrodynamics. This source of natural variability far exceeds other sources of variance in the explorations here (see Figure 3.3), rendering many of the speculative changes to fishing mortality relatively insignificant, and very unreliable, in terms of increasing adult numbers.

The outputs suggest that, because of the large inter-annual variability in sandeel recruitment combined with short lifecycle, management of the fishery is not scalable to the compensation levels required for the Applicant (a minimum of 73 kittiwake). Even at a larger scale, it is far from certain that any fisheries management would have a sustainable benefit to sandeel stocks as seen in the north-western North Sea sandeel closure. Were it deemed necessary from a wider nature conservation perspective, then a government-led ecosystem-based approach could be employed to consider impacts, and hence potential benefits through management, to multiple protected predators of sandeel.

Summary
• Models based on Carroll *et al*. (2017) and the most recent SA1 stock assessments show that a 4% reduction in 2018 fishing mortality resulted in a median of 190 additional adults after five years, with 147 additional adults projected at a nominal 95% lower confidence bound. • <u>These results should be interpreted with caution as there are a number of major necessary assumptions and approximations underpinning these results</u> • Sandeel SSB is hugely variable, driven by large variability in recruitment year-to-year and a short lifecycle. This source of natural variability far exceeds other sources of variance in the explorations here, rendering many of the speculative changes to fishing mortality relatively insignificant, and very unreliable, in terms of increasing adult numbers. • Management of the sandeel fishery to increase sandeel SSB is not scalable to the compensation levels required for the Applicant (a minimum of 73 kittiwake). Even at a larger scale, it is uncertain that any fisheries management would have a lasting benefit to sandeel stocks and hence increase availability to kittiwake.

Overview of Evidence Gaps

3.45 The aim of this section is to provide a summary evaluation of the available information supporting the compensation proposals to assist the interpretation of the evidence base. Discussion with stakeholders around the importance and relevance of the identified limitations in the evidence base is ongoing.

3.46 Notwithstanding the reported correlations (see Section 3.31) between fishing mortality and trends in sandeel biomass, the exact nature and strength of these correlations (and how they might relate to trends in predator populations) remain difficult to describe or predict. This is due to the complex inter-relationships among the fishery, sandeels and seabirds, a paucity of high-quality data on ecosystem function (including relationships among primary and secondary production, prey and predators) and the relevance of environmental conditions before and after a fishery closure, which are likely to be critically important (Daunt *et al*., 2007).

3.47 The significant relationship between sea surface temperature and sandeel spawning stock biomass (SSB), with higher SSB associated with lower temperatures (Carroll *et al*., 2017), for example, is likely to increasingly (as the climate changes) complicate understanding. This in terms of the implications for sandeel, their prey and fish, as the dominant source of predation mortality on sandeels (MacDonald, 2019).

3.48 Further, site-attached populations of sandeel vary markedly in density according to local productivity and mortality processes (Wright *et al*., 2019). Given this, and the need for monitoring and research across the trophic levels, the knowledge is not available to predict, quantify, separate or accurately match management actions to reported trends that may occur as a result of changes in climate as well as anthropogenic uses. Such are the complexities of marine ecosystems, it could be that no apparent variation in trends masks a significant positive effect on sandeel recruitment (MacDonald *et al*., 2019).

3.49 At the higher trophic levels, more knowledge is also needed to explain the precise mechanisms linking kittiwake breeding success to variations in sandeel abundance and fishing activity (Daunt *et al*., 2007), or where these mechanisms are limited for other predatory seabird species.

3.50 The methods applied to estimate trends in sandeel biomass (i.e. stock abundance assessments) have known limitations. Greenstreet *et al*. (2006) found that different survey methods (acoustic, demersal trawl, and nocturnal grab survey) which assess different components of the sandeel population provide inconsistent estimates, such that it was not possible to determine whether observed sandeel population biomass increases were related to the closure of a Scottish sandeel fishery. The International Council for the Exploration of the Sea (ICES) has referred to the difficulties evaluating changes in sandeel abundance due to the lack of a single reliable sampling method (ICES, 2016).

3.51 In addition to extrinsic factors, such as fisheries and climate change, kittiwake population size is influenced (as well as by other factors) by juvenile and immature survival rates, productivity and age at recruitment. The Offshore Wind Strategic Monitoring Research Forum (OWSMRF) hosted a workshop in February 2020 to identify research opportunities in relation to kittiwake population dynamics which had been identified by nature conservation stakeholders (JNCC, NE, Scottish Natural Heritage (SNH), MSS, RSPB) as a key uncertainty relating to UK windfarm consent. JNCC organised a workshop that aimed to identify research opportunities to improve understanding of kittiwake population dynamics and drivers of population change, thereby improving our ability to predict population response to novel impacts. The need to improve understanding of the wider context to reduce uncertainties in population viability analyses modelling and clarify drivers of population change were cited by the JNCC as core objectives to address gaps in current understanding (Ruffino *et al*., 2020).

Summary of findings for Part 1

The following key conclusions are drawn from the evidence review presented above:

- Sandeel are highly important prey species for kittiwake and can comprise up to 60% of the kittiwake diet on the east coast of England where FFC SPA is located;
- The sandeel fishery has been in recent years the largest single-species fishery in the North Sea and the sandeel stock biomass has declined often to a point that is below precautionary stock reference points;
- There is a temporal and spatial overlap between breeding kittiwake and key sandeel fisheries which can exacerbate impacts of fishing during the sensitive breeding season;
- Accessibility of sandeel to kittiwake during the important breeding season is influenced by the fishery, but also many environmental factors relating to recruitment of sandeel;
- Sandeel biomass and availability are generally considered to have a strong influence on kittiwake survival and breeding success;
- There are evidence gaps in terms of kittiwake diet and regional and temporal patterns of kittiwake prey types and quality in the UK. It is necessary to better understand how kittiwakes respond to spatial and temporal variation in food availability, in order to predict how these populations might respond to commercial fisheries management and climate change.
- The management of prey resource (sandeel) could improve kittiwake productivity although evidence suggests that the relationship between the fishery, sandeels and seabirds is complex and also influenced by environmental factors;
- Environmental conditions are highly important for determining sandeel recruitment, biomass and ultimately prey availability and these are being impacted by warming seas;

- In order to increase sandeel availability to kittiwake, an ecosystem-based approach to fisheries management is likely to be highly important due to complex trophic interactions and potential for top-down control.
- A number of evidence gaps currently exist (relevant to sandeel and kittiwake populations) which could make it difficult to predict, quantify or accurately match management actions to reported trends.

4. Part 2 – Delivery mechanisms

Introduction to Part 2

4.1 In Part 1, the evidence for increasing kittiwake productivity through increased prey availability and specifically, the availability of sandeel was reviewed. Though sandeel SSB has been linked to fishing mortality in the North Sea, the situation is complex and sandeel SSB is hugely variable, driven by large variability in recruitment year-to-year. This indicates that any reduction in fishing mortality with the ultimate goal of a lasting benefit to kittiwake cannot be scaled down due to large natural variance in stock recruitment and hence, fishing mortality.

4.2 In this section, consideration is given to potential delivery mechanisms for enhancing prey availability and the feasibility of such measures. This section of this report considers the implementation requirements of increasing prey availability as compensation for kittiwake mortality. The discussion is set with the relevant legal and policy context and the requirements set out in European Union (EU) guidance for the development of compensation measures. Possible compensation mechanisms within these categories are assessed for their technical, legal and political feasibility.

4.3 Part 2 is based upon a report produced for the Applicant by Howell Marine Consulting and was presented to NE, Marine Management Organisation (MMO) and the Department for Environment, Food and Rural Affairs (Defra) at a workshop on 11 August 2020. Following this workshop further evidence gathering was undertaken and relevant information has been added where appropriate.

Developing compensation options

Overview

4.4 In 2016, Defra undertook a review of the effectiveness of Natura 2000 sites compensation measures in England[8]. Although this was focused mainly on replacing habitat, rather than compensating for a loss in species abundance, several conclusions in this report are useful in informing this work, most notably:

- Each compensation scheme was influenced by a unique set of environmental and practical considerations and it is not possible to use any one case study as a model for future schemes.
- Ratios of compensation to loss above 1:1 reflect issues of uncertainty, and anticipated delays in the timescales which compensation habitat takes to develop replacement functionality.
- Objectives for compensation sites are highly case-specific and are not necessarily directly transferable to new projects.

[8] Defra, "Review of the Effectiveness of Natura 2000 Sites Compensation Measures in England", 2016

- In the majority of cases there has been a lag between the loss of Natura 2000 habitat and the point where compensation measures have become functionally effective.
- Inter-seasonal variation in waterbird numbers means that it is extremely difficult to disentangle issues arising from habitat loss and replacement from natural variation.
- There is considerable scope to improve consistency and transparency in advice and decision-making. This largely involves the need for a clear audit trail of the rationale for particular decisions, when and why they were taken.
- The case of compensation for Arcow Quarry highlights the risks to the integrity of the Natura 2000 network where compensation sites have not been formally designated[9].
- Where used, 'Regulators Groups' have proven to be an excellent way of ensuring ongoing dialogue between regulators and developers and establishing a process to track progress and sign off key stages. Standardised implementation of such an approach might help to avoid some of the historic problems identified in the report.
- Although there is ample guidance on how to create certain habitats, there is no clear distinction between general environmental improvement and the specific needs of compensatory habitat provision. A comprehensive yet simple report, setting out the relevant stages in objective setting, site selection and design, monitoring and reporting, could help to improve engagement with developers and to avoid confusion.

4.5 EU guidance[10] sets out a range of options for developing compensation measures found in current practice in the EU under the Habitats Directive:

- species reintroduction;
- species recovery and reinforcement, including reinforcement of prey species;
- land purchase;
- rights acquisition;
- reserve creation (including strong restrictions in land use);
- incentives for certain economic activities that sustain key ecological functions;
- reduction in (other) threats, usually to species, either through action on a single source or through co-ordinated action on all threat factors (e.g. factors stemming from space-crowded effects).

4.6 UK experience of compensation for marine impacts has been limited to coastal impacts, focused on intertidal areas, water birds and migratory fish. It is still the case that no substantive consideration has been given to compensatory measures in relation to seabirds or marine mammals. Some measures may be relevant as compensatory measures for offshore wind projects, for example reduction of impacts to nesting/roosting habitat for some seabirds through the creation of alternative sites[11]. These measures have been reviewed in Annex 2 (Kittiwake Artificial Nest Provisioning: Ecological Evidence) of the Kittiwake Compensation Plan (Appendix 2 of Applicant's Response).

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[9] Compensation land was owned by the developer and managed under a tenancy agreement by a third party. The former tenants have since purchased the land and should now be responsible for its management, but at the time of the report the mechanisms for securing appropriate management (s105 agreement and Higher-Level Stewardship Agreement) were not satisfactory.
[10] https://ec.europa.eu/environment/nature/natura2000/management/docs/art6/EN_art_6_guide_jun_2019.pdf
[11] ABPmer, (2020). UK Offshore Wind Expansion, Meeting the challenges of Article 6(4) of the Habitats Directive, ABPmer White Paper, January 2020.

4.7 When looking at impacts on species that are causing increased mortality, such as those under consideration here, it is reasonable that two different approaches could be taken. The first is to decrease mortality in the rest of the population and the second is to increase productivity. Each approach, if successful, would have the net effect of increasing population numbers and offsetting any impact. Set out below are broad categories of measure that could fit under each approach, in line with current thinking for the Applicant and work recently undertaken on options for compensating impacts on seabirds due to offshore wind farms[12].

- Decrease mortality
  - Predator control;
  - Reduce or remove pressure from collision risk;
  - Reduce or remove pressure from fisheries by-catch.
- Increase productivity
  - Reduce or remove pressures that increase mortality for sea bird prey resources;
  - Reduce or remove pressure on spawning grounds thereby increasing productivity of sea bird prey resources;
  - Artificial nesting.

4.8 For this report, the focus is on increasing productivity by reducing or removing pressures that increase mortality on sea bird prey resources. For this option, ABPmer note that "The removal/reduction of pressure on seabird prey species could provide benefit to seabirds but is likely to be difficult to demonstrate cause and effect, affecting confidence in the effectiveness of the measure." The conclusion on the matter of demonstrating cause and effect is the subject of Part 1.

4.9 In assessing different options, the following criteria were used. Each option is risk rated (red, amber, green) in line with the perceived confidence associated with the delivery of each criteria.

- Can a scientifically robust explanation be put together that shows success could be possible?
- Should the measure be in place for existing site management?
- Is the measure technically feasible?
  - Is it possible to practically implement the measure?
  - Will the measure be effective in meeting stated aims?
- Is the measure legally feasible?
  - Does the legal framework exist to support the measure?
  - Is there past legal precedent to support the measure?
- Is the measure politically feasible?
  - Is there political appetite to support the measure?

[12] ABPmer, (2020). UK Offshore Wind Expansion, Meeting the challenges of Article 6(4) of the Habitats Directive, ABPmer White Paper, January 2020.

- Does the current political climate make delivery of the measure harder or easier?

4.10 Where appropriate, commentary has also been made on the time that it would take to deliver a measure as well as potential financial costs. Following assessment of all options, it was noted that the first two criteria were consistently rated red or amber, mainly due to significant uncertainty. As such a discussion of these criteria in general has been brought forward to avoid duplication.

Additionality

4.11 As mentioned previously, EC guidance[13] states that compensatory measures should be additional to the actions that are normal practice under the Habitats or Birds Directives, or obligations laid down in EU law. For example, the implementation of conservation measures under Article 6(1), or the proposal/designation of a new area already inventoried as being of community importance, constitute 'normal' measures for a Member State. Thus, compensatory measures should be distinct from the normal/standard measures required for the designation, protection and management of Natura 2000 sites. The reason for this is to ensure that Statutory Nature Conservation Bodies (SNCBs) act in a proportionate way in line with the principles of Better Regulation and do not put their responsibilities for site management onto a third party through compensation.

4.12 The site improvement plan for the Flamborough and Filey Coast SPA [14] sets out that the target for kittiwakes is to restore the population above 83,700 breeding pairs from 51,535 pairs in 2017 (an increase of 62%). It also sets out that the top priority for the site is to investigate the cause of decline in the kittiwake population, which is said to be "*probably due to reductions in sand eel abundance and changes to sea temperature*". Work was planned from 2015 – 2020 on this but it is not clear what the work comprised or whether this has been delivered yet.

4.13 Since 2015, Natural England have considered that prey availability is most probably the most significant issue associated with the decline in kittiwakes and that measures to increase prey availability could be the most important priority in restoring the kittiwake population as a measure for the management of the site. However, the Flamborough Head European Marine Site management plan[15] (consisting of Flamborough Head SAC and Flamborough and FIley Coast SPA) sets out that "international commercial fisheries, are not within the powers of the Relevant Authorities to manage", the relevant authorities including the MMO and Natural England. As set out in the section on managing fisheries in MPAs below, the powers of the MMO and Natural England with regards to fisheries only extend to 12 nm. However, since this point JNCC have produced joint guidance with the MMO on the revised approach to managing fisheries in MPAs, including those offshore which sets out the mechanism for doing this.

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[13] EU Commission "Managing Natura 2000 sites the provisions of Article 6 of the Habitats Directive", 2018 update.
[14] http://publications.naturalengland.org.uk/publication/6404364100960256
[15] Flamborough Head European Marine Site Management Scheme 2016-2021

4.14 Any compensation measure taken by the Applicant, in this matter will need to be carefully articulated to demonstrate additionality. If the number of kittiwakes that are deemed to be compensated for is set at, for example 700 (350 pairs), then this would account for an increase in 1% of the population that is required to be delivered by existing management measures. Setting out how this 1% increase is to be delivered outside of existing or planned management may be a challenge, not least because existing management measures have not yet been specified.

4.15 The reality is that when a site is newly designated, compensation measures may be the same as management measures but should be seen as being in addition to them. For example, if a management measure for restoring a site's conservation objective for a particular habitat is to recreate 10 km^2 of that habitat, it would be unreasonable to expect that 1 km^2 was delivered within the original amount as compensation. That 1 km^2 would need to be delivered additionally so the total amount delivered was 11 km^2. In this instance, as there is a clear priority to deliver a management measure to significantly improve the kittiwake population, any compensation measure should ideally use the same mechanism as the SNCB has already determined is the most appropriate for the site. In this case it is important for the SNCB to determine for themselves what the appropriate management measure is to inform understanding of what a potential compensation mechanism for the same purpose should be.

4.16 As a minimum, any approach should reinforce the close working required with SNCBs through Defra guidance, as the management measures for the site and the required compensation measures for the Applicant are, at the very least, closely aligned.

Compensation options

Overview

4.17 The core aim of the compensation options that are examined in this paper is to increase the sandeel stock in SA1 within UK waters, although they are broadly applicable to sprat and herring as well. Though sandeel is the most important prey species of kittiwake during the breeding season at FFC SPA (Part 1), the barriers are similar for the other main forage fish prey of kittiwake, including herring and sprat.

4.18 As already discussed in Section 3, there is considerable natural interannual variation in the sandeel stock in the North Sea which is overlaid on a declining trend due to climate change[16]. Reducing fishing mortality has the potential to increase sandeel stock biomass. Denmark is the main EU fishing nation for sandeel. In 2020 Danish quota was set at 215,863 metric tons, nearly double that set in 2019 (115,886 mt) with the UK granted almost 5,000t, and Sweden almost 8,000t. This fishery is largely run as a collaborative venture between the Danish Fishermen Producers Organization (DFPO) and the Danish Pelagic Producers Organization (DPPO). 2020's quota is worth an estimated DKK 417m, or £51 million, based on 2019 prices.

Fisheries management

Fisheries policy

4.19 Fisheries in the UK and the EU are currently managed under the Common Fisheries Policy (CFP), although following EU Exit in December 2020, the UK will become an independent coastal state and will no longer be a formal part of the CFP. As negotiations continue, it is not yet clear the extent to which current access and quota arrangements will continue, which could range from a continuation of current practice to complete removal of all rights from EU vessels and redistribution of those rights to UK flagged vessels.

4.20 The UK will continue to be bound by the requirements of the UN Convention on the Law of the Sea (UNCLOS) and how this relates to the management of fisheries in any EU Exit outcome. This includes an obligation to co-operate with other coastal states on the management of shared stocks or stocks of associated species. In particular, coastal States have an obligation under UNCLOS to set an allowable catch and to grant other States Exclusive Economic Zone (EEZ) fisheries access if (and only if) they do not have the capacity to harvest the entire allowable catch themselves (Article 62(2)). It is entirely reasonable for a coastal state to set the total allowable catch (TAC) at the capacity of their domestic fleet.

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

4.21 The House of Lords Inquiry into Brexit: Fisheries[17] concluded that a new fisheries management regime within the UK will only be effective if there is a degree of alignment to, and co-operation with, neighbouring states. Such regional co-operation will necessitate co-ordinated objectives and similar management practices, without which the sustainability of shared stocks, such as sandeel, may be undermined. They stressed that the UK should not discard the positive elements of the CFP that successive Governments have worked hard to achieve, such as sustainability and regional co-operation.

4.22 They also stated that unilateral restriction on access to fishing in the UK EEZ would almost certainly lead to reciprocal restrictions being placed on UK vessels fishing in the EU EEZ. This would also have a profound effect both on the fishing industry in the EU and on the UK fleet that relies on fishing outside the UK EEZ. Some form of mutual access arrangements must therefore be negotiated.

4.23 Defra have stated[18] that given the heavy reliance of the EU fishing industry on UK waters and the importance of EU waters to the UK it is in both the interests of the EU and the UK to reach a mutually beneficial deal that works for the UK and the EU's fishing communities.

4.24 In summary[19]:

- The UK will be seeking to move away from the CFP principle of relative stability[20] towards a fairer and more scientific method for future Total Allowable Catch (TAC) shares as a condition of future access.
- The UK will continue to apply the principle of Maximum Sustainable Yield (MSY) when setting or agreeing TACs and will promote fishing within MSY ranges in line with international scientific advice on mixed fisheries. The UK will also continue to work towards ending fish discards, including through the development of new initiatives with industry and other interests.
- The UK will seek to agree a process with the EU for future annual negotiations on access and fishing opportunities, as well as an approach for continued cooperation on fisheries management and on longer term sustainable approaches.

4.25 The overarching domestic policy directing UK fisheries is the Government's 25 Year Environment Plan[21] which aims to seize what is described as a once in a lifetime chance to reform our agriculture and fisheries management, how we restore nature, and how we care for our land, our rivers and our seas. Specific commitments related to fisheries include:

- Implementing a sustainable fisheries policy as we leave the CFP;
- Ensuring that all fish stocks are recovered to and maintained at levels that can produce their maximum sustainable yield;
- Working with the devolved administrations as well as the UK fishing industry and other stakeholders to end wasteful discarding, putting in place the right incentives to ensure compliance, and collect data and use science in the policy decisions we make;

[17] http://www.parliament.uk/brexit-fisheries-inquiry
[18] http://www.parliament.uk/brexit-fisheries-inquiry
[19] Defra 2018 Innovative Technological Solutions for Sea Fisheries Control and Enforcement
[20] The principle of Relative Stability allocates a fixed share of fishing opportunities based on historical fishing patterns in 1973 - 1978
[21] https://www.gov.uk/government/publications/25-year-environment-plan

- Implementing science-based plans as part of our approach to managing fisheries sustainably and to recovering fish stocks to sustainable levels in the shortest time feasible;
- Upon leaving the EU, the Government will publish an annual statement on the state of fish stocks of interest to the UK; and
- Applying an ecosystem approach[22] to fisheries management that will account for, and seek to minimise, impacts on non-commercial species and the marine environment generally, including through technical conservation measures.

4.26 The Fisheries Bill is currently going through parliamentary process. After it comes into force, the UK Government and Devolved Authorities will have to produce a Joint Fisheries Statement that will provide more detailed policy context than that within the current 25 Year Environment Plan. Notwithstanding this, the Fisheries Bill does contain eight fisheries objectives which are:

- the sustainability objective,
- the precautionary objective,
- the ecosystem objective,
- the scientific evidence objective,
- the bycatch objective,
- the equal access objective,
- the national benefit objective, and
- the climate change objective.

4.27 These objectives give some guidance as to the importance of different factors guiding future fisheries management. It should be noted that the sustainability objective is the primary objective and sets out that:

1. Fish and aquaculture activities do not compromise environmental sustainability in either the short or the long term;
2. Subject to point (1), fishing fleets must:
   i. be managed to achieve economic, social and employment benefits and contribute to the availability of food supplies, and
   ii. have fishing capacity that is economically viable but does not overexploit marine stocks.

Fisheries control

4.28 Across member states, the CFP uses a mixture of input and output measures to control and manage fisheries sustainably and it is likely that these measures will broadly continue post EU Exit. Output measures include plans, catch limits, quotas, and gear control. Input measures include controlling which vessels can access different areas of the sea, limiting the length of time at sea or number of vessels in a fleet able to go out to sea at any one time; and regulating the gears and methods fishermen use.

[22] an ecosystem approach to fisheries strives to balance diverse societal objectives, by taking account of the knowledge and uncertainties about biotic, abiotic and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries

4.29 Output controls are mostly done through annual catch limits or TACs (Total Allowable Catches). The process for setting a TAC consists of scientific advice which is made up of national advice (in the UK from Cefas supported by Marine Scotland Science) and regional advice from ICES. This advice is then used in the Council of Ministers meeting every December (December Council) where TACs are then confirmed following political negotiation. TACs are then shared between EU countries in the form of national quotas based on the principle of relative stability which is a different allocation percentage per EU country that is fixed year on year. Multi-annual plans are in place as regionalised strategies to manage stocks on longer time frames and can include specific management objectives and measures.

4.30 TACs are designed to be set at the maximum sustainable yield for a population. This is a calculation of the harvesting yield which will result in at least 50% of a population still being viable at the end of a year, taking into account natural productivity and mortality (e.g. predation). While this calculation should take an ecosystem-based approach and account for linkages between prey species and quota species, in reality this is a very complex situation to understand and this is not often done.

4.31 Each Member State is responsible for allocating its quota share to its national fleet. In the UK, quota for each stock is split between devolved administrations according to the 2012 Concordat on Management Arrangements for Fishing Opportunities and Fishing Vessel Licensing [23]. It is then divided amongst the fleet via Fixed Quota Allocation (FQA) units. These are based on historic records and determine the proportions of quota for individuals or collective groups. In relation to buying quota, the Concordat Agreement in the UK governs the management of UK fish quotas. Rules have been developed pursuant to the Concordat concerning the methods by which relevant UK fish quotas are apportioned among UK fisheries administrations and administrative arrangements that will be operated on a UK basis.

4.32 In the UK managers also use technical measures and effort controls to manage both quota and non-quota stocks. The many kinds of technical measures include minimum landing or conservation sizes, specifications on design and use of fishing gear, and closed areas or seasons[24,25]. These measures aim to improve selectivity in fisheries and reduce ecosystem impacts, and for quota species they can be used as an additional management measure, for example, some gears are better at selecting out species for which fishers have no quota, and these can be regulated. Technical measures are often used as the main management tool for non-quota shellfish and can differ according to devolved, national and EU regulations.

4.33 Fishing effort controls can be used on certain stocks to limit fishing capacity and vessel usage. For example, limits to the number of days at sea apply to some vessels targeting the quota species Dover sole in the western Channel. In general, however, the UK has a rights-based management system rather than an effort-based one.

[23] https://www.gov.uk/government/publications/concordat-on-management-arrangements-for-fishing-quotas-and-licensing-in-the-uk
[24] https://www.gov.uk/government/publications/fishing-regulations-the-bluebook/section-e-technical-measures-for-the-conservation-of-fisheries-resources
[25] https://ec.europa.eu/fisheries/cfp/fishing_rules/technical_measures_en_105

4.34 Control and enforcement requirements for different fisheries management approaches are set out below:

- **Fisheries access** - This is one of the simplest requirements to understand. If a fisheries administration wants to put any type of management measure onto their fishery, they need to understand who is accessing that fishery, and to control that access. This requires some form of monitoring which can be based on the fishing vessel (e.g. vessel monitoring system (VMS), iVMS, Automatic Identification Aystem (AIS); on earth observation (e.g. Synthetic Aperture Radar); on land (landings data); or through other forms of surveillance (at-sea surveillance, aerial surveillance).
- **Rights-based management** is typically difficult to monitor and enforce but nevertheless is seen as being the most robust way to manage fisheries. In the UK system this is largely based around managing quota which is done through electronic logbooks, electronic landing data and electronic sales notes.
- **Effort based management** - Due to the limited effort-based management that exists in UK waters, any requirements around this area are themselves limited. The requirements that do exist, are largely met by a mixture of VMS and electronic logbooks which detail a vessel's location.

Spatial management

Overview

4.35 Work has already been undertaken for Ørsted by Howell Marine Consulting on managing the interaction between the fishing industry and offshore wind[26]. This work principally looked at the construction and operation of an offshore wind farm within an area that is both designated for offshore wind, and where the ancient common law rights that the public has to fish in tidal waters (referred to as common law fishery rights) apply. This interaction happens frequently and is often not one that developers can avoid as they have to develop in government mandated areas that have often been designated within existing fishing grounds.

4.36 It should be noted that the management approaches previously examined have been in the context of a future successful DCO application and deemed marine licence and were focused on managing the interaction between fishers and offshore wind during construction and operation, rather than in the context of compensatory measures under the Habitats Regulations. This is an important consideration as the measures were physically associated with an OWF site rather than further afield, as would be needed in the case of increasing prey availability. As such, measures such as closing the array to fishing would be unlikely to have any impact on populations of prey that live much further afield. Nevertheless, this previous work has shaped the understanding of some of the potential options in this report and there are some important conclusions to be taken from it, including:

[26] HMC "Managing Fisheries in Offshore Wind Farms" 2016

- It is accepted practice that when managing coexistence between the fishing and renewable energy industries, fishing liaison officers should follow non-statutory guidance set out by the Fishing Liaison with Offshore Wind and Wet Renewables Group (FLOWW).
  - The Applicant outlined their approach to co-existence with fishers within the Fisheries Coexistence and Liaison Plan.27 This sets out that as per the FLOWW (2014) and (2015) guidance, if co-existence is not possible, mitigation for disruption and displacement of fishing during construction is considered in the first instance with commercial compensation only being used as a last resort when there are significant residual impacts that cannot otherwise be mitigated.
  - The document makes clear that compensation should only be paid on the basis of factually accurate and justifiable claims. There is therefore an obligation upon affected fishers to provide evidence to corroborate any claims.
  - It should be noted that this guidance does not address compensatory measures under the Habitats Regulations. It also sets out that for the majority of matters, “it is for individual developers and the fishermen affected to reach a mutually agreeable position, using this guidance as a framework, during the project planning phase”. The majority of such approaches have been successful, however, in a minority of cases, reaching such a mutually agreeable position with a very diverse and numerous industry, and then maintaining that position throughout the construction, and potentially also through the operation, of a wind farm without having any statutory framework to fall back on can be challenging.
- Other than BEIS approved Safety Zones, there are no current statutory means being utilised for prohibiting fishermen from entering an area where a particular type of fishing is not compatible with the survey, preconstruction, construction and operation of an offshore installation (it should be noted that it may be possible for a statutory instrument to be put in place as a regulation from the future Fisheries Act, currently in the bill reading stage).
- From a legal perspective, it is important to understand that the current approach, one of balancing competing rights, is used as there are less enabling statutory powers offshore than there are onshore. For example, in order to compulsory acquire land onshore, the acquiring authority will rely upon enabling statutory powers. Those enabling powers are not currently available offshore, hence the need to balance competing rights.

4.37 Any spatial management measure must also consider the issue of displacement. As set out in a report for Natural England[28], unless managed, displaced fishing effort can impact on the marine environment, within and outside MPAs, including on the seabed and benthic communities, mobile species and commercial fish and shellfish stocks. The net effect will depend on the balance between improvements within MPAs, and increased levels of effort in the remaining areas. Displacement can result in fishing disturbance being more widely distributed, including to otherwise previously unfished areas, and can cause localised increases in intensity and impact.

[27] Fisheries Coexistence and Liaison Plan PINs Document Reference A8.10 APFP Regulation 5(2)(q) May 2018
[28] ABPmer, (2017). Displacement of Fishing Effort from Marine Protected Areas, ABPmer Report No. R.2790. Commissioned Reports, Number 241. York.

4.38 The effect of displacement on habitats and benthic communities depends on the sensitivity of the habitat where effort is displaced to, the gear type displaced, the level of fishing in the area prior to displacement and the relative change in fishing pressure compared to the baseline and to prevailing levels of natural disturbance. The net environmental outcome of protection of MPA features and impacts from displaced effort, for either site management or compensatory measures, is thus dependent on factors that vary on a case-by-case basis. If one is looking for an increase in abundance in a quota species both within and outside an MPA, then one must be sure that displacing fishing activity does not have a net zero effect on abundance.

4.39 In 2013, Defra introduced the Revised Approach[29], a structured approach for the assessment and management of fishing activities in European Marine Sites (EMS) and latterly, Marine Conservation Zones, to ensure compliance with Article 6 of the EU Habitats Directive and the Marine and Coastal Access Act 2009 (MCAA). The process for spatial management of fisheries in relation to marine protected areas is set out in Figure 4.1.

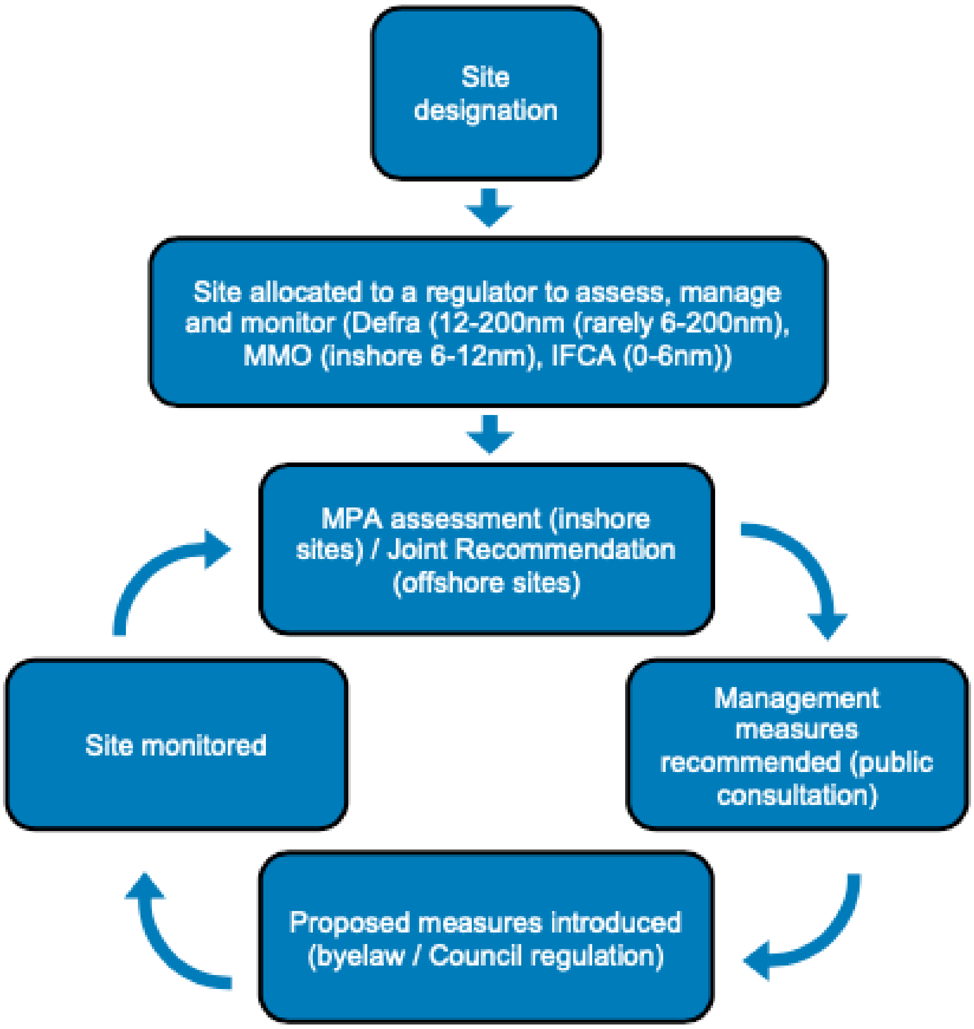

Figure 4.1 The process for spatial management of fisheries in relation to marine protected Areas

[29] Revised Approach to the management of Commercial Fisheries in European Marine Sites (EMS). Available at: https://www.gov.uk/government/publications/revised-approach-to-the-management-of-commercial-fisheries-in-european-marine-sites-overarching-policy-and-delivery

4.40 The options for spatial management include:

1. Fishing restriction order or byelaw.
2. European Commission delegated regulation establishing fisheries conservation measures for the protection of the marine environment.
3. Designation or extension of a new European marine site.

Fishing restriction order or byelaw

4.41 A fishing restriction order or byelaw can be implemented by the MMO or relevant IFCA under the Sea Fish (Conservation) Act 1967 as amended and the Marine and Coastal Access Act 2009. These can be put in place for marine environmental purposes[30] but only within 12 nm, as outside this spatial limit, fisheries are controlled through the CFP. The spatial extent of this measure limits its usefulness in this case as the prey in question live outside 12 nm, mainly on the Dogger Bank.

4.42 Following EU Exit, fisheries in all UK waters will be governed by the impending Fisheries Act which allows for the direct regulation of foreign fishing vessels in UK waters as well as provision to make regulations for a conservation purpose, which includes “the purpose of protecting the marine and aquatic environment from the effects of fishing or aquaculture, or of related activities”. As the Fisheries Act is still in the Bill stage, no such regulations have come into force, and the exact mechanism by which foreign vessels will be regulated is unknown. Therefore, no clear conclusion can be drawn at this time about the efficacy or applicability of any such regulation to the current situation.

4.43 In conclusion, the powers do not currently exist within UK domestic legislation to regulate fisheries for conservation purposes outside 12 nm. In the current legal framework, measures could be put in place inside 12 m in straightforward manner, and indeed this is a proven mechanism for managing impact on MPAs within 12 nm. However, such a measure would not be effective in increasing prey abundance, where the main fishing grounds are all offshore (see Figure 3.3) and would therefore not be technically feasible at the current moment in time.

Is the measure technically feasible?	(red)
Is the measure legally feasible?	(red)
Is the measure politically feasible?	(green)

[30] “marine environmental purposes” means the purposes—
(a) of conserving or enhancing the natural beauty or amenity of marine or coastal areas (including their geological or physiographical features) or of any features of archaeological or historic interest in such areas; or
(b) of conserving flora or fauna which are dependent on, or associated with, a marine or coastal environment.

European Commission delegated regulation

4.44 These are used for all EU fisheries measures outside 12 nm for all EU member states. Such delegated acts are legally binding acts that enable the Commission to supplement or amend non-essential parts of EU legislative acts, for example, in order to define detailed measures. The content of the act will need to be negotiated with relevant member states, at which time the Commission adopts the delegated act and if Parliament and Council have no objections, it enters into force. The majority of fisheries control measures associated with the Natura 2000 network are undertaken through this mechanism. The process by which such regulation is put in place is set out in JNCC's recent MPA Fisheries Management Toolkit[31] and copied in Figure 4.2.

[31] MPA Fisheries Management Toolkit, 2020. Developing a participatory approach to managing fishing activity in UK offshore Marine Protected Areas. JNCC, Natural England, National Federation of Fishermen's Organisation, Marine Management Organisation

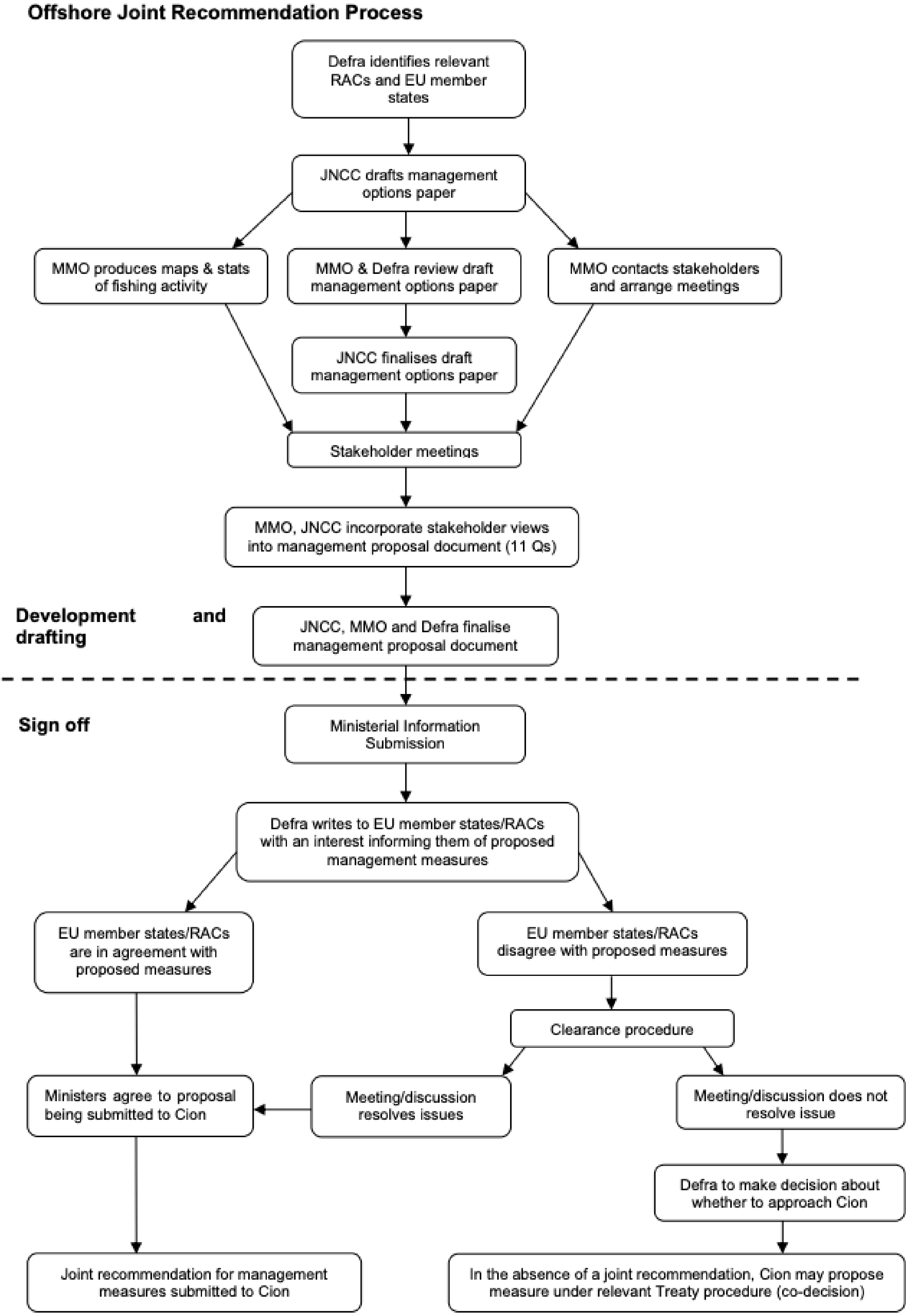

Figure 4.2 Offshore Joint Recommendation Process

4.45 As can be seen, this is a lengthy process that required substantial support from JNCC, MMO and Defra in order to proceed through the decision-making process at UK and EC levels and would be of interest in relation to management measures as well as compensatory measures.

4.46 This process is likely to take in excess of five years from start to finish, with uncertainty about the success of delivery due to the technical feasibility of the measure or the political appetite to take it through the European Commission. It should also be noted that following EU exit a new process for establishing management measures of shared stocks will need to be put in place based around prospective powers in the forthcoming Fisheries Act, as discussed.

Is the measure technically feasible?	
Is the measure legally feasible?	
Is the measure politically feasible?	

Designation or extension of a new Marine Protected Area

4.47 Designation or extension of a new MPA would still require additional fisheries management measures to be put in place as set out previously, either through the HRA process or through site management measures and would not technically achieve the desired aim on its own. The process for designation or extension of a new MPA is lengthy (>2-3 years) and requires significant consultation under either domestic or EU legislation.

4.48 An additional designation would add weight to any specific area that is considered important but as the main area for the sandeel fishery is Dogger Bank, which is already designated, and has restrictions in place, any additional weight may be insignificant.

Is the measure technically feasible?	
Is the measure legally feasible?	
Is the measure politically feasible?	

Quota management

4.49 Whereas spatial management measures have challenges in managing the impact of displacement such that the total biomass of sandeel caught does not actually reduce, due to increased take outside the spatially managed area, reducing the overall TAC would increase the total biomass of sandeel by directly reducing total fishing pressure in the North Sea. The process by which quota is set through the CFP has been discussed previously but in simple terms can be broken into two stages as set out in Figure 4.3.

4.50 The first part of this process consists of science advice given firstly by national science bodies (Cefas, supported by Marine Scotland Science, Natural England and JNCC) to ICES and then from ICES to December Council and can be thought of as science led and independent of political influence. The second part of this process consists of negotiations between member states and then management of allocated quota at a national level which is subject to political decision making albeit within the constraints of the relevant enabling legislation which sets certain boundaries with regards to good governance.

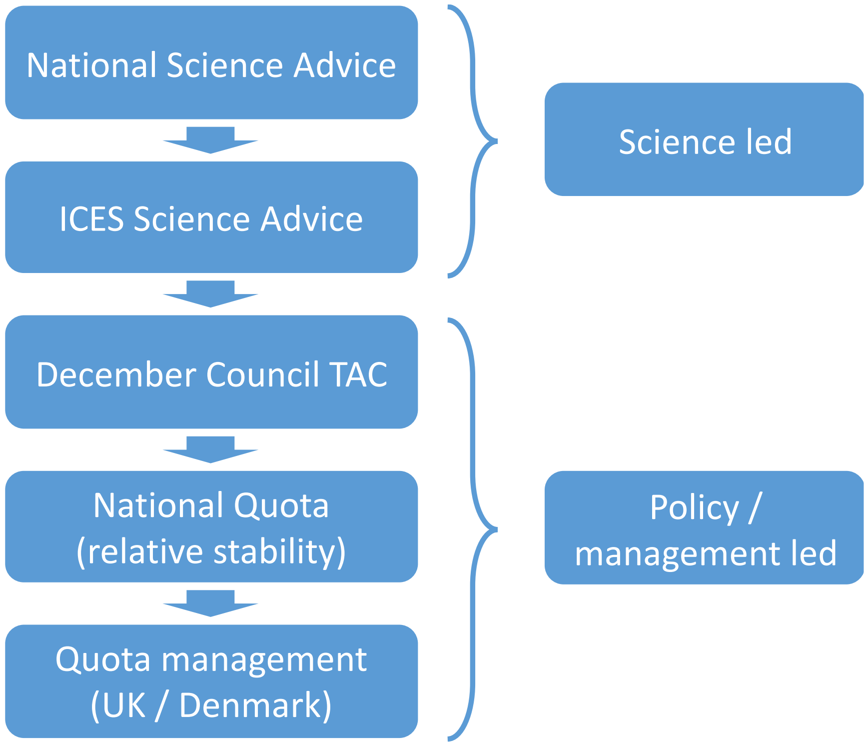

Figure 4.3 Process of setting quota through the CFP

Science led approach

4.51 A science-led approach is predicated upon close working with national science bodies (Cefas and Marine Scotland Science) and ICES, in collaboration with Natural England and JNCC, to improve the stock assessment model for sandeel such that it takes a full ecosystem-based approach to managing the sandeel stock. This would need to predict the sandeel biomass required to maintain the kittiwake population at an acceptable level and include this in a stock assessment model within the predation parameter. This could then feed into the overall calculation of MSY and effectively baseline a proportion of the sandeel biomass to maintain the kittiwake population.

4.52 This approach is undoubtedly much more complicated to carry out in practice and requires effective and complex ecosystem models, an understanding of the predator prey dynamics for different bird and sandeel populations and broad agreement within the fisheries science community to be successful.

4.53 This approach could potentially have a significant impact on restoring kittiwake populations within the SPA, in line with published management measures, much larger than the additional 1% increase in population that was assumed as a reasonable compensatory amount earlier in this paper.

4.54 A clear advantage of this approach is that it could permanently "ring fence" sandeel biomass for kittiwake consumption at the point of stock assessment and ICES advice. Sandeel Area 1r is the stock area adjacent to FFC SPA and relevant to foraging kittiwake. Since 1983, the total catch of sandeel in Area 1r has varied dramatically. From year to year, it is not uncommon for the TAC to double and, notwithstanding years when the fishery was shut apart from monitoring, the total catch has ranged from a minimum of 46,116 tonnes (2012) to a maximum of 610,123 tonnes (2002). Were rights acquisition via commercial agreement possible it could simply result in a change to quota advice the following year resulting in no net increase in the availability of sandeel prey to kittiwake.

4.55 It is likely that following EU exit, although the UK will no longer be part of the CFP, the stock assessment process will remain the same. With regards to the future, ICES is aware that the new UK Fisheries Bill will maintain ICES as the advisor on sandeel stocks, and ICES is in dialogue to create an MoU with the UK at the moment (M Dickey-Collas pers comm 18/08/2020). As such this option has the benefit of being both outside the political process, which will undoubtedly be challenging in the short term (1-3 years), and to have some stability of approach in the future. The main question around this approach is whether it can be secured within the relevant timeframes as it is likely to take between 3-5 years to have full traction. The cost of implementing this approach is largely centred on the research required to produce effective ecosystem models.

Is the measure technically feasible?	
Is the measure legally feasible?	
Is the measure politically feasible?	

Policy / management led approach

4.56 The policy / management led approach is predicated upon either influencing the decision making at December Council such that a TAC is set below the advice given by ICES to take into account the additional biomass needed, or that national agreement on the allocation of quota is made such that quota is withheld to the same end.

4.57 It would be very unusual for December Council to set TAC below the advice given by ICES, indeed in 2018 Fisheries ministers set 41% (45 of 110) of the TACs exceeding scientific advice and the remaining 51% were in line with scientific advice[32]. Any precautionary setting of TACs is always done on the basis of scientific advice rather than through unilateral decision making for other reasons. This is reasonable and is line with the objective to sustainably exploit a fishery for economic gain. Indeed, in the debate on the Fisheries Bill in 2018, George Eustice, current Defra Secretary of State but at the time Minister of State with responsibility for fisheries in Defra, stated in relation to this matter:

[32] https://www.pewtrusts.org/-/media/assets/2019/03/analysis-of-fisheries-council-agreement-on-fishing-opportunities-in-the-north-east-atlantic-for-2019.pdf

- *"sandeel stock is the most important access that Denmark receives from the UK, so we will have to consider it in the context of our annual fisheries exchanges";*
- *"The issue with a unilateral ban on the fishing of all sand eels in all UK waters is that we would be likely simply to displace that fishing activity, so there would be unsustainable catches of sand eels in waters outside the UK EEZ."; and*
- *"Given the way ICES advice is generated, based as it is on maximum sustainable yield, it tends not to place great weight on such considerations [an ecosystem based approach to stock assessment], but there is no reason why, in the context of future UK-EU bilateral negotiations, we should not seek to argue that there should be more restraint on species such as sand eels where they have an important role as a food source for birds."*

4.58 This is a matter that has had consideration at the highest levels of UK government and whilst broad support has been shown to resolve it, it is accepted that this cannot be done unilaterally at the current moment in time.

4.59 Withholding quota at a national level is possible, but would need strong cooperation from the managing authorities, which at the moment include the Danish and UK governments, but post EU Exit would be just the UK government. The MMO currently reserves the right to retain quota centrally for other purposes such as to clear certain overfishes or meet other policy objectives, for example when trialling new management approaches such as gear restrictions or remote electronic monitoring system. It is possible, though not certain, that the Danish Government may have a similar mechanism that could be accessed pre EU Exit that could be applied to the Danish sandeel fleet, or that the MMO may be able to withhold quota for the Danish sandeel fleet post EU exit.

4.60 Both of these options have significant uncertainty around them and would require robust cooperation from national governments and fisheries managing authorities, potentially in both Denmark and the UK, at a time when international negotiations are particularly sensitive. There would need to be careful articulation and understanding of why quota should be withheld above and beyond either the scientific advice or the TAC agreed at December Council which nominally sets the maximum sustainable yield and should be based upon an ecosystem approach. It is unlikely that any such approach could be brought to bear for December Council 2020, given the ongoing negotiations on EU Exit in general and the political sensitivities that surround fisheries in particular.

Is the measure technically feasible?	(amber)
Is the measure legally feasible?	(green)
Is the measure politically feasible?	(red)

Rights acquisition

4.61 The acquisition of rights to secure compensation is relatively common in terrestrial HRA, particularly with regard to agricultural practice or land rights. In this instance the acquisition of rights via commercial agreement would relate to buying a proportion of the fixed quota allocation (FQA) from one of the parties that owns it. This would most likely be the Danish Producer Organisation (PO) as the proportion owned by UK fisheries is so small (8000 t for 2020).

4.62 The EU CFP permits trading of quota between Member States and while this trading is administered by the relevant Fisheries Administrations, in practice the trading operates between POs and the equivalent organisations in other Member States. A similar situation applies within the UK where, after 1996, rules on quota trade between POs became more flexible and POs were allowed to make quota "gifts" (i.e. with no reciprocal transfer of quota, which had previously been required). This made it much easier for a vessel in one PO to lease quota from a vessel in another PO. Under the current FQA system, however, no permanent adjustments of vessels' FQAs are permitted[33].

4.63 However, the rules implementing the Concordat Agreement do not provide a mechanism for a non-fishing related organisation to purchase or lease the quota. It would be contrary to the objective of setting quota to ensure sustainability of fisheries for a non-fishing related organisation to then purchase that quota to achieve an alternative objective. Ørsted is of the view that it would not only contravene current fisheries policy but is unethical.

4.64 Denmark uses a system of Individual Transferable Quota (ITQ) in conjunction with measures to prevent the concentration of quota ownership and protect coastal fishermen. Quotas come in the form of tradable rights held by active fishermen and attached to vessels. These rights come in the form of a share of the national quota. They can be freely leased and swapped within Fishpool groups that facilitate transactions. Permanent trades of quotas can also be performed under the authorisation of the ministry. In order to keep quota ownership in fishermen' hands, only active fishermen can hold quota and any company holders must be two-thirds owned by fishermen. Additionally, any individual operator cannot hold more than 10% of the quota for demersal stocks. Under the current quota regulations, the purchase of quota by an offshore developer is not a viable proposal.

4.65 For reasons already discussed around removing quota allocation that is based upon science advice that has supposedly set the maximum sustainable yield for a fishery, it is unlikely that a third party who is not in the fishing industry would be permitted by a relevant Fisheries Administration to purchase quota for the purpose of setting it aside. In addition to this, the quota allocation for 2020 is worth £51 million, and even a small percentage contribution to this equates to a significant ongoing financial liability that would be prohibitive.

4.66 Furthermore, it is anticipated that fisheries organisations would, by default, position themselves against quota purchase as in effect this is a measure that results in a reduction in fishing opportunities. In this context it is important to note that the allocation of quota in many cases takes account of the track record of the fishery; a reduction in landings as a result of a developer buying quota would result in changes in the amount of quota that is allocated to a given fleet in the following years. Where quota is not fished, the excess may end up being allocated to another fleet segment or to another member state.

Is the measure technically feasible?	
Is the measure legally feasible?	
Is the measure politically feasible?	

[33] Cefas, 2018, An international review of fisheries management regimes

Commercial agreement

4.67 Commercial agreements have previously been used as a short-term arrangement during construction operations for offshore wind farms. The purpose would be to restrict *where* the fishers operate, though would not prevent unknown fishers fishing in an area. Various project companies within the Ørsted group have entered into commercial agreements with local fishers to compensate for not fishing within defined areas as a temporary measure. The areas are defined pursuant to rights granted by The Crown Estate in an Agreement for Lease or Lease granted to the developer. The commercial agreement is for specific periods of time during pre-construction and construction works. Ørsted has not, to date, entered into commercial agreements with fishers to restrict fishing activity during the operational lifetime of a windfarm in the UK. The Applicant can only negotiate commercial agreement to restrict the movement of fishers within their Agreement for Lease area because the Crown Estate has demised the Rights to the Applicant.

4.68 There have been several issues associated with these commercial agreements including:

- There are limited statutory means of ensuring compliance with any arrangements, which can lead to fishers asking for changed terms at very short notice.
- There have previously been few dispute resolution mechanisms employed, other than action through the High Court.
- For offshore wind developers, reaching a mutually agreeable position with a very diverse and numerous fishing industry, and then maintaining that position throughout the operation of a wind farm without having any statutory framework to fall back on is very challenging. Even though developers look to enter into binding commercial agreements, the lack of a statutory framework can cause difficulties.
- It is considered that to manage the interaction between fisheries and offshore wind construction and development the following is needed, much of which does not exist in state or regulation, but which is left to the High Court to deliberate on:

    1 A statutory mechanism for fairly and openly compensating fisheries vessels for any loss of earnings.
    2 A statutory mechanism for managing and enforcing the movement of fisheries vessels in an area held under a lease or agreement for lease from the Crown Estate for development of an offshore wind farm.
    3 A mechanism for dispute resolution.
    4 A means of ensuring that the regulatory process can be administered in a cost-effective way.

4.69 Ørsted have tried to find alternative means of dispute resolution if agreement cannot be reached or if the fisher breaches an existing agreement but the only action available is injunctive proceedings. The fishers are not incentivised to engage in alternative dispute resolution. Applying for an injunction is a costly and time-consuming process. It is also draconian as a breach of an injunction can result in committal proceedings. Ørsted has also investigated whether there are other statutory mechanisms available to safeguard a site from fishing vessels during pre-construction surveys and during construction and concluded after extensive engagement with stakeholders, including the MMO, BEIS and the MCA that there are no satisfactory statutory mechanisms available outside of territorial waters.

4.70 A commercial agreement could not prevent unknown fishers from operating within the array and it would also not prevent the reallocation of quota at a future date. If a producer organisation does not catch their quota allocation over a three-year period, then that quota would simply be reallocated. In addition to this, restricting fishing within the array would not preclude the fishers from finding alternative grounds in order to catch their quota.

4.71 Finally, the quota allocation for 2020 is worth £51 million, and even a small percentage contribution to this equates to a significant ongoing financial liability that would be prohibitive. For these reasons, this is not a preferred mechanism.

Is the measure technically feasible?	
Is the measure legally feasible?	
Is the measure politically feasible?	

Summary of findings for Part 2

4.72 None of the measures considered within this paper are simple to deliver as can be seen from Table 4.1, which presents an initial summary of the review undertaken in Part 2.

4.73 All have some measure of technical difficulty and most have some measure of political challenge associated with them. All measures, apart from a commercial agreement, would need significant support from Defra, MMO, JNCC, Natural England and in some cases the Danish Government, as well as significant engagement and interaction with the Danish sandeel fishing industry.

4.74 In addition to the challenges set out above, uncertainty remains over the scientific robustness of any measures associated with prey availability on the kittiwake population at the Flamborough and Filey Coast SPA. It would also be interesting to understand the progress that Natural England have made in exploring prey availability in relation to the management of the site as set out in the Site Improvement Plan. Any progress that has been made in this regard, or indeed any views that Natural England may have on the best approach to measures required for restoration of the kittiwake population in relation to site management would be pertinent to any potential compensatory measure.

Table 4.1 Summary of findings for measures considered

	Fishing restriction order / Byelaw	EC Delegated Regulation	Designation / Extension of new	Science led approach to quota	Policy / management led approach to	Rights acquisition	Commercial agreement
Is the measure technically feasible?							
Is the measure legally feasible?							
Is the measure politically feasible?							

Conclusions

4.75 Based upon this review of mechanisms, Ørsted advocate the need for a science-led and ecosystem-based assessment of predicted mortality to understand the predation rate needed to feed into the maximum sustainable yield calculation. Any commercial agreement with the DFPO and the DPPO, by way of example, would not serve any purpose until as a first step, an effective ecosystem model is deployed to "ring fence" any increase in sandeel for kittiwake consumption. This is pertinent to any North Sea forage fish prey of kittiwake. Thus, a government-led approach to sustainable management of the fishery seems the only feasible proposition for long-term measure addressing prey availability.

4.76 The current legal and political obstacles in place mean that the Applicant cannot secure or deliver prey availability as a compensation measure pursuant to Article 6(4). However, the Applicant can fund and deliver research to provide evidence to support a government-led process that would consider management of the sandeel fishery in order to increase the availability of prey to kittiwake.

5. Part 3 - Hornsea Three prey availability proposal

Science-led approach to quota allocation

5.1 Based upon a review of the ecological linkages between kittiwake and sandeel together with an assessment of available delivery mechanisms (Part 2), it was concluded that the most feasible means of delivering a sustainable increase in sandeel availability in the long-term is through a science-led approach to quota allocation (Section 4.75)This is predicated upon close working with national science bodies (Cefas and Marine Scotland Science) and ICES, in collaboration with MMO, Natural England and JNCC, to improve the stock assessment model for sandeel so that it takes a full ecosystem-based approach to managing the sandeel stock. Sandeel are the most important forage fish species in the North Sea and, in addition to kittiwake, are a key component in the diet of certain other seabirds (Sandwich tern, European shag, great skua, Atlantic puffin, common guillemot, razorbill, northern gannet), piscivorous fish (whiting, horse mackerel, grey gurnard, haddock, mackerel), and marine mammals (minke whale, harbour seal, and grey seal) (Engelhard *et al.*, 2014). Many of these species are afforded protection under the Habitats or Birds Directives[34] due to their conservation status.

5.2 Information about predation rates on forage fish can provide better estimates of natural mortality and are already being used to improve stock assessment. These can result in robust estimates of biological reference points that account for the direct removal of forage fish biomass, such as sandeel, by predators such as kittiwake. Furthermore, the establishment of forage fish in the middle of complex foodwebs and the interaction of forage fish populations by various top-down and bottom-up processes suggest that ecosystem-level impacts of forage food exploitation will only be fully appreciated by including estimates from models simulating a large part of the foodweb (Lassalle *et al*., 2014; Peck *et al*., 2014). Reference points estimated at the end of the process would aim to ensure that the predicted spawning stock biomass (SSB) dictated by a given TAC is sufficient to support predator consumption (Goss-Custard *et al* 2004; Furness 2006, 2007).

5.3 Any ecosystem-based model is required to predict the sandeel biomass required to maintain the kittiwake population, as it is critical to consider how trophic interactions between sandeel and other species would also vary. Such information will then feed into an overall calculation of MSY and effectively baseline a proportion of the sandeel biomass to maintain the protected kittiwake population. UK government and advisers may also want to consider modelling the degree to which sandeel is necessary to support other protected species, as otherwise any management measures in a highly connected foodweb may result in unintended effects (Peck *et al*., 2014).

Proposed way forward

5.4 This government-led, science-based approach assumes agreement from Defra, SNCBs, relevant authorities and the SoS with the conclusions that:

[34] https://www.gov.uk/government/publications/protected-marine-species

- the only feasible and sustainable way to deliver improved sandeel biomass and therefore increase the availability of sandeel as prey for kittiwake in the long term, both to meet MPA management objectives and to provide compensation, is to implement conservation measures through the statutory fisheries management regime, rather than any unilateral action; and
- such a measure is not legally securable as compensation in the short term, certainly not before EU Exit, and likely to be up to 24 to 36 months after this date.

5.5 It is proposed that any conservation measure that focuses on fisheries management to improve commercial fish stocks (i.e. stock assessment and quota allocation of sandeel), should be part of a wider, government-led initiative to meet national statutory and policy targets in relation to the restoration of kittiwakes and other protected species relying on forage fish arising from the UK MPA network (including, but not limited to FFC SPA) and the UK Marine Strategy.

5.6 The Guidance[35] is clear that any compensation measure put forward under Article 6(4) should be additional to the actions that are considered normal practice under the Habitats and Birds Directives or obligations laid down in EU law, including the standard measures required for designation, protection and management of Natura 2000 sites. The Applicant would submit at this stage that prey availability measures consisting of fisheries management fall into the normal practice under the Directives. However, further research may result in the identification of a specific measure that allows the standards within the Guidance to be upheld.

5.7 The law requires the Secretary of State to have a rational basis for finding that he has discharged his duty to secure that necessary compensation measures will be delivered. As explained in Section B, it is not possible currently for a single Project to secure or deliver an increase in prey availability as a stand alone compensation measure via fisheries management, including commercial agreement and rights acquisition. Natural England have recognised this in their comments on Norfolk Boreas In Principle Habitats Regulations Derogation, Provision of Evidence Appendix 1 Flamborough and Filey Coast SPA In Principle Compensation at Deadline 9 (EN010087 REP9-047):

> *"4.11. We recognise that [fisheries management] is not in Norfolk Boreas's gift to deliver alone, but it would likely require facilitation by the UK Government/the regulating authority. However, the benefits of this approach could be supportive of the wider offshore windfarm industry and help facilitate future progress towards 'net zero'."*

5.8 The Applicant therefore is not in a position at this stage to provide the rational basis required by the Secretary of State to conclude that increasing prey availability as a compensation measure can be secured or delivered.

[35] Managing Natura 2000 sites. The provisions of Article of the "Habitats" Directive 92/43/EEC 2018

5.9 In light of the above, this pathway to fisheries management should be led by UK Government and include Defra, Marine Scotland, Natural England, JNCC, NatureScot and MMO. The primary aim of this initiative will be to meet government targets for kittiwakes enshrined in MPA conservation objectives and the UK Marine Strategy. It will look to deliver a solid evidence base that will enable an ecosystem-based approach to the stock assessment of kittiwake prey species, and then use this evidence base to build regional scientific consensus on shared stocks (ICES) and to subsequently take measures to manage fisheries in UK waters appropriately. It would assume that the enabling legislative framework and the management tools required to take an ecosystem-based approach to quota allocation and stock management post EU Exit will be available. An alternative option could be for the UK to institute a domestic spatial management plan through new powers in the Fisheries Bill, such as that used in the Norwegian exclusive economic zone (within SA3), whereby subareas within actively fished grounds are closed to prevent stock depletion (ICES, 2017).

5.10 Based upon the evidence review in Part 1, there are key knowledge gaps that are necessary to understand what would be effective in terms of increasing sandeel availability to kittiwake and avoid unintended consequences. The Offshore Wind Strategic Monitoring Research Forum (OWSMRF) hosted a workshop in February 2020 to identify research opportunities in relation to kittiwake population dynamics which had been identified by nature conservation stakeholders (JNCC, NE, SNH, MSS, RSPB) as a key uncertainty relating to UK windfarm consent. Subject to being granted a DCO, the Applicant will fund and deliver a number of these identified research initiatives where they are relevant to understanding the relationship between kittiwake and prey species (as identified in Section 5.1) , in order to inform future NE and JNCC advice relating to their statutory nature conservation responsibilities for sustainable fisheries management and MPAs.

5.11 The Applicant is willing to make a legal commitment outside of the DCO to manage, fund and deliver the research projects identified. The Applicant's parent company has discussed and is pursuing a Memorandum of Understanding (MoU) with Defra subject to a positive DCO award. It is acknowledged however that an alternative form of legal agreement could be entered into with an alternative counterparty such as Natural England. A commitment to fund research would be flexible to the route chosen by UK government to manage the fishery and would also provide valuable information regardless in relation to understanding the status of kittiwake and what may change under different future climate scenarios.

Additionality

Any operational mechanism for delivering the conservation measures should focus not only on long-term benefit to kittiwake, but also in meeting key statutory targets for the management of kittiwakes which are owned by different government bodies within the Defra Group. These include the targets under the UK Marine Strategy and site-specific targets for the Flamborough and Filey Coast SPA (FFC SPA).

UK Marine Strategy	Target	Indicator	Threshold
	Widespread lack of breeding success in marine birds caused by human activities should occur in no more than three years in six.	Kittiwake breeding success.	a) In addition, annual breeding success of blacklegged kittiwakes should not be significantly different, statistically, from levels expected under prevailing climatic conditions (i.e. sea surface temperature). b) The UK target is met if, at a significant proportion of kittiwake colonies, breeding success was not significantly lower than the baseline in at least five years out of six. The baseline is different for each colony and varies between years. The baseline is the annual mean breeding success at a colony in a given year as predicted by the annual mean winter SST (measured during February and March) of the preceding year (i.e. SST-1). If breeding success is significantly lower than the baseline, it is considered not to be in line with prevailing climatic conditions.

FFC SPA	Assessed condition for kittiwake	Conservation objective
	Unfavourable declining (2015)	Ensure that the integrity of the site is maintained or restored as appropriate, and ensure that the site contributes to achieving the aims of the Wild Birds Directive, by maintaining or restoring; • The extent and distribution of the habitats of the qualifying features; • The structure and function of the habitats of the qualifying features; • The supporting processes on which the habitats of the qualifying features rely; • The population of each of the qualifying features, and; • The distribution of the qualifying features within the site.

5.12 There is a great focus on kittiwake restoration in Scotland as the large majority of SPAs with kittiwake as a designated feature are in Scotland. However, kittiwake restoration is still an important feature of both the FFC SPA and the UK Marine Strategy target on marine bird breeding success. To date, the majority of management measures related to kittiwake outside Scotland have been focused on site-based approaches. These have issues with delivering long-term improvements in the population as they cannot increase availability of prey which requires measures outside the site, as has been explored in the Applicant's consenting process.

5.13 In order to increase availability of sandeel sufficiently to benefit kittiwake as features of SPAs, the relevant authorities must take a wider ecosystem-based approach to meeting conservation objectives, which may sit outside site-based measures and across jurisdictions. The route for such a mechanism is already established through the Revised Approach36, a structured approach for assessment and management of fishing activities in EMS and latterly, Marine Conservation Zones, to ensure compliance with Article 6 of the EU Habitats Directive and the Marine and Coastal Access Act 2009 (MCAA). Whilst this has, up to now, had a focus on site-based impacts and measures, there was acknowledgment from NE and MMO in the 11 August workshop that this approach could be used, in conjunction with sustainability objectives within the forthcoming Fisheries Bill, as the basis for an ecosystem-based approach to fisheries management that explicitly considered the connectivity of commercial fish species on bird species designated under Annex 1.

5.14 Any conservation mechanism for kittiwake should be aligned with such broader, more complete management measures to restore the kittiwake population in the North Sea and in particular at the FFC SPA. This is important to ensure that maximum leverage is made of any management measure that may be in place (e.g. to potentially benefit other protected species that rely on forage fish) and also to ensure that any measure is not lost in the natural large interannual variability in recruitment of the prey population.

Prey availability proposal

5.15 Hornsea Three, or its parent company Ørsted Power UK Limited, will commit following Hornsea Three's award of a DCO to fund and deliver research to inform an ecosystem-based assessment and support inter-agency government decision-making. It is proposed that an inter-governmental task force could be formed led by Defra to help steer the work, review any outputs, and consider future proposals on this theme in order to add strategic value. It is envisaged that this will include relevant authorities and statutory bodies, as well as relevant academics. There would be value in including Scottish Government scientists who have worked on the Wee Bankie and Shetland sandeel closure as well as both kittiwake and fisheries specialists.

5.16 The Applicant has identified two research opportunities from the OWSMRF workshop that would significantly increase our understanding of kittiwake-prey interactions and the sustainability of these in the future (Ruffino *et al*., 2020):

[36] Revised Approach to the management of Commercial Fisheries in European Marine Sites (EMS). Available at: https://www.gov.uk/government/publications/revised-approach-to-the-management-of-commercial-fisheries-in-european-marine-sites-overarching-policy-and-delivery

- Kittiwake diets during the breeding season, and the relationship between prey availability and productivity. This project is a combination of desk-based and field studies to determine kittiwake dietary patterns on the English east coast during the breeding season and improve our understanding of the relationship between non-sandeel prey availability and productivity. This research will help build confidence in how kittiwake populations are responding to declines in sandeel availability and thus assess their resilience to additional mortality. This would also provide key evidence to inform conservation measures, such as how kittiwake populations might respond to changes in management of commercial fisheries.
- Assessing the current and future condition of alternative fish prey populations: a desk-based study. With this research, it is proposed to review the literature on forage fish species, specifically population status and trends, drivers of population dynamics, current fishing pressure and projected impacts of climate change on forage fish populations. This information will assist with identifying kittiwake colonies that are vulnerable to additional mortality and those that are likely to be more resilient to additional mortality, e.g. from OWF development, due to predicted availability of prey/forage fish species. Additionally, this will help assess which conservation management measures may be ineffective due to changes in forage fish populations.

5.17 It is essential to carry out such work as a precursor to inform what any conservation management measures might look like and allow evaluation of the effectiveness of any conservation-related management measures. What is clear from the sandeel management at Wee Bankie and Shetland (Greenstreet *et al*., 2010) and the recent work of Carroll *et al*. (2017) is that the relationship between kittiwake productivity and sandeel biomass is multi-faceted and regionally variable. This is predominately due to the wild variability in sandeel stock recruitment, but also due to the difference in foraging options available to kittiwake in different parts of the North Sea.

5.18 The Applicant remain committed to progressing this work for the benefit of the industry and therefore commit to fund and deliver the research outlined above. The purpose of the research is to inform a science led approach to quota allocation which may lead to Ørsted and other developers being able to deliver prey availability measures as a compensatory measure for future projects.

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Annex 1 - Modelled relationships between sandeel spawning stock biomass, fishing mortality, and FFC SPA black-legged kittiwake (DMP Stats 2020)

Effects of sand-eel fishing mortality reductions in SA1 on the FFC SPA Kittiwake population

1 Summary

- Work was commissioned to look at relationships between changes in sand-eel Spawning Stock Biomass (SSB) in the stock management area SA1 and the kittiwake population in the Flamborough and Filey Coast Special Protection Area (the FFC SPA).

- Rudimentary calculations were conducted based on Carroll *et al.* (2017) and the most recent SA1 stock assessments, providing estimates of the increases in chick numbers from increases in productivity (via probability of fledging). This productivity increase is expressed as a function of increased sand-eel SSB and an implied decrease in fishing mortality (*F*).

- Naïve calculations were conducted with approximated parameter uncertainty based on Carroll *et al.* (2017), providing estimated changes in chick numbers. These estimated approximately 175 to 237 additional chicks for an increase of 2% in SA1 sand-eel SSB, equivalent to a 0.5% increase in kittiwake productivity or decrease of 4% in fishing mortality in the preceding year.

- A series of Population Viability Analysis (PVA) style simulations were further run to estimate the effects of SSB changes on the population structure of the FFC SPA kittiwakes, in particular adult numbers, assuming a range of reduced mean fishing mortalities.

- The smallest reduction in fishing mortality (<4% of 2018 levels) considered within these PVAs resulted in a median of 190 additional adults after 5 years, with 147 additional adults projected at the 2.5th percentile of simulations i.e. a nominal 95% lower confidence bound.

- There are necessary assumptions and approximations underpinning these results, so should be treated tentatively. A number of these approximations can be eliminated with more thorough analysis and assumptions should generally be subjected to sensitivity analysis.

- Annual variability in the sand-eel SSB is very high, driven by recruitment variance, meaning uncertainty in stock size projections renders all sources of uncertainty relatively insignificant. Any future robust investigation into the influence of *F* on kittiwake populations should consider these stock dynamics and uncertainties in depth.

2 Contents

3 Overview

We outline here exploratory analyses looking at how potential reductions in the SA1 sand-eel fishing burden might impact the FFC SPA kittiwake population, through possible increases in productivity (increased probability of fledglings from eggs). The work was requested/conducted in a limited time-period (*pers. comm.* G. E. Johnson, Ørsted, 21/08/2020), such that important inputs are crudely approximated where unable to be obtained from primary sources.

Works done by Carroll *et al.* (2017) indicate that increases in the SSB of sand-eels are positively associated with the probability of successful fledging of a kittiwake's egg. Here we further consider that the SSB might be influenced by adjustments to the fishing mortality, thereby relatively increasing the numbers of kittiwake chicks within the FFC SPA.

The basic calculation process is straight forwards, but subject to many sources of uncertainty that must be addressed for a robust view. We begin by a naïve calculation, extend this to cover immediately estimable sources of uncertainty, provide caveats and describe what future works are required for robust results.

4 Scope of problem

The motivating question is quoted here (*pers. comm.* G. Johnson, Sept 2020):

> *"Of particular relevance in the current context might be Carrol et al. (2017), who present information on the productivity of kittiwakes at FFC SPA and the biomass of sandeel in SA1. Analyses of the univariate relationships in Carroll et al. (2017) would allow a series of steps to be made from the number of additional chicks required per annum by way of compensation, to the increase in chicks/pair needed at the existing FFC colony over and above the current productivity level, to the increase in sandeel SSB needed to deliver that increase in chicks/pair (from the relationship between productivity and SSB), and finally to the decrease in fishing mortality (F) needed to deliver that increase in SSB (from the relationship between SSB and F)."*

This is interpreted as a multi-step problem. In the first instance, what changes in successful fledging are associated with changes in SSB. Secondly, how changes in fishing mortality might drive this alteration of SSB. Thirdly by implication, how these relate to changes in adult numbers as the "compensation" indicated likely relates to adult mortalities.

The basic relationships between the SSB, *F* and chick numbers, along with uncertainties, are considered in the first instance. This is integrated into a PVA to provide effects on adult numbers, as well as avoid unreasonable assumptions of near instantaneous effects on the kittiwake population from sand-eel stock fluctuations.

5 Basic calculation process

Carroll *et al.* (2017) provide univariate relationships between the probability of successful fledging of kittiwake eggs, as a function of sand-eel SSB, or relatedly the level of fishing mortality. This allows simplistic direct calculation of changes in kittiwake populations as a function of changes in the sand-eel fishing mortality, with some knowledge of the FFC SPA population (Ørsted, 2019) and recent stock assessments for the SA1 sand-eels (ICES 2015, 2019).

Carroll *et al.* (2017) fitted a Generalized Linear Mixed Model (GLMM) to predict kittiwake breeding success from 1984 to 2014. Fixed effects included spawning/total biomass, recruitment, fishing mortality (at different lags) for sand-eels, all from an integrated stock assessment model in the SA1 area. Year is treated as random effect and model selection was conducted using Akaike Information Criterion (AIC). Two types of models were implemented, those with only one fixed effect, and one with multiple fixed effects. Attention here is restricted to single fixed effect models[1].

5.1 Relating SSB to F and to chick numbers

From Carroll *et al.* (2017) the FFC SPA kittiwake population is, in part, functionally related to the SSB of the SA1 sand-eels. Naïve calculations are immediately possible from published point estimates - under assumptions of the number of breeding pairs, each providing 2 eggs, a decrease of *X*% in the fishing mortality corresponds to an increase in *Y* fledged chicks. This is clearly a simplistic view and ignores substantive uncertainty at the very least. Nonetheless, an example calculation follows which illustrates the functional underpinnings of the more comprehensive calculations of sections 5.3 & 6.

Breeding success here will refer to the proportion/probability of eggs resulting in fledged chicks. Carroll *et al.* (2017) adopt the Carroll *et al.* (2015) method of estimating breeding success. Denote success *S*, as the number of fledged chicks. Carroll *et al.* (2015, 2017) obtain the total number of eggs by assuming 2 eggs per nest (total number of nests *N*) - denoting breeding success as θ:

$$\theta = \frac{S}{2N}$$

As a probability of success, θ lends itself to modelling via logistic regression. The GLMM applied in Carroll *et al.* (2017) similarly models θ along with random effects, although these are not sufficiently described to use in simulations here. The univariate models are simply:

[1] *Pers. comm.* G. Johnson. The models are not readily accessible, so only simple relationships are feasible.

$$logit(\theta) = \ln\left[\frac{\theta}{1-\theta}\right] = \beta_0 + \beta_1 X_1$$

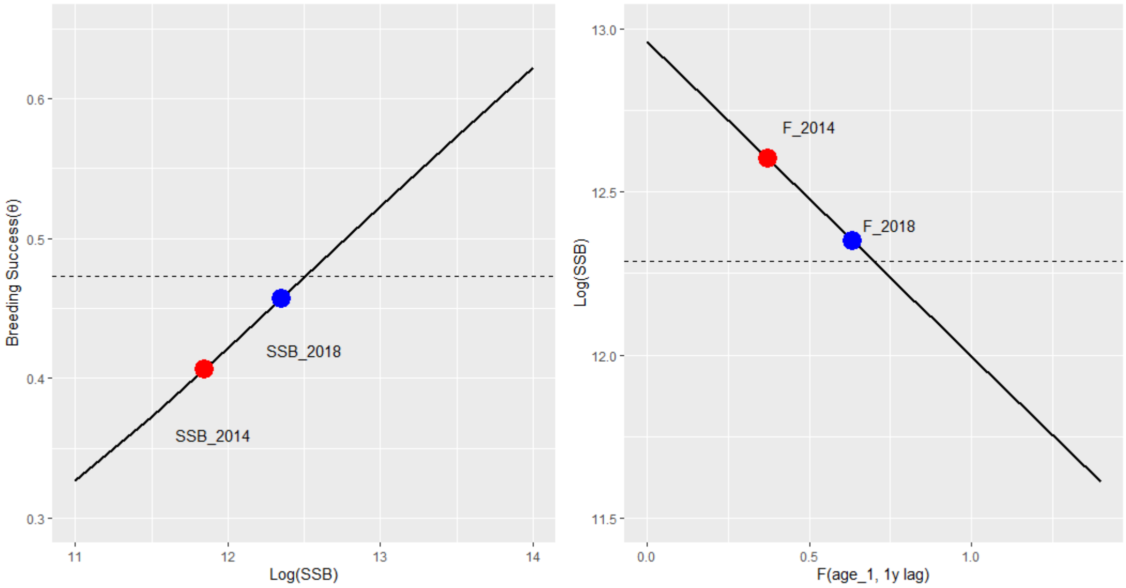
$$\theta = \frac{e^{\beta_0+\beta_1 X_1}}{1+e^{\beta_0+\beta_1 X_1}}$$

Where β_0 , β_1 are the link-scale intercept and slope parameters related to covariate X_1. Here our covariate of interest is the sand-eel spawning biomass (SSB) on the log scale (ln(SSB)). According to Carroll *et al.*'s (2017) Table 2 and Figure 3 the slope parameter for ln(SSB) without lag, is $\beta_1 = 0.407\ (0.133\ SE)$. The intercept parameter β_0 is not provided, but extrapolation from Figure 3 gives an estimate of $\beta_0 \approx -5.2$. For comparison, the derived parameters give the relationship in Figure 1a which is consistent with Carroll *et al.* (2017). An estimated figure for the 2014 SA1 sand-eel SSB can be obtained from the associated stock assessment (ICES 2015) as 11.84 (log scale) providing a predicted breeding success of 0.41 in the same year.

The overarching question is posed in terms of altering sand-eel fishing mortality (*F*) to influence θ, rather than SSB directly. By way of example, to achieve a 20% increase in breeding success (0.41 x 1.2= 0.492), the implied log SSB is 12.65 ($\theta = 0.492, X_1 = 12.65$). Accounting for the log scale, this is an increase in SSB by a factor of 2.4 i.e. from the 2014 level of 139,000 tonnes to over 300,000 tonnes.

Reposing in terms of fishing mortality of age 1 sand-eels (F_1), Carroll *et al.* (2017) provide a linear regression between SSB and F_1 (Table 4), giving $\beta_1 = -0.963\ (0.312)$ and $\beta_0 \approx 12.96$ by approximation. According to ICES (2015) the 2014 fishing mortality was F_1=0.371. Therefore, seeking a log SSB increase to 12.65 (a 20% increase in breeding success) corresponds to a reduction in F_1 to 0.312, approximately 15% of F_1 or an 85% relative decrease.

Figure 1: [a – left] Breeding Success (θ) and spawning biomass (SSB) of sandeels. The dotted line is the median and coloured dots are the SSB from ICES reports (2014, 2018). [b – right] Spawning biomass (SSB) of sandeels and Fishing Mortality (F) at age 1, and one year lag. The dotted line is the median and coloured dots are F from ICES reports (2014, 2018).

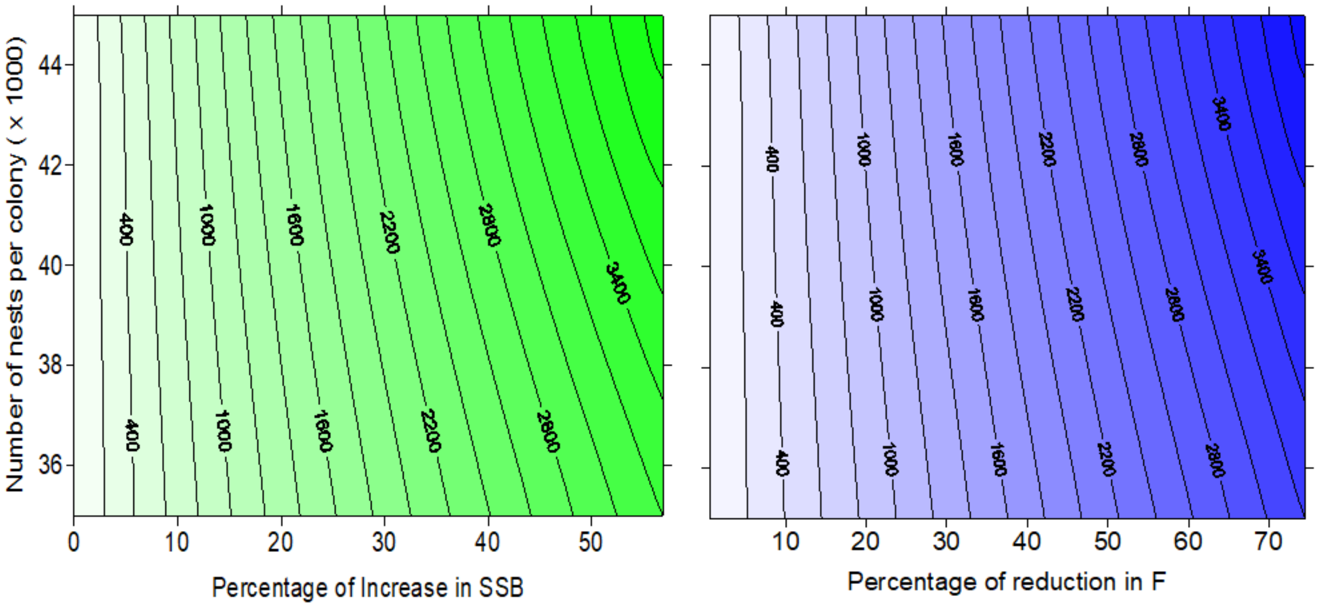


5.2 Changes in chick numbers under differing productivities – direct calculation

The FFC colony size is deemed to be approximately 89,000 breeding adults (*pers. comm.* G. Johnson), or 44,500 potential nests (i.e. breeding pairs). A range of colony sizes are considered, along with speculative changes in the productivity (θ, probability of a fledgling from an egg) related to increases in sand-eel SSB, and by extension reductions in sand-eel age 1 fishing mortality (based on 2018 stock estimates – ICES, 2019).

Without consideration of parameter uncertainty, direct calculation provides the estimates in Figure 2. For example, an increase of approximately 5% in the SSB corresponds to increases in chick numbers of roughly 400 for a colony size of 36,000 nests. This relates to an approximate reduction in fishing mortality of slightly less than 10% for the same sized population.

Figure 2: Contour plots of numbers of increased chick numbers (delta-chicks) relative to 2018. Based on the number of nests within the population with increased breeding success (theta), increased in spawning biomass (SSB) and implied reduction in fishing mortality *F*.



5.3 Approximating and adding parameter uncertainty

Uncertainty was incorporated by resampling from a multivariate normal distribution encapsulating the intercept and slope parameters ($\hat{\beta}_0, \hat{\beta}_1$) and their standard errors ($\hat{S}_{\hat{\beta}_0}, \hat{S}_{\hat{\beta}_1}$) relating breeding success to SSB, and the subsequent relationship between SSB and fishing mortality reported in Carroll *et al.* (2017). Neither the intercept estimates or their uncertainty are presented in Carroll *et al.* (2017), hence these are derived from extrapolation and their standard errors ($\hat{S}_{\hat{\beta}_0}$) are assumed proportional to the standard error of the slope $\hat{S}_{\hat{\beta}_1}$. For the j[th] resampled $\beta_{1,j}$, the $\beta_{0,j}$ is calculated semi-arbitrarily assuming a parameter correlation of $\hat{r}_{\hat{\beta}_0,\hat{\beta}_1} = -0.8$ and method described in Roa *et al.* (1999):

$$\beta_{0,j} = \hat{\beta}_0 + \hat{r}_{\hat{\beta}_0,\hat{\beta}_1}\left[\frac{\hat{S}_{\hat{\beta}_0}}{\hat{S}_{\hat{\beta}_1}}\right][\beta_{1,j} - \hat{\beta}_1]$$

Each resampling provides a realisation of kittiwake productivity, given a level of SSB, or by extension *F*. The baseline case utilises the 2018 sand-eel stock assessments, and a range of scenarios are simulated under differing SSB/*F*. The results are presented in Table 1 where 95% confidence intervals are computed using the percentile method (5,000 iterations). Here *delta* refers to changes from the 2018 sand-eel assessment and its implied productivities.

					Delta Birds					
Breeding Success (%)	ln(SSB)	% Increase SSB (ton)	F (lagged -1)	% reduction F	Nests=35k	95%CI	Nests=40k	95%CI	Nests=45k	95%CI
0.5	12.377	2	0.606	4	160	136-184	183	155-211	206	175-237
1	12.399	5	0.582	8	320	271-369	366	310-421	411	349-474
1.5	12.422	7	0.559	12	480	407-553	549	465-632	617	523-711
2	12.444	9	0.535	15	640	543-737	731	620-843	823	698-948
2.5	12.467	12	0.512	19	800	678-922	914	775-1053	1029	872-1185
3	12.489	15	0.489	23	960	814-1106	1097	930-1264	1234	1046-1422
3.5	12.512	17	0.465	27	1120	950-1290	1280	1085-1475	1440	1221-1659
4	12.535	20	0.442	30	1280	1086-1475	1463	1241-1686	1646	1396-1896
4.5	12.557	23	0.418	34	1440	1222-1659	1646	1396-1896	1851	1571-2133
5	12.580	25	0.395	38	1600	1357-1844	1829	1551-2107	2057	1745-2370
5.5	12.602	28	0.372	41	1760	1493-2027	2011	1707-2317	2263	1920-2607
6	12.625	31	0.348	45	1920	1630-2211	2194	1862-2527	2468	2095-2843
6.5	12.647	34	0.325	49	2080	1765-2396	2377	2017-2738	2674	2269-3080
7	12.670	37	0.302	52	2240	1900-2581	2560	2171-2949	2880	2443-3318
7.5	12.692	40	0.278	56	2400	2035-2764	2743	2326-3159	3086	2617-3554
8	12.714	43	0.255	60	2560	2171-2949	2926	2482-3370	3291	2792-3791
8.5	12.737	47	0.232	63	2720	2308-3133	3108	2637-2581	3497	2967-4028
9	12.759	50	0.208	67	2880	2447-3317	3291	2797-3791	3703	3146-4265
9.5	12.782	53	0.185	71	3040	2583-3501	3474	2951-4002	3908	3320-4502
10	12.804	57	0.162	74	3200	2718-3686	3657	3106-4212	4114	3494-4739

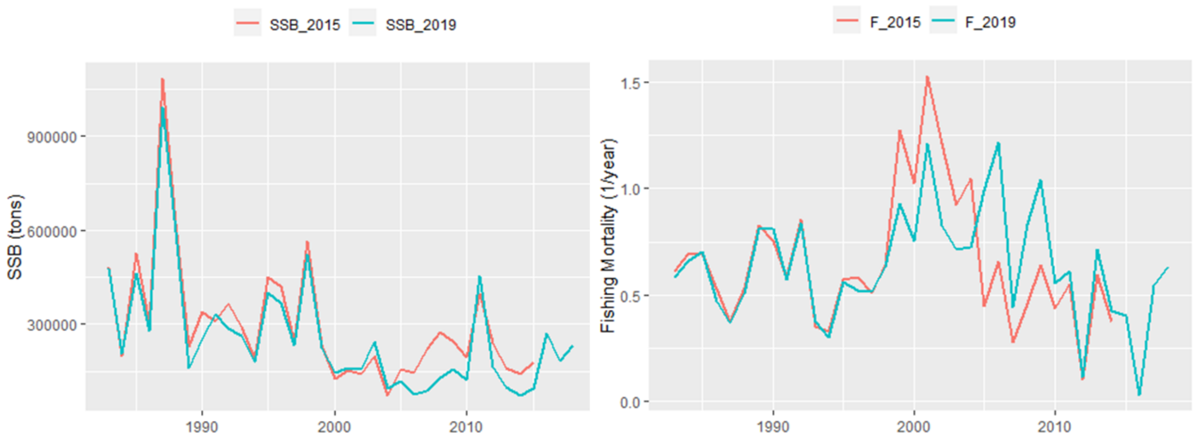
Table 1: Number of chicks estimated according to changes (%-age) in breeding success (θ), Spawning Stock Biomass (SSB) and Fishing mortality (*F*) and number of nests in the colony. All changes are relative to the most recent (2018) stock assessment estimates, which have θ=0.457, ln(SSB) = 12.35, F=0.633. The 95% confidence intervals reflect parameter uncertainties and are via resampling as described.

5.4 Uncertainty from changing stock definitions

All the estimates in Carroll *et al.* (2017) are based on the 2014 stock assessment of sand-eels (ICES, 2015). Here we have used figures from the latest assessment (ICES, 2019), which estimates for 2018.

Over 2017, the sand-eel stock boundaries were altered. Hence, data from the ICES (2015) assessment on which Carroll *et al.* (2017) are based, and the ICES (2019) assessment used for calculations here are not strictly comparable (Figure 3). The significance of the change is not clear, however for robust results either the Carroll *et al.* (2017) models ought to be refitted or some suitable correction be devised, the former being more desirable.

Figure 3: Comparison of spawning biomass (tonnes) and fishing mortality between 2015 and 2019 assessments for sand-eels.



6 Extension to PVA projections

The effects of changes to the sand-eel SSB on the kittiwake population will be compounding over time, through usual population dynamics. A standard approach to examining population projections is Population Viability Analysis (PVA), often based on projection matrix calculations combined with monte-carlo simulation to address parameter uncertainties.

Here we adopt the PVA outlined in the Ørsted Hornsea Project Three offshore wind-farm submission for the FFC SPA kittiwake populations, specifically assuming population size to be density independent and subject to environmental stochasticity only (i.e. demographic variations not considered in this instance). The principle modification is via productivities (i.e. breeding success, θ), which are generated from the relationships and uncertainties within Carroll *et al.* (2017) as previously described. The related/implied effects of changes to *F* are similarly presented.

7 Simulation results

PVAs for the FFC kittiwake population were run for 5 years. The PVA parameters were assumed to be that of a recent Hornsea Project 3 report (Ørsted, 2019). A five-year window was chosen to provide sufficient time for any effects on fledgeling success to be observed through to the adult population (being age >3). The initial size of the breeding population is approximately 89,000, providing for approximately 44,500 breeding pairs and a calculated overall population size of approximately 167,000.

The baseline scenario assumes the population is impacted with 80 additional adult deaths per annum due to windfarm-related effects, as considered approximately/conservatively relevant to questions of compensation (*pers. comm.* M. Hodge, 01/09/2020). The absolute number of additional deaths only strictly applies in the first year of simulation. It is converted to per-capita mortality rate for projection forwards so that additional deaths in a year will increase proportionately with an increase in the simulated population size and vice-versa. Baseline productivity is given by the sand-eel SSB in 2018. Altered scenarios diverge from baseline by assuming different productivity distributions derived from changes of sand-eel SSB (via *F*). Comparisons between baseline and altered scenarios can then be evaluated in terms of how changes in SSB levels could potentially compensate for 80 adult additional annual losses.

The investigation was done in a matched-runs fashion. Specifically, random parameter draws were the same for pairs of altered and baseline simulation runs, except for productivity. Productivity was drawn from altered or baseline distributions, as provided from their relationships with SSB and *F*.

Simulation outputs are voluminous, providing detailed views of numbers of kittiwakes in each age class over time. Here we present a selection of plots showing the overall population projections and the differences in adult numbers, between the altered and baseline scenarios. Only 2 sets of plots are given: the smallest reduction in *F* considered (<4%) and a relatively extreme reduction (approximately 50%), although larger reductions were explored and available in supplementary materials.

Reference points are provided in each of the plots showing changes in adult numbers. A reference line of 80 adults is plotted together with a further reference line giving the 5th percentile of the distribution of additional adults after 5 years. This indicates a reasonably likely lower level of additional adults, given the uncertainties propagated here.

7.1 Summary plots

Figure 4: Projections of additional adult birds when comparing an altered productivity scenario, with recent estimated productivity levels. Projections run over 5 years and assume productivities from distributions with the indicated means. Reference lines are plotted for 80 additional adults and the 2.5th percentile of simulations at year 5.

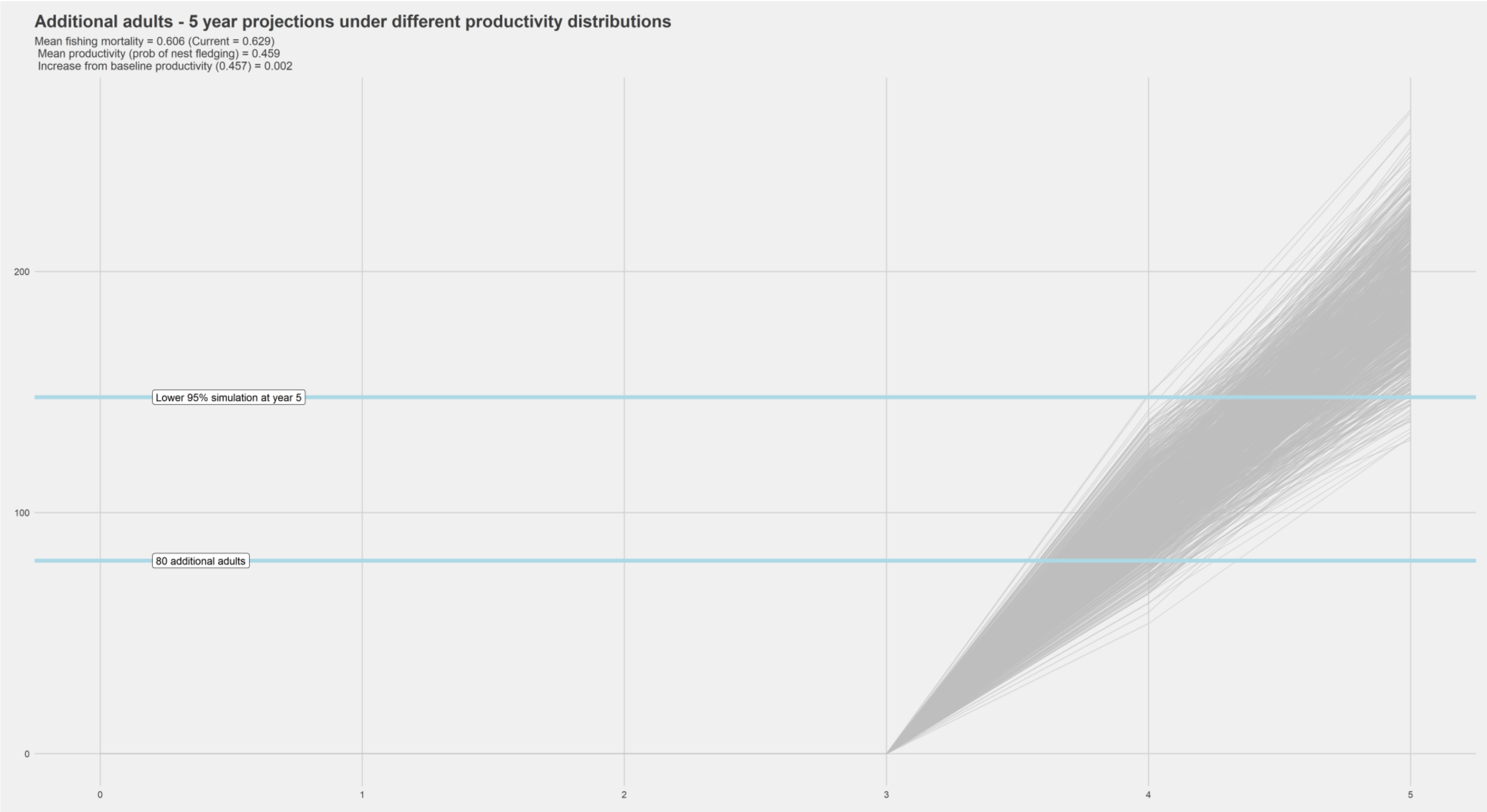


Figure 5: Projections of total population sizes when comparing an altered productivity scenario, with recent estimated productivity levels. Projections run over 5 years and assume productivities from distributions with the indicated means.

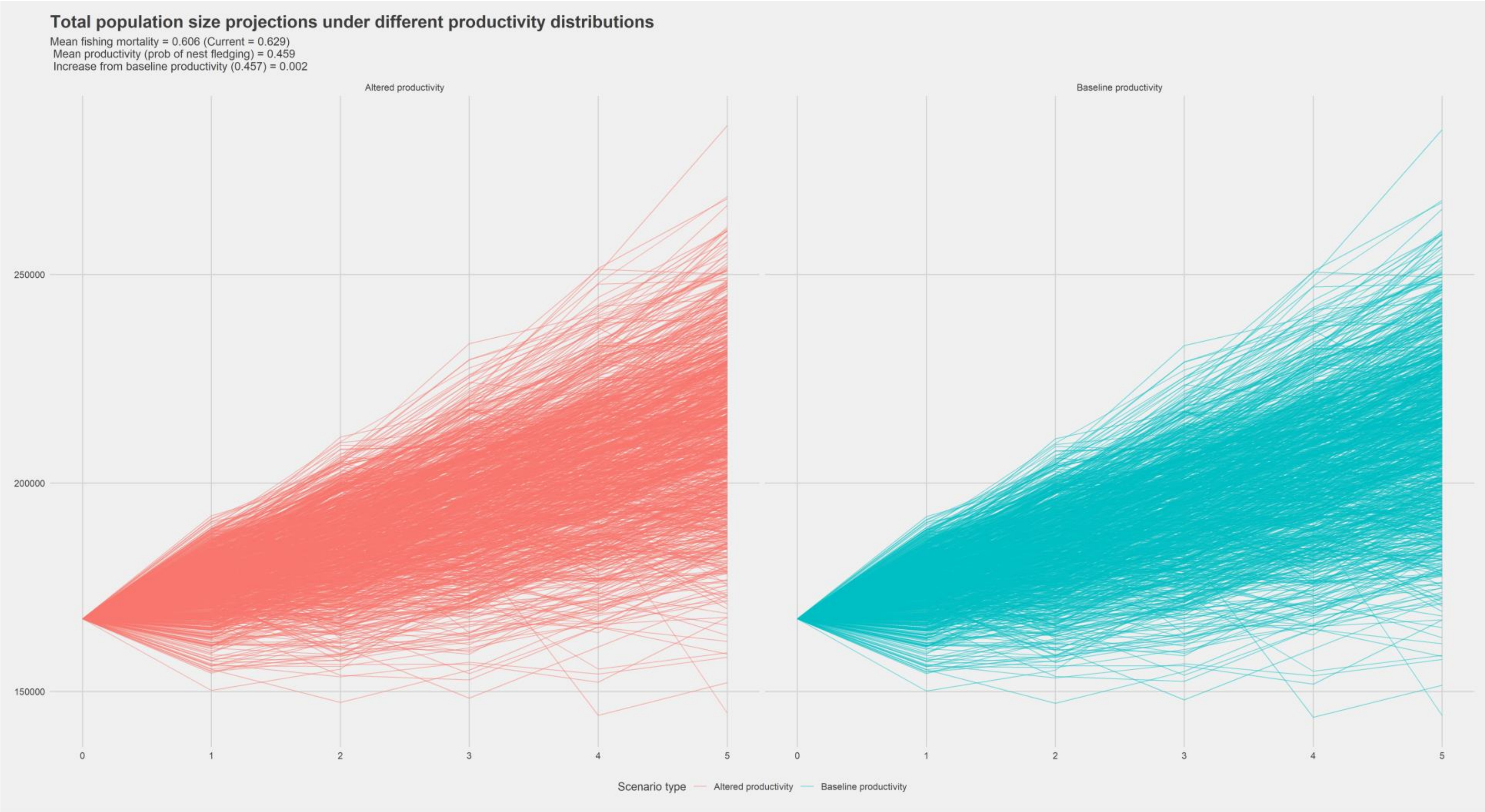


Figure 6: Projections of additional adult birds when comparing an altered productivity scenario, with recent estimated productivity levels. Projections run over 5 years and assume productivities from distributions with the indicated means. Reference lines are plotted for 80 additional adults and the 2.5th percentile of simulations at year 5.

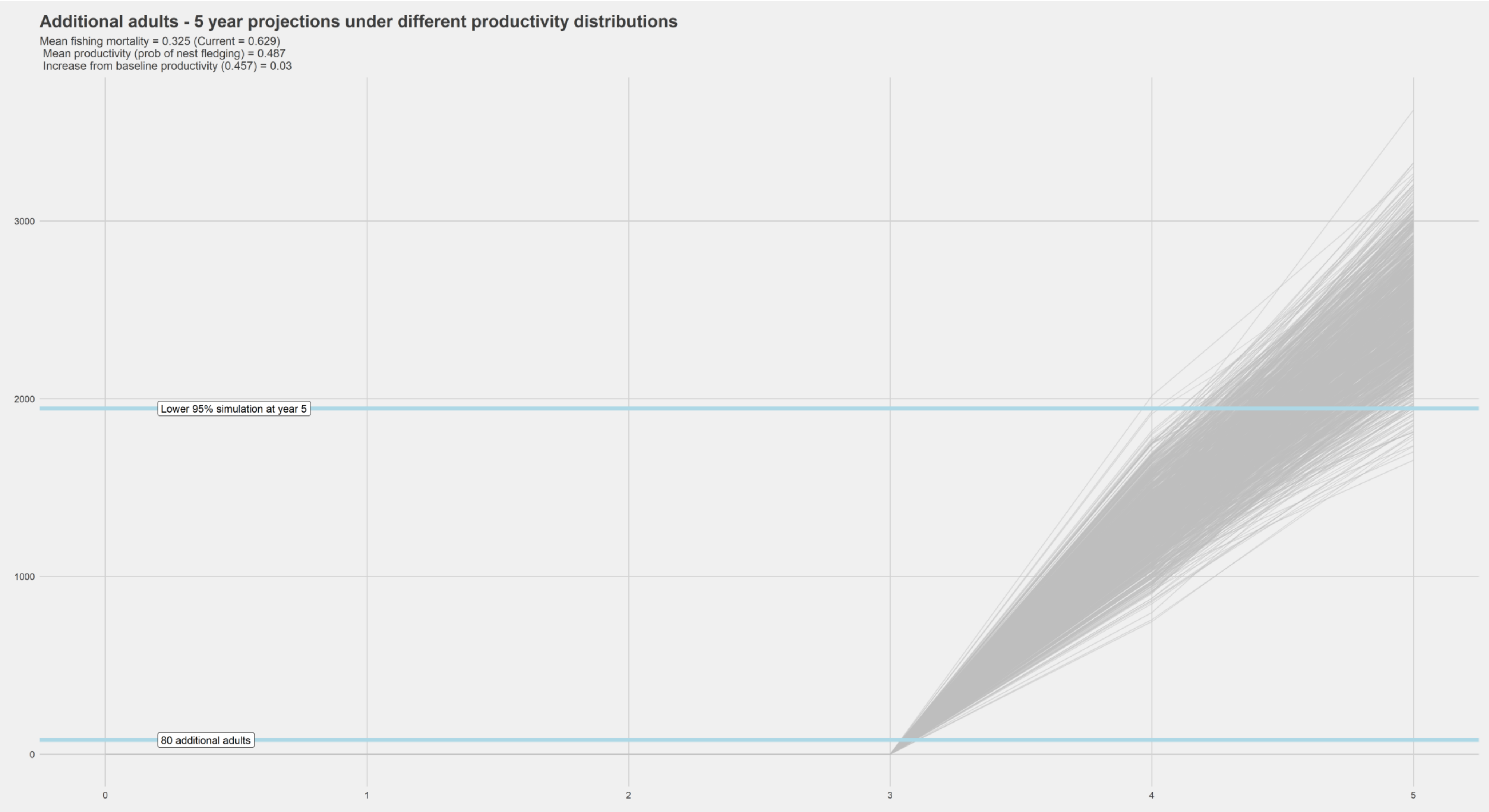
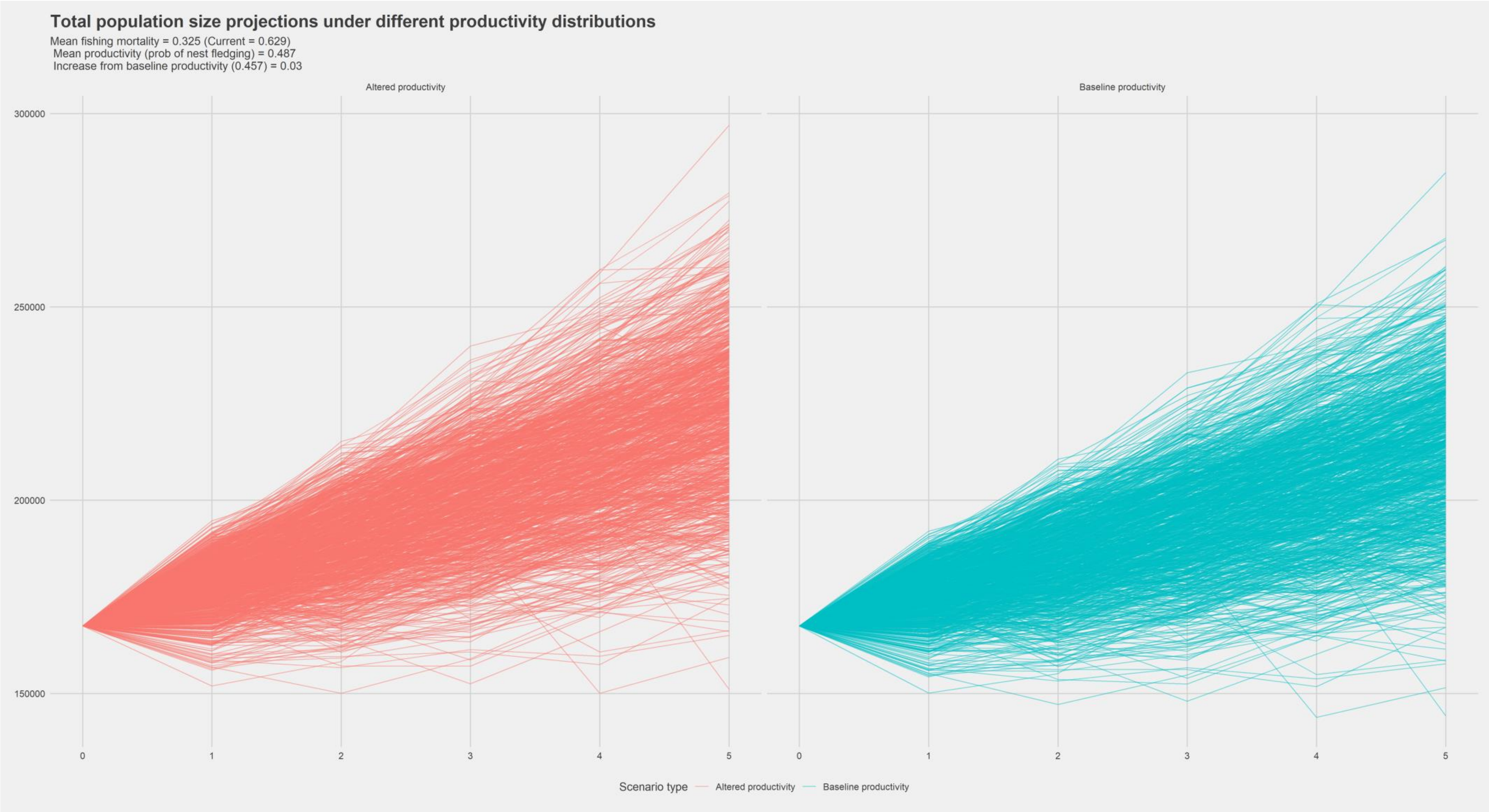


Figure 7: Projections of total population sizes when comparing an altered productivity scenario, with recent estimated productivity levels. Projections run over 5 years and assume productivities from distributions with the indicated means.



7.2 Summary tables

Productivity change from 2018	F change from 2018	Year	Minimum	Median	Maximum	Lower 95%	Upper 95%
0.5%	-3.7%	4	54	101	149	71	131
		5	130	191	267	148	236
1.0%	-7.4%	4	118	201	308	146	263
		5	254	383	547	296	478
1.5%	-11.2%	4	177	298	452	219	393
		5	376	570	815	448	710
2.0%	-14.9%	4	204	401	613	292	529
		5	475	760	1106	596	942
2.5%	-18.6%	4	273	504	730	363	654
		5	646	954	1358	736	1198
3.0%	-22.3%	4	341	602	906	441	787
		5	728	1145	1583	890	1420
3.5%	-26.0%	4	426	701	1041	524	921
		5	858	1339	1840	1042	1659
4.0%	-29.8%	4	478	799	1179	591	1037
		5	1057	1521	2068	1195	1889
4.5%	-33.5%	4	465	909	1289	650	1175
		5	1131	1720	2429	1331	2136
5.0%	-37.2%	4	490	1007	1492	732	1315
		5	1268	1922	2649	1488	2389
5.5%	-40.9%	4	656	1108	1611	815	1423
		5	1313	2105	2919	1654	2622
6.0%	-44.6%	4	662	1199	1891	864	1571
		5	1549	2283	3166	1789	2894
6.5%	-48.3%	4	746	1312	2017	957	1685
		5	1654	2497	3625	1945	3085
7.0%	-52.0%	4	790	1406	2215	1007	1841
		5	1613	2693	3734	2074	3327
7.5%	-55.8%	4	831	1501	2176	1089	1965
		5	1897	2870	3899	2247	3559
8.0%	-59.5%	4	941	1610	2456	1174	2089
		5	2088	3073	4302	2377	3813
8.5%	-63.2%	4	981	1725	2575	1245	2232
		5	2193	3258	4491	2568	4073
9.0%	-66.9%	4	911	1807	2692	1307	2368
		5	2417	3435	4740	2666	4279
9.5%	-70.6%	4	1077	1899	2842	1410	2531
		5	2420	3624	4980	2792	4561
10.0%	-74.3%	4	1191	2012	3060	1458	2618
		5	2475	3832	5277	2980	4749

Table 2: Numbers of additional adults by year and simulated changes to the productivity/fishing mortality. Based on 1000 runs of projection Models.

8 Immediate limitations and caveats of analysis

There are a number of approximations and assumptions required to obtain the figures here, which mean they should be treated tentatively. The most immediate are listed here.

Uncertainty in the Carroll *et al.* (2017) estimates. The Carroll *et al.* (2017) paper presents uncertainty for some parameter estimates, but not all, nor are random effects components detailed. Correspondence with the authors (pers. comm. M. Bolton, Sept 2020) indicate that a full set of parameter values and confidence intervals may take several months to obtain. For this reason some parameters (intercepts and their standard errors) have been extrapolated from the paper's plots and necessary variance/covariance figures similarly approximated between slope and intercept parameters. These approximations permit some Infeasible parameter combinations under simulation, which were subsequently discarded. In addition, there are indications of standard errors and confidence intervals being interchanged within the paper.

Uncertainty in fisheries data. Sand-eels are a fecund and short-lived species, whose fishery is effectively managed over two age classes. As such, recruitment is a significant driver of uncertainty in SSB that operates on effectively annual time-scales. An amount of this variance will be reflected in the Carroll *et al.* (2017) uncertainties, given the 30 year's data underpinning the models, but as the dominant source of uncertainty in the work here, ought to be given careful consideration in forwards projections i.e. the significant uncertainty in stock projections should be propagated fully into the kittiwake PVA or similar. This is abundantly clear from Figure 3, where the simulated changes in productivity/SSB/fishing mortality from 2018 levels are very small in comparison to natural, rapid, stock fluctuations.

Furthermore, there was a redefinition of the SA1 stock in 2017, meaning application of the Carroll *et al.* (2017) models, being based on 2015 assessments, to current stock assessment data is not strictly correct.

9 Future requirements for robust analysis

The models found within Carroll *et al.* (2017) ought to be refitted. This would allow an accounting for the redefining of the sand-eel stock in 2017, as well as updating generally for recent year's data. This would also provide a full set of required parameters and their uncertainties, including random components, if from a mixed model.

Sand-eel SSB is hugely variable, driven by large variability in recruitment year-to-year. This source of natural variability far exceeds other sources of variance in the explorations here, rendering many of the speculative changes to *F* relatively insignificant, and very unreliable, in terms of increasing adult numbers. Future work should consider the contribution of sand-eel stock dynamics in depth.

Projections here are necessarily based on parameters from an extant PVA for the FFC kittiwake population. This ought to also be based on the most up-to-date parameters/data and be externally agreed as suitable.

10 Supplementary materials

A wider range of plots can be obtained here:
https://www.dropbox.com/s/py60t8yy33qsxry/simulationPlots.zip?dl=0

A range of PVA outputs can be similarly obtained here:

https://www.dropbox.com/s/nb1bqrmc64elj82/PVA_outputs.zip?dl=0

Containing projections under the range of scenarios in Table 2, broken down by:

- Complete age structure (kittiwake_FFC_n_ya_sims_tbl.csv),
- population sizes (kittiwake_FFC_N_y_sims_tbl.csv),
- additional birds of all ages (kittiwake_FFC_gained_ya_sims_tbl.csv),
- additional adult counts (kittiwake_FFC_Adults_gained_y_sims_tbl.csv):

11 References

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