# Sheringham Shoal and Dudgeon Offshore Wind Farm Extension Projects

## Annex 1B - Sandwich Tern and Kittiwake Ecological Evidence

August 2022
Document Reference: 5.5.1.2
APFP Regulation: 5(2)(g)

China Resources
Better Life Together

Masdar
A MUBADALA COMPANY

equinor

| | | |
|---|---|---|
| Title:<br>**Sheringham Shoal and Dudgeon Offshore Wind Farm Extension Projects DCO Application**<br>**Annex 1B Sandwich Tern and Kittiwake Ecological Evidence** | | |
| PINS Document no.:<br>5.5.1.2 | | |
| Document no.:<br>C282-RH-Z-GA-00185 | | |
| Date: | Classification | |
| **6th November 2021** | **Final** | |
| Prepared by: | | |
| **MacArthur Green** | | |
| Approved by: | | Date: August 2022 |
| **Sarah Chandler, Equinor** | | |

MacArthur Green

# Report to Royal Haskoning

# Considerations of compensation options for Sandwich terns and kittiwakes


| | |
|---|---|
| Date: | 6 November 2021 |
| Tel: | 0141 342 5404 |
| Web: | [redacted] |
| Address: | 93 South Woodside Road \|Glasgow \| G20 6NT |

## Document Quality Record

| Version | Status | Person Responsible | Date |
|---|---|---|---|
| 0.1 | Draft | Bob Furness | 27/09/2021 |
| 0.2 | Review | Ross McGregor | 28/09/2021 |
| 1 | Complete | Bob Furness | 30/09/2021 |
| 2 | Revised | Bob Furness | 06/11/2021 |

# CONTENTS

## EXECUTIVE SUMMARY

In relation to Dudgeon Extension Project and Sheringham Shoal Extension Project, discussions with stakeholders indicated topics where a review of evidence may be useful in developing outline in-principle compensation plans for predicted impacts on North Norfolk Coast SPA Sandwich tern and Flamborough & Filey Coast SPA kittiwake. Those nine topics (listed in Section 2) have been reviewed here, providing the following conclusions:

Sandeels and clupeids (sprats and juvenile herring) are the main breeding season foods of Sandwich terns in north-western Europe. The relative importance of these prey types varies from year to year, almost certainly in relation to relative abundance of the stocks. There is also consistent evidence of clupeids being more important as chicks get larger but sandeels being more important when chicks are small. There is some evidence indicating that Sandwich terns tend to forage on clupeids close to the colony and along the coast but may commute further offshore to forage on sandeels over sandbanks, possibly especially when tidal flow brings sandeels closer to the sea surface. Strong winds inhibit foraging by Sandwich terns and may influence their choice of foraging area and prey species.

Evidence indicates that measures to increase abundance of sandeels, sprats and juvenile herring in waters near to Sandwich tern colonies can be expected to result in an increase in breeding success, and probably an increase in adult survival, of Sandwich terns. Continuation of sandeel fishery under existing ICES management advice (an escapement strategy) is likely to have an adverse impact on Sandwich tern numbers and demography at colonies in the east of England by keeping sandeel biomass much lower than in the absence of a fishery. Local stocks of sprats in coastal areas of east England and east Scotland may be especially important for breeding Sandwich terns, but evidence indicates links between these local stocks and the wider North Sea sprat stock. Reductions in fishing pressures on sprat stocks would be expected to result in increased breeding success, and probably increased adult survival of Sandwich terns.

While the Natura 2000 suite for breeding Sandwich tern in Britain and Northern Ireland holds more breeding pairs now than it did when these sites were designated, some sites are in unfavourable conservation status, either as a consequence of impacts of predators (especially fox predation) or flooding, or development of vegetation over nesting areas, or human disturbance, or reduced abundance of forage fish. Sandwich terns have been lost from some regions (such as west Scotland) and the UK population is now more concentrated in fewer sites, making it potentially less resilient to pressures caused by environmental change.

There is considerable scope for management interventions to improve the breeding conditions for Sandwich terns, both at some SPA sites where the species has been in unfavourable condition for many years, and at non-SPA sites where many have lost their Sandwich tern populations. Interventions could include predator exclusion, reducing/eliminating flood risk, vegetation management, or a combination of these. Sites suitable for such actions are identified, and best practice guidance is reviewed, indicating that management needs to be carried out in line with best practice in order to achieve success. For some sites, management would need to address more than one of these pressures and may need to control risks of human disturbance too.

There is strong empirical evidence that Sandwich tern populations within SPAs are more resilient and stable if the SPA contains more alternative breeding sites. That evidence provides a case for

considering the possible restoration of a third Sandwich tern breeding site within North Norfolk Coast (NNC) SPA to add to the two successful sites currently in use.

Evidence indicates that kittiwakes can achieve higher breeding success on offshore platforms than they do at coastal colonies, probably because they have less far to commute to foraging grounds and are less exposed to potential predators and disturbance. It would be difficult to locate an offshore kittiwake colony in the southern North Sea without it being close to offshore wind farms. A site off Northumberland could provide good access to high densities of sandeels, and could be moderately distant from offshore wind farms, so might represent an optimal choice if an offshore site was to be selected as a compensation mechanism.

Adaptations to existing artificial structures that increase breeding success of kittiwakes in a population could be a significant contribution to kittiwake conservation that would be complementary to provision of new structures and would reduce risk that the pool of site-seeking immatures might be depleted by overprovision of new structures in a short timescale. Allowing increased breeding success on structures that avoid conflict with local people, especially where kittiwakes nest on buildings where they are not welcome, could not only provide compensation by increasing mean productivity of the population as a whole but could also reduce conflict by allowing birds to move off structures where they are prevented from breeding successfully, so represent a population sink.

There is now clear empirical and modelling evidence that depletion of sandeel stocks is caused by the sandeel fishery. There is strong evidence that kittiwake breeding success declines when sandeel stock biomass is reduced, and there is now further evidence that kittiwake adult survival is also reduced when sandeel stock biomass is reduced. Existing management of sandeel stocks by an escapement strategy has resulted in exploited stocks being reduced to close to $B_{lim}$ (the limit reference point for spawning stock biomass likely to still enable recruitment to be maintained), well below the threshold at which kittiwake breeding success is reduced, but stocks can recover if fishing mortality is constrained or removed. There is, therefore, strong evidence that closure of sandeel fishing in UK North Sea waters would benefit kittiwake populations. Since some kittiwakes also forage on sprats/juvenile herring, closure of fisheries targeting sprats/juvenile herring may also benefit kittiwakes.

# 1 INTRODUCTION

In relation to Dudgeon Extension Project (DEP) and Sheringham Shoal Extension Project (SEP), outline in-principle compensation plans have been drafted and consulted on with ornithology ETG members in the event that derogation is required. The aim of those documents was to:

a) identify a long list of potential measures to take forward in the reporting process; and
b) identify a shortlist of measures preferred by the project for further development.

With the objectives of:

a) de-risking the consent by identifying options at an early stage and associated requirements, for example data/assessment/consultation/landowner/programme;
b) developing information to inform consultation on the options at the pre-application stage; and
c) ultimately, demonstrating that the Project has explored and (where possible) agreed matters with relevant consultees pre-application.

The shortlisted measures will be investigated in further detail to inform further consultation and confirm the approach to be taken to compensation in the final outline plan, which will be submitted with the DCO application. That process is supported here by review of nine topics considered to be important evidence-based background to guide potential plans.

# 2 TOPICS

Discussions with stakeholders indicated a need to consider evidence regarding nine topics:

1) Review evidence on Sandwich tern diet, with particular reference to birds at North Norfolk Coast SPA;
2) Review evidence on likely relationship between prey fish abundance and demography of Sandwich tern (especially productivity);
3) Review evidence on sprat and sandeel stocks likely to influence North Norfolk Coast SPA Sandwich tern food availability, the likely impact of fisheries on those stocks, and therefore the feasibility of reducing fishing mortality as a compensation measure;
4) Review the conservation status of Sandwich terns at UK colonies, considering both those that are SPAs and those that are not;
5) Review the broad scope for management measures to increase breeding numbers and productivity of Sandwich terns through predator exclusion, reduced human disturbance, flood protection and/or vegetation control to improve conditions for breeding;
6) Review the potential to create a third safe breeding site for Sandwich terns within North Norfolk Coast SPA but away from Scolt Head and Blakeney Point, by habitat improvement measures (perhaps at Stiffkey/Holkham to restore the previous population that clearly did occur in the past). Increasing the number of safe breeding sites within North Norfolk Coast SPA would increase resilience for this important population, but could potentially also allow further increase in breeding numbers;

7) Briefly review the scope for provision of artificial breeding sites for kittiwakes on offshore structures;
8) Clarify the case for improving existing onshore artificial structures for kittiwake breeding to increase breeding numbers and productivity;
9) Review recent developments in evidence regarding the strategic reduction in sandeel fishing effort as a potential compensation measure for kittiwakes.

These nine topics are considered below, drawing primarily on available evidence from the scientific literature to create an objective evidence-based assessment, fully referenced to appropriate primary literature. The text below is additional to that in previous texts on compensation options provided to stakeholders for consideration, and therefore aims to avoid replicating material that had already been included in previous texts.

# 3 REVIEWS

The nine topics listed above are considered in turn.

## 3.1 Sandwich tern diet, with particular reference to birds at NNC SPA

Historical data on Sandwich tern feeding behaviour and diet are summarised by Cramp (1985) as "*Chiefly surface-dwelling marine fish. Hunts by plunge-diving, usually from 5-10 m.*" Cramp (1985) indicates that Sandwich terns breeding at North Sea colonies feed mainly on sandeels and clupeids (sprats and young herring), with a tendency to feed more on sandeels early in the breeding season and more on clupeids in June-July as chicks reach fledging. Woodward et al. (2019) list the foraging range of breeding Sandwich terns as mean 9 km, mean maximum 34.3 km, maximum 80 km. However, these distances are likely to apply more along the coast than directly out to sea, given the preference of UK breeding Sandwich terns to remain near the coast. Their fishing success is severely hampered by strong winds and rough seas (Dunn 1973, Taylor 1983, Stienen et al. 2000), so they tend to feed mainly in sheltered bays and estuaries (Mitchell et al. 2004), although they may commute to shallow banks further out to sea where those hold large stocks of forage fish.

### 3.1.1 Dornoch Firth

Bourne and Smith (1974) reported that sandeels represented about 50% of the diet of Sandwich terns nesting at Morrich More firing range (between Tain and Inver, Easter Ross, Dornoch Firth) in 1969. The other 50% was made up of a wide range of small "*young fish from the estuary and the sea*". No sample size for this data set was provided.

### 3.1.2 Farne Islands, Northumberland

Pearson (1968) reported on 885 prey items brought to the colony by Sandwich terns at the Farne Islands in summers 1961-1963. Sandeels were by far the most important prey for that population. Most prey were around 2 g in weight, and 74% were sandeels (mostly 5 to 10 cm in length), 15% clupeids (probably sprats), 6% gadids (mostly whiting), 2% sticklebacks, 1% butterfish, 1% cephalopods and 1% crustacea. However, clupeids represented 24% of diet fed to chicks by estimated weights of prey as they tended to be heavier than the sandeels. Pearson (1968) calculated that Sandwich terns at the Farne Islands almost all foraged considerably less than 25 km from the colony, making about 7 feeding trips per adult per day during chick-rearing, spending between 40% and 75% of daylight hours foraging.

### 3.1.3 Coquet Island, Northumberland

At Coquet Island, Langham (1968) found that Sandwich terns fed exclusively on sandeels and sprats in 1965, but that sprats made up 89% of prey (452 out of 509 fish) and sandeels only 11%. In 1966, the diet was also composed of sandeels and sprats, but with similar proportions of these two species (131 sandeels and 153 sprats). Langham (1968) found that Sandwich terns tended to feed very young chicks on sandeels but fed large chicks more on sprats and suggested that this was because sprats were larger so less suitable as food for small chicks. Langham (1968) noted that Sandwich terns from Coquet Island mainly fed in sandy bays close to shore, especially in Druridge Bay, between 3 and 10 km from the colony.

### 3.1.4 North Norfolk

Centrica Energy (2009b) reported on prey brought by Sandwich terns to nests at Scolt Head in 2006 and 2007, and Blakeney in 2007. The data are limited as presented in that report, as results are presented as percentages without sample sizes, so the amount of data on which the descriptions are based is unknown and possibly small. Furthermore, the text indicates that very few data were obtained in 2006, or from one of the two colonies in 2007. However, the data suggest that on the five listed sampling dates at least 80-90% of prey brought to chicks were either sandeels or clupeids (about 2 to 22% of prey being classified as "*unidentified*"). Sandeels apparently decreased in frequency from May to July from at least 72% of prey in late May (when 22% of prey were not identified) to 42% in mid-June (as chicks were fledging) and 15% in mid-July (after chicks had fledged). Conversely, clupeids increased from 0% in May to 70% in July. The clupeids were described as mostly 2-year old sprats of about 6 cm length, and the sandeels as mean length between 7 and 12 cm. Tracking studies indicated that Sandwich terns fed both close to the coast near the colony (possibly mainly on sprats/juvenile herring) and to a smaller extent at offshore sandbanks (presumably on sandeels).

Studying Sandwich terns at Blakeney in 2008, Perrow (2010) presented data on prey consumed by adults at sea (n=55), delivered to the colony (n=199) and presented/fed to chicks (n=33). Half the prey consumed at sea could not be identified at all, and a further nearly 20% was identified as fish, but not identified further. However, about 20% of the prey consumed at sea was identified as unidentified invertebrate. Of the relatively few fish identified as sandeel or clupeid, about three times as many were identified as sandeels rather than clupeids. For prey items delivered to the colony, 40% were clupeids, 55% sandeels, and most of the remaining 5% were unidentified fish. For prey items presented/fed to chicks, 40% were clupeids, 35% were sandeels, 25% were unidentified fish. Prey items consumed at sea were estimated to average 3.5 cm in length whereas those brought to the colony averaged 6.7 cm in length. Perrow et al. (2010) summarise data on prey captured at sea by Sandwich terns off north Norfolk in 2006-2009 (n=1,089 prey items), where 40% were identified as clupeids, 7% as sandeels, 16% as unidentified fish and just over 30% as unidentified prey. For items delivered to the colony and presented to chicks in 2006-2009 (n=827), 55% were clupeids, 40% sandeels, and 5% were unidentified fish. Perrow (2011) noted that of 49 items taken by Sandwich terns at sea off north Norfolk in summers 2006-2008, 13 were invertebrates (probably crustaceans), and 36 were fish. Only ten of these fish were identified, six sandeels, four clupeids. In contrast, none of 132 items fed to chicks were invertebrates.

Perrow (2017) found that on average, foraging Sandwich terns in north Norfolk reached up to 10.7 km from the colony in a trip lasting about 33 minutes. About half of the prey items caught at sea by Sandwich terns were clupeids, with sandeels the next most important prey type. However, large numbers of larval fish were also caught, and swallowed at sea, whereas most of the prey carried back to the colony was clupeids or sandeels (Perrow et al. 2017).

Fast boat following flight tracking data (Perrow et al. 2010) suggest that most foraging activity occurred close to the colony, possibly targeting inshore sprats, whereas some long foraging trips were to areas likely to hold sandeel stocks on sandbanks further offshore.

Evidence from these studies indicates that the proportions of sandeels and clupeids varies among years, presumably in relation to the relative abundances of these forage fish stocks in the area.

#### 3.1.5 Clyde Sea Area

Monaghan and Zonfrillo (1986) speculate that a major factor causing the decline in breeding numbers of common, Arctic, roseate and Sandwich terns in the Clyde Sea area has been the decline in abundance of juvenile herring in the Clyde. They do not present any data on Sandwich tern diet but note that the largest declines have been in seabird species that feed predominantly on sandeels and clupeids. Sandwich tern breeding numbers in the Clyde decreased from about 400 pairs in the 1950s to zero around 1980, at an average rate of decline of 20% per annum, the most rapid decrease of any seabird species there (Monaghan and Zonfrillo 1986).

### 3.1.6 Anglesey, Wales

In 1999, Sandwich terns at Cemlyn Bay fed their chicks predominantly on sandeels, with clupeids (mostly sprat, some herring) contributing the remainder (Newton and Crowe 2000, cited in Green 2017). In 2009, Sandwich terns at this colony fed chicks mostly on sandeels and clupeids, and a small number of gadoids and rockling (Perrow et al. 2010). Clupeids were estimated to account for a greater proportion of the energy delivered to Sandwich tern chicks at Cemlyn Bay, despite being fed to chicks less frequently than sandeels (Perrow et al. 2010). At sea, sandeels and clupeids made up a much lower proportion of items ingested by adults, although many more items of these prey types were likely to be included within the relatively high proportion of unidentified fish (21.9%). Also prevalent within the sample of items ingested offshore were small larval fish (generally < 3 cm in length), which could not be identified to species (Perrow et al. 2010). Invertebrates of similar size were also taken. These very small items were never recorded being brought back to the colony (Perrow et al. 2010).

### 3.1.7 Netherlands/Belgium

Fijn et al. (2017) studied Sandwich terns in Haringvliet SPA, Rhine/Maas Delta area of the Netherlands in 2012-2015. Chick diet (n=905) comprised 77% clupeids, 20% sandeels, 3% other fish species. Sandeels tended to be caught further offshore than clupeids. On longer foraging trips, Sandwich terns tended to come back with larger fish. Results from fish monitoring in the study area suggest that larger individuals of the most important prey items of Sandwich terns reside further from the coast compared to smaller fish (Fijn et al. 2017). Core foraging area was up to 40 km from the coast, and up to 60 km from the colony. Fijn et al. (2017) noted that these were unusually long distances for this species and state "*This might indicate that Sandwich terns in the Delta area have to travel further than conspecifics in other colonies to find appropriate food items, although it can also not be ruled out that some birds equipped with GPS-loggers performed longer foraging trips due to brood loss.*"

Courtens et al. (2017) used faecal samples to study diets of breeding adult Sandwich terns in five different colonies in the Netherlands and Belgium in 2007 to 2015. This is an important study because it is unusual in providing data on adult diet (rather than food brought to chicks) and is based on a large quantity of data from multiple colonies in multiple years. Breeding adult Sandwich terns in the study area took only three main prey types. Clupeidae were the most abundant fraction by number, making an average of 48% of the diet by numbers. The clupeid fraction almost exclusively consisted of relatively small (<9.5 cm) herring and sprat. The ratio of sprat to juvenile herring seemed to vary considerably among years, but most clupeids could not be identified to species so the relative importance of these two prey species was uncertain. Sandeels accounted for another 40% of the diet by numbers, 8–14 cm being the most common length class taken. Because sandeels tended to be slightly larger than clupeids in the diet, the contribution by mass was probably slightly more from sandeels than from sprats/herring. The remaining 12% of diet (by numbers of prey items) consisted of a wide variety of juvenile fish and a few squid, shrimps and marine worms. The relative contribution of clupeids versus sandeels varied somewhat among years, suggesting that Sandwich terns will feed on either of these prey types, depending on their abundance in a particular year. Courtens et al. (2017) noted that the between year variation in diet composition is much more pronounced than between colony variation, suggesting that it is annual variation in stock abundance of the main prey fish in the southern North Sea that is driving variation in diet, rather than differences in local fish stocks around different colonies.

In the North Sea, sandeels and clupeids are the predominant prey fish of Sandwich tern chicks, normally representing >95% of the chick's diet (Courtens et al. 2017). In Zeebrugge, the clupeid fraction amounted to 67–92% of chick diet in 2001–2007 (Stienen et al. 2015). In the Dutch Delta area, between 2009 and 2015, clupeids made up 49–88% of total prey delivered (unpublished results INBO cited in Courtens et al. 2017). These ranges match with the diet composition of the adult diet reported by Courtens et al. (2017), suggesting little difference in diets of chicks and adults in terms of these main prey types. In the Netherlands Delta area, the mean length of Clupeidae brought to the chicks was 8.5–13.5 cm and that of sandeels 11.0–14.5 cm (unpublished results INBO cited in Courtens et al. 2017). Considering the mean lengths in the adult diet of clupeids (3.7–6.8 cm) and sandeels (9.0–11.4 cm) reported by Courtens et al. (2017), the chicks are fed much larger clupeids and slightly larger sandeels than the adults consume themselves at these colonies. That conclusion fits with expectation based on optimal foraging theory for a single prey-loader such as Sandwich tern. These results suggest that Sandwich terns forage on much the same prey for self-feeding as for chick-provisioning but select larger prey items to carry back to the colony to feed to chicks.

### 3.1.8 Wadden Sea

Veen (1977) studied Sandwich terns nesting at Griend, Wadden Sea. In 1966, 468 fish being fed to the partner comprised sandeel in 52% of cases, clupeids in 44% and other or unidentified in 4%. In 1966, 2,351 fish fed to chicks were sandeel in 31% of cases, clupeid in 66%. In 1967, 395 fish fed to chicks were sandeel in 36% of cases, clupeid in 63%. In 1970, 356 fish fed to chicks were sandeel in 64% of cases, clupeid in 34%. Veen (1977) commented that the relative abundance of sandeels and clupeids in different years was most likely responsible for these differences between years. Veen (1977) calculated that most foraging trips resulted in adults foraging about 10 to 25 km from the colony.

Brenninkmeijer and Stienen (1994) also studied Sandwich tern diet at Griend, in 1992 and 1993, providing a comparison with the earlier work by Veen in the 1960s. They found that sandeels and clupeids comprised 99.2 to 99.7% of the chick diet. The proportion of clupeids varied among colonies between 46% and 58%. Sizes of fish brought to chicks varied from day to day, in relation to weather conditions, in relation to chick age, and as a result of kleptoparasitic activity of black-headed gulls that stole fish from Sandwich terns carrying food to the colony.

Stienen et al. (2000) reported seven years of data (1992–1998) for Sandwich tern chick diet at Griend (Table 3.1.1), including the two years (1992 and 1993) that were included in Brenninkmeijer and Stienen (1994).

**Table 3-1-1 Prey types brought to chicks by Sandwich terns on Griend, 1992-1998 (data from Stienen et al. 2000).**

| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|
| **Clupeid** | 49.5% | 55.0% | 84.0% | 69.7% | 32.7% | 79.0% | 46.6% |
| **Sandeel** | 49.7% | 44.7% | 14.9% | 29.8% | 66.6% | 20.3% | 52.9% |
| **Other** | 0.8% | 0.3% | 1.1% | 0.5% | 0.7% | 0.7% | 0.5% |
| **Sample size** | 630 | 3,469 | 3,279 | 1,290 | 3,262 | 2,579 | 3,428 |

As chicks grew, instead of making more foraging trips, in all years parents brought in increasingly longer fishes to keep pace with the growing energy demands of their growing chicks. On average the daily prey mass brought to the colony per bird was less than 15 g at hatching but increased to about 55 g near fledging (Stienen et al. 2000). The number of fish transported to the colony was particularly low at wind speeds less than 3 m $s^{-1}$ and at wind speeds higher than 14 m $s^{-1}$. In between, food delivery to the colony was fairly stable at a rate of about 0.5 fish $chick^{-1}$ $hr^{-1}$. Wind speed also had a marked effect on the composition of the chicks' diet: the proportion of clupeids gradually decreased from 65% when wind was weak to <50% at wind speed of 16 m $s^{-1}$. Proportions of sandeel and clupeid prey also varied with time of day and state of the tide (Stienen et al. 2000).

Prey brought to the colony by Sandwich terns breeding on Juisi, an East Frisian Wadden Sea island, was studied in June 1997 by Garthe and Kubetzki (1998). Sandeels formed 72.5% of 1,025 prey items, clupeids 27.0%, and other fish species just 0.5%. Prey size ranged from 5 to 16 cm in sandeels (mean = 10 cm: n = 242) and from 5 to 15 cm in clupeids (mean = 9 cm: n = 113), calculated prey mass from <0.5 to 13 g in sandeels (mean = 4 g) and from 1 to 27 g in clupeids (mean = 6 g).

**All of the studies reviewed above indicate that sandeels and clupeids are the main breeding season foods of Sandwich terns in north-western Europe, and that the relative importance of these two prey types varies from year to year, almost certainly in relation to relative abundance of the stocks. There is also consistent evidence of clupeids being more important as chicks get larger, and sandeels being more important when chicks are small. There is some evidence indicating that Sandwich terns tend to forage on clupeids close to the colony and along the coast but may commute further offshore to forage on sandeels over sandbanks, possibly especially when tidal flow brings sandeels closer to the sea surface. Strong winds inhibit foraging by Sandwich terns and may influence their choice of foraging area and prey species.**

## 3.2 Relationship between prey fish abundance and demography of Sandwich tern

All of the studies of Sandwich tern diet reviewed above indicate that while breeding this species feeds mainly on sandeels and clupeids (probably most of the clupeids being sprats at UK colonies as juvenile herring tend to be more abundant in the south-east North Sea rather than in UK waters; Heessen et al. 2015). Brenninkmeier and Stienen (1994) showed that the total breeding numbers of Sandwich terns in the Netherlands correlated with the abundance of juvenile herring in the southern North Sea. They concluded "*the results in this study suggest a relationship between the abundance of young herring and the number of breeding Sandwich Terns, which confirms the findings that food is in short supply for further growth of the population. But in order to draw firm conclusions about such relationship, research on fish abundance of all prey species at the local feeding grounds of the terns is needed*". The relationship between breeding numbers of Sandwich terns in The Netherlands and juvenile herring abundance makes biological sense in that this species feeds extensively on juvenile herring off the coast of The Netherlands. However, at UK colonies, Sandwich terns are less likely to be able to find juvenile herring locally, and so any relationship with the main prey species at UK colonies, would probably be more likely to be with abundances of sandeels and sprats rather than juvenile herring, though all three of these could be important and may differ among regions of the UK.

Relative importance of sandeels and clupeids varies among sites, among years, and with chick age, suggesting that Sandwich tern breeding success, and possibly adult body condition and hence potentially adult survival rate, may be influenced by the abundance of both sandeels and clupeids in the vicinity of the breeding colony. Perrow et al. (2017) state "*although predation is the most conspicuous cause of breeding failure, the abundance, distribution and availability of prey is essential to breeding success*". Brown and Grice (2005) note that breeding Sandwich terns normally forage within 15 km of their colony. They also note that "*overfishing and poor weather are likely to have significant impacts on food availability and hence breeding success*".

Since most Sandwich tern foraging occurs within 15 km of the colony, and foraging at distances greater than 35 km from the colony is exceptional, the prey fish stock relevant to Sandwich tern demography is the prey fish stock within a distance of about 35 km from the colony. However, sandeel and sprat stocks are monitored at much larger spatial scales than this, and so there is a huge mismatch between data on prey fish stocks and fisheries, and the limited areas over which Sandwich terns from any particular colony will be foraging. This kind of spatial mismatch between seabird data and fish stock assessment data is typical (Sydeman et al. 2017). However, in many cases the dynamics of fish stocks is synchronous across large spatial areas so that seabird data can be compared to fish stock data from much larger areas (Sydeman et al. 2017).

Demographic parameter estimates for Sandwich tern are: adult (5 years and older) survival 0.898 (s.e. 0.029), immature (2, 3, 4 year old) survival 0.741, juvenile survival 0.358, age of first breeding 3 years, incidence of missed breeding uncertain, breeding success generally around 0.7 chicks per pair, natal and adult dispersal uncertain (Horswill and Robinson 2015). However, there are no robust time series of annual survival rates of Sandwich tern. There are time series of breeding success from a number of colonies. JNCC Seabird Monitoring Programme data suggest Sandwich tern breeding success in the UK as a whole has shown no trend from 1986 to 2018, but has been rather variable, from almost zero up to 0.7 chicks per pair, but generally around 0.3 chicks per pair

(JNCC 2021). In contrast, breeding success in England has tended to be higher, around 0.5 chicks per pair, but shows some decline from around 0.6 chicks per pair in 1986-2002 to 0.4 chicks per pair in 2004-2015, but higher breeding success, around 0.6, in 2016-2018 (JNCC 2021). Variation in breeding success may be driven by many factors, including prey fish abundance, but also predation impacts at individual colonies, and changes to nesting habitat.

Data on breeding success of Sandwich terns are summarised in Table 3-2-1.

**Table 3-2-1 Summary of breeding success of Sandwich terns at colonies in UK (data from JNCC 2021).**

| Site | SPA | N years of data | Mean chicks fledged per AON |
|---|---|---|---|
| Loch of Strathbeg | Loch of Strathbeg | 14 | 0.317 |
| Sands of Forvie | Ythan Estuary, Sands of Forvie & Miekle Loch | 29 | 0.568 |
| Inchmickery | Forth Islands | 5 | 0 |
| Isle of May | Forth Islands | 5 | 0.169 |
| Long Craig | Forth Islands | 8 | 0.645 |
| Farne Islands | Farne Islands | 2 | 0.356 |
| Coquet Island | Coquet Island | 19 | 0.553 |
| Blakeney Point | North Norfolk Coast | 31 | 0.556 |
| Scolt Head | North Norfolk Coast | 31 | 0.562 |
| Stiffkey/Holkham | North Norfolk Coast | 4 | 0.738 |
| Havergate | Alde-Ore Estuary | 16 | 0.65 |
| Foulness | Foulness | 9 | 0.712 |
| Chichester & Langstone Harbours | Chichester & Langstone Harbours | 9 | 0.226 |
| Hurst Point to Pitts Deep | Solent & Southampton Water | 5 | 0.024 |
| North Solent NNR | Solent & Southampton Water | 13 | 0.502 |
| Brownsea Island | Poole Harbour | 29 | 0.611 |
| Carlingford Lough | Carlingford Lough | 7 | 0.315 |
| Larne Lough | Larne Lough | 1 | 0.396 |
| Strangford Lough | Strangford Lough | 1 | 0.21 |
| Foulney Island | Morecambe Bay & Duddon | 10 | 0.484 |
| South Walney | Morecambe Bay & Duddon | 3 | 0.186 |
| Hodbarrow | Morecambe Bay & Duddon | 25 | 0.444 |
| Cemlyn | Anglesey terns | 28 | 0.728 |
| Ynys Feurig | Anglesey terns | 1 | 1 |

The data (Table 3-2-1) suggest that breeding success is considerably higher at some colonies than others, but this could relate to predator impacts, flooding and human disturbance as much or more than to effects of food abundance.

Within North Norfolk Coast SPA, Sandwich tern breeding success has been monitored in most years at Scolt Head and Blakeney. For those years where both sites were monitored (n=27), there was no correlation in performance between these two sites (Figure 3.2.1; r=0.024, n.s.). The lack of correlation seems to relate to years where breeding success was zero, or extremely close to zero, which in the time series occurred more at Blakeney than at Scolt Head, but in years with zero breeding success at one of these two colonies, breeding success at the other was generally good (Figure 3.2.1). This is consistent with the main cause of breeding failure being predator impact causing failure at a colony in a particular year.

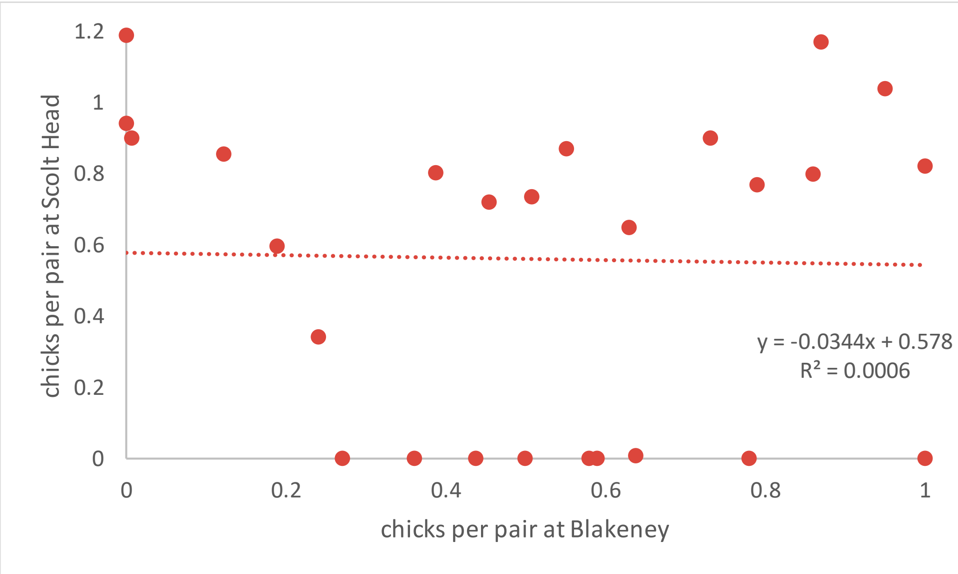


**Figure 3.2.1. Breeding success of Sandwich terns at Scolt Head and Blakeney in years where this has been measured at both sites (data from JNCC 2021).**

Considering only those years in the time series where breeding success was reported for both colonies and was not zero at either colony, there is a positive and statistically significant correlation (Figure 3.2.2; r=0.63, n=15, $p<0.05$). This suggests that, in years when breeding failure was not caused by severe impacts of predators/flooding/human disturbance, the two colonies are being influenced by a common factor affecting productivity, which is likely to be forage fish abundance (Frederiksen and Wanless 2006, Stienen et al. 2015, Fijn et al. 2017) although it could include other factors such as weather conditions which probably also interact with food abundance (Dunn 1973, Taylor 1983, Stienen et al. 2000). Unfortunately, there are no time series of abundances of sandeel or sprat, or fish catch data in the area within a few tens of km of the Sandwich tern colonies in North Norfolk Coast SPA that could be used to test the influence of forage fish abundance directly for these populations.

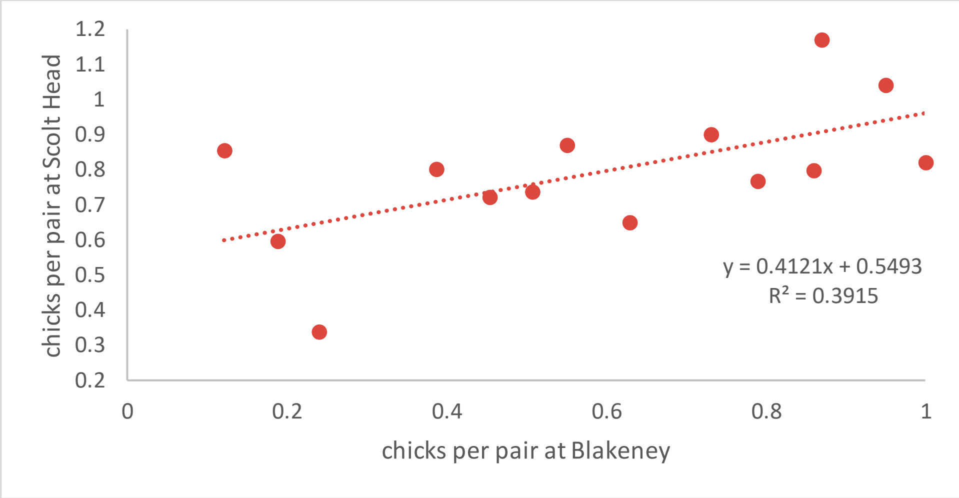


**Figure 3.2.2. Breeding success of Sandwich terns at Scolt Head and Blakeney in years where this has been measured at both sites and breeding success was not zero at either site (data from JNCC 2021).**

Foraging effort and breeding success are strongly influenced by food availability (Stienen et al. 2015, Fijn et al. 2017), with adult body condition at colonies where forage fish are scarce being reduced by high breeding effort, suggesting that shortage of forage fish probably affects adult survival as well as colony breeding success (Stienen et al. 2015). Stienen et al. (2015) suggest that the evidence supports the hypothesis that Sandwich tern parents use their own body mass to evaluate future fitness costs so that the degree of flexibility in parental foraging effort depends on adult body reserves.

Food shortage has been implicated as a cause of reduced productivity at several of the main UK colonies (reviewed in Furness et al. 2013). Considering the situation in eastern Scotland when the sandeel stock collapsed after heavy fishing mortality had been imposed, Frederiksen and Wanless (2006) concluded that '*Sandwich terns may have been affected by reduced sandeel availability during the 1990s in a similar way to black-legged kittiwakes*'.

**These results together strengthen the evidence that measures to increase abundance of sandeels, sprats and juvenile herring in waters near to Sandwich tern colonies can be expected to result in an increase in breeding success, and probably an increase in adult survival, of Sandwich terns.**

## 3.3 Sandeel and sprat stocks likely to influence NNC SPA Sandwich tern food availability, the likely impact of fisheries on those stocks, and therefore the feasibility of reducing fishing mortality as a compensation measure

### 3.3.1 Sandeel

Sandeels in the North Sea are mostly the lesser sandeel *Ammodytes marinus*. This is the target of the sandeel fishery, mostly carried out by Danish vessels, with the catches mostly used to prepare fish oils and fish meal. For many years the sandeel resource of the North Sea was treated as two stocks, a minor stock at Shetland, and a much larger stock distributed around the rest of the North Sea. However, the sandeel resource is now treated as seven distinct management units in different parts of the North Sea. Sandwich terns at a particular colony will be influenced by the sandeel stock closest to their colony. In the case of Loch of Strathbeg SPA, Ythan Estuary, Sands of Forvie, and Meikle Loch SPA, Forth Islands SPA, Farne Islands SPA, and Coquet Island SPA, the relevant sandeel stock is the ICES sandeel management area 4 stock (Figure 3.3.1). In the case of North Norfolk Coast SPA, Alde-Ore Estuary SPA, and Foulness SPA, the relevant sandeel stock is the ICES sandeel management area 1r stock (Figure 3.3.1).

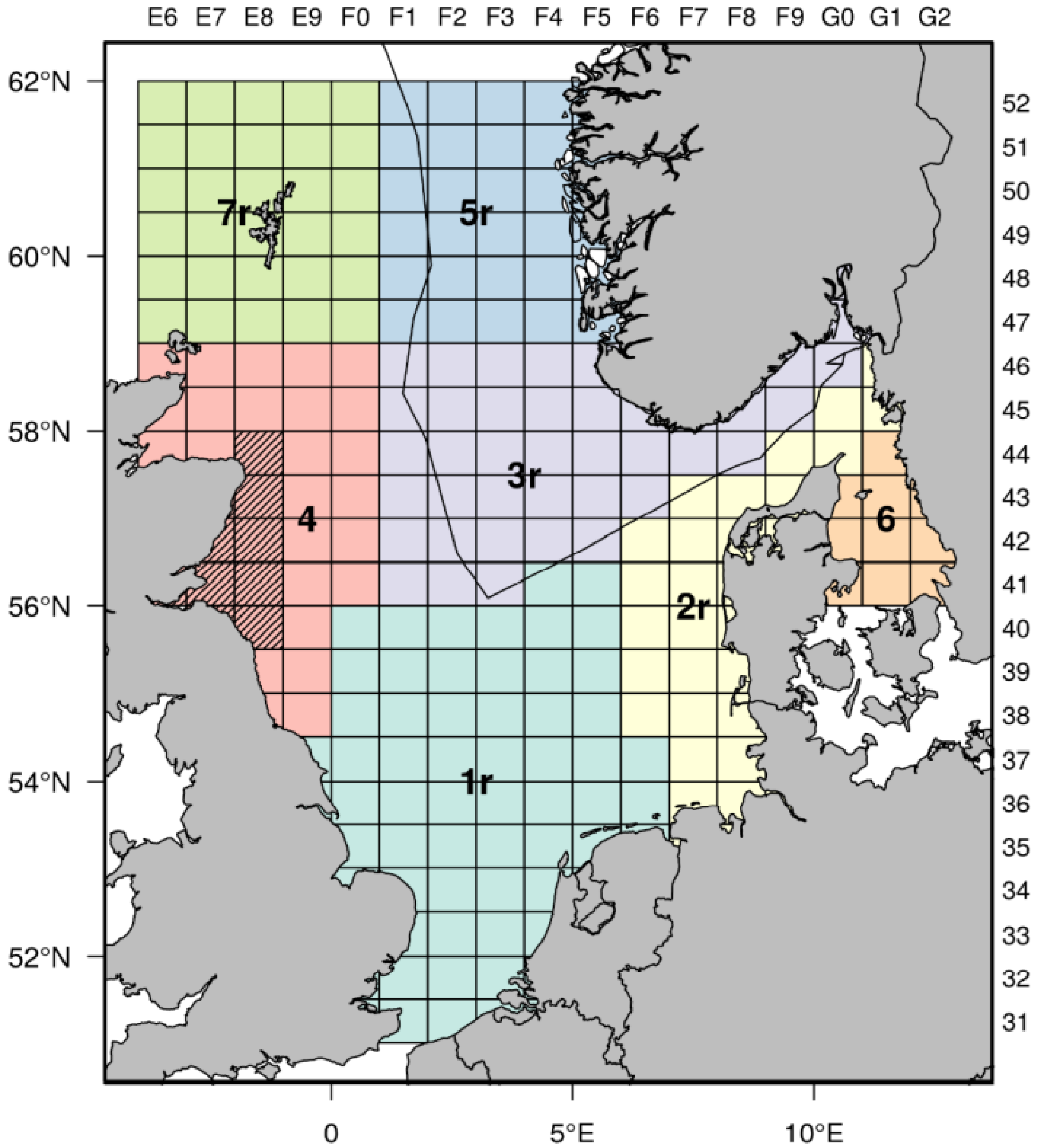


**Figure 3.3.1. Sandeel in the North Sea: Stock areas for the seven sandeel stocks. The border of the Norwegian Exclusive Economic Zone (EEZ) is also shown. The closed part of Sandeel Area 4 is shown with hatched markings.**

Frederiksen and Wanless (2006) reviewed the evidence that the closure of sandeel fishing off east Scotland from 2000 increased productivity of seabirds. They found clear evidence that the closure resulted in increased productivity of kittiwakes within the study area compared with a control area outside the closure zone, results which agreed with the earlier findings of Frederiksen et al. (2004) that the sandeel fishery in this area reduced productivity of kittiwakes on the Isle of May during the years of the fishery. 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). Analysis of productivity data for monitored colonies of other seabirds was based on much smaller sample sizes and showed less clear results due to high stochastic variation. However, for Sandwich tern the pattern was similar, within the study zone there was higher productivity in no fishery years (0.62 chicks per pair) than in fishery years (0.38 chicks per pair) whereas productivity in the control area was consistently high. However, high variation and small sample size (there were only two colonies within the closure zone) resulted in this difference not being statistically significant. Data on Sandwich terns in the closure zone showed that the colony at Sands of Forvie was more or less completely deserted from 1992-1998 during the peak period of the sandeel fishery off east Scotland, and that this species did not breed on the Isle of May until 1999. Combined with the observed (non-significant) reduction in productivity in the closure zone during the fishery years, Frederiksen and Wanless (2006) concluded that '*this suggests that Sandwich terns may have been affected by reduced sandeel availability during the 1990s in a similar way to black-legged kittiwakes*'.

The abundance of sandeels in ICES area 4 (which includes the sandeel no-take box off east Scotland) declined during 1993-2001 (Figure 3.3.2). However, after the closure of the sandeel fishery off east Scotland, this stock eventually recovered (Figure 3.3.3).

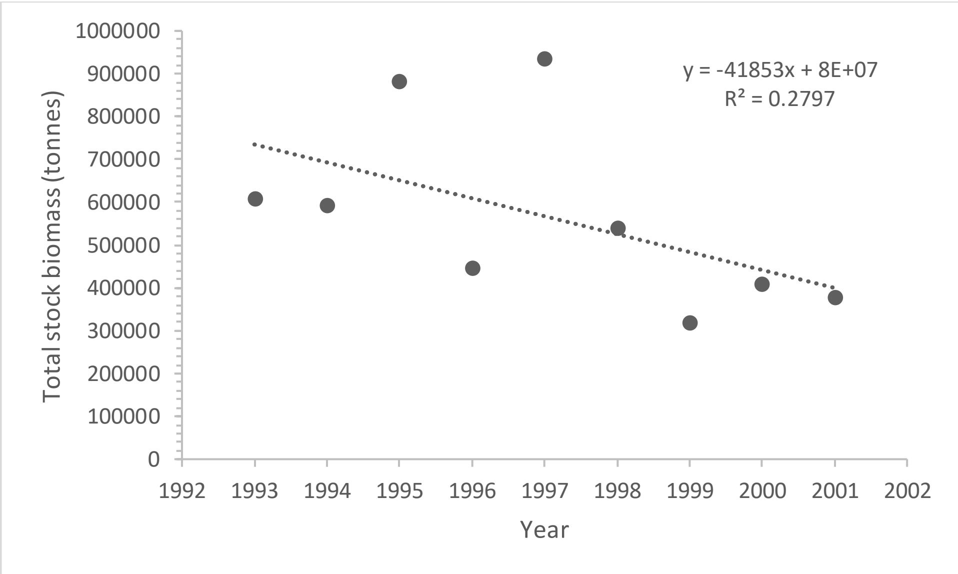


**Figure 3.3.2. Abundance (total stock biomass in tonnes) of sandeels in ICES area 4 (which includes the no-take zone off east Scotland that was established in 2000) in the period 1993 to 2001. Data from ICES (2020).**

Sandeel catches from ICES area 4 decreased considerably when the sandeel no-take box was established off east Scotland, but a large part of ICES area 4 remained open to sandeel fishing. Commercial catch from the open part of area 4 was low in 2005 to 2012 because the stock biomass had been depleted and so commercial fishing was no longer sufficiently profitable to justify fishing in that area (while better catches could still be obtained elsewhere such as area 1r Dogger Bank). However, as sandeel stock began to recover in area 4 the potential profitability of fishing there increased. Commercial catches have increased considerably in the last few years (Figure 3.3.4). The return to high fishing effort on sandeel in area 4 threatens to impact this recovering stock again, with potential effects on Sandwich tern numbers, breeding success, and adult survival in east Scotland.

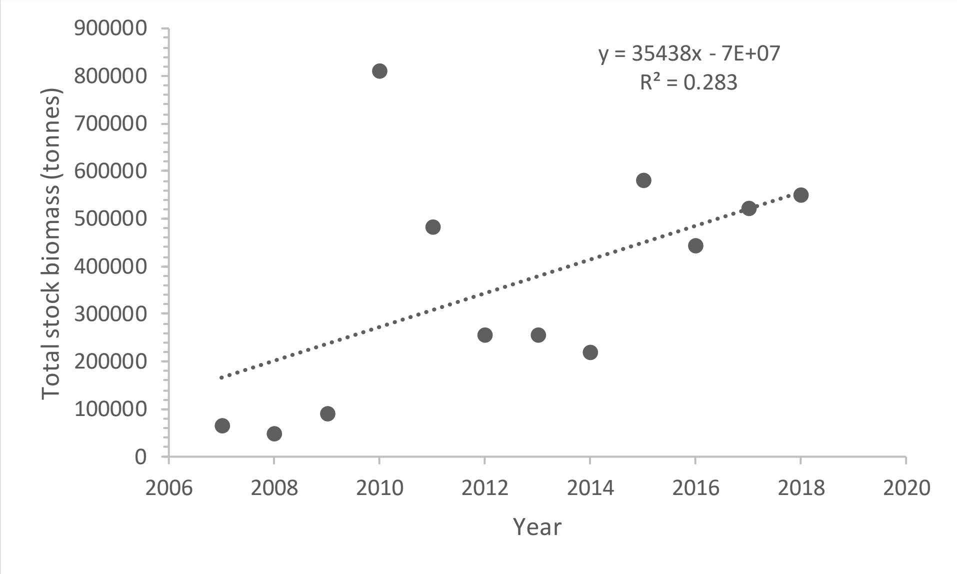


**Figure 3.3.3. Abundance (total stock biomass in tonnes) of sandeels in ICES area 4 (which includes the no-take zone off east Scotland that was established in 2000) in the period 2007 to 2018. Data from ICES (2020).**

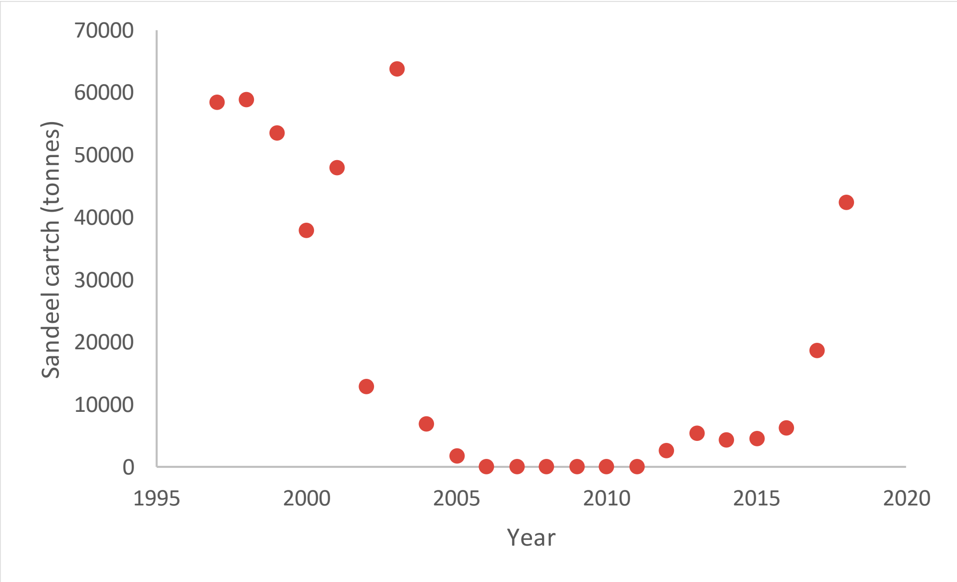


**Figure 3.3.4. Catch (tonnes) of sandeel by the commercial sandeel fishery in ICES area 4 from 1997 to 2018 (data from ICES 2020). Note that the sandeel no-take box was established in 2000 but fishing in parts of area 4 that are outside the box was permitted throughout the period and the low catch from 2005 to 2015 was due to low stock biomass and not just to the existence of the no-take box in part of area 4.**

At present, the sandeel stock in ICES area 1r (often known as the Dogger Bank stock) remains considerably below its long term average abundance and is subject to a fishing mortality around F=0.6 (ICES 2020), a figure above the level tested in the scenario of Lindegren et al. (2018), and a figure which their scenario modelling clearly demonstrates has a negative impact on sandeel abundance. Indeed, at present the spawning stock biomass in this area 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 an increased risk of recruitment failure in this stock (ICES 2020).

Cury et al. (2011) used empirical evidence from several seabird-fishery interactions around the world to suggest that management should aim to keep food fish stocks such as sandeels and sprats 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. Maximum total stock biomass in ICES area 1r was just below 2,000,000 tonnes during the 1980s at a time of high fishing effort, so likely to be reduced relative to unfished biomass (Lindegren et al. 2018). Nevertheless, if we take 2,000,000 tonnes as maximum biomass for this stock, then the Cury et al. (2011) threshold to avoid impacts on dependent predators such as Sandwich terns would be a fished total stock biomass of 666,667 tonnes. Using this rule of thumb, the sandeel fishery has been harvesting from a stock biomass that was below this threshold abundance in 13 of the 16 years 2003-2018 (ICES 2020). The long-term deterioration of this heavily fished stock and its tendency to be below the Cury et al. (2011) threshold in recent years is clear in Figure 3.3.5.

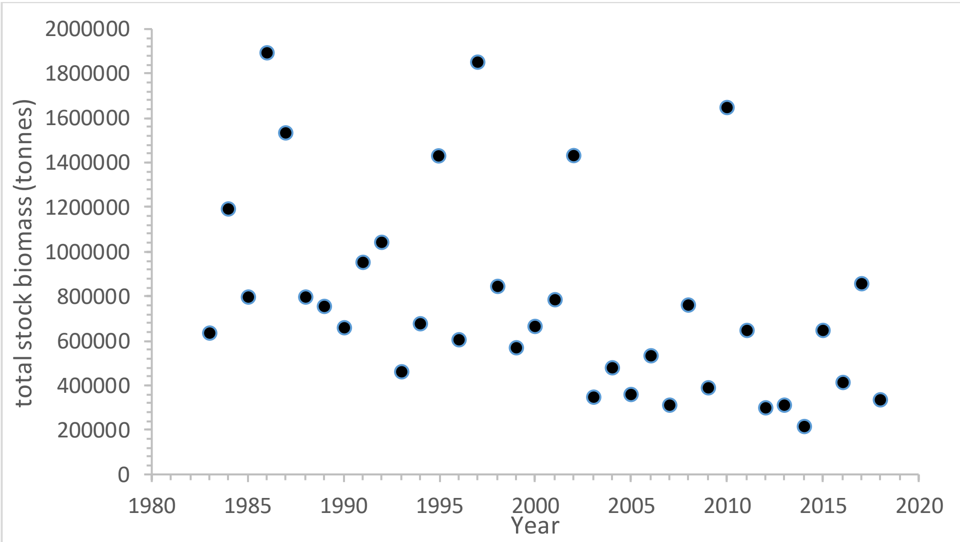


**Figure 3.3.5. Total stock biomass (tonnes) of sandeels in ICES area 1r (Dogger Bank stock) from 1983 to 2018 (ICES 2020), in relation to the Cury et al. (2011) 'rule of thumb' that stock biomass should be maintained above one-third of the historical maximum (in this case above 666,667 tonnes) to avoid adverse impacts on dependent seabird populations.**

**Continuation of sandeel fishery under existing ICES management advice is likely to continue to have an adverse impact on Sandwich tern numbers and demography at colonies in the east of England.**

### 3.3.2 Sprat

The sprat is a small, schooling clupeid. In the North Sea, sprats are most abundant in relatively shallow waters of about 20 to 50 m, and are highly tolerant of low salinity, so often aggregate in estuarine areas. Sprats feed on zooplankton, so move up into the surface waters to feed, where they can be caught by surface-feeding seabirds such as terns. The highest concentrations occur in the southern part of the North Sea, especially south-east of a line from northern Denmark to Yorkshire, and particularly east of Dogger Bank (Heessen et al. 2015). However, there are also high local concentrations in inshore areas that are not well surveyed by ICES surveys, such as in the Firth of Forth (Fernandez et al. 2005, Jennings et al. 2012). Heessen et al. (2015) indicates high concentrations of sprats inshore at the Moray Firth, Aberdeenshire, Firth of Tay, Firth of Forth, Northumberland, The Wash, Lowestoft, and the Outer Thames. The areas between these inshore stocks and the offshore stock hold lower densities of sprats (Heessen et al. 2015). These inshore stocks are thought to be separate from the main North Sea stock, with independent dynamics. Little is known of the local inshore stocks, and there is a risk that exploitation of those local stocks may be unsustainable, and certainly cannot be managed with the existing stock assessment and quota setting system (ICES 2018, 2021). However, there may also be exchange between the main North Sea sprat stock and these local inshore stocks. Indeed, the inshore stocks may depend on immigration of juvenile fish from the offshore stock, so their abundance may be strongly influenced by fishing mortality not only locally, but also on the more extensive offshore stock, as juvenile sprats are often found in dense schools in shallow coastal waters (Heessen et al. 2015). Sprats are short-lived, rarely attaining an age of >5 years, and first spawn when 1 or 2 years old (Heessen et al. 2015). Lindegren et al. (2020) show that North Sea sprat growth is influenced by sprat stock density (density-dependence) and by climate. Most fishing on sprat is for reduction to fish meal. Most of the catches in the North Sea are taken by Danish fishing boats, with variable amounts taken from UK waters in different years (Figure 3.3.6). In 2020, the total catch was 179,746 tonnes, of which 84% was taken by Danish fishermen, most of the remaining 16% by Norway, Germany and Sweden (ICES 2021). UK fishermen typically take between 500 and 3,500 tonnes per year, with much of the UK catch taken from local coastal stocks (ICES 2021).

Keyl (2017) mapped the distribution of sprat in the North Sea (Figure 3.3.7) and showed a pattern closely similar to that of the distribution of fishery catches (Figure 3.3.6). But note that the mapping did not include coastal areas that can hold high local densities of sprats, such as Moray Firth, Firth of Forth, The Wash, Outer Thames. Sprat abundances can be much higher in these small areas of inshore estuarine habitat, as reported by Johnson et al. (1982) who found densities in the Outer Thames and the Wash 10 to 200 times higher than found in the open sea. Sprat abundance peaks in the Thames Estuary in mid-winter (Power et al. 2000) and supports a local fishery (Colclough et al. 2002). Similarly, sprat abundance can be high inshore along the Suffolk coast in winter, where it supports a local fishery, and the tidal movements over coastal sandbanks can make sprats available at the surface to flocks of kittiwakes and other gulls (Dare and Read 2007).

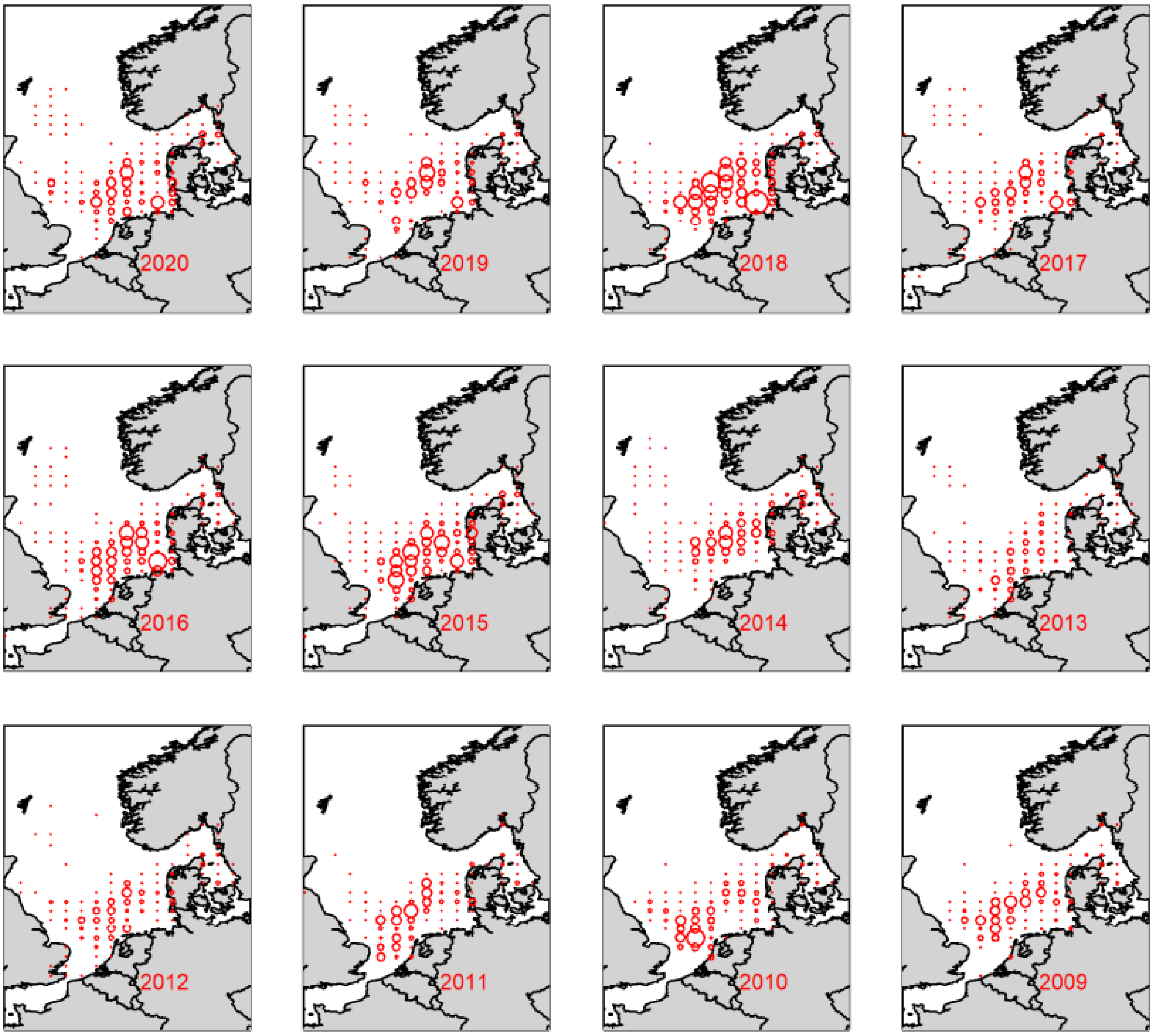


Figure 3.3.6. Sprat catches in the North Sea and Division 3.a (tonnes) for each calendar year by ICES statistical rectangle. From ICES (2021).

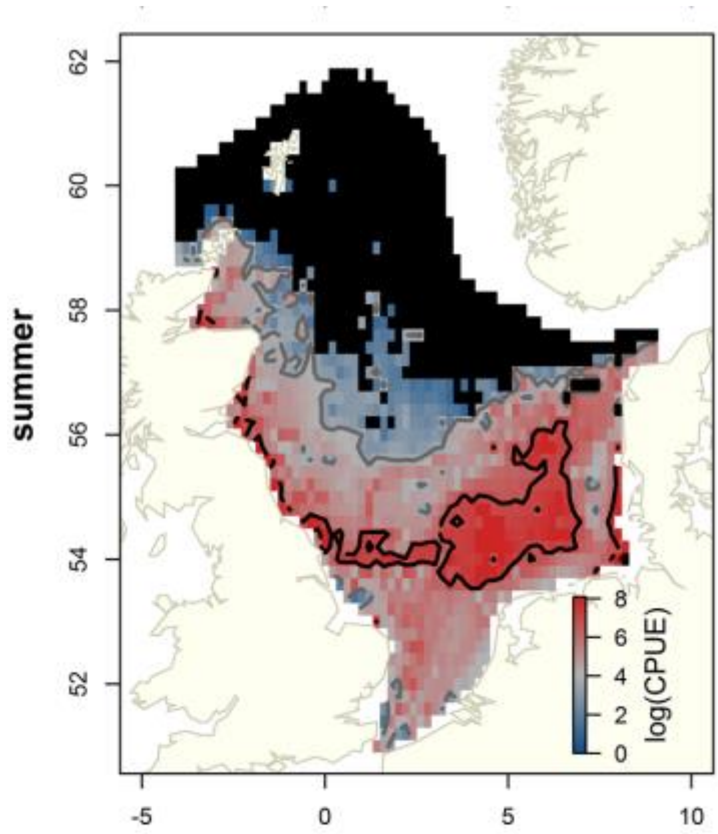


**Figure 3.3.7. Abundance of sprat in the main North Sea stock in summer. From Keyl (2017).**

In 2018, ICES decided to manage the entire North Sea (ICES Division 4) plus the Skagerrak-Kattegat (ICES Division 3a) as a single management unit for sprat stock assessment and setting of sprat fishery quota. This decision was made based on study of sprat genetics which found no significant differences in genotype between sprats in Divisions 3a and 4, and a correlation of the time series of abundances of sprat in these two areas suggesting that these populations are subject to the same drivers of abundance/demography. However, ICES also highlighted that peripheral areas have local stocks of sprats that appear to behave as separate stocks from the main stock, and therefore fishing that targets local peripheral stocks could cause local depletion and ecological problems that cannot be managed by assuming all sprat in Divisions 3a and 4 are a single coherent management unit.

According to ICES (2021) there is no management plan for the North Sea sprat fishery. ICES (2021) states "*A management plan needs to be developed for this stock. Sprat is an important forage fish; thus, also multispecies considerations should be made*". This implies that not only is there no management plan for the fishery, but also the ecosystem interactions between sprat stocks and other ecosystem components, such as seabirds, have not been considered in detail. Nevertheless, ICES (2021) states "*there are several peripheral areas of the North Sea and Division 3.a where there may be populations of sprat that behave as separate stocks from the main stock. Local depletion of sprat in such areas can be an issue of ecological concern*". ICES (2021) also states, "*The influence of the sprat fishery on other fish species and seabirds are at present not documented*".

The text on Ecosystem considerations in the Benchmark Report of 2018 (ICES 2018) states "*predation impacts are taken into account explicitly in the stock assessment for North Sea sprats by* *including annual estimates of natural mortality imposed by predators based on predator abundances, prey preferences and abundances of other prey stocks*". Thus, the ecosystem considerations do consider the impact of seabirds on sprat stocks by explicitly including seabird consumption of sprats in the stock assessment model. However, the ecosystem considerations fail to take any account of the impact of sprat stock depletion by the fishery on prey availability for seabird populations. The ecosystem considerations are one-sided, despite clear evidence that depletion of prey fish stocks can have severe impacts on dependent wildlife such as seabirds and so establishing reference points for fish stock management to protect seabird populations is entirely possible as well as highly desirable, and indeed essential if ecosystem-based management of fish stocks is to be achieved in future (Cury et al. 2011, Sydeman et al. 2017, Hill et al. 2020, Saraux et al. 2021).

The local sprat stock and fishery in the Firth of Forth provides a useful case study. That stock was the target of a locally based reduction fishery (a fishery to manufacture fishmeal and oil) that harvested a total of 88,000 tonnes between 1966 and 1980 from this small local stock (Marine Scotland Database). As mean sprat mass in this fishery was only a few grammes (Appendix 2 in Fernandez et al. 2005), this is equivalent to tens of billions of fish, a large harvest from a relatively small sea area. This fishery was mainly carried out by small boats from ports in Fife, on the north shore of the Firth of Forth, using light trawl gear (Fernandez et al. 2005). After 1980, catches fell to extremely low levels as the stock collapsed (Fernandez et al. 2005), and the fishery was progressively abandoned by local fishers in the early 1980s due to the lack of a profitable catch rate. It ceased completely in 1985. It has never reopened, although sprat abundance in the Firth of Forth has subsequently recovered (Fernandez et al., 2005). There have been many attempts since the late 1990s by local fishers to argue that sprat fishing in the Firth of Forth should be allowed to resume. To date, these have been rejected by the Scottish Government. One consequence of this has been a recovery of the common tern population in the Firth of Forth that had declined when the sprat stock collapsed (Jennings et al. 2012) and which feeds predominantly on sprats while breeding. Jennings et al. (2012) concluded "*The data clearly show that tern numbers were reduced in the region when sprat abundance was too low to sustain a fishery and that numbers subsequently recovered to be similar to numbers before the sprat stock collapse*."

Defra (2021) report in the context of sprat fisheries that, "*Delegations noted that, since 2019, the International Council for the Exploration of the Sea (ICES) advice for sprat encompasses both the North Sea and Skagerrak/Kattegat and considers this a single stock. The parties agreed that as a consequence, the stock should now be reviewed through the trilateral consultations between the European Union, Norway and the United Kingdom. The Norwegian and the European Union Delegations noted that, in 2020, they agreed on a method to distribute the ICES single stock advice, which resulted in an allocation of 18.3% of the overall advice as the basis for setting the TAC for the Skagerrak/Kattegat. The United Kingdom delegation noted that it had not, in its own right, been party to that 2020 decision on allocation. It further noted that the 2018 ICES bench-marking exercise for the stock had proposed a variety of metrics which could guide the decision on allocating the TAC between the 2 areas in addition to the use of historic TACs. It urged the parties to adopt an allocation method which more accurately reflects the spatial distribution of the resource. The Norwegian Delegation agreed with the UK delegation that, as a principle, allocation methods should reflect the spatial distribution of fish stocks.*

*The Delegations agreed to recommend to their respective authorities the following fishery arrangements for the period 1 July 2021 to 30 June 2022, as outlined in this Agreed Record. The*

*Delegations noted that ICES released the advice on sprat in Division 3a and Subarea 4 (Skagerrak, Kattegat and North Sea) on 13 April 2021. Based on its Maximum Sustainable Yield (MSY) approach, ICES advises that catches in the Skagerrak, Kattegat and North Sea for the period from 1 July 2021 to 30 June 2022 should be no more than 106,715 tonnes. The Delegations agreed to apply a split of the TAC between North Sea and Skagerrak which would allocate 18.3% of the TAC to the Skagerrak in the period 1 July 2021 to 30 June 2022. The Delegations consequently agreed to establish a TAC for sprat in ICES Division 3.a (Skagerrak and Kattegat) of 19,529 tonnes and for ICES Subarea 4 of 87,186 tonnes for the period 1 July 2021 to 30 June 2022. This is a decrease of 49% compared to the previous TAC period. The Delegations agreed to work in order to increase the quality of the scientific advice for sprat in ICES Division 3a and Subarea 4, both in the short and longer term. For the period 1 July 2021 to 30 June 2022, should surveys undertaken later in 2021 indicate that there may be a significant change in the stock abundance, Delegations will consult further ahead of the 2022 to 2023 annual consultations*."

In the Clyde Sea area, herring stock collapsed as a consequence of overfishing in the latter half of the 20th century (Lawrence and Fernandes 2021). These authors carried out acoustic surveys of pelagic fish abundance in the Clyde Sea area in 2014 to 2016 and compared the results with similar acoustic surveys in the 1980s. They found up to a 100-fold increase in forage fish biomass between the 1980s and 2014-2016, with sprat contributing most of the increase and little or no recovery of herring. In this context, it is interesting that the numbers of juvenile Sandwich terns seen in the Clyde have reached the highest totals ever recorded, in the last few years (Machrihanish Seabird Observatory 2021), suggesting a reversal of the decline reported to have followed the demise of the herring stock in the 1960s-1980s (Monaghan and Zonfrillo 1986). However, there is now increasing pressure from local fishermen to reopen the Clyde clupeid stocks to fishing, and if that occurs then the recovery of tern numbers in the Clyde may be short-lived (Lawrence and Fernandes 2021).

**Local stocks of sprats in coastal areas of east England and east Scotland may be especially important for breeding Sandwich terns, but evidence suggests links between these local stocks and the wider North Sea sprat stock. Reductions in fishing pressures on sprat stocks would be expected to result in an increased breeding success, and probably increased adult survival of Sandwich terns.**

## 3.4 Conservation status of Sandwich terns at UK colonies

The International Union for Conservation of Nature classify Sandwich tern among species of 'Least Concern'. Birds of Conservation Concern issues 2, 3, and 4 all classified Sandwich tern as Amber. The EU Birds Directive list Sandwich tern in Annex 1 and as a migratory species. Sandwich tern breeding numbers in the UK increased from the 1920s to the mid-1980s, after major reductions caused by human exploitation and hunting (JNCC 2021). National surveys showed an increase in the UK population of 33% from 1969 to 1986, but a decrease of 15% from 1986 to 2000 (JNCC 2021). JNCC SMP data show no clear long-term trend for UK breeding numbers between 1986 and 2018, with the index in 2018 almost the same as in 1986 (JNCC 2021). However, JNCC SMP data suggest a decline in Scotland, the index in 2018 being about half that in 1986, though based on small sample sizes (JNCC 2021). Ratcliffe et al. (2000) identified "*localised events at individual colonies rather than widespread declines across its range*" as the cause of decreases in breeding numbers at some colonies in Britain in 1969 to 1998. They particularly identified abandonment of colonies at Sands of Forvie, Foulness, Havergate, and Foulney as being caused by fox predation. Mitchell et al. (2004) concluded "*only colonies on [predator-free] offshore islands are immune from attack, and these are scarce within the Sandwich tern's British and Irish range. Restoration of existing offshore islands or creation of new islands from dredge-spoil may be necessary to maintain Sandwich tern populations into the 21st century*".

Stroud et al. (2016) listed 13 SPAs in Great Britain with Sandwich tern as a breeding feature, three in Scotland (Loch of Strathbeg SPA; Ythan Estuary, Sands of Forvie and Meikle Loch SPA; Forth Islands SPA;), nine in England (Farne Islands SPA; Coquet Island SPA; North Norfolk Coast SPA; Alde-Ore Estuary SPA; Foulness SPA; Chichester and Langstone Harbours SPA; Solent and Southampton Water SPA; Duddon Estuary SPA; Morecambe Bay SPA) and one in Wales (Ynys Feurig, Cemlyn Bay and The Skerries SPA, now known as Anglesey terns SPA). Since the Stroud et al. (2016) review, Poole Harbour SPA has been designated, with Sandwich tern as a breeding feature, increasing the proportion of the GB breeding population that is within SPAs designated with Sandwich tern as a breeding feature. Also, Duddon Estuary SPA and Morecambe Bay SPA have been amalgamated into Morecambe Bay & Duddon SPA.

Stroud et al. (2016) listed 3 SPAs in Northern Ireland with breeding Sandwich tern as a feature (Carlingford Lough; Larne Lough; and Strangford Lough). The SPAs for breeding Sandwich tern in Great Britain were estimated to hold during the 2000s a total of 7,932 pairs out of a national population estimate of 11,000 pairs, so about 72% of the GB breeding population of this species (Stroud et al. 2016). The three sites in Northern Ireland held a further 1,302 pairs, which represented about 35% of the all-Ireland total during the 2000s (Stroud et al. 2016).

Three sites were listed in the 3$^{rd}$ UKSPA review as designated for nonbreeding (passage) Sandwich terns (Stroud et al. 2016). These are Firth of Forth SPA (classified 30 October 2001, a winter peak mean count of 1,617 Sandwich terns 1993/94 to 1997/98) Teesmouth and Cleveland Coast SPA (classified 1995, 1,900 Sandwich terns in autumn 1988-1992) and The Dee Estuary SPA (classified 17 July 1985, revised 10 December 2009, 957 Sandwich terns 5-year mean 1995-1999). The more recently designated Northumberland Marine SPA includes Sandwich tern as a feature, incorporating the Farne Islands SPA and Coquet Island SPA breeding populations of Sandwich terns, and citing their breeding populations (2010 to 2014) as means of 862 pairs and 1,300 pairs respectively.

Most Sandwich tern colonies in the UK are large, and many are located on RSPB or National Trust sites where wardens routinely census breeding numbers each year. As a result, data on breeding numbers of Sandwich terns are exceptionally detailed for all the largest colonies, and these data are available online in the JNCC Seabird Monitoring Programme database, expressed as 'pairs' which are equivalent to 'Apparently Occupied Nests – AONs' (JNCC 2021). The data include the sites where Sandwich tern is a SPA breeding feature. However, few sites that are not designated SPAs for this species hold large numbers of breeding Sandwich terns, and the coverage of non-SPA sites for Sandwich tern is very much less detailed in the SMP database (JNCC 2021).

Before considering each breeding Sandwich tern SPA population in turn, it may be useful to consider the suite of Natura 2000 sites with breeding Sandwich tern as a feature. Details are summarised in Table 3.4.1.

**Table 3-4-1 Summary of UK Natura 2000 Sandwich tern breeding feature suite**

| SPA | Years of count data used for designation | Pairs in citation | Most recent published count | Year of most recent count | Percent change |
|---|---|---|---|---|---|
| **Loch of Strathbeg** | 1985-1990 | 280 | 0 | 2015 | -100 |
| **Sands of Forvie, Ythan Estuary & Meikle** | 1989-1991 | Up to 1,125 | 1,000 | 2020 | ca.0 |
| **Forth Islands** | 1980s | 440 | 10 | 2019 | -98 |
| **Farne Islands** | 2010-2014 | 862 | 417 | 2019 | -52 |
| **Coquet Island** | 1987-1991 | 1,500 | 1,652 | 2019 | +10 |
| **North Norfolk Coast** | 1992-1996 | 3,700 | 6,585 | 2020 | +78 |
| **Alde-Ore Estuary** | 1992-1996 | 170 | 0 | 2018 | -100 |
| **Foulness** | 1992-1996 | 320 | 0 | 2019 | -100 |
| **Poole Harbour** | 2010-2014 | 181 | 174 | 2015 | ca.0 |
| **Chichester & Langstone Harbours** | 1993-1997 | 31 | 0 | 2019 | -100 |
| **Solent & Southampton Water** | 1993-1997 | 231 | 93 | 2020 | -60 |
| **Anglesey Terns** | 1993-1997 | 460 | 1,972 | 2020 | +329 |
| **Morecambe Bay & Duddon** | 1988-1992 | 804 | 805 | 2019 | 0 |
| **Carlingford Lough** | 2000-2004 | 717 | 24 | 2019 | -97 |
| **Larne Lough** | 1993-1997 | 189 | 1,010 | 2019 | +434 |
| **Strangford Lough** | 1992-1997 | 593 | 252 | 2020 | -58 |
| **Entire SPA suite** | | **11,603** | **14,004** | | +21 |

The most recent counts (most of which are from 2020 or 2019) show that the UK Natura 2000 suite for breeding Sandwich terns currently holds about 14,000 birds, whereas at designation of these sites the total was around 11,600. Although there have been decreases at several SPA sites, the increases at other sites are considerably greater than the decreases. Overall, the SPA suite holds about 21% more breeding Sandwich terns than the numbers on which designation of these sites was founded.

### 3.4.1 Loch of Strathbeg SPA

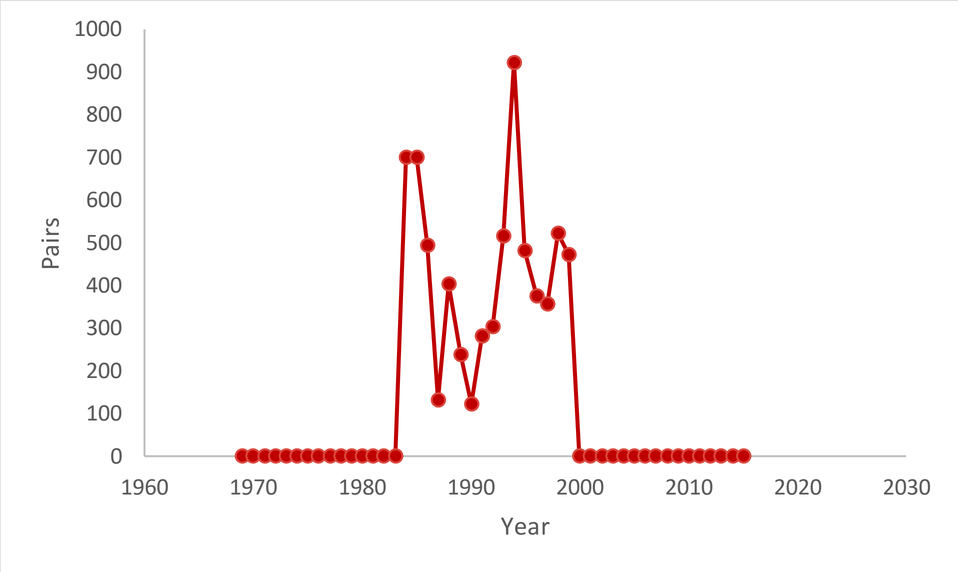


**Figure 3.4.1. Numbers of pairs of Sandwich terns nesting at Loch of Strathbeg SPA 1969-2021 (data from JNCC 2021) downloaded 31/8/2021.**

Loch of Strathbeg is an RSPB reserve as well as an SPA. The site was designated as an SPA on 27 November 1995. At designation, the Sandwich tern feature was based on a mean of 280 pairs (1985-1990). Sandwich tern breeding was disrupted by fox predation in 1993, resulting in 0.08 chicks per pair that year compared to 0.49 in the previous year when foxes were not active at the colony (Walsh et al. 1994). Numbers at Loch of Strathbeg fell to zero in 2000, and this appears to have been due to predator impacts at that colony, although other factors apparently cannot be ruled out, and there seems to be little published about Sandwich terns at this site. Following severe impacts from fox predation, the islands on which terns had nested were damaged by erosion, and restoration work by RSPB in 2007 was unsuccessful. Furthermore, the birds that do breed on the islands (black-headed gulls and common terns) are now subject to heavy predation by otters (RSPB management plan, cited by NatureScot in litt.). According to NatureScot Sitelink (viewed 1/9/2021) the conservation status of the Sandwich tern feature at Loch of Strathbeg SPA is "*Unfavourable no change*" as updated on 31 July 2013. However, there is a note that "*Management measures are in place that should, in time, improve the feature to Favourable condition (Unfavourable Recovering Due to Management)*". There are no breeding records of Sandwich tern at Loch of Strathbeg SPA since the assessment in 2013, so that management has yet to provide any detectable improvement. NatureScot (Dr Andy Douse in litt.) provided the following information, taken from the reserve management plan "*Sandwich terns used to nest on the islands in the loch. These have been lost since 2001 due to erosion. Artificial islands were provided but have not to date resulted in the re-colonisation of terns, possibly due to predation by otters and competition from other bird species. The plan recognises the importance of this species and provides appropriate proposed actions. Sandwich tern is a coastal lagoon reserve priority species in the new Reserves Strategy. We will maintain the bigger of the loch islands, managing the vegetation annually to provide suitable nesting habitat for the terns. If/when they do abandon Forvie and/or return we may need to put more resources into managing the islands e.g. predator proofing the island, or creating rafts*".

Based on the failure of the present provision of nesting platforms at Loch of Strathbeg to provide predator-free breeding habitat for terns, there would seem to be an opportunity for development of predator-proof platforms for terns at this site using the proven model of mink-proof tern platforms developed by Dr Clive Craik and deployed at sites in Argyll, but neither RSPB nor NatureScot has had sufficient financial resource available to be able to provide the resources required to achieve this in the 21 years since Sandwich terns abandoned this SPA.

### 3.4.2 Sands of Forvie, Ythan Estuary and Meikle Loch SPA

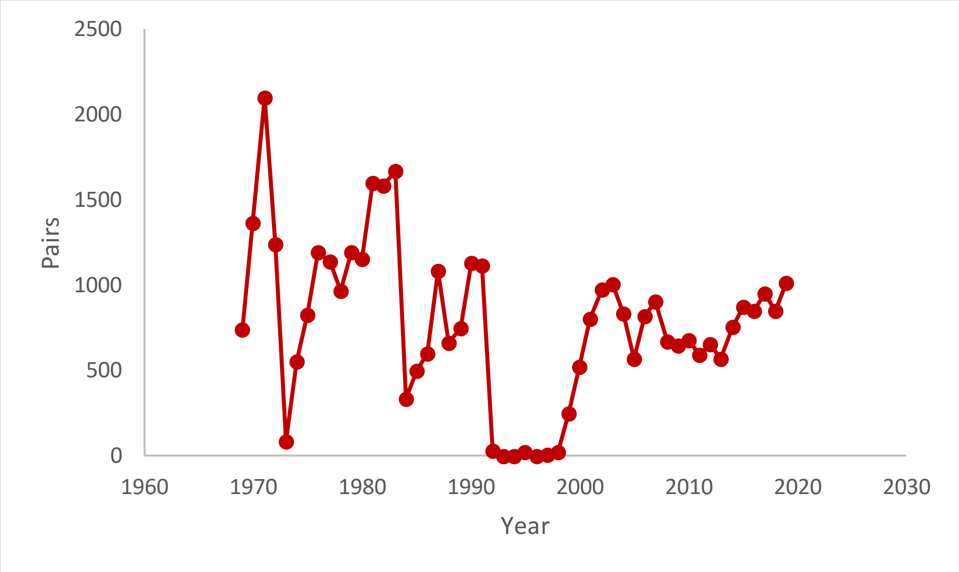


**Figure 3.4.2. Numbers of pairs of Sandwich terns nesting at Sands of Forvie, Ythan Estuary and Meikle Loch SPA 1969-2021 (data from JNCC 2021) downloaded 31/8/2021.**

Disturbance and predation have been major impacting factors on the breeding success of terns at Forvie in the past. Predation of birds and eggs by foxes, stoats, crows and gulls has been common in some years, and may be exacerbated by disturbance from human visitors and dogs (Short 2020).

Sandwich tern breeding numbers at Sands of Forvie dropped from over 1,500 pairs in 1983 to only 315 pairs in 1984 as a result of predation by foxes in that colony (Forrester et al. 2007). Electric fencing was used to exclude foxes and numbers recovered between 1985 and 1990, but the exclusion of foxes was not fully effective. In 1991, foxes took most chicks in the colony (Walsh et al. 1992) and that led to colony desertion in 1990 to 1999, followed by another recovery after 2000 with more effective electric fencing (Figure 3.4.2). However, productivity in 2003 was reduced by predation by stoats and large gulls (Mavor et al. 2004).

Ythan Estuary, Sands of Forvie and Meikle Loch SPA was designated on 30 March 1998, with the citation document noting "*up to 1,125 pairs*" of Sandwich terns in 1989-1991. According to NatureScot Sitelink (viewed 1/9/2021) the conservation status of the Sandwich tern feature at Ythan Estuary, Sands of Forvie and Meikle Loch SPA is "*Favourable Maintained*" as updated on 1 August 2012. Although not yet included in the JNCC database and so missing from Figure 3.4.2, there were estimated to be 1,000 pairs of Sandwich terns nesting at the site in 2020 (Short 2020). This is an example of successful management that has maintained good breeding numbers and breeding success of Sandwich terns in most years, with electric fence exclusion of foxes being a key management measure at this site (Short 2020), now after many years of experience providing an outstanding example of best practice that could be adopted elsewhere.

### 3.4.3 Forth Islands SPA

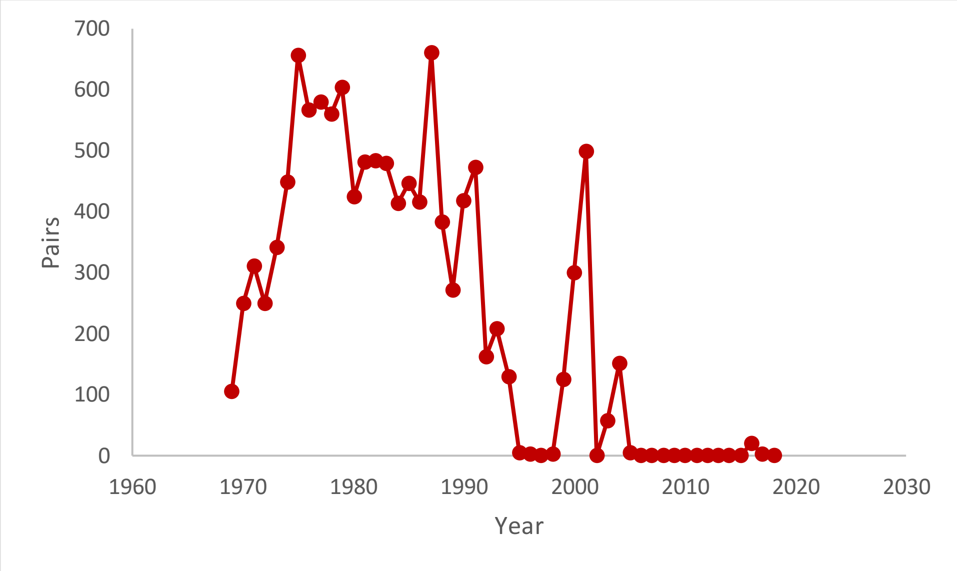


**Figure 3.4.3. Numbers of pairs of Sandwich terns nesting at Forth Islands SPA 1969-2021 (data from JNCC 2021) downloaded 31/8/2021.**

The Forth Islands SPA has held breeding Sandwich terns on Isle of May, Inchmickery, Fidra, and Long Craig. The terns have moved between these sites. Between 1926 and 1956 up to 1,500 pairs nested on the Isle of May, but these deserted as herring gull numbers grew and rabbit numbers decreased, resulting in development of rank nitrophilous vegetation that made the nesting site unsuitable for Sandwich terns (Forrester et al. 2007). Although at the time the increase in gull numbers was considered a main influence on tern numbers on the Isle of May, with hindsight it may be that changes in vegetation on the island also played an important a role. Since the 1950s, Sandwich terns nested on Inchmickery and Fidra, but declined through the 1990s, and deserted those sites, apparently at least in part in response to increasing herring gull numbers on those islands. Provision of tern nest box terraces where terns can breed without risk of predation of eggs and chicks by gulls has resulted in a small recent increase in numbers, and high breeding success, on the Isle of May (Steel and Outram 2020), suggesting that gull predation, in addition to loss of suitable nesting habitat, rather than forage fish availability, has been limiting Sandwich tern breeding numbers in the Forth Islands SPA in recent years. Forth Islands SPA was designated on 25 April 1990, with the citation document noting 440 pairs of Sandwich terns, but the years of count not specified. According to NatureScot Sitelink (viewed 1/9/2021) the conservation status of the Sandwich tern feature at Forth Islands SPA is "*Unfavourable Declining*" as updated on 30 June 2016. The creation of new nesting habitat and nest box protection from predators appears to have much promise as a management measure to recover the Sandwich tern population but is still at a very early stage of development (Steel and Outram 2020). Further funding resource might allow this to be developed further and faster.

### 3.4.4 Farne Islands SPA

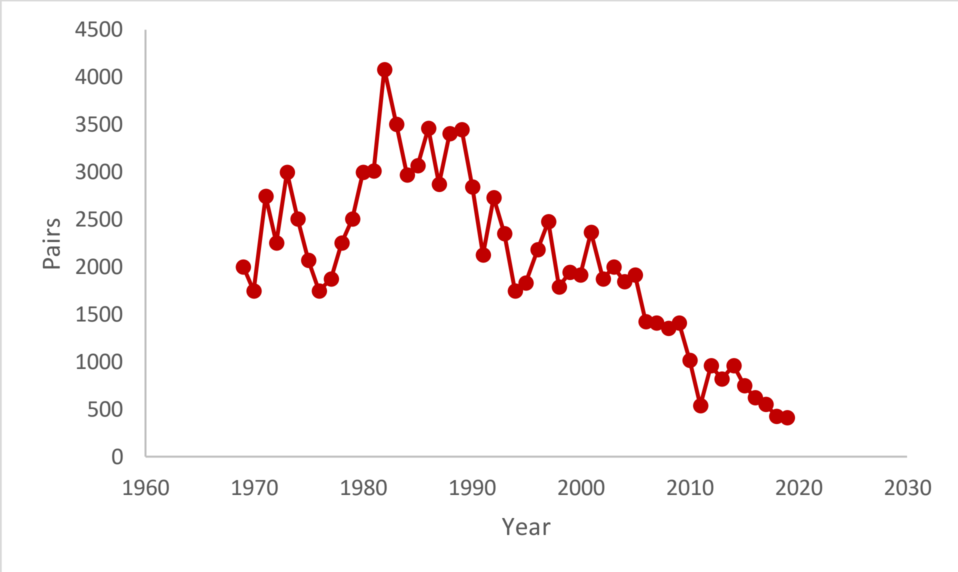


**Figure 3.4.4. Numbers of pairs of Sandwich terns nesting at Farne Islands SPA 1969-2021 (data from JNCC 2021) downloaded 31/8/2021.**

The SPA citation document states an average of 862 pairs of Sandwich terns in 2010-2014. However, that number is far smaller than the numbers that were present in the 1970s to 1990s (Figure 3.4.4). On the Farnes, a high proportion of surviving Sandwich tern chicks were reported to have been eaten by large gulls in 2001 (Mavor et al. 2002). However, predation has not been reported to be a problem at this site in most years.

BBC (2021) report huge concern about the failure of National Trust to manage vegetation on Inner Farne in a way that would allow terns to breed there. Emphasis in the published article is on Arctic terns, but the same applies for Sandwich tern. The main breeding area of Sandwich terns on Inner Farne was an area that was closely grazed by the abundant rabbits on the island, which maintained a very short sward on which terns nested. The rabbit population was removed by MAFF pest officers in 1968, although "*unauthorised*" reintroductions occurred in 1974 and again in 2013 (Tooth and Blakely 2015). The vegetation in the area has changed over the years from a close-cropped sward of grass to more rank nitrophilous vegetation, less suitable for terns to nest among. According to Tooth and Blakely (2015) who wrote the current management plan for the Farnes for 2016 to 2021 "*The current condition is unfavourable declining for Sandwich, Roseate, Common and Arctic Tern and Eider, therefore management policy is not meeting the objectives set. This would suggest the current management needs to be modified.* ***For years the islands have been in a state of decline due to the rapid colonisation and growth of common nettle and hemlock, which has been allowed to spread over Inner Farne virtually uncontrolled, encroaching on the nesting areas of all three tern species that currently breed on the islands. Rapidly growing Yorkshire fog, as well as nettle beds, limited the amount of short turf required by the terns.*** *After consultations with the RSPB, who have similar difficulties on Coquet Island and Natural England, it has been agreed that a combination of strimming, digging and spraying of nettle is required to provide open areas near existing colonies on Inner Farne. The resulting biomass is to then be piled to provide ideal nesting areas of Common Eider. In addition to this due to the multiple number of staff annually getting open sores despite wearing appropriate PPE (thought to be a reaction to hemlock sap with U.V) Hemlock on Inner Farne will be dug out where possible and spot sprayed over the next 5 years to eradicate it.*

*It is believed that if the vegetation is strimmed hard down at the beginning of the season this could create areas which birds later choose to colonise and potentially continue to suppress naturally. In addition to this, test plots, where matting will be laid and shingle laid on top in the veg-patch area will be trialled to create a better nesting habitat for the terns. This will be used in areas where nettle growth causes the loss of suitable habitat for nesting terns could create areas which birds later choose to colonise and potentially continue to suppress naturally. In the case of rabbit grazing - although this option may remain open currently the cost and logistics are unfeasible*."

Although the 2016-2021 management plan expired in March 2021, no management plan for April 2021 onwards had been agreed between National Trust and Natural England by September 2021 (Gwen Potter, National Trust, pers. comm.), so it has been impossible to evaluate whether future management for terns at the Farnes will be any more successful than it has been up to now.

The management plan for 2016-2021 does not indicate how much vegetation management was carried out in those years. Vegetation cutting cannot be carried out at tern colonies once terns have settled to nest, and the lack of grazing results in the rapid growth of nitrophilous plants fuelled by seabird guano. The gradual decline in breeding numbers of Sandwich terns on Farne Islands SPA appears to be a response to the progressive deterioration of the nesting area, which became particularly obvious in 2021 because no cutting at all was carried out before the tern nesting season. That decline is in stark contrast to the situation on nearby Coquet Island (Figure 3.4.5) which is managed by RSPB and where Sandwich tern numbers have remained consistently high over the period of decline at the Farnes. Since breeding numbers and breeding success are consistently high at nearby Coquet Island, there seems to be no problem of food shortage limiting Sandwich tern numbers at the Farnes; the problem appears to be one that could be solved with a change in management to restore the nesting area habitat to conditions suitable for nesting terns.

Tooth and Blakely (2015) report "*Large gulls (LBB and Herring) eggs are destroyed each year to keep the population at a level agreed with Natural England*" but there is no information in the management plan as to how much predation on tern chicks is caused by large gulls at this site, although that was noted in 2001 (Mavor et al. 2002).

If the failure to manage vegetation on the Farnes over recent years is simply a consequence of a lack of resources for that work, then possibly this could be a site where compensation might help to recover the declining Sandwich tern population of this important SPA.

### 3.4.5 Coquet Island SPA

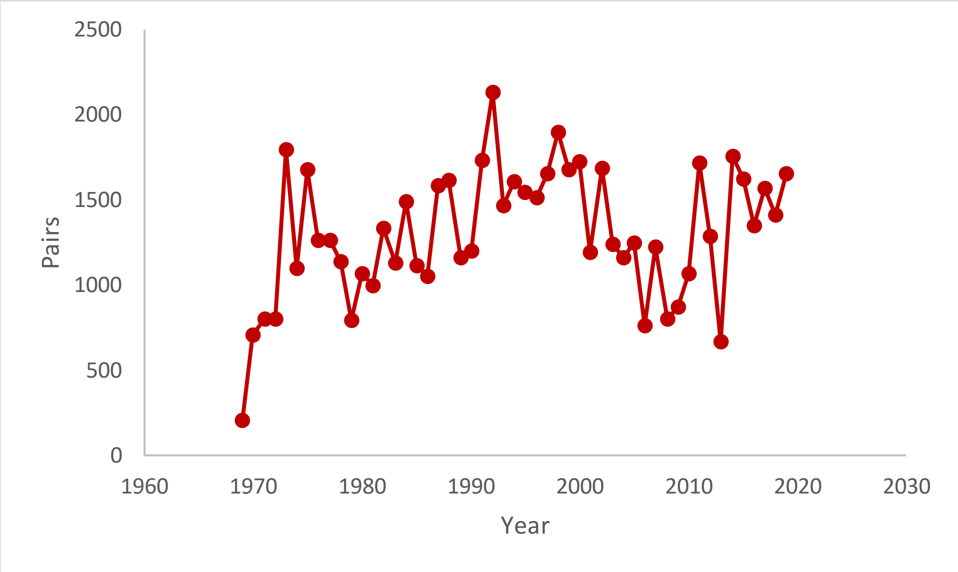


**Figure 3.4.5. Numbers of pairs of Sandwich terns nesting at Coquet Island SPA 1969-2021 (data from JNCC 2021) downloaded 31/8/2021.**

Coquet Island is managed by RSPB, and the favourable conservation status of Sandwich tern at that site is clear from the data in Figure 3.4.5. The intensive management of vegetation every winter, spring and autumn at this colony has been important in achieving this success (Babcock and Booth 2020).

### 3.4.6 North Norfolk Coast SPA

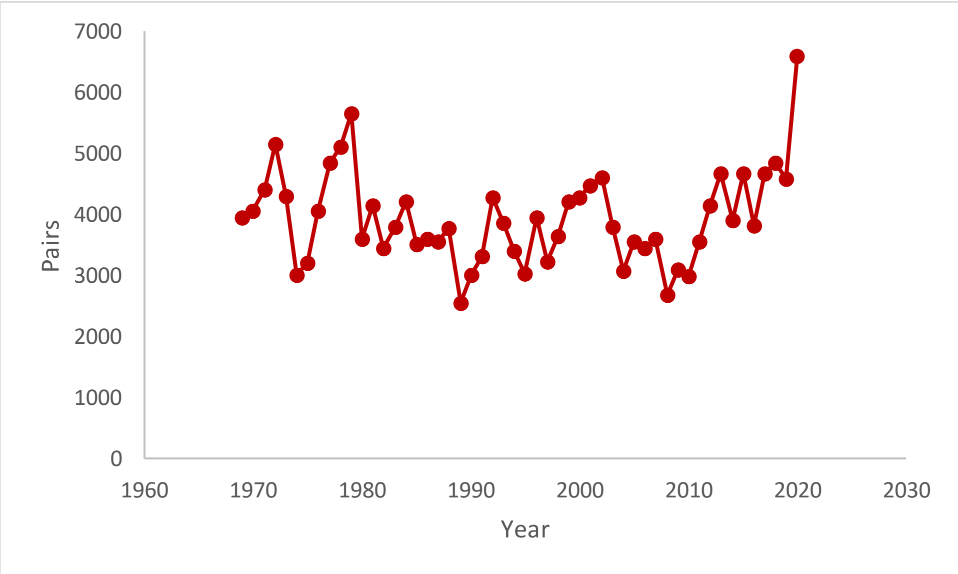


**Figure 3.4.6. Numbers of pairs of Sandwich terns nesting at North Norfolk Coast SPA 1969-2020 (data from JNCC 2021) downloaded 31/8/2021.**

According to Perrow et al. (2017) factors influencing productivity of Sandwich terns at North Norfolk Coast SPA include weather and predators, of which foxes are probably the most damaging. Other predators include stoats, large gulls, an increasing population of Mediterranean gulls, and occasional raptors. Although predation is the most conspicuous cause of breeding failure, the abundance, distribution, and availability of prey is essential to breeding success (Perrow et al. 2017).

Fox predation at Scolt Head resulted in almost complete breeding failure in 1989 (Walsh et al. 1991). The colony at Scolt Head failed completely in 1997 and 1998 as a result of flooding at high tide and herring gull predation of nests (Thompson et al. 1999). At Blakeney, predation by herring gulls resulted in total failure at that colony in 2000 (Mavor et al. 2001). Productivity at Blakeney in 2003 was reduced by predation by rats (Mavor et al. 2004). In 2007, the colony at Scolt Head failed to produce any fledglings due to fox predation, and subsequent predation of remaining chicks by large gulls (Centrica Energy 2009b). However, the presence of two separate breeding sites (Blakeney and Scolt Head) allows Sandwich terns to move from one to the other to reduce predator impacts as those build up at one site. Exclusion of foxes by electric fence has also improved productivity in recent years compared to periods affected by fox access.

### 3.4.7 Alde-Ore Estuary SPA

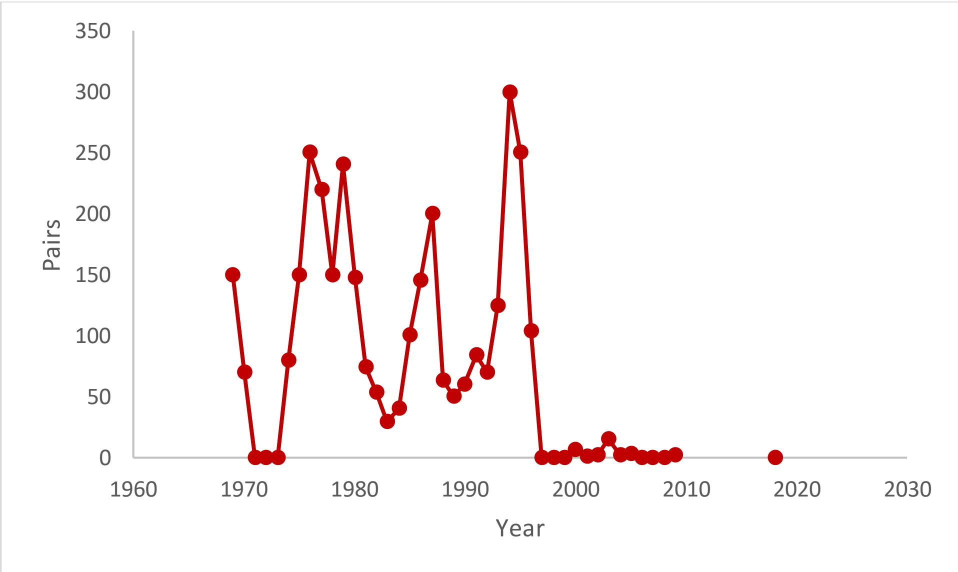


**Figure 3.4.7. Numbers of pairs of Sandwich terns nesting at Alde-Ore Estuary SPA 1969-2021 (data from JNCC 2021) downloaded 31/8/2021.**

At Havergate, Alde-Ore Estuary SPA, there were between 50 and 300 pairs nesting each year from 1986 to 1995, but the colony experienced complete breeding failure in 1995 due to foxes (Thompson et al. 1996), and the loss of the population on the Alde-Ore Estuary SPA (Figure 3.4.7) after 1995 appears to be attributable to that impact of foxes (Ratcliffe et al. 2000). No management measures put into effect at this site have yet allowed Sandwich terns to resume breeding at Alde-Ore Estuary SPA. It seems possible that fences to exclude foxes might be a suitable conservation measure to deploy at this site, but that would require dedicated resources (not only fence materials, but staff time to erect and remove the fence each year, and to carry out daily checks and maintenance throughout the pre-breeding and breeding season, following best practice (Short 2020)).

### 3.4.8 Foulness SPA

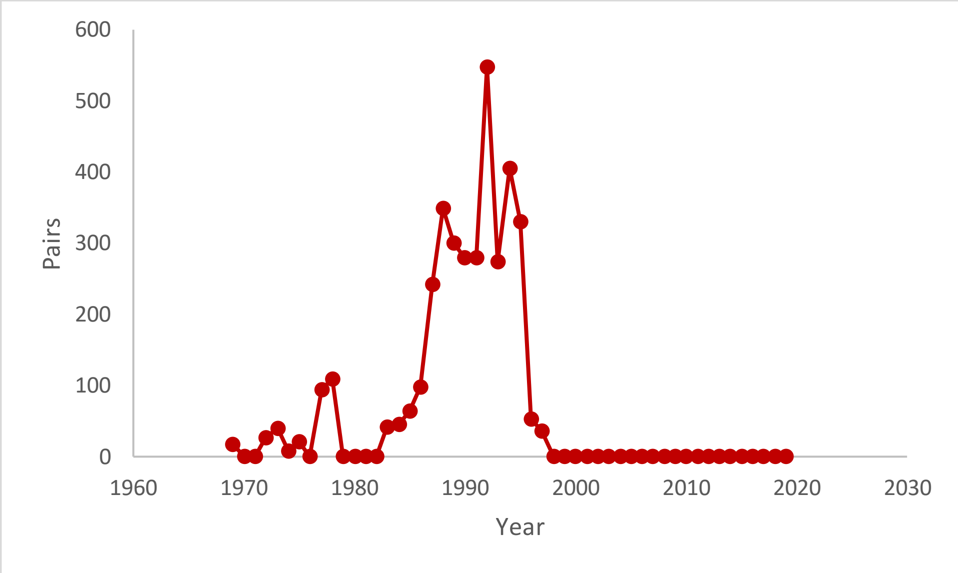


**Figure 3.4.8. Numbers of pairs of Sandwich terns nesting at Foulness SPA 1969-2021 (data from JNCC 2021) downloaded 31/8/2021.**

Ratcliffe et al. (2000) identified predation by foxes as the cause of the desertion of Foulness SPA by Sandwich terns since the late 1990s. No management measures put into effect at this site have yet allowed Sandwich terns to resume breeding at Foulness SPA (Figure 3.4.8). It seems possible that fences to exclude foxes might be a suitable conservation measure to deploy at this site, but that would require dedicated resources (not only fence materials, but staff time to erect and remove the fence each year, and to carry out daily checks and maintenance throughout the pre-breeding and breeding season, following best practice (Short 2020)).

### 3.4.9 Poole Harbour SPA

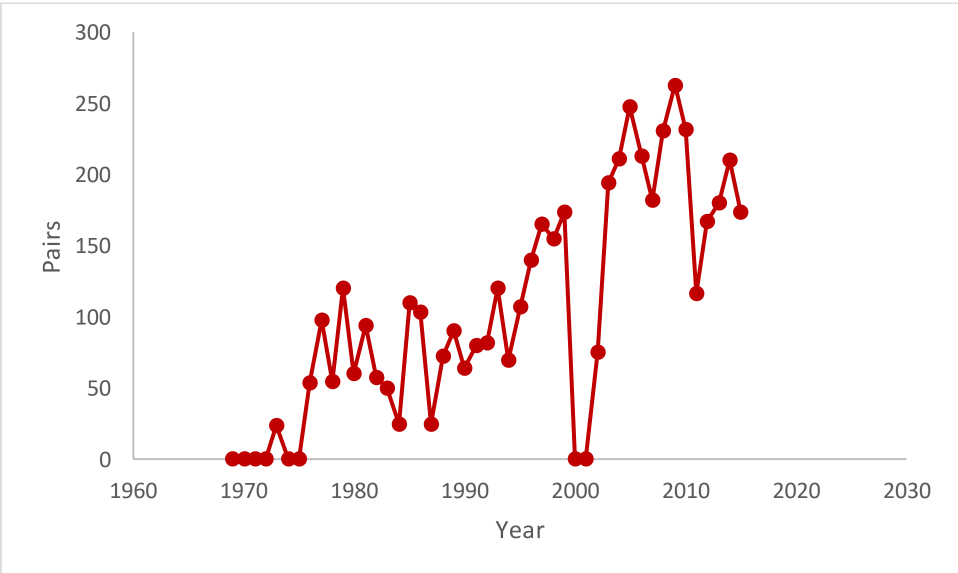


**Figure 3.4.9. Numbers of pairs of Sandwich terns nesting at Poole Harbour SPA 1969-2021 (data from JNCC 2021) downloaded 31/8/2021.**

Numbers at Poole Harbour SPA appear to be doing well overall, although there clearly have been some years where numbers have been greatly reduced compared to the overall trend. However, there seems to be little information published about this population apart from the annual counts.

### 3.4.10 Chichester and Langstone Harbours SPA

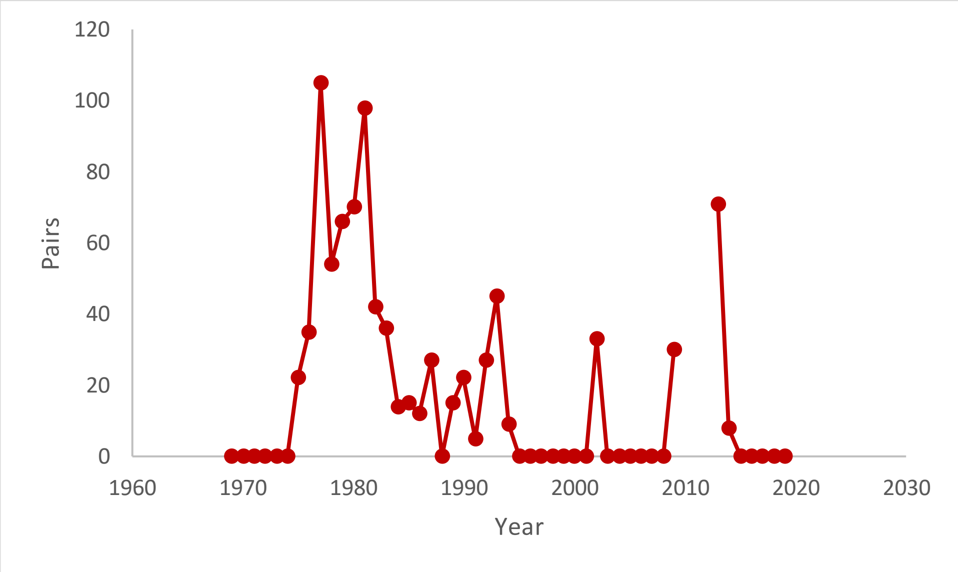


**Figure 3.4.10. Numbers of pairs of Sandwich terns nesting at Chichester and Langstone Harbours SPA 1969-2021 (data from JNCC 2021) downloaded 31/8/2021.**

At Langstone Harbour, Sandwich tern breeding success was greatly reduced by predators in 2006 (Mavor et al. 2008). It seems possible that fences to exclude foxes might be a suitable conservation measure to deploy at this site, but that would require dedicated resources (not only fence materials, but staff time to erect and remove the fence each year, and to carry out daily checks and maintenance throughout the pre-breeding and breeding season, following best practice (Short 2020)).

### 3.4.11 Solent and Southampton Water SPA

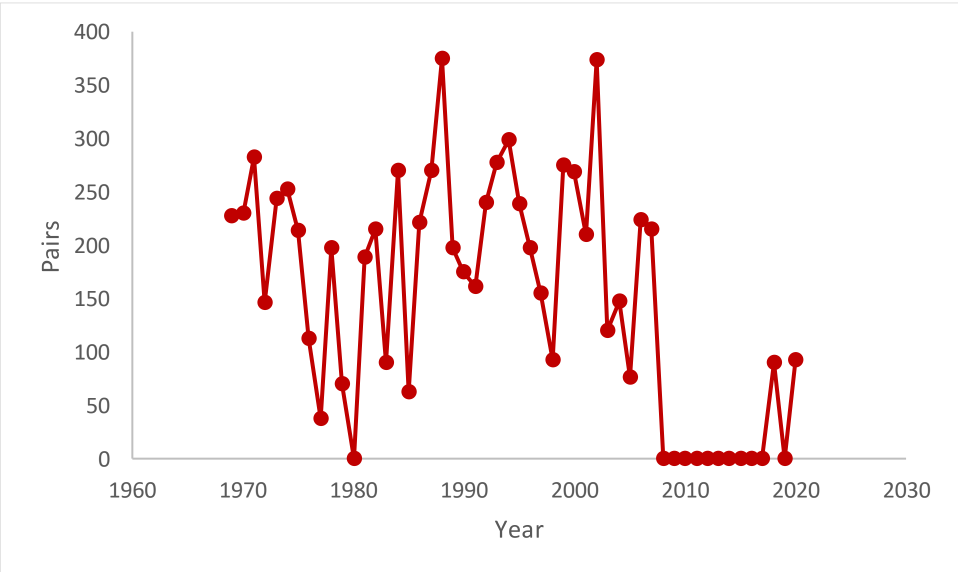


**Figure 3.4.11. Numbers of pairs of Sandwich terns nesting at Solent & Southampton Water SPA 1969-2021 (data from JNCC 2021) downloaded 31/8/2021.**

Solent and Southampton Water SPA has held quite variable numbers of breeding Sandwich terns, and in the period since 2007 has held very few (Figure 3.4.11).

### 3.4.12 Anglesey terns SPA

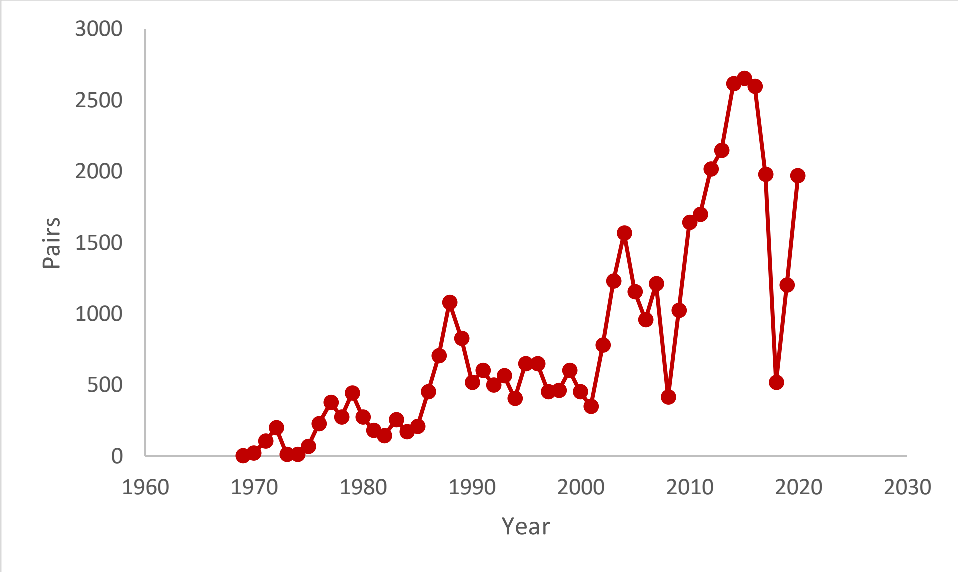


**Figure 3.4.12. Numbers of pairs of Sandwich terns nesting at Anglesey terns SPA 1969-2021 (data from JNCC 2021) downloaded 31/8/2021.**

Anglesey terns SPA has held an increasing number of breeding Sandwich terns, although with a few years where numbers have been much reduced (Figure 3.4.12).

### 3.4.13 Morecambe Bay & Duddon SPA

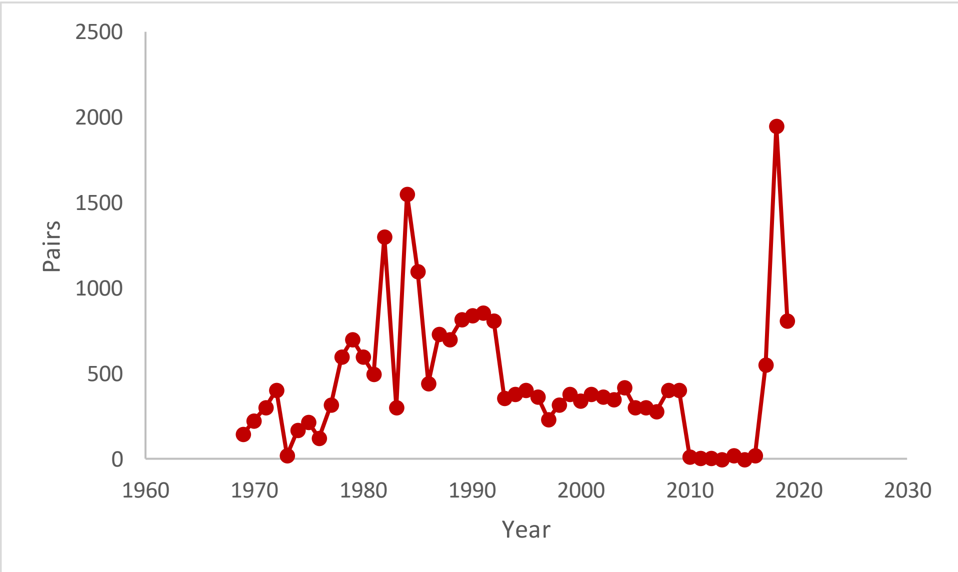


**Figure 3.4.13. Numbers of pairs of Sandwich terns nesting at Morecambe Bay & Duddon SPA 1969-2021 (data from JNCC 2021) downloaded 31/8/2021.**

At Hodbarrow, all chicks were taken by foxes in 1991 and 1992 (Walsh et al. 1993) and all chicks (from 100 pairs) were taken by stoats in 1993 (Walsh et al. 1994). At Foulney, fox predation was thought to be the cause of complete breeding failure in 1995 (Thompson et al. 1996), and that colony was deserted in 1996, 1997 and 1998 (Thompson et al. 1999). Ratcliffe et al. (2000) identified predation by foxes as the cause of desertion of Foulney by Sandwich terns. It seems possible that fences to exclude foxes might be a suitable conservation measure to deploy at these sites, but that would require dedicated resources (not only fence materials, but staff time to erect and remove the fence each year, and to carry out daily checks and maintenance throughout the pre-breeding and breeding season, following best practice (Short 2020)).

### 3.4.14 Carlingford Lough SPA

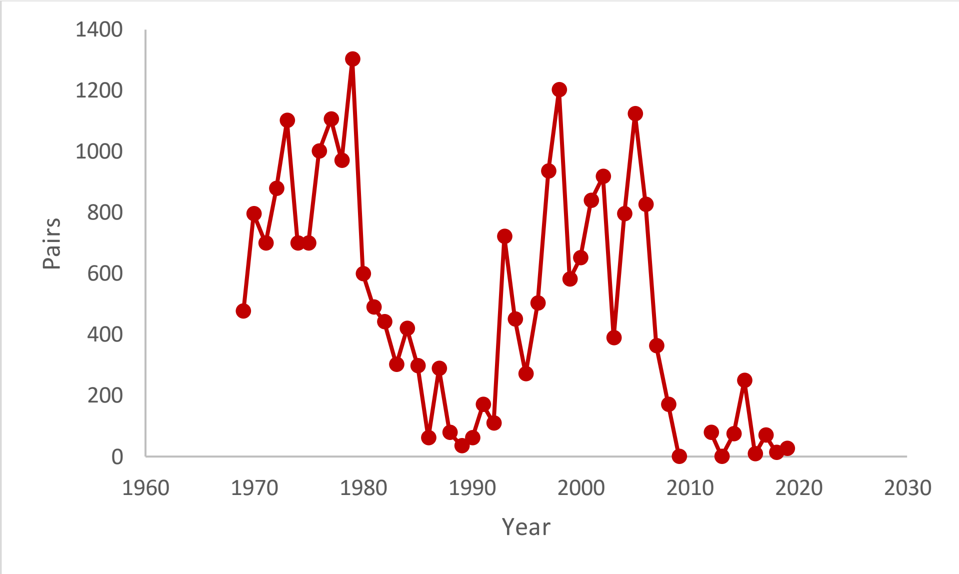


**Figure 3.4.14. Numbers of pairs of Sandwich terns nesting at Carlingford Lough SPA 1969-2021 (data from JNCC 2021) downloaded 31/8/2021.**

Numbers of breeding Sandwich terns at Carlingford Lough have fallen with very few there since 2010 (Figure 3.4.14). It seems possible that those birds moved to Larne Lough SPA (Figure 3.4.15, as numbers there have increased while the decline was occurring at Carlingford Lough. However, I have been unable to locate information on the detailed reasons for changes at the sites in Northern Ireland.

### 3.4.15 Larne Lough SPA

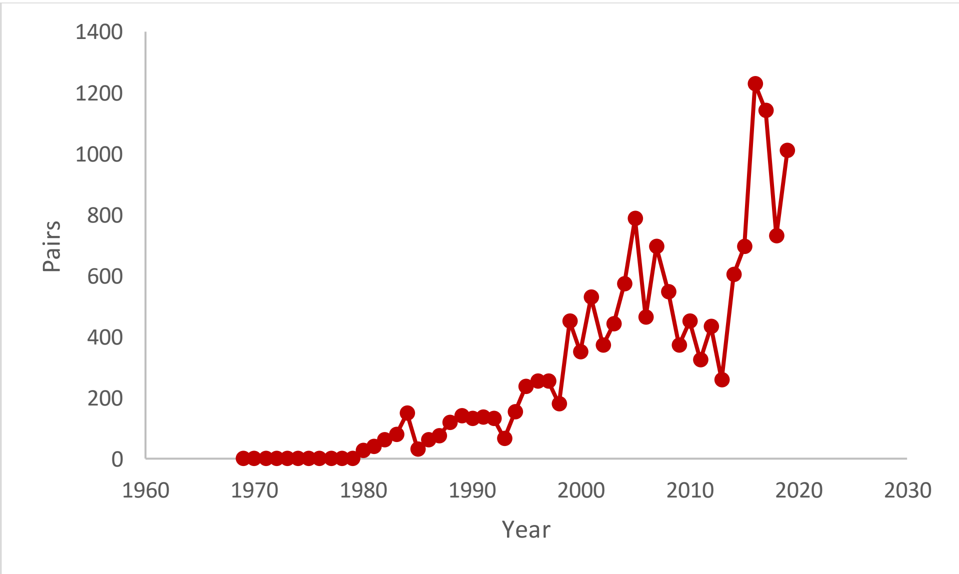


**Figure 3.4.15. Numbers of pairs of Sandwich terns nesting at Larne Lough SPA 1969-2021 (data from JNCC 2021) downloaded 31/8/2021.**

The increase at Larne Lough may relate in large part to vegetation management there by RSPB (Babcock and Booth 2020). However, I have been unable to locate information on the detailed reasons for changes at the sites in Northern Ireland.

### 3.4.16 Strangford Lough SPA

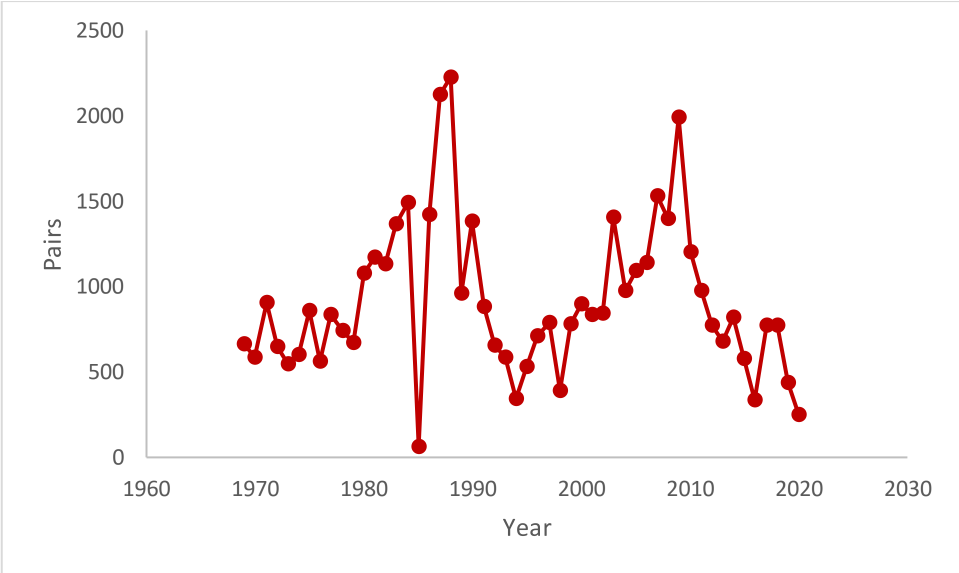


**Figure 3.4.16. Numbers of pairs of Sandwich terns nesting at Strangford Lough SPA 1969-2021 (data from JNCC 2021) downloaded 31/8/2021.**

Numbers of breeding Sandwich terns at Strangford Lough have fallen with very few there since a peak in numbers in 2009 (Figure 3.4.16). It seems possible that since 2009 some of those birds may have moved to Larne Lough SPA (Figure 3.4.15). However, I have been unable to locate information on the detailed reasons for changes at the sites in Northern Ireland, apart from the evidence that vegetation management at Larne Lough SPA by RSPB has apparently resulted in breeding numbers increasing there (Babcock and Booth 2020).

### 3.4.17 Non-SPA sites

In contrast to SPA sites where breeding Sandwich tern is a feature (Figures 3.4.1 to 3.4.16), the JNCC SMP database holds very few counts of numbers of Sandwich tern pairs at non-SPA sites. Since 2000, only 16 sites are listed in England, Wales and Scotland, and only 5 of these sites held more than 50 pairs of Sandwich terns in any year between 2000 and 2021 (Table 3.4.2).

**Table 3-4-2 Peak number of pairs/AONs of Sandwich terns in any year 2000 to 2021 listed in JNCC SMP database for sites where Sandwich tern is not a SPA breeding feature.**

| Site | Area | Year | Pairs/AONs |
|---|---|---|---|
| **Medway Estuary and Marshes SPA** | Kent | 2000 | 333 |
| **St John's Pool** | Caithness | 2019 | 115 |
| **South Ronaldsay** | Orkney | 2000 | 90 |
| **Westray** | Orkney | 2002 | 75 |
| **Scar Point** | Wigtownshire | 2000 | 70 |
| **Lamb Holm** | Orkney | 2005 | 18 |
| **Hunterston** | Strathclyde | 2016 | 17 |

| Site | Area | Year | Pairs/AONs |
|---|---|---|---|
| **Holy Island Sands (Lindisfarne SPA)** | Northumberland | 2002 | 14 |
| **Papa Westray** | Orkney | 2012 | 14 |
| **Muckle Skerry** | Orkney | 2006 | 13 |
| **North Ronaldsay** | Orkney | 2001 | 11 |
| **Redcar Ore Terminal** | Cleveland | 2007 | 2 |
| **Egilsay** | Orkney | 2001 | 2 |
| **Holm of Scockness** | Orkney | 2007 | 2 |
| **Machrihanish** | Argyll | 2016 | 1 |
| **Summer Isles** | Ross & Cromarty | 2000 | 1 |

Over 1,000 pairs nested in the Morrich More firing range (between Tain and Inver, Easter Ross, Dornoch Firth) in 1969, but deserted in 1971, apparently because of increasing human disturbance (Bourne and Smith 1974, Forrester et al. 2007). It might be possible to attract Sandwich terns back to this site if issues of human disturbance could be resolved. The site may also require deployment of fences to exclude foxes as this is a mainland site where fox predation is likely to be a problem.

Although JNCC (2021) list 115 pairs of Sandwich terns breeding at St John's Pool, near Dunnet Head, Caithness, in 2019, the online Scottish Bird Reports suggest that there were 180 pairs there in 2019 (count dated 7 May 2019), and 65-70 pairs in 2018, and 60 pairs in 2017. Caithness Bird Report for 2020 lists 102 pairs nesting at St John's Pool in 2020. This site (in St John's Pool Nature Reserve) comprises artificially created gravel islands in a loch that provide ideal nesting habitat for Sandwich terns, and the site is protected by a steel fox-proof and otter-proof fence to keep the colony safe from predation by these mammals (Hughes et al. 2021). This represents a rare example of successful management at a non-SPA site for breeding Sandwich terns that has maintained a small, but successful population there. This could be a useful case study for any compensation plan involving improvement to Sandwich tern nesting habitat. Sandwich terns breeding at St John's Pool that had been individually ringed as adults at other colonies included two birds from South Ronaldsay and four from Ythan Estuary/Sands of Forvie, indicating breeding dispersal (as is well known in terns). Sandwich terns breeding at St John's Pool that had been individually colour ringed as chicks at other colonies included four from Ythan Estuary/Sands of Forvie and two from Farne Islands (indicating natal dispersal). Sandwich terns seen at, but not known to be breeding at St John's Pool, that had been individually colour ringed elsewhere included two birds from Lady's Island Lake, Wexford, another two birds from Farne Islands, several more from Ythan Estuary/Sands of Forvie, and one from Scheelhoek Eilanden, Netherlands (Hughes et al. 2021). The large number of ringed birds seen at St John's Pool, originating from different Sandwich tern colonies as far away as Netherlands and Republic of Ireland, indicate the meta-population structure in this species, with connectivity among colonies throughout much or most of the North Sea, UK and Irish waters (Hughes et al. 2021).

All 40 pairs nesting at Lindisfarne in 1993 were predated by foxes and the colony was deserted that year (Walsh et al. 1994). It seems possible that fences to exclude foxes might be a suitable conservation measure to deploy at this site, but that would require dedicated resources (not only fence materials, but staff time to erect and remove the fence each year, and to carry out daily checks and maintenance throughout the pre-breeding and breeding season, following best practice; Short 2020). It may be difficult to encourage Sandwich terns to recolonize a site such as this where they have not been nesting regularly for many years. However, during late summer, Sandwich terns visit many areas where they do not breed (Forrester et al. 2007), and it seems likely that those exploratory movements are partly related to seeking potential breeding sites for future use.

At Dungeness, Kent, there were between 100 and 250 pairs in most years from 1988 to 1997, but in 1997 all nests failed in late May, with evidence of predation by mink and badgers (Thompson et al. (1998). None nested at Dungeness in 1998, 1999 or 2000, suggesting that predation caused the abandonment of that colony (Mavor et al. 2001). It seems possible that predator-proof fences to exclude foxes, mink and badgers might be a suitable conservation measure to deploy at this site, but that would require dedicated resources (not only fence materials, but staff time to carry out daily checks and maintenance). It may be difficult to encourage Sandwich terns to recolonize a site such as this where they have not been nesting regularly for many years. However, during late summer, Sandwich terns visit many areas where they do not breed (Forrester et al. 2007), and it seems likely that those exploratory movements are partly related to seeking potential breeding sites for future use, as seen in many other seabird species (Oro et al. 2021).

Forrester et al. (2007) note 31 sites in Scotland where Sandwich terns bred in the past but had abandoned the site before the 2000s, and only seven sites in Scotland still used by Sandwich tern for breeding in the early 2000s. At least four of those seven sites have been abandoned since the 2000s (JNCC 2021), leaving only Sands of Forvie, Forth Islands, and St John's Pool Caithness, as continuing to hold regular Sandwich tern breeding colonies. There is, therefore, considerable potential to manage sites in Scotland to increase breeding numbers and breeding distribution of Sandwich tern. One site from which Sandwich terns have been lost is Scar Point, Loch Ryan, Wigtownshire. That is a site in SW Scotland which, if restored, would significantly improve the geographical coherence of the Sandwich tern breeding range in Britain and Ireland. This site is discussed further in Section 3.5.3 Flood protection, as an interesting case study.

**While the Natura 2000 suite for breeding Sandwich tern in Britain and Northern Ireland holds more breeding pairs now than it did when these sites were designated, some sites are in Unfavourable conservation status, either as a consequence of impacts of predators (especially fox predation) or flooding, or development of vegetation over nesting areas, or human disturbance, or reduced abundance of forage fish. Sandwich terns have been lost from some regions (such as west Scotland) and the UK population is now more concentrated in fewer sites, making it potentially less resilient to pressures caused by environmental change.**

## 3.5 The broad scope for management measures to increase breeding numbers and productivity of Sandwich terns through predator exclusion, reduced human disturbance, flood protection and/or vegetation control to improve conditions for breeding

Sandwich tern nesting habitat is almost exclusively coastal areas of highly dynamic balance between erosion and vegetation succession (Mitchell et al. 2004). Nesting habitat can be lost to erosion by winter storms or become overgrown with rank herbage or scrub (Brown and McAvoy 1985, Mitchell et al. 2004). Sandwich terns require extensive, sheltered, shallow waters that provide abundant sandeel or small clupeid prey within foraging range of suitable nesting habitat (Mitchell et al. 2004). Their foraging success is severely reduced by strong winds or rough seas (Dunn 1973, Taylor 1983, Stienen et al. 2000), so the species is restricted to relatively sheltered coasts (Mitchell et al. 2004). Sandwich terns tend to nest in few but large colonies, in areas safe from mammalian predators (Mitchell et al. 2004). Mammalian predation often causes complete breeding failure and usually leads to the colony being abandoned. Several colonies have declined or were either briefly or permanently abandoned following mammal predation, mainly by foxes, including Sands of Forvie, Scolt Head, Hodbarrow, Foulness, Havergate, Foulney, and Dungeness (Mitchell et al. 2004). Predation by gulls can also affect Sandwich tern breeding success and the resilience of colonies (Mitchell et al. 2004). Human disturbance at colonies can also lead to breeding failure and colony abandonment (Gregersen 2006, Forrester et al. 2007, Garthe and Flore 2007, Herrmann et al. 2008, Spaans et al. 2018). These features of limited potential nesting habitat, vulnerability to mammalian and avian predators and to human disturbance, a requirement for abundant forage fish close to the colony, and vulnerability of colony sites to erosion and to vegetation development provide a number of opportunities for management to improve Sandwich tern prospects.

Data from JNCC annual reports on seabird numbers and breeding success, 1986 to 2006, reviewed by Furness et al. (2013), indicate that the most frequently reported cause of breeding failure of Sandwich terns at colonies in Britain and Ireland was fox predation (23 cases). The next most frequently reported factors were tidal flooding (11 cases) and food shortage (10 cases). Extreme weather was a factor in 9 cases. Predation by gulls (9 cases), mink (5 cases), rats (3 cases), stoats (3 cases) and badgers (2 cases) also occurs.

### 3.5.1 Predator exclusion

Electric fences are used to exclude foxes and badgers from several Sandwich tern colonies, including Sands of Forvie (Short 2020), Scolt Head, and Blakeney. Some applications of electric fencing have been unsuccessful, in that foxes have been able to enter the protected area and cause breeding failure of terns. There is, therefore, a need to identify best practice to ensure that use of electric fences is effective. Short (2020) outlines the practice followed in 2020 that has been successful for many years at Sands of Forvie NNR. One large area containing bare sand, marram grass and exposed raised-beach pebbles in the dune complex at Forvie was identified as being likely to support breeding tern populations. That area was cleared of rank vegetation and marram tussocks in February to create the species' favoured bare ground and open space well before birds return to the site. The fence comprised flexible mesh netting of the type designed to contain domestic livestock, measuring 1.2 m in height and 950 m in total length. The fence is not a circle surrounding the tern colony but is a straight line of fence across a peninsula, with the tern nesting area about 800 m from the fence (Short 2020). Outside the mesh fence, two lines of electrified steel wire were run around the entire fence perimeter at approximately 10 cm and 30 cm above ground level respectively, supported by plastic poles. The bottom of the mesh fence was pegged to the ground and weighted down with rocks, while the netting was strained-up using guy-ropes and tent-pegs to improve the structural strength of the fence. The fence was erected in March. The enclosed area was thoroughly checked for any evidence of fox presence, and the electric current switched on in early April. Throughout the season, the fence was checked and maintained on a daily basis. Maintenance involved digging out and reinstating the fence after high winds and sand-blow, repairing holes in the mesh, and suppressing the growth of vegetation around the electrified wires. The last is essential for preventing short-circuits to earth, thereby preserving battery life and improving the fence's shock potential. The fence-line voltage was checked daily; battery changes were carried out as soon as the fence voltage began to drop significantly. **This maintenance is crucial to successful exclusion of foxes, but even so is not completely successful in that regard.** For example, in 2020 at Forvie, foxes breached the fully functional fence on two occasions (Short 2020), as has happened in previous years. It is, therefore, essential to monitor the protected area **on a daily basis** for presence of predators and to remove foxes immediately if they get into the area (Short 2020). The success of this management has been maintenance of a breeding population of 500 to 1,000 pairs of Sandwich terns each year from 2007 to 2020, achieving good breeding success, with several hundred fledged chicks produced every year (Short 2020).

The presence of a predator-exclusion fence around St John's Pool, Caithness, is likely to explain why this is one of the few sites in Scotland where Sandwich terns continue to nest successfully.

While temporary fences set up prior to breeding may be successful where fox predation is the key impact, such fences will not exclude mink, stoats or rats, and probably do not work well where badgers are a problem for Sandwich terns. Therefore, deployment of permanent predator-proof fences may be a better solution for some sites. Those structures are very much more expensive to construct, but require less staff time to check for functionality and to maintain, and do not need to be removed at the end of the tern nesting season each year. However, they are also visually intrusive, and limit access for people, so may be inappropriate in some locations.

#### 3.5.2 Human disturbance

Sandwich terns nest on open ground of the marine coast or islands, and generally select areas that are distant from human activity. Sandwich tern colonies are considered to be highly vulnerable to human disturbance, and colonies may be deserted as a result of human disturbance (Brown and Grice 2005, Gregersen 2006, Forrester et al. 2007, Garthe and Flore 2007, Herrmann et al. 2008, Spaans et al. 2018). However, the response of breeding Sandwich terns to human activity seems to vary considerably among colonies. At the Farne Islands, Sandwich terns have habituated to presence of people on limited footpaths around the perimeter of their colony and continue to incubate when people are no more than 25 m away. At many other Sandwich tern colonies where people are not normally present, Sandwich terns will leave their nests and chicks when people approach at much greater distances.

Short (2020) notes that human disturbance of nesting terns at Forvie remains an ongoing problem, despite signage and the electric fence across the peninsula. Short (2020) states "*In most cases, incursions were due to people not noticing the signs, or not understanding the signs (in the case of* *international visitors), and only in a very few cases were the access restrictions deliberately ignored. Light disturbance was noted on occasion from walkers, anglers and kayakers. Staff and volunteer presence remains an important factor in protection of the colonies from predation and disturbance*."

Recognising that monitoring numbers and breeding success of Sandwich terns by visiting colonies tends to cause excessive disturbance, Spaans et al. (2018) tested the use of a drone, flown 15-20 m above nesting Sandwich terns at appropriate dates through the breeding season at colonies in The Netherlands, to count breeding numbers and breeding success from photographs. They found that the drone caused "*hardly any visible disturbance to the birds*" but gave highly accurate data on breeding numbers and breeding success, so was considered much better than using human observations at Sandwich tern colonies. The same conclusion was reached by Valle and Scarton (2021) in Italy.

Away from their colony, Sandwich terns seem to be at relatively low risk of human disturbance when at sea. Perrow et al. (2011) followed breeding adult Sandwich terns foraging at sea from colonies in north Norfolk over distances of up to 72 km, keeping the boat about 20 to 100 m from the bird. They note that "*birds generally seemed to ignore the boat*". On the rare occasions (<1% of tracked birds) where birds seemed to respond to the boat, they increased their distance from the bird, and considered that foraging tracks and behaviours were broadly unaffected by their boat following the selected individuals. Sandwich terns will rest on shore at quiet coastal sites, especially during late summer after breeding is completed. Locations used by Sandwich terns for post-breeding roosting seem to indicate that they select open areas with low risk of human disturbance (Tierney et al. 2016).

Short (2020) noted that low-flying helicopters passing over Forvie caused much disturbance to terns, especially early in the breeding season when the birds had not yet fully settled. He suggested that avoiding helicopter flights over the colony would reduce disturbance impact.

### 3.5.3 Flood protection

The JNCC Annual Reports on seabird numbers and breeding success in Britain and Ireland, 1986-2006 included 11 instances of flooding reducing Sandwich tern breeding success during those years and affecting a number of colonies in different regions (Furness et al. 2013). There would therefore seem to be some scope for compensation through site engineering to reduce risk of flooding, where such engineering would be possible. Although both Scolt Head and Blakeney have been subject to flooding that greatly reduced Sandwich tern breeding success in a few years, those sites are also protected for their coastal ecology features and that designation most likely rules out engineering solutions at those sites. The risk of impacts from flooding may be better addressed at other sites where engineering solutions may be practical. However, it seems likely that the greatest gain for Sandwich tern conservation could be obtained by addressing protection of forage fish stocks, exclusion of predators, and vegetation control at established colony sites, rather than addressing flood risk. Nevertheless, carrying out engineering works at sites where Sandwich terns do not have an established tradition of regular and successful nesting with the objective that they can be attracted to such novel sites might be a means of increasing the breadth of Sandwich tern breeding distribution in Britain.

One site where Sandwich terns have nested but have not had a suitable colony site safe from flooding is Loch Ryan, Wigtownshire (Furness et al. 2013). The JNCC Seabird Monitoring

Programme database (JNCC 2021) records that there were no Sandwich terns nesting at Scar Point, Loch Ryan (54.968°N, 5.061°W), in 2021, and that there was "*low vegetation on spit above high tide, area of shingle above high tide significantly reduced compared to map*". No data are recorded for 2007 to 2020. However, there were 24 pairs in 2006, 20 pairs in 2005, 45 pairs in 2004 (JNCC 2021). There were 120 pairs in 1998 (JNCC 2021). This site clearly has potential to hold breeding Sandwich terns. It seems that a combination of flooding of the shingle spit and encroachment of vegetation onto the shingle has resulted in the loss of Sandwich terns from this site. Given the large increase in sprat abundance in the Clyde in recent years (Lawrence and Fernandes 2021) and the large increase in Sandwich terns seen at nearby Machrihanish Bird Observatory in recent years, this site seems like a good option for restoration as a Sandwich tern nesting area, through a combination of engineering to reduce flood risk, vegetation control, and predator exclusion.

Information from the local Bird Recorder for Dumfries and Galloway, Paul Collin, is "*I moved to the area in 1984 at which point a small colony of breeding terns at the Scar existed. I was told they were seldom successful, the thought that rats were probably the main cause was mooted. The site is a raised shingle spit which in 1984 had a low point halfway down, at high tide forming a large shingle island perhaps 150m x 30m. I put up some signs asking people not to go beyond a rope line from May to July and the colony quickly expanded with great success. I think people and dogs were perhaps the cause of previous failures. It was a brilliant tern colony with common terns nesting on the high tide wrack line, Arctic and Sandwich on the higher ground with Sandwich dominating the poorly vegetated highest ground and up to 9 little terns mainly confined to the NE side of the island. Intrusion by dog walkers and fishermen was a common problem. Large ferries located at Stranraer sailed passed regularly creating a dangerous wash which at times overtopped the whole island, causing losses and almost certainly erosion, although erosion on a northerly wind is an ongoing natural process. The situation was probably exacerbated by the introduction of high speed ferries. There were cases of people getting washed off their feet from unexpected waves from the ferries and also concerns of increased erosion. Ferries finally relocated to Cairnryan, possibly reducing some of these issues, but in many respects it was too late because by the early 2000s terns had virtually abandoned the site and the shingle ridge/peninsula had been much reduced. The role which vessels had in the erosion process and how much of it was natural could be long debated. It is not beyond the realms of possibility to get diggers and dumper trucks out each spring to rebuild the island, it could even be shored up as a more permanent island.*"

Restoration of that site (Figures 3.5.1 and 3.5.2) would fill a significant gap in Sandwich tern breeding distribution. Although there are 11 sites in the west of Scotland where Sandwich tern has been recorded to breed in the past, nine of these sites were abandoned before 2007 (Forrester et al. 2007), and both the sites still used in 2007 (which included Scar Point, Loch Ryan), have now been abandoned (JNCC 2021).

Figure 3.5.1. The end of Scar Point spit, and tidal island, Loch Ryan, Galloway, photographed around high tide on 8 October 2021, showing the very small size of the tidal island and its vulnerability to flooding by wave action, a large tide, or bow waves from passing ships. Most of the spit is covered by thick vegetation (foreground) with only the extreme edge that is subject to tidal flooding remaining free of vegetation (but much of that covered by large amounts of rotting seaweed). The spit is accessible by a track that allows vehicle access up to within 200 m of the end of the spit. The spit and adjacent shoreline, track, and large car park are used for recreational purposes by large numbers of people, including people exercising dogs.

Figure 3.5.2. The tip of the spit, and the remaining tidal island, at Scar Point, Loch Ryan, Galloway, photographed around high tide on 8 October 2021. The site was being used by large numbers of roosting birds; there was a flock of 35 turnstones on the tip of the spit, and there were about 80 Brent geese, 6 mallards, 5 red-breasted mergansers, 30 cormorants, 50 oystercatchers, 20 curlews, 20 golden plovers, 20 turnstones, 20 dunlins, 4 knots and 10 gulls roosting on the island.

Successful flood control has been achieved at St John's Pool, Caithness, by the creation and maintenance of man-made artificial islands of gravel, stones and sand within the loch (Figure 3.5.3) that provide nesting habitat for Sandwich terns as well as for other terns and black-headed gulls (Caithness 2021, Hughes et al. 2021).

Figure 3.5.3. St John's Pool, Caithness, showing the artificial islands created for tern nesting. From Caithness (2021).

### 3.5.4 Vegetation control

Most terns choose to nest in areas with very sparse vegetation and are inhibited from areas where vegetation becomes thicker/taller. This is especially the case with Sandwich tern. Numerous studies have shown that management of vegetation at tern colonies is an effective measure to enhance breeding success (Saliva and Burger 1989, Feare et al. 1997, Cook-Haley and Millenbah 2002, Lamb 2011, Lamb et al. 2014, Lamb 2015, Denac and Bozic 2019, Babcock and Booth 2020).

Vegetation management at seabird colonies presents challenges in terms of timing, as tern nesting coincides with the vegetation growing season. Mowing and most herbicides cannot be applied during plant growth when they are most effective, because nesting terns would be disturbed. The inaccessibility and ecological sensitivity of seabird colonies may also prevent the use of vegetation management techniques that require heavy equipment, bulky materials, or dangerous chemicals.

Lamb (2011, 2015) carried out a literature review to collect information on vegetation management on tern nesting islands between 33° and 55° N latitude and developed a summary of different vegetation control techniques used. She identified 14 techniques suitable for use in nesting colonies, that can be applied before and after (but not during) the nesting period of May-July, that do not cause destructive impacts to the surrounding ecosystem, and that involve materials and labour that can be reasonably transported to inaccessible offshore islands. Of these techniques, eight created usable tern nesting habitat for a full breeding season. The success of different methods (including herbicide application, burning, hand-weeding, mechanical weeding, soil removal, controlled grazing by large mammals, introduced small mammal grazers, addition of weed supressing membrane/fabric, addition of gravel, solarization, addition of salt, addition of mulch, and addition of dredge material) depended heavily on the plant communities and soil types involved, although the most successful techniques required constructing habitat over existing vegetation (i.e. laying a weed-supressing membrane/fabric on the surface and covering that with gravel). A field test of controlled burning of vegetation prior to tern arrival was unsuccessful as a management technique because vegetation grew during the tern incubation period, leading to abandonment of nests (Lamb et al. 2014). However, a field test of deployment of artificial weed suppressant fabrics covered with gravel worked well, achieving breeding success on the experimentally created colony site as good as in natural colonies on high quality nesting habitat (Lamb et al. 2014).

Babcock and Booth (2020) describe current best practice RSPB vegetation management to enhance nesting habitat for Sandwich and other terns. At Larne Lough SPA, a new vegetation management programme combining strimming and chemical control has been implemented since autumn 2018. A trial that created plots for Sandwich terns by strimming alone was unsuccessful, because the vegetation grew back too quickly. Babcock and Booth (2020) note that Sandwich terns seem to prefer to nest close to the edge of open areas where they are next to vegetation, and so cutting scalloped edges creates suitable conditions of open vegetation-free nesting areas close to vegetation that can provide cover for chicks. In autumn 2019, restoration works on Blue Circle Island, Larne Lough SPA, included the creation of new tern habitat with a geotextile membrane to supress vegetation, covered with nesting substrate. RSPB plan that emerging vegetation will be treated with herbicide before the breeding season.

RSPB Coquet Island is strongly fertilised by the breeding seabird assemblage there, and as a result the surface of the island is dominated by rank grasses with patches of nettles. Tree mallow was planted on Coquet in the late 1990s in the mistaken belief that roseate terns use it preferentially. In 2000 the process of removing the tree mallow by hand pulling was begun, and as of 2020 it is almost completely extirpated from the island. The area of the island occupied by terns is divided into plots, largely surrounded by nettlebeds, with vegetation left in between plots to provide shelter for chicks. The plots are of different sizes and shapes, a layout that evolved over time around the physical features of the island. Twenty-five plots are maintained specifically for tern nesting. These are strimmed at the end of each breeding season, and then cut four times with mowers over the course of the winter, including a cut as close as possible to the start of the tern breeding season. Patches of nettles, dock and thistles are treated with topical herbicide at the start of the season. Vipers bugloss is pulled by hand. The Sandwich terns maintain nearly bare ground through the breeding season in the plots they occupy as a result of the trampling by large numbers of adult terns in this small area. In 2020, one plot was sown with yellow rattle seed in the hope that over time this semi-parasitic species will naturally suppress the coarse grasses. On Coquet Island large chick shelters designed to have the additional effect of supressing vegetation are also in use, and these also provide the tern chicks with protection from predators and weather (Babcock and Booth 2020). This management has been extremely successful in maintaining the Sandwich tern population of Coquet Island.

Tern Island is a small island (0.24ha) within RSPB Pagham Harbour on the south coast of England. In March 2018, work to remove vegetation and restore open habitat for breeding birds was undertaken on Tern Island. The shingle on parts of the island was mechanically 'raked' using a digger and toothed landscaping bucket, to reduce the dominance of coarse vegetation. Parts of the cleared shingle were recharged with smaller shingle, more suitable for nesting terns, and sand patches to reduce air flow through the stones and potential chilling of tern eggs. A predator-proof (combination stock and electric) fence was installed around the island. In 2018, larger numbers of little, common and Sandwich terns fledged compared to before the project. The improved fencing protected the enclosed area, but predation took place outside the fence (Babcock and Booth 2020).

These case studies of RSPB management show that vegetation control can be a powerful way to improve nesting habitat for Sandwich terns, and can result in increases in breeding numbers and breeding success. However, there are also case studies demonstrating that where vegetation control is not carried out, terns decline in breeding numbers and may desert the site as a consequence of the overgrowth of nitrophilous vegetation that develops as a result of the nutrient input from the terns. One clear example of this is the Farne Islands SPA. Despite the site being owned and managed by The National Trust, the numbers of Sandwich terns nesting there have progressively declined over many years (Figure 3.4.4). That decline is in stark contrast to the situation on nearby Coquet Island (Figure 3.4.5) which is managed by RSPB and where Sandwich tern numbers have remained consistently high over the period of decline at the Farnes. Since breeding numbers and breeding success are consistently high at nearby Coquet Island, there seems to be no problem of food shortage limiting Sandwich tern numbers at the Farnes; the problem appears to be one that could be solved with a change in management to restore the nesting area habitat to conditions suitable for nesting terns. The gradual decline in breeding numbers of Sandwich terns on Farne Islands SPA appears to be a response to this progressive deterioration of the nesting area, which became particularly obvious in 2021 because no cutting at all was carried out before the tern nesting season that year. However, there seems to have been a progressive shift in vegetation condition over many years (an example of a shifting baseline) and the Covid situation has come at a time when conditions had apparently progressed to very unsatisfactory even before the onset of the pandemic and the short-term lack of any management of vegetation on the site. Failure to manage vegetation on the Farnes in a way that allows terns to nest has been explicitly stated in the management plan (Tooth and Blakeley 2015) "*For years the islands have been in a state of decline due to the rapid colonisation and growth of common nettle and hemlock, which has been allowed to spread over Inner Farne virtually uncontrolled, encroaching on the nesting areas of all three tern species that currently breed on the islands. Rapidly growing Yorkshire fog, as well as nettle beds, limited the amount of short turf required by the terns*".

**Figure 3.5.2. A view of the vegetation now found over most of the surface of Inner Farne; this shows high density of rank nitrophilous plants that make most of the surface of the island unsuitable for tern nesting. Photo taken in June 2021.**

**Figure 3.5.3. The very small patch of suitable nesting habitat on Inner Farne that remains and is still used by Sandwich terns (photographed in June 2021); this bare area has been encroached by surrounding rank nitrophilous vegetation, and while**

**that vegetation boundary is probably desirable as cover for chicks, the area left for nest construction by terns is very limited and is shared with black-headed gulls and puffins.**

It seems highly likely that appropriate management of vegetation on the Farnes, as carried out on nearby Coquet Island by RSPB, would lead to recovery of the Sandwich tern population on the Farne Islands SPA.

**There is considerable scope for management interventions to improve the breeding conditions for Sandwich terns, both at some SPA sites where the species has been in Unfavourable condition for many years, and at non-SPA sites. Interventions could include predator exclusion, reducing/eliminating flood risk, vegetation management, or a combination of these. Sites suitable for such actions are identified, and best practice guidance is reviewed, indicating that management needs to be carried out in line with best practice in order to achieve success. For some sites, management would need to address more than one of these pressures and may need to control risks of human disturbance too.**

## 3.6 Potential to create a third safe breeding site for Sandwich terns within NNC SPA but away from Scolt Head and Blakeney Point, by habitat improvement measures

Increasing the number of safe breeding sites within North Norfolk Coast SPA would increase resilience for this important population but could potentially also allow further increase in breeding numbers.

Where an SPA holds more than one breeding site suitable for Sandwich terns, there is clear evidence that breeding numbers fluctuate more on individual sites within an SPA than they do for the SPA population as a whole. For example, at North Norfolk Coast SPA over the years 1969 to 2020 (all the years for which census data are available from JNCC (2021)), the Coefficient of Variation for the total SPA population was 0.19, whereas for individual sites within the SPA it was 0.75, 0.75, and 4.05 (Table 3.6.1).

**Table 3-6-1 Variability in annual counts of numbers of breeding Sandwich terns at North Norfolk Coast SPA, 1969 to 2020 (52 annual counts, data from JNCC 2021).**

| Site | Mean number of pairs | Standard deviation | Coefficient of Variation |
|---|---|---|---|
| **North Norfolk Coast SPA** | 3,939.3 | 756.1 | **0.19** |
| **Blakeney** | 1,802.2 | 1,354.5 | 0.75 |
| **Scolt Head** | 2,007.8 | 1,510.5 | 0.75 |
| **Stiffkey/Holkham** | 129.3 | 523.2 | 4.05 |

The same pattern can be seen for the Forth Islands SPA Sandwich tern population (Table 3.6.2), for Morecambe Bay & Duddon SPA (Table 3.6.3) and Anglesey terns SPA (Table 3.6.4). Years included differ among these SPAs because not all have reported counts for the most recent years, or possibly counts have stopped at a few sites (in particular Forth Islands sites have poor coverage reported since 2006). However, the pattern is clear and consistent.

**Table 3-6-2 Variability in annual counts of numbers of breeding Sandwich terns at Forth Islands SPA, 1969 to 2006 (38 annual counts, data from JNCC 2021).**

| Site | Mean number of pairs | Standard deviation | Coefficient of Variation |
|---|---|---|---|
| **Forth Islands SPA** | 307.4 | 210.0 | **0.68** |
| **Fidra** | 15.0 | 58.8 | 3.92 |
| **Inchmickery** | 254.1 | 238.8 | 0.94 |
| **Isle of May** | 29.6 | 95.3 | 3.22 |
| **Long Craig** | 8.7 | 32.5 | 3.74 |

**Table 3-6-3 Variability in annual counts of numbers of breeding Sandwich terns at Morecambe Bay & Duddon SPA, 1969 to 2019 (51 annual counts, data from JNCC 2021).**

| Site | Mean number of pairs | Standard deviation | Coefficient of Variation |
|---|---|---|---|
| Morecambe Bay & Duddon SPA | 452.4 | 390.8 | **0.86** |
| Foulney Island | 233.9 | 363.8 | 1.56 |
| South Walney | 34.4 | 98.8 | 2.87 |
| Hodbarrow | 184.1 | 317.9 | 1.73 |

**Table 3-6-4 Variability in annual counts of numbers of breeding Sandwich terns at Anglesey terns SPA, 1969 to 2020 (52 annual counts, data from JNCC 2021).**

| Site | Mean number of pairs | Standard deviation | Coefficient of Variation |
|---|---|---|---|
| Anglesey terns SPA | 799.4 | 724.1 | **0.91** |
| Cemlyn | 769.5 | 750.1 | 0.97 |
| Ynys Feurig | 29.9 | 59.6 | 1.99 |

The fact that numbers are relatively less variable for the combined sites within an SPA, as shown in all examples tabulated above, implies that Sandwich terns may move between sites within an SPA from year to year, causing higher variability in breeding numbers at individual sites than for the SPA as a whole. These data provide a clear message: having more sites within an SPA that can be used by Sandwich terns will increase resilience and stability of the SPA population. Another aspect of that is the observation for many sites that breeding numbers fall to zero in some years. This can be seen in Figures 3.4.1,2,3,7,8,9,10,11,12,13,14, and 15, so has affected 12 of the 16 SPA populations at some period during 1969-2021. That is a well-known aspect of Sandwich tern breeding ecology and may be due to multiple causes including predator impacts, human disturbance, flooding, erosion, vegetation encroachment. This provides a strong case for seeking the possibility of developing a third site within North Norfolk Coast SPA that could be made suitable for nesting by Sandwich terns. Because North Norfolk Coast SPA now holds almost 50% of the breeding population of Sandwich terns in Great Britain, the increased resilience of having a third breeding site within the SPA would be beneficial not only to the SPA population, but also to the wider population within Great Britain.

Since Sandwich terns did breed at Stiffkey/Holkham for many years, that would seem to be the obvious possible site for management to make it suitable for Sandwich tern nesting, should it be considered that this would be the most appropriate compensation measure. If this suggestion is to be developed, it would require input of local ornithological expertise to assess suitability of sites that might be developed for Sandwich tern nesting within North Norfolk Coast SPA.

**There is strong empirical evidence that Sandwich tern populations within SPAs are more resilient and stable if the SPA contains more alternative breeding sites. That evidence provides a case for considering the possible restoration of a third Sandwich tern breeding site within North Norfolk Coast SPA to add to the two successful sites currently in use by birds.**

## 3.7 A brief review of the scope for provision of artificial breeding sites for kittiwakes on offshore structures in the UK southern North Sea

To provide successful compensation, new artificial nest sites need to be adopted by kittiwakes which were otherwise unable to breed due to lack of nesting opportunities, or need to result in increased breeding success relative to existing nearby established (natural or artificial) colonies. Pairs breeding at new artificial sites probably need to produce at least 0.6 chicks per nest (based on PVA models using best available demographic data; Horswill and Robinson 2015) or possibly about 0.8 chicks per nest (based on the empirical observation that colonies with lower output tend to decline while those with higher output tend to increase; Coulson 2011, 2017) just to maintain the population at the new artificial site itself. So only breeding success >0.8 chicks per nest will represent potential compensation for losses of birds through collision mortality or barrier effects at offshore wind farms. Artificial sites therefore need not only to be used, but also need to achieve higher breeding success than at natural colonies of kittiwakes, so that the surplus production provides compensation. Kittiwakes show strong competition for high quality nest sites (Coulson 2011, Acker et al. 2017). There is clear evidence not only of density-dependent competition for nest sites at large kittiwake colonies (Acker et al. 2017), but there is also evidence of density-dependent competition for food in the waters around these large colonies (Wakefield et al. 2017). Breeding success may be reduced at large colonies as a result of increased effort (energy expenditure) required due to this competition for resources. The evidence therefore indicates that creation of small breeding aggregations on artificial colonies in areas between large natural colonies could potentially result in higher breeding success if the artificial colonies provide conditions with less intra-specific competition and higher nest site quality.

Offshore platforms provide an opportunity for kittiwakes to nest in new locations. Kittiwakes were found to be breeding on Morecambe Central Platform in Morecambe Bay in 1998 when there were two nests with one and two young respectively (Thorpe 2001). Two pairs nested there in 1999 (Brown and Grice 2005). Numbers increased, with 66 chicks produced in 2003 and 58 chicks produced in 2004 (Anon 2004). However, no further data appear to have been published and the platform, which was installed in the mid-1980s, has now been decommissioned.

The first breeding record of kittiwakes in the Netherlands was on an uninhabited offshore gas platform (L8-P) in the southern Bight 65 km NW from Texel, which was constructed in 1994. Camphuysen and de Vreeze (2005) found 45 apparently occupied nests (AONs = pairs) on this platform in June 2005 and noted that the droppings indicated a diet of mostly sandeels and a few sprats. They noted that this new colony was growing rapidly in breeding numbers (the birds first nested there in 2000 only six years after construction, and there were 3 AONs in 2001). Since 2005 no subsequent published accounts seem to be available. At least one of the nesting birds was in 3rd calendar year plumage, indicating an unusually young age of recruitment, consistent with this being a very small rapidly growing colony. The kittiwake nests were located on narrow steel girders, mostly below overhanging structures that gave the birds protection from large gulls. A second platform, the nearby L8-alpha was colonised by two pairs of kittiwakes in 2005 Camphuysen and de Vreeze (2005).

Christensen-Dalsgaard et al. (2019) describe breeding by kittiwakes on six offshore oil platforms in Norwegian waters (five in the Norwegian Sea and one in the Barents Sea). The largest of these colonies was 674 nests on the oil platform Draugen, operated by OKEA, 75 km offshore. There were also 252 nests on Heidrun platform, operated by Equinor, 165 km offshore. Christensen-Dalsgaard et al. (2019) found over 1,200 pairs of kittiwakes nesting on these oil rigs in 2019 (exact numbers were not counted on two rigs so are not included in the total), and breeding success on the oil rigs was significantly higher than at coastal artificial colonies in the same part of the Norwegian coast (they list for comparison colony sizes and breeding success achieved at four artificial colonies on the Norwegian coast at fishing ports), and on average about four times higher than at natural colonies in the same part of Norway (they list for comparison colony sizes and breeding success at four neighbouring natural colonies). Christensen-Dalsgaard et al. (2019) suggest that the higher breeding success on oil rigs is likely to be due to higher food availability (the birds nesting offshore being at foraging grounds so not having to commute as far as birds that nest at the coast), and also to the fact that there are fewer predators at the oil rigs. They point out that predation on kittiwake nests on the oil rigs may not by zero. In particular, "*kittiwakes breeding on the exposed parts of the rigs, had a lower productivity than those breeding on more sheltered parts of the rig*". Christensen-Dalsgaard et al. (2019) suggest that this may be due to predation by large gulls, which are able to access nests that are in open areas but cannot access nests that are sheltered. However, the difference could potentially relate to exposure to rain and direct sunshine, which can also cause breeding failure of exposed nests. While artificial nest sites offshore in the southern North Sea may provide similar advantages in terms of proximity to kittiwake feeding grounds and protection from disturbance and predators, at sea artificial colonies may increase collision risk if located near to offshore wind farms and would be much more difficult to monitor to demonstrate effective compensation. In addition, novel sites created in areas distant from existing kittiwake colonies may be less likely to be colonized by prospecting kittiwakes, so may be less successful than new artificial sites on the coast in areas where kittiwakes are already prospecting and possibly nesting in relatively small numbers that could more easily be encouraged to increase. For these reasons, the approach of providing offshore nest sites for kittiwakes in the southern North Sea may be lower priority in terms of suitability for compensation.

Because there are so many consented and proposed offshore wind farm sites in the UK southern North Sea waters, an offshore kittiwake colony in southern North Sea waters may be very difficult to position so that it is distant from offshore wind farms, and therefore has a low collision risk for kittiwakes that nest there. An alternative may be to consider either a site off Cornwall, or off Northumberland. Sandeel abundance off Cornwall appears to be lower than in most parts of the North Sea (Heessen et al. 2015), so a site there may not provide ideal foraging conditions for breeding kittiwakes although it would be in a location where collision risk from offshore wind turbines would be relatively low. Offshore platforms off Cornwall may also be subject to greater risk of storm impacts on nesting kittiwakes from sea spray. There may also be possibilities for floating offshore wind in the southern approaches in the longer term future in which case that region may not remain turbine free. A site off Northumberland could provide good access to high densities of sandeels (Heessen et al. 2015) and could be moderately distant from offshore wind farms (Figure 3.7.1), at least as currently planned, so might represent an optimal choice.

**Evidence indicates that kittiwakes can achieve higher breeding success on offshore platforms than they do at coastal colonies, probably because they have less far to commute to foraging grounds and are less exposed to potential predators and disturbance. It would be difficult to locate an offshore kittiwake colony in the southern North Sea without it being close to offshore wind farms. A site off Northumberland could provide good access to high densities of sandeels,**

**and could be moderately distant from offshore wind farms, so might represent an optimal choice if an offshore site was to be selected as a compensation mechanism.**

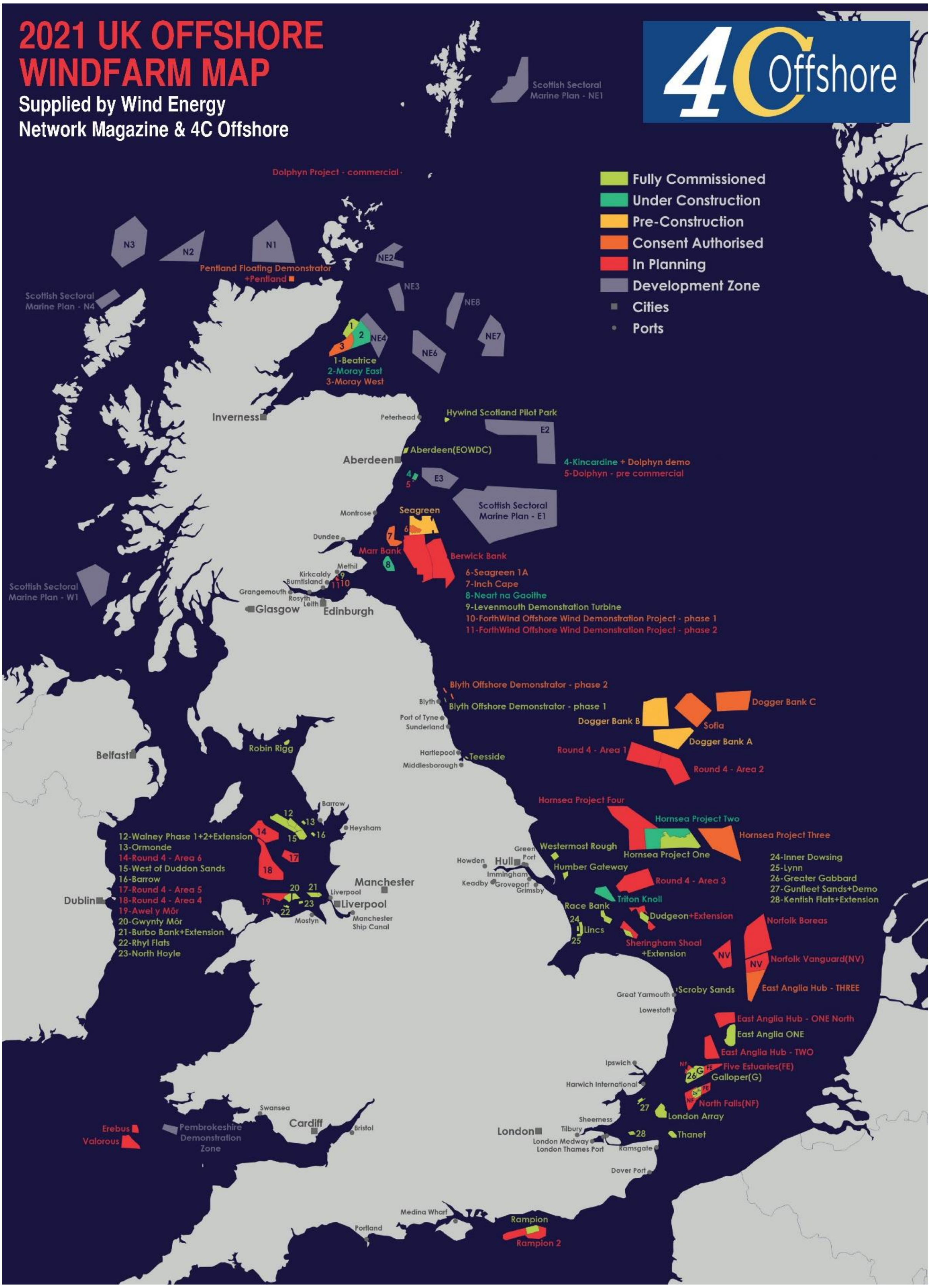


Figure 3.7.1. Map of the locations of offshore wind farm developments in UK waters.

## 3.8 A case for improving existing onshore artificial structures for kittiwake breeding to increase breeding numbers and productivity

Hornsea Three has proposed constructing four new artificial colonies for kittiwakes at two sites in the vicinity of Lowestoft to Sizewell, and two sites in the vicinity of the Tees Estuary to south of Seaham. Their plan (Ørsted 2020b) states "*The design specifications for the artificial nesting structures are at this stage unconstrained. They may take the form of a bespoke structure or be a modification to an existing building or piece of infrastructure (such as a seawall). Where two structures are located in the same search zone, the intent is that they are different designs to maximise the opportunity for kittiwake to colonise. The structure designs will likely be influenced by landowner negotiations, landscape character, and existing environment of the selected location.*" Similar structures, in the same part of England, have been proposed as compensation, if required, by Norfolk Boreas (Royal Haskoning DHV 2020).

There is a limit to how many sites would be satisfactory locations for new artificial colonies of kittiwakes, but there is also a limit to how many immature prospecting kittiwakes will be available to take such opportunities. Although there clearly is a pool of immature kittiwakes seeking to recruit into colonies, the size of that pool is uncertain. Therefore, other possible, and complementary, approaches to increasing productivity of kittiwakes should be explored. One obvious approach would be to enhance existing artificial structures in order to increase breeding success achieved by kittiwakes using those structures, rather than just aiming to increase breeding numbers.

As far as we are aware, this approach has not yet been proposed by any of the Developers that are required to consider provision of compensation for kittiwakes. But in principle, an adaptation to an existing structure that increased breeding success could be a greater contribution to kittiwake conservation than provision of new structures if those new structures achieved no greater breeding success than currently achieved by kittiwakes already nesting on existing artificial sites.

To give a simple example: the Saltmeadows tower at Gateshead is an artificial structure that was created specifically for kittiwakes. It has three sides, one of which faces south and is exposed to direct sunshine throughout most of the day. However, the evidence indicates that the south-facing nest sites on the tower are relatively unattractive, as the south-facing side is used by fewer kittiwakes than the other two faces that are not exposed to direct sunshine, and the south-facing nests achieve lower breeding success. The two faces preferred by kittiwakes are now virtually fully occupied, so further growth in numbers nesting on the tower is likely to force more pairs to accept sites on the south face, resulting in a further decrease in average productivity. Providing a north-facing alternative to the south-facing part of the structure would allow more pairs to nest without exposure to direct sun and would be expected to result in an increase in long-term productivity of that site, as well as permitting further increase in breeding numbers. In quantitative terms based on the situation in 2021, the south facing side of the tower held only 15 nests in June 2021 and Northumbria Ringing Group ringed 14 chicks there on 5 July (0.93 chicks per nest), whereas the east face (exposed to morning sun but not afternoon sun) held 54 where 63 chicks were ringed (1.17 chicks per nest) and the north-west face (sheltered from direct sun) 55 nests where 92 chicks were ringed (1.67 chicks per nest). The discrepancy in output from the different orientations of a structure that is identical in other respects is striking. Allowing kittiwakes to choose sites on another north-facing extension to the tower could not only allow more pairs to nest, but could increase nesting success by about 0.5 to 0.7 chicks per nest based on the 2021 data compared to the productivity achieved on the south-facing area of the tower. Similar differences in productivity between the three faces of the tower have been recorded in previous years (Dan Turner, pers. comm.).

Another example: the 'kittiwake ledge' on Lowestoft harbour wall has been abandoned by kittiwakes. It was accessible to foxes and large gulls, because the design was flawed; the ledge is too wide so allows large gulls to land on it and walk from kittiwake nest to nest, and it is open at the landward end so allows foxes to jump onto the end of the ledge and walk along it. Some kittiwakes that relocated from that site onto buildings in the town centre (which can be identified from their individual colour rings) are currently achieving high breeding success, but some do not, because they have colonised buildings where they are not welcome. Nests are destroyed on some of those sites and breeding by some birds can be disrupted by deployment of anti-bird netting. Provision at the 'kittiwake ledge' on Lowestoft harbour wall of new narrow ledges that are gull-proof and fox-proof would allow kittiwakes to re-colonise that structure and to achieve higher breeding success there than they achieve on sites where they are unwelcome in town. Because kittiwakes that are unsuccessful in their breeding attempt are likely to relocate to a different nesting area, birds from sites where they are persecuted or deterred will be likely to move to the improved site, so will increase the overall productivity of the population. This provides a 'win-win' scenario, both reducing conflict between kittiwakes and residents in Lowestoft by providing kittiwakes with the opportunity to relocate to sites where they are welcome, as well as providing kittiwakes with superior nesting sites away from the town centre, new nest sites that will result in higher overall productivity and so provide compensation.

Although the average breeding success of kittiwakes in Lowestoft in 2021 was around 1.19 chicks per nest, some specific sites fell far below that level. For example, one house in Commercial Street held 6 nests in May 2021, but all six nests disappeared between then and July, so no chicks fledged. A neighbouring house with 4 nests fledged only 2 chicks. Three properties in London Road North held 13 nests in May, but fledged only 2 chicks. The BT building, where exclusion netting was put up early in 2021, held 49 nests in 2017, but only 33 in 2021, and those produced only 28 chicks (0.85 chicks per nest) despite BT removing the exclusion netting and providing new nesting ledges for the kittiwakes in May 2021. As kittiwake breeding numbers have increased in Lowestoft rapidly over the last few years, the number of sites on which they nest in Lowestoft has increased considerably. Further increases are likely in future (based on current trend, high breeding success, and the presence of large numbers of immature birds looking for nest sites), and the further increase will undoubtedly increase conflict as more kittiwakes nest on buildings where they are not welcome. Renovation of the existing harbour wall site to provide high quality nest sites would attract birds from sites where they are being displaced and are failing in breeding attempts as well as provide high quality nest sites for new recruits joining the population, and that would increase the mean breeding success achieved by the population as a whole. That increase would represent appropriate compensation. It would also be complementary to provision of new sites elsewhere, by providing compensation that would not be dependent on the existence of a continuing excess pool of site-seeking immatures.

**Adaptations to existing artificial structures that increased breeding success of kittiwakes in a population could be a significant contribution to kittiwake conservation that would be complementary to provision of new structures and would reduce risk that the pool of site-**

**seeking immatures might be depleted by overprovision of new sites in a short timescale. Allowing increased breeding success on structures that avoid conflict with local people where kittiwakes nest on buildings where they are not welcome could not only provide compensation by increasing productivity of the population but could also reduce conflict by allowing birds to move off structures where they are prevented from breeding successfully.**

## 3.9 Update on evidence for strategic compensation for kittiwake by limiting sandeel harvest

RSPB (Dunn 2021) reviewed the latest evidence regarding impacts of sandeel fishing on seabirds in the North Sea and stated that "*we identify three serious flaws in the current management of the fishery.*

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

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

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

RSPB (Dunn 2021) conclude "*the greatest benefits for a variety of UK breeding seabirds (and other top predators, notably marine mammals and commercial fish like cod) would come from putting an end to the sandeel fishery across the greatest possible area of sea adjacent to the UK coast*".

Kittiwakes breeding at most colonies around the North Sea feed mainly on sandeels throughout the breeding season (Furness and Tasker 2000, Coulson 2011). Sandeel abundance strongly influences breeding success of kittiwakes (Frederiksen et al. 2004, Cury et al. 2011, Carroll et al. 2017, Christensen-Dalsgaard et al. 2018), and breeding success strongly influences whether kittiwake colonies increase or decrease in breeding numbers (Monnat et al. 1990, Cadiou et al. 1994, Coulson 2011, 2017). In Shetland, kittiwake breeding success, and breeding numbers, decreased dramatically after the collapse of the Shetland sandeel stock (Furness and Tasker 2000). At Foula, kittiwake breeding success shows a strong relationship with Shetland sandeel total stock biomass (Figure 3.9.1). Kittiwake breeding success was much lower in most years of sandeel biomass below 40,000 tonnes but was high in almost all years when sandeel biomass was above that level.

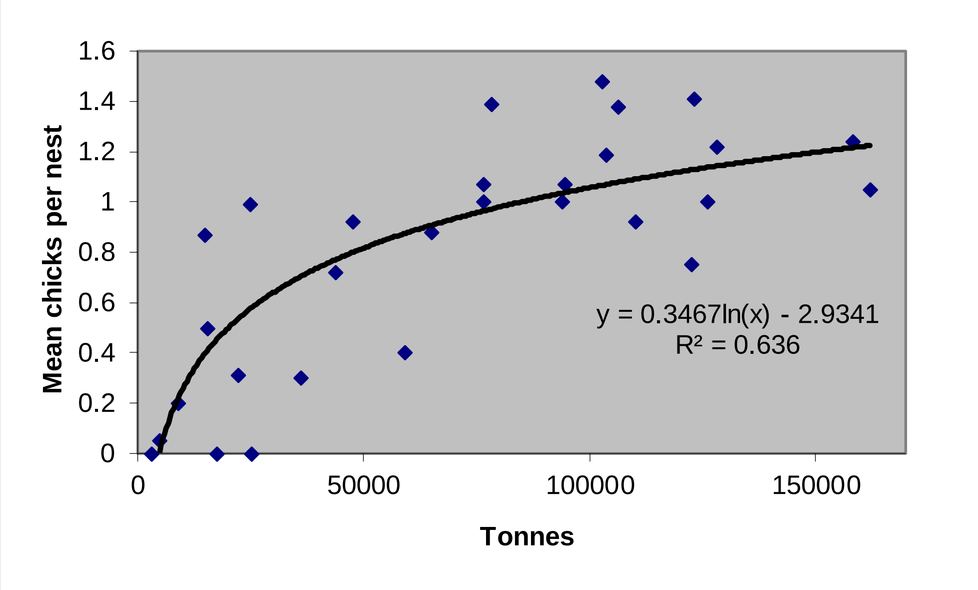


**Figure 3.9.1. Breeding success of kittiwake at Foula, Shetland, in relation to the Shetland sandeel total stock biomass for the years 1976 to 2004**

Kittiwake breeding success has also been affected at the Isle of May, 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 2017, Olin et al. 2020) was heavily fished (Frederiksen et al. 2004). Sandeels are the target of what has been the largest single-species fishery in the North Sea over recent decades, with that fishery now particularly concentrated on the sandeel stock on Dogger Bank. Kittiwakes at Flamborough and Filey Coast SPA (FFC SPA), now the largest kittiwake colony in the British Isles, forage over a large area from that colony, and their foraging area includes some of the most important sandbanks supporting high densities of sandeels and the sandeel fishery (Carroll et al. 2017). There is strong evidence that the sandeel fishery has caused depletion of sandeel biomass in this region (Lindegren et al. 2018), and that reduced abundance of sandeels as a result of the high fishing effort on sandeels has led to reduced breeding success of kittiwakes at FFC SPA (Carroll et al. 2017). Reducing the level of fishing effort on sandeels or closing the fishery in waters close to the colony, would, therefore, represent mechanisms to improve breeding success of kittiwakes at that colony by making it possible for the biomass of the sandeel stock to recover from the high fishing mortality that has been imposed in recent decades. Reduction in fishing mortality would be anticipated to lead to rapid, though probably incomplete, recovery of sandeel abundance (Lindegren et al. 2018). Sandeel is a short-lived fish which starts to breed when only 1 or 2 years old, with high reproductive potential, and since kittiwakes will feed on all age classes of sandeels but especially on 1 and 2 year old sandeels, the increase in sandeel abundance would be likely to influence kittiwake breeding success with a time lag of only 1 or 2 years.

Frederiksen et al. (2004) 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 (Figure 3.9.2). Adult survival was also lower during years with sandeel fishing in the area (Frederiksen et al. 2004).

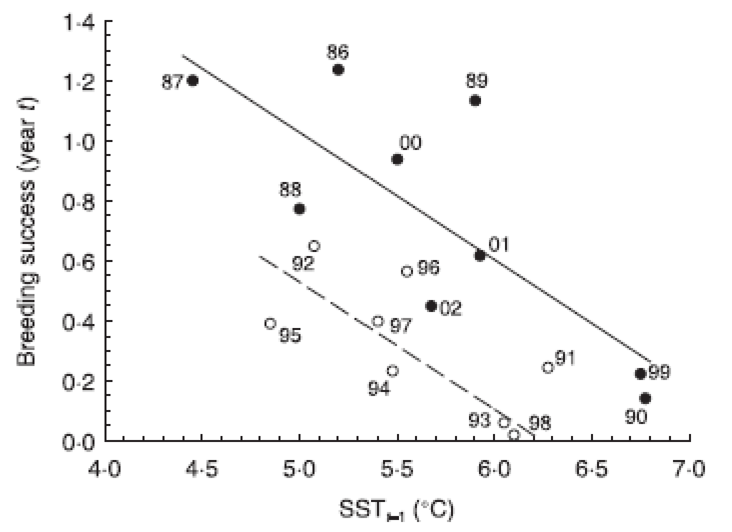


**Figure 3.9.2. Kittiwake breeding success at the Isle of May in relation to local Sea Surface Temperature in February-March of the previous year, and the presence (open circles and dashed line) or absence (black dots and solid line) of a sandeel fishery off east Scotland. From Frederiksen *et al.* (2004).**

A decision was taken to close an area to sandeel fishing (the 'sandeel box' off the east of Scotland) because of persistent low breeding success of kittiwakes indicative of the poor condition of the sandeel stock in the area. The consequence of that closure was monitored. Closure of the fishery resulted in an increase in sandeel stock biomass (Greenstreet et al. 2010) and an increase in kittiwake breeding success at colonies within the closed area compared to those outside (Daunt et al. 2008, Frederiksen et al. 2008), providing experimental evidence for the mitigation of fishery impact by closing the fishery. Recovery of sandeel abundance in the closed area has led to the sandeel fishing industry seeking the opportunity to resume fishing within the closed area, but until now the regulator has retained this closed box, although fishing for sandeels has occurred right up to the offshore (eastern) edge of the closed box.

Closure of the sandeel fishery off east Scotland also altered the age structure of the sandeel population. When the stock was heavily fished, very few sandeels lived beyond two years old, resulting in high variability on stock abundance from year to year depending on the highly variable level of production of young fish. When the fishery was closed, sandeels tended to live longer, with large cohorts remaining in the stock for up to six years (Peter Wright, pers. comm.). The longer life expectancy of sandeels when not subject to fishing not only increases mean biomass of the stock, but also reduces variability in abundance driven by variable recruitment. This in turn will also be beneficial to kittiwake breeding success, by ensuring that even if sandeel recruitment is poor, the biomass of the stock is buffered by presence of several older age classes of fish.

The abundance of sandeels in ICES area 4 (which includes the sandeel no-take box off east Scotland) declined during 1993-2001 (Figure 3.9.3). However, after the closure of the sandeel fishery off east Scotland, this stock eventually recovered (Figure 3.9.4).

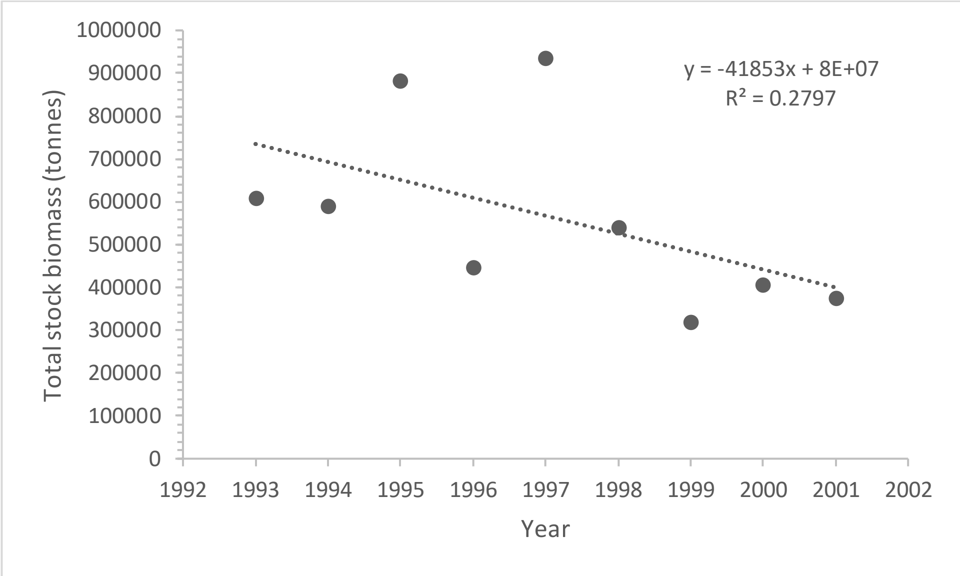


**Figure 3.9.3. Abundance (total stock biomass in tonnes) of sandeels in ICES area 4 (which includes the no-take zone off east Scotland that was established in 2000) in the period 1993 to 2001. Data from ICES (2020).**

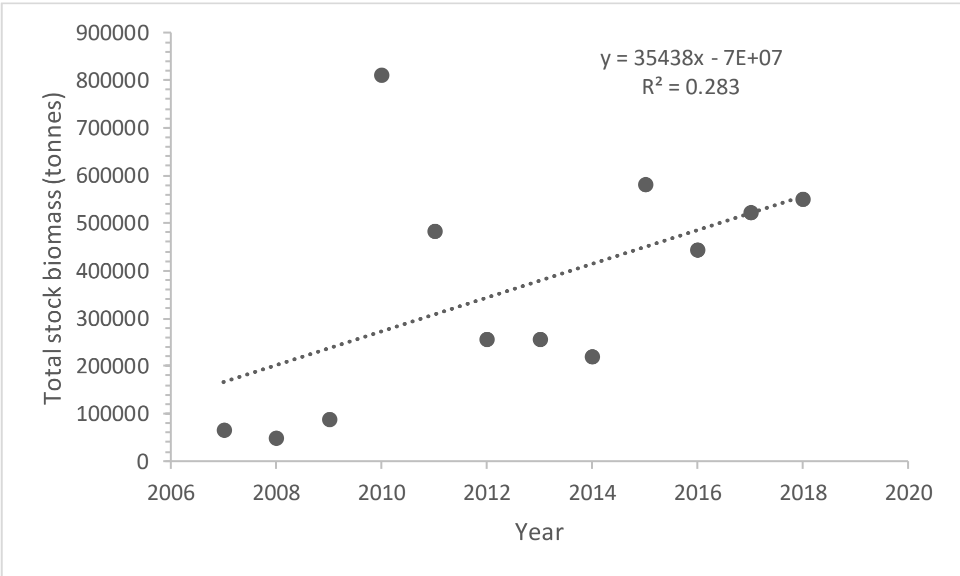


**Figure 3.9.4. Abundance (total stock biomass in tonnes) of sandeels in ICES area 4 (which includes the no-take zone off east Scotland that was established in 2000) in the period 2007 to 2018. Data from ICES (2020).**

Sandeel catches from ICES area 4 decreased considerably when the sandeel no-take box was established off east Scotland, but a large part of ICES area 4 remained open to sandeel fishing. Commercial catch from the open part of area 4 was low in 2005 to 2012 because the stock biomass had been depleted and so commercial fishing was no longer sufficiently profitable to justify fishing in that area (while better catches could still be obtained elsewhere such as area 1r Dogger Bank). However, as sandeel stock began to recover in area 4 the potential profitability of fishing there increased. Commercial catches have increased considerably in the last few years (Figure 3.9.5). The return to high fishing effort on sandeel in area 4 threatens to impact this recovering stock again, with potential effects on kittiwake breeding success in east Scotland.

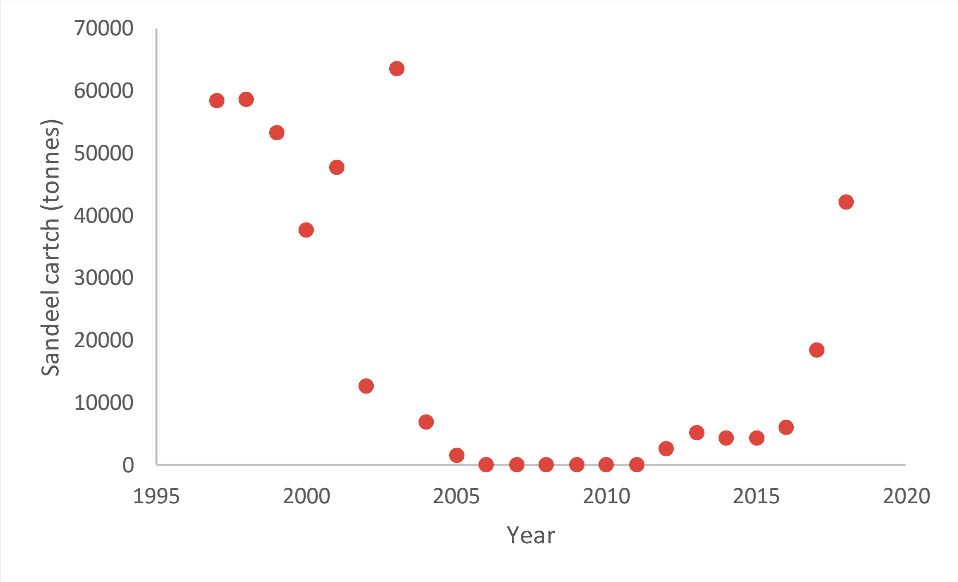


**Figure 3.9.5. Catch (tonnes) of sandeel by the commercial sandeel fishery in ICES area 4 from 1997 to 2018 (data from ICES 2020). Note that the sandeel no-take box was established in 2000 but fishing in parts of area 4 that are outside the box was permitted throughout the period and the low catch from 2005 to 2015 was due to low stock biomass and not just to the existence of the no-take box in part of area 4.**

Kittiwake breeding success and adult return rate from the previous year (an index of adult survival rate but not corrected for birds missed in that year but that returned in later years, so an underestimate of true survival) at the Isle of May, which is monitored every year by UKCEH, averaged 0.88 chicks/pair and 0.81 in 2011-2016 (data from UKCEH annual reports on Isle of May seabird studies) when the sandeel stock biomass in ICES area 4 was generally above 200,000 tonnes, but averaged only 0.44 chicks/pair and 0.75 in 2004-2010 (data from UKCEH annual reports on Isle of May seabird studies), when sandeel stock biomass was generally below 200,000 tonnes. Sandeel stock biomass is not only a major driver of kittiwake breeding success, but also affects adult survival, as originally found at Shetland (Oro and Furness 2002). Indeed, the relationship between kittiwake return rates and sandeel stock biomass over the period of recovery of this stock (2004 to 2018) appears remarkably strong (Figure 3.9.6).

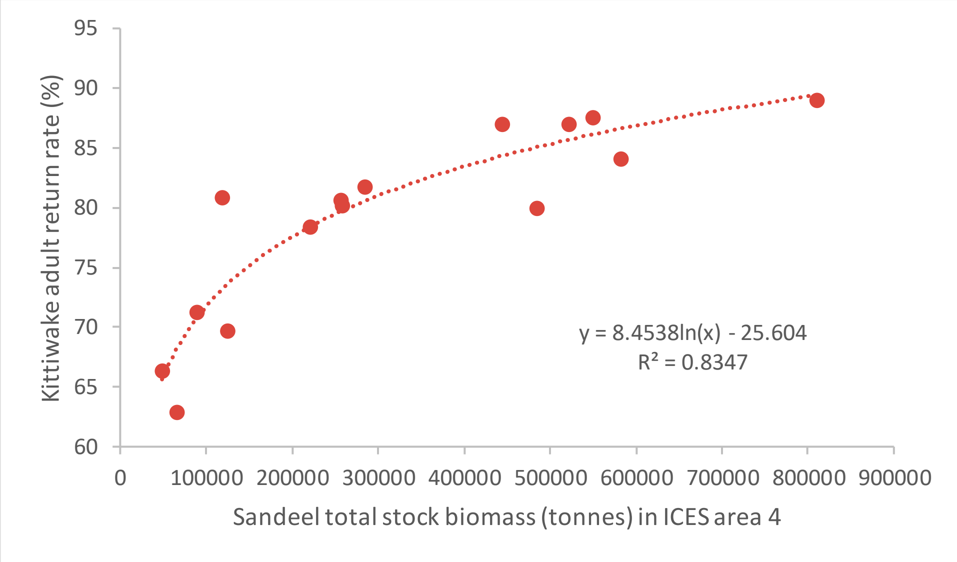


**Figure 3.9.6. Annual return rates of adult kittiwakes at the Isle of May (UKCEH data from online annual reports) in relation to ICES estimates of annual sandeel total stock biomass (tonnes) in area 4 between 2004 and 2018. Data for 2019 and 2020 are not yet published.**

The productivity of kittiwakes at FFC SPA is significantly correlated with sandeel stock biomass. The relationship found by Carroll et al. (2017) for kittiwakes at FFC SPA in relation to sandeel stock in ICES North Sea sandeel management Area 1r ('Dogger Bank' and neighbouring areas) is similar to that previously identified elsewhere: kittiwake breeding success and adult survival at Shetland was closely related to changes in sandeel stock biomass in that area (Furness and Tasker 2000, Oro and Furness 2002, Furness 2007), and kittiwake breeding success at the Isle of May was strongly influenced by effects of sea surface temperature and sandeel fishing on the sandeel stock off the Firth of Forth, east Scotland (Frederiksen et al. 2004).

Christensen-Dalsgaard et al. (2018) showed that kittiwake breeding success was higher at a colony in Norway when kittiwakes were able to feed chicks on sandeels but was much reduced in years when sandeel availability was lower and kittiwakes had to switch to feeding chicks on mesopelagic fish.

Lindegren et al. (2018) carried out a hindcast analysis of the Dogger Bank sandeel stock to assess the consequence of the high fishing mortality. They estimated that sandeel spawning stock biomass would have been about twice as large now as it is, if the fishery had maintained fishing mortality (F) at F=0.4 rather than at the levels of F=0.8 to 1.2 as seen during 1999-2009 in the history of this fishery. Indeed, the stock would be even larger now if there had been no fishery harvesting sandeels, although Lindegren et al. (2018) did not report on that scenario. However, their results further support the conclusion that the high fishing mortality imposed on the sandeel stock has been a major influence on the abundance of the sandeel, and hence on the breeding success of kittiwakes. Lindegren et al. (2018) also identified influences of sea temperature and copepod abundance on the abundance of sandeels and suggested that long term trends in those drivers may inhibit recovery of sandeels if fishing pressure was reduced. In addition, severe reduction in forage fish stock biomass can lead to increased natural mortality that may inhibit recovery, and there is evidence of this with sandeel declines to low biomass (Saraux et al. 2020). At present, the

Dogger Bank sandeel stock remains considerably below its long term average abundance and is subject to a fishing mortality around F=0.6 (ICES 2020), a figure above the level tested in the scenario of Lindegren et al. (2018), and a figure which their scenario modelling clearly demonstrates has a negative impact on sandeel abundance. Indeed, at present the spawning stock biomass in this area 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 an increased risk of recruitment failure in this stock (ICES 2020).

Off east Scotland, there is still fishing for sandeels, but that is limited to outside the sandeel box. However, the modelling by Lindegren et al. (2018) suggests that closure of sandeel fishing in the area of UK waters beyond the existing sandeel box would contribute to recovery of the sandeel stock biomass throughout that area, so could be a compensation measure that would be effective for kittiwakes at colonies in east Scotland.

Cury et al. (2011) used empirical evidence from several seabird-fishery interactions around the world to suggest that 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. Maximum total stock biomass in ICES area 1r was just below 2,000,000 tonnes during the 1980s at a time of high fishing effort, so likely to be reduced relative to unfished biomass (Lindegren et al. 2018). Nevertheless, if we take 2,000,000 tonnes as maximum biomass for this stock, then the Cury et al. (2011) threshold to avoid impacts on dependent predators such as kittiwakes would be a fished total stock biomass of 666,667 tonnes. Using this rule of thumb, the sandeel fishery has been harvesting from a stock biomass that was below this threshold abundance in 13 of the 16 years 2003-2018 (ICES 2020). The long-term deterioration of this heavily fished stock and its tendency to be below the Cury et al. (2011) threshold in recent years is clear in Figure 3.9.7.

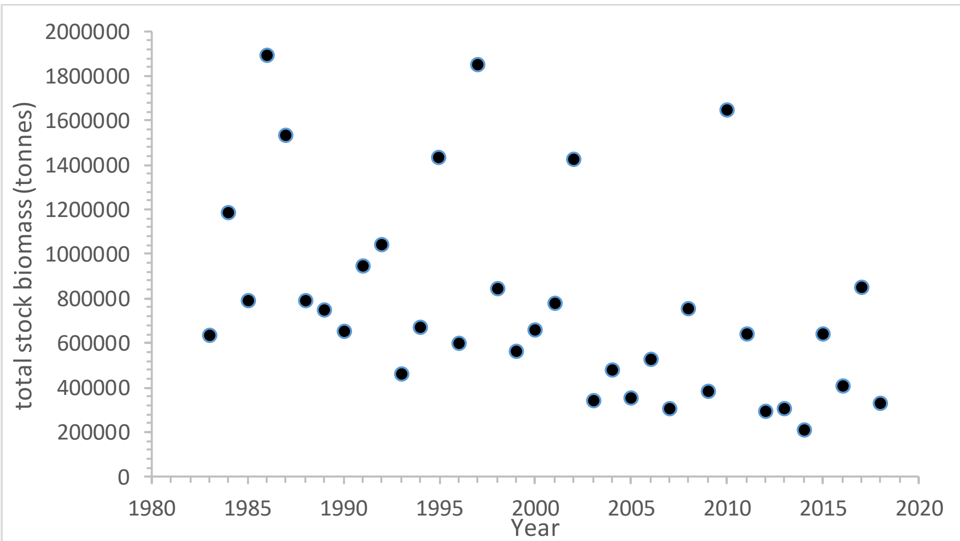


**Figure 3.9.7. Total stock biomass (tonnes) of sandeels in ICES area 1r (Dogger Bank stock) from 1983 to 2018 (ICES 2020), in relation to the Cury et al. (2011) 'rule of thumb' that stock biomass should be maintained above one-third of the historical maximum (in this case above 666,667 tonnes) to avoid adverse impacts on dependent seabird populations.**

This suggests that the continuation of sandeel fishery is likely to continue to cause mortality of many thousands of kittiwake chicks per year compared to a scenario with no fishing of the sandeel stock. It also identifies that the single most effective practical management action to assist the kittiwake population would be closure of the sandeel fishery (Carroll et al. 2017, Lindegren et al. 2018, Wright et al. 2018). Mortality of chicks has less impact on the kittiwake population than the same mortality of adults. On the basis of the demographic parameters of kittiwakes in the North Sea (adult survival 0.854, juvenile survival 0.79, age of first breeding 4 years; Horswill and Robinson 2015), two fledglings would be required, on average, to give rise to one adult surviving to recruit into a local colony at 4 years of age. If sandeel fishing reduced productivity at FFC SPA by an average of 0.5 chicks per pair per year which appears to be approximately the scale of the impact indicated by the data for this region and equals the estimate for the kittiwakes at the Isle of May, that would be equivalent to 50,000 pairs x 0.5 chicks per pair, or 25,000 chicks that die due to scarcity of sandeels. If those chicks had survived to fledge, they would result in about 12,000 adults per year surviving to recruit into colonies at 4 years of age. That is more than an order of magnitude more than losses estimated to be caused by collision mortality at offshore wind farms in the region, so represents a potential for far greater compensation than the precautionary estimate of losses incurred due to offshore wind.

In view of the large numbers of kittiwake chicks dying at Flamborough and Filey Coast SPA as a consequence of reduced abundance of sandeels due to fishing impacts, there is evidently scope for compensation through either reducing fishing effort directed at sandeels, or through closing areas within the main foraging range of this kittiwake population to sandeel fishing. ICES promotes ‘ecosystem-based management’ of fish stocks. However, their management of the sandeel stock has recently been criticised as not being ‘ecosystem-based’ because it sets a quota only on the basis of sustaining the sandeel stock and not on the basis of the needs of higher trophic level predators such as kittiwakes (Hill et al. 2020). ICES should therefore be highly receptive to the need to better manage that sandeel stock to avoid adverse impacts on kittiwakes and other top predators. An extension to a proposed fisheries management area or a new proposal would need to be facilitated by the UK Government in allocating appropriate powers to a relevant management body and, potentially, through the delivery of legislation to secure the necessary powers.

The same case applies though to a smaller extent for the separate sandeel stock in ICES area 4; reduced fishing effort on that stock can be expected to result in an increase in sandeel biomass, and a concomitant increase in kittiwake breeding success, but that recovery may fail if fishing effort increases in the part of area 4 that remains open, as seems to be the trend since 2015.

Sandeel is the main breeding season food of kittiwakes in the North Sea, but sprat can also be taken by birds at a few colonies. During summer, sprats tend to be in shallow marine habitats influenced by freshwater inflows into the sea. Their distribution in the North Sea is predominantly southern, mainly south and east of the Dogger Bank, but spreads over much larger areas when the sprat stock increases in biomass (Heessen et al. 2015, ICES 2020). Similarly, sprat catches tend to focus on the highest sprat density areas in the southern North Sea, but catches are taken as far north as Shetland in years of high stock biomass, as in 2019 (ICES 2020). Diets of breeding kittiwakes are not well known for many colonies, but at most sites where these have been studied there has been an overwhelming dominance of sandeel in kittiwake breeding season diet. Exceptions to this include small colonies of kittiwakes in the upper Firth of Forth and at Lowestoft, where sprats are believed to represent a significant part of breeding kittiwake diet and to support high breeding success at those colonies (Lothian Ringing Group, pers. comm., Mike Swindells, pers. comm.). Regurgitates have been collected from kittiwakes ringed at sites in Lowestoft each year between 2007 and 2016. A total of 179 samples (M. Swindells, in litt.) included 114 containing sandeels and 93 containing clupeids (sprats, where species could be identified). Sampling during ringing limits the data to one or two days in late June or early July in most years. Nonetheless, in most years sandeels were the most frequent prey, with sprats appearing to represent an important alternative and possibly were the predominant prey in a few years. At the Saltmeadows tower, Gateshead, all regurgitates sampled in 2020 were sandeels. However, at Howick, Northumberland, some kittiwakes regurgitated sprats as well as sandeels in 2021 (Andy Rickeard, in litt.). The importance of sprats for these populations remains uncertain, but appears to be higher than for kittiwake colonies in north or east Scotland. It is therefore likely that kittiwakes at such colonies would benefit from a sprat no-take zone being established since that would be expected to lead to an increase in sprat stock biomass.

**There is now clear empirical and modelling evidence that depletion of sandeel stocks is caused by the sandeel fishery. There is strong evidence that kittiwake breeding success declines when sandeel stock biomass is reduced, and there is now further evidence that kittiwake adult survival is also reduced when sandeel stock biomass is reduced. Existing management of sandeel stocks has resulted in exploited stocks being reduced to close to $B_{lim}$, well below the threshold at which kittiwake breeding success is reduced, but stocks can recover if fishing mortality is constrained or removed. There is, therefore, strong evidence that closure of sandeel fishing in UK North Sea waters would benefit kittiwake populations. Since some kittiwakes also forage on sprats/juvenile herring, closure of fisheries targeting sprats/juvenile herring may also benefit kittiwakes.**

# 4 REFERENCES


Acker, P., Besnard, A., Monnat, J-Y. and Cam, E. 2017. Breeding habitat selection across spatial scales: is grass always greener on the other side? Ecology 98: 2684-2697.

Anon 2004. Kittiwake success story. Bulletin of the North Sea Bird Club 106: 4.

Babcock, M. and Booth, V. 2020. Habitat: Vegetation Management. Tern conservation best practice. Produced for "Improving the conservation prospects of the priority species roseate tern throughout its range in the UK and Ireland" LIFE14 NAT/UK/000394.

BBC 2021. Overgrown Farne Island plants spark Arctic tern nesting fears - BBC News

Bourne, W.R.P. and Smith, A.J.M. 1974. Threats to Scottish Sandwich terns. Biological Conservation 6: 222-224.

Brenninkmeijer, A. and Stienen, E.W.M. 1994. Pilot study on the influence of feeding conditions at the North Sea on the breeding results of the Sandwich tern *Sterna sandvicensis*. IBN Research Report 10.

Brown, A. and Grice, P. 2005. Birds in England. T & AD Poyser, London.

Brown, R.A. and McAvoy, W. 1985. Nesting terns in Strangford Lough, 1969-84 – a review. Irish Birds 3: 33-47.

Cadiou, B., Monnat, J.Y. and Danchin, E. 1994. Prospecting in the kittiwake, *Rissa tridactyla* – different behavioural patterns and the role of squatting in recruitment. Animal Behaviour 47: 847-856.

Caithness 2021. St John's Loch and St John's Pool Bird Nature Reserve, Caithness, Scotland [redacted]

Camphuysen, C.J. and de Vreeze, F. 2005. Black-legged kittiwakes *Rissa tridactyla* nesting on an offshore platform in the Netherlands. Limosa 78: 65-74.

Carroll, M.J., Bolton, M., Owen, E., Anderson, G.Q.A., Mackley, E.K., Dunn, E.K. and Furness, R.W. 2017. Kittiwake breeding success in the southern North Sea correlates with prior sandeel fishing mortality. Aquatic Conservation: Marine and Freshwater Ecosystems 27: 1164-1175.

Centrica Energy 2009a. Population Viability Analysis of the North Norfolk Sandwich tern (*Sterna sandvicensis*) population. Centrica, Uxbridge.

Centrica Energy 2009b. Race Bank, Chapter 6: Biological Environment. Centrica, Uxbridge.

Christensen-Dalsgaard, S., May, R.F., Barrett, R.T., Langset, M., Sandercock, B.K. and Lorentsen, S-H. 2018. Prevailing weather conditions and diet composition affect chick growth and survival in the black-legged kittiwake. Marine Ecology Progress Series 604: 237-249.

Christensen-Dalsgaard, S., Langset, M. and Anker-Nilssen, T. 2019. Offshore oil rigs – a breeding refuge for Norwegian black-legged kittiwakes *Rissa tridactyla*? Seabird 32: 20-32.

Colclough, S.R., Gray, G., Bark, A. and Knights, B. 2002. Fish and fisheries of the tidal Thames: management of the modern resource, research aims and future pressures. Journal of Fish Biology 61 (Supplement A): 64-73.

Cook-Haley, B.S. and Millenbah, K.F. 2002. Impacts of vegetative manipulations on common tern nest success at Lime Island, Michigan. Journal of Field Ornithology 73: 174-179.

Coulson, J.C. 2011. The Kittiwake. T & AD Poyser, London.

Coulson, J.C. 2017. Productivity of the black-legged kittiwake *Rissa tridactyla* required to maintain numbers. Bird Study 64: 84-89.

Courtens, W., Verstraete, H., Vanermen, N., Van de walle, M. and Stienen, E.W.M. 2017. Faecal samples reveal the diet of breeding adult Sandwich terns *Thalasseus sandvicensis* in Belgium and the southern part of the Netherlands. Journal of Sea Research 127: 182-193.

Cramp, S. (Ed.) 1985. The Birds of the Western Palearctic, Vol. IV. Oxford University Press, Oxford.

Cury, P.M., Boyd, I.L., Bonhommeau, S., Anker-Nilssen, T., Crawford, R.J.M., Furness, R.W., Mills, J.A., Murphy, E.J., Österblom, H., Paleczny, M., Piatt, J.F., Roux, J-P., Shannon, L. and Sydeman, W.J. 2011. Global seabird response to forage fish depletion – one-third for the birds. Science 334: 1703-1706.

Dare, P.J. and Read, P. 2007. Foraging behaviour of pomarine skuas off the Suffolk coast in winter 1999/2000. British Birds 100: 138-142.

Daunt, F., Wanless, S., Greenstreet, S. P. R., Jensen, H., Hamer, K. C., and Harris, M. P. 2008. The impact of the sandeel fishery closure on seabird food consumption, distribution, and productivity in the northwestern North Sea. Canadian Journal of Fisheries and Aquatic Sciences 65: 362-381.

Defra 2021. Agreed record of fisheries consultations between the EU, Norway and the UK for sprat for the period 1 July 2021 to 30 June 2022 - GOV.UK (www.gov.uk)

Denac, D. and Bozic, L. 2019. Breeding population dynamics of common tern *Sterna hirundo* and associated gull species with overview of conservation management in continental Slovenia. Acrocephalus 40: 5-48.

van Deurs, M., Grome, T., Kaspersen, M., Jensen, H., Stenberg, C., Sørensen, T., Støttrup, J., Warnar, T. and Mosegaard, H. 2012. Short- and long-term effects of an offshore wind farm on three species of sandeel and their sand habitat. Marine Ecology Progress Series 458: 169–180.

Donato, B. 2019. Sandwich tern colour ringing at Hodbarrow. Birds and Wildlife in Cumbria 2019: 228-230.

Dunn, E.K. 1973. Changes in fishing ability of terns associated with wind speed and sea surface conditions. Nature 244: 520-521.

Dunn, E. 2021. Revive our Seas: The case for stronger regulation of sandeel fisheries in UK waters. RSPB, Sandy.

Ellis, J.R., Milligan, S.P., Readdy, L., Taylor, N. and Brown, M.J. 2012. Spawning and nursery grounds of selected fish species in UK waters. Science Series Technical Report 147, Cefas, Lowestoft.

Feare, C.J., Gill, E.L., Carty, P., Carty, H.E. and Ayrton, V.J. 1997. Habitat use by Seychelles sooty terns *Sterna fuscata* and implications for colony management. Biological Conservation 81: 69-76.

Fernandez, T. F., Hollywood, C., Huxham, M., and Kinross, J. 2005. Sprat survey of the Firth of Forth, December 2004. Commissioned by Fife Council, Napier University.

Fijn, R.C., de Jong, J., Courtens, W., Verstraete, H., Stienen, E.W.M. and Poot, M.J.M. 2017. GPS-tracking and colony observations reveal variation in offshore habitat use and foraging ecology of breeding Sandwich terns. Journal of Sea Research 127: 203–211.

Forrester, R.W., Andrews, I.J., McInerny, C.J., Murray, R.D., McGowan, R.Y., Zonfrillo, B., Betts, M.W., Jardine, D.C. and Grundy, D.S. 2007. The Birds of Scotland. Scottish Ornithologists' Club, Aberlady.

Frederiksen, M., Wanless, S., Harris, M.P., Rothery, P. and Wilson, L.J. 2004. The role of industrial fisheries and oceanographic change in the decline of North Sea black-legged kittiwakes. Journal of Applied Ecology 41: 1129-1139.

Frederiksen, M., Wright, P.J., Harris, M.P., Mavor, R.A., Heubeck, M. and Wanless, S. 2005. Regional patterns of kittiwake *Rissa tridactyla* breeding success are related to variability in sandeel recruitment. Marine Ecology Progress Series 300: 201-211.

Frederiksen, M. and Wanless, S. 2006. Assessment of the effects of the Firth of Forth sandeel fishery closure on breeding seabirds. PROTECT Work Package 5/Case Study 2.

Frederiksen, M., Jensen, H., Duant, F., Mavor, R.A. and Wanless, S. 2008. Differential effects of a local industrial sand lance fishery on seabird breeding performance. Ecological Applications 18: 701–710.

Furness, R.W. 2007. Responses of seabirds to depletion of food fish stocks. Journal of Ornithology 148: 247–252.

Furness, R.W. and Tasker, M.L. 2000. Seabird-fishery interactions: Quantifying the sensitivity of seabirds to reductions in sandeel abundance, and identification of key areas for sensitive seabirds in the North Sea. Marine Ecology Progress Series 202: 253–264.

Furness, R.W., MacArthur, D., Trinder, M. and MacArthur, K. 2013. Evidence review to support the identification of potential conservation measures for selected species of seabirds. Report to Defra.

Garthe S. and Kubetzki, U. 1998. Diet of Sandwich Terns *Sterna sandvicensis* on Juist (Germany). Sula 12: 13-19.

Garthe, S. and Flore, B.O. 2007. Population trend over 100 years and conservation needs of breeding Sandwich terns (*Sterna sandvicensis*) on the German North Sea coast. Journal of Ornithology 148: 215-227.

Green, E. 2017. Tern diet in the UK and Ireland: a review of key prey species and potential impacts of climate change. RSPB, Sandy.

Greenstreet, S., Fraser, H., Armstrong, E. and Gibb, I. 2010. Monitoring the consequences of the northwestern North Sea sandeel fishery closure. Scottish Marine and Freshwater Science 1: 1–31.

Gregersen, J, 2006. The breeding population of Sandwich tern in Denmark, 1993-2005. Dansk Ornitologisk Forenings Tidsskrift 100: 88-96.

Heessen, H.J.L., Daan, N. and Ellis, J.R. 2015. Fish Atlas of the Celtic Sea, North Sea, and Baltic Sea. KNNV Publishing, The Netherlands.

Hill, S.L., Hinke, J., Bertrand, S., Fritz, L., Furness, R.W., Ianelli, J.N., Murphy, M., Oliveros-Ramos, R., Pichegru, L., Sharp, R., Stillman, R.A., Wright, P.J. and Ratcliffe, N. 2020. Reference points for predators will progress ecosystem-based management of fisheries. Fish and Fisheries 21: 368-378.

Horswill, C. and Robinson, R.A. 2015. Review of seabird demographic rates and density dependence. JNCC Report No. 552. JNCC, Peterborough.

Hughes, R.D., O'Hanlon, N. and Smith, J. 2021. Colonisation of St John's Pool, Caithness by terns and gulls. Scottish Birds 41: 205-212.

ICES 2017. Report of the Benchmark Workshop on Sandeel (WKSand 2016) 31 October – 4 November 2016 Bergen, Norway. ICES CM 2016/ACOM:33. 319pp.

ICES 2018. Benchmark Workshop on Sprat (WKSPRAT 2018). ICES WKSPRAT Report 2018, 5–9 November 2018. ICES HQ, Copenhagen, Denmark. ICES CM 2018/ACOM:35.

ICES. 2020. Sprat in the North Sea and 3.a. Section 10 in Herring Assessment Working Group for the Area South of 62°N (HAWG). Sandeel in Division 3.a and Subarea 4. Section 9 in Herring Assessment Working Group for the Area South of 62°N (HAWG). [redacted]

ICES 2021. Herring assessment working group for the area south of 62°N (HAWG). ICES Scientific Reports 3:12. [redacted]

Jennings, G., McGlashan, D.J. and Furness, R.W. 2012. Responses to changes in sprat abundance of common tern breeding numbers at 12 colonies in the Firth of Forth, east Scotland. ICES Journal of Marine Science 69: 572-577.

Johnson, P.O., Iversen, S., Edwards, J.I. and Bailey, R.S. 1982. Report on echo-integrator surveys for sprat undertaken in the North Sea during the 1981-82 winter season. ICES CM 1982/H:13.

JNCC 2021. Seabird Monitoring Programme online database. Seabird Monitoring Programme | JNCC (bto.org)

Keyl, F. 2017. Inter-annual variability in distribution and spatial abundance of sprat, Norway pout and small herring in the North Sea. Hydrobiologia 795: 239-256.

Lamb, J.S. 2011. Managing vegetation to restore tern nesting habitat in the Gulf of Maine. MSc thesis, University of Massachusetts, Amherst.

Lamb J.S. 2015. Review of vegetation management in breeding colonies of North Atlantic terns. Conservation Evidence 12: 53-59.

Lamb, J. S, Hall, C. Scott, Kress, S. W. and Griffin, C. R. 2014. Comparison of burning and weed barriers for restoring common tern (*Sterna hirundo*) nesting habitat in the Gulf of Maine. Waterbirds 37: 286-297.

Langham, N. P. E. 1968. The comparative biology of terns, Sterna spp. PhD thesis, University of Durham. Available online: [redacted]

Langham, N.P.E. 1974. Comparative breeding biology of Sandwich tern. Auk 91: 255-277.

Lawrence, J.M. and Fernandes, P.G. 2021. A switch in species dominance of a recovering pelagic ecosystem. Current Biology 31: 1-7.

Lindegren, M., van Deurs, M., MacKenzie, B.R., Clausen, L.W., Christensen, A. and Rindorf, A. 2018. Productivity and recovery of forage fish under climate change and fishing: North Sea sandeel as a case study. Fisheries Oceanography 27: 212-221.

Lindegren, M., Rindorf, A., Norin, T., Johns, D. and van Deurs, M. 2020. Climate- and density-dependent regulation of fish growth throughout ontogeny: North Sea sprat as a case study. ICES Journal of Marine Science 77: 3138-3135.

Machrihanish Seabird Observatory (2021) Machrihanish seabird & Wildlife Observatory [redacted]

Mavor, R.A., Pickerell. G., Heubeck, H. and Thompson, K.R. 2001. Seabird numbers and breeding success in Britain and Ireland, 2000. UK Nature Conservation No. 25. JNCC, Peterborough.

Mavor, R.A., Pickerell. G., Heubeck, H. and Mitchell, P.I. 2002. Seabird numbers and breeding success in Britain and Ireland, 2001. UK Nature Conservation No. 26. JNCC, Peterborough.

Mavor, R.A., Pickerell. G., Heubeck, H. and Schmitt, S. 2004. Seabird numbers and breeding success in Britain and Ireland, 2003. UK Nature Conservation No. 28. JNCC, Peterborough.

Mavor, R.A., Heubeck, H., Schmitt, S. and Parsons, M. 2008. Seabird numbers and breeding success in Britain and Ireland, 2006. UK Nature Conservation No. 31. JNCC, Peterborough.

Mitchell, P.I., Newton, S.F., Ratcliffe, N. and Dunn, T.E. 2004. Seabird Populations of Britain and Ireland. T & AD Poyser, London.

Monaghan, P. and Zonfrillo, B. 1986. Population dynamics of seabirds in the Firth of Clyde. Proceedings of the Royal Society of Edinburgh, Section B: Biological Sciences 90: 363-375.

Monnat, J.Y., Danchin, E. and Estrella, R.R. 1990. Assessment of environmental quality within the framework of prospecting and recruitment – the squatterism in the kittiwake. Comptes Rendus de l'Academie des Sciences Serie III Life Sciences 311: 391-396.

Natural England 2012. Sandwich tern: species information for marine Special Protection Area consultations. Natural England Technical Information Note TIN135.

Newton, S.F. and Crowe, O. 2000. Roseate Terns - The Natural Connection. Maritime Ireland/Wales INTERREG Report NO.2. IWC-BirdWatch Ireland, Monkstown, Co. Dublin.

Olin, A.B., Banas, N.S., Wright, P.J., Heath, M.R. and Nager, R.G. 2020. Spatial synchrony of breeding success in the black-legged kittiwake *Rissa tridactyla* reflects the spatial dynamics of its sandeel prey. Marine Ecology Progress Series 638: 177-190.

Oro, D. and Furness, R.W. 2002. Influences of food availability and predation on survival of kittiwakes. Ecology 83: 2516-2528.

Oro, D., Bécares, J., Bartumeus, F. and Arcos, J.M. 2021. High frequency of prospecting for informed dispersal and colonisation in a social species at large spatial scale. Oecologia doi.org/10.1007/s00442-021-05040-4.

Ørsted 2020a. Hornsea Project Three Offshore Wind Farm Response to the Secretary of State's Minded to Approve Letter Appendix 1: Compensatory Measures.

Ørsted 2020b. Hornsea Project Three Offshore Wind Farm Response to the Secretary of State's Minded to Approve Letter Appendix 2: Kittiwake compensation plan.

Ørsted 2020c. Hornsea Project Three Offshore Wind Farm Response to the Secretary of State's Minded to Approve Letter Appendix 2, Annex 1: Outline kittiwake implementation and monitoring plan.

Ørsted 2020d. Hornsea Project Three Offshore Wind Farm Response to the Secretary of State's Minded to Approve Letter Annex 2 to Appendix 2: Kittiwake artificial nest provisioning: Ecological evidence.

Ørsted 2020e. Hornsea Project Three Offshore Wind Farm Response to the Secretary of State's Minded to Approve Letter Annex 3 to Appendix 2: Kittiwake artificial nest provisioning: Site selection and the pathway to securement.

Ørsted 2020f. Hornsea Project Three Offshore Wind Farm Response to the Secretary of State's Minded to Approve Letter Appendix 3: Supporting evidence for kittiwake prey resource.

Pearson, T.H. 1968. The feeding biology of sea-bird species breeding on the Farne Islands, Northumberland. Journal of Animal Ecology 37: 521-552.

Perrow, M.R., Gilroy, J.J., Skeate, E.R. and Mackenzie, A. 2010. Quantifying the relative use of coastal waters by breeding terns: towards effective tools for planning and assessing the ornithological impacts of offshore wind farms. ECON Ecological Consultancy Ltd. Report to COWRIE Ltd. ISBN: 978-0-9565843-3-5.

Perrow, M.R., Skeate, E.R. and Gilroy. J.J. 2011. Visual tracking from a rigid-hulled inflatable boat to determine foraging movements of breeding terns. Journal of Field Ornithology 82: 68-79.

Perrow, M.R., Harwood, A., Berridge, R. and Skeate, E. 2017. The foraging ecology of Sandwich terns in north Norfolk. British Birds 110: 257-277.

Power, M., Attrill, M.J. and Thomas, R.M. 2000. Temporal abundance patterns and growth of juvenile herring and sprat from the Thames estuary 1977-1992. Journal of Fish Biology 56: 1408-1426.

Ratcliffe, N., Pickerell, G. and Brindley, E. 2000. Population trends of little and Sandwich terns *Sterna albifrons* and *S. sandvicensis* in Britain and Ireland from 1969 to 1998. Atlantic Seabirds 2: 211-226.

Royal Haskoning DHV 2020. Norfolk Boreas Offshore Wind Farm In Principle Habitats Regulations Derogation Provision of Evidence Appendix 1 Flamborough and Filey Coast SPA In Principle Compensation. Doc. Ref. ExA.Dero.D7.V1.App1. (REP7-025).

Saliva, J.E. and Burger, J. 1989. Effect of experimental manipulation of vegetation density on nest-site selection in sooty terns. Condor 91: 689-698.

Saraux, C., Sydeman, W., Piatt, J., Anker-Nilssen, T., Hentati-Sundberg, J., Bertrand, S., Cury, P., Furness, R.W., Mills, J.A., Österblom, H., Passuni, G., Roux, J-P., Shannon, L.J. and Crawford, R.J.M. 2020. Seabird-induced natural mortality of forage fish varies with fish abundance: evidence from five ecosystems. Fish and Fisheries doi 10.1111/faf.12517.

Short, D. 2020. Breeding of four species of tern and black-headed gull at Forvie National Nature Reserve, 2020. Report to NatureScot.

Spaans, B., Leopold, M. and Plomp, M. 2018. Using a drone to determine the number of breeding pairs and breeding success of Sandwich terns *Sterna sandvicensis*. Limosa 91: 30-37.

Steel, D. and Outram, B. 2020. Terns – restoring biodiversity to the Isle of May's breeding seabirds. Scottish Birds 40: 206-211.

Stienen, E.M.W., van Beers, P.W.M., Brenninkmeijer, A., Habraken, J.M.P.M., Raaijmakers, M.H.J.E. and van Tienen, P.G.M. 2000. Reflections of a specialist: patterns in food provisioning and foraging conditions in Sandwich terns *Sterna sandvicensis*. Ardea 88: 33-49.

Stienen, E.W.M., Brenninkmeijer, A. and Courtens, W. 2015. Intra-specific plasticity in parental investment in a long-lived single-prey loader. Journal of Ornithology 156: 699-710.

Stroud, D.A., Bainbridge, I.P., Maddock, A., Anthony, S., Baker, H., Buxton, N., Chambers, D., Enlander, I., Hearn, R.D., Jennings, K.R., Mavor, R., Whitehead, S. and Wilson, J.D. 2016. The Status of UK SPAs in the 2000s: the Third Network Review. JNCC, Peterborough.

Sydeman, W.J., Thompson, S.A., Anker-Nilssen, T., Arimitsu, M., Bennison, A., Bertrand, S., Boersch-Supan, P., Boyd, C., Bransome, N., Crawford, R.J.M., Daunt, F., Furness, R.W., Gianuca, D., Gladics, A., Koehn, L., Lang, J., Logerwell, E., Morris, T.L., Phillips, E.M., Provencher, J., Punt, A.E., Saraux, C., Shannon, L., Sherley, R.B., Simeone, A., Wanless, R.M., Wanless, S. and Zador, S. 2017. Best practices for assessing forage fish fisheries – seabird resource competition. Fisheries Research 194: 209-221.

Taylor, I.R. 1983. Effect of wind on the foraging behaviour of common and Sandwich terns. Ornis Scandinavica 14: 90-96.

Thompson, K.R., Brindley, E. and Heubeck, M. 1996. Seabird numbers and breeding success in Britain and Ireland, 1995. UK Nature Conservation No. 20. JNCC, Peterborough.

Thompson, K.R., Brindley, E. and Heubeck, M. 1998. Seabird numbers and breeding success in Britain and Ireland, 1997. UK Nature Conservation No. 22. JNCC, Peterborough.

Thompson, K.R., Pickerell, G. and Heubeck, M. 1999. Seabird numbers and breeding success in Britain and Ireland, 1998. UK Nature Conservation No. 23. JNCC, Peterborough.

Thorpe, A.W. 2001. The North Sea Bird Club 17th Annual Report. North Sea Bird Club, Aberdeen.

Tierney, N., Whelan, R. and Valentin, A. 2016. Post-breeding aggregations of roosting terns in south Dublin Bay in late summer. Irish Birds 10: 339-344.

Tooth, E. and Blakely, L. 2015. Farne Islands National Nature Reserve Management Plan April 2016-March 2021. National Trust, Newcastle.

Valle, R.G. and Scarton, F. 2021. Drone-conducted counts as a tool for the rapid assessment of productivity of Sandwich terns (*Thalasseus sandvicensis*). Journal of Ornithology 162: 621-628.

Veen, J. 1977. Functional and causal aspects of nest distribution in colonies of the Sandwich tern (*Sterna s. sandvicensis* Lath.). Behaviour (Supplement 20): 1-193.

Wakefield, E.D., Owen, E., Baer, J., Carroll, M.J., Daunt, F., Dodd, S.G., Green, J.A., Guilford, T., Mavor, R.A., Miller, P.I., Newell, M.A., Newton, S.F., Robertson, G.S., Shoji, A., Soanes, L.M., Votier, S.C., Wanless, S. and Bolton, M. 2017. Breeding density, fine-scale tracking, and large-scale modelling reveal the regional distribution of four seabird species. Ecological Applications 27: 2074-2091.

Walsh, P.M., Sim, I. and Heubeck, M. 1991. Seabird numbers and breeding success in 1990. Nature Conservancy Council CSD Report No. 1235, Peterborough.

Walsh, P.M., Sim, I. and Heubeck, M. 1992. Seabird numbers and breeding success in Britain and Ireland, 1991. UK Nature Conservation No. 6. JNCC, Peterborough.

Walsh, P.M., Sim, I. and Heubeck, M. 1993. Seabird numbers and breeding success in Britain and Ireland, 1992. UK Nature Conservation No. 10. JNCC, Peterborough.

Walsh, P.M., Brindley, E. and Heubeck, M. 1994. Seabird numbers and breeding success in Britain and Ireland, 1993. UK Nature Conservation No. 17. JNCC, Peterborough.

Wilson, L.J., Black, J., Brewer, M.J., Potts, J.M., Kuepfer, A., Win, I., Kober, K., Bingham, C., Mavor, R. and Webb, A. 2014. Quantifying usage of the marine environment by terns *Sterna* sp. around their breeding colony SPAs. JNCC, Peterborough.

Woodward, I., Thaxter, C.B., Owen, E. and Cook, A.S.C.P. 2019. Desk-based revision of seabird foraging ranges used for HRA screening. BTO Research Report No. 724.

Wright, P., Regnier, T., Eerkes-Medrano, D. and Gibb, F. 2018. Climate change and marine conservation: Sandeels and their availability as seabird prey. MCCIP, Lowestoft.