Hornsea Project Four

G6.2 Onshore Site Selection and Pathway to Securement

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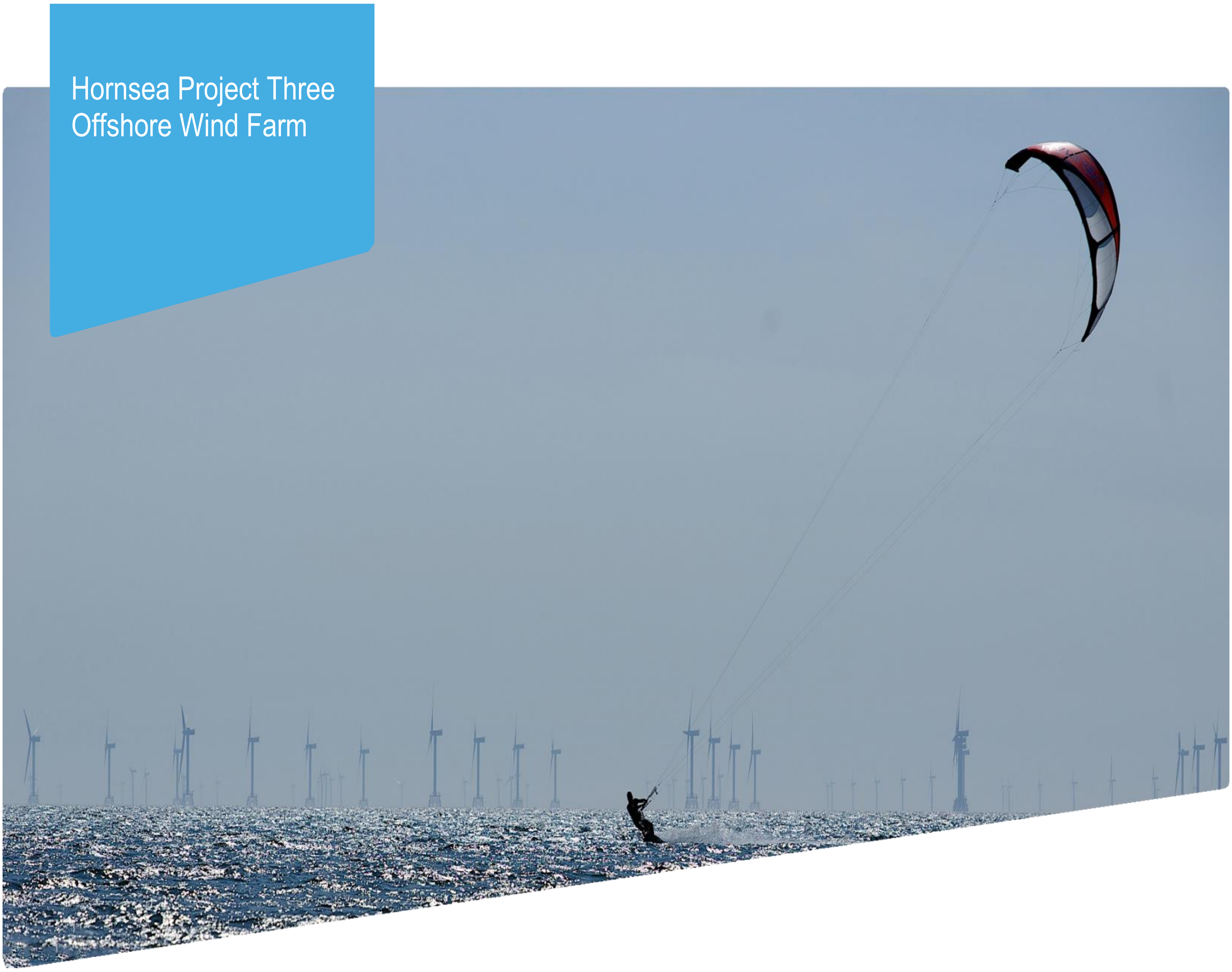

Hornsea Project Three

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

Date: September 2020

Hornsea 3
Offshore Wind Farm

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Response to the Secretary of State's Minded to Approve Letter

Annex 2 to Appendix 2 (Kittiwake Compensation Plan):

Kittiwake Artificial Nest Provisioning: Ecological Evidence

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Front cover picture: Kite surfer near a UK offshore wind farm © Orsted Hornsea Project Three (UK) Ltd., 2018.

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Acronyms

Acronyms	Description
AEOSI	Adverse Effect on Site Integrity
AON	Apparently Occupied Nest
BEIS	Department for Business, Energy and Industrial Strategy
DCO	Development Consent Order
EC	European Commission
EU	European Union
FFC SPA	Flamborough and Filey Coast SPA
HRA	Habitats Regulations Assessment
ICES	International Council for the Exploration of the Sea
JNCC	Joint Nature Conservation Committee
OOEG	Offshore Ornithology Engagement Group
RSPB	Royal Society for the Protection of Birds
SoS	Secretary of State
SPA	Special Protection Area

1. Introduction

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

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

1.3 The current main drivers of kittiwake populations are food abundance, fisheries (depletion of stock, reduction in discards) and climate change. This report considers a management option based on the provision of artificial nest sites so as to increase the annual recruitment of kittiwake into the wider Eastern Atlantic population. This is considered feasible as evidenced by the colonisation of man-made structures in open seas, coastal sites and urban areas, and in significant numbers. In doing so, the intention would be to compensate for the annual loss of the predicted mortality of kittiwakes from FFC SPA due to collisions with turbines at Hornsea Three (73, based on the upper end of the collision risk estimates provided in the SoS' HRA (range 65-73).

1.4 This report reviews the evidence base on the potential for artificial nest sites to increase the annual recruitment of kittiwake into the regional population of the southern North Sea, which forms part of the wider Eastern Atlantic population. Suitable coastal locations and sea areas are defined in the southern North Sea for installation of or modification to existing / in plan structures to provide artificial nesting structures for kittiwakes. An outline plan of its design and delivery is provided, with the focus on delivery of compensation for the Adverse Effect on Site Integrity at the FFC SPA.

2. Methods

Literature Review

2.1 Coulson's (2011) monograph on the kittiwake provides a comprehensive review of biology and research on the species up to the year of its publication. In order to update the state of current knowledge on kittiwake biology to inform this report, a literature search was performed for relevant research published since 2010. An image search and web search of grey literature was also undertaken to extract additional information and population trends from areas where kittiwakes have been documented nesting on man-made structures.

Data Search

2.2 Data on population and productivity trends of birds in the Southern North Sea region were extracted from the JNCC's Seabird Monitoring Program (SMP) database (https://jncc.gov.uk/our-work/seabird-monitoring-programme/).

3. Propensity for kittiwake to colonise artificial nesting structures

3.1 Providing additional nesting opportunities for kittiwakes could potentially enhance productivity and therefore be effective as a compensatory measure. Kittiwakes are known to nest successfully on man-made structures and have readily adapted to artificial nesting structures provided elsewhere. For this scheme to be effective, new birds must be available to colonise and breed successfully on structures provided. This section considers the evidence on kittiwake biology which indicates how likely birds are to colonise new nesting sites. It also identifies the factors which are likely to be important for the long-term establishment of a new colony (e.g. ecological requirements - proximity to food, lack of predation, low intraspecific competition, proximity to seed population). Finally, it highlights areas in the southern North Sea which could meet these requirements by recruiting kittiwake into the wider Eastern Atlantic population.

Life History Characteristics

3.2 Kittiwakes are colonial seabirds which naturally breed on vertical rocky sea-cliffs (Coulson 2011). They are particularly well adapted to nest on narrow ledges making substantial nests from mud, grass and/or seaweed.

3.3 Birds breed in colonies with numbers ranging from a few pairs to a few thousand. Colonialism offers birds greater protection from predators and the presence of other kittiwakes is required for birds to reach breeding condition (Coulson 2011). Birds generally lay two eggs during the breeding season (March – July) (Coulson 2011). After fledging, young birds generally remain at sea for 2-3 years before attempting to recruit into the breeding population. Kittiwakes are long-lived birds with an average life expectancy of around 12 years (Robinson *et al.* 2005).

Conclusion	Context
Kittiwakes breed, on average, in their third or fourth year, rearing up to two (very occasionally three or four) chicks per year.	There would be a time-lag between when chicks fledged from a structure and the point where they could contribute to the impact in question.

Colony Recruitment / Philopatry

3.4 Kittiwakes are not highly philopatric, meaning birds do not tend to return to their natal colony to breed (Coulson and Coulson 2008). Between 11-23% of birds are thought to return to the colony where they were raised (and those that do are mostly males) (Coulson 2011, Horswill and Robinson 2015). Birds seem to visit several colonies as juveniles before settling on a breeding site. First-time breeders tend to arrive at colonies later in the season and may attempt to pair up and breed, however, they are typically unsuccessful (Coulson 2011).

3.5 The mechanisms driving prospecting behaviour and settlement decisions in seabirds are unclear, but perhaps these attempts allow birds to gain information on the quality of the site before returning in subsequent years to join the breeding population (Boulinier *et al*. 1996). Birds have been recorded breeding up to 1,600 km away from their natal colony, however, the majority of birds usually choose sites within a neighbouring colony (<100 km) (Coulson 2011). For kittiwakes in the Atlantic, natal dispersal occurs more frequently at large colony sizes (McKnight *et al*. 2019). Juveniles may therefore be more likely to disperse to new sites from sizable UK colonies such as the FFC SPA.

Conclusion	Context
As few as 11% of kittiwakes breed in their natal colony, majority choose sites within a neighbouring colony (<100 km) so connectivity between UK breeding colonies is high.	A structure on the east coast of England is likely to be colonised with birds from across other east coast colonies and beyond.

3.6 Once birds have successfully recruited into a breeding colony, they show high levels of site fidelity, often returning to the same nest year after year (Coulson, 2011). Thus, once established, locations of colonies tend to be retained over many decades.

3.7 However, site fidelity is ultimately dependent on individual and conspecific[1] reproductive success (Boulinier *et al*. 2008; Danchin *et al*. 1998). A recent study using bird-borne telemetry devices showed that failed breeders may make prospecting movements to other colonies within the same breeding season, and that this behaviour becomes more prevalent if they nest within a colony experiencing widespread breeding failure (Ponchon *et al*. 2015; Ponchon *et al*. 2017). Successful breeders (and birds nesting at successful colonies) do not seem to make these prospecting trips. Individual and colony success impacts the likelihood of birds returning to a colony, failed breeders had a return rate of 45% compared to 75% for successful breeders (Ponchon *et al*. 2017). However, birds nesting in successful colonies are less likely to disperse after a failure. The chance of dispersal (at a local scale) also seems to be higher in low density colonies and for first time breeders (Acker 2017).

[1] Individuals of the same species

Conclusion	Context
Once a bird has established a site within a successful breeding colony, high site fidelity is shown. If repeated breeding failures occur, then birds are more likely to switch sites.	If an artificial structure is successful, birds are likely to return to breed for the duration of their lifespan (avg. 12 years)

3.8 Immigration is an important regulator of colony population dynamics in kittiwakes, so, the availability of recruits from nearby colonies will be an important consideration in determining the location of potential new nesting sites. It is unlikely that placing an artificial nesting site near another colony would diminish the population of established breeders, providing the colony was not in decline.

Conclusion	Context
Colonisation of new sites is largely driven by immigration, once birds have established a nesting site (providing conditions are good) they are unlikely to relocate.	It is unlikely that placing an artificial nesting site in close proximity to another colony would diminish the population of established breeders, providing the colony was not in decline.

Diet and foraging behaviour

3.9 Seabirds are central-place foragers, constrained to a restricted range of feeding sites within reach of their colony during the breeding season. On average, kittiwakes forage within 54.7(±50.4) km of their breeding colony but can travel up to 156.1(±144.5) km to find food. The maximum foraging range for the species is currently 770 km (Woodward *et al*. 2019), however, shorter foraging trips are generally linked to higher breeding success (e.g. Daunt *et al*. 2002, Lewis *et al*. 2001).

3.10 Seabird colony size and location are strongly influenced by prey availability (Frederiksen *et al*. 2005, Jovani *et al*. 2015). Kittiwake diet consists mainly of marine fish and invertebrates obtained offshore, but they also take discards from fishing activities (Coulson 2011). Birds generally feed in flocks and can only access prey in the top metre of the water column. This surface feeding strategy is high risk and leaves the birds vulnerable to changes in prey distribution.

3.11 Kittiwake show a well-defined seasonal change from foraging on planktonic crustacea in early spring, to 1+ group sandeels in April and May, to 0 group sandeels in June and July (Lewis *et al*. 2001). During the rearing of chicks, birds require small fish of a young age class. Other than size, birds do not seem to be too selective of the prey they catch, taking what is available in the local area (Coulson 2011). Diets can differ between UK colonies but sandeels appear to be dominant in the majority of locations (Chivers *et al*. 2012, Bull *et al*. 2004, Furness and Tasker 2000). In two colonies in Ireland, regurgitates from kittiwakes during the early chick-rearing period showed Clupeids to be the dominant food source at both colonies (Chivers *et al*. 2012).

3.12 Around the UK coast, sandeels are a particularly important energy-rich prey species during the breeding season, with sprats and young herring key alternative prey species. Sandeel have a restricted and patchy distribution due to their particular habitat requirements (Wright *et al*. 2000, Holland *et al*. 2005). Kittiwake reproductive performance is strongly linked to local sandeel availability (Harris and Wanless 1997, Cury *et al*. 2011, Cook *et al*. 2014). As such, seabirds nesting at specific colonies are heavily reliant on regional sandeel aggregations (Frederiksen *et al*. 2005).

3.13 There has been a reduction in the prevalence of sandeel in the diets of North Sea seabirds in recent decades (Wanless *et al*. 2018). Kittiwakes have experienced the largest population declines in recent years in areas where birds are heavily reliant on sandeel with no alternative prey available i.e. northern regions of the North Sea. In the southern North Sea, where juvenile herring and sprats are abundant population declines have been less pronounced (Frederiksen *et al*. 2005, Daan *et al*. 1990), however, sandeel still makes up a major (60%) component of seabird diet during the breeding season in this region (Furness and Tasker 2000).

3.14 Sandeel are subject to fishing pressures in UK waters (ICES 2018), and these have been linked to declines in kittiwake breeding success (Cook *et al*. 2014, Carroll *et al*. 2017). There is some evidence that climatic changes such as increases in sea surface temperatures may be decreasing the nutritional quality of sandeel and may cause a northward range shift in the future (Frederiksen *et al*. 2012 but see Eerkes-Medrano *et al*. 2016). Therefore, proximity to multiple foraging opportunities is a key consideration to ensure resilience of a population to local food shortages (e.g. see Peredes *et al*. 2012). This topic is also covered in depth in the Supporting Evidence for Kittiwake Prey Resource report (Appendix 3 to the Applicant's Response).

3.15 Alongside nesting habitat and prey availability, kittiwake distributions may be modulated by density dependent competition between individuals nesting at other colonies nearby (e.g. Wakefield *et al*. 2013). Kittiwakes can display high foraging-site fidelity (Irons 1998, Harris *et al*. 2020). Recent tracking studies show birds tend to avoid foraging in areas that are populated with a higher number of birds from a neighbouring colony than from their own colony (Wakefield *et al*. 2017). There is also some evidence to suggest that these patterns may also operate on smaller scales i.e. at a sub colony level (e.g. within RSPB FAME tracking data). This may be an important factor to consider when choosing an area in which to enhance kittiwake populations, as increased competition for the same food resources could potentially impact the breeding success (and therefore population numbers) of birds in both the 'new' or established colonies. However, density dependent processes are secondary to food availability and there appears to be no negative relationship between colony size and breeding success in kittiwakes (Frederiksen *et al*. 2005).

Conclusion	Context
Kittiwake require small forage fish to feed their chicks. Group 0 sandeel seem to be the most important, but birds can be successful if there are key alternatives if these become unavailable. Birds may have higher foraging (and subsequent breeding) success at lower levels of density dependent competition.	The location of a structure would need to be within the foraging range of kittiwakes (<156 km) to these resources. Structures may have a higher chance of success at increasing distances from very large colonies e.g. FFC SPA population.

Use of artificial /man-made structures for nesting

3.16 Kittiwakes do not seem to show a preference between natural or artificial nesting sites (Coulson 2011). Man-made structures such as buildings and piers meet similar nesting requirements to cliffs (i.e. vertical faces with narrow ledges, close to the water's edge) and have readily been adopted by kittiwakes in areas where natural breeding sites are in short supply. Table 3.1 details known artificial nesting sites for kittiwakes in the north Atlantic (photographs of the type of nesting sites used can be found in Appendix A). Key features of these 'urban' kittiwake sites in the UK appear to be linked with old industrial fishing ports and harbours or aging seaside fishing towns with disused piers and buildings. However, once birds have established within a town setting, they also appear to favour ornate buildings like churches and town halls. Kittiwakes are known to feed on fishery discards (Coulson 2011) and birds may have initially been attracted to ports and harbours by following fishing vessels.

3.17 Offshore platforms such as those used for oil/gas exploration or other metal structures where ledges exist also appear attractive as prospective breeding sites (see Table 3.1). These sites may provide an additional benefit as they may be closer to potential foraging sites. Recent studies on birds nesting on offshore platforms off the Norwegian coast suggest breeding success may be higher at these locations than at natural sites (see examples within McArthur Green 2020).

3.18 Breeding success and survival rates of birds nesting in these urban sites are comparable (if not better) to those nesting at natural sites, most likely due to a lower risk of predation and less disturbance from other species (Turner 2010, Coulson 2011, McArthur Green 2020). Numbers appear to be increasing and productivity trends appear to be good at urban kittiwake sites in the UK, namely the Tyne colonies and at Lowestoft (see Section 4.1; Table 4.1, Table 4.2 and Table 4.3). Numbers are also increasing at the urban site of Boulogne sur Mer on the French Coast (McMurdo-Hamilton 2016), and populations which have colonised offshore structures in the southern North Sea i.e. kittiwake at Sizewell Rigs also appear to be thriving with numbers having increased from 200 pairs in 2001 to 502 apparently occupied nests (AON) in 2008; the latter population is space-limited and unlikely to exceed 500 pairs (McMurdo-Hamilton 2016). Tracking devices deployed on birds nesting at the Tyne colony (which is the furthest inland (17 km) breeding kittiwake colony in the world) indicate urban birds seem to be using similar marine foraging areas to natural colonies on the north-east coast (Redfern and Bevan 2014).

3.19 Urban colonisation began in the UK as the kittiwake population was increasing, first occurring in 1931 with a pair nesting on Edinburgh pier (Coulson 2011). Since then, sites which have been colonised seem to be associated with areas where natural nest sites are becoming limited. In the north-east of England, it has been argued that the colonisation of buildings on the Tyne estuary occurred during a period where breeding numbers in the region more than doubled, indicating there were no shortages of natural nest sites in the region (Turner 2010). However, on the Tyne river, colonisation of buildings coincided with a time when many birds began to lose natural nest sites due to coastal erosion at Marsden cliffs (Coulson 2011)[2]. Kittiwakes on the Tyne now appear to be limited by the availability of suitable nesting sites (Turner 2010) and birds have begun to move further into the town centre resulting in some unusual nesting locations including the top of lampposts (see photos in Appendix A).

3.20 Once an urban nesting site has been established birds show a persistent ability to colonise structures, despite the presence of bird nesting deterrents (causing much frustration for town planners!). In the UK, France and in some Norwegian towns, attempts have been made to move birds from man-made nesting structures (due to health and safety issues, or if buildings are to be demolished or repurposed). Various artificial nesting structures have been designed to dissuade birds from nesting on buildings, or as compensatory measures during building/demolition works (see Table 3.2). The success of these projects has been mixed (Table 3.2 and Table 3.3).

3.21 It is important to note that these situations involve(d) trying to move established breeding birds rather than attract new recruits. Birds show strong nest site fidelity once they have established territories, meaning most will try to return to an area as close to their original site as possible. For example, in Newcastle, 85% of kittiwakes evicted from the Baltic Flour Mill ended up nesting on other buildings along the riverside rather than on a compensatory artificial tower provided near their original nesting site. The artificial tower did successfully attract nesting birds, but these arrived later in breeding season (suggesting they were younger birds), so were most likely first-time breeders (Coulson 2011). The tower colony grew to support around 100 pairs per year, but due to health and safety issues regarding droppings, it was relocated to a less public site 2 km downstream (Coulson 2011). The tower continues to be used by birds to date, but productivity appears to be lower than birds nesting further along the Tyne, possibly due to issues with crow predation at the new site (D. Turner, pers comm.). Another tower of a similar design was built on the Tyne at South Shields in 2014. However, birds did not colonise this structure and it has since been removed (D. Turner, pers comm.).

Conclusion	Context
Kittiwakes show no preference for purpose-built artificial vs man-made structures. New recruits take to artificial sites faster than established breeders.	If designed correctly, in the right location, an artificial structure should have every chance of success in supporting a colony.

[2] Though the Marsden colony also continued to grow throughout this time period (Coulson 2011).

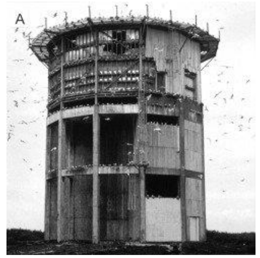
Table 3.1: Artificial nesting sites for kittiwakes

Location	Site	Nesting habitat	Occupation and Population	Source
Alaska	Middleton Island	Abandoned military buildings and an island shipwreck	1950s - several thousand reported, population increased during the early 1980s but has subsequently declined to about 12,470 individuals in 2007.	Hatch *et al*. 1993.
Norway	Rost, Alesund, Lofoten island.	Sheds and houses in coastal towns	1950s-present in many sites around Norway	Wagner 1958
Norway	Grumant Island	Abandoned buildings	Currently nesting on the window ledges of abandoned buildings	Harris *et al*. 2019
Norway	Tromso	Buildings & artificial nesting platforms on buildings	2014/15-present. Currently 115 pairs (2019). Platform installed to discourage nesting on buildings 2019?	National Geographic online News.
Norway	Norwegian Sea/ Barents Sea	Offshore oil/gas platform	Currently nesting on several platforms	McArthur Green 2020
Norway	Utsira	Warehouses, wooden buildings	Current	Tveit *et al*. 2004.
The Netherlands	Texel	Offshore oil/gas platforms	2000-present? Nesting on many offshore platforms in the Frisian Front area (Southern North Sea)	Camphuysen & de Vreeze 2005, Camphuysen & Leopold 2007
France	Boulogne-sur-Mer	Industrial buildings close to harbour. Also on an artificial wall and tower.	2000s-present. 891 breeding pairs in 2014	Pochon *et al*. 2017. (online: Flickr)

Location	Site	Nesting habitat	Occupation and Population	Source
England	Tyneside	Factory buildings, town and artificial nesting towers	1949-present. Population has spread from factories by fishing ports into Newcastle town centre. Artificial platforms provided in 1998 colonised in same year by a small number of birds.	Coulson 2011
England	Seaham, County Durham	Buildings within harbour	1960s-present	Coulson 2011
England	Bridlington, East Yorkshire	Buildings and harbour wall	1960s-present	Coulson 2011
England	Hartlepool, Cleveland	Warehouse buildings, fish quay, town and pier	1960-present. First used warehouse buildings which were demolished, birds moved to fish quay and now nest on many industrial and residential buildings and also a disused pier.	Coulson 2011; E, Morgan pers obs.
England	Lowestoft, Suffolk	Pier, artificial cliff and town buildings	1946-present. Colony on South pier was demolished in 1988, birds moved to an artificial wall provided in harbour and now nest on other piers and town buildings.	Casey and Hooton 1991, M Swindells pers. Comm.
England	Sizewell rigs, Suffolk	Inshore structures	1994-present. On metal structures of decommissioned power plant - due to be demolished.	Casey and Hooton 1991

Location	Site	Nesting habitat	Occupation and Population	Source
England	Morecambe Bay Gas Field, Irish Sea	Offshore oil/gas platform	1998-present. Two pairs nested in 1998, still present mainly on the central platform (220 AON in 2006)	Brown and Grice 2005
England	Scarborough, North Yorkshire	Town Buildings	mid-1990s- present. Currently nesting on natural cliffs and many buildings in the town. Spread from Natural cliffs into town	Hopper 2012
Scotland	Edinburgh	Pier	A few pairs for a couple of years (1931)	Coulson 2011
Scotland	Dunbar	Warehouse buildings	1934-1960 (structure demolished), birds then moved to natural cliff and harbour areas	Coulson 2011
Wales	Mumbles, Swansea	Mumbles pier and artificial platform	1993-present. Currently most are nesting on artificial ledges provided on Mumbles pier c.30 pairs 1993 up to 160 pairs 2011, 90 pairs now. Artificial shelving erected 2012 while renovation work was carried out to pier	Gower wildlife blog

Table 3.2: Sites where purpose made artificial nesting sites for kittiwake have been successful

Artificial nesting sites	Tyne kittiwake tower(s)	Lowestoft wall	Mumbles Shelves	Boulogne Wall	Middleton Island Tower
	 © [redacted]	 © Mike Swindells	 © By Nilfanion - Wikimedia UK	 © Jean-Michael Sauvage	 Image adapted from Gill & Hatch 2002.
Location	Saltmeadows, Gateshead	Lowestoft harbour, Suffolk	Mumbles Pier, Swansea	Boulogne-Sur-Mer harbour, France	Middleton Island, Alaska
Sighting notes	Banks of River Tyne, on scrubland behind industrial area	Wall at entrance to fishing harbour	Shelves attached to existing pier structure	On top of sea wall within an industrial port (Loubet basin)	On old Air Force radar tower on offshore island
Materials	Radio mast structure with shelving platforms on top	Concrete wall with ledges	Wooden shelving units	Concrete wall with discrete compartments	Old radar tower modified to allow access to birds for scientific research

Artificial nesting sites	Tyne kittiwake tower(s)	Lowestoft wall	Mumbles Shelves	Boulogne Wall	Middleton Island Tower
Height, dimensions etc.	3 Panels with ledges in triangular design. Each panel c.6m long with 8 ledges on each	Top ledges on both sides of wall, inward facing side 2 ledges (wide spacing between ledges)	Ledges on one side only. Multiple units (at least 5) installed on existing pier structure 3-6 shelves on each unit. c.5m-10m long	Compartments one side only, space for 3 nests per compartment Length = 85m Compartments are 140cm x 60cm	Individual shelved compartments size of one nest
Aspect	Sites occupied on all 3 sides. NE and NW generally have more nests than the S side Breeding success is higher on NE and NW sides (These are the sides pointing towards river)	Main occupied nesting sites on landward side of harbour wall over water (N/NW facing)	All over water beneath front and rear of lifeboat station (approx. N and S facing) and along pier supports on NE and SW sides	Corner plot facing out to sea (NW and NE)	Circular, all sides occupied
Date installed	1998	1988	2012	2017	Modified in mid 1990s
Potential number of nest sites	Max record = 143 nests (2007). Space for many more nests	Max record = 259 nests (in 1995)	c.200 nests	584 nests	Over 400 pairs
Number sites occupied/ productivity	111 nests 2019 (overall productivity = 0.79 2019)	In 2015 82 nests but raised zero chicks. 2016 only 22 nests. 2020 at end of July no birds seen nesting on wall (NB. some birds may have fledged) (E. Morgan, pers. obs.)	76 nests in 2013 (90 AON reported in 2018 but for whole Mumbles region – SMP)	In 2017 155 nests with chicks	Unknown

Artificial nesting sites	Tyne kittiwake tower(s)	Lowestoft wall	Mumbles Shelves	Boulogne Wall	Middleton Island Tower
Known issues	Tower provided as compensatory measure due to renovation of old buildings along river where birds had established nesting sites. Some issues with avian predation (crows) which resulted in all breeding kittiwakes deserting the site for the 2013 breeding season Clay decoys used to attract birds initially	Wall built as compensatory measure due to demolition of adjacent to pier where birds had established nest sites. Issues with gull predation (top shelves) and mammalian predation (fox lower shelves) Accessible on foot from rear	Shelving put up in 2011/12 as temporary compensation while renovation work carried out on pier with established nest sites. Birds initially tried to access old nest sites beneath deterrents on pier but gradually moved to ledges.	Wall built as compensatory measure due to demolition of building which had nesting birds established. Structure in same location as old building.	Bird breeding success on the island is decreasing. Additional food is provided for birds during the breeding season (Gill and Hatch, 2002)

Table 3.3: Purpose made artificial nesting sites for kittiwake where birds have (as yet) failed to colonise.

Artificial nesting sites:	**Boulogne Buildings and tower**	**South Shields Tower**	**Tromso kittiwake hotels**	**Finnmark kittiwake hotel**
NB. Image credits/copyright				
Location	Boulogne-Sur-Mer harbour, France	South Shields, UK	Tromsø, Norway	Berlevåg, Finnmark, Norway
Sighting notes	Shelves on existing tower of ferry terminal located over water within harbour channel	Banks of River Tyne, on dockyard/ industrial area	‘Artificial nests’ attached to the side of a building on end of pier	Outside town on coast
Materials	Wooden shelving units, on side of existing building	Radio mast structure with shelving platforms on top	Wooden individual shelves on building	Wooden structure with open shelves
Height, Dimensions etc.	Ledges of varying size	4 Panels with ledges in rectangular design. Each panel has 7 ledges on each	Nests installed on a building owned by Tromsø Havn at the “SørSjeteen” Dimensions unknown	Exact dimensions unknown
Aspect	South and East sides of building	4-sided design	Aspect unknown – on pier	Aspect unknown – on coast

Artificial nesting sites:	Boulogne Buildings and tower	South Shields Tower	Tromso kittiwake hotels	Finnmark kittiwake hotel
Date installed	2017	2014	2018	2019
Potential number of nest sites	unknown	Unknown (similar to Gateshead tower)	30 nests	320
Number sites occupied/ productivity	Zero	Zero	No nests established (2019)	No nests established (2019)
Known issues	Ledges added as compensation for renovation work on areas of building where birds already nested. Sites were not adopted by birds, most likely due to issues with sun exposure (JM Sauvage pers. Comm.) Small tower in water channel was also constructed in this area and is believed to be unsuccessful.	Tower was built in 2014 but was never used by birds and has now been removed.	No birds on sites in 2019 or 2020 breeding seasons (S. Dalsgaard pers. Comm.)	Nests from town were moved onto the structure to encourage relocation, but birds showed no interest in site as of 2020. A Different design is being considered.

4. Potential southern North Sea locations for artificial nesting structures

North Sea population trends

4.1 In general, kittiwake populations across the UK have decreased over the past 20 years (SMP 2020). These population declines have been most pronounced in Scotland (Furness and Tasker 2000, Oro and Furness 2002, Furness 2007, Frederiksen *et al*. 2004), however, populations in the southern England have also declined, with a high proportion of colonies abandoned (McMurdo-Hamilton 2016). In contrast, there is evidence of colony expansion in the southern North Sea (McMurdo-Hamilton, 2016) e.g. in Suffolk (Lowestoft and Sizewell), off the Dutch coast (colonisation of several oil and gas platforms), and Denmark (Bulbjerg in Thy).

4.2 Kittiwake population trends are primarily driven by productivity rates and to achieve a sustainable population, annual breeding success should be maintained at least 0.8 chicks per nest (Coulson 2017). It has been suggested that higher productivity rates are required to sustain kittiwake populations (Frederiksen *et al*. (2004): 1.17 chicks; Cook & Robinson (2010): 1.5 chicks), however, these values are higher than the average productivity rates reported at most colonies and productivity rates have been lower than this when population trends at some colonies were increasing (Coulson, 2017).

4.3 If populations in the surrounding area are decreasing (i.e. productivity trends are consistently lower than 0.8), this may be indicative of food shortages or other issues within the site that may make it unsuitable as a potential new colonisation site.

4.4 The SoS has noted in his “Minded to Approve” letter to Hornsea Three (paragraph 7.47) that compensation not directly benefiting the FFC SPA does not preclude fulfilling the requirement to preserve the coherence of the network of kittiwake Natura 2000 sites if it benefits the wider Eastern Atlantic population of kittiwake generally. The search area has initially been limited to the English southern North Sea as there is a preference for compensation to be located close to the impact where possible. The provision of artificial nest habitat could boost the wider Eastern Atlantic kittiwake population if breeding success at these new sites averaged more than 0.8 chicks per nest (Coulson, 2017). New colonies would also need to be large enough to buffer the effects of demographic stochasticity i.e. >40 nests (Wright, 1995) and to increase the chances of attracting new recruits.

Conclusion	Context
Although kittiwake populations have declined at many UK sites, there are a number of sites where populations seem to be doing well (or are at least stable) particularly in the Southern North Sea region.	To increase likely success of colonisation and subsequent breeding success, new nesting structures should be close to areas where populations and productivity trends are stable or increasing. To maintain numbers in the long term, it will be necessary for productivity to be over 0.8 chicks per year at the new site.

Table 4.1: Population trend AON for East Coast kittiwake colonies between 2010-2020 (for colonies with two or more counts within the last 10yrs)

Colony	Type	Number of years	Most recent count (year)	Linear trend (corr) 2010	Trend
Farne Islands SPA	Natural	9	3,158 (2018)	-0.41095	DEC
Coquet Island SPA	Natural	10	439 (2019)	0.924596	INC
River Tyne Natural?	Natural	6	246 (2015)	0.475058	INC
River Tyne Urban	Urban	6	1,011 (2015)	0.611839	INC
Marsden Bay	Natural	6	2,388 (2016)	-0.02292	DEC
Hartlepool Fish Quay	Urban	2	161 (2018)	1	INC
Saltburn Coast	Natural	7	1,610 (2018)	-0.33594	DEC
Boulby Cliffs	Natural	7	1,260 (2018)	-0.68444	DEC
Scalby to Rocky Point	Natural	4	0 (2019)	-0.97649	DEC
Scarborough to Osgodby Point	Natural	10	1,773 (2019)	0.08673	INC
	Urban	10	769 (2019)	0.949564	INC
Flamborough and Filey Coast SPA	Natural	2	51,535	1	INC
Lowestoft (Town)	Urban	8	(2017)	0.858978	INC

Table 4.2: Productivity trends from English kittiwake colonies between 2015 to 2019. Highlighted cells show colonies whose reproductive rate is currently at or above sustainability threshold identified by Coulson 2017 (* indicate colonies where the most recent data are 2-3 years old)

SMP SITE	type	numb. years data	Prod. 5yr Mean	Linear trend value (correlation)	Visual trend	At or above threshold for sustainable pop. (Coulson 2017)
Coquet Island SPA	Natural	5	1.07	-0.82	↓	YES
River Tyne to Seaton Sluice	Mix	5	0.92	0.00	→	YES
(Tyne Urban Only)	*(Urban)*	*(5)*	*(0.89)*	*(0.02)*	(→)	(YES)
Flamborough and Filey Coast SPA	Natural	5	0.56	-0.42	↓	NO
Lowestoft (Town)	Urban	3*	0.97	0.98	↑	YES
St Bees Head and Town	Mix	5	0.45	-0.58	↓	NO
Lundy	Natural	4	0.45	0.33	↑	NO
Isles of Scilly SPA	Natural	3	0.12	-0.78	↓	NO

Table 4.3: Productivity trends from English kittiwake colonies between 2010 to 2019. Highlighted cells show colonies whose reproductive rate is currently at or above sustainability threshold identified by Coulson 2017 (* indicate colonies where the most recent data are 2-3 years old)

SMP SITE	type	numb. years data	Prod. 10yr Mean	Linear trend value (corr)	Visual trend	At or above threshold for sustainable pop. (Coulson 2017)
Coquet Island SPA	Natural	10	1.17	-0.73	↓	YES
Farne Islands SPA	Natural	6*	0.87	-0.76	↓	YES
River Tyne to Seaton Sluice	Mix	10	0.96	-0.50	↓	YES
(Tyne Urban Only)	(Urban)	(10)	(0.96)	(-0.61)	(↓)	(YES)
Flamborough and Filey Coast SPA	Natural	8	0.58	-0.42	↓	NO
Lowestoft (Town)	Urban	8*	1.08	-0.48	↓	YES
Straight Point and Otterton Ledge to Ladram Bay	Natural	5	0.76	0.99	↑	NO
Mount's Bay, Cornwall	Natural	4*	0.18	-0.53	↓	NO
Isles of Scilly SPA	Natural	3	0.12	-0.78	↓	NO
St Agnes Island	Natural	4	0.36	-0.95	↓	NO
Lundy	Natural	9	0.51	-0.17	↓	NO
St Bees Head and Town	Mix	10	0.59	-0.34	↓	NO

Foraging areas used by kittiwakes in the North Sea

4.6 Figure 4.1 and Figure 4.2 shows sandeel habitat for the same region. The distribution of foraging kittiwakes matches closely to the major areas of sandeel habitat, however, there are a few potential sandeel locations within the southern North Sea where kittiwake foraging hotspots have not yet been recorded. There is strong evidence that kittiwakes in the southern North Sea are limited by nesting habitat availability (Coulson 2011). Providing artificial nest sites within this area could potentially open some of these locations to breeding kittiwakes.

Additional location factors to consider

4.7 Sites identified as good potential locations based on population and/or productivity trends need to meet additional biological and logistical requirements to be considered a feasible location for an artificial structure. These factors include:

- Prey availability (and diversity) within foraging range.
- The size of nearby colonies e.g. to weigh up competition versus source of recruits (see Figure 4.3 and Figure 4.4).
- Proximity to wind farms[3] or other infrastructure/development.
- Proximity to attractant features (e.g. Fish Quays, Inflows/Outflows).
- Habitat opportunities and constraints i.e. Natural England have advised (3rd September meeting) that SPAs not designated for kittiwake are a suitable potential option.
- Availability of waterfront locations suitable for construction.
- Accessibility for maintenance and monitoring.

4.8 Sites could be ranked based on these criteria to narrow down search areas. The scale of the search areas could then be narrowed to specific sites within a chosen area based on fine scale features (see Annex 3 of this document), which should also influence the design of artificial nesting structures.

[3] Defining acceptable distances required to avoid the new site potentially increasing collision rates from existing nearshore/offshore wind developments is challenging. The greater the distance and the more inappropriate the habitat at the OWF is for foraging kittiwakes, the better, though birds may transit an OWF en route to feeding grounds. Tracking data could assist in establishing the most likely flight paths of birds to/from colonies, however, currently tracking data from most colonies is limited. Examining overlap of core foraging areas (Cleasby *et al* 2018) with existing OWFs within mean foraging range from proposed colony sites could provide qualitative information to aid decision making. At Teesmouth, there is a colony of kittiwakes on a Conoco-Phillips jetty (c. 4 km from the Tees Wind Farm) which has grown during the period of construction and operation of the windfarm. Post-construction monitoring has found a reduction in numbers of kittiwakes using the area within the windfarm footprint and no collisions were observed in the period of 2015-2016 (Percival 2016).

Figure 4.1: Location of UK east coast kittiwake colonies with 50% core range and 95% home range of Kittiwake in the North Sea reproduced from UK-level utilisation distributions as derived by Cleasby et al. (2018) from tracking studies of breeding birds at various UK colonies

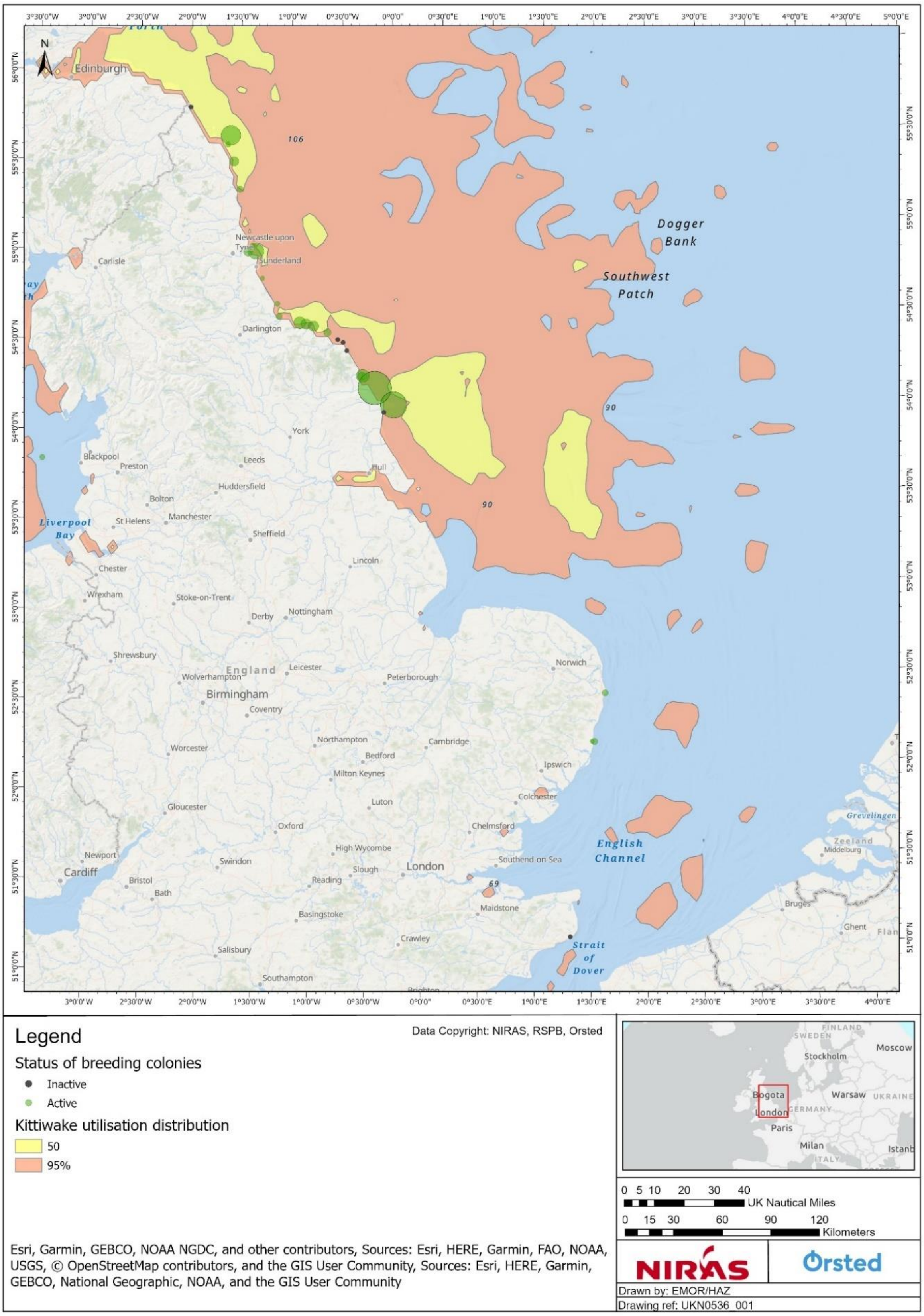


Figure 4.2: Sandeel habitat areas (areas with potentially high density of non-buried sandeel) and the locations of the fishing grounds (reproduced from Jensen *et al*. 2010)

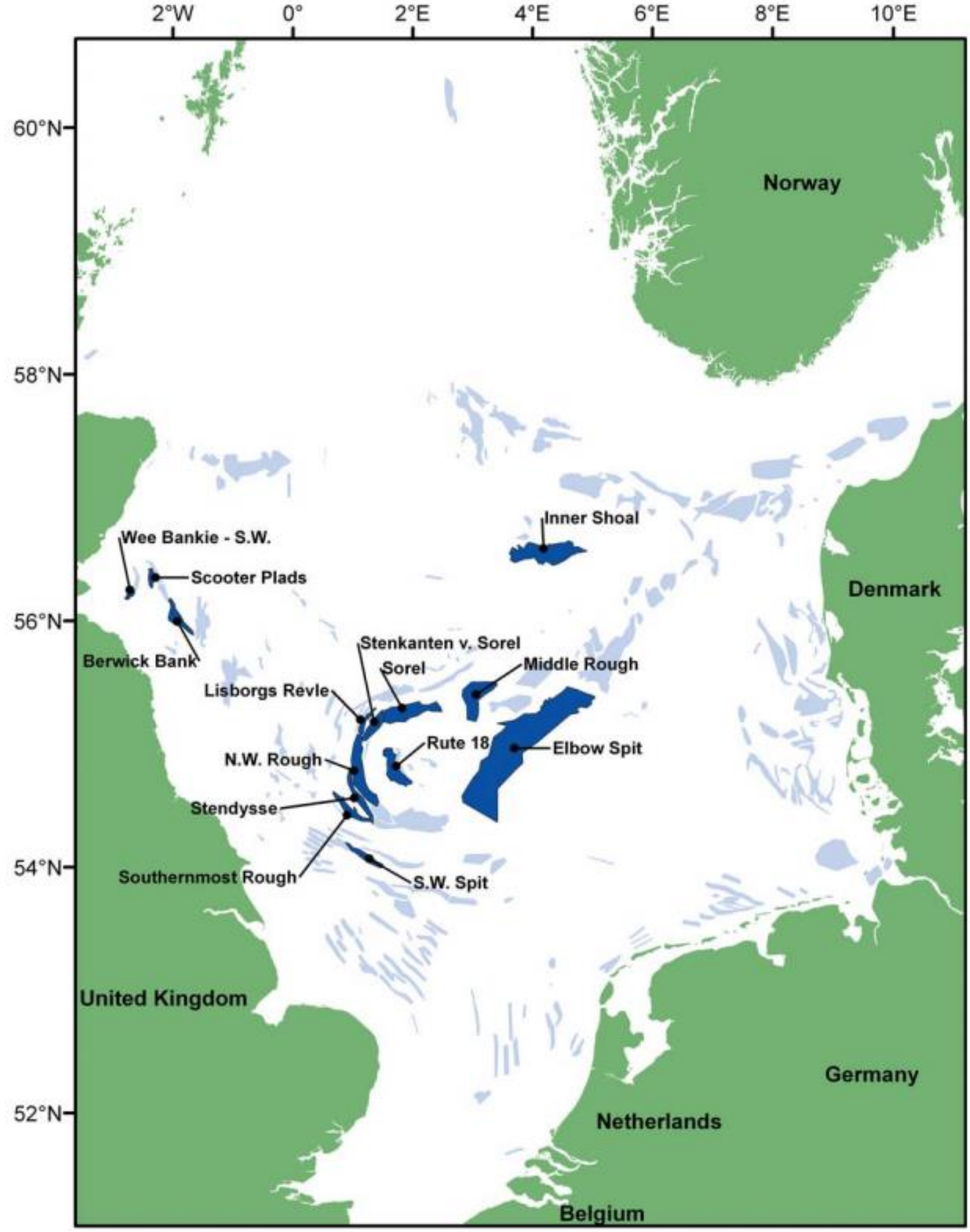


Figure 4.3: Location of north-east UK kittiwake colonies alongside 50% core range and 95% home range of Kittiwake in the North Sea reproduced from UK-level utilisation distributions as derived by Cleasby *et al*. (2018). Relative population sizes are shown by size of points.

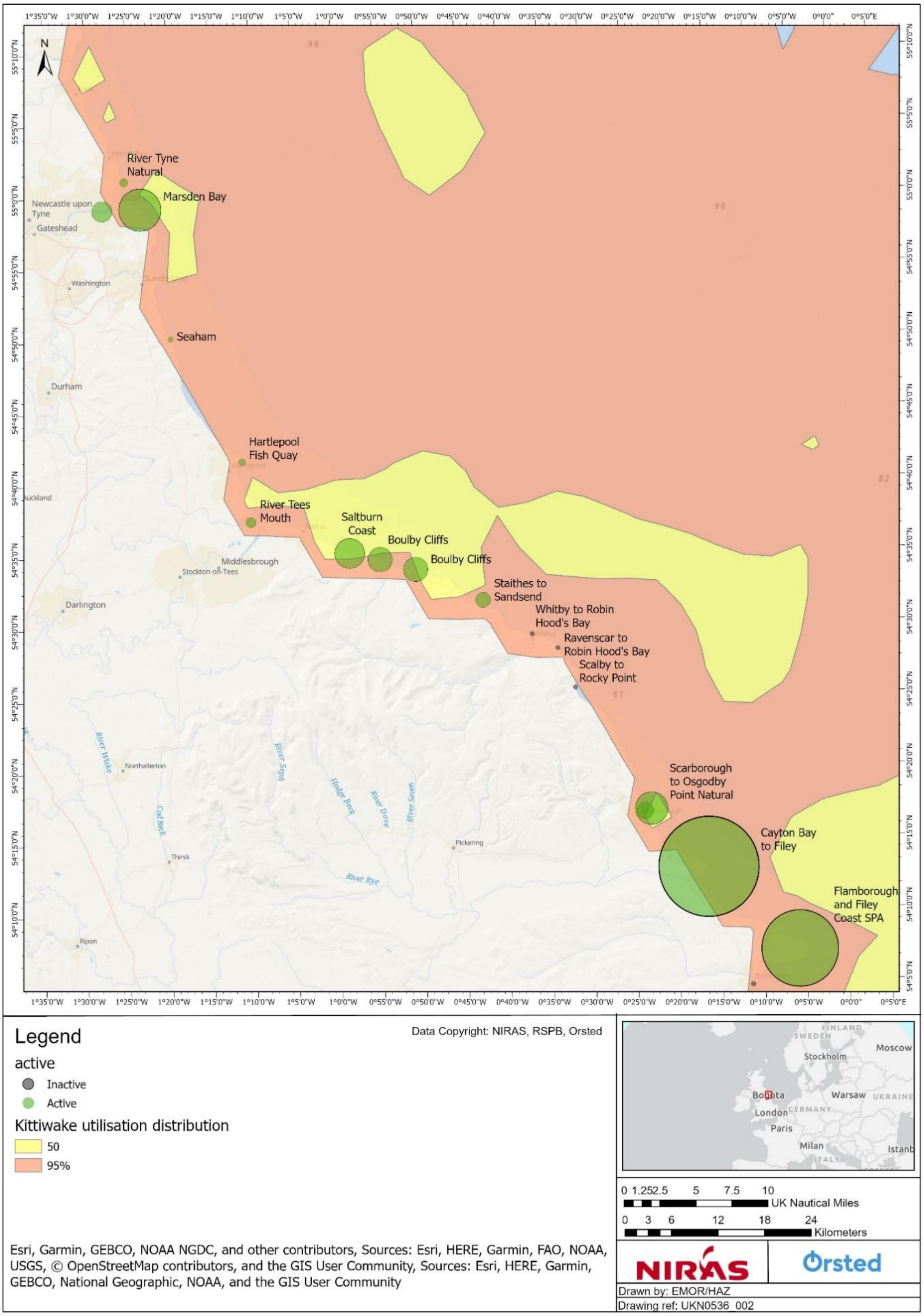
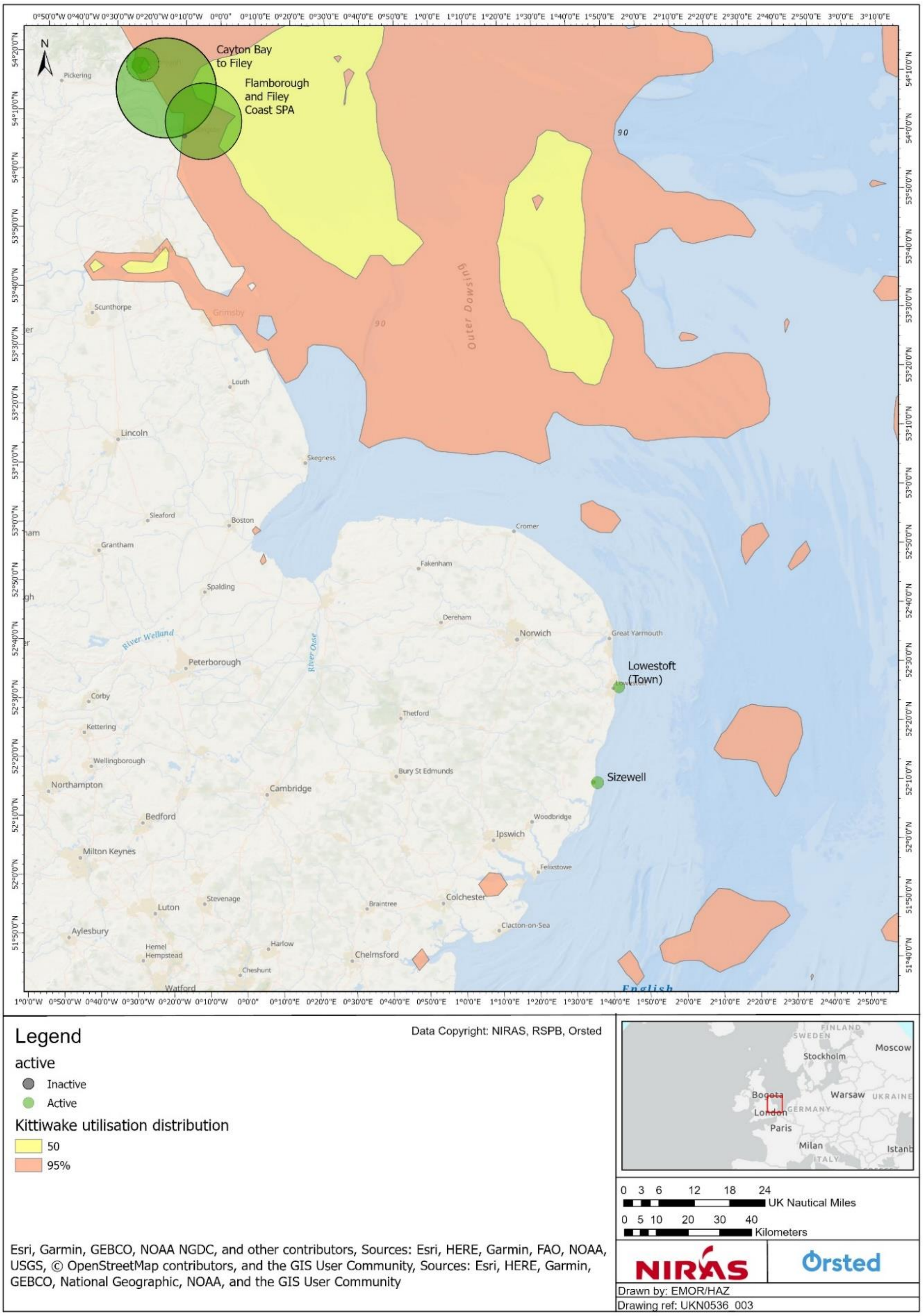


Figure 4.4: Location of UK south-east kittiwake colonies alongside 50% core range and 95% home range of Kittiwake in the North Sea reproduced from UK-level utilisation distributions as derived by Cleasby *et al*. (2018). Relative population sizes are shown by size of points.



Sandeel / food stock status in the North Sea

4.9 The reason for declines in kittiwake productivity has been strongly linked to food availability, specifically sandeel, in the northern UK (Furness and Tasker 2000, Oro and Furness 2002, Furness 2007, Frederiksen et al. 2004). The largest UK population of kittiwakes occurs along the Flamborough and Filey Coast (see Table 4.1) with birds nesting at this site primarily foraging out towards the Dogger Bank, which holds a large population of sandeels, but is subject to fishing pressures (Lindegren et al. 2018). Fishing effort has recently been linked to reduced breeding success of kittiwakes at the FFC SPA, which concurs with previous studies elsewhere showing reduced breeding success and survival of kittiwake associated with a decline in sandeel abundance in parallel with fishing pressure (Carroll et al. 2017). The relationship between kittiwake productivity and prey at FFC SPA is also covered in depth in the Supporting Evidence for Kittiwake Prey Resource report (Appendix 3 to the Applicant's Response)

4.10 Though sandeel are thought to be an important part of birds' diet in the southern North Sea i.e. sandeels comprise 60% of diet in breeding birds (Furness and Tasker 2000), their diet across this region does however appear to be more varied (with clupeids and gadids available as alternative food sources; M Swindells pers. comm). In the eastern part of the southern North Sea, stability at colonies in Denmark and Germany has been attributed to the likelihood that kittiwakes differ in their main food source from the well-studied colony on the Isle of May (Lerche-Jørgensen *et al*. 2012). Moreover, the alternative prey species (Small Sandeel *Ammodytes tobianus* and the Great Sandeel *Hyperoplus lanceolatus*) or fishery discards these populations of breeding kittiwake may rely on as a food source may be less affected by sea temperatures (Lerche-Jørgensen *et al*. 2012). Some kittiwake colonies in southern England are also considered to be less likely to be dependent on sandeels than those farther north (McMurdo-Hamilton 2016).

4.11 Sandeels in the North Sea can be divided into a number of more or less reproductively isolated sub-populations, due to the short period that larvae drift and the dependency of later life stages on specific areas of sand, and there has been evidence of local depletions in some regions (ICES). ICES has divided the North Sea into seven management regions. Kittiwake are constrained to forage within range of their breeding colony and are therefore reliant on these specific sandeel sub-population areas. Trends in breeding success of areas reliant on the same food stocks generally show similar population trends (Frederiksen *et al*. 2005, Olin 2020). Interestingly Olin *et al*. (2020) found that the population trends associated with colonies in Lowestoft and East Yorkshire do not appear to be as similar as expected given their proximity. This may suggest birds are reliant on different local food sources. Diet data from Lowestoft show birds are feeding on sandeel, with some clupeids (e.g. herring, sprat), and gadids (e.g. cod, pollock) (M Swindells pers. comm.). A small number of foraging tracks have been collected at Lowestoft and kittiwakes appear to be foraging close to Lowestoft (M Swindells pers comm). A shorter foraging range is generally associated with higher productivity (Daunt *et al*. 2002). Kittiwakes from Bempton/Filey are foraging towards the Dogger Bank, an area with a sizeable sandeel fishery (see Figure 4.1 and Figure 4.2). We understand diet samples have been collected from Bempton/Filey but have yet to be analysed.

4.12 Kittiwakes are likely to be subject to high levels of intra-specific competition at very large colonies (Wakefield *et al*. 2017). Therefore creating small new colonies in locations away from (i.e. not at or extremely close to FFC SPA) would be likely to increase breeding success of birds in new artificial colonies as it would reduce competition for food (providing an adequate stable food supply is available within the foraging range of birds).

Conclusion	Context
Birds may have higher foraging (and subsequent breeding) success in areas where there is less competition, both from fisheries and other kittiwake colonies.	A structure may be more successful if there is a variety of prey species within range that are not subject to intense pressure from fisheries. Structures may have a higher chance of success (i.e. productivity) at increasing distances from very large colonies e.g. FFC SPA population.

5. Optimal design specification for artificial nest sites

Natural nest sites characteristics / preferences

5.1 At natural sites, kittiwakes show a preference for the mid to lower sections of a cliff with steep vertical faces and small ledges on which to make their nests. Substantial nests are made from mud and vegetation/seaweed in order to hold the eggs/chicks (Cullen 1957). Kittiwakes are adapted to nest on much narrower cliff ledges than other seabirds (Cullen 1957, Coulson 2011). This helps them avoid terrestrial and aerial predators, notably larger gulls do not appear to be able to land on very small ledges (Cullen 1957).

5.2 Natural nest site characteristics are summarised in Table 5.1. The slope of horizontal ledges appears to be of less importance as kittiwakes build substantial nest structures, but more horizontal platforms appear to be more successful than steeply sloped ledges, with birds preferring a range of 16º - 25º (Olsthoorn & Nelson 1990). A small overhang or roof cover above the nest is also a common feature of natural nests and may enhance productivity (Kidlaw 1999, Olsthoorn & Nelson 1990). The mechanism behind this may be to prevent rain entering the nest (Olsthoorn & Nelson 1990) or it could reduce predation pressure from aerial predators. From examining various artificial nesting sites as part of this report, it appears that birds tend to avoid building nests on the top shelves of these structures (E Morgan, pers. obs). Sites where the top ledges are open, and the top of the structure is wide (i.e. wall at Lowestoft) have reported issues with large gull predation (M Swindells pers. comm.).

Table 5.1: Natural nest site preferences of kittiwakes reported in scientific literature.

Study	Coulson (2011)	Kidlaw (1999)	Olsthoorn & Nelson (1990)
Geographical location	Tyne, England	St George Is, Alaska	Bullers of Buchanan, Scotland

Study	Coulson (2011)	Kidlaw (1999)	Olsthoorn & Nelson (1990)
Width of ledge	Min = 8 cm by 8 cm	Mean 21.4 cm (±8.2) by 38.8 cm (±23.8)	30 cm by 20 cm. Can be narrower than nest but rarely longer than size of nest i.e. <50cm
Other ledge features	-	Slight overhang. Back wall 82.4º (±14.7)	Roof may be beneficial Dry site important. No sites were exposed on all 3 sides
Height	-	3-30m above sea level	Above wave spray height
Adjacent space	Not mentioned	Not mentioned	Approx. 50% of nests had perching space for adult to roost next to nest the off-duty adult to stand beside the nest
Density of other kittiwakes	High (within 5ft of another nest)	High (figures not specified)	High (6-15 birds within a 2m radius)

5.3 In Spain and Portugal, the few breeding kittiwakes only nest on north-facing cliffs where sites are in the shade (Coulson 2011). Problems with colonisation of artificial shelves at a site in France are believed to be due to issues with sun exposure of the south facing ledges added to a harbour building (see Table 3.3, JM Sauvage Pers. Comm.).

5.4 Around the UK, prevailing winds and storm conditions may be of more importance to nest site selection. Wind strength affects kittiwake attendance at colonies early in the season, with fewer birds present as wind speed increases (Coulson 2011). The occurrence of storms and prevailing weather conditions can disproportionately affect the breeding success of seabirds nesting on different sides of the same island (e.g. Newell *et al*. 2015).

5.5 Providing artificial sites facing different directions may provide a buffer in the event of unfavourable weather conditions. Artificial nest sites which have small partitions between nests (e.g. Middleton Island, Alaska and Boulogne Wall, France) are reported to be beneficial in buffering birds from detrimental weather conditions. Olsthoorn & Nelson (1990) found birds preferred nest sites which were less exposed, i.e. had more than one wall consisting of back and sides.

5.6 Of the artificial nesting structures examined for this report, there does not appear to be a particular design favoured over another in terms of attracting birds to nest at these sites (see Table 3.2). However, all the successful designs have a few key features in common; narrow ledges with steep back walls, are high enough for birds to feel safe (i.e. minimise disturbance), have features which limit exposure to adverse weather, and are in view of the sea. Further details of these design specifications can be found in Section 3 (Table 3.3 and Table 3.2). Minimising risk of predation is also key as birds have been known to abandon sites where predation pressure is too high (D Turner Pers. Comm.).

5.7 Sites where success has been limited could be due to design or location (see Table 3.3). Only one location exists where more than one design was trialed in the same area, Boulonge-Sur-Mer, which has a wall and a modified building/ tower structure. Ledges added to buildings were too exposed to the sun and were not adopted by birds, whereas the wall structure (which is NW and NE facing) was highly successful. An unsuccessful design in Finnmark, Norway is most likely due to the lack of backing to the structure leaving birds too exposed to the elements.

5.8 The second kittiwake tower built on the River Tyne was a similar design to the first tower, yet it was unsuccessful in attracting birds. Photographs of this tower suggest different materials were used which stand out from the surrounding environment (brightly stained timber was used for the nesting platforms). Perhaps, like many other birds, kittiwakes are wary of strange new looking structures. Having structures which blend in with the surrounding area may be important. However, this tower was also located away from existing kittiwake nesting sites and away from any other building like structures (though it was located between a natural site and the urban nesting sites upstream), which may make it less attractive to birds (see Appendix B: Successful and unsuccessful artificial nesting sites).

5.9 Location seems to be more important than building materials. Areas where artificial sites have been adopted quickly (often within a year or two of construction) have been sites where the new structure was built directly adjacent (or very close to) a site which had been demolished/made inaccessible. In many of these sites, birds were also present nesting on other similar structures within the harbour/town areas. Social environment appears to have a greater influence on adoption of artificial ledges than physical characteristics (Kidlaw 1999).

5.10 Playing kittiwake calls and setting up dummy nests and birds at a site has been suggested as a way to entice birds into a new structure (Coulson 2011, D. Turner, pers comm.) but remains largely untested. Few of the existing successful artificial sites examined (Table 3.2) have used these methods to encourage birds to nest (see Section 7.5).

Protection of Visitors and Kittiwakes

5.11 Kittiwakes at St. Abb's Head, East Scotland have shown reduced nesting success and even nest failure linked to human disturbance (Beale and Monaghan, 2004, 2005). The structure will need to be secure from unwanted visitor access (for health and safety of visitors and kittiwakes) but this will probably only comprise appropriate security fencing around the perimeter of the installation. The need for wider exclusion would need to be considered if there were a risk of disturbance of the site, although elevated designs, and likely location (away from human habitation) would likely render this unnecessary. The need for any wider exclusion will probably depend on the specific setting.

5.12 Predator deterrents have been installed on some of the existing artificial nest sites. The Tyne kittiwake tower has spikes on the top of the structure to deter avian predators from landing. The wall at Lowestoft had wire/fencing installed on parts of the pier to prevent foxes from accessing the wall.

Conclusion: Key Features for Artificial Nest Sites
• High and steep sided, narrow horizontal ledge, small roof • Inaccessible to predators • Located close to water, facing out to sea • Materials which fit in with surroundings • Not too exposed to adverse weather • Presence of other breeding kittiwakes

Design Specification Options

5.13 The overall design of an artificial nesting structure for kittiwakes can be flexible provided a set of critical physical features are met. Various designs (using a range of materials) have been successful ranging from shelves attached to existing structures, to purpose-built towers and walls (see Section 3.5). In terms of increasing the attractiveness to kittiwakes (i.e. increasing the likelihood of colonisation), design options are likely to be secondary to choosing the correct location. A design which fits in with the structures and locations birds are already using at an existing site should be key in informing the design of a structure. Temporary design features could be added to structures to encourage recruitment i.e. decoy nests/birds and audio systems to play kittiwake calls to attract birds in.

5.14 Certain design features could increase productivity at a site once established e.g. Walls/partitions between groups of nests and a small overhang/roof to buffer against weather conditions, and additional predator deterrents.

5.15 By ensuring that the structures are designed to incorporate key specifications, the compensation measure will increase changes of success and support resilience of the measure. The following sections provide detail, and associated evidence for potential options to include in the initial design. Structure design will form an integral component of discussions within the Hornsea Three Offshore Ornithology Engagement Group (OOEG) with the following information highlighting the likely key components.

Critical Features

5.16 Physical design elements should compromise;

- Horizontal ledges 20 cm by 30cm
- Vertical back wall
- Height above ledge >30cm

Location

- Nest adjacent to / above harbour waters / sea
- >2m above ground/mean high water level
- Avoid South facing aspect (potential over exposure to sun)

Optional: design features

5.17 A range of potential structures and materials could incorporate the key design features to provide artificial sites appropriate for kittiwake nests. Additional features could be incorporated to enhance the monitoring, maintenance and management potential of these structures. These options are detailed in Figure 5.1. All design structures should be positioned in locations which would allow visibility and access for monitoring purposes (see Section 14). However, a more complex design structure could reduce disturbance to birds during research/monitoring activities and would provide greater opportunities for additional research projects.

Anti-predation features:

5.18 Initial nesting structure design will incorporate features aimed at preventing avian and/or mammalian predation i.e. steep vertical walls and built at a height where ground predators should not be an issue. However additional features could be added to designs to reduce predation pressure on the colony:

Avian predator deterrents

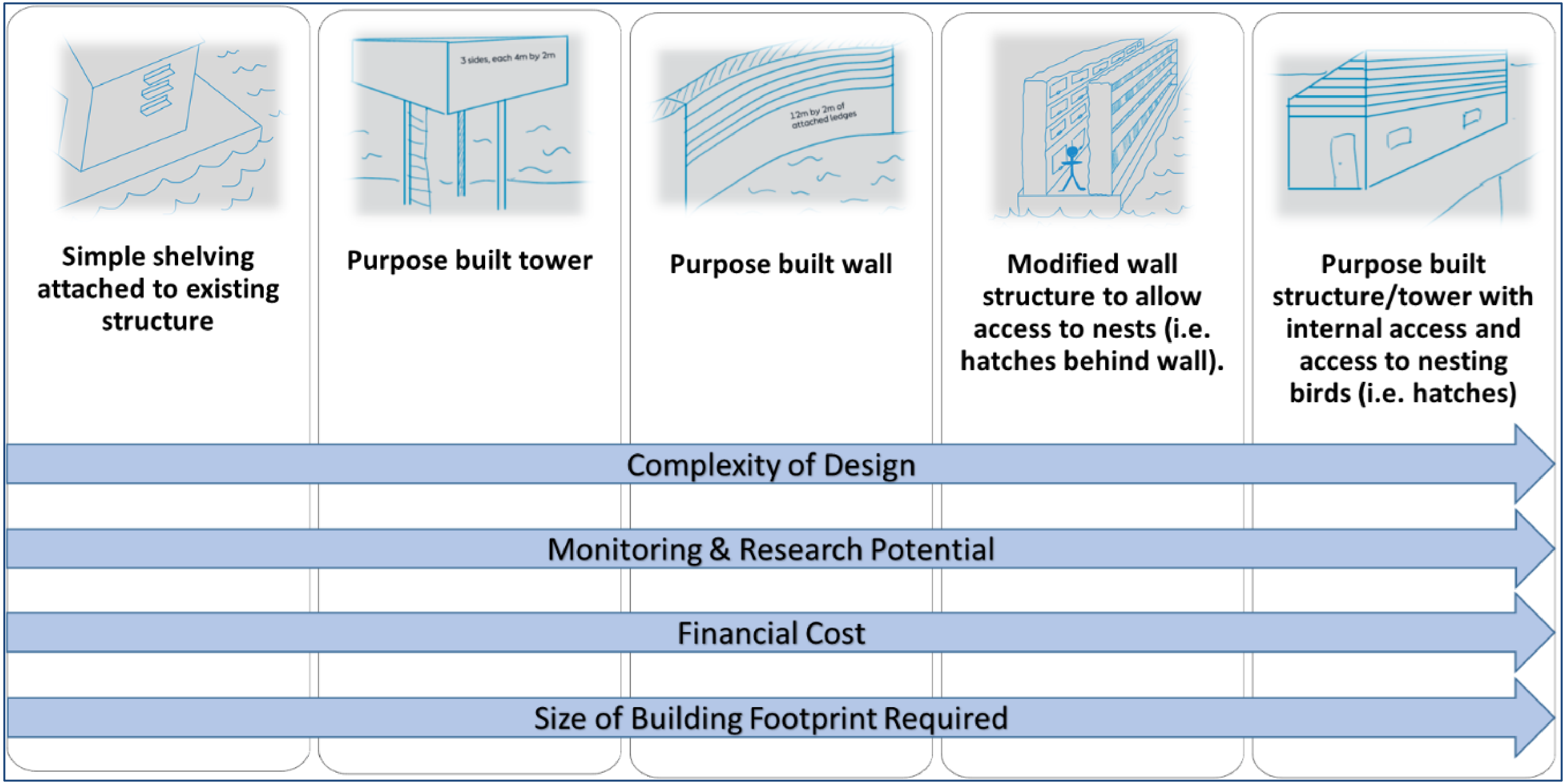
5.19 Large gull species, such as herring gull and lesser black-backed gull, are known predators of kittiwake chicks and eggs (Coulson, 2011). Their presence at a kittiwake colony can also cause unrest of breeding kittiwakes. The design of the artificial nesting structures will attempt to discourage large gulls from landing on the structures (i.e. no flat roof to land on). However, some adaptations may need to be added to the structures if it is found that the initial design has not prevented large gulls from landing (see adaptive management section). A review of urban gull management was undertaken by Calladine *et al*., (2006) on behalf of the Scottish government, and presents a number of potential methods which could be added to the structure initially or as adaptive management. One common practice is the addition of spikes to the top of the structure to deter avian predators from landing.

5.20 Spikes have been used with success to deter lesser black-backed gulls from nesting in a housing estate in Kilmarnock (Scotland), by placing these at precise favoured nesting locations on approximately one-fifth of the houses and bungalows on the estate (Wellpark Action Group, pers. comm. referenced via Calladine *et al*., (2006). This method has also been successfully installed on the Tyne kittiwake tower to prevent large gulls from landing on the structure. Consideration will be given to avoid any potential implications to kittiwakes themselves as a result of large gull deterrents.

Mammalian predator deterrents

5.21 As potential design of the artificial kittiwake nesting structures remains unrestricted and the exact location yet to be determined, there is a potential that the structure could be reached by mammalian predators. This was shown to be the case and the subsequent causation of mortality for breeding kittiwake along the breeding wall at Lowestoft (Furness *et al*., 2013) when a fox accessed the breeding ledge. As a result of this incident, wire fencing was added to the nesting wall to prevent access. Similar adaptations could be made to a wall-based design that without anti predator adaptions, may allow access to ledges.

Figure 5.1: Design options for artificial kittiwake colonies



Methods to enhance chances of initial colonisation

5.22 Further to the initial design options listed above, other methods to increase chances of initial colonisation could be incorporated at the design stage. Below are a number of potential methods which have been widely used across multiple seabird conservation programmes globally (Friesen *et al*., 2017) and may assist this compensation measure.

Playback

5.23 Playing calls of kittiwakes at a newly established site has been suggested as a way to entice birds to colonise new nesting structures (Coulson, 2011) but remains untested. The kittiwake hotels set up in Tromsø harbour are using tape lures to attract birds, however no birds have yet been recorded nesting (though the structures were only put in place in 2019) (Markusson, 2020).

Decoys

5.24 Models of conspecifics can work well for colonial breeding species that are attracted to nesting locations by the presence of their own species (Evans and Cash, 1985; Podolsky, 1990). Visual cues are of relevance to kittiwake as the species is diurnal, attending the colony during the day, and therefore using visual stimuli to locate nesting locations. Noting the differences in breeding biology between gulls and terns, Jeffries and Brunton (2001) found that decoys (with and without a playback stimulus) attracted 80% more New Zealand fairy terns than the control treatment which used no decoys or calls. Decoys have previously been used at artificial kittiwake colonies. Turner (2010) mentions kittiwakes were lured to the Tyne tower by clay decoys and disused nests placed on the ledges but does not comment on the success of these methods. The kittiwake hotels set up on the side of buildings in Tromsø harbour are using tape lures to attract birds, however no birds have yet been recorded nesting (though the structures were only put in place in 2019) (Markusson 2010). In Finnmark, Norway existing nests were moved onto the new artificial structure, but this failed to attract birds away from their nest sites within the town (Wormdal 2020). Enhancing a colony by providing artificial nest sites on a structure where nesting space is limited (e.g. a pier) is more likely to increase the chance of successfully attracting prospecting birds.

Nests

5.25 Real nests (obtained from old, unused nests, or from birds displaced from urban settlements) or fake nests could be used to entice potential breeders to the artificial nesting structure and was proposed as a potential method during the relocation of the Baltic Flour Mill kittiwakes. In Finnmark, Norway existing nests were moved onto the new artificial structure, but this failed to attract birds away from their nest sites within the town (Wormdal, 2020). Nests placed on the structure (real or fake) could also be splattered with white paint to mimic the whitewashing of colonies to act as a visual cue (Coulson 2011).

5.26 Using real nests will also contribute to chemosensory abilities of seabirds. Friesen *et al*., (2016) found this to be the least-explored method of sensory-based conservation for seabirds. Despite its lack of application in conservation programmes, many seabirds have an excellent sense of smell. This is especially relevant in tube-nosed Procellariforms, but also in other bird families, for example, kittiwakes have both individual and sex differences in odour (Leclaire *et al*., 2011).

5.27 Many taxa communicate and detect cues in multiple sensory modes, i.e. simultaneous acoustic, olfactory and visual signals (Candolin, 2003; Hebets and Papaj, 2005). This can assist in conservation management as multiple stimuli may provoke a stronger behavioural response than a single sensory mode. For example, in the diurnal Laysan albatross, more individuals landed at sites where both vocalisations and visual stimuli were utilized than sites using visual stimuli alone (Podolsky, 1990). Therefore, a combination of calls, models and nests could be incorporated into initial structure design. Testing of any methods incorporated into the monitoring programme would provide valuable empirical evidence of such methods for this species and subsequently inform further artificial nesting structures.

6. Identification of coastal areas for deploying artificial nest sites

Area of search

6.1 As noted previously in 4.1.4, the area of search has initially been limited to the English southern North Sea based on the preference for compensation to be located close to the source of impact where possible. The SoS has clarified in paragraph 7.47 of his “Minded to Approve” letter that the coherence of the network of kittiwake Natura 2000 sites can be maintained if a compensatory measure benefits the wider Eastern Atlantic population of kittiwake generally.

6.2 Detailed studies of recruitment would suggest that the number of immigrants recruited into the adult breeding population of an established kittiwake colony probably exceeds the number of philopatric individuals (Coulson 2011). These recruits are coming from a pool of young produced in many colonies within 1,600 km. In other words, the FFC SPA population is not a discrete self-perpetuating unit, but part of the broader UK population together with birds from other European countries i.e. a metapopulation. However, the majority of the 76% birds that are not philopatric choose sites within a neighbouring colony (<100 km) to breed, with a reasonable assumption being that FFC SPA largely contributes to, and draws upon, one multi-colony regional population, the southern North Sea.

6.3 For the purposes of this study, the southern North Sea regional population is defined as the English North Sea Kittiwake colonies, Northumberland to North Kent. It is within this coastal zone and its adjacent offshore waters that a search of areas to host artificial nesting sites is focused.

Identification of coastal areas

6.4 From the preceding review of kittiwake colonies, recruitment and population trends, the following criteria are identified that predispose an area to hosting artificial nesting sites that will be occupied by new recruits to the southern North Sea regional population, whilst contributing to an increase of breeding adults:

- Connectivity already exists with the southern North Sea regional population to facilitate initial colonisation by prospective breeders e.g. following trawlers for fish discards into fish quays (e.g. Hartlepool, Tyneside), and power station inflow and outflow seawater pipes (e.g. Sizewell).

- Areas that lie beyond proximity to existing colonies in decline or where nesting failure is generally occurring as this may increases pressure on already limiting factors, that may be driving the decline/failures e.g. food supply.
- A preference for those areas lying within 100 km of existing colonies as the evidence has suggested the majority of 76% birds that are not philopatric choose sites within a neighbouring colony (<100 km).
- Areas lying within mean maximum foraging range of known sandeel habitat areas with potentially high density of non-buried sandeel, as a major prey resource for kittiwake i.e. within 156 km (Woodward *et al*. 2019).
- Waterfront locations away from urban housing which minimises human interaction and where purpose built artificial nests can overhang water, reducing risk to health, safety and the environment.

6.5 The paucity of kittiwake colonies between Yorkshire and Kent reflects the near absence of natural nest sites along this coast i.e. high vertical cliffs. Where colonies have established - on Lowestoft outer harbour and thereafter in 1994 on Sizewell rigs, about 30 km to the south (Suffolk Wildlife Trust 2007) - these lie over 100 km from the nearest colonies in Kent and Yorkshire. Areas beyond the distance most birds would be recruited from their natal colony, < 100km, should therefore not automatically be discounted for the establishment of new colony through the provisioning of artificial nesting structures.

6.6 Establishing artificial structures for nesting in two or more different areas would further help ensure success in buffering against localised events e.g. adverse weather conditions, local changes in prey resources due to fisheries or changes in SST, or more unpredictable events like high adult mortality from localised toxin-producing algal blooms (Coulson and Strowger 1999). Furthermore, it would increase the likelihood of connectivity with prospective breeders as over 95% of all recruits select older, established colonies (Coulson 2011). The establishment of multiple new colonies has the potential to also minimise on the lead in time to achieving the size of compensatory population required (see Section 8).

6.7 Usually, new colonies are created by young birds which have been present at the new site one or more years before the first eggs are laid (Coulson 2011). New colonies typically grow rapidly, and often double in size annually for the first two three years, but thereafter increase at a progressively lower rate. Their initial growth for the first ten years or so is almost entirely dependent on successfully attracting immigrants because potentially philopatric individuals have not reached breeding age for four or five years and in any case the number of young produced in the first few years of the colony is few (see Section 9).

Table 6.1: Examples of locations with the potential to successfully host the development of artificial nesting structures for kittiwake

Area	Connectivity	Distance to and productivity of neighbouring colonies	Proximity to known sandeel habitat areas	Comments
Tees Estuary	286 pairs breed within the estuary, on Conoco Phillips Jetties, Seal Sands (Cleveland Bird Report, 2019)	Several colonies (c. 1,295 pairs; Cleveland Bird Report, 2019) breed outside the estuary up to 20 km distant	< 156 km	Potential opportunities to develop on existing industrial wasteland with a water frontage
Hartlepool Headland	275 pairs breed at several sites in Hartlepool (C. Brown pers. comm., 2020)	Several colonies (c. 1,456 pairs; Cleveland Bird Report, 2019) breed nearby, up to 20 km distant	< 156 km	Opportunity to modify the disused (from 2005) 2,000ft long Steetley Pier. Several pairs already breed on site
Lowestoft	446 pairs breed within the town (2018)	Sizewell Rigs at 30 km	< 156 km	Enhancement opportunities exist in the harbour
Sizewell Rigs	502 pairs breed on Rig 1 (last available count, 2008)	Lowestoft at 30 km	< 156 km	Enhancement opportunities exist on the rigs

6.8 Section 5 has already identified potential key elements in the physical design of existing artificial nesting structures that may have contributed to their success in becoming a flourishing breeding kittiwake colony. Table 6.1 lists examples of locations that fulfil all or some of the above-mentioned criteria for area selection, within which the opportunity is likely to exist of sites to host the development of artificial nesting structures as per the optimal design.

Conclusion	Context
Suitable coastal locations exist where an artificial colony would have an enhanced chance of success. These areas have potential connectivity to existing colonies where productivity has been good over the last five years, are within range of known prey habitats and show evidence that natural nesting habitat may be limited.	Key areas identified are in the north-east of England – Tees Estuary to south of Seaham and East Anglia – Sizewell to Lowestoft. Provision of structures at multiple sites would maximise the chance of success.

7. Identification of offshore areas for deploying artificial nest sites

Area of Search

7.1 As noted previously in 4.1 and 6.1, the area of search has initially been limited to the English southern North Sea.

Identification of offshore locations

7.2 The following criteria are identified that predispose an area to being suitable for the hosting of artificial nesting sites that will be occupied by new recruits to the southern North Sea regional population, whilst contributing to an increase of breeding adults:

Connectivity

7.3 Kittiwakes are dispersed widely in the southern North Sea throughout the year, with numbers peaking during November and March (Stone *et al*. 1995), when colonies are largely vacated, reflecting the species preference for pelagic habitats. In deploying artificial nest sites offshore in the southern North Sea, whether it be to a new or existing structure, it can safely be assumed that connectivity across the region already exists to facilitate initial colonisation by prospective breeder.

Prey Resources

7.4 As with deploying artificial nest sites onshore/nearshore, a key criterion for deployment to a new or existing structure offshore will be locating it within mean maximum foraging range of known sandeel habitat areas with potentially high density of non-buried sandeel, as a major prey resource for kittiwake i.e. within 156 km (Woodward *et al*. 2019). This constraint only becomes a potential limitation when considering localities in the vicinity of the Thames Estuary, though colonies are not necessarily wholly dependent on sandeels as a single major prey resource as clupeids (e.g. herring, sprat), gadids (e.g. cod, pollock) and planktonic crustacea can also be important (e.g. Lewis *et al*. 2001, Chivers *et al*. 2012).

Nest Building Resources

7.5 Kittiwake build nests of mud-based foundation to which further grasses and seaweed are added on top with these collected from the tideline, cliff edges and sea surface typically within 2 km of the colony (Coulson 2011). The species does nest on offshore structures and at 30 km or more away from land (e.g. Morecambe Gas Platform). It has not been established however, as to what extent distance from a source of mud, is a constraint or negatively impacts colony development and the breeding success of those birds attempting to nest offshore.

Bird Strike Risk

7.6 Any deployment of artificial nest sites on existing offshore structures which are in proximity to platforms which house helipads, needs to consider the safety of flight operations and the risk assessment of bird strikes where routine operational helicopter landings are on-going or proposed. The bird strike risk to aircraft using offshore structures immediately rules out the vast majority of, operational offshore structures associated with the wind, oil and gas industries as a location at which to deploy artificial nest sites. Moreover, the presence of a seabird colony attracts aerial predators such as the large gull species (e.g. great black-backed gull), which themselves may be considered of a heightened bird strike risk; these predators loaf and fly above colonies waiting for opportunistic moments to predate. A bespoke tower located offshore away from other platforms could negate these risks.

Offshore Wind Farm Collision Risk

7.7 The positioning of any artificial nest sites offshore needs to avoid or minimise inadvertently increasing the collision risk of kittiwake with existing, consented and, more problematically to define with a high degree of spatial resolution, areas proposed for offshore wind farms. This process needs to consider changes that may increase the cumulative impact on kittiwake populations at Natura 2000 sites.

Deployment of Offshore Structures

7.8 Deployment of artificial nest sites offshore remains a viable option. However, it is fair to state that more work is needed on understanding the specifications required in doing so, not least from the perspective of safeguarding against additional cumulative impacts occurring on kittiwake populations at Natura 2000 sites. The logistics of building offshore would be more complex and financial implications greater. A structure offshore would also have reduced monitoring, maintenance and research opportunities than an onshore location. If empirical evidence in delivering the measure can be gained from an onshore structure, then offshore structures should not be ruled out in the future.

Conclusion	Context
An offshore location could meet *all* the biological requirements for the location of artificial nesting sites.	An offshore site would be more challenging logistically and financially. It would also have reduced monitoring, maintenance and research opportunities compared to an onshore site.

8. Size of Compensatory Population Required

8.1 The Secretary of State concluded, on a precautionary basis, that the potential magnitude of the collision mortality impact of Hornsea Three on the kittiwake population of the FFC SPA was 65-73 adults per annum. If the aim of compensation is to fully offset this impact, then sufficient additional nesting sites should be provided to provide a corresponding increase in the population size. As a precautionary measure, and to account for uncertainty, the upper limit of this range has been used in calculations (i.e. an additional 73 adults per year).

8.2 To calculate the breeding population required to achieve this amount requires several factors to be considered:

- Breeding productivity – the average number of young produced by each breeding pair
- Age at which birds start to breed (age of recruitment)
- Survival rate of birds which varies by age
- Breeding dispersal

8.3 The productivity of British kittiwake colonies was reviewed by Horswill & Robinson (2015). As expected, there is variability between colonies but an average productivity rate of 0.819 was calculated for colonies located in the east of the country. In addition, productivity rates were also presented for birds based on their breeding experience:

- 1st attempt – 0.898 chicks / pair
- ≥ 2nd attempt – 1.379 chicks / pair

8.4 Applying this experience-based difference in productivity to the east of Britain average, then the expected productivity rate would be[4]:

- 1st attempt – 0.561 chicks / pair
- ≥ 2nd attempt – 0.862 chicks / pair

8.5 The age at which kittiwake breed varies and, whilst it is typically assumed that most birds do not breed until four years and that the majority of birds are recruited to the breeding population between the ages of 3 and 5, some birds may breed at year 2 and others may not breed until year 10. Coulson (2011) observed the proportion of birds recruited into the breeding population by age at a colony in North Shields and the results are shown in Table 8.1.

Table 8.1: Proportion of kittiwakes within the breeding population at North Shields by age at recruitment (Source: Coulson, 2011)

Age at recruitment	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
% of recruits	0.7	26.5	35.2	22.7	10.5	2.5	0.9	0.9	0.4

[4] The experience-based productivity rates quoted by Horswill & Robinson (2015) for all UK birds have been scaled to fit the average east of Britain productivity rate. The adult survival rate for kittiwake is 85.4% so it is assumed that in any one year 14.6% of birds are 1st time breeders (i.e. replacement of lost existing breeders). So if the productivity rate for 1st attempt birds of 0.898 is scaled assuming it applies to 14.6% of birds and the rate for ≥ 2nd attempt of 1.379 is scaled assuming it applies to 85.6% of birds then the values presented here (0.561 and 0.862, respectively) would lead to an average productivity rate in the breeding population of 0.819.

8.6 The survival rate of birds also varies by age with juvenile birds typically experiencing slightly higher levels of mortality than older birds. Horswill and Robinson (2015) cite mortality rates as follows:

- Juvenile (0-1 year) – 0.790
- Adult (>2 year) – 0.854

8.7 With respect to breeding dispersal, it is known that a proportion of birds that have been reared within a colony tend to be faithful to that colony and return there to breed (philopatry, see section 3.3). The remaining birds will disperse to find other breeding sites. Horswill & Robinson (2015) indicate that natal dispersal is thought to be high and cite a value of 0.89 (i.e. 11% philopatry, based on data in Porter & Coulson, 1987).

8.8 Other data (e.g. Coulson 2011) suggest a natal dispersal rate of between 0.89 and 0.77, with 0.77 (23% philopatry) considered to be a reasonable "worst case" for the purposes of this exercise and 0.890 a likely typical value for UK colonies.

8.9 Once established, kittiwakes tend to be faithful to a site and Horswill & Robinson (2015) cite an adult dispersal rate of only 0.012 for colonies that are increasing (and a somewhat higher figure of 0.062 for those that are in decline). Relocation has been documented for kittiwakes experiencing declining habitat quality (e.g. Danchin & Monnat 1992).

8.10 Using the ranges of values above, the number of additional breeding pairs required to generate an additional 73 birds that would increase the annual recruitment of kittiwake into the regional population of the Eastern Atlantic has been calculated (see Table 8.2 and Appendix E: Additional information on calculations for size of compensatory population required).

Table 8.2: Calculation of additional breeding population required to produce an additional 73 breeding adults

Productivity (chicks / pr)		**Age of recruitment (yrs)**	**Survival rate**		**Breeding dispersal**		**Additional breeding population required (pairs)**
1st yr	**Adult**		**1st yr**	**Adult**	**Natal**	**Adult**	
0.562	0.863	2 – 10	0.790	0.854	0.770	0.012	**467**
					0.890		**404**

8.11 In order to increase the regional Eastern Atlantic breeding population of adult birds by a sufficient margin to offset the predicted impact of Hornsea Three on an annual basis (i.e. 73 additional adult breeding birds recruited into the population), it is calculated that approximately 404 – 467 additional breeding pairs will be required. The additional population of 404 is based on a natal dispersal rate of 0.890, which is the average cited by Horswill & Robinson (2015) for UK colonies, but this rises to 467 if a worst-case value of 0.770 is assumed instead.

8.12 It can also be seen that, once breeding has successfully commenced, the required additional population will be produced within approximately five years. Although birds may be up to 10 years old before they breed, the very large majority are recruited into the breeding population by the time they are 5 years old (see Table 8.1).

Conclusion
A population of 404 - 467 pairs will produce enough breeding adults (73 birds per year) to offset the impact of Hornsea Three.

9. Growth rate of new colonies

9.1 Projecting the growth rate of a new artificial site is challenging as data on the colonisation of artificial structures is limited e.g. France and the Tyne (see data in Appendix D: Growth rates of existing artificial nesting sites). In both these situations, birds were actively pushed from original nesting sites on to the new structures so may not be representative of natural colonisation processes.

9.2 At natural sites, new colonies are usually created by young birds and will typically grow rapidly, and often double in size annually for the first two three years, but thereafter increase at a progressively lower rate. Their initial growth for the first ten years or so is almost entirely dependent on successfully attracting immigrants because potentially philopatric individuals have not reached breeding age for four or five years and in any case the number of young produced in the first few years of the colony is few. Figure 9.1 shows growth rates observed at three natural colonies in North East England (Coulson 2011). Coquet Island has been monitored from the first initial breeding in 1991, so is likely to show the best scenario for establishment of a new colony at a new site where birds had not previously bred nearby. However, Coquet was colonised during a period of population expansion of kittiwakes across the UK in general, so these rates may be opportunistic as recent UK trends show a decrease in kittiwake numbers (SMP 2019).

9.3 Kidlaw *et al*. (2005) described the growth of colonies in Alaska and record that they are typically founded by variable numbers of pioneers (23 pairs on average) and exhibit rapid growth in the first four years. Thereafter, growth declined to 10%–20% per annum and exhibited lower interannual variability.

9.4 Coulson (2011) noted that new colonies are usually formed by between 3 and 20 nesting pairs. An infrequent exception to this pattern occurs when an existing colony becomes unsuitable (e.g. Tyne) and relocation occurs.

9.5 The way in which individuals establish and introduce themselves to the colony explains some of these patterns. New recruits prefer occupancy in the centre of a colony. After the first few years, the availability of breeding space in the centre of the colony is primarily controlled by the death of previous site owners. New recruits are increasingly forced to find sites closer to the edge of the colony where there is more space (although it is assumed birds will seek to nest within 3-5m of existing sites). However, as the colony grows in size its edge (as a proportion of the whole colony) and the space within it declines, slowing the rate of growth.

9.6 It should be expected, therefore, that newly established artificial nesting sites will grow rapidly in the first 3-5 years, followed by growth at a slower rate thereafter. In addition, young prospecting breeders often visit colonies and loaf around breeding sites for 1-2 years before breeding attempts occur (Coulson 2011). Birds require social stimulation of other breeding pairs to initiate breeding activities (Coulson 2011), The Tyne kittiwake tower initially used decoy birds to attract recruits to the Tyne tower (Turner 2010), so this may be a possible way to encourage new breeders in more quickly.

9.7 Colony success and growth rates are also dependent on availability of recruits, food resources, survival rates. The size of the pool of recruits available in the North Sea is unknown and is difficult to ascertain (Black & Ruffino 2020). The availability of food resources in an area can be implied by proxy by choosing a location near an existing colony with good productivity rates.

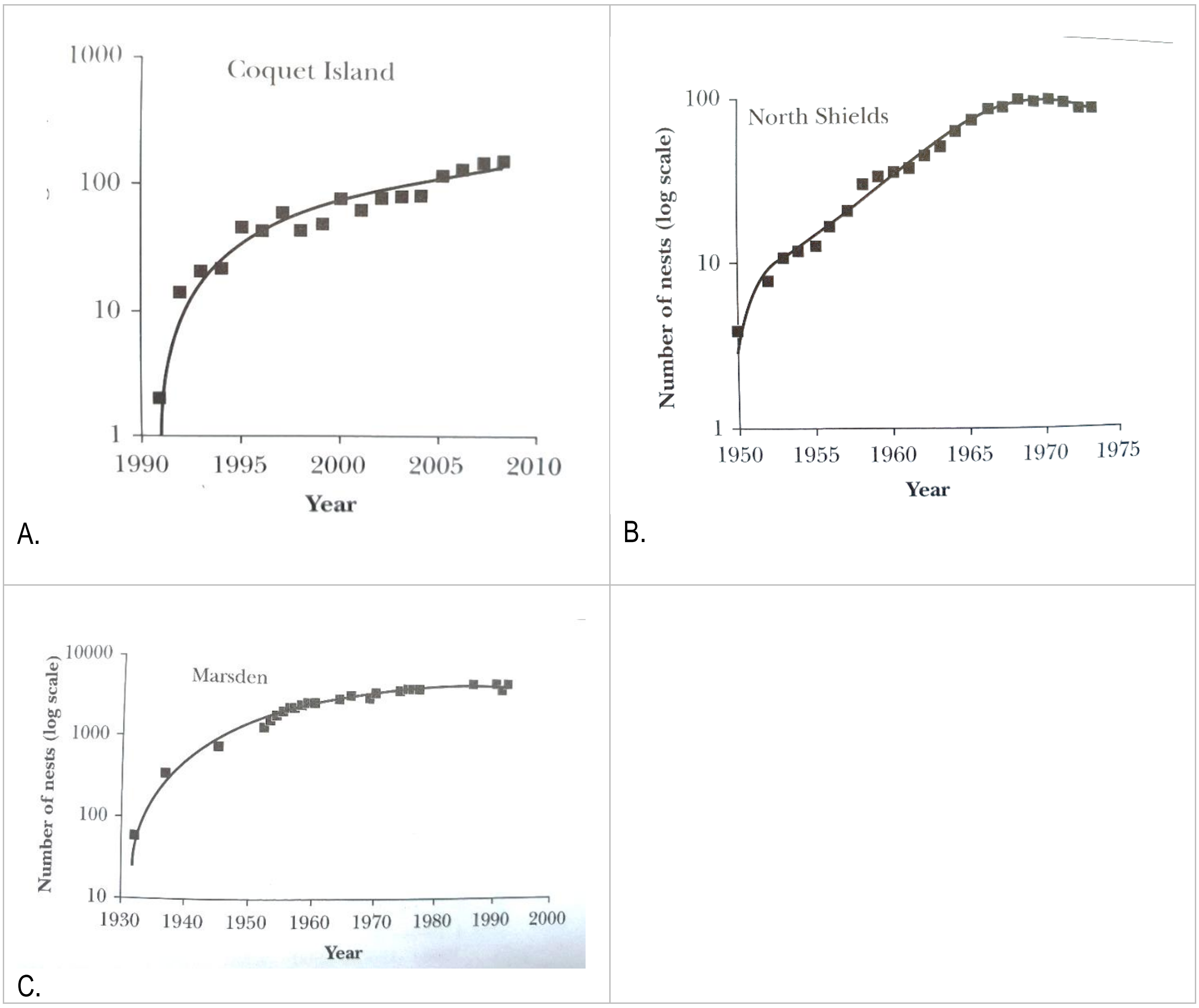


Figure 9.1: Population trajectories for three colonies during a period of growth. A. Coquet Island, B. North Shields, C. Marsden Rocks. Adapted from Coulson (2011)

Conclusion	Context
Projecting the growth rate of a new artificial kittiwake colony is challenging due to data on colonisation of new artificial nesting structures being limited.	A newly established artificial nesting sites is likely to grow rapidly in the first 3-5 years, followed by growth at a slower rate thereafter.

10. Artificial nest sites as a conservation measure

10.1 Where competition is intense for limited nest sites within established colonies, potential recruits may make use of lower-quality nest sites or, defer breeding and join a pool of "floaters" rather than colonize unoccupied habitat that is often available nearby. The size of this pool of "floaters" has been acknowledged by OWSMRF to be a gap in current knowledge (Black & Ruffino 2020). However, digital aerial surveys for the Hornsea Zone plus a 10km radius found large numbers of immature birds in the area during the breeding season (Webb *et al*., 2017).

10.2 It is known that poorer food conditions decrease productivity, reduce growth rates of chicks, and affect age-at-recruitment of the same cohort (Vincenzi & Mangel 2014). Food supplementation may have long-term positive effects on a colony (Gill and Hatch 2002) but comes with logistical and financial constraints.

10.3 The success of this measure is dependent on the availability of nest sites being a limiting factor for kittiwake populations. For the majority of areas in the North Sea, this does not appear to be the case (McArthur Green 2013), however, evidence exists that this measure would be a feasible compensation measure along the East Anglia region of the southern North Sea to recruit into the wider Eastern Atlantic population (McArthur Green 2013, McArthur Green 2020). There is strong evidence that kittiwakes in the southern North Sea are limited by nesting habitat (Coulson 2011), as there is a lack of suitable cliffs along much of the south-eastern coast of England.

10.4 *"Seabird 2000 (Mitchell et al. 2004) found no kittiwakes breeding in Norfolk or Essex, and only 369 pairs in Suffolk (those birds all nesting on man-made artificial structures, and not in natural habitat). In contrast, the cliffs of Flamborough and Filey Coast in Humberside hold over 40,000 pairs of kittiwakes, the largest colony of the species in the UK (Mitchell et al. 2004). Exceptionally large colonies occur only where there is little or no suitable nesting habitat elsewhere within the foraging range of seabirds from that colony (Furness and Birkhead 1984). This implies that provision of artificial nest sites in south-east England would be likely to attract kittiwakes to nest at sites where competition for resources would be less than at the exceptionally large colony of Flamborough and Filey Coast SPA." – McArthur Green (2020).* In combination, these observations support an opportunity to increase kittiwake productivity in East Anglia by provisioning of desirable residences.

10.5 By providing additional nesting space within a productive location there is the potential that this will attract birds from this pool that may have otherwise nested elsewhere at colonies experiencing lower productivity trends. However, with our current state of knowledge on the species ecology proving that this is the case is empirically challenging. Studying the colonisation of a new structure could help contribute to this knowledge base.

10.6 Some additional points to consider when thinking about the best sites for artificial nesting structures for kittiwakes are:

- Proximity to nesting material may be especially important if artificial structures were located offshore. Mud is required at an early stage of nest building to ensure the nest remains firmly attached to the ledge, the availability of mud may influence the timing of nest building activity (Cullen 1957).

- Initial colonisation of sites may take time and younger birds tend to have lower breeding success (Coulson 2011). Therefore, it may take a few years before colony productivity would reach a productivity threshold where birds are contribution to the wider regional population. However, as a colony grows it is more likely to attract new recruits.
- Little is known about prospecting movements of juvenile kittiwakes i.e. if they would be willing to travel to areas where no historic colonies exist (e.g. low-lying area like the Norfolk coast). In recent years birds have attempted to nest on the ground at Minsmere in Suffolk (indicating a lack of alternative nesting sites), however birds nesting at Sizewell rigs use this site to gather nesting material so the site may have been familiar to the birds.

Conclusion	Context
As a colony grows it will become more attractive to first time breeders, 95% of new recruits select older established colonies (Coulson 2011).	In order to establish a new site there will be a higher chance of success if breeding birds are already present nearby.

11. Monitoring the Effectiveness of the Compensatory Mechanism

11.1 The success in deployment of artificial nest sites for kittiwake would need to be monitored through observations of the numbers of breeding birds and their breeding success. The methodology of Walsh *et al*. (1995) should be followed, as specified by JNCC's Seabird Monitoring Programme. This is consistent and therefore comparable to on-going monitoring at existing colonies along the east coast of England, including that undertaken by RSPB at FFC SPA (Babcock *et al*. 2018). The monitoring comprises of whole colony counts and productivity monitoring.

11.2 In order to establish whether trends at artificial nests are colony specific or site specific, these monitoring strategies should be applied to the new artificial structure (once in place) and adjacent colonies. Monitoring should be undertaken before construction of artificial sites at existing colonies, as this will provide better understanding of why the location of the artificial colonies is the right course of action e.g. mixed dietary requirements, good productivity etc.

Whole colony counts

11.3 Where possible, counts would be made several times within a breeding season during the latter half of incubation (when numbers of nests are most stable), usually late May to mid-June, although a single count in early to mid-June is acceptable. The count unit for kittiwake is apparently occupied nests (AONs), defined as a well-built nest capable of containing eggs with at least one adult present.

Productivity monitoring

11.4 Photographs of the colony are taken in early to mid-May when the birds are present and, preferably on nests. Nests are individually marked on the photographs, which are updated each year as necessary, to record nest distribution and aid in the identification of the individual nests. Best practice would be to visit the colony every week between May and August, during which the presence and number of eggs or chicks at each AON is recorded. Whilst weekly visits are consistent with productivity monitoring at e.g. FFC SPA (Babcock *et al*. 2018), it may not be achievable for a colony located offshore, in which case a minimum of two visits, one in late May and the second in mid-June, is recommended. Whole colony productivity is calculated as the number of chicks fledged divided by the number of completed nests. Further details on survey protocol are provided in Walsh *et al*. (1995).

Accessibility

11.5 A purpose-built structure or suitably modified pre-existing building, for the study of the breeding kittiwake would be preferable to ease the accessibility of the colony for monitoring. Monitoring may require where offshore, the use of drone-captured digital imagery.

Empirical testing

11.6 The deployment of artificial nest sites for kittiwake presents the opportunity to conduct empirical testing of various design feature with respect to the colonisation and productivity of the colony. For example, the aspect, width and height of nesting ledges. Such a study together with those described for diet and adult survival (section 11), are examples of the research opportunities that deployment of artificial nest sites for kittiwake can offer.

Diet and adult survival

11.7 A purpose-built structure or suitably modified pre-existing building, for the study of the breeding kittiwake, should be considered that enables easy access to the nest, adults and chicks for ringing studies over the long term. This would enable the monitoring of survival/return rates to be undertaken, enabling a comparison with other colonies, including FFC SPA, which contribute to the Retrap Adult Survival (RAS) study on kittiwake coordinated by the British Trust for Ornithology (BTO). The methodology of the RAS study entails ringing adult birds with uniquely engraved colour-rings so that each bird can be identified in the field in future years. The BTO uses re-sightings of colour-marked individuals and captures of adult birds to calculate what proportion survives each year. The aim of a RAS study is to capture or, for birds colour-ringed from previous years, re-sight birds breeding within a defined area of the colony each year.

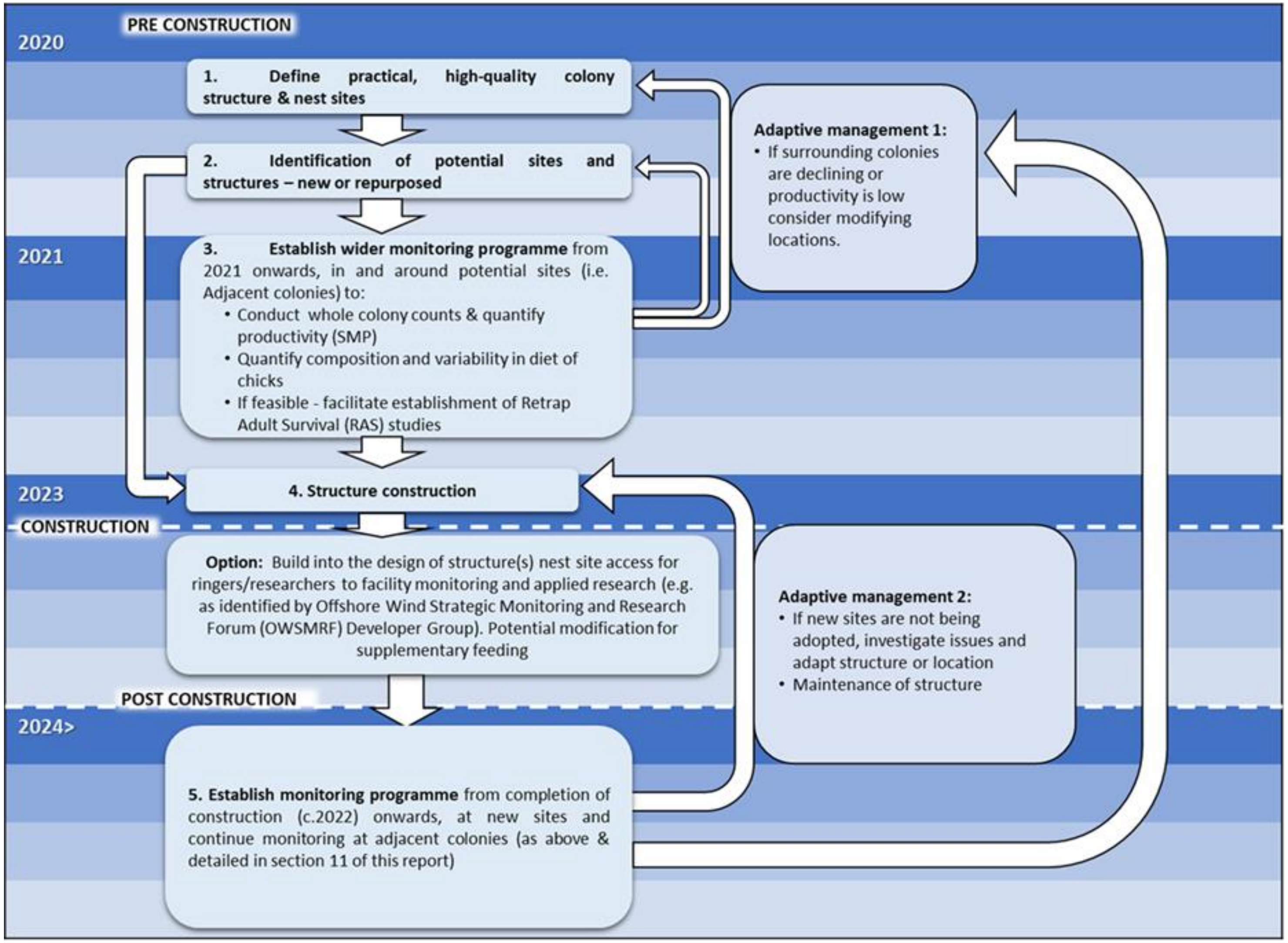
11.8 Access to adults and chicks will also enable monitoring of their diet, to look at the prey species available to kittiwakes at these new (or previously unstudied) locations. Diet analyses samples generally require 2-3 days processing before samples can be analysed/identified. Approximately 50 samples can be analysed in one day by a trained observer (C. Gunn pers. comm.). Most seabird dietary analyses undertaken in the UK is currently carried out by the Centre for Ecology and Hydrology.

12. Roadmap for deployment of artificial nests: Pre- & post- construction

12.1 The following process is proposed to maximise success of the proposed mitigation measure:

12.2 Following the roadmap presented in Figure 12.1, that there is a degree of management feedback required at certain stages to ensure objectives are met. Issues which may arise post construction and potential solutions are discussed in detail below. Adaptive management options will be linked to the monitoring plan and developed in close association with the Hornsea Three Offshore Ornithology Engagement Group (OOEG). Post-construction monitoring will identify required maintenance and potential additional works to be undertaken at the structure, following the breeding season.

Figure 12.1: Flow chart for roadmap to implement provision of artificial nests for kittiwake



Adaptive Management

12.3 Adaptive management is an iterative, post-consent process which combines management measures and subsequent monitoring with the aim of improving effectiveness whilst also updating knowledge and improving decision making over time. Adaptive management will be an important component of the compensation measure and used as a method to address unforeseen issues or deviations from expected time scales (i.e. colonisation rate of structure). Adaptive management measures are therefore designed to support the compensation measure once functioning as a way of furthering the success and supporting resilience of the measure.

12.4 Any adaptive measures will be thoroughly discussed and explored with relevant stakeholders as part of the OOEG to identify an initial list of potential approaches within identified parameters. At this early stage, potential adaptive management options have been identified for issues which could theoretically arise. Further detail on each adaptive management option is presented below.

12.5 As detailed in the preceding sections of this report, kittiwake populations show a varying degree of interannual variability. It is therefore important to note at this stage that monitoring, and any subsequent adaptive management measures, will require that population variability is an integral consideration before action is taken.

12.6 Multiple adaptive management measures will be explored prior to the construction of the artificial structure as it is important to consider the differences between intelligent structure design (which is covered in Section 5 above) and maintenance activity, and adaptive management.

Supplementary feeding

12.7 The process to select the site for the artificial structure put great weight on locations where productivity is favourable, and the population is expanding. This provides confidence that prey availability is unlikely to be an issue in the short- to medium-term. Different regions were chosen for platform locations to mitigate against regional changes in forage fish populations. Monitoring of kittiwake diet at the platforms will be carried out to understand the site-specific importance of local prey and will be compared with adjacent natural colonies.

12.8 One study (Gill and Hatch 2002) found that providing supplementary food at the nest, increased fledging success in kittiwake at the colony. This study provides both robust and compelling species-specific evidence that supplementary feeding as an adaptive management measure would likely increase the productivity of kittiwake, if deemed necessary. While this is a key finding, further studies at the colony highlighted a number of other benefits learned from supplementary feeding. For example, Vincenzi *et al*., (2013) found that fed chicks grew faster than unfed chicks and that birds were more likely to reproduce at younger ages when recruiting into fed nests. The same study also found increased chick growth when parents were fed at the nest (Gill, Hatch and Lanctot, 2002). Additionally, White *et al*., (2010) found that the sustained increase in food supplies as a result of supplementary feeding of kittiwake chicks also reduced broodmate aggression at the colony (a factor which may influence productivity).

12.9 Supplementary feeding has been used with other seabird species with compelling evidence of success. Although there is only limited evidence for supplementary feeding in kittiwake, it remains a potential adaptive management measure that can be empirically tested in the UK with the likelihood of increasing fledgling success. However, there is no evidence on the effectiveness of providing supplementary food to increase the likelihood of colonisation of a site or encouraging recruitment. As mentioned above, exact methods will be discussed with the OOEG.

Attachment of 'bolt on' to provide additional nesting space

12.10 The initial design of the artificial kittiwake nesting structure will aim to provide nesting capacity for 404-467 breeding pairs (as this is deemed the required number of breeding adults to subsequently produce 73 breeding adult kittiwake). This size structure will be constructed at two locations: a North East Search Zone and an East Anglia Search Zone.

12.11 It is likely that the initial structures will include nesting space which surpasses this amount of potential breeding pairs. However, if monitoring of breeding pairs at the structure suggests that additional nesting space is required to ensure the growth of the colony, a 'bolt on' of additional nesting space in the form of an extension to the structure can be provided. This will likely be determined by the initial design of the structure (i.e. potential to be unfeasible due to landowner or planning constraints).

12.12 This option at the colony would be installed during the non-breeding season when birds are absent and therefore cannot be disturbed. The trigger point for application would be influenced by the monitoring programme which will be set out in full within the Kittiwake Implementation and Monitoring Plan (Annex 1 to the KCP).

Relocation of structure

12.13 The relocation of an artificial nesting structure is unlikely to be required due to the diligent design and site selection process which will be undertaken prior to construction. However, unforeseen issues may result in a structure being less favourable, for example if there is persistent unauthorised access. If this is determined by the monitoring programme, consideration will be given, in-line with discussions with the OOEG and relevant land acquisition consultation, to the relocation of the structure.

Adaptation of Structure

12.14 At this stage of development, the design of the artificial nesting structures remains unconstrained. This report provides a compelling account of previous and current kittiwake nesting towers from across the species breeding range. This is likely to result in the initial structure factoring in many of the key design features required for a successful structure (see Section 5.3). However, monitoring may indicate that small adaptations are required to improve sustainability of the colony for the following breeding season. For example, this may include weather proofing to reduce the exposure of nesting birds to the elements which was not deemed necessary during the design stage. This was found to be the cause of colonisation issues of artificial shelves at a site in France where sun exposure of the south-facing ledges added to a harbour building were less favourable to prospecting birds (see Table 3.3, JM Sauvage Pers. Comm.).

Predator Deterrents

12.15 Initial nesting structure design will incorporate features aimed at preventing avian and/or mammalian predation. However, it is acknowledged that the approach to predator deterrents may need to be adapted if initial process is unsuccessful or predators are able to surpass initial deterrents. If this is found to be the case as a result of site monitoring, solutions will be discussed within the OOEG on how to resolve the issue, with the aim that adaptations could be made to the structure during the non-breeding season when birds are absent.

Provision of Nesting Material

12.16 Kittiwake nests are bonded to the 'cliff' surface by the mud used by the birds during nest construction. Kittiwake usually collect mud from a localised point along sea cliffs, and often after periods of rain when the mud is easier for them to collect in their bills (Coulson, 2011). Birds then collect vegetation such as seaweed and grass which is then compacted into the mud foundation to form a shallow cup. At natural colonies, this material is collected at the top and base of cliffs and usually within 2 km of the colony, although some records document further distances (Coulson, 2011). In an urban setting such material may be limited and may therefore require extended journeys by the birds in order to collect.

12.17 At an artificial colony, these materials could be provided in proximity to the structure to limit the need for birds to search and travel to collect them during the nest building stage. The provision of nesting material has been used by the artificial nesting structures built in Norway to compensate for the lack of suitable nesting material in Tromsø. Provision of materials such as wet mud (in the form of manure) and straw was spread in a cliff top field in proximity to the Marsden kittiwake colony during April (when most nest building occurs) which reportedly resulted in almost every nest having visual evidence of using the provided material (Coulson, 2011). Therefore, nesting material could be provided within 2 km of the artificial nesting structure. This would be repeated each year to allow for birds to make new nests, or repairs to old nests from the previous breeding season. This option may be incorporated into project design if the chosen locations for artificial nesting structures are not deemed to be in proximity to nesting materials.

Maintenance

12.18 It is worth noting at this stage that ad-hoc maintenance, not linked to adaptive management, to the structure will also be highlighted by the monitoring plan. This will allow any remedial works or repairs to be conducted during the non-breeding season when breeding birds are not present at the structure.

12.19 While maintenance work will be informed by the monitoring plan, a number of potential works which may theoretically arise are listed below:

- Removal of kittiwake guano from structure;
- Remedial works to structure (i.e. storm damage to nesting ledges);
- Ensuring structure is structurally sound;
- Changing batteries used for speakers playing kittiwake calls; and

- Removal of litter, graffiti or any objects deemed hazardous to kittiwakes.

Potential to Contribute to OWSMRF Knowledge Gaps

12.20 The Offshore Wind Strategic Monitoring Research Forum (OWSMRF) is an industry-led collaborative forum that aims to better understand the impact of large-scale offshore wind development on marine birds. It has identified critical gaps in our understanding and identified research opportunities to fill these gaps. Many of these research opportunities require a hands-on approach at seabird breeding colonies i.e. catching and handling birds.

12.21 Kittiwakes do not allow close approach to the nest by humans to enable adult birds to be captured by hand. Where within reach and individual birds allow, breeding adults can be lifted off the nest safely using a noose on the end of a 5-metre pole by an appropriately trained and licensed seabird ringer. However, a design option which allows hidden access to birds (e.g. access to birds through hatches in the structure) (see Figure 12.1) would be beneficial to RAS studies Horswill *et al*. (2018) recommend that for RAS studies to be successful, studies should have a ten-year trajectory and a recapture rate of 0.6, and should aim to mark at least 200 new adults per year. A well-designed and monitored artificial nest site has potential to contribute to research opportunities identified for OWSMRF (Ruffino *et al*. 2020). The research will be focussed at the artificial nest structure and adjacent colonies nearby specifically:

- RO3.1c - Undertake targeted empirical data collection as informed by the sensitivity analyses (RO3.1b)
- RO3.3c - Deploying strategic adult kittiwake mark-recapture at multiple colonies, and analyses of re-sighting data (RAS studies)
- RO3.3d - Deploying strategic chick mark-recapture at multiple colonies, and analyses of re-sighting data
- RO3.9 - Regional comparison of kittiwake diets during the breeding season: field studies[5]

12.22 An additional commitment by the Applicant to further progress these research opportunities is described in the Supporting Evidence for Kittiwake Prey Resource report (Appendix 3 to the Applicant's Response).

13. Why it delivers on compensation for the Adverse Effect on Site Integrity

13.1 The Secretary of State is minded to approve Hornsea Three subject to receiving a Kittiwake Compensation Plan which gives confidence that any compensatory measures proposed will be sufficient to offset the impact to the kittiwake feature of the FFC SPA. This would thereby maintain the coherence of the network of SPAs designated, at least in part, for kittiwake.

[5] This is distinct from the work proposed in the Prey Resource Plan as it is intended to inform adaptive management at the nest sites, as opposed to building the East Coast evidence base to inform international sustainable fisheries advice by relevant authorities.

13.2 The magnitude of the potential impact that should be offset is calculated to be between 65-73 adult kittiwakes with this being the number of adult birds predicted to die through collision each year once Hornsea Three becomes operational. Although the impact from Hornsea Three alone is not considered to be sufficient to cause an adverse effect on the integrity of the FFC SPA, when taken together with the effects of other plans and projects in-combination, it was concluded that there could be an adverse effect.

13.3 A feasible strategy to deliver compensation is to provide additional breeding opportunities for kittiwake such that the overall breeding population is maintained. It is known that kittiwake will nest on man-made structures and so this review has considered whether it is possible to:

a) Create artificial nesting sites that would be used by breeding kittiwakes, and,

b) Specify the design, location and scale of those sites sufficient to offset the predicted impact.

13.4 On the basis of this review it is considered that it is feasible to provide artificial nesting sites at a coastal location(s) to provide additional breeding habitat for kittiwakes. There are successful examples of sites designed specifically for this purpose as well as many other sites where kittiwakes have opportunistically made use of man-made structures to successfully breed. These sites typically support self-sustaining breeding populations within a relatively short period of time.

13.5 However, it is also known that young kittiwakes will disperse and potentially make use of other breeding locations. A relatively small proportion (as few as 11%) tend to remain at their natal sites (and thus create the basis for the development of a sustainable additional colony) with the remainder finding other breeding sites.

13.6 It is expected that the majority of young produced by birds nesting at additional artificial sites will, therefore, be recruited into the Southern North Sea population of kittiwakes which in turn provides the breeding adult birds that colonise the cliffs of the FFC SPA as well as other colonies on the east coast of England. If sufficient additional breeding can be encouraged then the overall breeding population, including potentially that at the FFC SPA will increase by at least the same amount as that predicted to be lost through collision mortality.

13.7 On the basis of this review it is considered that the creation of artificial nesting structures that can support at least 404 pairs of nesting kittiwakes will produce sufficient young that will in turn mature and disperse to provide additional breeding adult birds in the population to fully offset the potential impact of collision mortality of kittiwakes at Hornsea Three. This approach will be sustainable for at least the lifetime of Hornsea Three offshore wind farm and hence the period within which collision mortality would occur.

14. Conclusion

14.1 Kittiwakes will utilise artificial nesting structures and therefore it is considered that the establishment of artificial nest sites would provide an appropriate compensation option to offset the collision impact associated with Hornsea Three. The establishment of breeding colonies at these sites would produce young that would become part of the wider Eastern Atlantic population of kittiwake.

14.2 The predicted impact for Hornsea Three was 65-73 birds. A breeding population of 404 - 467 breeding pairs would provide a comparable number of young that would survive to adulthood to offset the impact of Hornsea Three and there are examples of artificial nest sites supporting breeding populations of this size. The upper limits for these predictions were factored into calculations to account for uncertainty and provide estimates which are likely to be an overcompensation.

14.3 There are a number of suitable locations on the coast of the southern North Sea (East Anglia and the North East) where artificial nest sites could be installed and there are a number of other site-specific factors (including design, orientation and accessibility) that should be taken into account when a site is selected.

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Appendix A

Urban nesting site examples

Hartlepool Headland – Photo credit Chris Brown	
	
	
	

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<tr><td colspan="2">Lowestoft photo credit Mike Swindells</td></tr>
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Appendix B

Successful and Unsuccessful Artificial nesting sites

i. Successful North Sea sites:

Tyne Kittiwake Tower

Figure 0.1 Tyne Kittiwake tower. Photos © [redacted]

Figure 0.2 Tyne Kittiwake colonies in relation to artificial nest site provision

Lowestoft Wall

Figure 0.3. Lowestoft wall (post breeding season). Photo E Morgan.

Figure 0.4. The end of the Lowestoft Wall. Photo credit M. Swindells.

Figure 0.5. Location of Kittiwake sites in Lowestoft. Image credit M. Swindells

Boulogne-Sur-Mer wall

Figure 0.6. Boulogne-Sur Mer wall. Photo copyright J. M. Sauvage.

a. Mumbles Pier

Figure 0.7. Mumbles lifeboat station and kittiwake shelves close up. Photo © [redacted]

ii. Unsuccessful sites

a. South Shields Tower (right tower in Figure 0.9)

Figure 0.8 Kittiwake tower designs, from right to left: Tyne/Gateshead, Boulogne, South Shields. Photo copyright J-M Sauvage.

Figure 0.9. Location of South Shields Tower, a) in relation to wider Tyne colonies, and b) Fine scale location showing surrounding environment.

Boulogne Tower(s)

Figure 0.10Boulogne kittiwake tower on old ferry terminal. Photo copyright J-M Sauvage.

Tromso Kittiwake Hotel

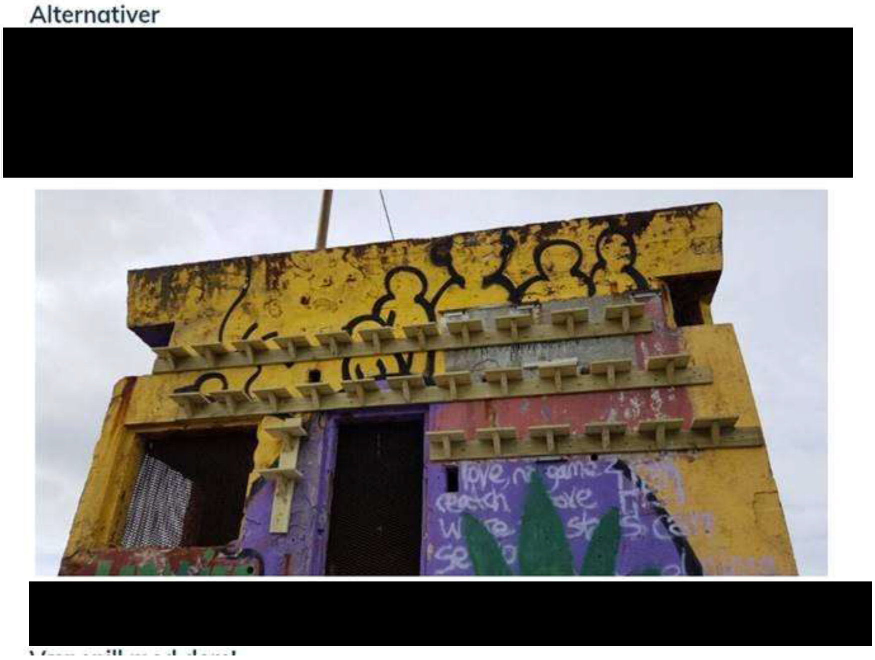

Figure 0.11.Image of Tromso kittiwake hotel image from news article available @ [redacted]

Finnmark kittiwake hotel:

IMAGE NOT AVAILABLE

Figure 0.12. An image of Finnmark kittiwake hotel can be found online @
[redacted]

Appendix C

List for site selection criteria

Kittiwake potential artificial nest site location considerations

1.1 Broad scale :

- Coastal location
- Natural nesting sites are limited
- Connectivity for initial colonisation possible i.e. known regular occurrence of the species within proximity to locality (within < 1 km), whether it be foraging/roosting birds (e.g. following trawlers to fish quay) or breeding at a nearby successful colony
- Within 100 km of existing colonies where populations are stable/increasing
- Food resources available within foraging range of species (successful colonies nearby as proxy)

1.2 Narrow scale:

Ecological

- Breeding kittiwakes already present in area (Smaller populations are prefered to minimise density dependent competition i.e. colony specific competition for foraging areas, and ideally higher productivity and population trends).
- Wharf side, or within 100 m
- Lack of natural nesting sites
- Possible to exclude mammalian predators
- Not overly exposed to adverse weather conditions (areas where multiple aspects possible preferred)
- Human disturbance minimal

Logistical

- Space for structure (minimum 12 m x 2 m) and potential for expansion with adaptive management. Or existing structures exist with potential for modification.
- Unrestricted visibility of all potential nesting faces to enable monitoring of individual nests using optics when positioned within 200 m of structure
- Access to structure from the base or above, to enable surveyors to lift adults from nests using a noose and roach pole (6 m), or if the structure was to be a building, nest site access internally via purpose built hatches onto the nests, for the purposes of monitoring
- Reduce likelihood of human conflict i.e. not close to residential/ active business properties.
- Wharf side location with no required use of wharf by vessels / vehicles
- Avoid being in close proximity to existing OWF (i.e. < 5 km) to avoid increasing collision risk

Legal

- Land Ownership / planning rights achievable

Appendix D

Growth rates of existing artificial nesting sites

Figure 0.1: Population trends since year of construction at two artificial sites; Tyne kittiwake tower and Boulogne wall. A. shows number of breeding pairs occupying structures, B. Shows productivity rates. Tyne data (D. Turner available online at [redacted] Boulogne data courtesy of J-M Sauvage & Eric Petit-Berghem)

Appendix E

Additional information on calculations for size of compensatory population required (section 8)

Row	A	B	C	D	E	F
1	READ lines 40 downwards FIRST			cell B15 x C	cell E15 x C	cells B20, B21^{-1}
2		Year class	Recruits (proportions; Coulson 2011)	Contribution from year group to 73	Contribution from year group to 94.8	Survival rate^{-1}
3		0	0	0	0	1.265822785
4		1	0	0	0	1.170960187
5		2	0.0065	0.4745	0.616233766	1.170960187
6		3	0.2645	19.3085	25.07597403	1.170960187
7		4	0.352	25.696	33.37142857	1.170960187
8		5	0.2265	16.5345	21.47337662	1.170960187
9		6	0.1045	7.6285	9.907142857	1.170960187
10		7	0.0245	1.7885	2.322727273	1.170960187
11		8	0.009	0.657	0.853246753	1.170960187
12		9	0.009	0.657	0.853246753	1.170960187
13		10	0.0035	0.2555	0.331818182	
14						
15	Collision rate/yr	73	1	73	94.80519481	21.80519481

Row	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year Class		
2	Calculations below are Survival rate^{-1} [cells F2:F12] multiplied by number of birds in year (cell) below. Exception being bottom cells of column where Survival rate^{-1} [cells F2:F12] multiplied by Year Group contribution (cells E3:E13)											253.192	breeding pairs without accounting for annual adult mortality
3	0	0.913398995	43.52261471	67.82254698	51.102455	27.607811	7.5792094	3.260186602	3.8175487	1.7384102	0	207.364	chick productivity from S2 pairs i.e. 253 prs
4		0.721585206	34.38286562	53.57981211	40.37094	21.810171	5.9875754	2.575547415	3.0158635	1.373344	1	163.8177	
5			29.36296724	45.75715955	34.476783	18.625886	5.1133894	2.199517493	2.5755474	1.1728358	2	139.9003	
6				39.07661425	29.443172	15.906507	4.3668345	1.878387939	2.1995175	1.0016018	3	118.9486	
7	NOTE:				25.144469	13.584157	3.7292767	1.6041433	1.8783879	0.8553679	4	80.16723	
8	(1)					11.60087	3.1848023	1.369938378	1.6041433	0.7304842	5	39.96361	
9	H1:S12 is the calculation for each contributory age group						2.7198212	1.169927375	1.3699384	0.6238335	6	15.79066	
10	into the 94.8 birds (natal dispersal + philopatric), of the number of							0.999117978	1.1699274	0.5327538	7	5.024526	
11	chicks that this requires to be fledged for each contributing age cohort (cell S3)								0.999118	0.4549718	8	2.307336	
12	(2)									0.3885459	9	1.241793	= no. of Y10 recruits (+ those that died btw Y9 & Y10)
13	Cell S2 is the number of breeding pairs required to generate the number of chicks										10		+ recruits for Y9
14	in cell S3, when ignoring replacements for inter-annual adult mortality & adult dispersal, of a stable population												

Row	A	B	C	D	E
17				Natal disperal + philopatric birds	
18	Productivity	0.819		94.80519481	
19	Natal Dispersal rate	0.77		(cell D15 / B19)	
20	Adult survival rate	0.854			
21	1st year survival rate	0.79			
22	adult dispersal	0.012			
23	Productivity proportion change				
24	First time	Experienced			
25			Ratio		
26	0.898	1.379	0.651196519		
27	Approach				
28	14.6	85.4			
29	0.146	0.854			
30	13.1108	117.7666	1.308774		
31	0.686138325	1.053657851		0.651196519	
32	0.561947288	0.86294578		0.651196519	
33	8.204430406	73.69556959	81.9	0.819	
34			Breeders (pairs)		
35		Ist time	Experienced	Total	
36					
37	No. of pairs	36.96602029	216.2258995	253.1919198	breeding pairs without accounting for annual adult mortality & dispersal
38	Chicks fledged	20.77295486	186.5912275	207.3641823	

Row	F	G	H	I	J	K
18	Cell D37 x 2 =	breeding adults	506.3838396	0.854	adult survival	
19		annual deaths	73.93204059	= cell H18 x (1 - I18)		
20		adult dispersal	6.076606076	= cell H18 x B22		
21						
22			cell E15 x C	cells B20, B21^{-1}	Repeat computation of H1:S12, formulas amalgamated	
23	Year class	Recruits (as C2:13)	Contribution	Surv R^{-1}	466.86737	breeding pairs required to provide 73 breeding adults to disperse into the wider population
24	0	0	0	1.265822785	382.36438	chick productivity
25	1	0	0	1.170960187	302.0678582	
26	2	0.0065	1.13628997	1.170960187	257.9659509	
27	3	0.2645	46.23826107	1.170960187	219.3325305	
28	4	0.352	61.5344722	1.170960187	147.8225061	
29	5	0.2265	39.59533509	1.170960187	73.68998092	
30	6	0.1045	18.26804643	1.170960187	29.11682754	
31	7	0.0245	4.282939116	1.170960187	9.264859064	
32	8	0.009	1.573324573	1.170960187	4.254559635	
33	9	0.009	1.573324573	1.170960187	2.289774743	
34	10	0.0035	0.611848445			
35			174.8138415	=73 breeders from natal dispersal + 21.8 breeders remaining philopatric + 74 annual deaths of existing breeders + 6 adults relocating colony		

Row	A	B
40		EXPLANATION TO ABOVE CALCULATIONS

Row	A	B	C
42	Parameter values	Cells B18 - B22	Parameter values for productivity, natal dispersal rate, adult survival rate, 1st year survival rate and adult dispersal
43	Parameter value	Cell B15	Require 73 breeding adults to disperse into the wider population from a stable colony population
44	Step 1	Cell D18	In addition to the 73 birds that recruit into the wider population (= 77%), are an additional 23% of philopatric birds, the sum being 73 / 0.77 = 94 birds
45	Step 2	Cells E5:E13	Those 94.8 first time breeders are recruited from across year classes 2-10
46	Step 3	Cell S3	The number of fledged chicks required to provide the 94.8 first time breeders taking into account the different contributing year groups
47	Step 4	Cells S2 & D37	The number of breeding paris to provide 207 fledged chicks (cell S3) before accounting for annual adult mortality & dispersal
48			S2 = 1 / mean productivity (0.819) x chick productivity (207). This correctly equates to the same answer to D37 when using the proportionality of productivity of first time versus experienced breeders, where the mean productivity is 0.819 [shown in cells A23:D38]
49	Step 5	Cells J23 & J24	The number of breeding pairs to provide the fledged chicks required to provide the first time breeders taking into (1) account the different contributing year groups, and (2) requirement for 174 first time breeders (i.e. 73 breeders from natal dispersal + 21.8 breeders remaining philopatric + 74 annual deaths of existing breeders + 6 adults relocating colony)