Little tern *Sternula albifrons* use of Scroby Sands Offshore Wind Farm in 2013

Little Tern in the Scroby Sands area
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Executive summary

Little terns have recently begun to use the main bank of Scroby Sands as a nesting site, following the decline of the mainland North Denes colony within the Great Yarmouth North Denes SPA. There is concern that breeding Little Tern *Sternula albifrons* may be at increased risk of collision with turbines at Scroby Sands offshore wind farm.

The objectives of this study were thus to:

- Assess the current density of Little Tern usage of Scroby Sands wind farm
- Use current density data for Little terns to inform collision risk modelling
- Assess why any increased usage of Scroby Sands wind farm by Little terns is occurring and whether this could affect collision risk.

Eight boat-based surveys over a route of 46 km incorporating 10.3 km within the wind farm, utilising snapshots for flying terns every 250 m (n=185) were performed approximately every two weeks from early May to mid August 2013. Recording of the distance of birds allowed Distance sampling to be used, which clearly showed a decline in detectability over 300 m for all tern species, with 200 m being a more realistic detection distance for Little Tern. The route also incorporated the previous sampling protocol adopted from 2002-2006 that included 12 one km long survey stations where all birds were recorded and a specifically designed surface tow net was used to sample the prey available to Little terns.

The key finding from prey sampling was evidence of the recovery of the Herring stock known to have been previously affected by pile-driving during construction of the wind farm. The peak density of young clupeids, mainly comprised of young-of-the-year Herring was around 0.38 individuals m^{-2} and thus best described as 'moderate'. The trends in distribution and abundance of young clupeids mirrored previously described patterns. Namely, fish were concentrated around North Denes and nearby inshore sites and peaked in early June before declining. Incursion of YOY Sprat also occurred but in insufficient numbers to replace Herring including later in the season.

The mean density surface produced by kernel density estimation (KDE) showed concentration of Little terns around the former colony at North Denes in association with the higher fish densities and also at the southern end of Scroby Sands. The latter reflected the use of the main bank as a breeding site. The first nesting attempt by about 33 pairs of Little Terns in mid-June was unsuccessful as a result of a high tide in late June. Re-nesting occurred with a peak of 70 nests by mid-July. Most nests appear to have failed although a few juveniles (perhaps up to 9) may have fledged over the course of the season. Otherwise, the main colony of the East Norfolk Little Tern population in 2013 was located at Winterton.

The relatively small and fluctuating Little Tern population on Scroby Sands with no evidence of nesting at North Denes or Caister was reflected in the lack of use of the OWF, with no Little terns recorded in snapshots during the surveys, and only a single record outside of snapshots. As a result there was no predicted collision risk in 2013.

The simultaneous sampling of snapshots yielding density (individuals km^{-2}) during counts of Little terns at the 12 sampling stations allowed the relationship between the two to be established. Count data from 2002-2006 at the single station within the wind farm and the two stations on its fringes could then be converted to density.

Collision risk modelling using the Band (2012) Option 1 model was performed on this data for comparison with previous estimates of collision risk derived from radio telemetry data. Although the year of greatest risk varied between datasets the mean predicted collisions per annum from 2004-2006 was remarkably similar (19 cf 16 per annum at 98% avoidance respectively). Using the same protocol and incorporating sites just outside the wind farm for data from 2013 predicted 3 collisions at 98% avoidance, reinforcing that collision risk was very low in the current year.

Greater collision risk was predicted for breeding Common Tern *Sterna hirundo* (174 nests) and breeding (2 nests – first since 1976) and passage Sandwich Tern *Sterna sandvicensis*. Breeding Common Tern frequently used the southern and especially south-eastern part of the wind farm as reflected in the KDE density surface. The main concentration of use was around the southern part of Scroby. The predicted collision risk was 2-11 Common Terns per annum at 98% avoidance for Distance-corrected and uncorrected density estimates respectively.

No population modeling was undertaken to assess the effect of this rate of loss, but previous modeling of the similar-sized Little Tern population suggested that the important population of Common Tern (the mean of 116 pairs from 2010-2013 inclusive represents 1.15% of the GB breeding population) could well be damaged if the predicted higher collision risk was realised.

The density surface for Sandwich Tern encountered mainly at the beginning and end of the breeding season suggested only moderate use of the north-western part of the wind farm, linked to the main area of use to the north of the study area. The predicted collision ranged from 2-7 Sandwich Terns per annum at 98% avoidance for Distance-corrected and uncorrected estimates respectively.

The likelihood of damage to the embryonic breeding population of Sandwich terns at Scroby Sands appeared to be very low, with most birds probably linked to larger colonies elsewhere in Great Britain (e.g. North Norfolk). Any loss would make a further small contribution to the cumulative collision encountered by these populations from wind farms around the UK and along their migration route.

In conclusion, although there is potential for the Scroby Sands wind farm to be a threat to the East Norfolk Little tern population, the actual risk cannot be truly quantified until sampling is conducted in a season when Little Terns nest at Scroby Sands in large numbers. Further sampling is therefore recommended, preferably over at least two further seasons to compensate for changes in the population during the course of the season (i.e. birds may fail or alternatively re-nest at Scroby Sands).

More thorough monitoring of the actual numbers of nests put down by the different species and their ultimate productivity is also recommended, with any landing on the bank being undertaken with the utmost care to avoid disturbance. The sighting of a possible pair of the rare Roseate Tern *Sterna dougallii* in the Common Tern colony in 2013 reinforces the importance of Scroby Sands and the need to assess the risks to its breeding terns.

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1. Aim & objectives

The overall aim of this project was to assess the current use of Scroby Sands Offshore Wind Farm (OWF) by Little Tern *Sternula albifrons* and the associated risk of collision that this poses. The study was to inform the management of Great Yarmouth North Denes Special Protection Area (SPA) and its designated population of Little terns, with the increased incidence of nesting on the main bank of Scroby Sands first noted in 2010, rather than on the mainland beach at North Denes (see 2.1 below).

To address the overall aim, the current project had the following objectives:

- To assess the current density of Little tern usage of Scroby Sands OWF
- To use current density data for Little terns to inform collision risk modelling for Scroby Sands OWF
- To assess why any increased usage by Little terns of Scroby Sands OWF is now occurring and whether this could affect collision risk.
- The project was to build upon the previous monitoring of Little terns in the area undertaken for the assessment of the effect of the Scroby Sands OWF (see below and Perrow *et al.* 2006, 2008, 2011a) to supply comparative data for analysis. Previous monitoring had included sampling of the prey resource available to Little terns and the same sampling regime was conducted in the current study for comparative purposes.
- It was also deemed pertinent to include an analysis of the other tern species recorded during the surveys with the advent of nesting by Common Tern *Sterna hirundo* on the main bank of Scroby, also in 2010. In a similar fashion to Little Tern, breeding Common Tern is otherwise a designated feature of a nearby SPA at Breydon Water SPA.
- Where possible, we also aimed to collect information relating to the use by nesting and roosting birds of the main Scroby Sands bank, with counts being conducted on a number of occasions. These records provide important data for future reference.

2. Background information

2.1 The East Norfolk Little Tern population

The known number of pairs of Little terns nesting in East Norfolk (the East Norfolk Little Tern population) and the number of young successfully fledged where known is documented in Table 1. Five centres of breeding activity, loosely termed colonies are recognised. From south to north these are Scroby Sands, North Denes, Caister, Winterton and surrounds and Eccles (Table 1).

The earliest documented records of what is best termed date back to 1919 when 20-40 pairs were recorded nesting in the Horsey-Winterton area by Riviere (Taylor 1999). In 1920, 50 to 60 pairs returned but 'the nests were robbed [of eggs] by young boys'. Thirty pairs nested on shingle swept inland of a breach of the Old Hundred stream by a severe storm in 1938.

Table 1. Numbers of pairs (with fledged young in parentheses) at the known colonies in East Norfolk from 1919 to the present day. The absence of years indicates a lack of data rather than an absence of birds.

Year	Colony				
	Scroby Sands	North Denes	Caister	Winterton[1]	Eccles
1919				30 (?)	
1920				55 (0)	
1945		many			
1948-51	27[2](?)				
1955-63	15[2] (?)		attempt		
1967				73 (68[3])	
1972				93 (13)	
1974				82 (179)	
1975			1 (0)	66 (122)	
1976	15 (?)				
1977		5 (?)	8 (?)	19 (?)	3 (?)
1978				4 (?)	
1979				18[3] (?)	
1980				6 (3)	
1981				12 (12)	
1982		6 (?)			
1983		4(?)	3 (?)	6 (?)	
1984		17 (?)			
1985		27 (6)		20 (?)	
1986		55 (95)		?	
1987		70 (96)			
1988		140 (244)			
1989		180 (160)			
1990		210 (15)			
1991		277 (12)			
1992		249 (176)			
1993		168 (105)			
1994		230 (203)		2 (?)	
1995		241 (126)		6 (3)	
1996		197 (0)		14 (0)	
1997		191 (142)		16 (0)	
1998		216 (336)		0	
1999		200 (79)		16 (6)	
2000		220 (36)		45 (0)	1[4] (2[4])
2001		265 (103)		0	
2002		98 (5)		127 (58)	11[8] (12)
2003		10 (2)		233 (447)	37[9] (58[10])
2004		40 (0)		150 (0)	47 (0)
2005		196 (11)		83 (0)	36[5] (0)
2006		369 (673)		0	0
2007		261 (156)		83 (0)	25[5] (0)
2008		350 (165)		9[6] (0)	0
2009		339 (20)		87 (0)	0
2010	200 (?)	0	1[7] (1)	45 (1)	0
2011	190[3] (80)	5[5] (0)	38 (22)	38 (0)	21[5] (13)
2012	35 (?)	5 (0)	10 (2)	197[11] (410)	56 (0)
2013	70 (9[4])	?	0	171 (180[12])	100[13]

Notes [1] includes areas to Bramble Hill (Horsey) and Hemsby, [2]maximum [3] median of estimate [4] possible [5] number of nests [6] 15 nests actually laid [7]10 pairs observed making nest scrapes [8] recorded by N Bowman in 2011 as 12 [9] recorded by N Bowman in 2011 as 38 [10] recorded by N Bowman in 2011 as ~80 [11] 230 nests laid [12] preliminary total [13] unconfirmed report of unprotected nests lost to disturbance on May Bank holiday.

Riviere also noted that Little Terns have been known to attempt to nest at Caister since the early 20th Century but again that 'the nests were invariably robbed by collectors' (Taylor 1999). A 'large' colony became established at nearby Great Yarmouth in 1945 at the end of World War II when the presence of mines and barbed wire restricted human activity along the beach. With the resumption of human disturbance in peace-time, some birds were displaced to Scroby Sands, which was then permanently exposed as an offshore island, except at times of storm and extremely high tides. Up to 27 pairs were present between 1948 and 1951. The island was submerged in the year of the Great Flood in 1953 but reappeared again in 1954. Breeding resumed in 1955 with up to 15 pairs to 1963 (Taylor 1999). Even then, success appeared to be generally limited as a result of high tides. A switch to North Denes occurred following the submersion of Scroby Sands in 1965 where a few pairs (maximum of nine) had intermittently attempted to breed since 1950 and continued to do so until 1983. Scroby Sands again supported 15 pairs of Little Terns in 1976 after the bank re-emerged at high water for a few years. It had submerged again by 1977.

The main focus of the East Norfolk population in the 1970s was Winterton, which peaked at 90 pairs (with three further pairs between Winterton-Hemsby) in 1972, the second largest in the county behind Blakeney Point at that time. With increasing human pressure the colony declined and by the early 1980's, <10 pairs were present. North Denes then became the focus of activity in 1983 and 1984, when part of the beach was fenced off to allow a sewage pipe to be laid. From 1986 onwards, this was then followed by fencing and proactive wardening and protection by the Royal Society for the Protection of Birds (RSPB) on behalf of Great Yarmouth Borough Council (GYBC) with financial support from Natural England (NE).

Following this, North Denes became the premier nesting site for Little Terns, not only in East Anglia, but also the UK. At its peak in 1991, the colony contained 277 pairs and throughout the 1990s to 2001 regularly supported >200 pairs. Data from the Seabird 2000 surveys (RSPB 2002), suggested that the colony supported some 11% of the Little Terns in the UK in 2000.

The aggregation of birds at North Denes led to the concomitant demise of other colonies that were under pressure of human disturbance. A small colony between Winterton and Hemsby that had held 20 pairs in 1985 had been deserted by 1990. However, the use of Winterton and Bramble Hill immediately to the north increased over the 1990s from 0 pairs in 1993, 2 in 1994, 6 (raising 3 young) in 1996, 14 in 1997, 16 in 1999, 45 in 2000 and 127 in 2002 (Skeate *et al.* 2004). Re-nesting of birds that had originally failed at North Denes for whatever reason appeared to be primarily responsible for use of Winterton. In 2002, for example, vandalism of the North Denes colony and the loss of 98 nests early in the season on 31st May led to mass displacement to Winterton. Ultimately, only a small number of pairs (~ 7) managed to persist and fledge chicks (~5) at North Denes (Manderson & Mead 2002). In 2003, low-flying helicopter patrols looking for a lost child were thought to be responsible for the failure of Little terns to establish a colony and just ten pairs ultimately nested fledging just two chicks. At that time, this was the lowest number of nesting birds at colony since 1983 (Table 1). Conversely, Winterton was hugely successful with 233 pairs fledging 447 young, the single largest production of chicks in a single colony in the UK since records began in 1969 (Mavor *et al.* 2004).

Little terns had previously been noted nesting in the area from Sea Palling to Waxham in 1977 (Table 1), but in 2002, a new colony formed at Eccles-on-sea on the reconstituted beach behind the northernmost of the nine rock reefs installed in 1997 to reduce coastal erosion. Little Terns began to prospect the area behind the northernmost reef with the largest and most undisturbed area of beach in 1998. Two pairs were seen nest scraping in 1999 and a pair with two recently fledged chicks was observed in 2000, although nesting was not actually confirmed until 2002 with 11 pairs fledging 12 chicks (Skeate *et al*. 2004). Local naturalist Neil Bowman protected the nesting birds by demarcating the area with ropes and poles donated by NE. Whilst this offered no protection against predators, it did have the desired effect of limiting human disturbance in what is a popular area for tourists and local dog-walkers. In accordance with the success at Winterton in 2003, the number of pairs at Eccles increased to 37 in 2003, with 58 young fledged. Nesting thereafter has been sporadic and although a new peak nest count of 56 was recorded in 2012, the total of fledged chicks in 2003 has not been superseded (Table 1).

Unprecedented abandonment of nests in 2004 particularly at Winterton saw the complete failure of the SPA for the first time since its designation. The lack of young-of-the-year (YOY) herring *Clupea harengus* the principal prey item of Little Terns appeared to be responsible (see below and Perrow *et al*. 2011a). In 2005, abandonment was again an issue at Winterton and although late-nesting birds at North Denes successfully hatched many chicks, a pair of Kestrels *Falco tinnunculus* feeding their own brood of five chicks predated an estimated 455 Little Tern chicks, dooming the colony to virtual failure, with just 11 thought to have fledged (Smart *et al*. 2005). Diversionary feeding of the Kestrel pair appears to have been instrumental in the success of the North Denes colony in 2006, as despite the continued low abundance of prey, a peak nest count of 369 resulted in 673 fledged chicks, breaking the record set at Winterton in 2003.

On the 25th anniversary year of the North Denes colony, no birds were recorded nesting, with only relatively few at Winterton (45 pairs). The historic colony at Caister supported up to 10 pairs, but remained unprotected. A boat trip to Scroby Sands revealed that a large colony of 200 pairs had become established on the main bank that had re-emerged in 2004 immediately after the period of wind farm construction (see below). The colony was washed out by a high tide on 18th June, with 80 pairs re-nesting by 5th July, although the outcome was unknown. In 2011, the colony on Scroby re-established with an estimated 180-200 pairs, ultimately fledging 80 chicks, the highest ever recorded at Scroby (Table 1). The Caister colony was also successful with 22 young fledged from 38 nests within a small fenced area of 80 m by 20 m. A few attempted at North Denes (5 nests) and Winterton (38 nests) but these were predated.

In 2012, storm surges are thought to have supressed the use of Scroby Sands and Winterton again emerged as the successful colony with a peak nest count of 197 nests and 410 fledglings. Some use of Scroby Sands was later recorded with 35 pairs nesting but with an unknown outcome. Low use of North Denes (5 nests) and Caister (10 nests) continued. The pattern in 2013 was largely similar, with Winterton again the main colony (peak nest count of 171), but with several attempts on Scroby Sands. The current study recorded a minimum of 33 nests on 19 June, but these appear to have been lost to a high tide on 25/26th June. Re-nesting occurred with 15 pairs recorded on 2nd July that presumably comprised part of the peak count of 70 nests made by local ornithologist Peter Allard on 15th July. Nine fledged juveniles were recorded on 31 July, although it is unclear if these originated from the Scroby Sands colony or were from elsewhere, in particular the successful colony at Winterton, where 180 chicks had fledged by 22nd July.

In summary, the East Norfolk population breeds at a limited number of localities, with one locality being the focus of breeding activity for a variable length of time. The colony at Winterton, the main site in the 1970s was superseded by North Denes in the 1980s after its protection for over 20 years, with the more recent shift back to Winterton in the last decade and the re-emergence of Scroby Sands in very recent times, following its re-establishment as a more or less permanent barrier island.

It is clear from the experiences at North Denes that breeding may only be attempted at this highly disturbed site if protection (intentional or not) is already in place. The same may also apply to Caister. At other sites with a lower intensity of human footfall, birds may become established prior to fencing being erected and wardening initiated, although this clearly helps. Birds may thus not choose the ideal location from the perspective of prey abundance, which has previously been shown to be North Denes and the Scroby area in general (Perrow *et al.* 2004). Although an adequate prey supply is obviously a prerequisite for successful breeding, other factors including high tides, climatic conditions and an array of avian and mammalian predators from the more important Kestrel and Red Fox *Vulpes vulpes* to domestic cat *Felis catus*, European Hedgehog *Erinaceus europaeus*, Carrion Crow *Corvus corone*, Black-billed Magpie *Pica pica* and large gulls *Larus spp*. amongst others,may determine the actual success of a colony.

Ground predators may be successfully controlled by the use of electric fencing and intensive wardening, although this has no effect on avian predators. As a result, a programme of supplementary or diversionary feeding of Kestrel was trialled from 2006 onwards for six years in a 'one year on and one year off' pattern (with the first year of feeding in 2006). The provision of artificial shelters for Little Tern chicks to reduce potential predation more or less continued as standard practice at North Denes in particular.

The size of the population over time is difficult to fully establish as a result of the lack of recording and the occurrence of a protracted nesting period that may include new nesting pairs for that season as well as re-nesting birds that have previously failed at the same or different colonies. Nonetheless, the East Norfolk population appears to currently stand at >300 pairs, which is substantially larger than the 200 or so pairs in the 1990s to the turn of the century, itself far larger than the maximum of 100 or so pairs in the 1970s-1980s. Periodic pulses of spectacular recruitment over the last decade (e.g. 2003, 2006 and 2012) over and above a more variable picture may be particularly important.

2.2 Monitoring of Scroby Sands offshore wind farm

Between October 2003 and August 2004 E.ON UK (formerly PowerGen) Renewables Offshore Wind Ltd., Scroby Sands Offshore Wind Farm was constructed immediately to the north of the dynamic sand bar system of Scroby Sands, in water depths between 0 and 8 m (chart datum). The development is comprised of 30 x 2 MW turbines each with a total height of 100 m, a hub height of 60 m and a rotor diameter of 80 m.

The wind farm is located directly offshore at ~3km from the Great Yarmouth North Denes SPA and Site of Special Scientific Interest (SSSI). The SPA designation that includes the disjunct colonies of North Denes and Winterton some 12 km away to the north was based on the presence of 220 pairs from 1992-1996 as 9.2% of the GB breeding population of Little terns in the UK.

During planning, an Appropriate Assessment of the likely impact of the wind farm upon the Little Tern colony and other species known to use the area was undertaken (Percival & Percival 2000) using information from bird surveys conducted in 1995 (Ecosurveys Ltd. 1995) and 1999 (Econet Ltd. 1999). This assessment concluded that, although Little Terns used Scroby Sands as a feeding area, the impact of the wind farm on local bird populations was likely to be of moderate significance at most.

The wind farm was ultimately consented with the proviso that monitoring should be continued to validate the conclusions of the Appropriate Assessment. Thus, monitoring was undertaken with the aim of assessing the impact of the proposed wind farm upon Little Terns based on data collected between 2002 and 2006 inclusive (Perrow *et al.* 2008). This monitoring included feeding studies, breeding colony studies, prey studies and bird strike studies. Bird collision risk work was only feasible following the construction of the wind farm after 2004. Wherever possible, monitoring was also conducted at the Winterton colony when this was occupied.

The study highlighted the interaction between Little terns and their prey, the most important of which was shown to be young clupeid fishes comprised of YOY herring supplemented by Sprat *Sprattus sprattus*. The timing of colony formation appeared to be linked to the recruitment of Herring, although the appearance of Sprat, typically later in the breeding season was important in the latter stages of chick provisioning and also supported later breeding attempts. Perrow *et al.* (2008) suggested that fish recruitment was focussed on the area around Scroby Sands and the immediate vicinity including at the colony at North Denes an incorporating Caister and California to the north. Fish abundance at Winterton appeared to be dependent on northwards drift and in years of reduced fish abundance, this was unlikely to reach Winterton. Only the inshore waters at Winterton including a sand bar a few hundred metres offshore appeared suitable for small clupeids being rather turbid with potential to support phytoplankton and zooplankton, unlike the clear deep waters further offshore.

Extremely noisy (to 260db) pile-driving of monopiles in the late autumn spawning period of the local Herring stock in 2003 limited the availability of YOY in the Little tern breeding season of 2004 (Perrow *et al.* 2011a). As hearing specialists, Herring have been shown to be particularly sensitive to anthropogenic noise (Thomsen *et al.* 2006). The stock had not recovered by the time the monitoring finished in 2006 and feeding rates of adult Little terns foraging to feed chicks remained very low compared to the period before (2002 and 2003) construction began (Perrow *et al.* 2011a). This appears to have been responsible for the unprecedented abandonment of eggs in 2004 and 2005 noted at Winterton in particular. However, Little terns appeared to compensate for low prey abundance by extending the time spent foraging and the distance travelled in foraging bouts and perhaps with both parents foraging to feed chicks (normally a focus of the male). In-combination with the diversionary feeding of Kestrels, which would otherwise have surely undone any compensatory mechanism, a record number of chicks fledged at North Denes in 2006 despite the low abundance of prey.

It remained unknown if the Herring stock had recovered prior to the current project, although successful recruitment of chicks at Scroby Sands themselves in 2011 and Winterton in 2012 suggested reasonable prey density, although of course, different prey such as young sandeels may have been important. It is also noted that predation was known or thought to be virtually non-existent at these localities in those years.

The increased foraging range of Little terns from North Denes colony observed in 2006 meant that the frequency of occurrence of Little terns within the area occupied by the wind farm increased, and with it the risk of collision with turbines, although the frequency of flights estimated to occur at risk height (>20 m) was low at 7% (Perrow *et al*. 2008). Initial modelling of collision risk based on the data delivered by radio telemetry of individual Little terns suggested that this could be important for the small population. This was reconfirmed by a revision of collision risk modelling followed by the use of population modelling to determine if the prospective rates of collision could indeed have implications for the population (Mackenzie *et al*. 2011).

Collision risk modelling suggested that up to 39 Little terns could collide with turbines at the precautionary rate of 98% (19 at 99%) based on the use of the site as recorded in 2006. The predicted annual rate of collision in 2006 represented at increase compared to that in 2005 (10 at 98%) and 2004 (0) and was simply reflective of an increase in numbers of birds at the colony (Table 1) coupled with the increase in time spent in the wind farm by tracked birds.

Using a mean of rates from 2005 and 2006, modelling predicted that the population would fall by 46% of its unharvested state after 25 years of operation, which was significantly higher than the natural underlying decline of 0.37% per annum (Mackenzie *et al*. 2011). The key issue for the modelling was the relatively low confidence in the predicted rate of collision as it was not based on density-derived passage rates and used a variant of the original Band (2000) model reported by Band *et al*. (2007).

2.3 Implications of the use of Scroby Sands

In 2010, Little terns largely abandoned the North Denes colony and nested on the main bank of Scroby Sands. Although the distance to the wind farm is approximately the same as it was when North Denes was occupied, there was concern that the use of the wind farm by Little terns may have increased beyond the levels reported in 2006 (see 2.2 above). This in turn suggested at even greater associated risk of collision than that suggested in 2006, which would further exacerbate the threat to the small internationally significant population. Thus, this study was commissioned to provide information on the current use of the habitat around the colony and wind farm site.

Usage of the wind farm, if it is occurring as suspected was thought likely be linked to prey availability within and surrounding the array. Therefore, prey studies, alongside ornithological surveys, were also carried out to provide an indication of prey availability and associated bird distribution.

3. Methods

The survey strategy combined specific data gathering to allow the density of Little Tern to be determined inside and outside the wind farm, with the methods used in the original monitoring programme (see Perrow *et al.* 2008). The same primary observer (Dr Martin Perrow) as used in the original studies was used for consistency. In the current surveys, Dr Andrew Harwood and/or Paul Lines, Charles Lines, Frank McCarthy and Tristan de Roquefort assisted with data recording and prey trawls.

Density of Little Tern for input into collision risk modelling, was determined through the use of a standard line transect survey approach with snapshots conducted every 250 m along the survey route. A density surface model was also produced to help understand the distribution of terns across the study area.

In addition, the historic method of conducting counts of all bird species, as well as Little Terns over short (1 km) transects at twelve sampling stations both within and outside the wind farm was adopted. Through comparison between counts and the snapshots within the count area it proved possible to provide a calibration between count and density data, which could be applied to historic information to further understand the changing risk of collision risk to Little terns. A tow net designed specifically to sample the prey resource available to Little Tern was deployed simultaneously with each count.

Further information pertaining to bird behaviour, flight heights and interactions with the wind farm were also collected throughout the surveys. In particular, counts of nesting birds were undertaken wherever possible, as presented in Table 1 above.

3.1 Study area, survey route and survey logistics

The vessel used for the surveys was the MRV Sea Badger (Enviroserve Ltd), an 11 m survey catamaran (Figure 1) stationed at Lowestoft and skippered by Jamie Cox with 1-2 crew. With a flying bridge, the vessel offers an eye-height of >5 m to a seated observer and excellent all-round visibility for seabird surveys. The solid bridge front also offers protection from the elements for the observers.

The route designed for the 2013 surveys aimed to mirror that adopted in the historic surveys, essentially sampling the same count and prey trawl locations for comparative purposes. The incorporation of snapshots into the survey design required some modifications to the route and an initial survey design was developed (Figure 2a).

A key aspect of the design was to incorporate as much transect within the wind farm as possible in order to enhance the prospect of delivering density estimates for Little terns, that were likely to occur at low density and could readily be missed by low survey effort. A continuous transect route with a series of parallel survey lines at 400 m apart was developed within the wind farm, the area of which was set as including a buffer of 300 m from the turbine bases to give an area of 6.46 km^2 (Figure 2a).

Figure 1. The MRV Sea Badger used for all bird and prey surveys during 2013. Surveyors were positions above the bridge and prey trawls were conducted from the aft deck (image from http://www.enviro-serve.co.uk/vessels).

The transect spacing adopted assumed that Little terns would be seen in snapshots (see below) to 200 m on either side of the vessel thus providing complete coverage between these transects and covering a large proportion of the wind farm area overall.

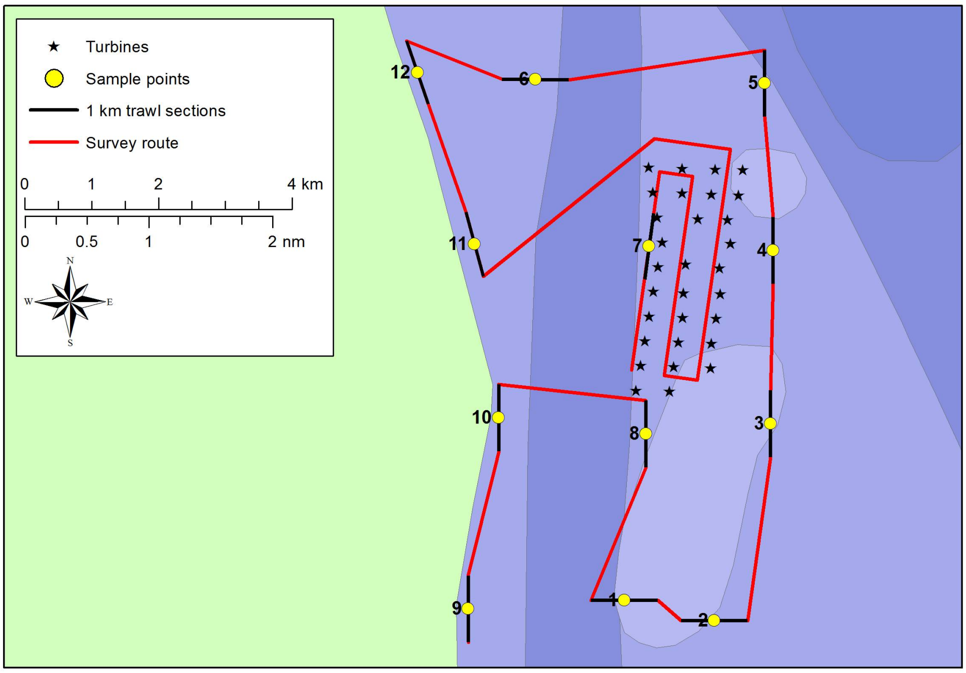
In total, the route was 44.54 km in length, with a higher proportion of transect within the wind farm (24.7% from 11 km) than suggested by the proportion (12.3%) of its area (6.46 km^2) to the study area in general (52.65 km^2).

The first attempt of this route on 3rd May (Table 2) revealed that a number of sand banks became an obstacle to safe passage on some tidal states as a result of the relatively large tidal range and generally shallow waters. The route was therefore modified during the survey and changes were incorporated into a revised survey route design adopted in the remaining surveys (Figure 2b).

In particular, the position of station 7 was corrected as this had been erroneously plotted on the outer fringe of the wind farm rather than fully inside. Moreover, the parallel transects within the wind farm had to be modified as a result of a sand bar running north to south within the wind farm that could not be readily crossed on all tidal states. A safe route could only be provided at greater distance from the wind farm on its western edge and to compensate for this, the eastern north-south transect was brought into the edge of the wind farm to increase coverage of it in this area (Figure 2b).

The revised route was 46 km in length, with a slightly reduced proportion of transect within the wind farm (22.4% at 10.3 km). Although not affecting the transect length or the area covered, it became clear as the surveys were undertaken that even the revised route could not always be conducted in a continuous manner, with different parts being surveyed at different times due to the constraints of tide and weather conditions.

a)



b)

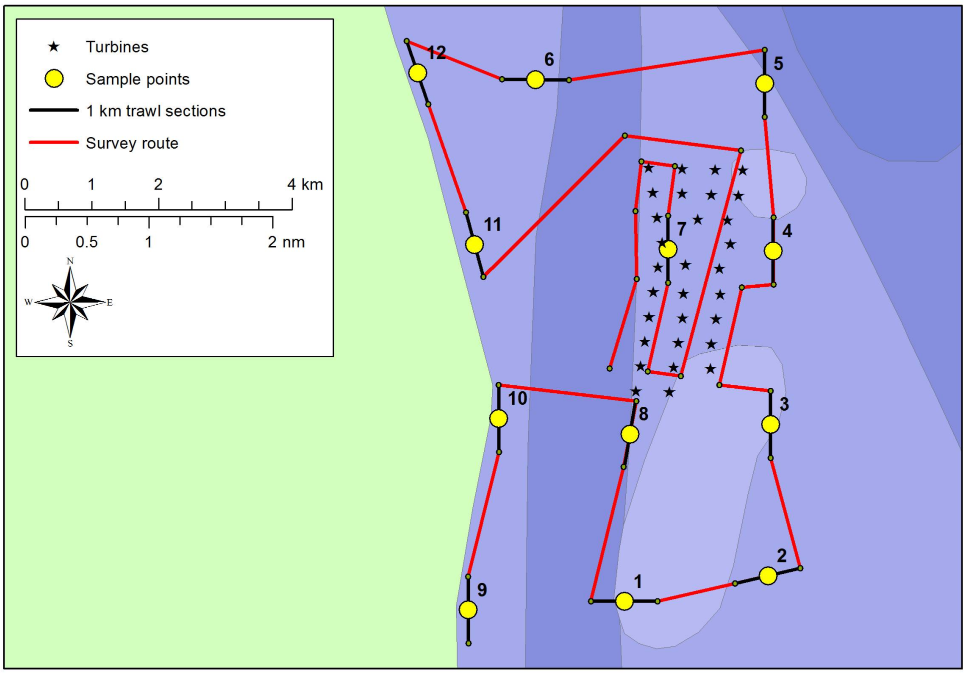


Figure 2. Maps showing the survey route adopted, the wind farm site, survey transects, prey trawl locations (1 km sections) and count stations (mid point of 1 km count transects) for: a) the first survey and b) the modified route for the remaining surveys.

As in previous years (2003-2006), boat-based ornithological surveys of the Scroby Sands OWF were carried out on eight occasions over the breeding period of Little Terns (late April to August inclusive). Table 2 provides the dates of the Scroby boat-based surveys in 2013 alongside the historic survey dates (2002-2003) for reference.

Table 2. Calendar of sampling (bird counts and prey trawls) in the Scroby Sands study area in the current year compared to previous years.

Year	Relative timing of visit								
	1	2	3	4	5	6	7	8	9
2002				12+13/06	26/06	10/07	26/07	07/8	05/09
2003	06/05	26/05*	02/06	11/06	03/07	14/07	31/07	07/08	21/08
2004	07/05	17/05	04/06	10/06	30/06	16/07	22/07	13/08	
2005	02/05	20/05	30/05	04/06	22/06	02/07	21/07	04/08	
2006	02/05	19/05	01/06	14/06	06/07	16/07	27/07	16/08	
2013	03/05	27/05	05/06	19/06	02/07	22/07	31/07	15/08	

* Prey studies only

3.2 Sampling with snapshots

In an attempt to provide the best possible estimate of density, fixed (between survey occasions) snapshots were conducted at 250 m intervals along the survey route. Snapshots represent an instantaneous observation of all birds within an 180^o forward facing arc covering both the port (90^o) and starboard (90^o) sides of the vessel. This method 'fixes' all birds in space and time, which is essential when surveying birds in flight birds (such as terns) that are typically moving faster than the survey platform and would be overestimated using a count over a fixed area of transect.

Birds were assigned to radial distance bands (A=<50 m, B= 50-100 m, C= 100-200 m, D= 200-300 m and E= >300 m) for Distance analysis (Thomas *et al*. 2010 – see below) Birds were also assigned to height bands as described for the count method (see 2.1.2 above) and age, sex, behaviour and other details were also recorded routinely.

The locations for the 185 snapshots of the revised route was predefined and loaded on to a hand-held GPS, which was then used as a reference for snapshot locations by the team member acting as the data recorder.

Snapshot densities for each survey were calculated for:

- The whole study area (using all snapshots surveyed);
- Inside the wind farm site (using snapshots within the site and half snapshots where one side of the snapshot was inside the site + 300 m buffer i.e. port or starboard side);
- Outside of the wind farm site (using snapshots outside of the site and half snapshots where one side of the snapshot was outside of the site + 300 m buffer i.e. port or starboard side).

Simple densities were calculated by summing the numbers of birds seen in all relevant snapshots or half-snapshots dividing by the respective areas surveyed by the corresponding snapshots to provide the numbers of birds per km².

For Little Tern, as previously mentioned (see 3.1.1 above), it was assumed that there would be a substantial drop-off in detection past 200 m due to the small size of this species. Thus, uncorrected densities (as opposed to corrected density using Distance – see 3.1.3 below) for Little Tern were based on snapshot counts to a distance of 200 m and the corresponding area surveyed only. The uncorrected density of larger tern species, snapshots

Where full snapshots were included these represented a radial survey area of 0.141 km² (300 m snapshots) and 0.063 km² (200 m snapshots). Where half snapshots were incorporated into the calculations the areas of these snapshots were effectively halved before being included in the overall area surveyed.

Population size of any species could be calculated wherever required by multiplying the respective densities (either from counts or snapshots) by the relevant full study areas:

- Whole study area (including wind farm site) = 52.65 km²
- Wind farm site (including 300 m buffer) = 6.46 km²
- Outside of the wind farm site (excluding the wind farm site) = 46.19 km²

3.3 Distance analysis

Distance analyses (Buckland *et al.* 2001) were performed in order to correct for the decrease in the ability of the surveyor to detect individuals or groups of birds in flight with distance from the survey platform. The work of Barbraud & Thiebot (2009) showed that for a strip half-width of 300 m, the typical strip width used in seabird surveys, detection was 0.869 (SE = 0.115) for large-sized (albatross sized) seabirds, 0.725 (SE = 0.096) for medium sized seabirds (petrels) and 0.693 (SE = 0.091) for small seabirds (storm petrels), with detection depending on flight speed and action of the birds in question as well as the prevailing conditions. The eye-height on the vessel used was 17.5 m, far higher than the typical 5 m or so used in most seabird surveys where detection was likely to be even lower. Analyses by Perrow *et al.* (2010) also specifically indicated a risk of underestimating the density of smaller, fast-flying species such as terns in surveys.

In practice, Distance models have rarely been applied to birds in flight due in part to some species exhibiting attraction or avoidance in response to the survey platform and the general lack of assigning birds in flight to distance bands. However, the tern species investigated here were deemed very unlikely to exhibit attraction based on previous knowledge of their behaviour (Perrow *et al.* 2011b). Fast and often low flight coupled with crypsis against both the sea and sky also means they are more difficult to see at increasing distance, especially in the case of Little Tern. Overall, the application of Distance correction appeared to be justified.

A Distance model is composed of a key function (uniform, half-normal, hazard-rate or negative exponential) and can be made more robust by adding an adjustment term (cosine, simple polynomial or hermite polynomial). The model is fitted to be complex enough to describe the underlying trend, but not so complex as to describe all noise in the data (Buckland *et al*. 2001). The selection of the number of parameters is a trade-off between a good fit of the probability detection function to the data and low variance of estimates.

Several tools are available to select the 'best' model among several models produced with different key functions, without or with adjustment terms. These include the shape of the probability density function (*f(x)*), the Akaike Information Criterion (AIC), the Chi-squared test for grouped data and the coefficient of variation (*cv*), and a combination of all techniques were used here.

Distance models were run in Distance software 6.1 (Thomas *et al*. 2010) to estimate the density and the abundance of the tern species for the whole study area, inside the wind farm site including a 300 m buffer, and outside the wind farm site. Where half of the snapshot fell either within or outside the wind farm site and 300 m buffer, this was accounted for within the respective survey effort (i.e. an effort of 0.5 of the snapshot was applied). Probabilities of detection estimated by the best model for each species (see Appendix 7.1) were then used to correct counts in all snapshots for the kernel density estimation (KDE) analysis (see 3.4 below).

3.4 Spatial distribution of birds

Kernel Density Estimate (KDE) was used to produce a relative density surface of tern species with the objective of showing spatial trends of their distribution around Scroby Sands OWF. KDE smoothes point density on a grid surface by placing weighted Gaussian curves (the kernels) upon bird observations within a given bandwidth (O'Brien *et al*. 2012, Worton 1989).

The counts of birds were corrected in each snapshots performed during the eight surveys, using the probability of detection calculated in each species distance model and the Horvitz-Thompson estimator:

$$\widehat{N}_i = \sum_{j=1}^{n_i} \frac{s_{ij}}{\widehat{p}_{ij}}$$

Where $\widehat{N}_i$ is the estimated corrected count in snapshot i, n_i is the number of groups detected in snapshot i, s_{ij} is the cluster size of group j in snapshot i and $\widehat{p}_{ij}$ is the probability of detection of group j in snapshot i (Buckland *et al*. 2010).

The corrected count estimates were subsequently incorporated in a Geographic Information System (ESRI ArcGIS v.10.1) using snapshots latitude/longitude location and used to perform the KDE analysis in Geospatial Modelling Environment 0.7.2.1 (GME, Beyer 2012, R Development Core Team 2013). The corrected counts were used as a weighting factor and an optimal bandwidth was estimated with the Plug-in method (Gitzen *et al*. 2006, Walter *et al*. 2011). The relative densities were calculated within a grid cell of 250 m x 250 m (0.0625 km^2) resolution that was clipped to the boundaries of the study area so that only relevant estimates were included in the maps.

For each tern species, KDE analyses were performed for each survey and an average map was produced to summarize their spatial distribution.

3.5 Counts of birds at survey stations

Counts of all birds as well as Little terns were conducted using the same methodology that has been employed throughout previous studies in the area (2002-2006) and using the same observer for comparative purposes. Whilst counts of tern species other than Little Tern are included in this report, information on other species (e.g. gulls) is not.

At each 1 km survey station (1-12) on each occasion (surveys 1-8), all birds were recorded by eye supplemented by the use of high-resolution binoculars where required to confirm species identity. Counts were conducted simultaneously with prey trawls conducted over the 1 km long station divided into two 500 m sections (see 2.1.5 below).

As well as being identified to species wherever possible, birds were aged and assigned to one of several age categories (0 - juvenile, 1 year - including birds showing both 1st summer and 1st winter plumage, 2 year, 3 year etc. to 6 – adult) wherever possible. Birds were also assigned to one of five flight height categories (on surface, and in flight with A –0-5 m, B–5-10 m, C–10-15 m, D–>15-20 m and E->20 m above sea surface).

The count produced is most appropriately thought of as an index of abundance and thus an index of bird use. With simultaneous snapshots (typically four or occasionally five within each 1 km survey station depending on its position relative to the snapshot locations), it was possible to compare count data of Little terns with actual uncorrected estimates of density, using linear regression. This provided a means of converting historic count data to uncorrected density, which could then be subject to collision risk modelling (see 3.6 below) and provide a further indication of previous collision risk which had been previously based on radio telemetry data (see 2.2 above).

As only a single survey station has historically been placed within the wind farm (site 7), the paucity of count data delivered from this station alone was thought unlikely to be reflective of actual use of the wind farm. Therefore, counts of birds recorded at survey stations 4 (offshore of the wind farm), and 8 (to the south of the wind farm) were also included in the analysis. The latter is within 300 m of the wind farm, the same buffer as used in the current study (see 3.1 above). Moreover, birds would typically have to pass through the wind farm to reach survey station 4 from the colony North Denes used during the previous studies. The combination of records from survey stations 4,7 and 8 was thus taken as being indicative of the potential abundance of Little Tern using the wind farm site and areas close to it.

Counts of birds at these stations were converted to densities using the relationship derived for Little Tern. The resulting uncorrected densities were averaged for each survey and a monthly mean density was derived from respective surveys for the purposes of collision risk modelling (see 3.6 below). Corrected densities could not be provided due to the lack of distance information associated with the counts.

Data from the current study was treated in the same manner to provide a dataset to evaluate the change in collision risk over time to compare with that produced by Perrow *et al.* (2008) and modified for the modelling by Mackenzie *et al.* (2011)

described in 3.2 above. The predicted collision risk for 2013 produced by this method could also be directly compared with that produced using uncorrected and corrected density derived from snapshots.

3.6 Collision risk

The predicted mortality rate through collision with turbine blades of Little, Common and Sandwich terns was calculated using the extended Band model (Band, 2012) that was developed through the Strategic Ornithological Support Services (SOSS) commissioned by the Crown Estate as an industry-level solution to the requirements for offshore CRM.

The morphological and behavioural parameters of the three tern species under consideration (Table 3) were derived from the literature. Body length and wingspan were taken from BWPi (2004) and flight speeds from Wakeling & Hodgson (1992). Nocturnal activity was assumed to be zero for all species in keeping with personal experience and Steinen (2006).

Table 3. Morphological and behavioural parameters used in collision risk modelling of Little, Common and Sandwich terns.

Species	Bird length (m)	Wingspan (m)	Flight speed (ms^{-1})	Proportion at risk height (>20 m)
Little Tern	0.23	0.52	12.2	2.3
Common Tern	0.33	0.875	12.2	2.0
Sandwich Tern	0.385	1.0	14.3	9.9

The extended Band (2012) model provides four different options with respect to flight height distribution. Option 1 was selected for this study as this uses the proportion of birds at risk height based on flight heights derived during the surveys conducted here from all records (snapshots and counts) and assumes a uniform distribution of flights over the extent of the swept area.

Details of the wind turbine generators (WTGs) operational at Scroby Sands as required by the Band model (Band, 2012) are shown in Table 4 and have been obtained from the following website http://www.lorc.dk/offshore-wind-farms-map/scroby-sands, which also provided the latitude required for modelling (52.6458 decimal degrees). The monthly operational time of the WTGs was set at 90% based on experience gained from other operational wind farms, and includes time above cut-in wind speed and predicted operations and maintenance downtime.

The first two stages of the CRM calculate the passage rate of the species through the rotor swept area using density and the known flight speed of the bird species concerned, with the assumption that a constant density is maintained (i.e. as one bird leaves the site, another enters). Here, mean-monthly density for use in modelling was derived from both uncorrected and Distance-corrected densities of flying birds. The proportion of flying birds at risk height is then used to scale the passage rate accordingly (see Table 3).

Table 4. Details of the wind turbine generators (WTGs) used in collision risk modelling.

Number of WTGs	Rating (MW)	Number of blades	Pitch (degrees)	Rotor radius (m)	Rated rotor speed (rpm)	Maximum chord length (m)
30	2	3	10	40	16.7	3.5

The output of the CRM is a predicted mortality rate per month that is then summed to provide an annual estimate of mortality. As it is assumed that birds are not present outside of the breeding season this is effectively an estimate for breeding season mortality.

It is important to note that as Little Tern was not recorded in snapshots within the wind farm including 300 m buffer (although a single record was obtained outside of a snapshot) no densities were produced and hence no modelling could be undertaken for this species in relation to the snapshot-derived densities.

As described above (see 3.5), collision risk modelling of Little Tern was also conducted based on counts of birds recorded at survey stations 4 (immediately offshore of the wind farm), 7 (inside the wind farm) and 8 (immediately adjacent to the southern edge of the wind farm) in 2013 for the purposes of a comparison with historical data. Counts of birds at these stations were converted to densities using the relationship derived for Little Tern (see 3.5 above).

3.7 Prey trawls

Prey trawls were carried out at the 12 sample stations, repeating the sampling effort from 2002-2006 inclusive. On each survey occasion, sampling of all stations was undertaken over the course of one day, starting at different points in the tidal cycle.

Sampling was conducted with a bespoke larval tow-net (surface trawl) tapered to 2 m with 5 mm mesh, attached to a 92 x 30 cm stainless steel frame with two vanes set 15°. This net was designed to specifically sample the prey available to Little Terns near the surface as observations of foraging Little Terns have shown that they are incapable of plunge-diving to depths of more than one body length (22-24 cm).

Two tows of 500 m were conducted at each station to reduce the potential for the net to fill with animals, plants (seaweeds) or flotsam, which can result in reduced efficiency. Following each tow the net was hauled and inverted to allow for a careful search for any captured animals. Large fauna that were thought to be inedible to Little Tern such as large crabs, Ctenophora including Sea Gooseberry *Pleurobranchia pileus* comb jellies and jellyfish and molluscs (e.g. Razor Shell Clam *Ensis* spp.) were recorded and returned. Any fish and invertebrates that could comprise prey were immediately preserved in 70% industrial methylated spirit (IMS) for later analysis.

All specimens preserved in the field were later identified as far as possible and measured to the nearest mm body length (fork length for fish). Invertebrates were identified with reference to Hayward & Ryland (2000). Fish were identified using Wheeler (1969) and Hayward & Ryland (2000).

Unfortunately, it was impossible to separate between the larvae of Herring and Sprat when fish were very small (<30mm) with any confidence. At this size, identification features such as rays, ventral spines, the relative position of fins and differences in colour and head shape have not yet fully formed. Although still difficult to tell apart as juveniles at >30mm, identification was attempted wherever possible using several criteria, including counts of the number of fin rays, relative position of the ventral and pelvic fins, nature of the ventral keel and its serrations, and body shape and colour (see Perrow *et al.* 2008 for further details).

To obtain an estimate of the biomass of each specimen, length-weight relationships based on Log10 transformed data for clupeids, Sea Slater *Idotea linearis* and Ghost Shrimp *Schistomysis spiritus* as derived by Perrow *et al.* (2008) were applied to the most recent data for any fish, invertebrates other than shrimps and shrimps respectively, in the absence of sufficient samples of other species being available:

For clupeid fish (n=331)

$y = 2.438x - 4.8812$ $\quad r^2 = 0.623 \quad p < 0.0001$ (eq. 1)

For Sea Slater (n=272)

$y = 2.8041x - 5.0184$ $\quad r^2 = 0.924 \quad p < 0.0001$ (eq. 2)

For Ghost Shrimp (n=110)

$y = 5.1392x - 7.2648$ $\quad r^2 = 0.695 \quad p < 0.0001$ (eq. 3)

where y=weight (g) and x = Length (mm).

However, preserving fish using alcohol leads to shrinkage and weight change. Lengths of the clupeids captured during the surveys were therefore adjusted based on an established relationship between lengths before and after preservation, to account for shrinkage (see Perrow *et al.* 2008). The correction was based on Log10 transformed data where length decreased in a constant manner:

$y = 0.9325x + 0.1556$ $\quad r^2 = 0.959 \quad p < 0.0001$ (eq. 4)

where y=unpreserved length (mm) and x= preserved length (mm).

Whilst the length of invertebrates does not appear to change significantly with preservation, biomass does and the weights of the preserved specimens of both fish and invertebrates were therefore corrected based on relationships between preserved weight and fresh weight established by Perrow *et al.* (2008):

For clupeid fish (n=135)

$y = 0.8785x + 0.1825$ $\quad r^2 = 0.967 \quad p < 0.0001$ (eq. 5)

For Sea Slater (n=63)

$y = 1.0202x + 0.0175$ $\quad r^2 = 0.849 \quad p < 0.0001$ (eq. 6)

For shrimps (n=21)

$y = 0.9908x + 0.0567$ $\quad r^2 = 0.995 \quad p < 0.0001$ (eq. 7)

where y=unpreserved weight (g) and x = preserved weight (mm).

The resulting estimates of fresh length and weight of both fish and invertebrates were used as the most meaningful expression of the size and biomass of prey available to Little Tern.

Densities (ind. m^{-2}) and biomass (g m^{-2}) were calculated for the total available prey at each station on each survey and as overall values for each survey following division by the surface area estimated to have been sampled at each site (920 m^2). The density of Sea gooseberries and the density (ind. m^{-2}) and biomass (g m^{-2}) of clupeids were also calculated and expressed in the same way. Length frequency distribution of all clupeids and any actual identification of specimens were used to broadly determine the relative contribution of herring and sprat to the prey base for Little Tern. Seasonal patterns and trends were then assessed visually and described.

4 Results & discussion

4.1 Abundance and distribution of terns

4.1.1 Little Tern

The abundance of Little Terns across the study area and inside and outside the OWF was expressed as uncorrected density, Distance-corrected density and by counts at specific survey locations. The uncorrected and corrected density and estimates are shown in Tables 5 and 6 respectively.

Table 5. Density estimates (ind. km^{-2}) for Little Tern derived from snapshots with a radius of 200 m for the entire study area and inside and outside the wind farm.

Survey	Date	Density (ind. km^{-2})		
		Study area	Inside wind farm	Outside wind farm
1	03-May	0.467	0.000	0.625
2	27-May	1.315	0.000	1.670
3	05-June	0.172	0.000	0.221
4	19-June	3.432	0.000	3.833
5	02-July	0.343	0.000	0.433
6	22-July	0.000	0.000	0.000
7	31-July	0.686	0.000	0.863
8	15-August	0.785	0.000	0.881

A summary of the Distance model for Little Tern is provided in the Appendices (7.1 below). The model for Little Tern was based on a total of 41 observations, which is at the lower end of a desirable sample size. However, the model appeared to fit the data well with some drop-off in detection probability between bands A (0-50 m) and B (50-100 m) followed by a sharp drop off in band C (100-200 m) showing that it was indeed very unlikely that any birds would be seen at >200 m from the vessel. The corrected estimates were generally much larger than the uncorrected density estimates (see Table 5 & 6), accounting for the drop off in detection probability with increasing distance. For example, the peak Distance corrected density of Little Tern was 7.5 ind. km^{-2} outside of the wind farm on the 19th June (Table 5) compared with the uncorrected snapshot estimate which was almost half this at 3.8 ind. km^{-2} (Table 6). It is of note that the upper and lower confidence limits were not particularly large, reinforcing confidence in the estimate, especially when used for collision (see below).

Table 6. Distance corrected density estimates (ind. km^{-2}) for Little Tern based on snapshots with a radius of 300 m for the entire study area, inside the wind farm (including a 300 m buffer) and outside of the wind farm. Lower and upper 95% confidence intervals (LCI and UCI respectively) are also provided.

Survey /date	Study area			Inside wind farm			Outside wind farm		
	Density	LCI	UCI	Density	LCI	UCI	Density	LCI	UCI
1 - 03-May	0.731	0.481	1.110	0.000	0.000	0.000	0.978	0.644	1.486
2 - 27-May	1.716	1.131	2.606	0.000	0.000	0.000	2.180	1.436	3.310
3 - 05-June	0.336	0.221	0.510	0.000	0.000	0.000	0.433	0.285	0.657
4- 19-June	6.013	3.960	9.129	0.000	0.000	0.000	7.506	4.944	11.396
5 - 02-July	1.008	0.664	1.530	0.000	0.000	0.000	1.272	0.838	1.932
6 - 22-July	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7 - 31-July	1.679	1.106	2.550	0.000	0.000	0.000	2.113	1.392	3.209
8 -15-August	2.390	1.574	3.628	0.000	0.000	0.000	3.000	1.976	4.554

Being derived from the same dataset, uncorrected and corrected density estimates showed the same seasonal trends and relative abundance within and outwith the wind farm (Figure 3), with no Little terns recorded in snapshots within the wind farm during any of the surveys. Count data supported this trend, with no Little terns recorded at survey station 7, the only survey station completely contained within the wind farm, with none also recorded at survey station 4 to the east of the wind farm and only a few recorded at survey station 8 immediately to the south of the wind farm (Table 7).

In general, the density and count data showed similar trends over the course of the season (Figure 4). The anomalous zero density on 22nd July was mirrored by a lack of birds in counts (Table 7), even though Little terns were known to be nesting. However, the total count on 19th June (survey 4) was relatively lower than the density delivered on the same date, with a relatively higher count on 27th May (survey 2) than the density estimate would suggest. Nevertheless, there was sufficient agreement to allow the general patterns to be broadly described.

Little Tern density gradually increased in May, followed by a drop at the start of June (Table 5, Figure 3). This coincides with the lack of known breeding attempts at Scroby Sands, North Denes or Caister early in the season, although birds had been observed in display flights above North Denes in early May. By early June, relatively large numbers had been recorded nesting at Winterton (RSPB *pers comm.*), reaching a peak of 171 nests on 20th June suggesting this was going to be the major colony for the season.

Table 7. Counts of Little Tern conducted over the 12 surveys stations each with a length of 1 km and a width of 400 m.

Date	Survey station												Mean
	1	2	3	4	5	6	7	8	9	10	11	12	
1- 03-May	0	0	0	0	0	0	0	3	0	3	0	0	0.50
2- 27-May	0	0	0	0	0	0	0	2	0	6	14	19	3.42
3- 05-Jun	0	0	0	0	0	0	0	1	1	0	0	0	0.17
4- 19-Jun	1	0	0	0	0	0	0	1	2	22	0	21	3.92
5- 02-Jul	2	0	0	0	0	0	0	1	0	6	0	0	0.75
6- 22-Jul	0	0	0	0	0	0	0	0	0	0	0	0	0.00
7- 31-Jul	13	1	0	0	0	0	0	0	0	0	0	0	1.17
8 - 15-Aug	8	0	0	0	0	0	0	0	0	0	0	0	0.67

However, on 19th June, the density of Little terns in the Scroby study area increased considerably to a peak for the season (3.4 ind. km^{-2} uncorrected and mean of 6.0 ind. km^{-2} corrected), coincident with the discovery of at least 33 nests mainly on the periphery of the colony of Common Terns that had become established on the southern end of the main emergent bank of Scroby Sands. However, Little terns were widely distributed around the study area in this survey, with concentrations in inshore waters around North Denes and California with fewer records around Scroby Sands themselves (Figure 5). Whilst it is possible that some of the birds at North Denes could be associated with nesting at Scroby, the birds at California were largely out of foraging range (>6 km), and it would seem most likely that many of the birds present had become displaced from Winterton having failed in their first breeding attempt, as reports suggested the loss of clutches and chicks (especially to Kestrel). At least some of the Little terns on Scroby could also have been re-nesting at this time.

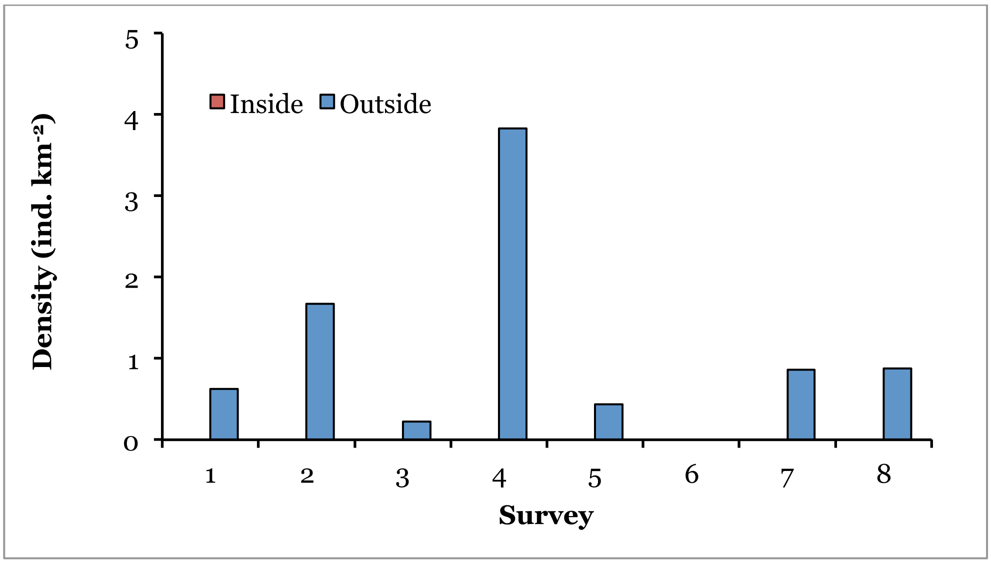
Unfortunately, all Little Tern nests appeared to be lost on the high tides of 25th/26th June, although few if any Common Tern nests were affected on the very highest point of the bank. Re-nesting of Little Terns occurred, with 15 nests in a different locality to the north-east of the main Common Tern colony, but in association with a small number (10) of further Common Tern nests.

In an independent visit to Scroby Sands on 15th July involving landing on the bank, local ornithologist Peter Allard recorded 70 Little Tern nests. Some of these appear to be have been lost, as only 25 nests were recorded during the count conducted as part of this study on 31st July, although 107 adults and 9 fledged juveniles were recorded at rest on the bank. What appeared to be a different set of 14 nests with no obvious chicks were still present on 15th August, alongside 46 adults and 5 fledged juveniles (Appendix 7.2).

It is of note that the nesting attempts during July and August coincided with relatively low (<0.7 ind. km^{-2}) and even zero (22nd July) density estimates across the study area, with concentration of birds around the colony itself (Figure 5). This suggests that most birds were coincidentally recorded at nest or at rest rather than actively foraging, although it is also possible that foraging was occurring outside the study area particularly to the south of Scroby Sands around Holm Sand. Observations made during surveys conducted for the Joint Nature Conservation Committee in

2013 suggested this was an important foraging area. Foraging trips to the south of Scroby Sands may partly explain the complete lack of records from snapshots from the OWF to the north, although there was a single record outside snapshots (Figure 5).

a)



b)

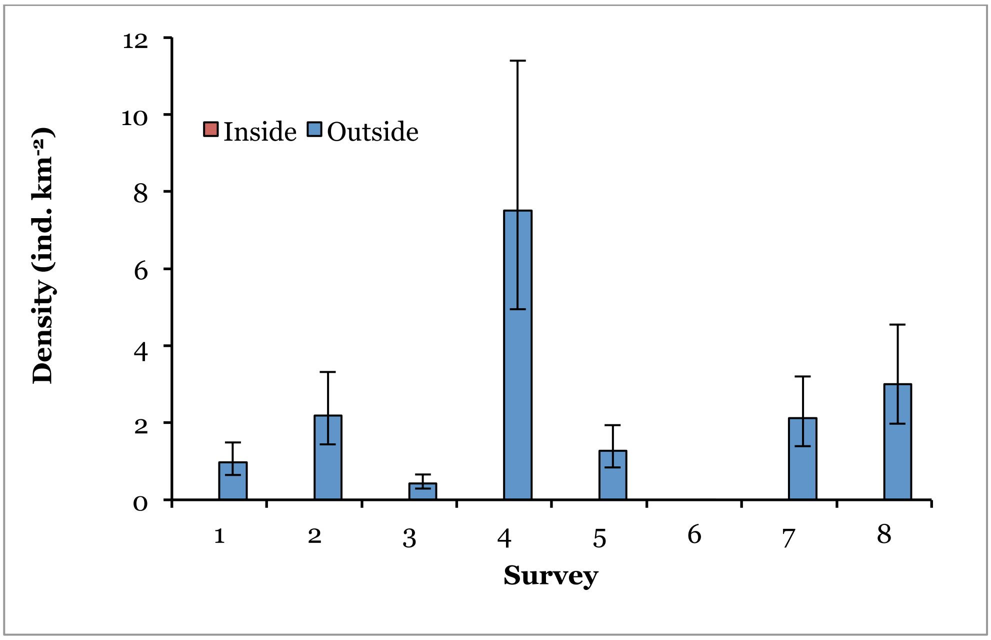
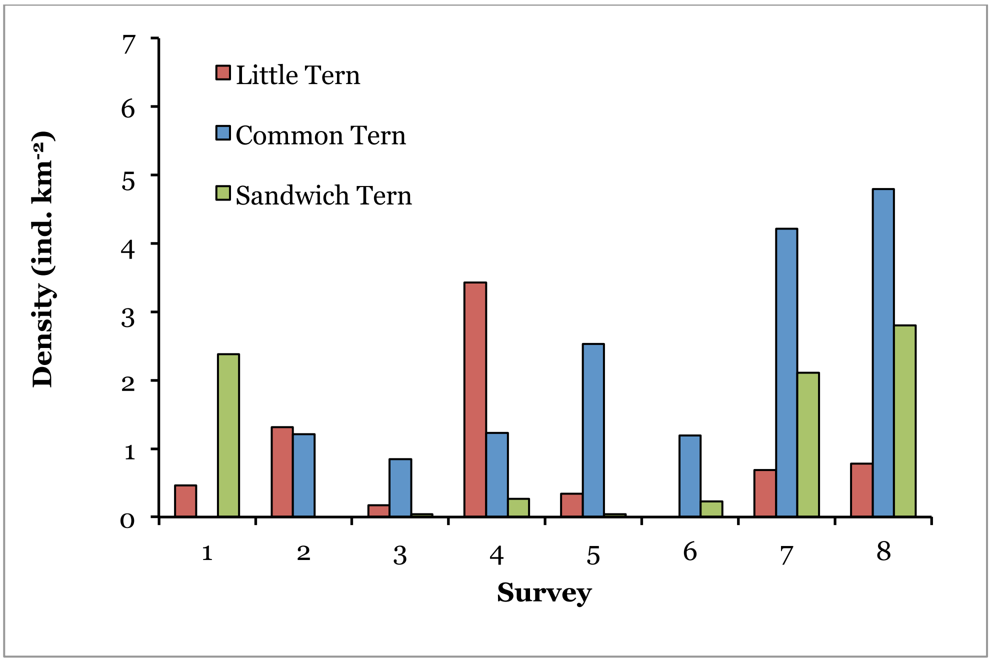


Figure 3. Uncorrected a) and Distance-corrected b) density of Little Tern derived from snapshots or parts of snapshots conducted inside and outside of the wind farm site. Note that data are derived from snapshots with a 200 m radius for Little Tern. Error bars on b) denote upper and lower 95% confidence intervals.

a)



b)

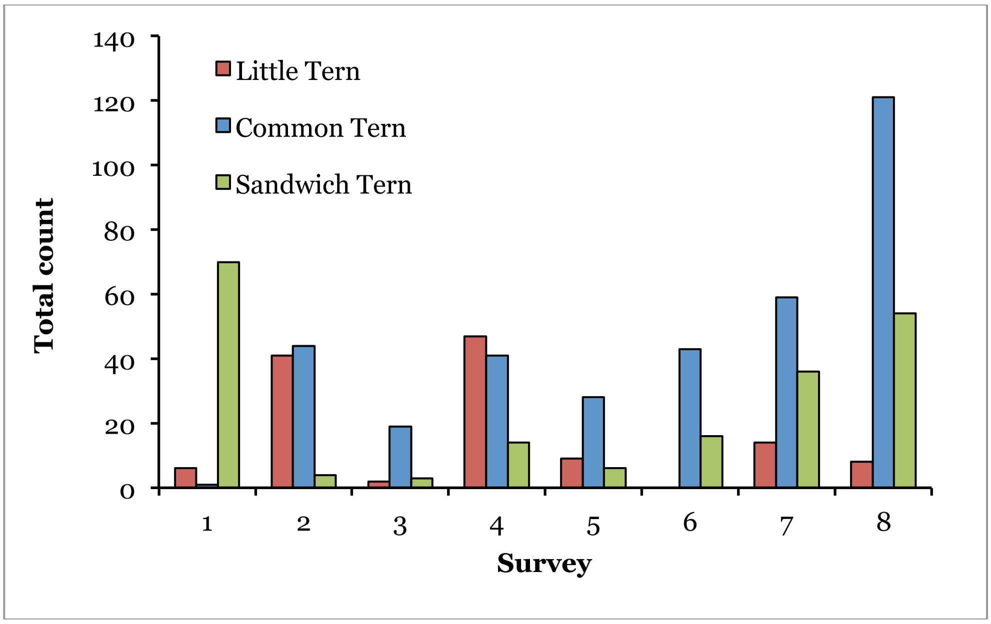


Figure 4. Uncorrected density (ind. km-2) estimates a) and total count b) within the 12 survey stations over the eight surveys during the survey period (May-August inclusive) for Little, Common and Sandwich Tern. Note that densities for Little Tern are based on a survey strip width of 400 m (2 x 200 m) and those for Common and Sandwich Tern use a survey strip width of 600 m (2 x 300 m).

The spatial distribution of all records, expressed as a relative density surface from mean values from the eight surveys in each of the 250 x 250 m grid cells (Figure 6) shows the concentration of Little Terns around the southern part of Scroby Sands near the colony and also around North Denes.

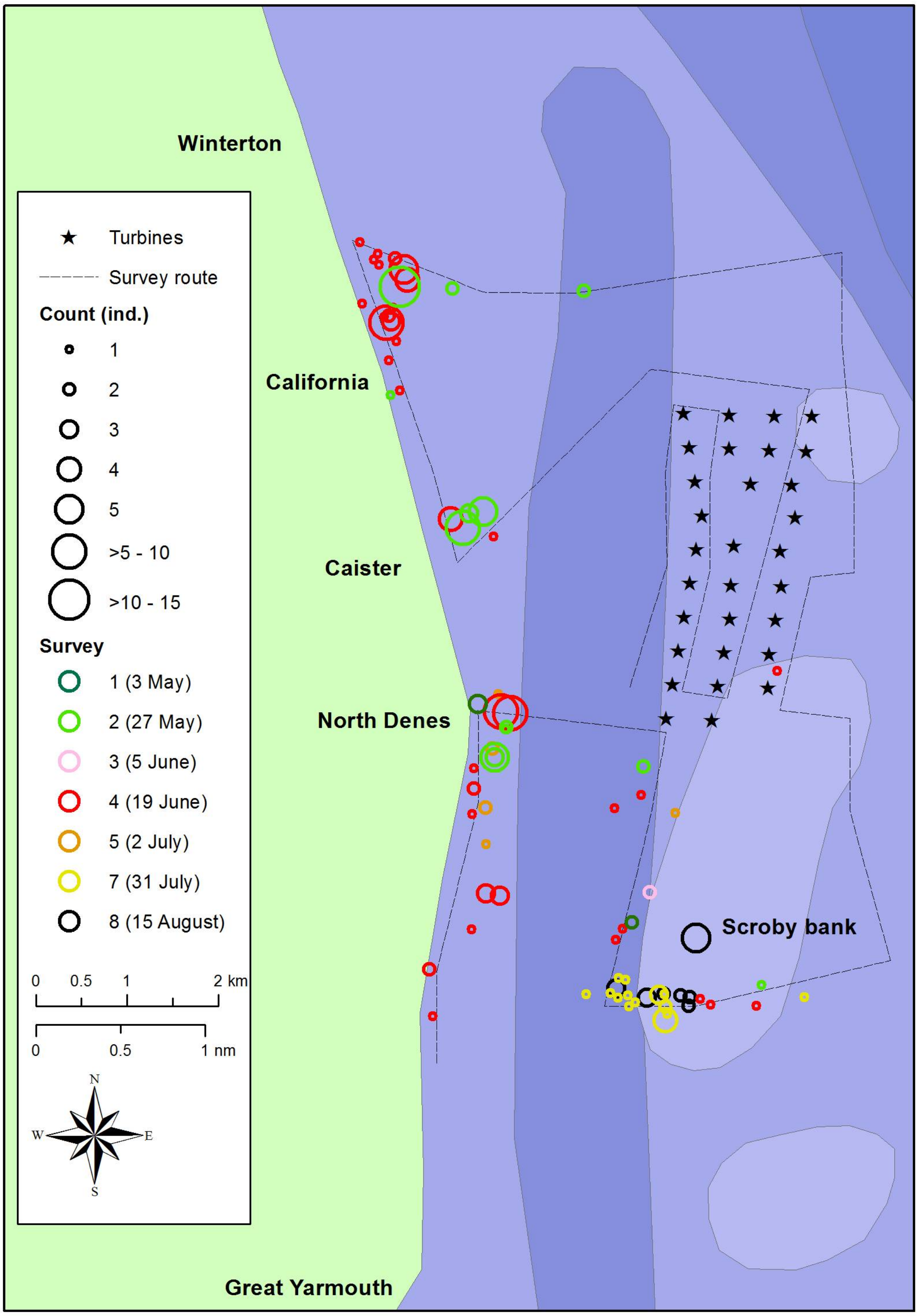


Figure 5. All observation of Little Tern recorded during the snapshot component of the surveys. Note that some additional opportunistic records of Little Tern are included which were not seen in snapshots and therefore are not included in standard density estimates.

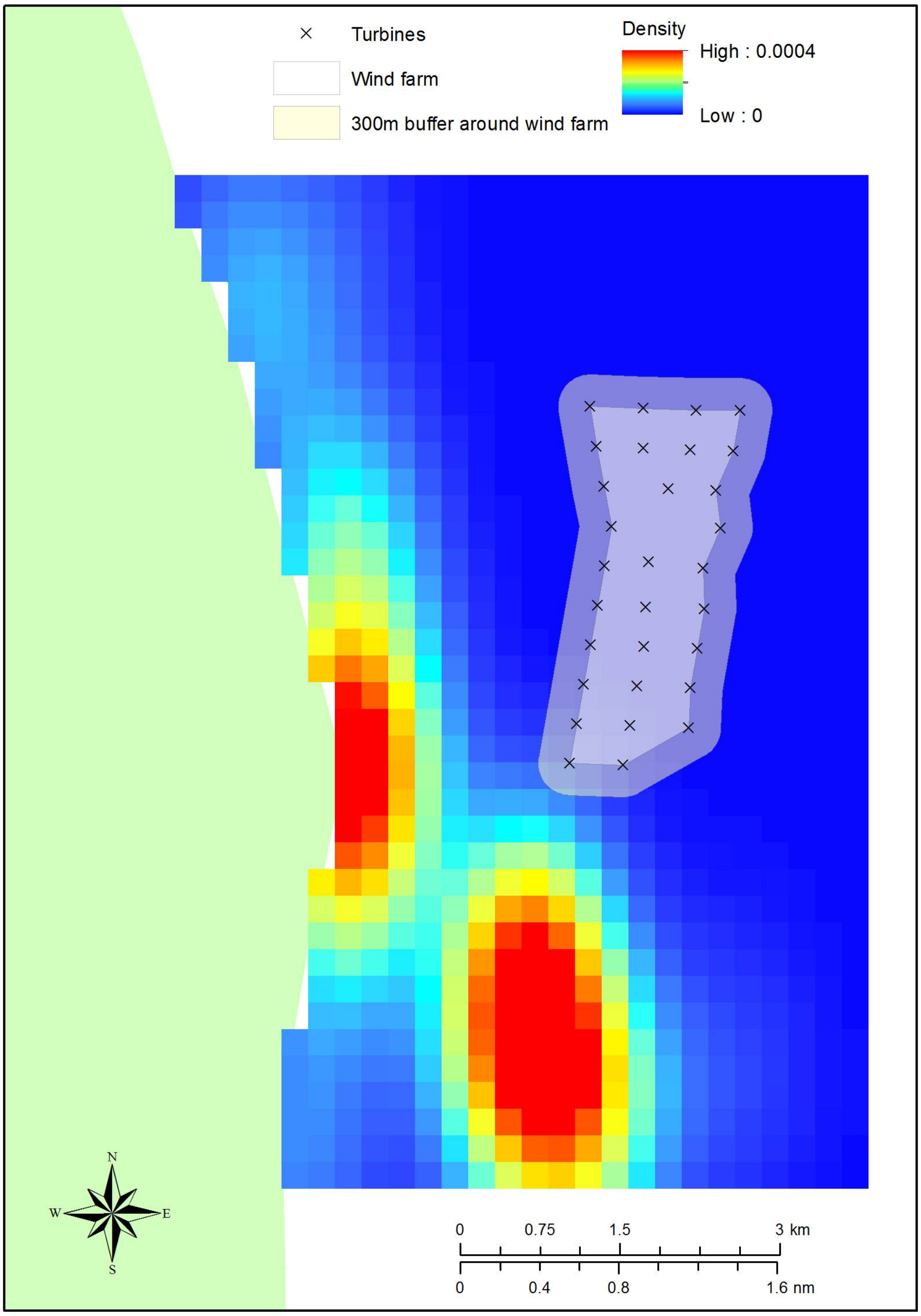


Figure 6. Mean relative density surface of Little Terns within the study area based on Distance corrected snapshot densities derived from each of the eight surveys conducted in 2013.

Attraction to the latter especially in the early part of the season until mid-June (Figure 5) would seem to be linked to the consistent recording of the highest density of prey (see 4.3 below) as described previously (Perrow *et al.* 2008), even if breeding was not possible on the unprotected and highly disturbed beach.

4.1.2 Common Tern

Distance correction of Common Tern was based on a much larger sample of observations (*n*=249) than Little Tern and not unexpectedly the model fitted well, describing the drop off in detection between distance bands (Appendix 7.1). The greatest drop off appeared to occur between bands B (50-100 m) and C (100-200 m) with a further drop off in band D (200-300 m), but not to the level seen for Little Tern. Nonetheless, corrected estimates for inside and outside the OWF were much greater than the uncorrected estimates (Tables 8 & 9). For example the highest uncorrected snapshot derived estimate for outside of the OWF was 6.058 ind. km^{-2} during the last survey, whereas the corresponding Distance corrected estimate was almost three times higher at 17.047 ind. km^{-2}. It is of note that despite the corrected estimates for outside the OWF being higher than inside, some were more similar (particularly on the 22nd July) and the confidence intervals overlapped (Figure 7), suggesting a more even density within and outwith the OWF.

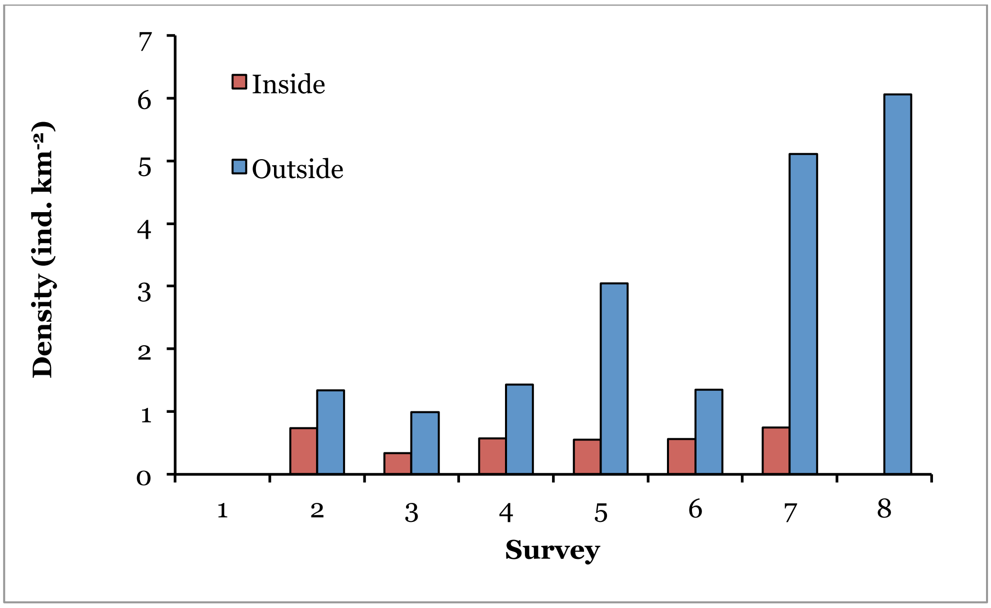
Table 8. Density estimates (ind. km^{-2}) for Common Tern derived from snapshots with a radius of 300 m for the entire study area and inside and outside the wind farm.

Survey	Date	Density (ind. km^{-2})		
		Study area	Inside OWF	Outside OWF
1	03-May	0.000	0.000	0.000
2	27-May	1.215	0.737	1.344
3	05-June	0.843	0.342	0.988
4	19-June	1.227	0.575	1.428
5	02-July	2.530	0.553	3.050
6	22-July	1.188	0.567	1.346
7	31-July	4.217	0.747	5.114
8	15-August	4.793	0.000	6.058

Table 9. Distance corrected density estimates (ind. km^{-2}) for Common Tern based on snapshots with a radius of 300 m for the entire study area, inside the wind farm (including a 300 m buffer) and outside of the wind farm. Lower and upper 95% confidence intervals (LCI and UCI respectively) are also provided.

Survey /date	Study area			Inside OWF			Outside OWF		
	Density	LCI	UCI	Density	LCI	UCI	Density	LCI	UCI
1 - 03-May	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2 - 27-May	6.155	4.209	9.001	4.521	3.092	6.612	6.597	4.511	9.646
3 - 05-Jun	2.635	1.802	3.853	1.678	1.147	2.454	2.911	1.991	4.257
4- 19-Jun	4.867	3.328	7.116	2.823	1.930	4.128	5.374	3.675	7.859
5 - 02-Jul	5.458	3.732	7.980	3.617	2.474	5.289	5.941	4.063	8.688
6 - 22-Jul	4.893	3.346	7.155	4.642	3.175	6.788	4.957	3.390	7.248
7 - 31-Jul	9.410	6.435	13.759	1.832	1.253	2.679	11.368	7.774	16.624
8 -15-Aug	13.582	9.288	19.860	0.000	0.000	0.000	17.047	11.658	24.928

a)



b)

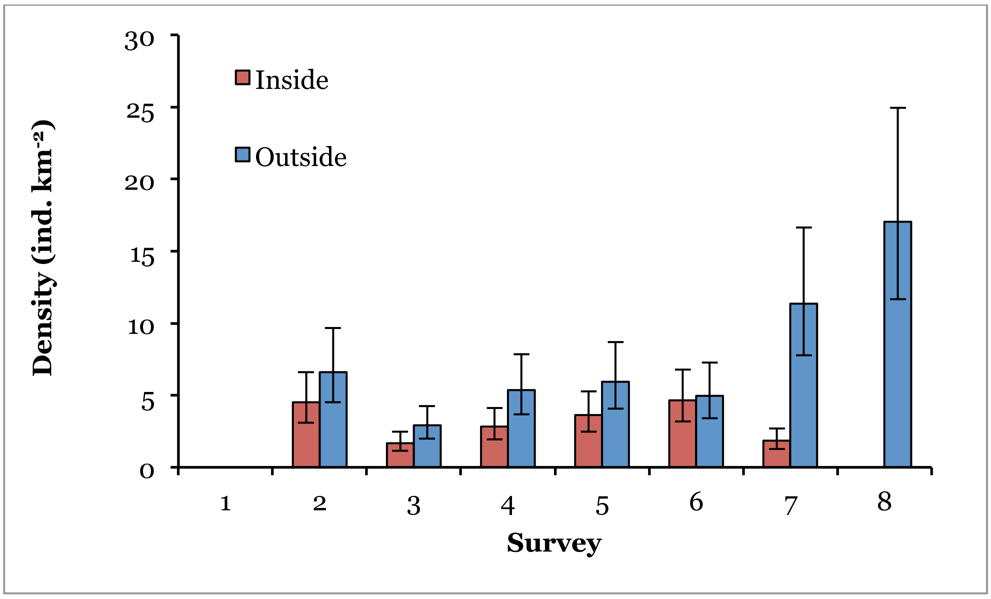


Figure 7. Uncorrected a) and Distance-corrected b) density of Common Tern derived from snapshots or parts of snapshots conducted inside and outside of the wind farm site. Note that data are derived from snapshots with a radius of 300 m. Error bars on b) denote upper and lower 95% confidence intervals.

The count data (Table 10) were in general agreement with the uncorrected density estimates delivered by the snapshots, with some difference in the relative abundance in the middle of the survey period from mid June to early July (surveys 4 and 5 respectively).

Table 10. Counts of Common Tern conducted over the 12 surveys stations each with a length of 1 km and a width of 600 m.

Date	Survey station												Mean
	1	2	3	4	5	6	7	8	9	10	11	12	
1- 03-May	0	0	1	0	0	0	0	0	0	0	0	0	0.08
2- 27-May	2	2	10	10	9	1	1	2	0	4	3	0	3.67
3- 05-Jun	3	4	0	0	0	1	0	9	0	2	0	0	1.58
4- 19-Jun	9	13	9	0	0	0	1	8	0	1	0	0	3.42
5- 02-Jul	16	4	0	0	0	0	0	2	2	1	3	0	2.33
6- 22-Jul	21	6	1	0	0	0	1	4	0	6	4	0	3.58
7- 31-Jul	29	8	0	4	1	2	0	1	2	6	5	1	4.92
8 - 15-Aug	13	3	3	8	2	7	1	23	23	10	15	13	10.08

Common Tern was only present in very low numbers at the start of May, only being recorded in count data (Table 7). Thereafter from late May until early July, the numbers and density present were broadly consistent coincident with the establishment of a large breeding colony on the southern end of the main bank of Scroby Sands, matching previous breeding attempts in 2010, 2011 and 2012. Prior to this, Common Terns had nested on Scroby from 1947-1965 and between 1971-1976 with between 50-368 pairs present

On 19th June, 174 nests were recorded, divided between the main colony of some 140 nests with 34 scattered in subsidiary colonies. The nests in the main colony survived the high tide of 25th-26th June although others appeared to be lost as was the case for Little Tern (see 3.1.1 above). On 2nd July, 100 nests were still present as well as some hatched chicks. By the 31st July, 100 fledged juveniles were recorded, which were thought to have originated from the colony and the presence of 73 nests in three separate locations (40, 28 and 5) indicated that re-nesting had occurred, perhaps including birds from elsewhere, most likely Breydon Water.

The marked increase in density (Figure 7) and counts (Table 7) at the end of July and into August may thus be partly linked to the increase in breeding birds, and especially to the development of an extremely large roost of Common Terns of unknown provenance from the end of July into mid-August at the end of the study. A total of 1,763 adult birds were estimated on 31st July, with at least 1,547 adults by the 15th August. The numbers of fledged juveniles on these two dates were 100 and 71 respectively. The continued presence of chicks (11 counted) on 15th August indicated that re-nesting birds had also been partly successful.

The densities of Common Tern using the wind farm (with 300 m buffer) were thus broadly consistent between the end of May and end of July (Figure 7), with uncorrected estimates ranging between 0.34 and 0.75 ind. km^{-2} and corrected estimates 1.68 to 4.64 ind. km^{-2}. Remarkably, no Common terns were recorded in the wind farm on the August survey despite the large numbers in the nearby roost.

The KDE neatly illustrated a concentration of Common Tern activity around the main bank to the south of the wind farm (Figure 8), with relatively high use to the north encompassing the southern and eastern portion of the wind farm in particular. Low densities of Common Tern were also recorded along the coast to the west of the study area. There is every possibility that areas of relatively high use would be recorded south of the main bank in the area of Holm Sands as suggested by the surveys for JNCC in 2013 and as described for Little Tern (see 3.1.1 above).

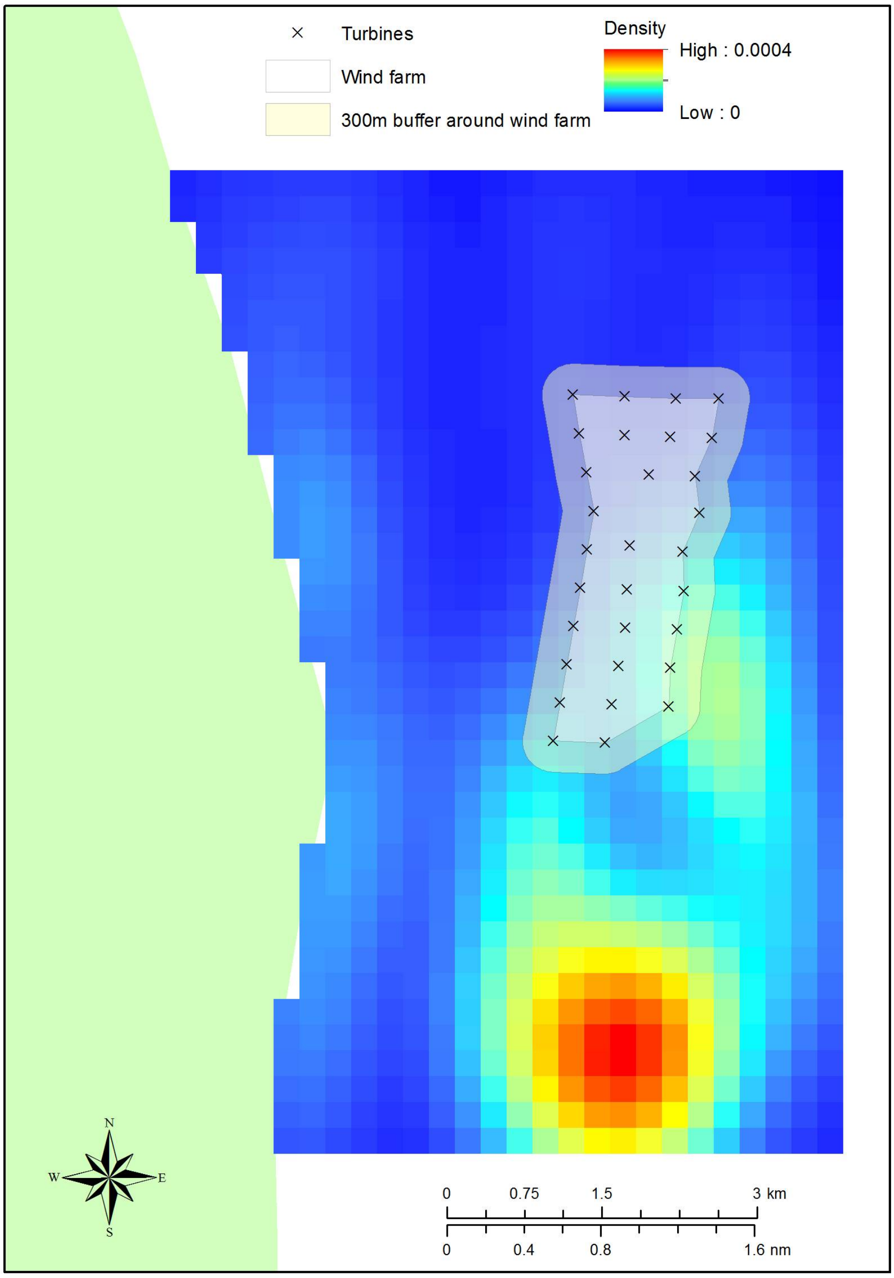


Figure 8. Mean relative density surface of Common Tern within the study area based on Distance corrected snapshot densities derived from each of the eight surveys conducted in 2013.

4.1.3 Sandwich Tern

The Distance model for Sandwich Tern was based on n=143 observations and as for the other species the detection probability exhibited a substantial drop off at distances greater than 100 m (Appendix 7.1).

The decline is perhaps more unexpected as Sandwich Tern is a larger species that tends to be more vocal and fly at greater height both of which may enhance detection. In fact, the model counter-intuitively suggested more birds in bands A and B, and that caution should be used when interpreting the results of the model. The considerably higher corrected densities compared to uncorrected estimates may thus tend to overestimation (Tables 11 & 12, Figure 9). For example, the highest uncorrected density estimate for outside the wind farm was 3.55 ind. km^{-2} on the 15th August, whilst the corresponding Distance corrected estimate was more than double this at 8.00 ind. km^{-2}.

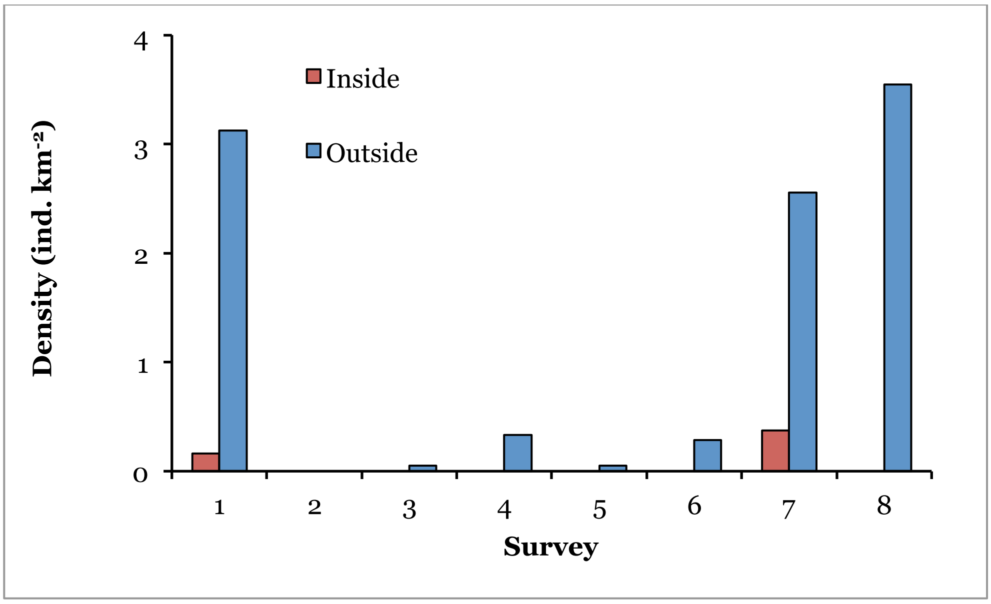
Table 11. Density estimates (ind. km^{-2}) for Sandwich Tern derived from snapshots with a radius of 300 m for the entire study area and inside and outside the wind farm.

Survey	Date	Density (ind. km^{-2})		
		Study area	Inside wind farm	Outside wind farm
1	03-May	2.378	0.165	3.127
2	27-May	0.000	0.000	0.000
3	05-June	0.038	0.000	0.049
4	19-June	0.268	0.000	0.333
5	02-July	0.038	0.000	0.048
6	22-July	0.230	0.000	0.288
7	31-July	2.108	0.373	2.557
8	15-August	2.806	0.000	3.546

Table 12. Distance corrected density estimates (ind. km^{-2}) for Sandwich Tern based on snapshots with a radius of 300 m for the entire study area, inside the wind farm (including a 300 m buffer) and outside of the wind farm. Lower and upper 95% confidence intervals (LCI and UCI respectively) are also provided.

Survey /date	Study area			Inside wind farm			Outside wind farm		
	Density	LCI	UCI	Density	LCI	UCI	Density	LCI	UCI
1 - 03-May	7.594	5.907	9.763	0.613	0.477	0.788	9.958	7.745	12.802
2 - 27-May	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3 - 05-Jun	0.285	0.222	0.366	0.000	0.000	0.000	0.367	0.286	0.472
4- 19-Jun	0.992	0.771	1.275	0.000	0.000	0.000	1.238	0.963	1.591
5 - 02-Jul	0.285	0.222	0.366	0.000	0.000	0.000	0.360	0.280	0.462
6 - 22-Jul	0.570	0.443	0.732	0.000	0.000	0.000	0.714	0.556	0.919
7 - 31-Jul	4.985	3.877	6.408	1.387	1.079	1.783	5.915	4.601	7.604
8 -15-Aug	6.370	4.954	8.189	0.000	0.000	0.000	7.995	6.219	10.278

a)



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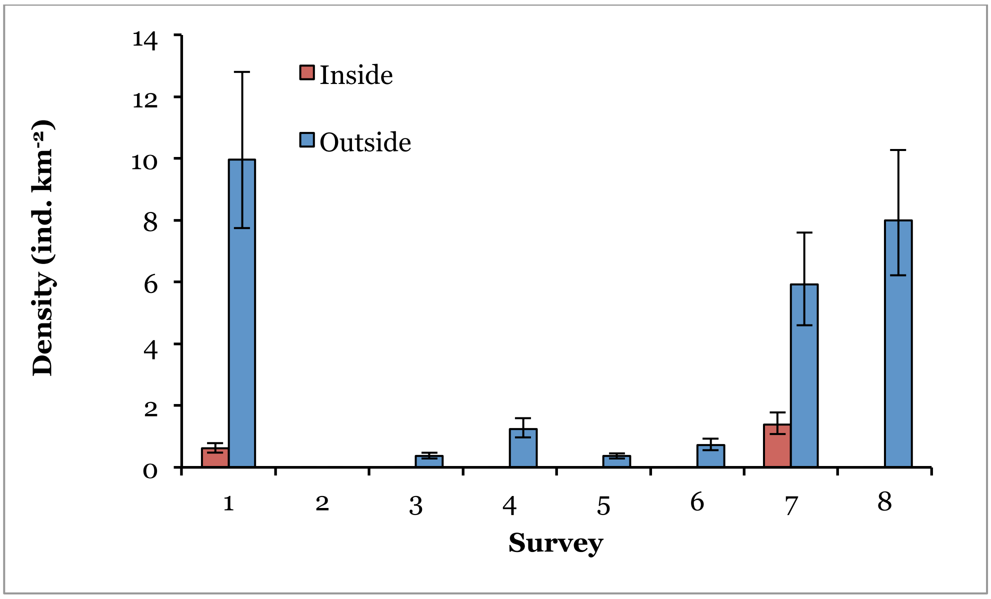


Figure 9. Uncorrected a) and Distance-corrected b) density of Sandwich Tern derived from snapshots or parts of snapshots conducted inside and outside of the wind farm site. Note that data are derived from snapshots with a radius of 300 m. Error bars on b) denote upper and lower 95% confidence intervals.

Distance correction also resulted in a change in the survey during which the peak density occurred. Instead of the peak occurring outside the OWF on the 15th August, Distance correction suggested a peak was reached on the 3rd May (9.96 ind. km^{-2}), in agreement with the count data (Table 13, Figure 4b). The corrected estimate for 3rd May represented more than a threefold increase in the estimate from the uncorrected snapshot derived density of 3.13 ind. km^{-2}.

Table 13. Counts of Sandwich Tern conducted over the 12 surveys stations each with a length of 1 km and a width of 600 m.

Date	Survey station												Mean
	1	2	3	4	5	6	7	8	9	10	11	12	
1- 03-May	13	9	16	4	1	1	2	19	0	0	2	3	5.83
2- 27-May	0	2	0	0	0	0	0	2	0	0	0	0	0.33
3- 05-Jun	0	0	3	0	0	0	0	0	0	0	0	0	0.25
4- 19-Jun	1	2	0	1	1	1	0	5	0	0	0	3	1.17
5- 02-Jul	2	1	3	0	0	0	0	0	0	0	0	0	0.50
6- 22-Jul	2	2	0	0	0	0	2	2	0	3	0	5	1.33
7- 31-Jul	5	5	3	6	0	0	1	2	0	0	4	10	3.00
8 - 15-Aug	5	3	1	6	4	5	0	11	1	1	2	15	4.50

The presence of Sandwich Terns in May is coincident with late passage to other more northerly breeding colonies in North Norfolk, the Farne Islands and Coquet Island, and the presence of unusually large numbers compared to previous surveys documented by Perrow *et al.* (2008) may have been linked to the particularly cold and tardy spring in 2013.

The persistence of some Sandwich terns throughout the breeding season was far more unusual and breeding was suspected. A photograph on 22nd July, showed two birds that were apparently incubating, with a later picture on 15th August showing one adult brooding a relatively large chick and thus confirming that breeding has taken place. This is thought to be the first incidence of breeding of Sandwich Terns at Scroby since the last known breeding attempt in 1976, when the main bank at Scroby was last emergent before its recent re-emergence in 2004. Prior to this, like Common Tern, Sandwich Tern was a regular breeder on Scroby Sands from at least 1947 when the colony was discovered, until 1965, with between 16-450 pairs present.

The occurrence of large numbers towards the end of breeding season is typical, although numbers are generally variable (Perrow *et al.* 2008). However, the numbers present in 2013 were particularly large with 1,612 adults and four fledged juveniles recorded at rest on the main bank on 31st July, alongside the large numbers of Common Tern (see 3.1.2 above). At least 816 adults were also present on 15th August.

As for the other tern species, the KDE for Sandwich Tern suggested the area around the main sand bank to the south of the wind farm was important (Figure 10), with a second concentration of activity around the often turbulent waters around Caister Shoal. A buoy at Caister Shoal is also particularly attractive to resting Sandwich terns. There was little connectivity between the two hotspots, although areas of lesser density did extend into the north-western and south-western corners of the wind farm.

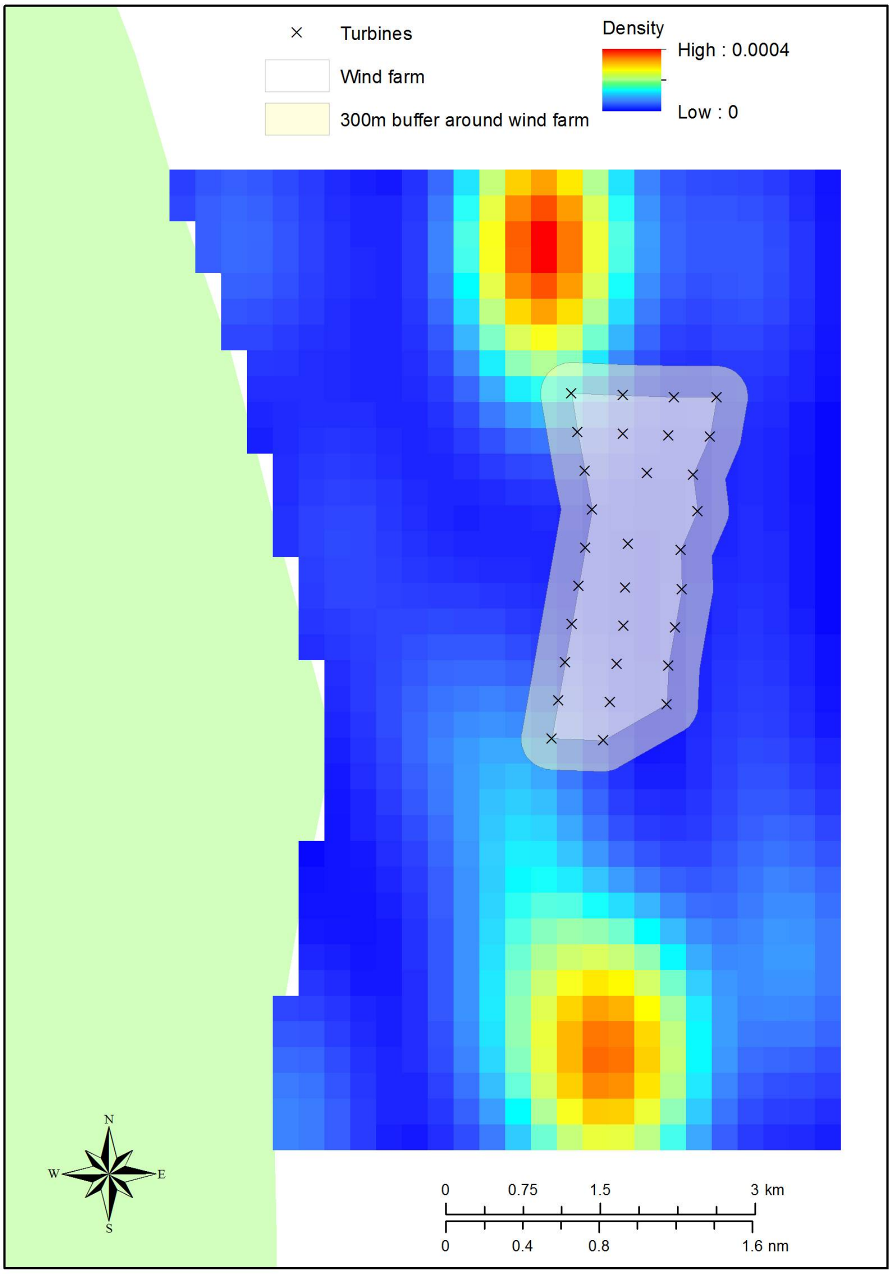


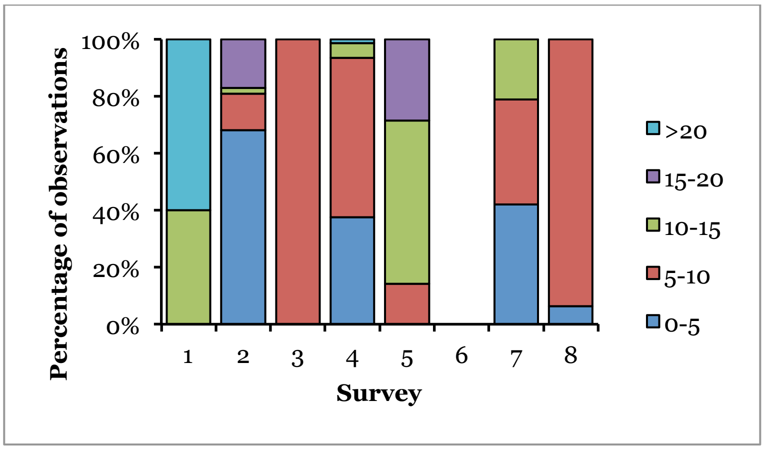
Figure 10. Mean relative density surface of Sandwich Terns within the study area based on Distance corrected snapshot densities derived from each of the eight surveys conducted in 2013.

4.2 Collision risk of terns

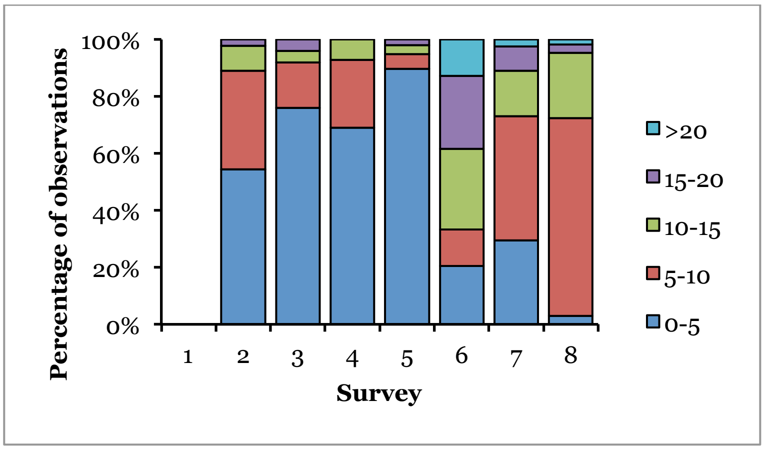
4.2.1 Flight height distribution

The flight height distribution of the three tern species based on the categories used during the surveys revealed species-specific differences (Figure 11). When recorded, Little Tern was generally seen at between 0 and 10 m above the sea (83.3% of all records). Some birds were seen at between 10 and 20 m (14.5% of all records) and very few birds were seen above this (2.3%). Common Tern was also generally recorded below 10 m (76.8% of all records) with fewer between 10 and 20 m (21.1% of all records) with only 2% of records above 20 m.

a)



b)



c)

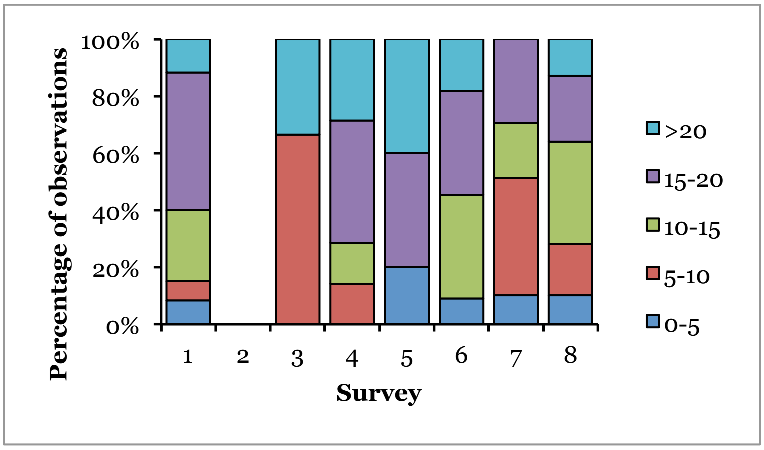


Figure 11. Percentages of a) Little Tern, b) Common Tern and c) Sandwich Tern recorded at different flight heights during snapshots in each survey.

In contrast, Sandwich Tern was less frequently recorded below 10 m (31.4% of all records) and was seen most often between 10 and 20 m (58.6% of all records). Out of the three species Sandwich Tern was recorded more at heights above 20 m (9.9% of all records).

There was considerable variation in the percentages of observations made in different flight height bands between surveys for all three species (Figure 11), dependent, in part, on the numbers of observations of birds made during each survey. Nevertheless, there were some discernible patterns that may be linked to particular events. For example, the high proportion of Little Tern at heights >20 m at the beginning of the season was linked to the small number of birds being observed in display flight, particularly near the previous North Denes colony. Thereafter, variation may be caused by difference in foraging or commuting behaviours. Although foraging appears to be generally conducted at <10 m, commuting birds may respond to wind direction and strength, either flying at just above wave height in a headwind and using a tailwind at greater height.

Common Tern appeared to shift flight height distribution as the season advanced, with a greater proportion of flights below 5 m from May to early July coincident with the bulk of the incubation period. A greater mixture of flight heights, particularly into the 5-10 m bracket as the season advanced could possibly be linked to changes in flight behaviour associated with commuting to and from the colony to provision chicks. It is of note that prey density had declined considerably in the study area by this time (see 3.3 below) suggesting an increase in search time and the potential commuting to the remaining more profitable areas.

In contrast to the other species, Sandwich Tern was generally more consistent, illustrating a greater tendency to occur in the higher flight heights, particularly above 10 m throughout the surveys. This is consistent with the general lack of change in status throughout the surveys, with most birds (with a few exceptions) being recorded prior to breeding at the beginning of the season, after breeding at the end of the season or non-breeding during the middle of the season.

4.2.2 Predicted mortality from snapshot density

The absence of Little Tern in snapshots in the OWF prevented the application of collision risk modelling for this species, although the alternative modelling approach did provide some information on possible risk especially in a historical context.

The predicted mortality rates of Common and Sandwich Tern using Option 1 of the extended model (Band, 2012) and based on both uncorrected and Distance-corrected densities of terns are presented in Table 14.

For both species, two individuals were predicted to collide per annum at an avoidance rate of 98% using uncorrected density estimates. If Distance corrected density estimates are used in the models, the estimated number of collisions rises to 11 for Common Tern and 7 for Sandwich Tern (Table 14).

Without further work, it can only be speculated what effect the rates of collision may have on the dynamics of the populations of Common and Sandwich Terns at Scroby Sands. For Sandwich, the prospects of the embryonic breeding population of Scroby Sands being affected appears to be very small, with the small number of breeding pairs outweighed heavily by non-breeding migrants. As the bulk of Sandwich Tern appear to be migrants, any effect is best judged on the populations concerned which may include colonies in North Norfolk, Farne Islands, Coquet Island and perhaps even the Sands of Forvie. Should the relatively small number of collision be distributed between these colonies this would appear to be relatively trivial at a population-scale. However, should there be a focus on a particular colony, the issue may be more serious, particularly in a cumulative context with other wind farms.

Table 14. Predicted annual number of collisions of Common and Sandwich Tern at Scroby Sands Offshore Wind Farm and at various avoidance rates using Option 1 of the extended Band (2012) model. Estimates are provided based on uncorrected and Distance-corrected density estimates.

Species	**Density**	**Avoidance rate (%)**				
		0	**95**	**98**	**99**	**99.5**
Common Tern	Uncorrected	104	5	2	1	1
	Corrected	568	28	11	6	3
Sandwich Tern	Uncorrected	89	4	2	1	0
	Corrected	328	16	7	3	2

For Common Tern, the loss of even a few birds could conceivably be important to the small breeding population. In many respects, the population of Common Tern is similar to the Little tern modelled by Mackenzie *et al.* (2011), albeit with a smaller population of ~400 individuals compared to the ~600 individuals within the Little Tern population. Assuming similar population dynamics, the loss of a maximum of 11 Common Terns per annum equating to ~2.75% of the population is similar to the modelled loss for Little tern under different scenarios (2-3% of the population per annum). Under all scenarios, the impact on the Little Tern population was marked over the lifetime of the Scroby Sands OWF. In turn, the implication is that the Common Tern may be of similar cause for concern, at least under the worst-case scenarios presented (avoidance rate of 98% using distance-corrected density estimates).

4.2.3 Predicted mortality of Little terns

The relationship between the counts of Little terns conducted over 1 km at the 12 stations during each survey and the uncorrected density estimates derived from snapshots conducted during the same 1 km transects suggested a strong linear relationship (Figure 12):

$$y = 1.6065\,x \qquad r^2 = 0.710 \qquad p < 0.001 \text{ (eq. 8)}$$

where y = snap derived density (ind. km^{-2}) and x = count from line transect and the intercept is assumed to be zero.

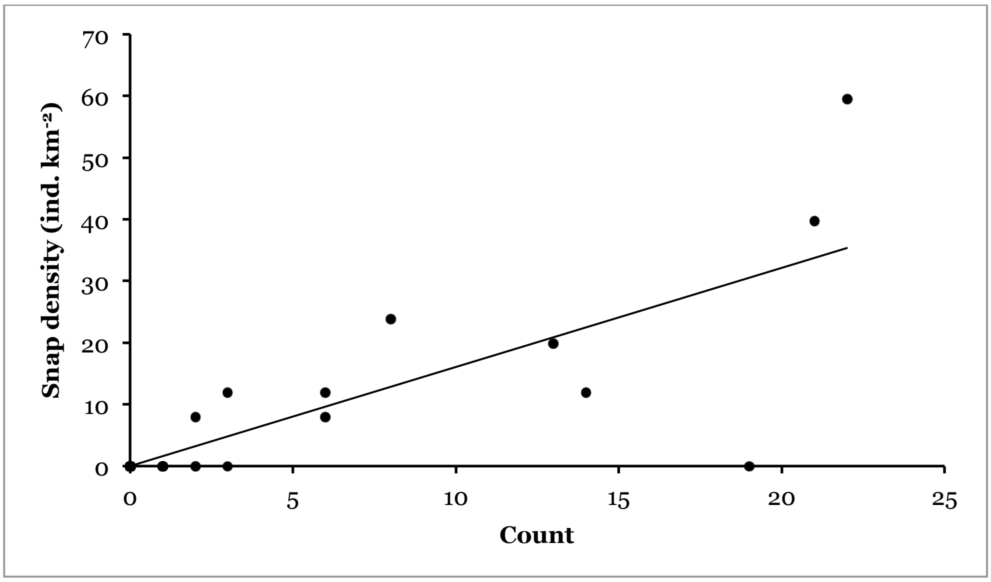


Figure 12. Relationship between counts at sample stations and uncorrected density estimates derived from snapshots with a 200 m radius for Little Tern from surveys in 2013.

Further collision risk modelling was undertaken for Little Tern. This used the densities derived from the count data, based on the relationship described in Section 3.1.4 applied to survey stations within and close to the wind farm (stations 4, 7 and 8). Note that the wind farm was fully commissioned in March 2004. These collision estimates suggest that in 2013, given a 98% avoidance rate, 3 individuals might collide with a turbine during the breeding season (Table 15).

Table 15. Predicted annual number of fatalities of Little Tern at Scroby Sands wind farm and at various avoidance rates using Option 1 of the extended Band (2012) model. Estimates are based on corrected count densities.

Year	Avoidance rate (%)				
	0	95	98	99	99.5
2002	49	2	1	0	0
2003	107	5	2	1	1
2004	977	49	20	10	5
2005	1429	71	29	14	7
2006	491	25	10	5	2
2013	128	6	3	1	1

This compares with historical collision estimates ranging between 1 and 29 individuals (at 98% avoidance) during the breeding season, reflecting inter-annual variation in the overall numbers of birds using the study area and the specific sampling stations (7, 4 and 8).

It is of note that the estimates for 2004, 2005 and 2006 broadly resemble those produced using radio-telemetry of individual adults and a different collision risk modelling system that were used by Mackenzie *et al.* (2013) as shown in Table 16.

The mean predicted annual risk from 2004-2006 inclusive using count data was 19 individuals per annum compared to 16 birds per annum using data derived from radio-telemetry. The key difference was the shift in the year of highest annual risk from the elevated collision risk in 2006 shown by radio-tagged birds to 2005 using count data, albeit pooling data from inside and close to the wind farm.

Table 16. Predicted annual number of fatalities of Little Tern at Scroby Sands OWF from 2004-2006 inclusive and at various avoidance rates derived from use of radio-tagged birds and the occupancy model of Band *et al.* (2007).

Year	Avoidance rate (%)				
	0	95	98	99	99.5
2004	0	0	0	0	0
2005	513	26	10	5	3
2006	1947	97	39	19	10

Whereas the levels of mortality predicted in 2004-2006 and especially in the latter years of this period were thought likely to induce a negative impact upon the population if actually realised, it seems unlikely that the precautionary risk predicted in 2013 would be unlikely to do so.

4.3 Prey available to terns

The prey trawls conducted during the 1 km transect counts of birds at the 12 survey stations captured a total of 10,058 organisms, allocated to 26 categories, including a number of fish species and invertebrates (Table 17). Generally, the most abundant component of the catches was Sea Gooseberry, with over 7,000 individuals sampled during the survey on the 2nd July (survey 5). Clupeids (Herring and Sprat) were also relatively abundant in some of the catches, particularly at the start of June (survey 3). Sea Slater were present in low numbers throughout the surveys supplemented by Ghost Shrimp on occasion.

Details of the densities and biomass of all prey items, clupeids and the densities of sea gooseberries as well as a summary of the water depths and measurements of water clarity at each station during each survey are provided in Appendix 7.3. Density and biomass trends from each survey over the season are shown in Figure 13 and Table 18 with the latter also showing mean clarity measurements.

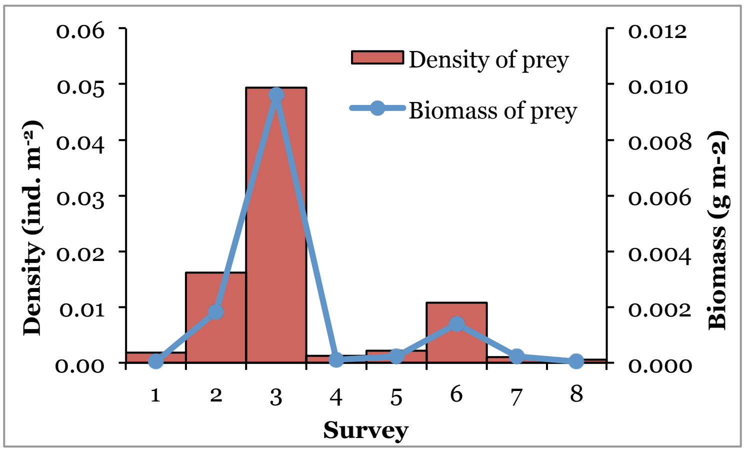
Overall prey density and biomass increased during May (surveys 1 and 2) peaking during the start of June (survey 3) at 0.049 ind. m^{-2} and 0.01 g m^{-2} respectively (Table 17 and Figure 14). Following this peak, both the abundance and biomass of all prey items fell sharply, but there appeared to be a smaller secondary increase during July (surveys 5 and 6) peaking at a density of 0.011 ind. m^{-2} and biomass of 0.001 g m^{-2}. The overall trends in the abundance and biomass of prey were ultimately driven by the clupeids present in the catch, as illustrated by the similarities between the density and biomass estimates (Table 18 & Figure 13). Interestingly, the abundance of Sea gooseberries appeared to demonstrate a similar trend as that shown by the clupeids but with a lag of approximately one month (Figure 13).

Table 17. Total numbers of organisms captured during prey trawls during each of the eight surveys (12 survey stations) conducted in 2013.

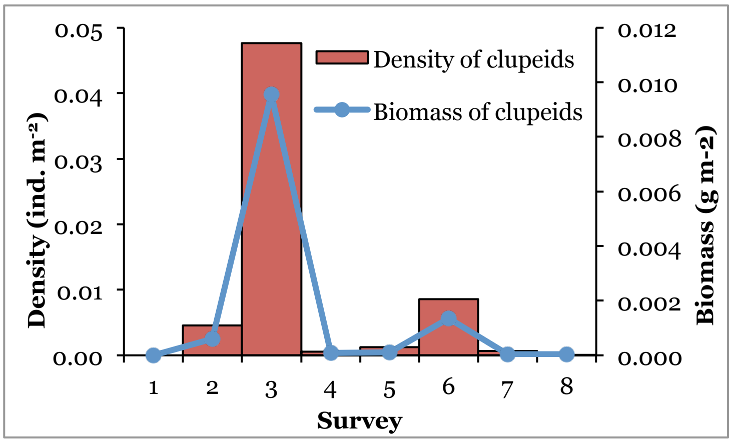
Taxon	Survey								Total
	1	2	3	4	5	6	7	8	
Lesser sandeel *Ammodytes tobianus*		31	1						32
Garfish *Belone belone*						2			2
Stickleback *Gasterosterus aculeatus*	1							1	2
Lesser pipefish *Sygnatus rostellatus*		3							3
Monkfish *Lophius piscatorius*		1							1
Herring *Clupea harengus*			14	3		21			38
Sprat *Sprattus sprattus*			17	1		1			19
Unidentifed larval clupeid		49	18	2	12	44	7		132
Unidentifed clupeid			465		1	27		1	494
Unidentifed larval sole		7							7
Unidentifed larval fish		4				1		1	6
Ghost shrimp *Schistomysis spiritus*	2	52	5	1			2		62
Schistomysis ornata		1							1
Chaetogammarus marinus	8	20	12	2					42
Sea slater *Idotea linearis*	6	2	1	3	9	1	1	3	26
Sea spider *Endeis spinosa*						19			19
Little cuttle *Sepiola atlantica*		1							1
Sea gooseberry *Pleurobranchia pileus*		86	397	1168	7040	106	188	111	9096
Unidentified Mysid shrimp							1		1
Unidentified Acorn worm					1				1
Razor shell clam *Ensis* spp.						63			63
Gnathopod				1					1
Water boatman Corixidae	1								1
Nematode worm		4							4
Fluke worm -Trematoda	1								1
Fly - Insecta	1								1
Total prey numbers	20	175	533	13	23	116	11	6	897
Total clupeid numbers	0	49	514	6	13	93	7	1	683
Grand Total	20	263	930	1181	7063	285	199	117	10058

In 2013, the peak density of clupeids (herring, sprat and unidentified clupeids combined) was 0.38 ind. m^{-2} at site 10 (North Denes) on 5th June. A peak relatively early in the season tends to indicate a relatively high proportion of Herring in the catch, as the young of this species hatch from eggs laid the previous autumn by the local stock. In other words, there is no reliance upon drift of young fish to the area, which is thought to be the case for young Sprat, which are spawned and hatched much later in the season further offshore (see Coull *et al*. 1998, Perrow *et al*. 2008). It is possible however that fish born the previous year (1+), rather than young-of-the-year (YOY) contribute to the catches early in the season and any 1+ could be either Herring or Sprat.

a)



b)



c)

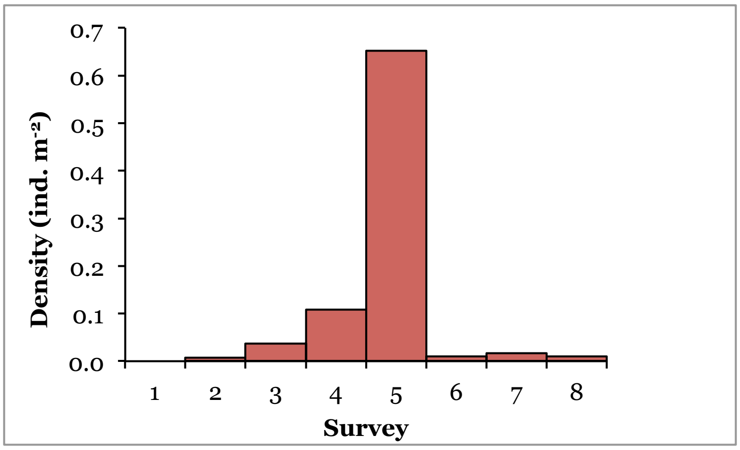


Figure 13. Density and biomass of a) all prey items and b) clupeids and c) density of Sea gooseberries in tow net samples during each survey.

Table 18. Overall densities and biomass of all prey items, clupeids alone and Sea gooseberries derived from prey trawls conducted in 2013.

Survey	Mean clarity (m) ± 1 SD	Density (ind. m^{-2})			Biomass (g m^{-2})	
		All prey	Clupeids	Sea Gooseberry	All prey	Clupeids
1	2.112 (0.839)	0.002	0.000	0.000	0.000	0.000
2	0.991 (0.613)	0.016	0.005	0.008	0.002	0.001
3	0.672 (0.349)	0.049	0.048	0.037	0.010	0.010
4	1.139 (0.585)	0.001	0.001	0.108	0.000	0.000
5	0.969 (0.558)	0.002	0.001	0.652	0.000	0.000
6	1.055 (0.653)	0.011	0.009	0.010	0.001	0.001
7	1.148 (0.555)	0.001	0.001	0.017	0.000	0.000
8	1.065 (0.337)	0.001	0.000	0.010	0.000	0.000

The length frequency distribution of clupeids is however consistent with the view that most fish captured were indeed YOY, although some 1+ fish were also represented in catches. Two peaks within the individuals sampled, shifted as the season progressed according to somatic growth of the fish (Figure 14). These two peaks were clearer during some of the surveys (e.g. surveys 2, 4 and 6) than others, perhaps when fewer 1+ fish were present to confound interpretation.

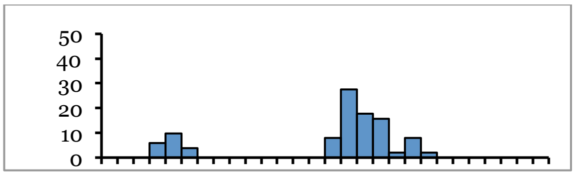
Previous studies support the view that the smaller fish entering samples at 10-12 mm, which are in fact too small to be sampled efficiently, are Sprat spawned offshore in spring that drift to the area. The larger group of fish entering samples at a mean of around 34 mm are most likely to be the locally-recruited Herring that are spawned in the previous winter and hatch in early spring. Attempts to identify individuals were not always conclusive, although a number of specimens were identified as Herring and Sprat and tended to support the basic conclusions drawn from length-frequency distributions.

In previous studies Herring have disappeared from samples later in the season, from about mid-June. This could be because they move further offshore, although they could abandon the surface layers where they are vulnerable to predation by birds or they may be depleted by predation by birds or even Sea Gooseberry. It is of note that Sea gooseberries are relatively frequently recorded containing small invertebrates or small clupeid fish, and the increase in their numbers in early July coincides neatly with the decline in clupeids

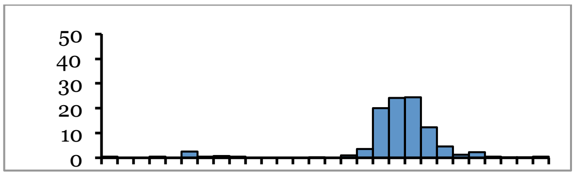
In 2013, whilst the general pattern held true with a radical decline in clupeid abundance after the peak in early June (Figure 13), the length-frequency distribution suggested that some Herring persisted almost through the entire season. Whilst the relative abundance of YOY Sprat generally increased over the season (Figure 14), their numbers did not compensate for the decline of Herring in terms of the overall abundance and biomass of clupeids (Figure 13).

Pile-driving to construct the wind farm was perceived to be the major factor in the decline of herring recruitment with consequences for the feeding rate and perhaps breeding success of Little Tern at North Denes (Perrow *et al.* 2011a).

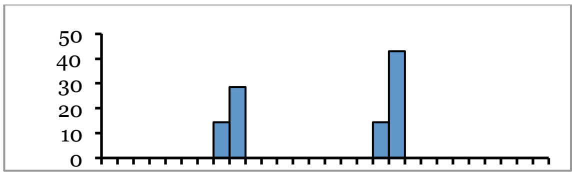
Survey 2 (3rd May)



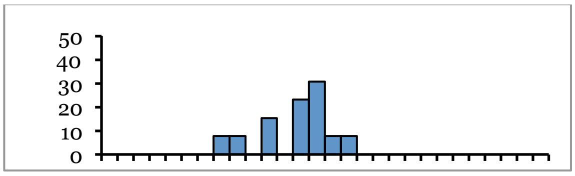
Survey 3 (27th May)



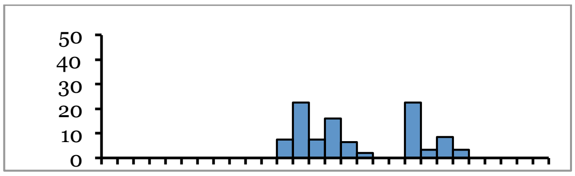
Survey 4 (19th Jun)



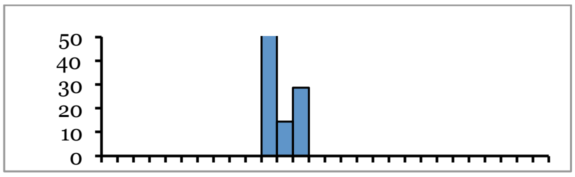
Survey 5 (2nd Jul)



Survey 6 (22nd Jul)



Survey 7 (31st Jul)



Survey 8 (15th Aug)

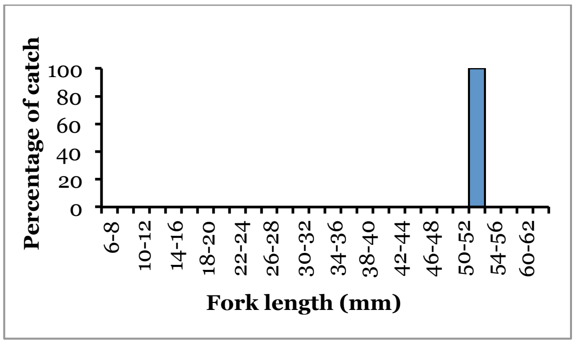


Figure 14. Length frequency distribution expressed as percentage of catch of all clupeids captured during all surveys in 2013. Note that no clupeids were caught during the first survey in the series.

Prior to the construction of the wind farm, the density of clupeids, mainly Herring within the study area reached a peak of >2 ind. m^{-2} in 2003, with a lower density in 2002 of 0.4 ind. m^{-2}, although missing early season samples meant that the true density was thought to be much higher.

From 2004-2006, peak density ranged between 0.07 and 0.15 ind. m^{-2}. In 2013, a peak density of 0.38 ind. m^{-2} thus provides clear evidence of some recovery of the Herring stock in the area. In general terms, this could be described as an average density, and bearing in mind the success of Little terns in 2006 at lower fish density, may be seen as being more than adequate to support a breeding population of Little terns.

5. Concluding summary

5.1 Terns breeding on Scroby Sands

The main bank of Scroby Sands was used as a breeding site by Common, Little and Sandwich Terns in 2013. What appeared to be a pair of Roseate Tern *Sterna dougallii* were observed within the Common Tern colony on 22nd July, although it is not known if these birds nested. The use of the bank as a breeding site continues its recent use by Common and Little terns that commenced in 2010 after the re-emergence of the bank at all states of tide in 2004, immediately after the construction of the wind farm.

Use as a breeding site supplemented the use of Scroby Sands as a stopover site particularly in late summer when extremely large numbers of Common (peak count of 1,763 adults at rest on the bank on 31st July) and Sandwich Terns (peak of 1,612 adults at rest on the bank on 31st July) were recorded, supplementing the breeding birds that still appeared to be largely present.

An initial nesting attempt by around 33 pairs of Little Terns in mid-June was unsuccessful as a result of a high tide in late June. Re-nesting occurred with a peak of 70 nests by mid-July. The fate of these nests is largely unknown but most appear to have failed although a few Little terns (perhaps 9) may have fledged over the course of the season. The occupancy of Little terns of the site was therefore sporadic and did not approach the level of use in recent years, especially in 2011 when 180-200 pairs fledged around 80 young.

Common terns maintained a large colony throughout the breeding season of 2013, with a minimum of 174 nests put down and at least 100 young thought to have fledged.

The record of breeding Sandwich terns (two nests) appears to be the first since 1976, the last year of a period of emergence for the main Scroby bank.

5.2 Use of the wind farm and predicted collision risk

No Little terns were recorded within the OWF in snapshots during the surveys, although there was a single casual record. As a result there was no predicted collision risk.

The mean density surface of Little terns showed concentrations around the southern end of Scroby Sands and around the former colony at North Denes. The use of the latter appears to be by birds prior to nesting and as a result of failure at the main colony at Winterton. The area around North Denes consistently produced the highest densities of prey across the entire Scroby area. Length frequency suggested some recruitment of young-of-the-year Herring and provided evidence of the recovery of the stock affected by pile-driving during the construction of the OWF in late 2003. Density could be described as average.

In contrast to Little tern, a moderate density of Common Tern was recorded in the southern and especially south-eastern part of the OWF, although the main concentration of use was around the southern part of Scroby, Distance-corrected density estimates were around three fold or more that of uncorrected estimates.

A similar pattern was also recorded for Sandwich Tern, although the density surface for this species, encountered mainly at the beginning and end of the breeding season suggested only moderate use of the north-western part of the OWF. The predicted collision ranged from 2-7 Sandwich Terns per annum at 98% and 2-11 Common Terns per annum at 98% avoidance for corrected and uncorrected estimates respectively.

5.3 Risk of population-scale impacts of collision

In an attempt to verify the previous suggested collision risk for Little Tern from North Denes and to provide context for an alternative means of estimating risk to Little Tern in 2013, a relationship was established between counts of Little terns at the 12 survey stations and the density suggested in snapshots within those surveys stations. This resulting linear relationship (with an $r^2 = 0.71$) allowed previous count data (from 2002-2006) to be converted to density and modelled in the same way as conducted in this study. To compensate for the fact that just a single survey station has been sampled within the OWF over time (sample station 7), in which very few Little terns had been recorded (when individually radio-tagged birds had shown higher use), two further stations immediately to the east (sample station 4) and south (sample station 8) of the OWF were also selected. The mean counts at these stations were converted to density and subject to collision risk modelling.

The mean estimates across years that were produced were remarkably similar to previous modelling using a different modelling system with data derived from radio-telemetry (mean of 19 individuals per annum compared to 16 individuals per annum respectively). This reinforced that although the risk of collision in 2013 was low (in the range of 0-3 individuals per annum with every likelihood this was closer to zero), the risk could easily be much higher and a threat to the population should this prove to be the case.

Using the previous population modelling of Little terns as a guide, where similar proportions of the population were predicted to be lost under some scenarios, suggested that the breeding population of Common Tern could well be damaged if the predicted collision risk was realised. The fact that the current Common Tern population of Scroby Sands (mean of 116 pairs from 2010-2013 inclusive) appears to represent 1.15% of the GB breeding population (Baker *et al.* 2006) provides inherent conservation interest.

The rise of the breeding population of Scroby coincides with the recent decline in numbers at Breydon Water SPA, where around 50 pairs have been 'lost'. It would seem likely that these have been incorporated into the Scroby Sands colony, with the majority of pairs perhaps taken from the pool of younger birds produced from previous successful recruitment at the Breydon Water SPA.

The likelihood of damage to the embryonic breeding population of Sandwich terns at Scroby Sands appeared to be very low, with most birds probably linked to larger colonies elsewhere in Great Britain (e.g. North Norfolk, Farne Islands and Coquet Islands). Any loss would make a further small contribution to the cumulative collision encountered by these populations from OWF's around the UK and along their migration route.

5.4 Conclusions & recommendations

In conclusion, although there is potential for the Scroby Sands OWF to be a threat to the East Norfolk Little tern population, the actual risk cannot be truly quantified until sampling is conducted in a season when Little Terns nest at Scroby Sands in large numbers. To date, it is the risk to birds previously nesting at North Denes that has been reinforced by this study.

Further sampling is therefore recommended, preferably over at least two further seasons to compensate for changes in the population during the course of the season (i.e. birds may fail or alternatively re-nest at Scroby Sands). The extension of the study area to the south to incorporate the relative use of Holm Sands is recommended, as it may be that this is a key area for Little Terns nesting at Scroby Sands, with the potential to reduce the use of the OWF to the north.

More thorough monitoring of the actual numbers of nests laid by the different species and their ultimate productivity is also recommended, with this being best undertaken by landing on the bank using a small craft from the main survey vessel. Scrupulous care to avoid excessive disturbance would be exercised.

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7. Appendices

7.1 Appendix 1: Distance correction of snapshot data

7.1.1 Little Tern

The best Distance model for the Little Tern (observations n=41) was composed of a half-normal key function without adjustment terms. It has an AIC of 112.17, a Chi-square test p-value of 0.133 and a coefficient of variation of 28.8%. The probability of detection for this species was 0.20.

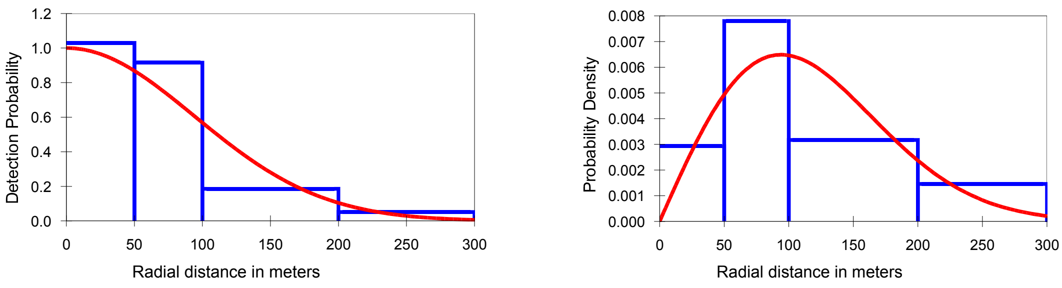

Figure 7.1. Detection probability and probability density of the best Distance model for Little tern.

7.1.2 Common Tern

The best Distance model for the Common Tern (observations n=249) was composed of a hazard-rate key function without adjustment terms. It has an AIC of 633.91, a Chi-square test p-value of 0.459 and a coefficient of variation of 21.2%. The probability of detection for this species was 0.32.

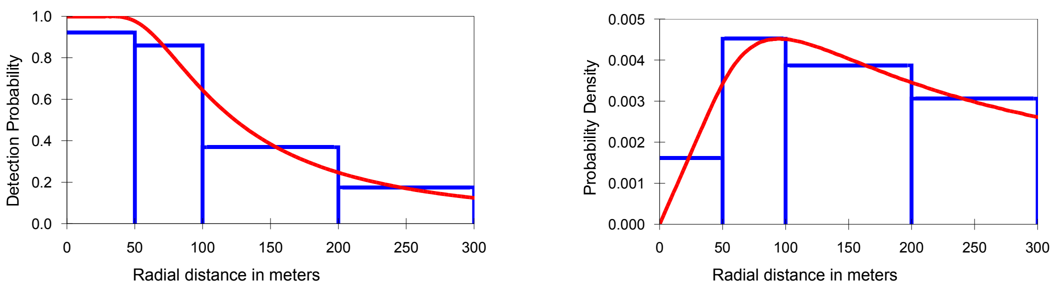

Figure 7.2. Detection probability and probability density of the best Distance model for Common tern.

7.1.3 Sandwich Tern

The best Distance model for the Sandwich Tern (observations n=143) was composed of an half-normal key function without adjustment terms. It has an AIC of 369.69, a Chi-square test p-value of 0.105 and a coefficient of variation of 16.9%. The probability of detection for this species was 0.42.

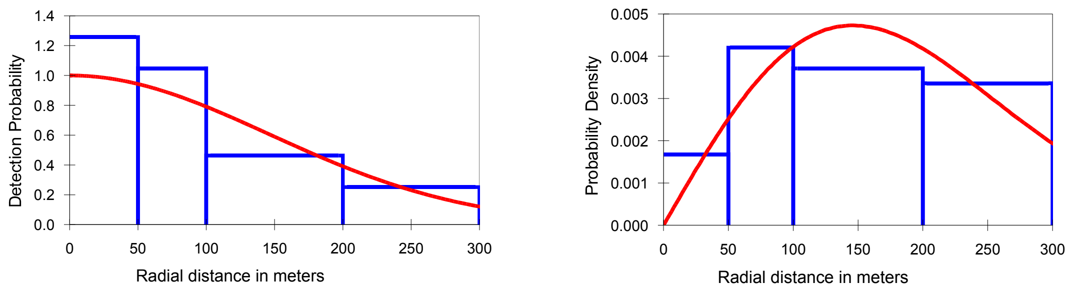

Figure 7.3. Detection probability and probability density of the best Distance model for Sandwich tern.

7.2 Appendix 2: Observations of terns on Scroby Sands main bank.

Table 7.1. Counts of terns on Scroby Sands during survey 7 (31st July 2013).

Species	Age	Count	Notes
Little	Adults	107	
	Juvenile	9	
	Nests	25	In two locations (2+23)
Common	Adult	1763	In three locations (306+1357+100)
	Juvenile	100	In two locations (74+26)
	Nests	73	In three locations (5+28+40)
Sandwich	Adult	1612	
	Juvenile	4	
Roseate	Adult	1	
Combined total		3694	

Table 7.2. Counts of terns on Scroby Sands during survey 8 (15th August 2013).

Area	Species	Age	Count	Notes
Eastern edge	Little	Adult	1	
	Common	Adult	40	
		Juvenile	31	12 not entirely fledged
Main colony	Common	Adult	28	
		Chick	1	
		Juvenile	19	
	Sandwich	Adult	95	
Roost	Common	Adult	1058	
		Juvenile	10	
	Sandwich	Adult	248	
Bathing	Little	Adult	11	
		Juvenile	5	
	Common	Adult	16	
		Juvenile	11	
	Sandwich	Adult	12	
Other Common tern colony (middle bank)	Common	Adult	10	
		Chick	10	
Inlet group	Little	Adult	34	On nests, no obvious chicks
TOTALS	Little	Adult	46	
		Juvenile	5	
	Common	Adult	1152	
		Juvenile	71	
		Chicks	11	
	Sandwich	Adult	355	
Combined total			1640	

Table 7.3. Counts of terns derived from a panoramic photograph of the main Scroby Sand bank during survey 8 on the 15th August 2013.

Species	Age	Count
Little	Adult	2
Common	Adult	1547
	Juvenile	62
Sandwich	Adult	804
Combined total		2415

7.3 Appendix 3: Summary of prey data by survey and survey station

Table 7.4. Summary of results from prey trawls at each survey station during the eight surveys in 2013.

Survey	Station	Depth (m)	Clarity (m)	Density (ind. m-2)			Biomass (g m-2)	
				All prey	Clupeid	Sea Goosebery	All prey	Clupeid
1	1	13.0	2.0	0.001	0.000	0.000	0.000	0.000
	2	3.0	2.0	0.001	0.000	0.000	0.000	0.000
	3	5.3	2.5	0.003	0.000	0.000	0.000	0.000
	4	8.7	2.5	0.001	0.000	0.000	0.000	0.000
	5	21.4	2.8	0.002	0.000	0.000	0.000	0.000
	6	5.1	2.0	0.001	0.000	0.000	0.000	0.000
	7	11.2	4.0	0.000	0.000	0.000	0.000	0.000
	8	7.8	2.6	0.001	0.000	0.000	0.000	0.000
	9	5.3	1.5	0.001	0.000	0.000	0.000	0.000
	10	9.1	1.0	0.003	0.000	0.000	0.000	0.000
	11	6.5	1.0	0.003	0.000	0.000	0.000	0.000
	12	6.6	2.0	0.003	0.000	0.000	0.000	0.000
2	1	11.8	1.5	0.002	0.000	0.049	0.000	0.000
	2	5.7	1.5	0.003	0.000	0.006	0.000	0.000
	3	6.2	2.0	0.008	0.000	0.000	0.000	0.000
	4	9.2	1.5	0.004	0.000	0.000	0.000	0.000
	5	17.5	1.5	0.001	0.000	0.000	0.000	0.000
	6	8.4	2.8	0.001	0.000	0.039	0.000	0.000
	7	6.2	1.5	0.003	0.000	0.000	0.000	0.000
	8	3.2	1.5	0.009	0.002	0.002	0.000	0.000
	9	7.0	0.5	0.080	0.014	0.000	0.005	0.001
	10	9.1	0.5	0.032	0.011	0.000	0.005	0.002
	11	4.7	1.0	0.020	0.013	0.000	0.004	0.002
	12	5.6	1.4	0.030	0.013	0.000	0.007	0.002
3	1	20.0	1.3	0.001	0.000	0.010	0.000	0.000
	2	6.5	1.5	0.003	0.001	0.037	0.000	0.000
	3	5.6	0.8	0.006	0.000	0.011	0.000	0.000
	4	11.9	2.3	0.000	0.000	0.014	0.000	0.000
	5	20.3	2.5	0.001	0.000	0.000	0.000	0.000
	6	4.6	1.8	0.000	0.000	0.030	0.000	0.000
	7	6.2	2.0	0.002	0.000	0.011	0.000	0.000
	8	10.3	1.3	0.000	0.000	0.007	0.000	0.000
	9	6.1	0.9	0.009	0.009	0.011	0.002	0.002
	10	11.2	0.5	0.378	0.377	0.069	0.080	0.080
	11	4.5	0.5	0.152	0.148	0.217	0.030	0.029
	12	5.5	1.0	0.040	0.037	0.024	0.004	0.004
4	1	11.0	2.0	0.000	0.000	0.054	0.000	0.000
	2	5.3	0.8	0.000	0.000	0.383	0.000	0.000
	3	4.9	1.2	0.001	0.000	0.001	0.000	0.000
	4	8.3	1.5	0.000	0.000	0.063	0.000	0.000
	5	15.2	2.0	0.000	0.000	0.047	0.000	0.000
	6	3.1	2.3	0.000	0.000	0.341	0.000	0.000
	7	5.3	1.0	0.001	0.000	0.000	0.000	0.000
	8	10.1	1.0	0.000	0.000	0.004	0.000	0.000
	9	5.3	1.0	0.000	0.000	0.002	0.000	0.000
	10	7.9	1.0	0.001	0.000	0.023	0.000	0.000
	11	3.9	0.5	0.004	0.002	0.108	0.000	0.000
	12	5.4	1.0	0.007	0.004	0.270	0.001	0.001
5	1	14.1	1.8	0.000	0.000	0.052	0.000	0.000
	2	4.7	2.0	0.000	0.000	0.152	0.000	0.000
	3	5.4	1.5	0.000	0.000	0.110	0.000	0.000
	4	8.7	1.6	0.000	0.000	0.064	0.000	0.000
	5	16.0	1.8	0.001	0.000	0.044	0.000	0.000
	6	4.2	1.0	0.000	0.000	0.262	0.000	0.000
	7	6.1	1.3	0.000	0.000	0.100	0.000	0.000

Survey	Station	Depth (m)	Clarity (m)	Density (ind. m^{-2})			Biomass (g m^{-2})	
				All prey	Clupeid	Sea Goosebery	All prey	Clupeid
	8	10.5	1.5	0.000	0.000	0.133	0.000	0.000
	9	6.5	0.8	0.002	0.002	0.088	0.000	0.000
	10	11.3	0.6	0.006	0.006	0.113	0.001	0.001
	11	4.7	0.5	0.007	0.007	3.086	0.001	0.001
	12	4.7	0.5	0.010	0.000	3.617	0.001	0.000
6	1	13.7	2.3	0.001	0.000	0.002	0.000	0.000
	2	5.8	2.0	0.000	0.000	0.043	0.000	0.000
	3	6.0	2.0	0.000	0.000	0.000	0.000	0.000
	4	10.2	2.0	0.000	0.000	0.000	0.000	0.000
	5	18.6	2.3	0.002	0.000	0.000	0.000	0.000
	6	5.2	2.0	0.000	0.000	0.017	0.000	0.000
	7	7.2	2.0	0.001	0.000	0.000	0.000	0.000
	8	10.6	2.0	0.000	0.000	0.003	0.000	0.000
	9	6.2	0.8	0.002	0.002	0.000	0.000	0.000
	10	10.1	0.5	0.078	0.071	0.052	0.010	0.010
	11	6.7	1.1	0.044	0.030	0.000	0.006	0.006
	12	5.8	1.8	0.000	0.000	0.000	0.000	0.000
7	1	19.9	1.0	0.000	0.000	0.008	0.000	0.000
	2	3.1	1.0	0.000	0.000	0.009	0.000	0.000
	3	5.8	1.9	0.000	0.000	0.000	0.000	0.000
	4	8.6	2.0	0.001	0.000	0.014	0.000	0.000
	5	14.3	1.8	0.000	0.000	0.001	0.000	0.000
	6	10.8	1.1	0.000	0.000	0.010	0.000	0.000
	7	7.0	2.0	0.000	0.000	0.034	0.000	0.000
	8	5.5	1.0	0.002	0.000	0.033	0.002	0.000
	9	5.1	1.3	0.000	0.000	0.006	0.000	0.000
	10	7.4	0.5	0.009	0.008	0.023	0.001	0.001
	11	6.0	0.6	0.000	0.000	0.012	0.000	0.000
	12	5.8	1.0	0.000	0.000	0.058	0.000	0.000
8	1	13.9	1.0	0.001	0.000	0.028	0.000	0.000
	2	4.5	1.1	0.000	0.000	0.018	0.000	0.000
	3	4.9	0.9	0.000	0.000	0.023	0.000	0.000
	4	8.9	1.0	0.000	0.000	0.003	0.000	0.000
	5	18.7	1.8	0.000	0.000	0.000	0.000	0.000
	6	5.2	1.3	0.000	0.000	0.027	0.000	0.000
	7	6.8	1.0	0.000	0.000	0.001	0.000	0.000
	8	10.8	1.5	0.000	0.000	0.017	0.000	0.000
	9	5.6	0.8	0.000	0.000	0.002	0.000	0.000
	10	6.8	1.1	0.001	0.001	0.003	0.000	0.000
	11	4.2	0.7	0.004	0.000	0.001	0.000	0.000
	12	5.9	1.0	0.000	0.000	0.000	0.000	0.000