From:	Dominika Phillips
To:	Hornsea Project Three; Kay Sully; KJ Johansson
Cc:	Andrew Guyton; Stuart Livesey
Subject:	Hornsea Project Three (UK) Ltd response to Deadline 3 (Part 6)
Date:	14 December 2018 21:01:35
Attachments:	image001.png D3_HOW03_Appendix 9_McGregor 2018.pdf D3_HOW03_Appendix 10_JNCC 2015.pdf D3_HOW03_Appendix 11_JNCC 2014.pdf D3_HOW03_Appendix 12_Band 2012.pdf D3_HOW03_Appendix 13_Figures to the WQ1.2.46.pdf

Dear Kay, K-J

Please find attached the sixth instalment of documents.

Best regards,

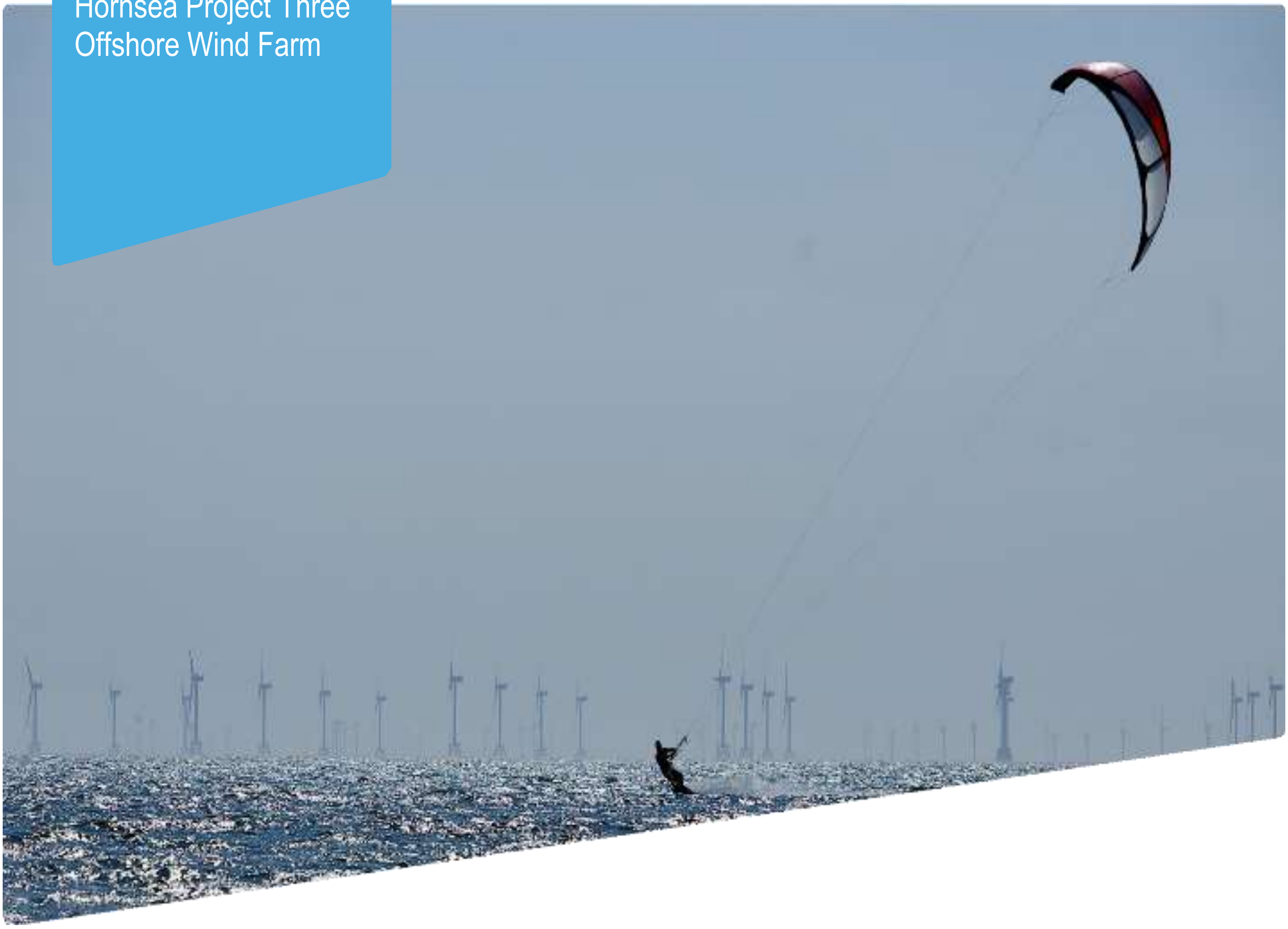
Dr Dominika Chalder PIEMA
Environment and Consent Manager

+44 (0) 7767 007 815

Environmental Management UK│ Wind Power
5 Howick Place │ London │ SW1P 1WG

Orsted

Hornsea Project Three
Offshore Wind Farm



Hornsea Project Three

Offshore Wind Farm

Appendix 10 to Deadline 3 Submission – JNCC Report no 548 – Parsons et al. 2015

Date: 14th December 2018

Hornsea 3
Offshore Wind Farm

Ørsted

Document Control			
Document Properties			
Organisation	Ørsted Hornsea Project Three		
Author	Matt Parsons et al.		
Checked by	n/a		
Approved by	n/a		
Title	Appendix 10 to Deadline 3 Submission – JNCC Report no 548 – Parsons et al. 2015		
PINS Document Number	n/a		
Version History			
Date	Version	Status	Description / Changes
14/12/2018	A	Final	Submitted at Deadline 3 (14/12/2018)

Ørsted

5 Howick Place,

London, SW1P 1WG

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

JNCC Report
No: 548

Quantifying foraging areas of little tern around its breeding colony SPA during chick-rearing

Matt Parsons, Jennifer Lawson, Mark Lewis, Rebecca Lawrence & Amanda Kuepfer

April 2015

ISSN 0963 8901

For further information please contact:

Joint Nature Conservation Committee
Monkstone House
City Road
Peterborough PE1 1JY
http://jncc.defra.gov.uk

This report should be cited as:

Parsons, M., Lawson, J., Lewis, M., Lawrence, R. & Kuepfer, A. 2015. Quantifying foraging areas of little tern around its breeding colony SPA during chick-rearing. *JNCC Report No. 548.* Joint Nature Conservation Committee, Peterborough.

NB This report was originally produced, but not published, in 2014.

Summary

- The EU Birds Directive requires Member States to classify Special Protection Areas (SPA) for birds listed on Annex I to the Directive and for regularly occurring migratory species. The little tern is both migratory and on Annex I to the Directive.

- In the UK, there are currently 28 breeding colony SPAs for which little tern is an interest feature, 23 of which are in England, four in Scotland and one in Wales/England.

- The breeding population size in Great Britain was estimated at 1,900 pairs and that in Ireland at 210 (Mitchell *et al* 2004). The biogeographic population (Europe) is 19,500 (Mitchell *et al* 2004).

- Little tern is categorised as being of "least concern" under the IUCN Red List, and as an "Amber" species in Birds of Conservation Concern 3 (Eaton *et al* 2009).

- In Great Britain, the long term trend has been upward, with a 22% increase between censuses in 1969-70 and 1999-2002 (Mitchell *et al* 2004). There has been a decrease of nearly 9% between 1999 and 2011 (JNCC 2012).

- This report describes work undertaken between 2009 and 2013 to quantify usage of the marine environment by little tern around its breeding colony SPAs in the UK where these remain regularly occupied (14 colony SPAs). Up to three years of targeted data collection were carried out per SPA at 13 colony SPAs. In addition, data were included from one SPA where little terns bred recently, but not regularly.

- Boat-based and shore-based surveys were undertaken, to quantify foraging extent; the former predominantly to estimate seaward extent, the latter largely to estimate alongshore extent. Results of earlier radio-tracking studies (Perrow & Skeate 2010) were also assessed.

- Field surveys yielded variable amounts of data across study colonies. Five SPA had good seaward and alongshore data, seven lacked seaward and/or alongshore data and two have no usable data. Tern ecology suggests that previously un-occupied locations may become colonised in future and that colony SPAs currently without regularly occurring little terns may be re-occupied.

- Hence the goal of this work was to develop and apply methods that can estimate sea usage at colonies where there are no direct survey data or where shore or sea data are deficient ("generic" method), or where there are good data for both ("site-specific" method).

- The analyses found that colony size and density had a weak effect on foraging range, and so methods were developed to pool data across study sites. Analyses considered the cumulative proportion of observations against distance from colony alongshore and out to sea. Simple metrics derived from the overall data set were compared with cumulative proportion in order to judge which metric provided the best option for objectively setting limits to little tern foraging areas.

- The metric which best represented site-specific seaward extent of foraging was found to be mean of the maximum extents of observations from repeat surveys at that site; site-specific alongshore extent was taken as the maximum extent of alongshore distribution at a site. The metric which best represented generic seaward extent was

found to be the mean of the mean maximum extent obtained for each site; the generic alongshore extent was taken as the mean of the maximum alongshore extents at other sites.

- Data constraints prevented the application of more sophisticated methods for quantifying sea use such as those used for larger tern species (Wilson *et al* 2013) or for similar transect and shore based surveys used for inshore divers ducks and grebes (O'Brien *et al* 2012).

- The quality of the data available for the study locations was assessed and recommendations made on whether to apply site specific or generic metrics for seaward and alongshore extent.

- The outputs from this work may be used to inform the conservation of little terns in the marine environment, including the identification of marine SPAs, marine planning and environmental impact assessments. Parallel work to quantify the marine foraging areas for larger terns is reported separately (Wilson *et al* 2013).

Contents

1. Background

There are five species of tern breeding in Great Britain (GB), all of which are colonial ground-nesters. In order of abundance they are: Arctic tern *Sterna paradisaea* (52,613 pairs), Sandwich tern *S. sandvicensis* (10,536 pairs), common tern *S. hirundo* (10,134 pairs), little tern *Sternula albifrons* (1,927 pairs) and roseate tern *Sterna dougallii* (52 pairs) (Mitchell *et al* 2004). The latter two species are among the rarest seabirds breeding in GB and all five species of tern are listed on Annex 1 of the EU Birds Directive (EU 2009). The EU Birds Directive requires Member States to classify Special Protection Areas (SPA) for birds listed on Annex I of the Directive and for regularly occurring migratory species. In the UK, there are currently 28 breeding colony SPAs for which little tern is an interest feature (Stroud *et al* 2001). These breeding birds are protected both at their breeding colony SPA and while they are at sea through implementation of the Habitats Regulations[1]. However the Birds Directive is widely interpreted to require additional suitable areas for terns at sea to be identified and designated as marine SPAs. Such areas may be extensions to existing SPAs and/or completely separate areas.

This report describes work undertaken between 2009 and 2013 to quantify usage of the marine environment by little tern around its breeding colony SPAs in the UK. The outputs from this work may be used to inform conservation of little tern in the marine environment, including the identification of marine SPAs, marine planning and environmental impact assessments. Parallel work to identify marine foraging areas for larger terns *Sterna spp.* is reported in Wilson *et al* (2013).

2. Status and Ecology of little tern

Little tern is the smallest of the five tern species that breed in the UK, with a body length of 22-24cm and a wingspan of 48-55cm (BWPi 2006) and nests solely on the coast, on sand or shingle beaches, islets and spits (Pickerell 2004).

Little tern is categorised as being of “least concern” under the IUCN Red List, and as an “Amber” species in Birds of Conservation Concern 3 (Eaton *et al* 2009).

The breeding population size of little tern in Great Britain was estimated at 1,900 pairs and that in Ireland at 210 (Mitchell *et al* 2004). Its distribution is wide within the UK but with a concentration of larger colonies in S and SE England and none in the far SW of England and most of Wales. Of the 28 breeding colony SPA in the UK where little tern is a feature, 23 are in England, one in England/Wales and four are in Scotland. The biogeographic population (Europe) is 19,500 (Mitchell *et al* 2004). In Great Britain, the long term trend has been upward, with a 22% increase between censuses in 1969-70 and 1999-2000 (Mitchell *et al* 2004). There has been an increase of 13% between 2000 and 2012 (Eaton *et al* 2013).

The foraging range of little tern – related to its body size - is smaller than that of the larger tern species (Thaxter *et al* 2012; Eglington 2012); this dictates that it nests close to shallow coastal waters with a supply of small shoaling fish such as sandeels and clupeids and invertebrates which comprise its diet (Taylor & Roe 2004; Bertolero *et al* 2005; Paiva *et al* 2008). Maximum foraging range from the colony from the literature is 11km, mean maximum range = 6.3±2.4, mean = 2.1km (Thaxter *et al* 2012), although the authors give low confidence to this assessment, due to the small number of studies. Eglington (2012), in a literature review of foraging ecology of terns, concluded that most studies, including those

[1] The term ‘Habitats Regulations’ refers to a suite of UK legislation transposing the EU Habitats Directive into national law. Currently the test of Likely Significant Effect (which if positive would lead to an Appropriate Assessment) is applied to features of any SPA which could potentially be adversely affected, even if a plan or project is not within the SPA (e.g. if the plan or project is within foraging range of a breeding colony SPA).

citing anecdotal information, reported a foraging radius less than 4km from the colony. Significant variation in foraging range occurs between colonies and between years (Eglington 2012). Within colonies, ranges have been found to be significantly greater during incubation (April-May ~1.6–2km) than during chick rearing (June-July ~1-1.2km) when foraging ranges would have been constrained by chick feeding duties (Paiva *et al* 2008). Diet may also change according to chick age, with smaller individuals of the same prey species being brought to younger chicks (Davies 1981; Bogliani *et al* 1994; Phalan 2000; Paiva *et al* 2006).

Population decline has been attributed to reductions in breeding success rather than to emigration or changes in adult survival (Pickerell 2004). Human disturbance, primarily as an unintentional result of recreation activity, is thought to have been a major cause of reduced breeding success in the past but now most colonies are wardened and cordoned off, greatly reducing such disturbance. More significant now is predation from foxes, kestrels , carrion crows and magpies, which are widely reported to cause colony failure or at least severe reduction to breeding success, and although fox control in particular has been effective, control of aerial predators remains a challenge (Pickerell 2004). Natural erosion and encroachment of vegetation have in many places reduced the area of suitable nesting habitat. Because little terns habitually nest very close to the high water mark, tidal inundation during storm surges if a frequent cause of nest loss; given predictions of future seal level rise and increase in storminess, these threats would be expected to become increasingly prevalent (Pickerell 2004).

3. Methods

Overview:

- This study collected data by shore observations of little terns foraging at sea at regular points along shore (to estimate alongshore extent) and from boat based transects (used primarily to estimate the seaward extent).
- Surveys were timed to coincide as far as possible with chick rearing, the period of greatest energetic demand to the species during the breeding season and therefore critical to the maintenance of the population. Furthermore, sample size was expected to be maximised during this period; as some colonies were very small, this was an important consideration.
- The study aimed to provide three years of colony specific data for all regularly occupied SPAs with little tern as a qualifying species. However logistics, colony failure at some locations, and other factors meant the coverage of data available for each colony varied.
- The study pooled data from colonies and tested a range of simple metrics against an analysis of the proportion of birds seen compared with distance from their colony of origin.
- The effect of breeding colony size on foraging extent was examined.

3.1 Study colonies

The 28 SPA in the UK for which little tern is a feature (Stroud *et al* 2001) are shown in Table 1 and Figure 1. This study sought to identify foraging areas adjacent to ‘recently occupied’ terrestrial little tern colony SPAs. Recent occupation was defined where the mean of peaks of the most recent five years of data equalled or exceeded the UK SPA selection guideline of 1% of GB population (19 pairs). Of the 28 SPA in the UK with little terns as a feature, 14 passed the test for regular occupation set (Table 1; Figure 1) and were therefore selected for survey. Colony counts were provided by the Seabird Monitoring Programme (www.jncc.defra. gov.uk/page-1550) and direct from site managers. Table 2 and Figure 1 show the sites at which boat transect surveys and shore-based surveys were conducted, out of all those sites judged to be regularly occupied. Details of the surveys and survey effort are provided in Appendix 1, A and B for boat-based and shore-based surveys, respectively.

There is considerable annual variation in breeding success, numbers and location of colonies from year to year (JNCC 2012), this being an inherent feature of the ecology of this species. Recent data on the number of Apparently Occupied Nests (AON) at each of the little tern colony SPAs are presented in Table 3 in order to provide information on recent occupancy at each of the sites. Despite some colonies having passed the occupancy test at the time of assessment, breeding numbers there during the subsequent survey period were low.

Table 1. SPA in the UK for which little tern is a feature and whether these are regularly occupied.

Name	**Country**	Regularly occupied
Alde–Ore Estuary	England	x
Benacre to Easton Bavents	England	x
Blackwater Estuary (Mid-Essex Coast Phase 4)	England	x
Chesil Beach & The Fleet[1]	England	x
Chichester & Langstone Harbours	England	✓
Colne Estuary (Mid-Essex Coast Phase 2)	England	x
Dee Estuary	Wales/England	✓
Dungeness to Pett Level	England	x
Firth of Tay & Eden Estuary	Scotland	x
Foulness (Mid-Essex Coast Phase 5)	England	x
Gibraltar Point	England	✓
Great Yarmouth North Denes	England	✓
Hamford Water	England	✓
Humber Estuary	England	✓
Lindisfarne	England	✓
Medway Estuary & Marshes	England	x
Minsmere–Walberswick	England	✓
Monach Isles	Scotland	x
Morecambe Bay	England	✓
North Norfolk Coast	England	✓
Northumbria Coast	England	✓
Pagham Harbour	England	x
Solent & Southampton Water	England	✓
South Uist Machair & Lochs	Scotland	x
Teesmouth & Cleveland Coast	England	✓
Thanet Coast & Sandwich Bay	England	x
The Wash	England	x
Ythan Estuary, Sands of Forvie & Meikle Loch	Scotland	✓

Note: 1: Chesil Beach and The Fleet was not judged to be currently occupied but as data were already available there, this site contributed to the analyses of generic extent.

Table 2: Currently occupied SPA at which boat transect surveys and shore-based surveys were conducted. Numbers in parentheses are the number of separate surveys undertaken each year.

SPA	Boat data	Shore-based data
Chichester & Langstone Harbours	-	2012 (3) 2013 (3)
Dee Estuary	2010 (1) 2011 (1)	2009 (4) 2010 (2) 2011 (2)
Gibraltar Point	-	2013 (1)
Great Yarmouth North Denes	2013 (2)	2013 (3)
Hamford Water	2012 (3) 2013 (2)	2013 (3)
Humber Estuary	-	2012 (3)
Lindisfarne	-	2012 (3) 2013 (3)
Minsmere–Walberswick	-	-
Morecambe Bay	-	2012 (2) 2013 (3)
North Norfolk Coast	2012 (2)	2012 (3)
Northumbria Coast	2011 (2)	2009 (2) 2010 (5) 2011 (2)
Solent & Southampton Water	2012 (2) 2013 (1)	2013 (3)
Teesmouth & Cleveland Coast	2012 (3) 2013 (2)	2011 (3) 2013 (3)
Ythan Estuary, Sands of Forvie & Meikle Loch	2011 (2)	2009 (5) 2010 (3) 2011 (2)

Table 3. Little tern Apparently Occupied Nests (AON) at each of the study colonies. Data taken from the JNCC Seabird Monitoring Programme and from site wardens.

Name of little tern colony SPA	No. breeding pairs at colony
SCOTLAND	
Ythan Estuary, Sands of Forvie & Meikle Loch	27 (2012) 31 (2011) 37 (2010) 36 (2009)
WALES	
The Dee Estuary	125 (2012) 126 (2011) 120 (2010) 115 (2009)
ENGLAND	
Northumbria Coast	40 (2012) 38 (2011) 31 (2010) 31 (2009)
Lindisfarne	14 (2013) 3 (2012) 8 (2011) 5 (2010)
Teesmouth & Cleveland	65 (2013) 110 (2012) 84 (2011)
Humber Estuary	23 (2012) 25 (2011)
Gibraltar Point	2 (2013) 0 (2012) 12 (2011) 32 (2010)
North Norfolk Coast	Blakeney 140 (2012) 160 (2011) 75 (2010) 116 (2003) Holkham 114 (2012) 144 (2011) Scolt Head 220 (2012) 105 (2011) 169 (2010) 90 (2003)
Minsmere & Walberswick	0 (2013) 0 (2012) 0 (2011) 30 (2010)
Hamford Water	30 (2013) 40 (2012) 45 (2011) 45 (2010)
Chichester & Langstone Harbour	14 (2013) estimate 40 (2012) 60 (2011)
Solent & Southampton Water	26 (2013) estimate 30 (2012) 0 (2011) 28 (2010)
Morecambe Bay	25 (2013) estimate 44 (2012) 62 (2011) 35 (2010)
Great Yarmouth North Denes	North Denes 0 Winterton 171 (2013) North Denes 5 Winterton 230 (2012) North Denes 5 Winterton 38 (2011) North Denes 0 Winterton 45 (2010) North Denes 339 Winterton 87 (2009) North Denes 350 Winterton 9 (2008) North Denes 261 Winterton 83 (2007) North Denes 369 Winterton 0 (2006) North Denes 214 Winterton 9 (2005) North Denes 17 Winterton 149 (2004)

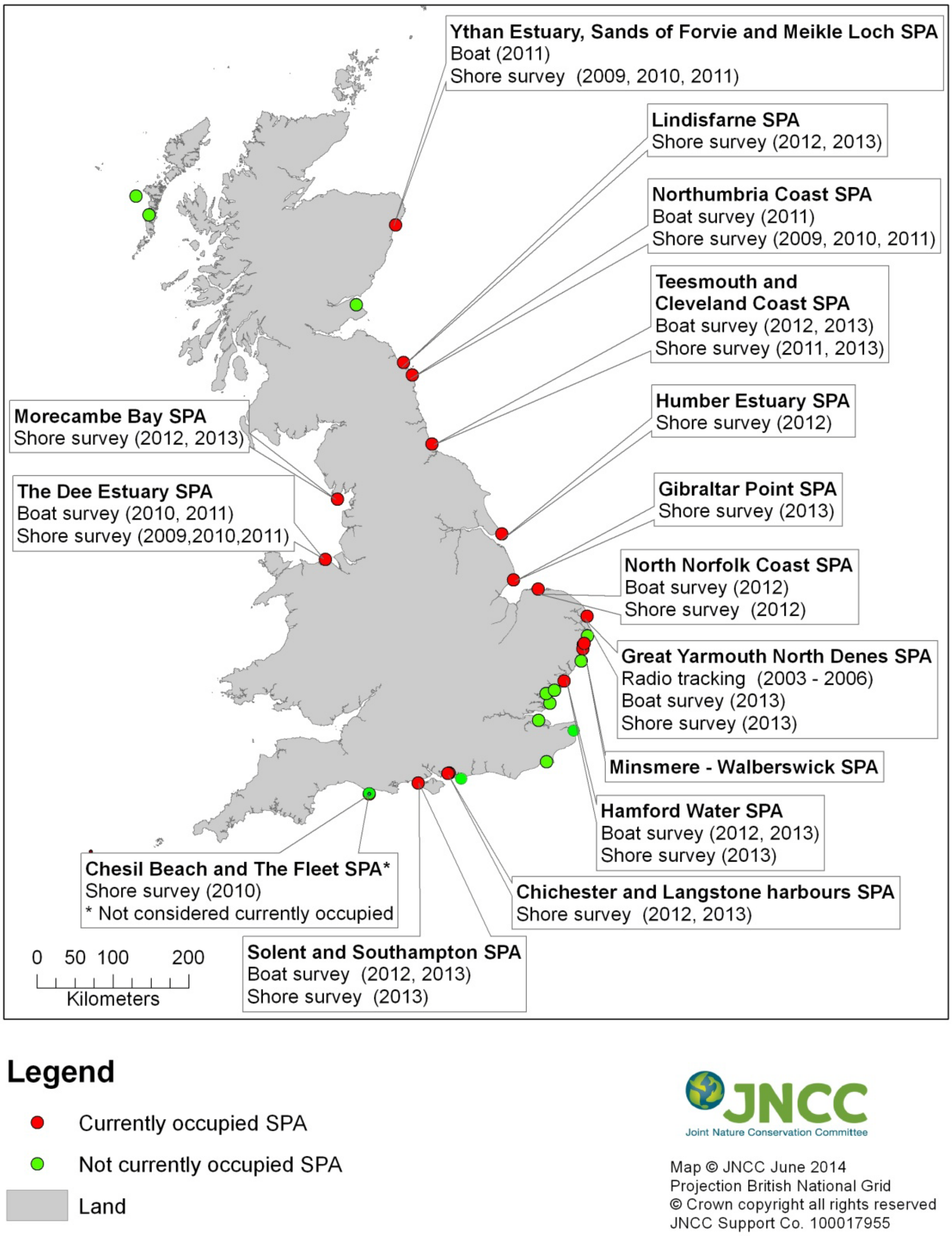


Figure 1: Location of SPA in the UK in which little tern is a feature, currently occupied colonies and the data collected at each.

3.2 Boat transect surveys

The objective of the boat transect surveys was to provide information on the seaward distribution of little terns around the breeding colony. Importantly, boat transect counts enable estimation of the seaward extent of foraging areas (as well as the distance along the coast from the colony).

The survey design varied slightly between years as in 2009-2011 survey also incorporated data collection on the distribution of the larger tern species in addition to little tern data, while the 2012-13 surveys were designed specifically to target little tern distribution. The boat transect surveys were based on a parallel line transect design created within the Distance programme (Thomas *et al* 2010); Distance was used solely as a convenient tool to establish transect design, not to adjust observations according to any detection function. Surveys tracks extended on average 5.5km seaward which, with the additional 300m range ahead of the survey vessel, extends an average of 5.8km offshore to encompass the approximate expected maximum extent as revealed from the literature (e.g. Thaxter *et al* 2012) and from preliminary JNCC observations.

Two methods of recording little terns along a transect line were employed:

(i) Instantaneous counts undertaken systematically at pre-determined points (between 300m-1800m apart, see Appendix 1A for details of each survey). The instantaneous count area was a 180° arc either ahead of, or off one side of, the boat depending on viewing conditions. All birds seen within this arc (out to a maximum estimated distance of 300m) were recorded, along with the distance and bearing of the sighting and information on behaviour where this did not compromise the ability to detect other little terns. The spacing of the instantaneous counts and the speed of travel of the vessel varied between survey areas, due to logistical rather than methodological imperatives. This was judged not to significantly affect the results since the key objective was to determine the seaward extent of observations, not to estimate tern density. However, the 'granularity' of results from the two sites with larger intervals would be slightly greater (500m interval rather than 300m), though the results from surveys with the greatest interval – Ythan Estuary, at 1.8km - yielded just one observation of little tern, which was discarded from the analyses. The preferred option was to travel at a constant speed of between 9-12knots and to undertake instantaneous counts at 300m intervals. On approach to the instantaneous count points the vessel slowed down so that the instantaneous counts were carried out while the vessel was travelling at *c*.9-12knots.

(ii) Continuous counts of any little terns observed between the instantaneous points were also recorded to provide an index of relative abundance. Although observers recorded behaviour (foraging/flying), restricting the analysis to just foraging observations would have limited the sample size. Therefore, all records (foraging and not foraging) were included in the analyses.

Surveys were aimed at the chick-rearing period as it was considered that energetically this represents the most critical period for seabirds. Surveys were conducted at a range of tidal states; indeed, due to the duration of surveys, both low and high water – and states in between – could be included within one survey.

3.3 Shore-based surveys

The shore-based surveys aimed to assess utilisation of the coastal strip (out to as far as the eye can see) by little terns either side of their breeding colony. Land-based counts are not ideal for marine species as individuals beyond 2km from the coast will not be counted (Webb & Reid 2004). However, for little terns land-based counts are the best method for assessing their numbers and distribution along the coast. The objectives of the shore-based survey were to:

i. Assess how the numbers of little terns within the coastal strip declined with distance from the breeding colony.
ii. Assess the relative utilisation of this coastal strip for foraging and for commuting to foraging sites.

Observation points with an unobstructed view to either side (resulting in a 180° arc) were chosen at 1km intervals either side of the colony centre, up to a distance of 6km in either direction along the coast, according to the mean maximum distance indicated by the literature. If birds were observed at 6km then additional count points were added if feasible. The shore based counts recorded passage rate and foraging use and if possible snapshot counts at one minute or two minute intervals were also recorded. The aim of the snapshot counts was to provide information on the intensity of foraging at each observation point. Ideally observation points were recorded concurrently; however, this varied according to the number of observers available. Failure to achieve concurrent sampling of observation points would increase the likelihood of potentially introducing bias to a survey. This might occur if, for example, sample points most distant (or nearest) from the colony were only sampled at a particular tidal state. However, such potential bias was reduced by ensuring that where two or more observers worked concurrently they spaced themselves as far apart as possible (in order to sample near and far areas at the same time). Possible bias was further reduced by ensuring as far as was possible that repeat surveys of each colony visited particular count points at a range of tidal states.

The method employed a count duration of at least 30 minutes at each observation point (if there was more than one observer this could be extended up to 60 minutes). This time is based on the mean foraging trip duration for little terns lasting 16–29 minutes according to Perrow *et al* (2006). However, in some cases this was not possible due to time constraints and/or logistical difficulties. In order to account for this difference in effort between observation points the shore-based count data was standardised to the number of birds observed per minute at each observation point. Further information on the observation effort for each survey is provided in Appendix 1 B 4. All little terns within 300m along the shore from the observation point were recorded, with care being taken not to double count individuals that were lingering in the area rather than passing through. For each bird observed, the time of the observation was recorded along with the direction of travel and behaviour (e.g. foraging, fish-carrying) of the bird(s).

To ensure that the data were comparable between sites the samples were analysed as a proportion of the total birds counted (per minute) at the first count point (usually 1km) in either direction alongshore from the centre of the colony (the graphs of shore data are presented in this way throughout the report). Each side of the colony was analysed as a separate sample. This approach assumes that 100% of birds leaving the colony in a particular direction reach the first count point, and that all birds reaching subsequent count points have passed through (and had been counted at) point one on their way. This is likely to be true for most colonies, although there are examples where this might not be the case (for example non-linear coast lines, where birds might fly directly over land to reach count points at 2km or 3km).

Observations indicated that little terns forage both in the intertidal zone and subtidal zone, so the landward limit of foraging extents should be taken to Mean High Water.

3.4 Data analysis

The density of little terns within each survey area was relatively small, leading to small numbers of observations within boat transects and shore based count points. This was particularly evident at the colonies with fewer breeding pairs. Given this, there are constraints on the type of analyses it was appropriate to undertake to quantify foraging range areas for little terns, compared with techniques successfully used for other seabird and waterfowl species (e.g. O'Brien *et al* 2012). For larger terns in a parallel study (Wilson *et al* 2013) tern observations were compared with environmental covariates (e.g. distance to colony, chlorophyll concentration, water depth, substrate, sea surface temperature) in order to generate models of predicted usage of the sea. The available environmental covariate data sets provide consistent data over large areas but typically do not cover the area very close to the shore, which is where most little terns forage. In addition, even in cases where covariate information is available close inshore, the small range of little terns provides a correspondingly small range of environmental covariates with which to model a relationship.

For inshore ducks divers and grebes observations gained from systematic transect surveys can be interpolated into density predictions using methods such as kernel density estimation (KDE; e.g. O'Brien *et al* 2012), and using distance techniques to correct for decreasing detectability of birds the further they are from the transect line (Thomas *et al* 2010). Given the relative scarcity of observations of little terns on transect surveys, distance correction functions would be unreliable, with wide confidence intervals. Therefore, density prediction methods were not used. In addition, KDE would be unlikely to provide a useful smoothed density surface, again due to this zero-inflated dataset.

The application of the technique of maximum curvature (as used in O'Brien *et al* 2012*)* on cumulative alongshore abundance with distance was considered to potentially provide an objective method for determining alongshore extent. Maximum curvature identifies the point where there is a change in the rate of increase in cumulative number of birds with increasing distance from the colony. However, as the shore count points were distributed at *c*.1km intervals, and in some cases the distribution of the birds was limited to 2km (two input points would be insufficient to identify a 'point of change' in maximum curvature analysis) this method was not suitable for all sites.

Given these constraints, the analyses concentrated on comparing a range of simple summary metrics to data pooled across all study colonies, in order to inform the selection of metrics that would best quantify the alongshore and seaward limits of tern foraging from a colony.

3.4.1 Comparing metrics for setting the limits of foraging areas

Whilst it is not possible - due to data limitations - to compare little tern observations with factors such as prey availability and quality, nor to proxies of them such as chlorophyll, water depth, *etc*., the data available do allow an analysis of whether there are density related effects influencing foraging range. Analyses compared colony size with mean maximum seaward extent at that colony, correcting for colony density and survey effort. Mean maximum extent was used to take account of the fact that on a given day there are relatively few survey data available and additional sampling effort could extend the observed maximum range further towards the outer limits of the survey extent; the mean of these values attempted to account for the variability of extents between samples.
Further analysis compared the proportion of birds observed (in all surveys combined for all colonies) with distance from shore, and distance alongshore from colonies.
The ultimate aim of the analyses was to find a set of objective metrics that could be easily derived from the available data, which would provide a reliable estimate of the foraging extent of little tern at a given colony.

A number of candidate metrics were devised. These seek a solution that balances a precautionary approach (i.e. favouring a larger range but accepting a greater likelihood that a significant proportion of that range would be little used) with a conservative approach (i.e. favouring a smaller range but a greater likelihood that a significant proportion of the foraging area would not be included).

Both 'foraging' and 'non-foraging' observations were included in the analysis as birds recorded as 'not actively foraging' may have been *en-route* to a foraging location and were therefore no less likely to be chick rearing/from the breeding colony SPA than a bird that was recorded as foraging. The risks of attempting to identify site boundaries based on one year of data or few data were considered and incorporated into the options we put forward.

Options were:

3.4.1.1 Site-specific seaward extent of foraging

- **Mean of the maximum extents of little tern observations from repeat surveys at that site.** This is considered a moderately conservative approach; within a given survey day maximum extent is proposed because we have relatively few survey data available and additional sampling effort would likely extend the observed maximum range. The mean of these maximum extents was proposed in order to express the variability of extents between samples. A more precautionary option would be the maximum seaward extent of observations at a site.

- **Maximum extent of observations at a site.** This approach is a precautionary option that could be applied given that we have relatively few survey data available; as outlined above it is likely that additional sampling effort may extend the observed maximum range further.

- **Seaward distance that encompassed x% (e.g. 95%) of observations.** This would probably under-estimate likely range because of the low number of repeat surveys at a site; further surveys would probably reveal the true range to be larger.

3.4.1.2 Site-specific alongshore extent of foraging

- **Maximum extent of alongshore distribution at a site** (the distribution either side of the colony would be assessed separately). This represents a precautionary approach, but could be justified on the basis that there would be relatively few repeat survey data for some sites, indicating that further surveys would probably extend the estimates of range.

- **Mean of the maximum extents of little tern observations from repeat surveys at that site.** This is a more conservative option; however given the expected variability between surveys it is possible that this may under estimate the full extent of usage at a site.

- **Distance from the colony that encompasses x% of observations.** An arbitrary percentage would need to be selected if this method was applied.

3.4.1.3 Generic seaward extent (for sites without sufficient boat survey data)

- **Mean of the mean maximum extent obtained for each site.** Overall, this represents a moderately conservative approach, combining as it does precautionary elements (using the maximum extent per individual survey) with more conservative elements (using the mean across surveys to estimate site-specific extent; using the mean across sites rather than the site with the greatest mean maximum extent).

- **Seaward distance identified from the site with the furthest mean maximum seaward extent.** The risks with this measure would be that it may be overly precautionary and would be reliant on data from just one site.

3.4.1.4 Generic alongshore extent (for sites without sufficient shore count data)

- **Mean of the maximum alongshore extents at other sites.** This represents a moderately conservative approach, combining as it does a precautionary element (maximum extent at a site rather than the mean) with a conservative element (using the mean of the values across sites, rather than the maximum.

- **Maximum alongshore extent of any site.** This would clearly represent a very precautionary approach and would risk including areas at some sites that would be not used at all or used only to a small extent.

The above options were then compared with the proportional seaward and alongshore usage relationships in order to define an appropriate metric to best describe foraging extent at a given colony.

4. Results

4.1 Boat and shore based surveys

At only one site – Minsmere to Walberswick – were no data at all collected (due to no breeding having occurred there in 2011-13; Table 3).

In accordance with their habit for moving location from one year to another, little terns within the Great Yarmouth North Denes SPA showed a redistribution within the two principal constituent colonies in 2010 (Table 3). This affected the number and distribution of observations from shore- and boat-based surveys that were undertaken at this SPA, though additional, high quality data from radiotracking data were available from an earlier study (Perrow & Skeate 2010).

Table 4 shows a summary of the seaward extents as estimated from boat-based transect surveys. Options for a measure of generic seaward foraging extent, as set out in 3.4.1.3, are shown. Predation occurred during surveys at Teesmouth and Cleveland Coast in 2012 and at Humber Estuary in 2012 (leading to the cancelling of planned boat surveys). Boat surveys at Teesmouth in 2012 were included in the analyses on the basis that: we have no good evidence to suggest foraging range would be atypical as a result of predation; because we have no way of knowing whether particular observations of birds in any of the surveys (during predation events or not) are breeders, failed breeders or non-breeders; and because predation is an inherent feature of little tern ecology so to exclude data on that basis could bias results.

Table 5 shows a summary of the maximum alongshore extents as estimated from shore-based surveys. Options for a generic alongshore extent that may be applied to colonies with insufficient site-specific data, as set out in as set out in 3.4.1.4, are presented

It is possible that density-dependent effects may influence foraging extent if, for example, at large colonies foraging birds on average dispersed further from the colony in order to avoid interference or other forms of competition with other individuals (Lewis *et al* 2001). This is theoretically possible, given that little terns are visual foragers and foraging efficiency would be expected to be related to the presence of conspecifics. Figure 2 shows that there is a weak relationship (R^2=0.135) between seaward extent (corrected for survey effort) and breeding colony size (corrected for a proxy of density by dividing total numbers in the SPA by the number of discrete colonies therein). The strength of the relationship is, given the relatively small number of colonies sampled, heavily dependent upon a small number of possible outliers; for example, if the colony with the greatest deviation from the regression line in Figure 2 were to be removed from the analysis the R^2 value would increase to 0.697. However, we can identify no reason to consider that data point to be atypical It should be remembered that the number of colonies comprising such a comparison is low and therefore the analysis is susceptible to factors other than colony size (or density) having significant influence over effective seaward extent. For example, differences in habitat availability or prey density between colonies are likely to have important effects upon seaward extent.

Table 4. Summary of seaward extent as estimated from boat-based transects.

Boat Survey	**Maximum seaward extent (m)**	**Mean of maximum seaward extent at each SPA (m)**
Teesmouth & Cleveland Coast 26/06/2012	1564	
Teesmouth & Cleveland Coast 27/06/2012	5661	
Teesmouth & Cleveland Coast 28/06/2012	4504	
Teesmouth & Cleveland Coast 10/07/2013	1357	
Teesmouth & Cleveland Coast 18/07/2013	4153	3448
Solent & Southampton Water 19/06/2012	492	
Solent & Southampton Water 28/06/2013	1620	1056
North Norfolk Coast 30/06/ - 01/07/2012	2077	
North Norfolk Coast 16/07/ - 17/07/2012	2129	
North Norfolk Coast (Allcorn *et al* 2003) 25/06 & 08/07/2003	1946	2051
Hamford Water 25/6/2013	2487	
Hamford Water 15/7/2013	1065	1776
Great Yarmouth North Denes		
2004 Radiotracking (Perrow & Skeate 2010)[1]	800	
2005 Radiotracking (Perrow & Skeate 2010)[1]	3120	
2006 Radiotracking (Perrow & Skeate 2010)[1]	3770	
2004-6 Radiotracking (Perrow & Skeate 2010)[2]	1390	
	1730	
2013 (21/6) boat transects[2]	3780	2430
2013 (05/7) boat transect[2]		
Northumbria Coast 23/06/2011	2185	
Northumbria Coast 27/06/2011	3011	2598
Dee Estuary 18/06/2010	1674	
Dee Estuary 03/07/2011	2070	1872
Mean of mean maximum seaward extents (see 3.4.1.3)		2176 (CV=0.345)
Site with the furthest mean maximum seaward extent (see 3.4.1.3)		3400 (rounded from 3448)
Mean of the maximum seaward extents from all surveys		2390 (CV=0.55)

Footnotes:
1. Derived from birds breeding at the North Denes colony; 85% kernel contours.
2. Derived from bird breeding (radiotracking; 85% kernel contours) or assumed to be breeding (boat transects) at Winterton colony.

Table 5. Maximum alongshore extents as estimated from shore-based counts.

SPA site	**Maximum alongshore extent (km)**	**Direction**	**Extent of survey points**
Ythan Estuary, Sands of Forvie & Meikle Loch SPA	**2**	North	0.55km-2.5km N
	5.35	South	1.35km-6km S
Dee Estuary SPA	**3**	West	1km-6km W
	3	East	1km-4km E
Northumbria Coast SPA	**5 (from boat survey)**	North	0.5km-6km N
	6	South	1.5km-6km S
Humber Estuary SPA	**6**	North	1km-8km N
	6	South	1km-6km S
North Norfolk Coast SPA	**7**	West	1km-7km W
	7	East	1km-9km E
Teesmouth & Cleveland Coast SPA	**5**	North	1km-5km N
	5	South	1km-5km S
Gibraltar Point	**2**	North	1km-6kmN
	NA	South	not surveyed
Great Yarmouth North Denes	**5**	North	1km-6km N
	4	South	1km-6km S
Minsmere to Walberswick	**NA**	North	
	NA	South	
Hamford Water	**4**	North	1km-5km N
	3.5 (from boat survey)	South	1km-6km S
Solent & Southampton Water	**1**	West	1-3km W
	NA	East	NA
Morecambe Bay SPA	**7***	West	2km-9km W
	2*	East	1.5km-7km E
Lindisfarne SPA	**3**	North	3km N
	4	South	1km-4km S
Chesil Beach & The Fleet SPA	**1**	West	1km-6km W
	0.5	East	1km-5km E
Not considered currently occupied	**1**	South	1km-4km S
Chichester & Langstone Harbours SPA	difficult to compare due to geography of site		
Mean of maximum extent (see 3.4.1.4)	3.9km (CV=0.50)		
Maximum alongshore extent (see 3.4.1.4)	7.0km		

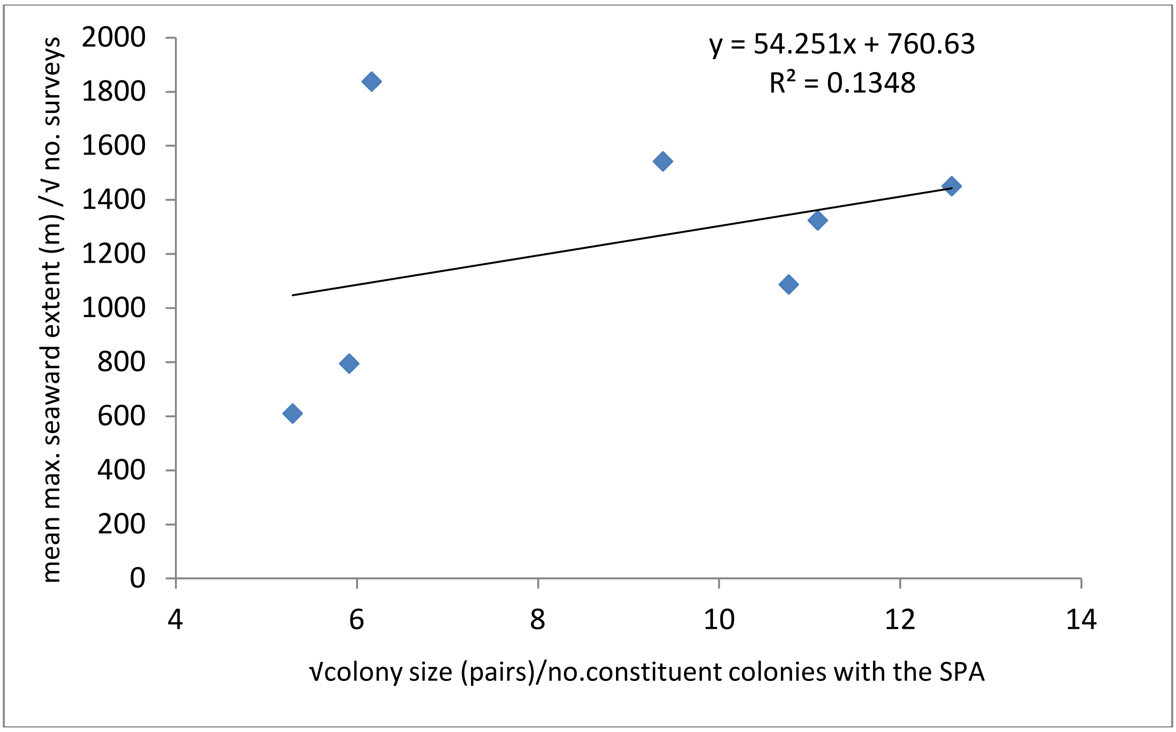


Figure 2 Relationship between mean maximum seaward extent of little terns - as estimated from boat surveys - and breeding colony size. Seaward extent adjusted for survey effort; colony size corrected for density (using proxy of number of constituent colonies within an SPA).

In relation to options for a generic alongshore extent, to apply to colonies with no or insufficient data, Figures 3 and 4 present an analysis of alongshore and seaward usage, respectively, across a number of colonies. One outlier was excluded from the alongshore analysis (a record from Northumberland Coast of 4.0 on y-axis at 4km); this was considered a valid exclusion because the magnitude of the recorded value is so much greater than comparable values at this distance from the colony – recorded from the same and other colonies. Its exclusion is balanced by the inclusion of other data points at this distance, albeit with more moderate values, so that the resultant form of the relationship (Figure 2) is as expected. Also excluded were data from colonies within harbours, where geography of the site makes comparison with others problematic. These graphs demonstrate the nature of the relationship of decreasing cumulative usage with increasing mean distance from colony (although sample sizes declined, too). For alongshore (Figure 3) approximately 0.86 of all usage occurred within 3.9km from shore, which represents the mean of maximum extents at other sites (see 3.4.1.4); at 7km from shore (i.e. the maximum extent of any site, see 3.4.1.4) approximately 1.0 of usage was encompassed. For offshore extent, approximately 0.97 of usage was encompassed by the "mean of mean maximum extent" metric, at 2.18km, while the metric of “site with furthest mean max extent”, at 3.4km, encompassed 0.99 of all usage.

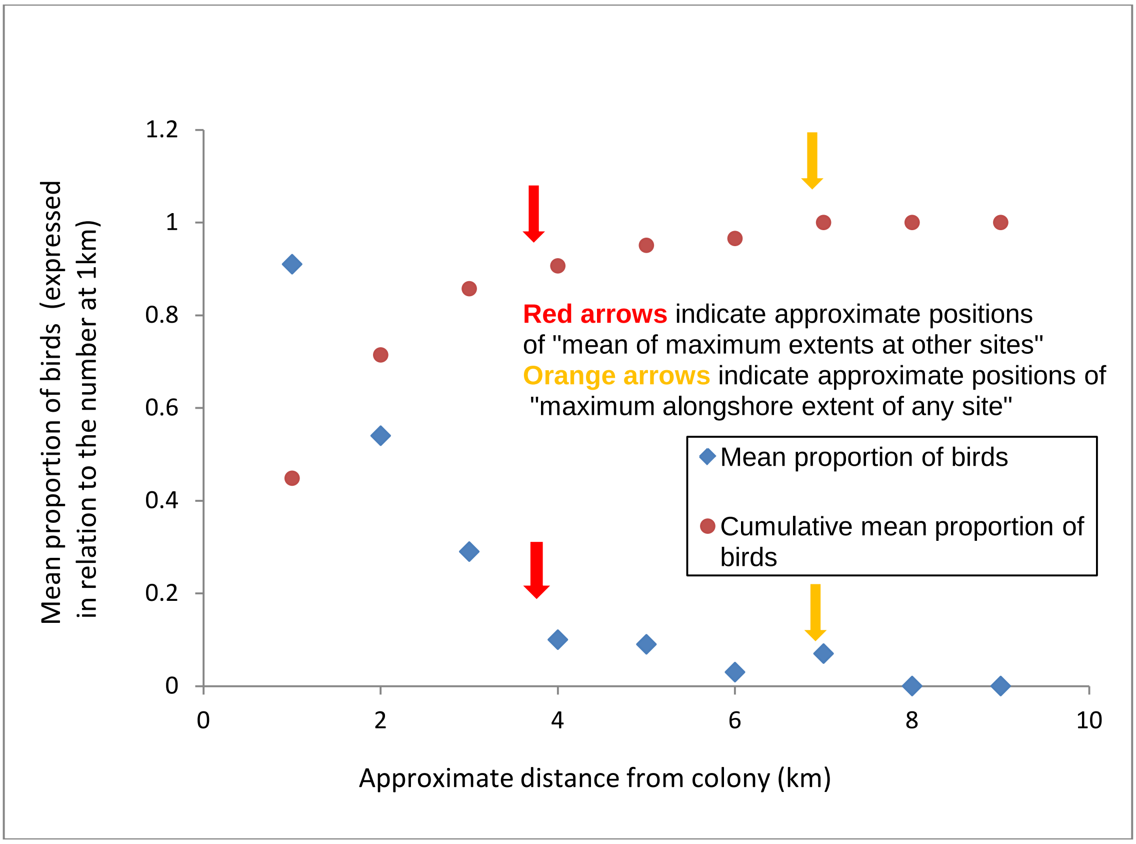


Figure 3. Mean proportion and cumulative mean proportion of little terns at increasing distances alongshore from the colony. Passage birds shown, which includes a variable proportion of known foragers. Each point represents the mean proportional usage at each distance band from the colony across colonies listed in Table 2. Proportion at each colony expressed relative to the number at the 1km mark. Mean proportion of birds at 1km is less than 1.0 because, in a few cases, no birds were observed at 1km.

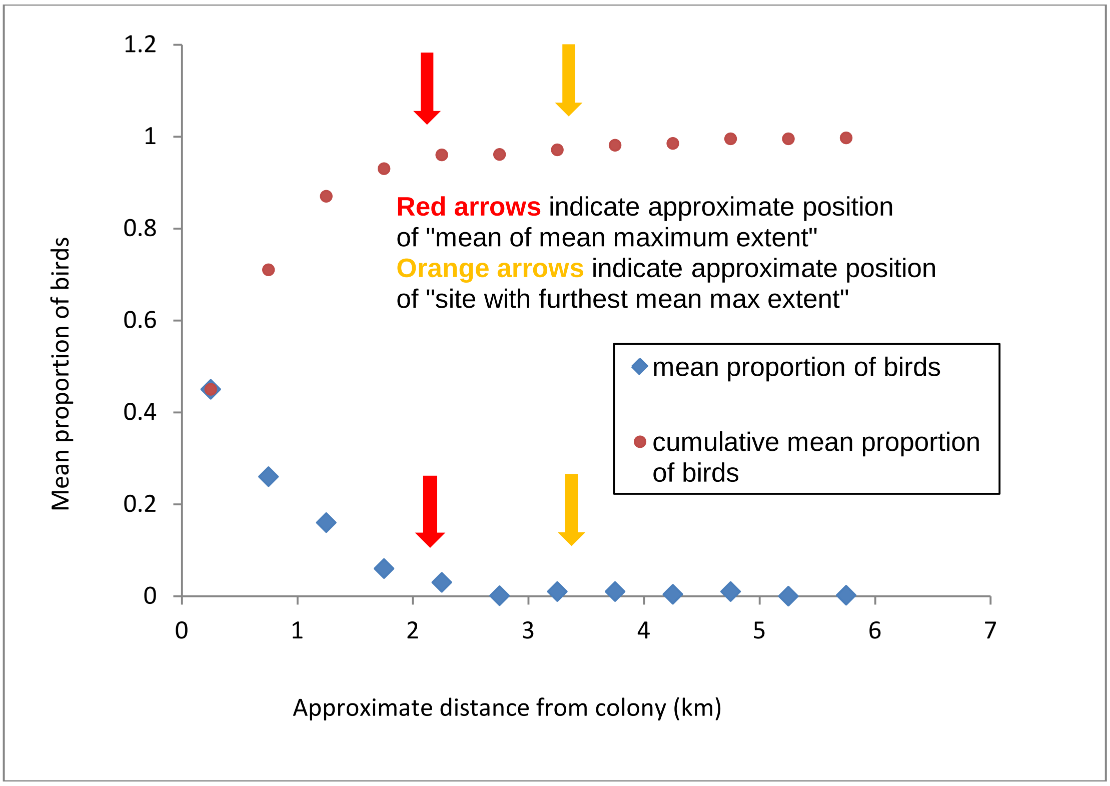


Figure 4. Mean proportion and cumulative mean proportion of little terns at increasing seaward distances from mean high water mark. Feeding and non-feeding records shown. Each point represents the mean proportional usage at each distance band from the colony across colonies listed in Table 2, plotted in the mid-point of 0.5km range bins.

5. Discussion

The aim of this study is to quantify usage of the marine environment by little tern around its breeding colony SPAs in the UK.

The foraging extents identified in this study derive from information gathered over multiple years using site-specific information where possible. Most information derives from data collected between 2009-2013, a combination of shore-based observation (to determine the alongshore extent of use) and boat-based transect surveys (to establish the seaward extent). At one SPA - Great Yarmouth North Denes – these data were supplemented by information from radiotracking, collected in 2003-6 (Perrow & Skeate 2010).

Data collection was targeted at chick-rearing, as during this period adults are required to provision their chicks at a rate which allows sufficient growth for fledging and survival in the immediate post fledging period. Field data collection did indeed span chick-rearing activities – confirmed by information relayed by site wardens, and although egg hatching is relatively synchronous at a colony, there was inevitably a spread of stages at any given time a colony was studied, for example birds still incubating while others fed chicks.

Tidal state is likely to play a significant role in determining the foraging locations of terns, as it determines water depth (little terns favour shallow waters in which to forage) and probably prey behaviour. However, no attempt was made to account for tidal state in the analyses. This would have required a considerably larger dataset, increasing survey and analytical costs but probably without concomitant changes to the estimates of foraging range. In practice, given the long duration of observation on a given day, a range of tidal states would be covered in a survey, therefore helping to reduce possible bias.

It is possible that bird behaviour could have been influenced by the presence of observers (during shore-based surveys) or survey vessel (during boat-based surveys), though we have no evidence that this occurred and we would expect any effects not to introduce systematic bias in terms of seaward extent.

We demonstrated little evidence for a density-dependent effect (Figure 2) i.e. a negligible correlation between breeding colony size and the maximum distance out to sea little terns travel; we conclude there is little empirical justification to scale generic seaward extent with colony size.

Collection of site-specific data was attempted at most currently occupied SPA, though in many cases data on seaward or alongshore extent could not be collected and at others no or few usable data were collected, either due to colony failure (caused by tidal inundation, predation or disturbance) or simply too few breeding pairs for sufficient observations to be detected by surveys (Table 3).

Therefore, methods are required which aim to quantify foraging extent under a range of cases of data availability: where there are no site-specific survey data; where data on seaward and/or alongshore extent are deficient; and where there are good data for both parameters. For the first two cases, a method to derive generic extents is proposed, based on data collected at other colonies. This aimed to weigh the risks of being overly precautionary (over-estimate foraging extent) or overly conservative (under-estimate foraging extent). Plots of mean usage across colonies (Figures 3 & 4) provide a measure against which to judge the degree of precaution that should be applied. Of the two options being considered for each parameter, there is a considerable difference in mean distance from shore between the options – 3.1km for alongshore and 1.2km for seaward. The gain in terms of the proportion of bird observations included within each rises from 0.86 to 1.0 for alongshore and from 0.89 to 0.96 for seaward extent. It would seem to be overly precautionary for an estimate of foraging extent to encompass all or nearly all observations, given that at any one site this would probably result in significant areas of vary low tern usage being included in the estimate. Therefore, we propose that the smaller of the two options be adopted for a generic estimation of foraging extent, that is the mean of the maximum alongshore extents at other sites (for alongshore extent) and mean of the mean maximum extent obtained for each site (for seaward extent). These are likely to encompass areas of high to moderate use while excluding areas which are likely to have very low usage.

For colonies with sufficient data on either or both alongshore and seaward extents, we propose to use the following site-specific measures. For seaward extent we propose the mean of the maximum extents of little tern observations from repeat surveys at that site (see 3.4.1.1). Using the mean of repeat surveys aim to represent average usage and is therefore moderately conservative, but avoids the risk of outliers having a large influence on extent, as would be the case if the alternative – maximum extent observed at a site – were used. For alongshore extent we propose the maximum extent of alongshore distribution at a site, on the basis that because there are relatively few survey data at each site, and the tendency for furthest count points to have received slightly less effort on average, further survey would probably extend the estimates of range. Because of this, we judge that choosing the maximum extent at a site would not be excessively precautionary nor would the influence of outliers pose significant risk of over-estimation of extent.

Table 6 summarises, for each SPA assessed as currently occupied, the quantity and quality of data on foraging extent available and gives our assessment of sufficiency, making suggestions as to whether a site-specific or generic extent would be justified. Data sufficiency was categorised at each location by separately assessing the number of observations of little terns along with survey effort, measured by the number of surveys undertaken. Judgement was applied rather than strict adherence to numerical thresholds for quantity of data. A simple “traffic light” categorisation of data sufficiency was adopted: red for insufficient data and therefore the need for generic approach; amber for intermediate; green for sufficient data and therefore justification for applying site-specific measures of foraging. The presence of additional independent data sources, such as those from radiotracking (Perrow & Skeate 2010), was also considered. In some SPA, such as Lindisfarne (Table 6), despite moderate numbers of bird observations having been made, access to all parts of the possible extent was not possible, so a generic extent for alongshore extent was judged appropriate.

The colony SPAs selected for study were those assessed to be currently occupied. This, however leaves a number of SPA where little tern is a feature, where it was judged that little terns are no longer regularly breeding (as well as those currently occupied SPA where no or few data could be collected). The assessment of occupation may change with time; indeed, during this study, colonies which were originally calculated not to be regularly occupied may now qualify as occupied. If the SNCBs wish to consider foraging extents for such SPA, this study has provided generic extents that could be applied to them.

The methods to estimate foraging extents that are presented in this report derive from field surveys and analyses of a nature appropriate to the data and the ecology of the little tern. Habitat modelling, such as that undertaken for the larger tern species (Wilson *et al* 2013) is not appropriate for the little tern, due to the combined effects of their more restricted inherent foraging range and the availability of habitat data at a suitable resolution or location. This assumption led to the approach detailed here.

The use of bird-borne telemetry devices is an intensive and resource-demanding method to obtain bird distribution information, and has not been extensively adopted for little terns for SPA identification in the UK. Perrow and Skeate (2010), however, provide radio tracking data for the Great Yarmouth North Denes SPA, which has enabled a synthesis of information of various methods.

The foraging extents of little tern estimated in this study fall within the range identified for little tern in a recent review of foraging ranges (Thaxter *et al* 2012). That study identified the mean extent of the three studies included in the review as 2.1km, with the mean of maxima across studies as 6.3km. Our study, on a larger number of colonies, gave a mean maximum extent of 2.4km, with a range of 1.1-3.4km (for seaward extent) and a mean maximum of 3.9km, with a range of 0.5-7km (for alongshore extent). Eglington (2012), in a literature review of foraging ecology of terns, concluded that most studies, including those citing anecdotal information, reported a foraging radius less than 4km from the colony, which accords with our results.

Table 6. Summary of basis for draft foraging extent at each site and of the supporting evidence base in each in terms of: i) seaward extent a) numbers of little terns recorded at sea and b) number of separate estimates of seaward limits of usage from boat data, ii) for alongshore extent a) the number of terns observed on surveys and b) the number of surveys done. Green indicates a judgement of sufficiency of data to justify site specific approach, red indicates insufficient data and therefore the need for generic approach and yellow is intermediate. *=includes 4 radio-tracking surveys from Perrow and Skeate (2010); **=includes 3 radio-tracking surveys from Perrow and Skeate (2010).

Site	Seaward extent	Boat survey (n terns)	Number of estimates of seaward extent from boat surveys	Alongshore extent	Shore-based surveys (n terns)	Number of shore-based surveys of alongshore extent
Ythan	Generic	2	-	Site-specific	204	10
Dee Estuary	Site-specific	45	2	Site-specific	792	8
Northumbria Coast	Site-specific	22	2	Site-specific	518	9
Lindisfarne	Generic	-	-	Generic	53	6
Teesmouth & Cleveland	Site-specific	102	5	Site-specific	656	6
Humber	Generic	-	-	Site-specific	455	3
Gib Point	Generic	-	-	Generic	3	1
N Norfolk Coast	Site-specific	344	2	Site-specific	2917	3
Minsmere & Walberswick	Generic	-	-	Generic	-	0
Hamford Water	either possible	51	5	Either possible	123	3
Chichester & Langstone	Generic	-	-	Generic	58	7
Solent & Southampton	Either possible	14	3	Either possible	62	3
Morecambe Bay	Generic	-	-	Generic	154 (but only 1 tern seen in the 3 surveys in 2013)	5
Great Yarmouth & N Denes	Site-specific	202	6*	Site-specific	937	7**

6. Acknowledgements

This work was undertaken on behalf of, and funded by, Countryside Council for Wales (CCW, later Natural Resources Wales), Natural England (NE), Northern Ireland Environment Agency (NIEA), Scottish Natural Heritage (SNH), and the Joint Nature Conservation Committee (JNCC). We would particularly like to thank Nigel Buxton (SNH), Matty Murphy (CCW), Peter Clement, Richard Caldow, Sarah Anthony, Vicky Gilson and Joanna Redgwell (NE) and Gregor Watson, Ian Enlander and Neil McCulloch (NIEA). Richard Caldow (NE) made many helpful comments throughout. Roddy Mavor, Sue O'Brien and Lawrence Way (all JNCC) commented on a draft. We are grateful for the support of RSPB (in particular Viv Booth) for carrying out survey work around the RSPB reserves (Coquet Island, Chesil Beach, Larne Lough, Skerries), and Martin Perrow for sharing his experience and advice. ECON Ecological Consultancy Ltd undertook the 2013 surveys, under contract to JNCC, and also kindly gave permission to reproduce figures from Perrow and Skeate (2010).

Fieldwork was carried out by: Zoe Allcock, Dave Allen, Sophy Allen, Sarah Alsbury, Richard Berridge, Tom Bickerton, Jonathan Bills, Julie Black, Craig Bloomer, Chris Bingham, Toby Burrell, M. Busch, Richard Caldow, Peter Clement, Joe Cockram, Paul Collins, Alan Cox, A. Craggs, John Dadds, Malcolm Davies, Chris Dieck, J. Dunn, Tim Dunn, Jenny Etiene, Caroline French, Amy Gallagher, Vicky Gilson, Mike Harcup, Kevin Johns, Andy Johnson, Emma Kellman, M. Kerby, Annabel Knipe, Mirium Knolly, Kerstin Kober, Cat Laverick, Jennifer Lawson, N. Lawton, Mike Leakey, Kerry Leonard, Mark Lewis, Louise MacCallum, Roddy Mavor, Roy McGregor, Clive Mellon, Guy Michelmore, David Minns, Matty Murphy, O. Myers, Marcus Nash, Sue O'Brien, John Oliver, Matt Parsons, Lyn Phippen, Anthony Phizacklea, A. de Poitier, Laura Radford, Colin Raven, M. Rooney, K. Rose, Ed Rowsell, John Shillitoe, Anne Simpson, James Spencer, Edward Stubbings, Martin Suanjak, Ajay Tegala, Stuart Thomas, C. Turner, Andy Webb, Dennis Weir, Paul Welsh, David Wileman, Pat Wileman, J. Williamson, Linda Wilson, Ilka Win, J. Woodhouse.

RIBs and skippers were provided by Benson Marine, Diablo Charters, ECON Ecological Consultancy, Environmental Research Institute, Explorer Fast Sea Charters, Farne Island Dive Charters, Farne Islands Divers, Highland RIBS, Marine Revolution, Safety Boat Services and Waterline Boat Charters.

We are grateful to the following for information and updates on the breeding season at the colony sites: Geoff Barber, (INCA – Industry Nature Conservation Association), Richard Bevan, Adam Burrows Senior reserve manager (Suffolk coast NNR), Chris Cockburn, (RSPB Langstone Harbour warden), Paul Collins (Spurn Bird Observatory Warden), Denice Coverdale, (Lead Conservation Adviser, Yorkshire East Team, Natural England), Andrew Craggs, (Senior Reserve Manager, Lindisfarne & Newham NNRs), Annabelle Drysdale (SNH), Pete Durnell (Senior Ranger, Lymington Keyhaven Nature Reserve), Bob Furness Clive Hartley, (BTO Regional Rep. Cumbria), Adrian Hibbert (Gronant), Pete Jones, (Assistant Reserves Officer, Cumbria Wildlife Trust), Kerry Leonard Laura Morris (University of Newcastle), Joe Murphy, (Senior Reserves Officer, Cumbria Wildlife Trust), Adrian O Hibbert (Denbighshire Countryside Services),Pete Potts (Hampshire County Council Ranger, Hayling Island), Colin Raven, (County bird observer, Walney Bird Observatory), Chris Redfern Kevin Redgrave (National Trust)Mike Rooney (Reserve Manager for Holkham and Scolt head NNRs), Ed Rowsell, (Conservation Officer, Chichester Harbour Conservancy), Daryl Short (Forvie)Edward Stubbing (Blakeney National Trust), Zoe Tapping Kevin Wilson, (Site Manager, Lincolnshire Wildlife Trust, Gibraltar Point National Nature Reserve), Leon Woodrow (Hamford Water NNR warden for NE and Tendring District Council).

7. References

ALLCORN, R., EATON, M. A., CRANSWICK, P. A., PERROW, M. R., HALL, C., SMITH, L., REID, J., WEBB, A., SMITH, K. W. S., LANGSTON, R. & RATCLIFFE, N. (2003). *A pilot study of breeding tern foraging ranges in NW England and East Anglia in relation to potential development areas for offshore windfarms.* RSPB/WWT/JNCC report to DTI,Sandy, UK.

BERTOLERO, A., ORO, D., VILALTA, A.M., & LOPEZ, M.A. 2005. Selection of Foraging Habitats by Little Terns (*Sterna albifrons*) at the Ebro Delta (NE Spain). *Revista Catalana d'Ornitologia,* **21**, 37–42.

BOGLIANI, G., FASOLA, M., CANOVA, L. & SAINO, N. 1994. Prey selection by parents and chicks of the Little Tern *Sterna albifrons*. *Avocetta,* **18**, 9–11.

BWPi. 2006. *Birds of the Western Palearctic interactive DVD ROM 2.0*. Oxford University Press, UK**.**

DAVIES, S. 1981. Development and Behaviour of Little Tern Chicks. *British Birds,* **74**, 291–298.

ECON (2013). JNCC Little Tern surveys 2013: Fieldwork summary report. Unpublished report to JNCC. Contract No. C13-0204-0674

EATON, M.A., BALMER, D.E., BRIGHT, J., CUTHBERT, R., GRICE, P.V., HALL, C., HAYHOW, D.B., HEARN, R.D., HOLT, C.A., KNIPE, A., MAVOR, R., NOBLE, D.G., OPPEL, S., RISELY, K., STROUD, D.A. & WOTTON, S. (2013). *The state of the UK's birds 2013*. RSPB, BTO, WWT, NRW, JNCC, NE, NIEA and SNH, Sandy, Bedfordshire.

EATON, M.A., BROWN, A.F., NOBLE, D.G., MUSGROVE, A.J., HEARN, R., AEBISCHER, N.J., GIBBONS, D.W., EVANS, A. & GREGORY, R.D. (2009) Birds of Conservation Concern 3: the population status of birds in the United Kingdom, Channel Islands and the Isle of Man. *British Birds* **102**, pp296-341

EGLINGTON, S. (2013). *Literature review of tern Sterna sp. foraging ecology*. Report to JNCC, under Contract ref. C13-0204-0686.

JOINT NATURE CONSERVATION COMMITTEE. 2012. *Seabird Population Trends and Causes of Change: 2012 Report* (http://www.jncc.defra.gov.uk/page-3201). Joint Nature Conservation Committee. Updated July 2012.

LAWSON, J. & PARSONS, M. (2013) Proposed methodology for identifying important marine areas for the little tern *Sternula albifrons*. Unpublished JNCC report April 2013.

LEWIS, S., SHERRATT, T.N., HAMER, K.C. & WANLESS, S. (2001). Evidence of intra-specific competition for food in a pelagic seabird. Nature **412**: 816-819.

O'BRIEN, S.H., WEBB, A., BREWER, M.J., & REID, J.B. 2012. Use of kernel density estimation and maximum curvature to set Marine Protected Area boundaries: Identifying a Special Protection Area for wintering red-throated divers in the UK. *Biological Conservation* **156**: 15-21.

PAIVA, V.H., RAMOS, J.A., CATRY, T., PEDRO, P., MEDEIROS, R. & PALMA, J. 2006. Influence of environmental factors and energetic value of food on Little Tern *Sterna albifrons* chick growth and food delivery. *Bird Study,* **53**, 1–11.

PAIVA, V.H., RAMOS, J.A., MARTINS, J., ALMEIDA, A. & CARVALHO, A., 2008. Foraging habitat selection by Little Terns *Sternula albifrons* in an estuarine lagoon system of southern Portugal *Ibis,* **150**, 18–31.

PERROW, M.R., & SKEATE, E.R. (2010). Offshore extension of a colony-based Special Protection Area (SPA) for a small seabird, the Little Tern *Sternula albifrons***.** Unpublished report to Natural England.

PICKERELL, G. 2004. Little Tern Sterna albifrons. Pp. 339-349. In: Mitchell, P.I., Newton, S., Ratcliffe, N. & Dunn, T.E. (eds.) *Seabird populations of Britain and Ireland.* T. & A.D. Poyser.

PHALAN, B. 2000. *The Diet and Early Growth of Little Terns (*Sterna albifrons*) at Kilcoole, Co. Wicklow in 1999*. BA, University of Dublin, Trinity College.

TAYLOR, I.R. & ROE, E.L. 2004. Feeding ecology of little terns Sterna *albifrons sinensis* in south-eastern Australia and the effects of pilchard mass mortality on breeding success and population size. *Marine and Freshwater Research,* **55**(8), 799-808.

THAXTER, C.B., LASCELLES, B., SUGAR, K., COOK, A.S.C.P., ROOS, S., BOLTON, M., LANGSTON, R.H.W. & BURTON, N.H.K. (2012). Seabird foraging ranges as a preliminary tool for identifying candidate Marine Protected Areas. *Biological Conservation*, **156**, 53-61.

THOMAS, L., BUCKLAND, S.T., REXSTAD, E.A., LAAKE, J.L., STRINDBERG, S., HEDLEY, S.L., BISHOP, J.R.B., MARQUES, T.A. & BURNHAM, K.P. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. *Journal of Applied Ecology* **47**: 5-14

WILSON, L. J., BINGHAM, C. J., BLACK, J., KOBER, K., LEWIS, M., WEBB, A. & REID, J.B. (2009)*. Identifying important marine areas for terns.* Unpublished JNCC 1st interim report, December 2009.

WILSON, L. J., BINGHAM, C. J., BLACK, J., KOBER, K., MAVOR, R.A., O'BRIEN S. H., WIN, I., WEBB, A. & REID, J.B. (2010). *Identifying important marine areas for terns*: Unpublished JNCC 2nd interim report. December 2010

WILSON, L. J., BINGHAM, C. J., BLACK, J., KOBER, K., MAVOR, R.A., O'BRIEN S. H., PARSONS, M., WIN, I., ALLEN, S. & REID, J.B. (2011). *Identifying important marine areas for terns*: Unpublished JNCC 3rd interim report. January 2012.

WILSON L. J., BLACK J., BREWER, M. J., POTTS, J. M., KUEPFER, A., WIN, I., KOBER, K., BINGHAM, C., MAVOR, R. & WEBB, A. 2013.Quantifying usage of the marine environment by terns *Sterna* sp. around their breeding colony SPAs. JNCC Report no. 500

Appendix 1. Summary information from (A) boat surveys 2010-13 and (B) shore-based surveys 2009-13

A: Summary of the boat surveys undertaken at each of the little tern colony SPA. Point count intervals were variable, according to the size of the survey area to be covered and other logistical constraints.

Name of little tern colony SPA	Year	No. of completed surveys	Survey dates	Boat count total no. little terns	Point count intervals	Transect spacing	No. of Apparently occupied nests
SCOTLAND							
Ythan Estuary, Sands of Forvie & Meikle Loch	2011	2	8 June 2011	1	1.8km[1]	1.8km	31
			10 June 2011	0			
WALES							
Dee Estuary	2011	1	3 July 2011	18	500m[1]	1km	126
	2010	1	18 June 2010	27			120
ENGLAND							
Northumbria Coast	2011	2	23 June 2011	20	500m[1]	1km	38
			27 June 2011	2			
Teesmouth & Cleveland	2012	3	26 June 2012	19	Continuous effort count and instantaneous counts every 300m	600m	110
			27 June 2012	27			
			28 June 2012	11			
	2013	2	10 July 2013	27	Continuous effort count and instantaneous counts every 300m	600m	65
			18 July 2013	18			
North Norfolk Coast	2012	2	28 June 2012	188	Continuous effort count and instantaneous counts every 300m	600m	474 sum of 3 colonies
			16-17 July 2012	156			
Great Yarmouth North Denes	2013	2	21 June 2013	57	Continuous effort count and instantaneous counts every 300m	600m	171 (all at Winterton)
			5 July 2013	145			
Hamford Water	2012	3	16 July 2012	0	Continuous effort count and instantaneous counts every 300m	1.2km	40
			17 July 2012	0		600m	
			19 July 2012	0		1.2km	
	2013	2	25-26 June 2013	38	Continuous effort count and instantaneous counts every 300m	600m	30
			15-16 July 2013	13			
Solent & Southampton Water	2012	2	18 June 2012	0	Continuous effort count and instantaneous counts every 300m	600m	30
			19 June 2012	5			
	2013	1	28 June 2013	9	Continuous effort count and instantaneous counts every 300m	600m	26

Footnote: 1. Boat transects for these sites undertaken primarily under a bespoke survey programme for larger terns; in these cases snapshots were the primary source of little tern locations, whereas at other sites continuous effort counts were used as the source of location information.

B: Summary of the shore based survey data. This table is provided as a summary and for reference purposes, but it should not be used to compare between sites or survey dates as the survey effort in respect of distance from the colony is not comparable in this format.

SPA site	Year	No. of completed surveys	Survey dates	Shore count total	Total observation time in minutes	No. of Apparently occupied nests	Comments
SCOTLAND							
Ythan Estuary, Sands of Forvie & Meikle Loch SPA	2011	2	23 June 2011	36	270	31	
			28 June 2011	23	300		
	2010	3*	3 June 2010	23	265	37	
			10 June 2010	1	115		
			17 June 2010	28	240		
			02 July 2010	12	240		
	2009	5*	15 June 2009	16	80	36	
			18 June 2009	5	100		
			23 June 2009	30	150		
			26 June 2009	30	220		
WALES							
Dee Estuary SPA	2011	2	30 June 2011	5	160	126	
			6 July 2011	26	160		
	2010	2	2 June 2010	135	100	120	
			30 June 2010	34	140		
	2009	4*	16 June 2009	0	150	115	
			18 June 2009	197	180		
			20 June 2009	174	180		
			30 June 2009	159	180		
			02 July 2009	62	180		
ENGLAND							
Northumbria Coast SPA	2011	2	18 & 19 June 2011	68	480	38	
			25, 26 & 30 June 2011	16	480		
	2010	5*	20 May 2010	134	520	31	
			23 May 2010	21	240		
			24 May 2010	10	240		
			25 May 2010	46	480		
			18 June 2010	36	160		
			20 June 2010	18	360		
			21 June 2010	72	240		
			22 June 2010	16	180		
			23 June 2010	12	60		

	2009	2*	19 & 21 June 2009	69	630	31	
Lindisfarne SPA	2013	3	3 July 2013	6	350	14	Low numbers at colony and correspondingly few at-sea observations
			9 July 2013	2	350		
			22 July 2013	0	350		
	2012	3*	11 July 2012	10	55	3	Low numbers at colony
			13 July 2012	24	110		
			20 July 2012	11	145		
Teesmouth & Cleveland SPA	2013	3	4 July 2013	13	360	65	Major egg-theft incident 18 June leaving c. 40 pairs on eggs; hedgehog predation reduce this number further soon after. Some relayed though expected no chicks fledged.
			13 July 2013	72	360		
			26 July 2013	140	360		
	2011	3	20 June 2011	53	194	110	Depredation occurred at the colony during the survey period.
			27 June 2011	168	184		
			11 July 2011	210	200		
Humber Estuary SPA	2012	3	27 June 2012	48	180	23	
			30 June 2012	61	180		
			10 July 2012	167	210		
			11 July 2012	83	200		
			12 July 2012	43	180		
			13 July 2012	53	180		
Gibraltar Point	2013	1	24 June 2013	3	360	2	Very low numbers of observations and breeding pairs
North Norfolk Coast SPA	2012	3 @ each of the 3 sites	26 - 27 June 2012	753	1065	474	AON (474) is the sum of colony counts at Scolt, Blakeney and Holkham
			2 & 3 July 2012	1079	1160		
			12 & 13 July 2012	1085	953		
Great Yarmouth North Denes	2013	1at 1 site and 3 at the other	21 June 2013	138	360	171	
			25 June 2013	181	360		
			12 July 2013	518	360		
			20 July 2013	100	360		
Minsmere-Walberswick	2009-13	0	-	-	-	Mean of 12 pairs	Very low numbers (0 in 2011-2013, 30 pairs in 2010 and 2009
Hamford Water	2013	3	24 June 2013	54	360	30	
			11 July 2013	36	360		
			19 July 2013	33	360		
Chichester & Langstone	2013	3	29 June 2013	0	380	14	No birds recorded on shore surveys. Low

Harbours SPA			8 July 2013	0	380		breeding numbers.
			16 July 2013	0	380		
	2012	3	11 July 2012	9**	360	40	11 July unrepresentative due to poor weather. Few observations & low numbers at colony
			18 July 2012	32	331		
			25 July 2012 (a)	0	281		
			25 July 2012 (b)	17	271		
Solent & Southampton Water	2013	3	30 June 2013	40	420	26	Fox predation meant unlikely any chicks were fledged.
			9 July 2013	22	420		
			17 July 2013	0	420		
Morecambe Bay SPA	2013	3	2 July 2013	1	360	25	Just one bird seen on surveys. Low breeding numbers.
			15 July 2013	0	360		
			19 July 2013	0	360		
	2012	2	30 June 2012	151	900	44	Colony failure – tidal flooding
			7 July 2012	2	900		
Chesil Beach & The Fleet SPA	2010	3*	20 May 2010	34	360	12	Not considered currently occupied
			28 May 2010	9	340		
			25 June 2010	13	360		
			2 July 2010	18	320		

* Some observation points at these sites had more repeat counts, but the minimum number is presented here in the table.
** Unrepresentative count due to poor weather conditions.