Natural England Commissioned Report NECR212

Tern verification surveys for marine sites

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NATURAL ENGLAND

Foreword

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Background

Five species of tern that breed in the UK are listed on Annex 1 of the EU Birds Directives and require special protection:

- Sandwich Tern *Thalasseus sandvicensis*;
- Common Tern *Sterna hirundo*;
- Arctic Tern *S. paradisaea*;
- Roseate Tern *S. dougallii*; and
- Little Tern *Sternula albifrons*.

Current Special Protection Areas (SPAs) protect breeding seabird colonies, but do not extend to foraging areas. Only three of the UK's 110 SPAs with marine components encompass entirely marine habitats occupied by seabirds.

To fulfil commitments to the global Convention on Biological Diversity and contribute to measures required under the EU Marine Strategy Framework Directive, the Joint Nature Conservation Committee (JNCC), working with the national statutory bodies including Natural England, aims to:

- Increase the area and number of marine SPAs by extending existing marine bird breeding colony/site SPAs.
- Identify important inshore areas used by waterbirds outside the breeding season.
- Identify important offshore areas used by marine birds.
- Consider individually other types of SPAs, including important marine areas around colonies of breeding terns.

Natural England commissioned these surveys to verify modelling work on terns carried out by the JNCC. The results will be used to help define the potential boundaries of marine SPAs by identifing the limits to important foraging areas for each species at each recently regularly occupied colony.

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Further information
This report can be downloaded from the Natural England website: **www.gov.uk/government/organisations/natural-england**. For information on Natural England publications contact the Natural England Enquiry Service on 0845 600 3078 or e-mail **enquiries@naturalengland.org.uk**.

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Tern verification surveys for marine sites

Common Tern above the River Tees

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Contents

1 Introduction

The five species of tern breeding in the UK - Sandwich Tern *Thalasseus sandvicensis,* Common Tern *Sterna hirundo,* Arctic Tern *S. paradisaea*, Roseate Tern *S. dougallii* and Little Tern *Sternula albifrons* - are listed on Annex 1 of the EU Birds Directives requiring special protection. In the UK, at least one of the five species is represented as an interest feature within 57 breeding colony Special Protection Areas (SPAs) designated under the European Union Birds Directive (EU 2009). However, protection of breeding colonies alone can only be of limited value in maintaining populations that are subject to the vagaries of key resources at sea, especially food (Perrow *et al.* 2015).

Currently, only three of the UK's 110 SPAs with marine components (e.g. sea inlets, estuaries and salt marshes) encompass entirely marine habitats occupied by seabirds. To fulfil commitments to the global Convention on Biological Diversity and contribute to measures required under the EU Marine Strategy Framework Directive, the Joint Nature Conservation Committee (JNCC) aims to increase the area and number of marine SPAs. This is to be achieved through: 1) extensions to existing marine bird breeding colony/site SPAs – as buffer zones around colonies as per McSorley *et al.* (2003); 2) identification of important inshore areas used by waterbirds outside the breeding season (Webb *et al.* 2006), 3) identification of important offshore areas used by marine birds (Kober *et al.* 2012) and 4) other types of SPA considered individually, but including important marine areas around colonies of breeding terns.

In relation to 4) the JNCC, in consultation with the statutory nature conservation bodies (SNCBs) in each of the 4 parts of the United Kingdom i.e. Natural England (NE), Scottish Natural Heritage (SNH), Natural Resources Wales (NRW) and Department of the Environment Northern Ireland (DoeNI) undertook a UK wide programme of survey work between 2009 and 2013 to record the foraging distributions of breeding terns at SPAs around the UK. In the case of the four larger terns this programme gathered data at 10 of 32 recently regularly occupied SPA colonies around the UK, with three of these study SPAs (Farne Islands, Coquet Island and North Norfolk Coast) being in England (Wilson *et al.* 2014). The principal method used was the visual tracking technique of Perrow *et al.* (2011a) in which birds leaving colonies on foraging trips are followed by observers aboard a high-speed rigid-hulled inflatable boat (RIB). Birds completely ignore the following vessel and all aspects of behaviour including foraging activity may be readily observed. The track of the following vessel is taken to be representative of the birds' flight path. A key advantage of the technique is that the different tracks are almost certainly represented by different individuals and can be considered independent records of patterns of usage.

In the case of little terns, survey data were gathered at 14 recently regularly occupied SPA colonies, with 12 of these being in England (Parsons *et al.* 2015). Eleven of these sites were sampled by shore-based surveys with six (eight in total across the UK) also sampled by boat-based surveys covering waters further offshore. Data was

gathered in one to three years in the period from 2009-2013. After initially undertaking boat-based surveys along the North Norfolk Coast in 2012 for the JNCC, ECON undertook shore-based surveys at eight sites and boat-based surveys at four sites under contract in 2013.

For the larger tern species, the data gathered were used to construct models to predict areas of highest tern foraging activity on the basis of associations between observed foraging locations and environmental covariates. In specific cases, sufficient data were gathered to allow models to be built to predict usage of a given species at a given site. In most cases, however, it proved necessary to describe tern usage patterns around SPA colonies using predictions from generic models based on pooled data gathered from several other colonies. Similarly, for little terns, at some colonies sufficient data were gathered to adequately characterise the alongshore and seaward limits to foraging activity, whereas at others with no, or limited, data, generic alongshore and seaward limits based on averages derived from the other colonies were applied.

The principal output of the work was the identification of limits to important foraging areas for each species at each recently regularly occupied colony, in order to define potential boundaries for marine SPAs (see Natural England 2014a). However, the fact that these boundaries were a mixture of the application of: 1) site specific empirical observations (some Little Tern sites), 2) generic averages of alongshore and seaward foraging limits (some other Little Tern sites), 3) predictions of site-specific models of habitat use (some larger tern sites) and, 4) predictions of generic models of habitat use derived from observations of terns at selected study colonies (many of the larger tern sites); called for an attempt to verify the proposed boundaries at some sites where these were based either on limited site specific information or the predictions of generic models. The modelling results (Wilson *et al.* 2014) generally predicted relatively high levels of usage by larger tern species close to the shore, and in the absence of data to the contrary, landward boundaries at English sites were clipped to mean high water mark (Win *et al.* 2013). By default, this approach led to many estuarine areas, channels, creeks, docks and other similar habitats being included within the boundaries. This called for an attempt to verify the usage of such areas by foraging terns.

On behalf of DoeNI, the Northern Ireland Environment Agency (NIEA) had already commissioned a similar programme of verification surveys at Carlingford, Stranford and Larne Loughs in Northern Ireland in 2014, through the use of both boat-based and shore-based observations (Allen & Mellon Environmental Ltd. 2015).

2 Aims & objectives

The overall aim of this project was to verify (or not) the information underpinning the proposed boundaries to important foraging areas utilised by breeding terns originating from five SPA's in England, comprised of the limited site-specific information on Little Tern distribution at Hamford Water and the application of generic model predictions of usage by Sandwich Tern on the Northumberland Coast,

and in Morecambe Bay and Duddon Estuary, and by Common Tern on the Teesmouth and Cleveland Coast and in Liverpool Bay.

Verification was to be achieved using direct observation by means of shore-based counts and, where this was unlikely to be possible at Teesmouth and Cleveland Coast, by a robust boat-based survey.

Specific objectives of this report were therefore to:

- Identify foraging areas for terns originating from the designated SPAs
- Validate proposed limits to areas identified currently as potential marine SPAs
- Identify any existing datasets associated with modelled areas and source breeding sites.

The latter point assumed that local NE staff with specific links to other researchers and/or specific organisations was the most likely source of further information, and would pass this on to the authors of this report. Moreover, during the tender process, it was noted that ECON held further information on Common Tern at Teesmouth & Cleveland Coast that may be of value to the current work.

In addition, Dr Richard Caldow of NE requested that the results of surveys conducted (also in 2015) by volunteers to verify the reliability of the proposed western extent of the Solent & Dorset Coast pSPA containing the SPA colony at Brownsea Island in Poole Harbour, be incorporated within this report. Selected information made available by Dr Caldow is largely reproduced verbatim and ECON cannot accept any responsibility for any omissions or inaccuracies in the datasets or reporting.

3 Study sites & survey locations

3.1 Hamford Water

3.1.1 Background information

Hamford Water is a large, shallow estuarine basin comprised of tidal creeks and islands, intertidal mud, sand flats and saltmarshes located on the north Essex coast, between Walton-on-the-Naze and Dovercourt. It was designated as an SPA in 1992 for its nationally important breeding population of Little Tern and internationally or nationally important populations of migratory waterfowl comprising Dark-bellied Brent Goose *Branta bernicla bernicla,* Black-tailed Godwit *Limosa limosa,* Common Redshank *Tringa totanus,* Common Ringed Plover *Charadrius hiaticula,* Common Shelduck *Tadorna tadorna,* Eurasian Teal *Anas crecca* and Grey Plover *Pluvialis squatarola*. The site is also a Site of Special Scientific Interest (SSSI), Ramsar site, with parts also a candidate Special Area of Conservation (cSAC).

Little Tern has recently bred on the northeast corner of Horsey Island (Ordnance Survey [OS] Grid reference TM240256), with a maximum of 37 apparently occupied nests (AON) in 2014. The same colony was occupied in 2015. The foraging areas of breeding Little Tern were assessed in 2012 and 2013 via shore-based surveys to determine alongshore extent (2013 only) and boat-based surveys to determine possible seaward extent of foraging activity. The latter suggested that the current SPA focussed on the inter-tidal areas should be extended out to sea by approximately 1.8 km, representing the mean maximum distance of the site-specific observations of Little Tern during the boat-based surveys (Natural England 2015a). From shore, Little Terns were recorded at up to 5 km from the north of the colony and 3 km south of the colony from a combination of three surveys. In addition, the boat-based surveys recorded Little Terns near shore at approximately 5 km south of the colony and was incorporated in the determination of the alongshore extent of the proposed SPA boundary (Natural England 2015a).

A repeat of the shore-based surveys in 2015 aimed to acquire further data to inform the boundary of the foraging extent of Little Terns breeding at Hamford Water.

3.1.2 Survey locations

No specific survey locations were proposed in the Request for Quotation declared by NE (dated 30 April 2015). As a result, we proposed the same twelve survey locations that were used for the JNCC in 2013, comprising six observation points to the north and six observation points to the south of the colony at broadly 1 km intervals (partly dependent on access). In addition, an observation point as close as possible to the colony (within ~ 400 m) was also added (Table 1, Figure 1). The position of each observation point was determined by hand-held GPS on the first sampling occasion with return to the same locality on subsequent occasions.

Table 1. OS grid reference of the survey locations for Hamford Water.

Observation point	Grid reference
Colony	TM 245 259
1	TM 248 259
2	TM 255 252
3	TM 264 247
4	TM 266 239
5	TM 263 229
6	TM 258 221
7	TM 234 261
8	TM 235 271
9	TM 240 280
10	TM 241 289
11	TM 246 297
12	TM 251 305

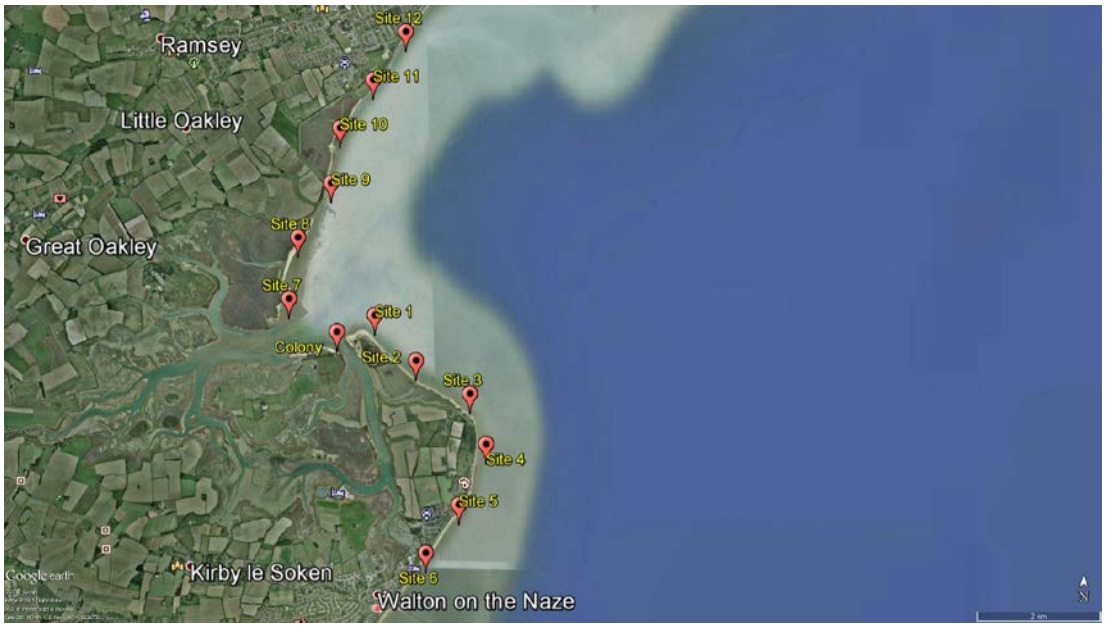


Figure 1. Map of the survey locations for Hamford Water SPA.

It should be noted that previous experience of the survey area was essential as access to Hamford Water and the area of the colony is not entirely straightforward and the advice of Leon Woodrow of Tendring District Council in both 2013 and 2015 was essential in order to allow the successful completion of the surveys. In particular, the two observation points nearest to the colony (1 & 7) are only accessible by foot and at low tide. In practice, this meant that the two surveyors worked independently to cover either the north or the south of the colony ending or starting at the two points nearest the colony. The surveyor on the southern side of the colony then accessed the observation point close to the 'colony' location.

The three surveys required were successfully conducted on 8th June, 22nd June and 13th July. Seven AON were recorded on the 8th June, with this increasing to eight on the 22nd June, subsequently declining to four on 13th July. The duration between records suggests that the four AON observed on the latter date may actually have been new re-nests rather than part of the initial quota of nest records. A more complete picture of the fortunes of the colony and the ultimate outcome of any nesting attempts may become available in due course.

3.2 Teesmouth & Cleveland Coast

3.2.1 Background information

The Teesmouth and Cleveland Coast Special Protection Area (SPA) centred on the Tees estuary and the adjacent open coastlines, comprises of a range of habitats including estuarine tidal waters, sandflats, mudflats, rocky foreshore, saltmarsh, wet grassland and freshwater lagoons. As well as being an SPA, the site is a Ramsar site and includes several SSSIs. The conservation value of the area belies the fact that much of the land use is heavily industrial, with a wide range of petrochemical and

manufacturing (steel), industries as well as containing the third largest industrial port in the UK.

The SPA was designated in 1995 for its nationally important populations of breeding Little Tern and passage Sandwich Tern and internationally important wintering populations of Red Knot *Calidris canutus* and Common Redshank, and its wintering waterfowl assemblage (>20,000 individuals). In addition, a nationally important colony of Common Tern (~ 400 pairs) has bred near the Tees estuary for some years, with the population now centred on the RSPB reserve of Salthome. NE is considering the potential to reclassify the SPA with the addition of Common Tern as a qualifying feature.

The JNCC modelled a possible marine boundary to protect foraging Common Tern should this species be added to the SPA in the future, with this based on the application of a generic model developed from visual tracking surveys at other colonies. The distance to the colony is the primary factor in the model. The possible boundary that is currently open to public consultation (Natural England 2015b) includes the main channel of the River Tees up to the Tees barrage, and estuarine and marine waters between Marske-by-the-Sea in the south and Castle Eden Dene in the north. This area links with that proposed to incorporate areas used by foraging Little Tern originating from Crimdon Dene within the Durham Coast SSSI.

Although Common Tern is known to forage in and around docks and harbours along the River Tees as well as further north along the coast in Hartlepool Bay including Hartlepool Marina (Perrow *et al*. 2010), further surveys were required to acquire specific data on River Tees channel to determine their usage to inform the boundary of the foraging extent of the Common Terns within the River Tees. NE was also specifically interested in assessing whether Common Tern also forage within Victoria Harbour in Hartlepool.

3.2.2 Survey locations

As the River Tees is heavily used by industry and subject to a number of different owners/occupiers, access for shore-based observers was thought likely to be problematic and therefore a boat-based survey was proposed to record Common Tern foraging activity at a number of identified vantage points along the River Tees. Specifically, five key locations at specific OS grid references along the length of the Tees from upstream to downstream were specified:

- Tees Barrage (NZ 462190)
- Middlesborough Dock (NZ 506208)
- Tees Dock (NZ 545233 - NZ 550229
- Bran Sands Lagoon/Dabholme Gut mudflat (NZ 555246)
- Seaton Channel confluence with River Tees (NZ 540262).

The geographically separate Victoria Harbour on the northern side of Hartlepool Bay (NZ 520341) was to be surveyed either by boat or from shore.

In practice, as the area to be surveyed is convoluted and quite extensive, and the survey vessel was moored in the nearby Hartlepool Marina, then the survey of Victoria Harbour as well as the Marina was conducted by boat (see 4.3 below), before crossing Hartlepool Bay to reach the mouth of the River Tees and thence to proceed upstream to Tees Barrage, a total distance of ~23 km.

In addition, the key specified locations (see above) were to be incorporated within a series of surveyed observation points at regular intervals of approximately 1 km along the length of the Tees from the Seaton Channel upstream to the barrage. As the stretch of river to be surveyed was thought to be approximately 15 km in length, this suggested a further ten or so sites would be surveyed. In practice, a total of between 14-17 sites were surveyed on each of the three[1] survey occasions on 18th June, 2nd July and 22nd July. Variation in the number of survey sites resulted from subtle variations in vessel speed (again due to the requirements of other river users) and the overriding requirement to maintain safe working distance from the active shipping activities over much of the River Tees. Thus, an exact distance of 1 km could not be maintained between the additional survey sites in between the five primary sites along the River Tees and its estuary (Table 2, Figure 2), the locations of which were largely fixed. Any change of a few hundred metres between points often meant that a further survey point could be added or excluded before reaching a specified key location.

Table 2. OS grid reference of the survey locations along the River Tees on the three different survey occasions from upstream to downstream. Specified key locations are highlighted.

Observation point	Survey occasion		
	18th June	2nd July	22nd July
Tees Barrage	NZ 463 191	NZ 463 191	NZ 464 191
A19 road bridge	NZ 472 194	NZ 471 194	NZ 475 195
Newport Bridge	NZ 478 205	NZ 478 206	NZ 478 204
Pinky & Perky water towers	NZ 479 216	NZ 482 220	NZ 480 217
OSB Warehouse slipways	NZ 486 221		
Transporter Bridge	NZ 495 215	NZ 496 215	NZ 494 215
Middlesborough Dock	NZ 506 208	NZ 503 207	NZ 506 208
Outfall channel	NZ 515 209	NZ 514 210	
MPI jack-up vessels	NZ 522 215	NZ 524 218	NZ 521 215
Mudflat lagoon	NZ 528 223		
Oil Refinery	NZ 535 229	NZ 533 230	NZ 532 226
Tees Dock	NZ 542 237	NZ 544 238	NZ 542 237
Dabholme Gut	NZ 547 250	NZ 547 250	NZ 547 249
Bran Sands cranes	NZ 545 259	NZ 545 258	NZ 543 263
Seaton Channel	NZ 539 264	NZ 539 264	NZ 539 265
Victoria Harbour	NZ 524 334	NZ 525 335	NZ 524 335
Hartlepool Marina	NZ 517 331	NZ 518 331	NZ 517 331

[1] The initial RFQ stated that six surveys should be completed, although this was modified to three following the posting of comments from prospective tenderers.

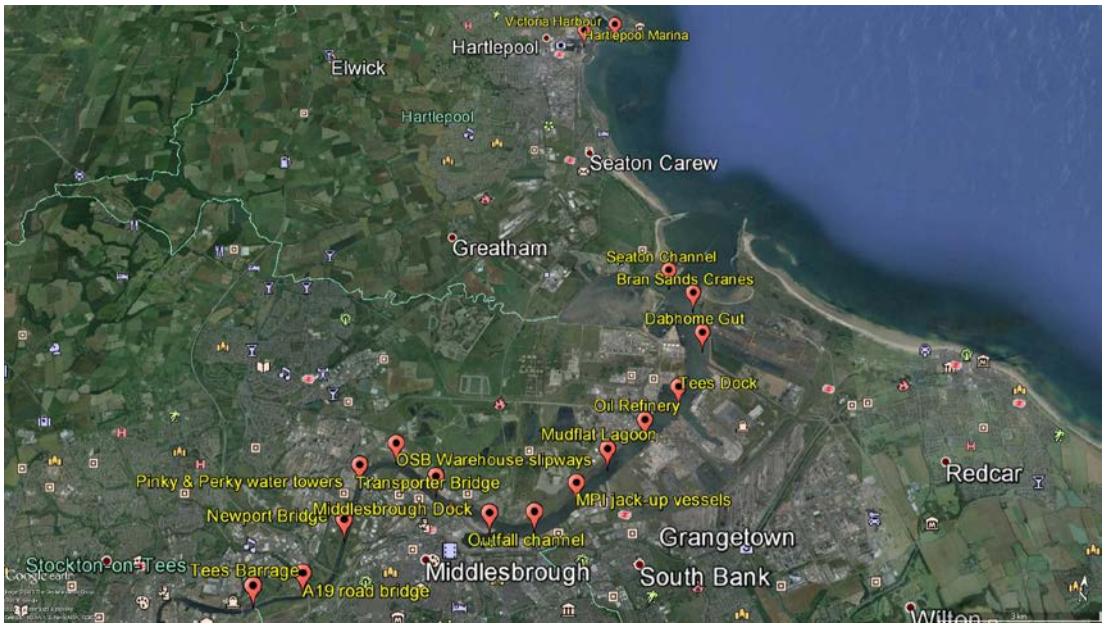


Figure 2. Map of the survey locations for Teesmouth and Cleveland Coast SPA.

As well as undertaking a static survey at fixed locations, the opportunity was taken to undertake a continuous survey during the transit to and from the mooring of the vessel within Hartlepool Marina and the furthermost upstream point on the River Tees at Tees Barrage (see 4.3.4 below). This added considerably to the dataset gathered primarily by providing comparable information on the abundance (density) and distribution of Common Tern at sea in Hartlepool Bay and Teesmouth relative to the river itself.

3.3 Northumberland

3.3.1 Background information

In combination, four SPAs in Northumberland – Farne Islands and Coquet Island (both classified in 1985), Lindisfarne (classified in 1992) and Northumbria Coast (classified in 2000) – support important populations of all five British breeding terns. In July 2014, Natural England started informal discussions with stakeholders around a possible marine SPA to protect the foraging areas of terns as well as important marine habitats used by the internationally important colonies of breeding seabirds (>20,000 individuals) of both the Farne Islands and Coquet Island, as well as the internationally important populations of Atlantic Puffin *Fratercula arctica* on both the Farne Islands and Coquet Island, and of Common Guillemot *Uria aalge* on the Farne Islands.

The draft boundary of the possible marine SPA extends alongshore from Scremerston in the north to Blyth in the south, and offshore to a maximum of 19 km from the mainland (Natural England 2014b).

The proposed boundary includes the outputs of species-specific models of habitat use from visual tracking of Arctic, Common, Sandwich and Roseate Terns from Coquet and Arctic Tern on the Farne Islands by Wilson *et al.* (2014). Robertson *et al.* (2014) provides further details of the habitat use of sympatrically breeding Arctic, Common and Roseate Terns from Coquet Island.

The models suggested that terns originating from Coquet Island would use the estuaries of the Aln, Coquet, Wansbeck and Blyth that all run broadly parallel to the open coast within the southern portion of the proposed site. Therefore, rather than seeking verification data on the extent to which terns forage alongshore from their colonies, NE sought to verify the general usage of these estuarine waters by foraging terns, and if used, which species were doing so. Moreover, it was of interest how far upstream any foraging terns penetrated any of the rivers used.

In addition, NE were interested in determining if North Sunderland (Seahouses) Harbour of most relevance to terns originating from the Farne Islands, was also used by foraging terns, and if so, which species were involved.

3.3.2 Survey locations

Surveys were to target the rising tide three hours before high water to high water, that was thought to coincide with peak tern foraging in these estuarine areas. However, it proved not to be possible to cover all potential survey locations even for two surveyors given the number of sites, each requiring an observation period of one hour[2] at each locality, and the distances between sites. For example, the first survey occasion downstream of the weir on the River Blyth coincided with low water, which precluded effective survey (Table 3). Otherwise, all sites were successfully covered in the survey periods of 10-12th June, 24-26th June and 6-8th July.

North Sunderland (Seahouses) Harbour was readily covered by a single vantage point, which also allowed terns passing by over the sea to be recorded (Figure 3, Table 3). In relation to surveys of the Rivers Aln, Coquet, Wansbeck and Blyth, the RFQ specified that vantage points should provide comprehensive coverage from the estuary mouth upstream to the lowest vehicular crossing point(s) such as the first road bridge or the weir in the case of the Coquet (Table 3, Figures 4-7). It was noted that the Coquet and Blyth estuaries both split into two channels upstream with each channel requiring survey sites (Figures 4 & 7 respectively).

Flexibility regarding additional vantage points was required should terns be observed flying further upstream. As a consequence, an additional site was added to both the Coquet (with this subsequently superseded by a better placed site) and Blyth on the second survey occasion on 24-26th June (Table 3). A better-placed site subsequently superseded the additional site on the Coquet on the third survey occasion.

[2] It only proved possible to undertake the minimum requirement of one hours observation at each site rather than the two hours suggested as the ideal in the RFQ.

Table 3. OS grid reference of the survey locations along the Northumberland rivers (and Seahouses Harbour) oriented from north to south.

River	Observation point	Survey occasion		
		10-12th June	24-26th June	6-8th July
	Seahouses Harbour	NU222323	NU222323	NU222323
Aln	River divide	NU 246101	NU246101	NU246101
	Bridge	NU 243108	NU243108	NU243108
Coquet	Harbour	NU 270049	NU270049	NU270049
	Marina	NU 263049	NU263049	NU263049
	Weir	NU 254054	NU254054	NU254054
	The Butts		NU249059	
	A1068 road bridge			NU247063
Blyth	West Pier	NZ 325806	NZ325806	NZ325806
	Quayside	NZ 319817	NZ319817	NZ319817
	Factory Point	NZ303825	NZ303825	NZ303825
	River join	NZ300825	NZ300825	NZ300825
	East Sleekburn		NZ293833	NZ293833
	Industrial estate	NZ284822	NZ291824	NZ291824
Wansbeck	Estuary Mouth	NZ301853	NZ301853	NZ301853
	Castle Island	NZ280855	NZ280855	NZ280855
	Rail bridge	NZ277857	NZ277857	NZ277857
	Weir	NZ294853	NZ294853	NZ294853

Figure 3. Map of the survey location for Seahouses Harbour.

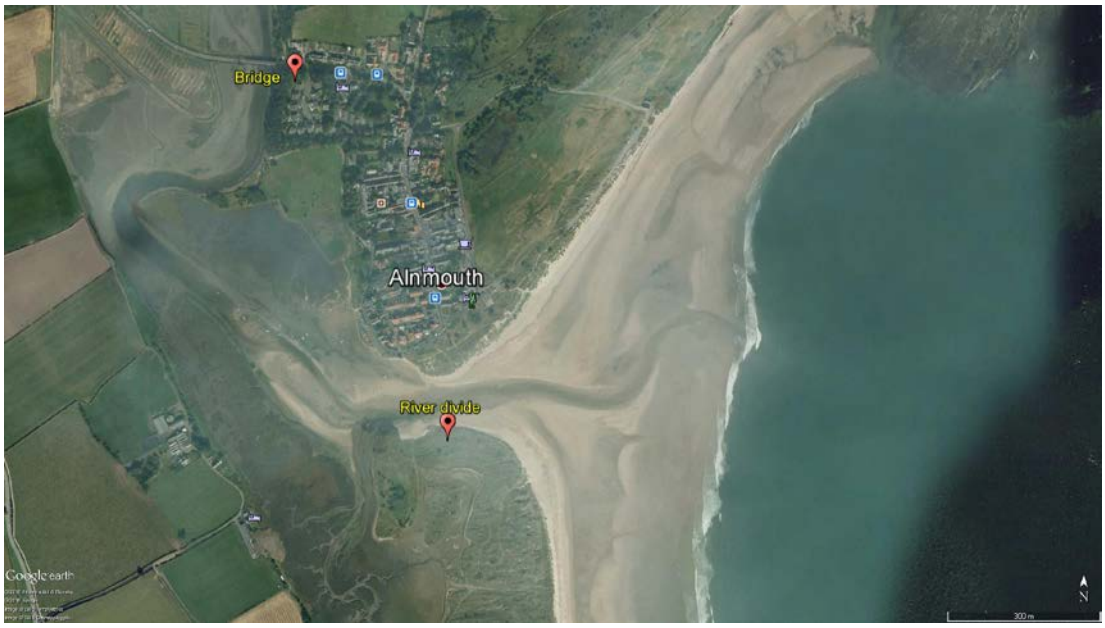


Figure 4. Map of the survey locations for the River Aln.

Figure 5. Map of the survey locations for the River Coquet.

Figure 6. Map of the survey locations for the Wansbeck.

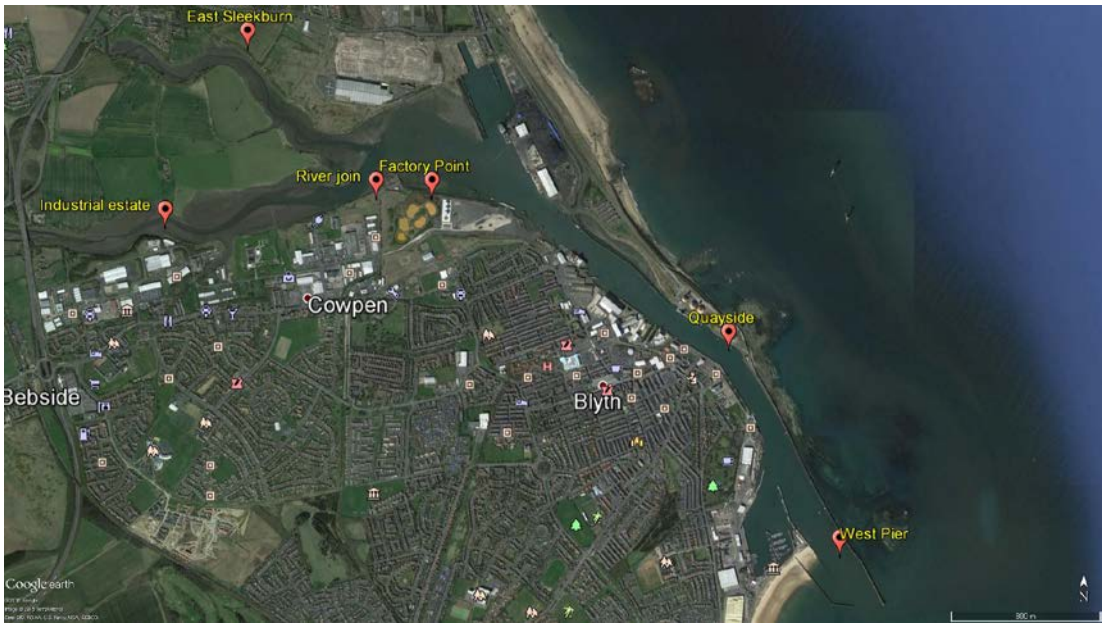


Figure 7. Map of the survey locations for the River Blyth.

3.4 Morecambe Bay & Duddon Estuary

3.4.1 Background information

Morecambe Bay was classified as an SPA in 1996 for supporting internationally important populations of regularly occurring breeding seabirds (Little Tern, Sandwich Tern, Herring Gull *Larus argentatus* and Lesser Black-backed Gull *Larus fuscus*) generating an internationally important seabird assemblage (>20,000 individuals) as well as internationally important populations of eleven species of passage and wintering waders and waterfowl which, in-combination with a range of other species, produce a wetland of international importance (containing >20,000 waterfowl), recognised with additional designation as a Ramsar site. The SPA also contains a number of component SSSIs.

Similarly, the Duddon Estuary SSSI was classified as an SPA in 1998 for supporting internationally important populations of breeding Sandwich Tern and five species of passage and wintering waders and waterfowl. The numbers of waterfowl present mean the site is a wetland of international importance (containing >20,000 waterfowl), which also qualifies the site as a Ramsar site. Both Duddon Estuary and Morecambe Bay form part of Morecambe Bay Special Area of Conservation (SAC).

The only currently extant breeding Sandwich tern colony lies within the Duddon Estuary SPA at the RSPB reserve of Hodbarrow Lagoon. No survey work has been completed in this area to identify to what extent the surrounding coastal waters are used for foraging by Sandwich Tern and as a result the JNCC used a generic model to identify a possible foraging area for Sandwich Tern at this site.

The model suggested the estuary of the River Esk and its component tributaries the Irt and Mite, in the area of Ravenglass on the West Cumbria Coast, lay at the northern foraging limit for Sandwich Tern originating from Hodbarrow. NE attempted a shore-based survey programme in 2014 to validate the northern boundary, north of Haverigg Point, but unfortunately this had to be cancelled, as the birds did not nest following possible anthropogenic disturbance. The current survey was conceived as a further attempt to elucidate the extent of Sandwich Terns originating from Hodbarrow as far north as the Esk Estuary (termed the Ravenglass estuary in the RFQ), but without the additional detail of surveying specifically within the estuary complex.

3.4.2 Survey locations

In 2014, NE intended to survey four coastal sites along the West Cumbrian coast north of Haverigg Point to the Esk Estuary, with a further five survey locations within the estuary complex. In contrast, the RFQ proposed a series of sites should be selected at 3 km intervals along the coast from Haverigg to the Esk estuary, with another to the north of the estuary for a total of nine survey locations. It was assumed that further points would be undertaken within the estuary complex, as had been proposed in 2014. Given the desire to survey the locations simultaneously

or at least within the same day, we proposed the survey of eight locations in total through the use of two surveyors[3] (Table 4 & Figure 8). These included four observation points at ~5 km intervals from Haverigg Point to the Esk estuary accessed from the road at Stubbs Place (SD 080 906) and the Silcroft Caravan Park (SD 121 809), with a further location north of the Esk accessed from Sandy Acre, and three locations within the Esk estuary at the Ravenglass Gullery and Nature Reserve (also accessed from Sandy Acre), and within Ravenglass village and Saltcoats (Table 4 & Figure 8).

Table 4. OS grid references of the survey locations for Morecambe Bay & Duddon Estuary.

Observation point	Grid reference
Haverigg Point	SD 140 779
Gutterby	SD 104 839
Hyton	SD 081 875
Eskmeals	SD 080 908
Drigg Dunes	SD 061 962
Drigg Point	SD 076 953
Ravenglass Main Street	SD 084 962
Saltcoats	SD 079 968

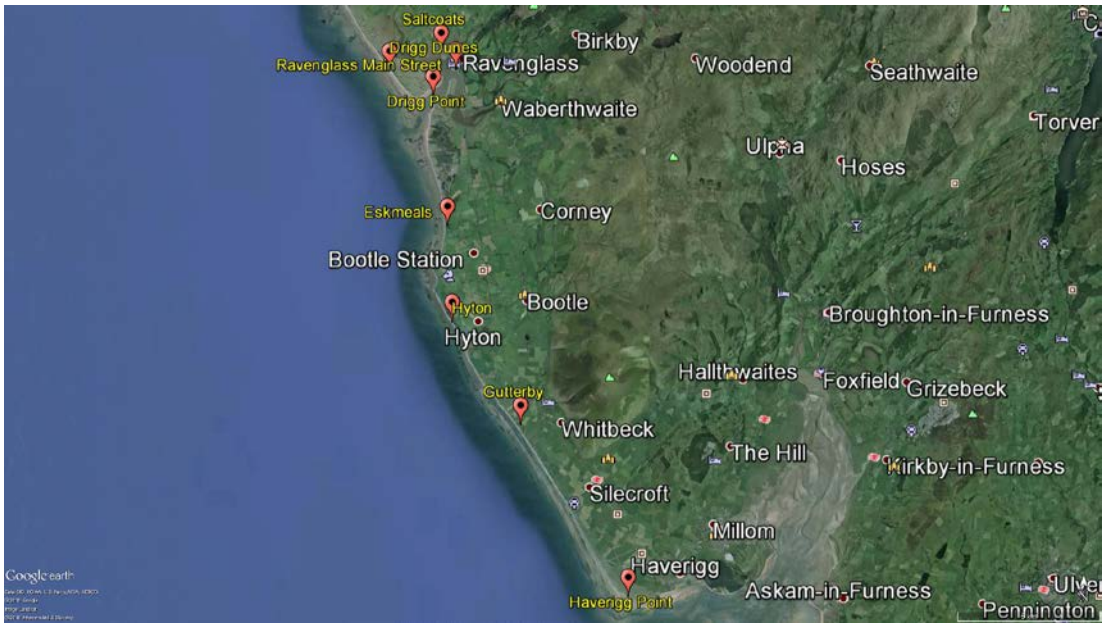


Figure 8. Map of the survey locations for Morecambe Bay & Duddon Estuary SPA.

[3] It was noted in the RFQ that local NE teams would be able to provide surveyors to help deliver the required surveys, but unfortunately this did not prove to be possible.

The sites proposed were successfully covered on 17th June, following a visit to the Hodbarrow colony on the evening of 16th June, where a maximum of 32 Sandwich Terns were seen with two AONs. This confirmed information we received from NE on 15th June stemming from the RSPB that only about 40 birds were present after the initial interest of some 200-300 individuals. In contrast, 36 pairs of Little Terns were beginning to lay eggs, which was the second highest total ever for the site.

Unfortunately, after having travelled to the area to undertake the second survey on 2nd July, the team was informed that Sandwich Terns had abandoned the Hodbarrow colony and the survey was to be cancelled with immediate effect.

3.5 Liverpool Bay

3.5.1 Background information

Liverpool Bay/Bae Lerpwl SPA was classified in 2010 for its internationally important wintering populations of Red-throated Diver *Gavia stellata* and Common Scoter *Melanitta nigra*. The boundary of the SPA is contiguous with the boundaries of The Dee Estuary SPA, Mersey Narrows and North Wirral Foreshore SPA, and Ribble and Alt Estuaries SPA (Natural England 2015c).

The Lancashire Wildlife Trust Seaforth Nature Reserve within the Seaforth docks area at the mouth of the Mersey has become a breeding colony for >150 pairs of Common Terns (http://www.rspb.org.uk/groups/Liverpool/places/342393/) over the past decade. The colony uses pontoons in the main area of the dock/reserve where they are safe from land predators. As well as the use of the Liverpool Bay SPA in a broad semicircle to the middle of north Wirral, the generic JNCC model also predicted the use of the lower 8 km of the Mersey from Seaforth to New Ferry. NE sought to establish if and how far upstream the Mersey Common Terns from the Seaforth were likely to forage.

3.5.2 Survey locations

The RFQ suggested that a number of observation points should be established at 1 to 3 km intervals down the east shore of the River Mersey (i.e. Liverpool side), which is easily accessible, either via the docks to the north or the open waterfront and promenades to the south. It was noted that the river is relatively narrow at these points, although it may be too wide to give accurate observations particularly towards the southern and northern ends of the survey area. In this case some observation points may be required on the west shore (i.e. Wirral side) in the areas of New Brighton to the north and Rock Ferry/New Ferry to the south.

As a result we proposed a total of eight observation points with the most northerly of these within the Seaforth Nature Reserve with another just to the south within the Peel Ports area. Of the remaining six sites, four were proposed on the eastern (Liverpool) side within areas of public access with two on the western (Wirral) side of the river, with one to the north and one to the south (Figure 9 & Table 5).

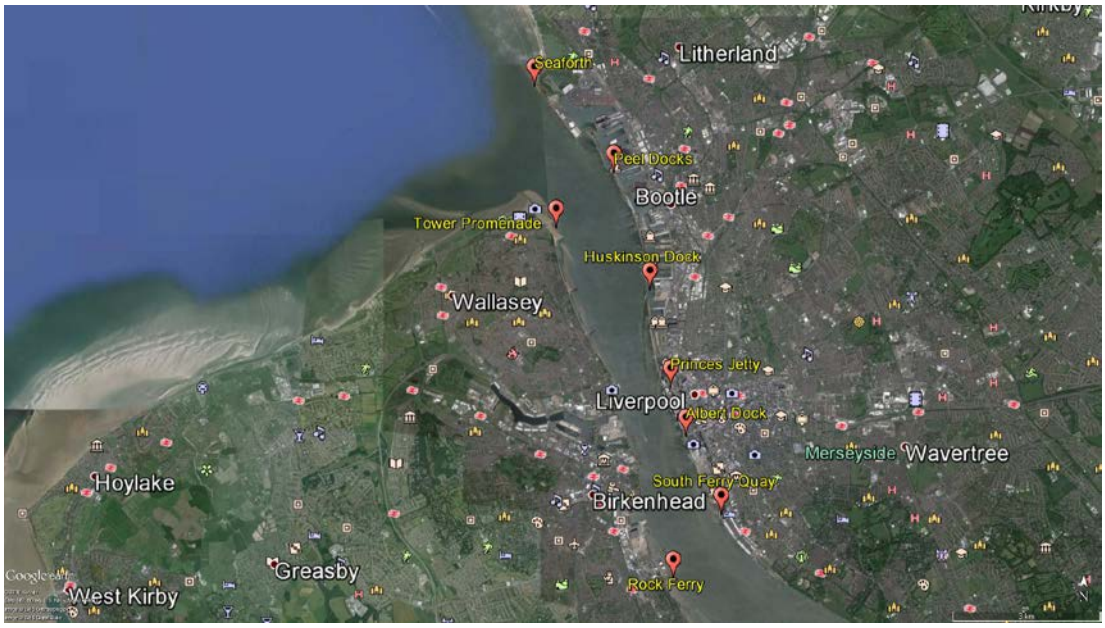


Figure 9. Map of the survey locations for the River Mersey in Liverpool Bay SPA.

Table 5. OS grid references of the survey locations for the River Mersey in Liverpool Bay.

Observation point	Grid reference
Seaforth	SJ 309 970
Peel Docks	SJ 325 952
Tower Promenade	SJ 313 941
Huskinson Dock	SJ 332 928
Princes Jetty	SJ 336 908
Albert Dock	SJ 339 898
South Ferry Quay	SJ 346 882
Rock Ferry	SJ 336 869

The three surveys were successfully undertaken over one day on 18th June, 1st July and 9th July. On the latter occasion, a Common Tern nest containing two eggs was discovered on the quayside in Sandon Half Tide Dock (SJ 3326192679) near survey location 3 illustrating the potential for Common Tern to exploit potentially suitable nesting habitat on quay headings in the area. Also on the 9th July, many of the terns observed at the radar station at Seaforth were seen carrying prey to the colony, indicating the presence of growing chicks in the colony at this time. However, no further information on the ultimate success of the colony was available by the time of the production of this report.

3.6 Solent & Dorset Coast

3.6.1 Background information

Poole Harbour was classified as an SPA in 1999 for its breeding populations of Common Tern (has reached >200 pairs) and Mediterranean Gull *Ichthyaetus melanocephalus,* passage populations of Aquatic Warbler *Acrocephalus paludicola* and Little Egret *Egretta gazetta*, and wintering populations of four species of waders and waterfowl, that also contribute to an internationally important (>20,000 individuals) assemblage. Recent increases in populations of breeding Sandwich Tern (>100<200 pairs) and non-breeding Little Egret means both these species now meet qualifying thresholds. Both Sandwich Tern and Common Tern breed on Brownsea Island managed by the Dorset Wildlife Trust within Poole Harbour.

NE proposes to extend the existing Poole Harbour SPA to include subtidal and intertidal areas that are not currently encompassed within the existing SPA (Natural England 2015d). The seaward boundary of the revised SPA would be at the harbour mouth, abutting the boundary of the proposed Solent and Dorset Coast SPA for foraging terns (Natural England 2015e). At present this proposed new marine SPA will cover an area from Worbarrow Bay in the west to Middleton-on-Sea in the east. The landward boundary will be at Mean Low Water (MLW) to abut any existing SPA where terns are already a feature, but otherwise will be at Mean High Water (MHW) in line with JNCC guidance (Webb & Reid 2004a) to afford the birds protection within the intertidal (e.g. at Portsmouth Harbour). The seaward extent of the new marine SPA boundary is a composite of various foraging ranges of Common, Sandwich and Little Terns originating from existing colonies within the area. However, the wider ranging behaviour of Sandwich Tern, means that much, if not all, of the seaward extent of the proposed boundary is derived from this species.

No species and site-specific data were gathered for derivation of a potential 'foraging' SPA for terns breeding in the area, and the proposed boundaries for the Solent and Dorset Coast pSPA were derived from generic JNCC models. Other than the observation of Aspinall & Tasker (1990) that identified Hook Sands outside the mouth of Poole Harbour as being the main feeding area for breeding Sandwich and Common Terns, virtually no information was available. As a result, NE were keen to undertake surveys to verify the reliability of the proposed western extent of the Solent & Dorset Coast pSPA by gathering quantitative data on the sightings of terns and of levels of foraging activity with increasing distance in a westerly direction along the Purbeck coastline from the presumed source colony at Brownsea island. It was hoped that the westernmost extremity of the boundary to the proposed Solent & Dorset Coast pSPA at Worbarrow Bay would be supported by observations of Sandwich terns passing along the coast and of terns engaged in foraging activity at least as far as this point (or beyond).

A team of volunteers compromising NE staff, staff and students from Bournemouth University and other interested individuals conducted the surveys. Several teams, each of two volunteers, conducted three surveys on separate days spaced at roughly weekly intervals over a period from 8th June - 10th July 2015, timed to coincide with the peak chick-rearing period for Sandwich Terns at Poole Harbour.

3.6.2 Survey locations

To cover the western extent of the boundary of the proposed SPA, a series of 13 survey locations were selected along the coastline between the mouth of Poole Harbour and a point beyond (west of) Worbarrow Bay (Table 6 & Figure 10).

Table 6. OS grid reference of the survey locations in relation to the Solent & Dorset Coast.

Observation point	Grid reference
South Haven Point	SZ037866
Knoll Beach	SZ035836
Handfast Point	SZ055824
Swanage seafront	SZ032792
Peveril Point	SZ041786
Durlston Head	SZ035773
Dancing Ledge	SY997768
Seacombe Cliffs	SY986766
St Aldhelm's Head	SY962752
Chapman's Pool	SY956768
Kimmeridge Bay	SY907786
Worbarrow Tout	SY868796
Lulworth Cove	SY825797
Osmington Mills[4]	SY734817

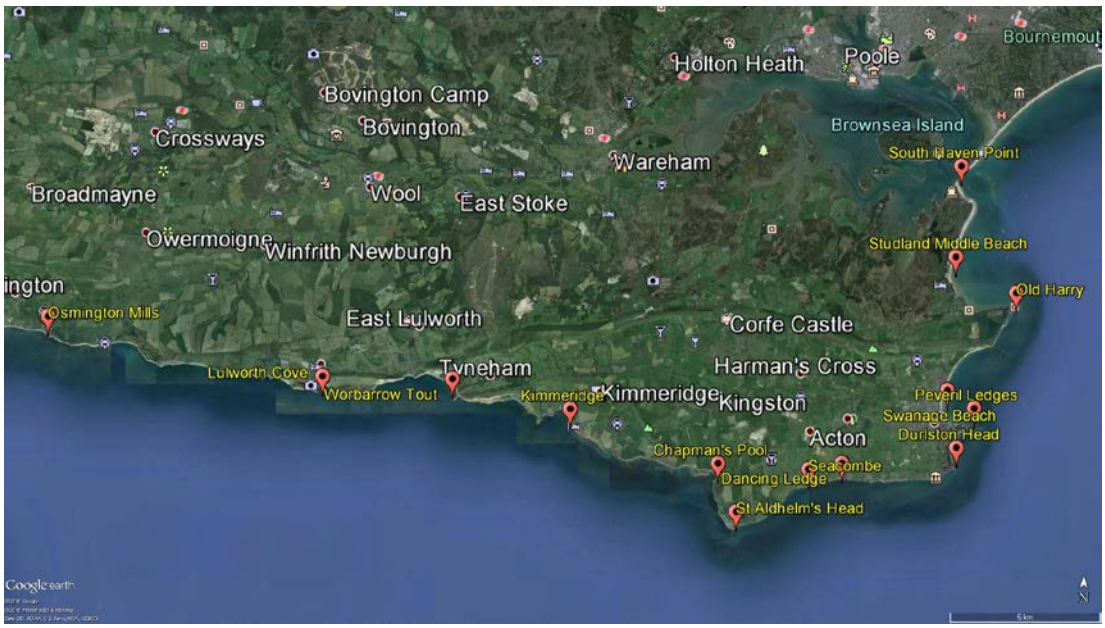


Figure 10. Map of the survey locations relating to the western end of the Solent & Dorset Coast pSPA.

[4] Surveyed on one occasion only.

A further survey location, at Osmington Mills was later added, but surveyed on only one occasion on an *ad-hoc* basis. Observation points were located at variable intervals of a few kilometres along the coastline and included beaches, rocky promontories, headlands and clifftops that all afforded good views out to sea.

4 Methods

4.1 Timing of surveys

At each site, it was thought to be ideal, if not absolutely essential, that the observation stations were surveyed simultaneously. In fact, this proved to be impossible in practice given the resources available to the project.

At the sites contracted to ECON, where no more than two surveyors could be deployed at any one time, sites within the same area were surveyed within the same day, although this invariably led to some variation within tidal state. An attempt was made to rotate the order of the sites on different survey occasions to sample sites in different tidal states where this was thought likely to lead to significant change in available habitat. For example at Teesmouth & Cleveland Coast, observation points were sampled sequentially either in an upstream or downstream direction bearing in mind the vessel left Hartlepool Marina at or near high water to navigate the lock system. Only in one site on the River Blyth in Northumberland was a survey precluded by falling at the lowest possible tide and the virtual absence of water in the channel.

The potential for bias between observers was also thought to have the possibility of being relatively important and in order to minimise this, the same two surveyors (Andrew Green and Dr Lorraine Chivers) surveyed all observation points at Hamford Water, Liverpool Bay, Northumberland and Morecambe Bay & Duddon Estuary. Meanwhile, Dr Martin Perrow exclusively undertook all surveys at Teesmouth & Cleveland Coast.

The use of a limited number of surveyors effectively undertaking surveys of one or two sites over a working week meant that the last sites were sampled two weeks after the first site within a tranche of surveys aimed at each of the three survey occasions. In order to reduce any bias resulting from this, the order of sites was swapped for the second survey occasion. Overall, all surveys at Hamford Water, Liverpool Bay, Northumberland and Morecambe Bay & Duddon Estuary were surveyed in a period of just over one month (10th June - 13th July), with this being very similar to that undertaken at Solent & Dorset Coast (8th June – 10th July). The Teesmouth & Cleveland Coast was also surveyed over the duration of just over one month (18th June - 22nd July), with this most affected by the late start of the contract due to unforeseen circumstances affecting NE procurement. However, Common Terns at Salthome, the relevant colony, often appear to breed later than at other sites (Perrow *et al.* 2010) and thus it was likely that the survey period was still likely to encapsulate the chick-rearing period (as well as part of incubation) rather than fall within the post-fledging period in a more typical colony in a normal season.

In the surveys of the Solent & Dorset Coast, a larger workforce promised more scope for simultaneous sampling, although the voluntary nature of that workforce meant that this could not be arranged. Nonetheless, in the Purbeck surveys many sites were surveyed simultaneously, with others generally following within a few days and always at the same tidal state. The three survey periods were scheduled to cover differing stages of the tidal cycle: low tide (half an hour either side of time of low tide in Poole Harbour), high tide (half an hour either side of time of high tide in Poole Harbour and flooding tide (between 1 and 2 hours after time of low water in Poole Harbour).

4.2 Shore-based observations

4.2.1 Basic methodology

A methodology developed by JNCC for Little Tern to determine the relationship between the alongshore extent of foraging from a specific, central colony location (Parsons *et al.* 2015) was used for all sites sampled in this project. As such, it was thought that the methodology was inherently suitable for application to Little Tern at Hamford Water, bearing in mind that the same methodology had previously been used to survey the site in 2013.

The RFQ suggested that the details of the methodology such as the limits to the alongshore extent of observation points, spacing of observation points and the duration of observations at each station, would need to be adjusted for use on the larger tern species and on a case-by-case basis depending upon the characteristics of the site in question and the areas of particular concern. In fact, no specific changes to the methodology were suggested by any of the site-leads during survey preparations and the same basic methodology was therefore used throughout the surveys.

The following basic information was recorded on a standard recording form at the start of each observation period at each of the survey locations established at each of the six SPA/pSPA sites:

- Date
- Survey location name, number and GPS position later converted to a six figure OS Grid Reference (as undertaken at Solent & Dorset Coast)
- Observers (initials)
- Start and end time of observation period
- Sea state (where applicable) wind direction, wind strength
- Tide times and heights (filled in in advance or later from local tide tables)
- General weather conditions

In essence, the survey itself was comprised of two separate methodologies that were performed by each observer simultaneously:

- Timed counts
- Snapshots at regular intervals

The specific details of each methodology are outlined below.

4.2.2 Timed counts

The European Seabirds at Sea (ESAS) protocol assumes all seabirds may be routinely detected to a distance of 300 m (see Camphuysen *et al.* 2004), bearing in mind this is from a survey platform at a minimum of 5 m above sea surface. Some birds at greater distances than 300 m may also be detected by eye, particularly when in groups. For Common and Sandwich Terns, experience dictates that birds at this distance are readily seen and as they are typically encountered in flight, may also be readily detected from an observer below or at a similar level to the bird.

Little Tern is considerably smaller than the larger tern species however, and accordingly there is a case for the use of 200 m as a detection distance. However, a default detection distance of 300 m was assumed at Hamford Water, given that the survey was dedicated to Little Terns and thus these were unlikely to be missed as observers were distracted by other bird species, coupled with the fact that the observers also undertook some scanning with binoculars to confirm that birds were not being missed.

Scanning with binoculars allows the ready identification of birds to at least 500 m and this was adopted at sites with few birds especially where the habitat being covered was expansive, such as on the Mersey in Liverpool Pool or at some of the estuarine sites on the rivers in Northumberland. Birds seen at distances clearly greater than 300 m were recorded and noted as such.

At the Solent & Dorset Coast the observers routinely used binoculars to cover a prospective radius of ~500 m. This survey area was determined by the degree of confidence that observers could record and identify all terns within the survey area, and by what was feasible at the observation point closest to the colony i.e. where passage rate was highest and therefore where the area that could be surveyed with complete coverage was most limited.

For the sake of consistency between all sites and to ensure that important records of birds that were seen at a survey location were not discounted on account of being further than 300 m from the observer, all birds seen were included in the timed count records expressed in relative terms as a mean number of birds of a particular species per observation period.

The duration of the shore-based count ranged from 30 minutes at Hamford Water (as well as at Teesmouth & Cleveland Coast during boat-based surveys – see 4.3.2 below) to one hour at all other sites (Liverpool Bay, Northumberland, Morecambe Bay & Duddon Estuary and Solent & Dorset Coast). The reason for the more limited survey time at Hamford Water was because of the tidal restriction at this site and the need to access all survey locations and travel to and from the site all within one day.

The JNCC methodology suggested that all terns seen over the timed count should be counted, taking care not to 'double count' any individuals that may be lingering in the area rather than passing through. In practice, the prospect of 'double-counting' was thought to be low in situations when birds were recorded simply passing along the coast or up and down a river. Conversely, the likelihood of double-counting was high in situations where individuals flew out of sight of the observer to be followed by a further sighting a few minutes later of a bird flying back into view in the other direction. In effect, the observer made a judgement whether this was likely to be the same or a different bird.

The basic methodology was to record the following:

- Number of birds travelling away from the colony
- Number of birds travelling towards the colony
- For each bird observed, whether it exhibited any foraging behaviour (f) (diving, hovering, actively searching e.g. circling around with its head down) or whether it was carrying a fish apparently back to the colony (+F).

At the Solent & Dorset Coast, the relative position of the colony within Poole Harbour to the survey locations to the west of the colony allowed birds flying east or west to be assigned as flights to or from the colony respectively. In addition to the basic protocol, the time of each observation was recorded.

In contrast, it is important to note that the selection of survey locations at several sites such as Northumberland, Morecambe Bay & Duddon Estuary and Teesmouth & Cleveland Coast (also see below) was not specially driven by a desire to establish the relationship between the numbers of birds and the distance from the colony. Rather, the focus of the survey was in particular locations, potentially at the extralimital range of the birds. As such, the likely provenance of birds relative to a particular colony was often difficult or even impossible to determine, thus affecting how the data was recorded. For example, at Northumberland and Teesmouth & Cleveland Coast (also see below), birds were recorded foraging within rivers potentially at considerable distance from the nearest colony and where the orientation of the river did not coincide with an obvious direction to the colony. In this circumstance, a foraging bird may be more likely to follow the river to the sea before reorienting to the colony where this has a coastal location. In these cases, travelling 'to' or 'from' the colony could not be recorded and this was substituted by travel 'upstream' or 'downstream' instead.

However, whether the bird passed the observer heading downstream having come from upstream of the observer, or whether the bird passed the observer heading upstream having come from downstream of the observer, can be seen as an irrelevance. In both cases, the bird would have accessed areas upstream and downstream of the observer. For this reason, the direction of birds was not used as a basic division in the data, but rather the term 'directional flight' was used (see Appendices 8.1-8.6). Moreover, terns are frequently foraging even during what appears to be directional flight, as exhibited by a sudden exploitation of an opportunity as it becomes available. That is unless they are already carrying prey to present to a partner or chick, or for the purposes of display.

Nonetheless, persistent and active foraging behaviour is readily recognised and is typically characterised as flight without clear direction. Terns, perhaps especially Common Tern, also rest frequently on available anthropogenic structures such as posts, buoys and other floating objects and quay headings as well as natural banks and beaches. Thus, the data gathered at all sites by ECON was simply expressed within three broad categories: 1) directional flight, 2) foraging without direction, and 3) resting. Within the category of directional flight, whether the birds were carrying prey as well as details of that prey (identity and size relative to bill length) was also recorded. Similarly, the details of prey captured during foraging events were also recorded.

4.2.3 Snapshots

Snapshots represent the instantaneous recording of birds within a defined field of view. In boat-based surveys (see 4.3.3 below in relation to Teesmouth & Cleveland Coast), snapshots are primarily used to determine the density of flying birds that would otherwise be travelling at higher speed than the survey platform and where continuous recording would overestimate the numbers of birds present within a defined survey area. Density may allow the calculation of a passage rate in some circumstances (see Camphuysen *et al.* 2004).

In the context of the fixed survey locations, the mean count of birds in each snapshot was readily derived. However, the use of semi-circular radius of 300 m from the observer sampling a fixed area of 0.141 km^2 also allowed the routine calculation of density. In this report, both mean count and density are presented, with the former typically shown in figures.

The JNCC methodology states that snapshot counts are an optional extra to the more important data collection of timed counts and state that if snapshot counts are too demanding or they are interfering with the other data collection, then they could be abandoned. However, snapshots at regular intervals are thought to offer a better representation of the frequency or overall time of different behavioural activities than observations in timed counts. This is because the activity of a bird is recorded instantaneously in a snapshot, providing little opportunity for ambiguity. In contrast, a bird recorded in a timed count may be observed for some time during which a number of behaviours or activities can be displayed. Despite the attempt to define the activity of the bird when first seen, there is still a tendency to record the more prevalent or intermittent behaviour in longer than instantaneous observations. Thus, a bird is perhaps more likely to be recorded as generally foraging rather than in directional flight (see 4.2.2 above).

In the context of this study, snapshots were seen as the primary means of defining the use of the area around the survey location, particularly for foraging. Therefore, the activity of a bird in a snapshot count was simply defined as ‘foraging’ or not ‘foraging’, with the former also divided into prey capture (fishing) and the latter also noting whether the bird was resting or perhaps actively engaged in courtship activity. Accordingly, no attempt was made to distinguish between particular individuals between snapshot counts. In other words, a relatively high mean count of foraging birds for example, could result from the same few birds being present for

an extended period whilst foraging or could represent high exchange of a much larger number of birds. For this reason, whilst the snapshot count (see 4.2.2) is indicative of the relative use of the area around the survey location, and in particular the relative proportion of time spent foraging, it should not be seen a specific measure of bird abundance, which is best represented by the timed count (see 4.2.2 above).

Snapshot counts were initially undertaken at 2-minute intervals over the 1-hour observation period at Northumberland, Liverpool Bay and Morecambe Bay & Duddon Estuary to provide 31 sampling occasions (as a snapshot was also taken at the end of the period). At Hamford Water with a 30-minute sampling period, 16 snapshots were taken. Following the experience of the first round of surveys, and in particular the experiences at Teesmouth & Cleveland Coast where 1-minute intervals were successfully undertaken despite the presence of a relatively large number of birds (see 4.3.3 below), the snapshot interval was reduced to 1-minute at all sites. Therefore, the activity time budget at different survey locations and sites was derived from 62 snapshots or 31 in the case of Hamford Water.

Moreover, snapshots were given a lower priority compared to the detail of the timed counts at Solent & Dorset Coast and were taken at five-minute intervals delivering 12 snapshots (without a snapshot at the end of the survey period). Given the relatively high number of birds encountered, this was still thought likely to provide a reasonable indication of the degree of foraging compared to non-foraging activity.

4.3 Boat-based observations

4.3.1 Basic methodology

The RFQ proposed a boat-based survey along the River Tees as a fundamental part of the work for the Teesmouth & Cleveland Coast on account of the complexity of ownership and likely difficulty of access for shore-based observers. In this respect, the survey was to effectively provide the same data as recorded by the shore-based observations.

However, in order to provide information on the use of the wider area of Hartlepool Bay that also falls within the known foraging area of Common Terns from Salthome (Perrow *et al.* 2010) and the proposed SPA (Natural England 2015b), relative to the River Tees, we also proposed the use of the boat-based methodology adopted by the JNCC for recording use of offshore waters around colonies by Little Terns (Figure 11). This in turn is broadly based upon the standard ESAS-style boat-based methodology (Camphuysen *et al.* 2004), although with a key difference of the use of snapshot counts within a radial (semi-circular) area of coverage that, in contrast to the standard ESAS 300m box approach, delivers only records of birds within a constant distance of 300 m from the observer.

As well as the behaviour of the terns encountered (foraging expressed as area restricted search or actively feeding), their direction of flight according to eight compass locations was also determined.

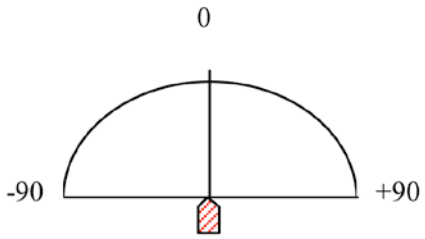
Constant effort counts

Binoculars may be used for confirming identification, but not for the detection of birds.
The following information is to be recorded for each bird encountered along the transect line:

1. Time of each observation (hh:min:ss)
2. Number of Little Terns observed
3. Estimated range of the bird
4. Estimated bearing of the bird
5. Behaviour of each tern / group of terns (according to a limited number of predefined options)
6. Flight direction of each tern / group of terns
7. If the count has not been done ahead of the boat, then record whether it was port or starboard, and a 180^0 arc or 90^0 sector

The data recording sheet will have boxes to record if a bird observation is within an instantaneous snapshot count.

Bearing should be recorded in reference to the boats track i.e. straight in front of the bow of the boat is 0 deg. Observations to port (left of the boat) are recorded as minus figures between 0deg to -90deg and observations to starboard (right of the boat) are recorded as plus figures between 0deg to +90deg.



Snapshot counts

Instantaneous snapshot counts will be recorded at 1 minute intervals given a constant speed of 10kts i.e. 300m apart. This time interval should be adjusted if the speed of the boat changes. There will be a box on the data sheet to record the snapshot count. The snapshot count section is a 180^0 arc forward of the boat. All birds seen within this arc should be recorded. A stopwatch with an alarm loud enough to be heard over the engine of the boat and which counts down at 1 min intervals should be used. Without this it is virtually impossible to remember to keep to 1 min snapshots.

For each snapshot count, the following data should be recorded, in order of priority:

1. Time of each snapshot count (hh:min:ss)
2. Number of Little Terns seen within the snapshot area (180^0 arc, to 300m)
3. If time allows, behaviour of the tern / group of terns (according to predefined options)
4. If the count has not been done ahead of the boat, then a note of whether it was port or starboard.

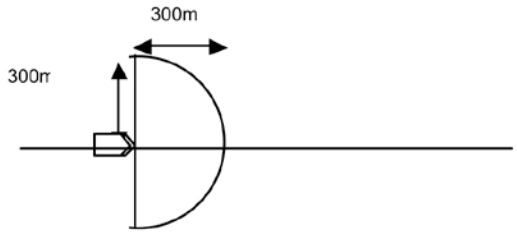


Figure 2. Diagram of a snapshot count. An area encompassing a 180^0 scan 300m either side of the boat's course on each side of the boat, and ahead for a distance of 300m. All terns within this area are recorded.

Figure 11. JNCC methodology for constant effort counts and snapshot counts used for terns at Teesmouth & Cleveland Coast.

The boat-based survey methodology undertaken therefore integrated three survey techniques:

- Timed counts at selected fixed survey locations
- Snapshots at selected fixed survey locations
- Snapshots and continuous survey from a moving platform along a transect route.

The boats used were the 11 m Ali-Cat (18th June) and 10 m Famous (2nd and 22nd July) catamarans of similar design skippered by local fisherman Dave Lumley under the auspices of Famous Angling Charters. Both catamarans offer excellent unrestricted forward vision from an eye-height of approximately 3.5 m above water surface. Both vessels are moored in Hartlepool Marina and access to and from the marina is possible at up to three hours to and from high water. Surveys were begun from around 05.00 and completed at between 18.00-19.00. Dr Martin Perrow undertook all surveys.

4.3.2 Timed counts

The timed counts at the six priority survey locations and the 8-11 additional locations at approximately 1 km intervals along the River Tees and including the site at Hartlepool Marina were undertaken in the same manner as described for shore-based observations. Counts were conducted over 30-minute periods in order to complete as many periods as possible over the length of the Tees from the Seaton Channel to the Tees Barrage (~15 km).

The only difference in methodology was that the radial field of view of 300 m from the observer was orientated facing upstream or downstream rather than perpendicular to the channel as it would be during shore-based observations. This was primarily in keeping with the requirement to be able to respond rapidly and move the vessel either up or downstream according to the needs of the shipping using much of the river, as well as providing the most suitable orientation to include the entire area of the Barrage, and of the river in general. The width of the river varies from ~100 m at the Barrage to at least 2 km near the Seaton Channel, with much of the river being around 300 m in width, in accordance with detection distance in any direction from the observer (see 4.2.2 above). Although the area of river surveyed reduced with the width of river in its upstream reaches, a detection distance of 300 m was maintained to include those Common Terns flying over land to access or leave the river, which was a relatively frequent occurrence.

The RFQ suggested that Tees Barrage should be sampled within three hours of high water. However, variation in the order of events of the transect survey (see 4.3.4 below) meant that the Barrage was sampled by a timed count at or around high water on the first and third survey occasions, but at low water on the second occasion. The variation in the part of the tidal cycle sampled at the Barrage and indeed, at most other survey locations was thought to better represent the conditions experienced by the birds and reduce any relative bias to a particular survey location introduced by always sampling at the same part of the tidal cycle.

4.3.3 Snapshots

The 31 snapshots over the 30-minute count periods at each of survey locations in relation to the Teesmouth & Cleveland Coast were undertaken in exactly the same manner as described in 4.2.3 above for the other sites surveyed (with the exception of Solent & Dorset Coast).

4.3.4 Transect surveys

A boat-based transect survey begun from Victoria Harbour in the north across Hartlepool Bay to Teesmouth and upstream to the Tees Barrage and thence in return to Hartlepool Marina, was undertaken on each survey occasion. A slightly different route across Hartlepool Bay was selected on each outward and return leg to try and cover the different depths and potentially habitats available to foraging terns. This was within the restrictions imposed by tidal state and the need to avoid areas of dangerous rocks as well as a considerable extent of fixed fishing gears. The total length of transect varied from 22.5 –26.5 km.

Either the outward (first and third occasion) or return (second occasion) leg was surveyed as shown in Figure 11 in a continuous fashion at 10 knots. The rotation of the survey protocol meant that the vessel reached Tees Barrage within three hours of high water on the first and third survey occasions, but at low water on the second occasion, thereby sampling a range of tidal conditions (see 4.3.2 above).

At 10 knots, snapshots recorded as waypoints on a hand-held GPS were taken at 1-minute intervals to coincide with a distance of 300 m (the detection distance). The other leg of the transect survey was punctuated by stops to conduct the timed counts at ~1 km intervals at the required survey locations. Where the survey location did not correspond to the position of a snapshot, the vessel returned to the snapshot location to resume the continuous survey. The rapid acceleration of the survey vessels taking just a few seconds to get to survey speed of 10 knots meant that adjustment of the timing of the following snapshot was deemed to be unnecessary.

An area of 0.141 km^2 was covered by a semi-circular field of view of 300 m from the observer (even where this extended beyond the width of the river) in each snapshot. As such, counts of the different species were converted to density as individuals (ind.) km^{-2}, which was useful for comparative purposes, especially in relation to data from other sources.

The location of any terns recorded during the continuous survey was determined through a combination of bearing and estimated distance from the vessel (see Figure 11) relative to vessel location as determined by the track recorded at 3 or 5 second intervals on a hand-held GPS, and the time of the observation recorded to the nearest second. This information as well as the behavioural information gathered during both the continuous recording and the snapshots along the transect route was ultimately considered to be beyond the needs of the current report.

4.4 Data analysis

4.4.1 Derivation of boundaries to be validated

The primary objective of this study was to validate the boundaries of a suite of potential SPAs predicted to contain areas of importance for foraging terns. In the case of Little Terns at Hamford Water, the boundary proposed by NE (Natural England 2015a), is based simply on the alongshore and seaward limits to previous site-specific observations of Little Terns around this colony. In the case of the larger tern species, the proposed boundaries were based on the predictions of habitat association models developed by JNCC with support from specialist contractors (Win *et al.* 2013, Wilson *et al.* 2014).

The habitat association models were used to make predictions of the distribution of tern foraging activity expressed as relative usage by each species around each colony. Wilson *et al.* (2014) present maps of relative usage that tend to include 'hotspots' of greatest relative usage by each species around each colony. In order to use that information as a basis to determine boundaries to areas included within potential marine SPAs, it was necessary to apply an objective threshold setting approach to the models' predictions of relative usage. In line with previous marine SPA work by JNCC, an approach based on maximum curvature (i.e. the law of diminishing returns) was applied (Win *et al.* 2013). Maximum curvature is an objective, repeatable method, which identifies a threshold value (of usage in this case) for each species, and all sea areas with a value greater than this threshold usage are included within the species-specific boundary (O'Brien *et al.* 2012).

Large areas of the predicted usage surfaces generated by the models described in Wilson *et al.* (2014) had no observations of a particular species (i.e. zero observed usage) and very low predicted usage. The threshold usage value identified by maximum curvature analysis is sensitive to the size of the area of search (Webb *et al.* 2009). Therefore, the usage surfaces were constrained before application of maximum curvature. A radius the size of the global mean maximum distance to colony was used as a species-specific constraint as follows: Arctic Tern = 30km, Common Tern = 20 km, Roseate Tern = 21 km and Sandwich Tern = 32 km. These values are based on a large amount of visual tracking data from JNCC/ECON Ecological Consultancy Ltd and data reviewed by Thaxter *et al.* (2012). Within those areas, predicted relative usage values of individual grid cells were then ranked in ascending order. The relationship between the cumulative usage of birds and cumulative area is curved, increasing rapidly at first as high usage areas are selected and then increasing more slowly as larger areas are required to capture the same number of birds in low usage areas. Maximum curvature identifies the point beyond which disproportionately large areas are required to support the same number of birds.

The software GenStat (15th Edition) was used to perform maximum curvature analysis on the predicted tern usage values. The point of maximum curvature was

determined by fitting a statistical model[5] that was either exponential ($y = b(1 – \exp(-rx))$, or double exponential ($y = b(1 – \exp(-rx) + c(1 – \exp(-sx))$ to best fit the relationship between cumulative usage and cumulative area supporting that usage. Having selected the model with the best fit, maximum curvature then identifies the point of greatest change in the relationship between the cumulative modelled usage of birds and the cumulative area that supports that usage of birds. The method aims to delineate an area that is as parsimonious as possible by identifying the highest value among the modelled curvature values and reading across the output spreadsheet to the usage column. All cells in the modelled usage prediction surface with a usage greater than the threshold value are then included within the boundary.

Boundaries to include all sea areas with usage in excess of the defined threshold value were drawn following an accepted protocol described by Webb & Reid (2004b). Lines of latitude and longitude were followed to the nearest 10 seconds, such that the boundary was always a minimum of 250 m from any grid cell with a predicted usage greater than the threshold value. The boundary was drawn following these guidelines but in as simple a manner as possible, which inevitably resulted in some lower usage areas being included within the boundary.

Possible breeding tern SPA boundaries were delineated in two different ways: 1) for breeding colonies where a single species is present boundaries were drawn as simply and with as few vertices as possible; 2) where there was more than one species of interest for a colony, the individual species boundaries were overlain to allow a composite boundary for all tern species to be delineated. The outermost (most seaward) boundary was chosen to ensure that all cells above the maximum curvature threshold were included, even if such cells did not meet the threshold for other species. This procedure reduced subjectivity while drawing the boundary. However, it was impossible to exclude some areas that did not exceed the usage threshold identified by maximum curvature. All landward boundaries were clipped to mean high water mark, which is the point at which terrestrial SPAs commence within England.

4.4.2 Comparison of survey data with the proposed boundaries

In accordance with the needs of the current project to verify whether specific tern species used particular locations as predicted by those habitat models, simple graphical display through GIS was used as the primary analytical tool.

For each site, plots for each survey occasion were generated showing total count for timed counts, mean count for snapshot counts and density (ind. km^{-2}) for snapshot counts in the case of the boat-based surveys at Teesmouth & Cleveland Coast, overlaid on a base map showing the boundary of the proposed SPA and the model predictions where relevant. The appropriate GIS layers were supplied by the JNCC. We understand that the NE team may have modified the boundaries slightly for the purposes of the departmental briefs, which led to the technical notes outlining the

[5] As taken from O'Brien *et al.* (2012), Y is the cumulative modelled usage of birds and x is the cumulative area supporting that usage. In the equations, b and c correspond to asymptotes as x tends to plus or minus infinity, depending on the sign of r and s. The parameters r and s are rate parameters, determining the shape of the curve.

proposals for each site i.e. Hamford Water (Natural England 2015a), Teesmouth & Cleveland Coast (Natural England 2015b), Liverpool Bay (Natural England 2015c), Northumberland (Natural England 2014b) and Solent & Dorset Coast (Natural England 2015e), with the latter associated with proposed changes to Poole Harbour (Natural England 2015d). We were not supplied with any modified files.

In the case of Teesmouth & Cleveland Coast, the distance to the Salthome Common Tern colony of each timed count and snapshot location from the transect route, was determined in GIS. The distance to Victoria Harbour in Hartlepool set an upper limit of 12 km. Data was then categorised into 1 km divisions beginning at 1-2 km as the colony is >1 km from any water. Whereas the coverage of the transect route meant that snapshot density was available for a complete range of distance categories from 1-2 to 11-12 km, for timed counts, data was only available for categories from 1-2 to 5-6 km corresponding to sections of the River Tees and then from 10-11 and 11-12 km corresponding to Hartlepool Marina and Victoria Harbour respectively. The number of observations in each category varied from 16 (11-12 km) to 81 (1-2 km) for the n = 494 snapshot counts and from 3 (10-11 and 11-12 km) to 12 (5-6 km) for the n = 46 timed counts. The mean ± 1 standard error (SE) of the counts or density ind. km^{-2}) within each distance category was then calculated.

The use of each 500 x 500 m grid cell predicted from the habitat model for Common Tern was provided by the JNCC. The straight-line distance of the centroid of each grid cell from the colony to a maximum distance of 12 km was then determined in GIS. A total of n = 222 cells were included. The number of cells within the same 1 km divisions applied to the survey data varied from 2 (2-3 km) to 54 (11-12 km). The mean ± 1 standard error (SE) of the predicted usage values in each distance division was then calculated and compared with the mean ± 1 standard error (SE) of the counts and density (ind. km^{-2}) delivered by the different survey methods.

At Solent & Dorset Coast, where survey locations were placed at increasing distance from the colony in Poole Harbour, a series of investigations of the abundance or behaviour of birds according to the distance from the colony were undertaken including:

- The average number of each species of tern seen passing each observation point per hour averaged over the three surveys and regardless of its direction of travel and engaged in actively searching or foraging within the survey area. Exclusion of the birds seen in transit was to allow a more direct comparison with the predicted usage levels generated by the models derived by analysis of locational records of terns that were actively searching and foraging.
- The average number of each species of tern recorded as actively searching or foraging during the instantaneous snapshot count at each observation station averaged over the three surveys.
- The average number of each species of tern seen per hour at each station carrying fish back in the direction of Poole Harbour averaged across the three surveys.

Caldow (2015) showed a series of plots for both Sandwich and Common Terns encompassing the distance spanned between the survey locations at which the above data outputs exceeded a defined threshold (typically >0 or well above 0). These plots

are replicated in this report in the relevant discussion of the performance of the models with the section comparing the distribution and abundance of the survey data relative to the proposed SPA.

5 Results & discussion

5.1 Hamford Water

5.1.1 Spatio-temporal abundance

A total of 196 Little Terns were recorded over the three surveys (Table 8.1.1 in Appendix 8.1) with similar numbers on the first two June surveys (50 and 52 birds respectively) and larger numbers on the third survey in mid-July (94 birds - 48% of the total). An increase in birds seen would seem to coincide with the breakdown of the colony or colonies in the area, as illustrated by the presence of fewer birds apparently attending nests (4 AON) on the final survey than on the previous two occasions (7 and 8 AON respectively).

Records were concentrated at the colony (31%) and the sites immediately adjacent (1 km) to the colony (site 1 – 23% and site 7 – 26%), with the only other significant number of records within 2 km of the north of the colony at site 8 (18%). The latter site was only used to any extent on the final survey, potentially after birds had failed in their breeding attempt.

Small numbers of both Common (27 records) and Sandwich Terns (31 records) were also recorded during the surveys (Tables 8.1.2 & 8.1.3 respectively in Appendix 8.1). It is of note that the majority of Common Terns (70%) were recorded on the first survey of 8th June, which is perhaps more consistent with these birds breeding locally although they could have failed early in a nesting attempt at colonies elsewhere. The fact that Common Tern was only recorded at sites 1 & 2 is also suggestive of local breeders.

The opposite pattern was observed with Sandwich terns with small numbers in the first two surveys consistent with non-breeding birds, followed by an increase in numbers (65% of records) on the final survey in mid-July suggestive of failed breeders. In both cases, the consistent occurrence of other species of terns alongside breeding Little Tern, especially at sites around the Little Tern colony would indicate the relative value of the area as a foraging ground.

5.1.2 Patterns of activity

In the timed counts, Little Terns were generally recorded either in directional flight (44%) or foraging (46%), with the records of resting birds (10%) limited to those apparently nesting in the colony (Table 8.1.1 in Appendix 8.1). Snapshots suggested a greater preponderance of foraging activity, compared to directional flight, with the focus of foraging activity within 1-2 km and especially to the north, of the colony (Figure 12). No resting birds were recorded in snapshot counts as birds within the colony were noted at a greater distance (>300 m), than covered by the snapshots.

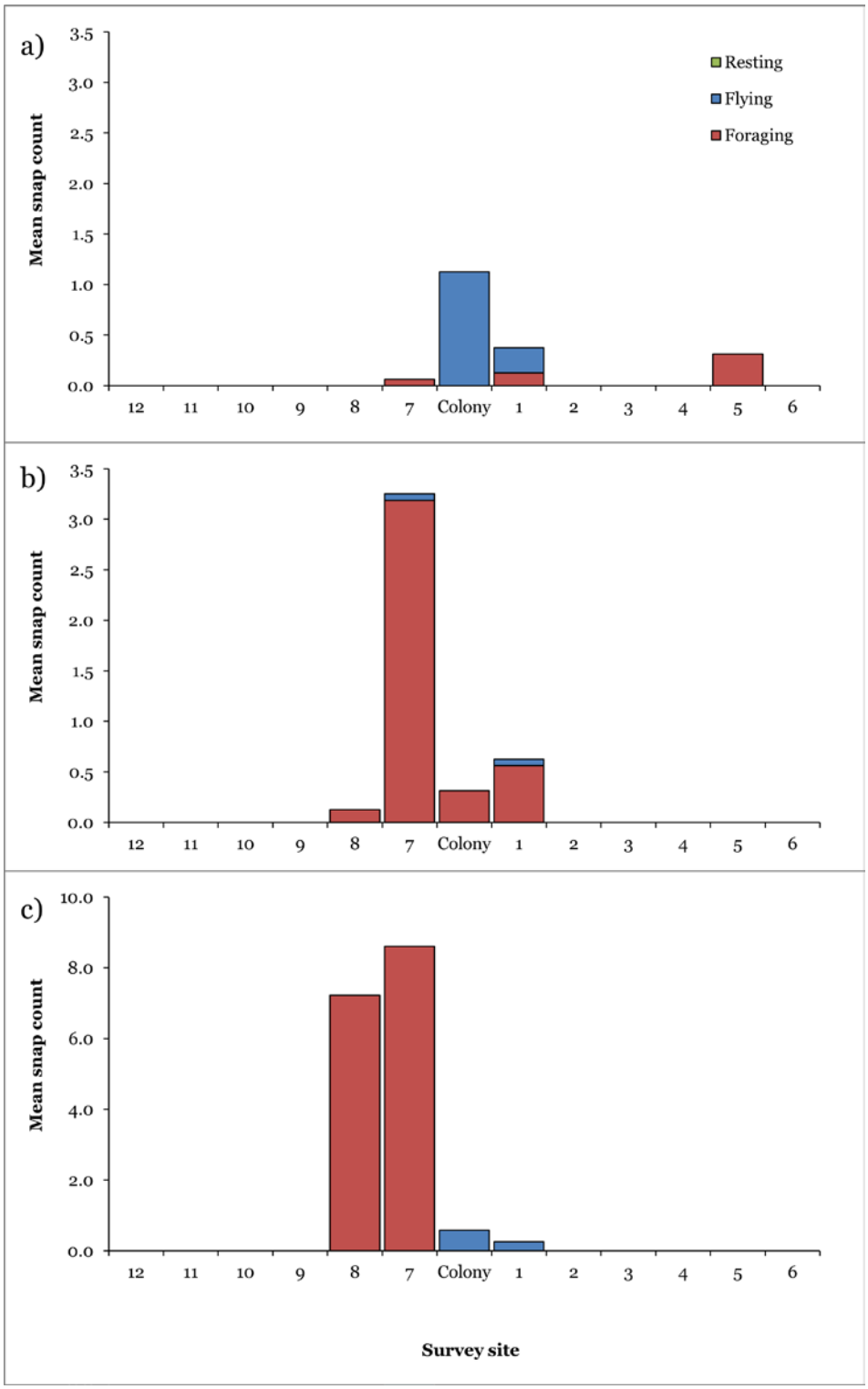


Figure 12. Activity patterns of Little Terns derived from mean count in snapshots at the different survey locations on each survey occasion at Hamford Water, represented by a) 8th June b) 22nd June and c) 13th July.

5.1.3 Comparison with the proposed SPA

Under contract to the JNCC, ECON conducted shore-based surveys to determine the alongshore extent of foraging Little Terns from the colony in 2013. Analysis of these surveys as well as boat-based surveys in both 2012 and 2013 (ECON conducted the latter only) resulted in proposals for possible SPA boundary by the JNCC (Figure 13).

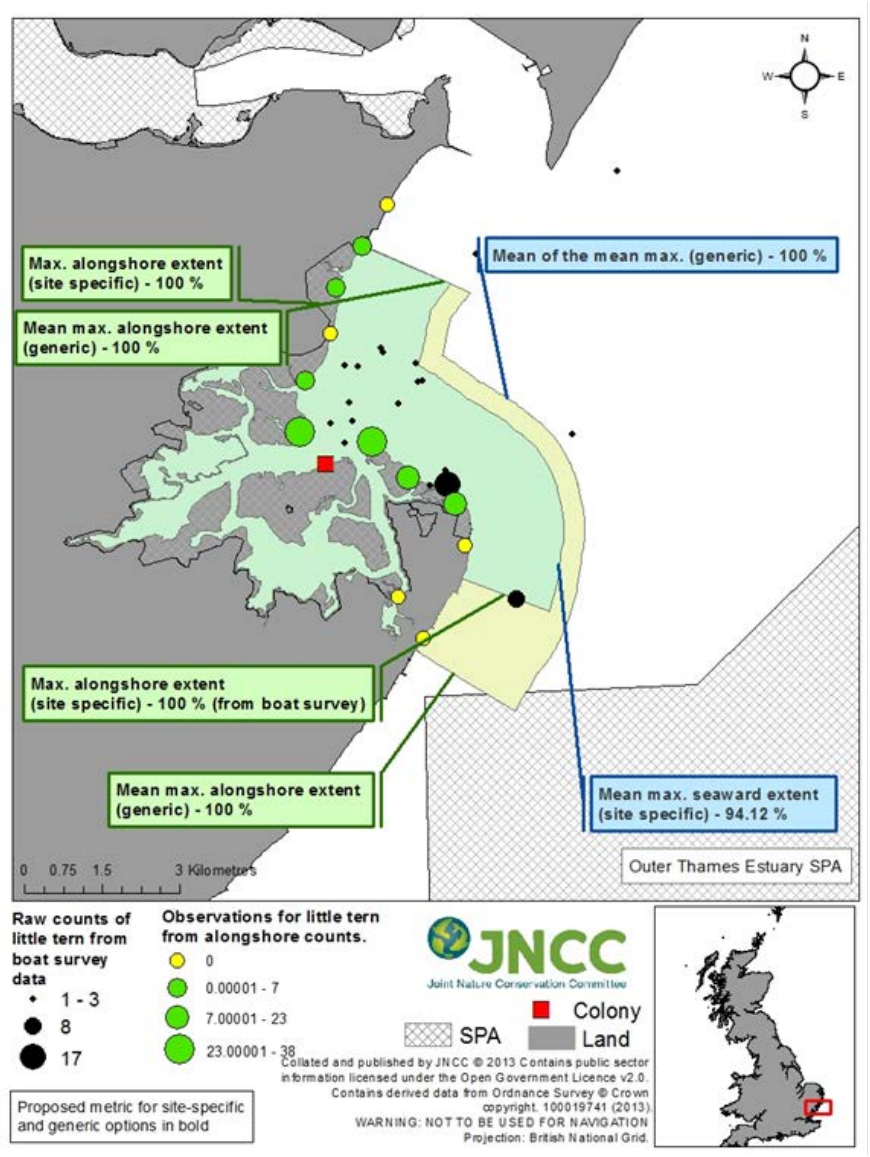


Figure 13. JNCC proposal for a revised boundary for Hamford Water SPA incorporating the interests of breeding Little Terns. Reproduced from Parsons *et al.* (2015)[6].

[6] It would appear that the location of site 5 is misrepresented on Figure 13 taken from Parsons *et al.* (2015), most likely as a result of a transcript error of the GPS waypoint taken.

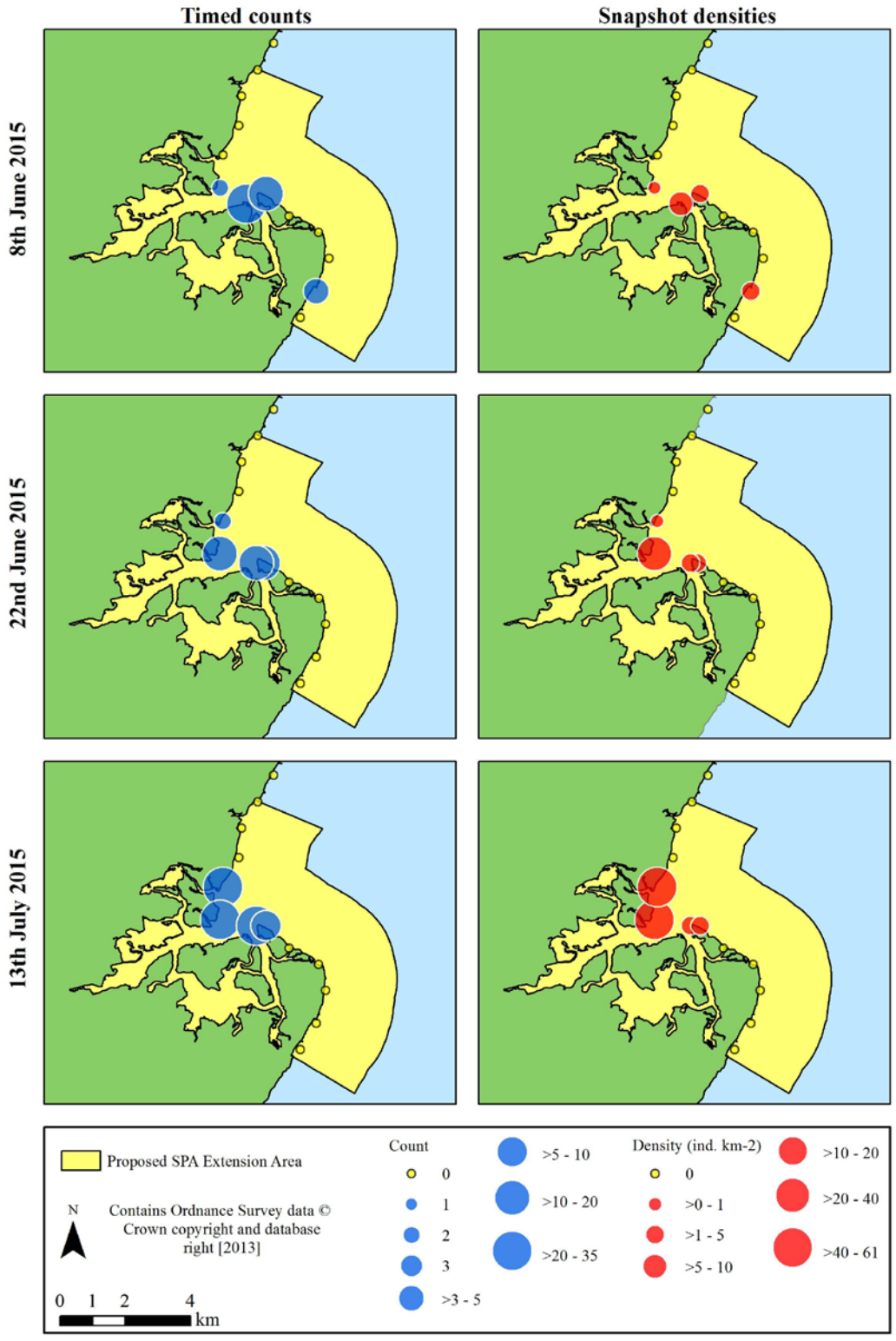


Figure 14. Abundance and distribution of Little Terns at Hamford Water as shown by timed counts and density (ind. km^{-2}) derived from snapshots within the timed count at the different survey locations in each of the sampling occasions in 2015.

The shore-based surveys conducted in 2015 at the same locations as those in 2013 show a broadly similar pattern of distribution irrespective of whether the data is derived from timed counts or expressed as density estimates from snapshots within the timed count period (Figure 14[7]). In simple terms, the bulk of activity was recorded within 1-2 km of the colony, but with a small number of records of foraging birds at site 5 around 5 km to the southeast of the colony (Figures 12 & 14). This corresponds to an area where a small number of foraging Little Terns were recorded in the boat-based survey of 2013 a few hundred metres from shore (Figure 13). In other words, there is some indication that this area is consistently used, thereby strengthening the case for this area to be incorporated within a revised SPA boundary based on alongshore boundary for *all* site-specific data including that gathered in 2015.

Otherwise, the shore-based records from 2015 would fall outwith the boundary derived from the site-specific data up to 2013 for alongshore extent proposed by the JNCC (green area in Figure 13) and subsequently adopted by NE and submitted for public consultation (Figure 15, Natural England 2015a). Alternatively, the shore-based records from 2015 and boat-based records from 2013 fall within the boundary derived from the generic data for alongshore extent as derived from several colonies proposed by the JNCC (yellow area in Figure 13).

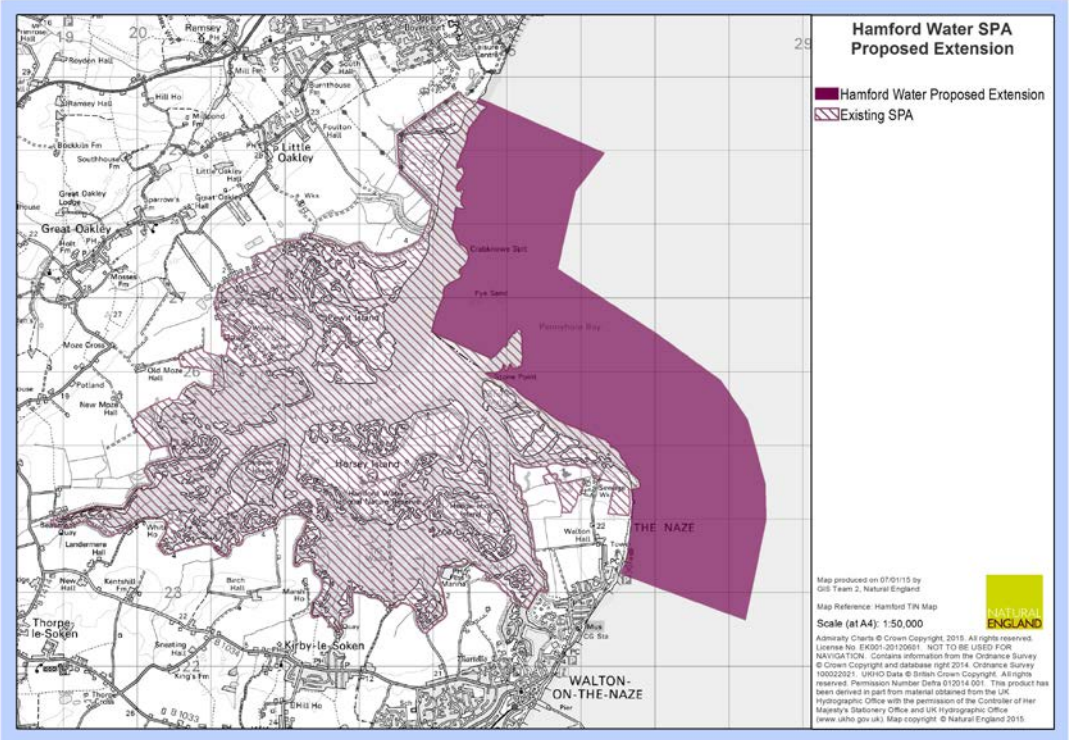


Figure 15. Possible Hamford Water marine pSPA boundary proposed by Natural England (2015a).

[7] Note that in Figure 14 the proposed SPA extension area is based on generic figures for little terns (pale green shading in Figure 13) and not the area based on the site-specific data available up to 2013.

5.2 Teesmouth & Cleveland Coast

5.2.1 Spatio-temporal abundance

A total of 957 Common Terns were recorded over the three surveys (Table 8.2.1 in Appendix 8.2), with no survey location at which Common Terns were not recorded at least once during timed counts. At the 14 sites that were consistently surveyed 916 Common Terns were recorded with the numbers of birds increasing considerably from 167 birds in mid-June to 307 by early July and then 442 by late July (48% of the total). An increase in birds seen would seem to coincide with the breakdown of the Salthome colony, perhaps with failed breeders spending more time self-foraging in the estuary and river. It is of note that no recently fledged juveniles were seen.

The number of overall records was concentrated at the estuary at the Seaton Channel (35%), which is the point at which birds on straight line transit to and from the Salthome colony and the estuary mouth and open sea first encounter the River Tees before/after crossing 3.5 km of industrial hinterland and roads before reaching the saltmarsh and mudflats of Seal Sands (Perrow *et al.* 2010). There was some fluctuation between surveys in the proportional use of important sites such as Seaton Channel (20-47% of records) and Tees Barrage (4-16%), with the latter being most important on the first survey when the former was at its least important.

Figure 16. Common Tern with captured Sprat at Tees Barrage.

At the Barrage, there was a noticeable traffic of birds arriving to forage and leaving typically carrying prey on all occasions. The pool below the barrage was particularly attractive to foraging birds, which flew in tight circles, diving on prey as they became available. The release of water generated particular excitement amongst the terns and the attendant Black-headed *Chroicocephalus ridibundus*, Lesser Black-backed and Herring Gulls, which frequently attempted kleptoparasitism of any terns with prey. All prey identified were marine Clupeids, probably mostly Sprat *Sprattus sprattus* (Figure 16). The extent of tidal influence was further illustrated by the frequent presence of a bull Grey Seal *Halichoerus grypus* in the pool, that may have

been targeting large fish such as migrating Atlantic Salmon *Salmo salar* attempting to use the fish ladder to cross the barrage.

Otherwise, records were rather equally distributed between survey locations (from 2-8% of records) all the way along the length of the Tees from Tees Barrage at the survey location furthest upstream (8% of records) to Victoria Harbour at Hartlepool (3 % of records) some 12 km from the colony as the tern flies. The use of most survey locations such as Middlesborough Dock (3-7% of records between occasions) and Tees Dock (0.6-3% of records) in what could be described as the middle to lower reaches of the river, was rather consistent at a low level compared to the estuary at Seaton Channel or Tees Barrage. These off-river sites that are of particular interest to NE, were seemingly used as part of the riverine environment.

The use of Dabholme Gut was more difficult to quantify, partly as we do not fully understand the relationship between the lagoon and what appears to be an overflow channel that discharges over a low weir into the Tees, and by the fact that the lagoon could not be seen from the river as the riverbank is too high relative to the water level within the lagoon. However, at high water in the river Common Terns could be seen foraging over the lagoon, particularly when near the bank closest to the river. Common Terns also consistently foraged in the base of the low weir and along the junction of the mixing between the waters of the overflow and the Tees. Birds were also observed specifically commuting directly to and from the lagoon.

A reasonable number of Sandwich Terns (148 birds) were recorded during the surveys (Table 8.2.2 in Appendix 8.2), although only in the estuary and lower reaches of the river as far upstream as the oil refinery (Figure 2), where the river is just over 300 m wide. This represents a point of transition as around 1 km further downstream at Tees Dock, the river is over twice the width at 680 m.

The majority of Sandwich Terns (79%) were recorded on the last survey of 22nd July, with 47% of the birds observed (55 ind.) being recently fledged juveniles. It would seem most likely these birds originate from the closest colonies at Coquet Island or the Farne Islands, although they could conceivably be of a mixture of origins including birds from North Norfolk or even from the Danish or Dutch coastal colonies, as there are records of rapid post-fledging dispersal involving considerable distances (Wernham *et al.* 2002). The presence of Sandwich Terns in the Tees estuary in late July is consistent with the inclusion of the species as a qualifying feature of the SPA when on passage (see 3.2.1 above).

5.2.2 Patterns of activity

Of the 957 Common Terns recorded in the timed counts, most were in directional flight (58%) or foraging with no clear direction (41%) (Table 8.2.1 in Appendix 8.2). A few resting birds (0.6%) were recorded on posts, quays or buoys at various points along the river. Snapshots suggested a greater preponderance of foraging activity with 84% overall (sum of mean snapshot counts) compared to birds engaged in directional flight (13%) and resting (2%). The proportion of foraging activity also increased considerably over time from a consistent level in the first two surveys (57% and 58% respectively) to 92% in late July (Figure 17).

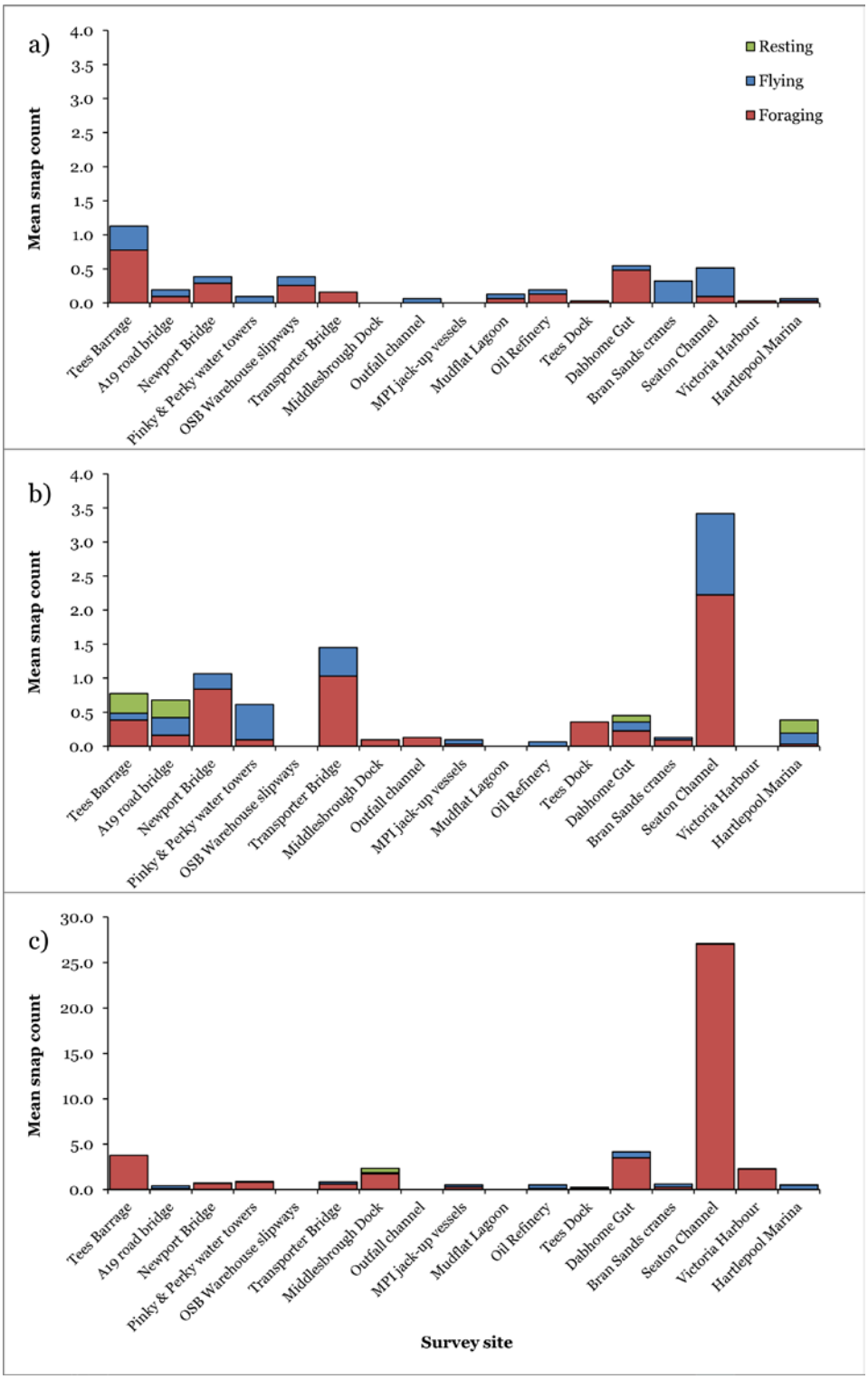


Figure 17. Activity patterns of Common Terns derived from mean count in snapshots at the different survey locations on each survey occasion at Teesmouth & Cleveland Coast, represented by a) 18th June b) 2nd July and c) 22nd July. Note the considerable increase in scale in c).

This is partly reflective of the large number of foraging Common Terns encountered in the estuary around Seaton Channel, but could also represent a change in foraging patterns after colony breakdown with birds primarily engaged in self-feeding activity in which they take any available items (e.g. invertebrates and small fish) rather than transiting to particular locations that offer the potential to capture larger, more profitable items to transport back to waiting chicks in the colony.

5.2.3 Comparison with the proposed SPA

As well as the use of the estuary and coastal waters north to Castle Eden Dene beyond Hartlepool in the north and Marske-by-the-Sea in the south the JNCC model predicted the use of the length of the Tees upstream to the Barrage (Figure 18).

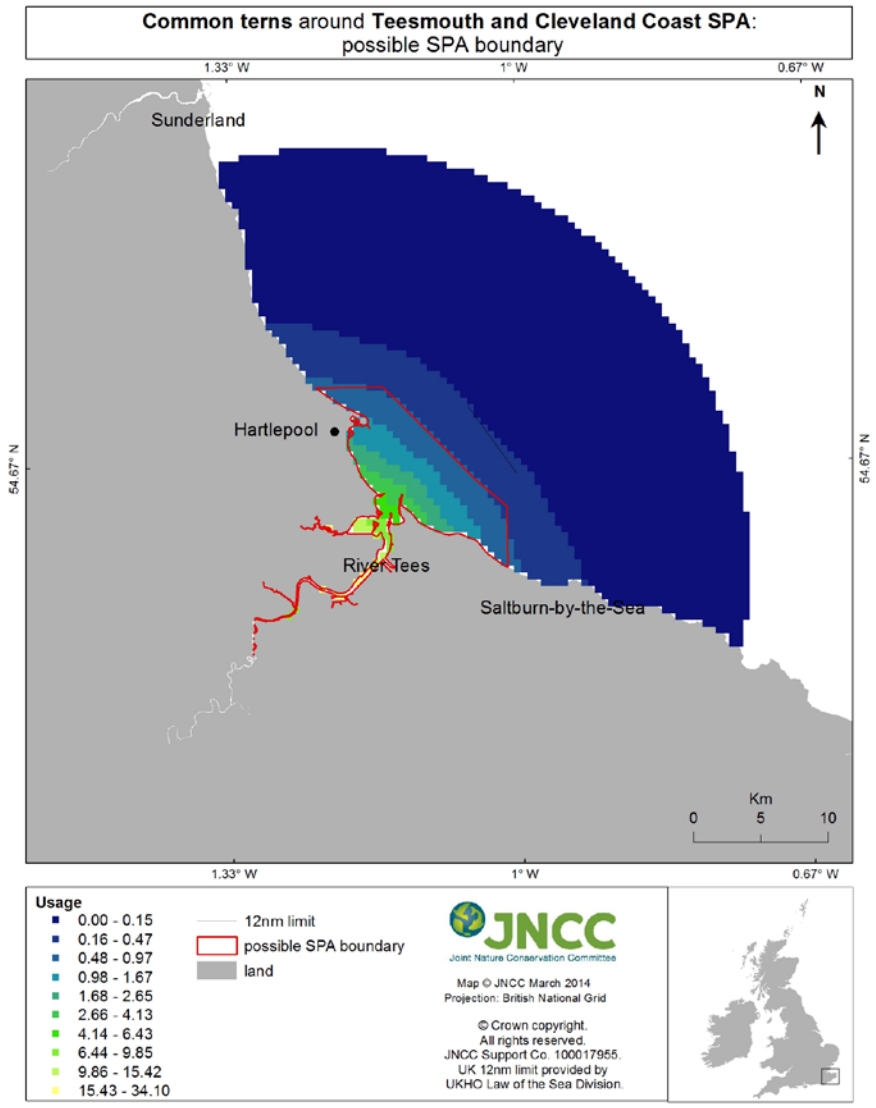


Figure 18. JNCC proposal for a revised boundary for Teesmouth & Cleveland Coast SPA incorporating the interests of Common Terns breeding at RSPB Salthome, as based on the output of a generic habitat model.

The predicted highest intensity of use of the middle reaches of the tidal Tees is simply a function of the dominant variable in the model, which is 'distance to colony' coupled with the fact that the Salthome colony lies near the middle reaches of the Tees and is some distance from the estuary (~5 km).

In keeping with model predictions Common Tern was consistently recorded along the length of River Tees from the Seaton Channel in the estuary upstream to the Tees Barrage throughout the surveys in 2015 (Figure 19). There are however, some subtle differences in the patterns of use suggested by the timed counts relative to the snapshot counts converted to density.

By recording all birds, many of which may pass through relatively quickly, timed counts are likely to record presence/absence effectively. In fact if recording occurs over a relatively long period of time, and especially where birds are actively using the river as a corridor that offers foraging opportunities even if they are mainly in transit flight, there will be little, if any, absence data. In contrast, the snapshot counts and resulting density estimates are more likely to better reflect more persistent use.

Accordingly, there is some suggestion that the middle and lower reaches of the river are used less than those further upstream (Figure 19). The somewhat reduced use of the river between Middlesborough Dock and the Tees Dock, is also apparent in the snapshot density data from the transect survey, which by moving rapidly through the survey area provides a true snapshot of the patterns of use (Figures 20-22).

Despite some variation in the intensity of use over time, there is clearly a greater prospect of zero density in the middle to lower reaches of the river than further upstream or in the upper part of the estuary near the Seaton Channel. The boat-based transect survey also revealed considerable variation in use, expressed as density, over Hartlepool Bay relative to the river and estuary. In the first survey, birds were recorded foraging over much of the transect route across the Bay (Figure 20), whereas this was reduced in the second survey when the focus of intense activity was Teesmouth itself (Figure 21). On the last survey, birds were concentrated in large foraging aggregations near Seaton channel (Figure 22). Although there may be some seasonal element in the trends, the fact that virtually no birds were recorded in the Bay on the return leg in the first survey points to the influence of tide and/or diel patterns in the availability of prey. It is noteworthy that aggregations somewhere in the Bay or estuary tended to be observed on a flooding tide nearing high water, although far more data would be required to unravel the effects of tide, time of day and season.

The middle to lower reaches of the river closest to the colony was used broadly equally to other areas at considerable distance, including parts of Hartlepool Bay including Victoria Harbour (Figure 23). Particularly attractive areas such as the upper reaches of the river near the Barrage as well as the estuary near Seaton Channel occurred at moderate distances of around 5-6 km (timed count) and 6-7 km (snapshots along the boat-based survey route) from the colony. As a result, the predicted usage from the model that is dependent on distance did not particularly reflect the data gathered in these surveys.

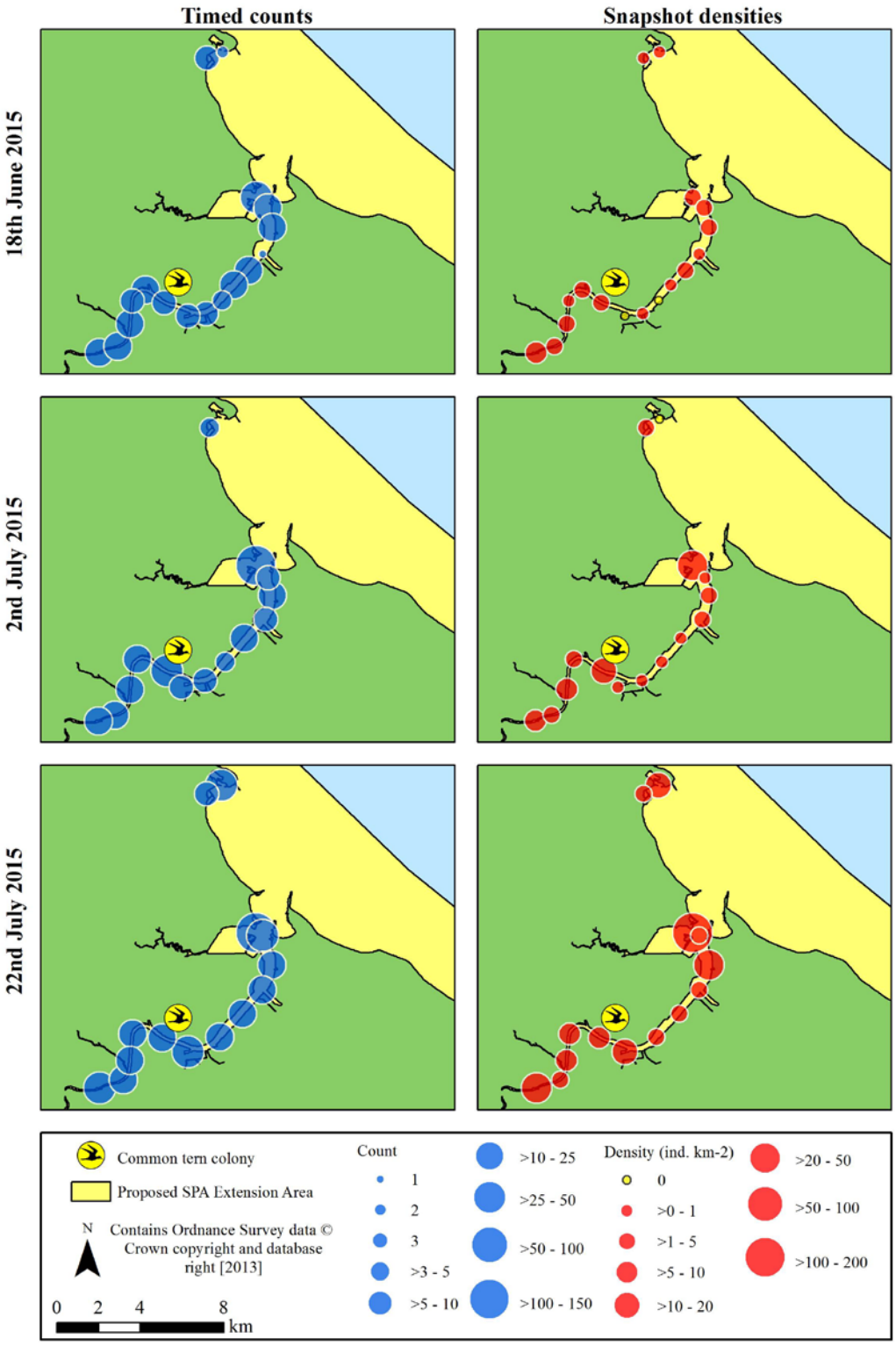


Figure 19. Abundance and distribution of Common Terns at Teesmouth & Cleveland Coast as shown by timed counts and density (ind. km^{-2}) derived from snapshots within the timed count at the different survey locations in each of the sampling occasions in 2015.

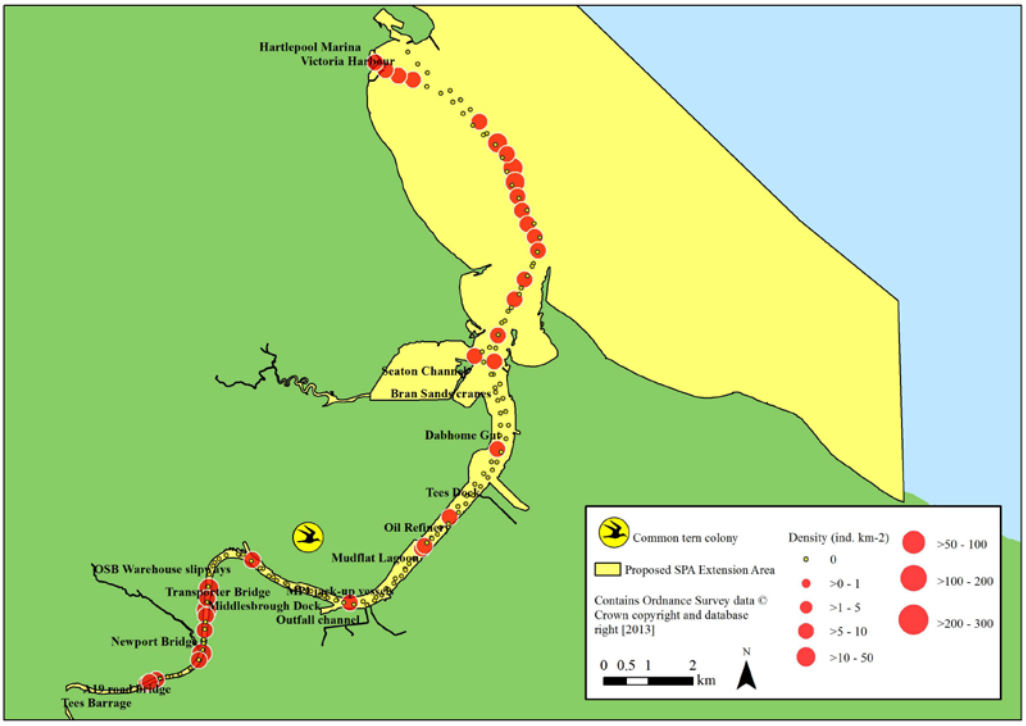


Figure 20. Density (ind. km^{-2}) of Common Tern from snapshots at 300 m intervals along the boat-based transect route from Hartlepool to Tees Barrage on 18th June 2015.

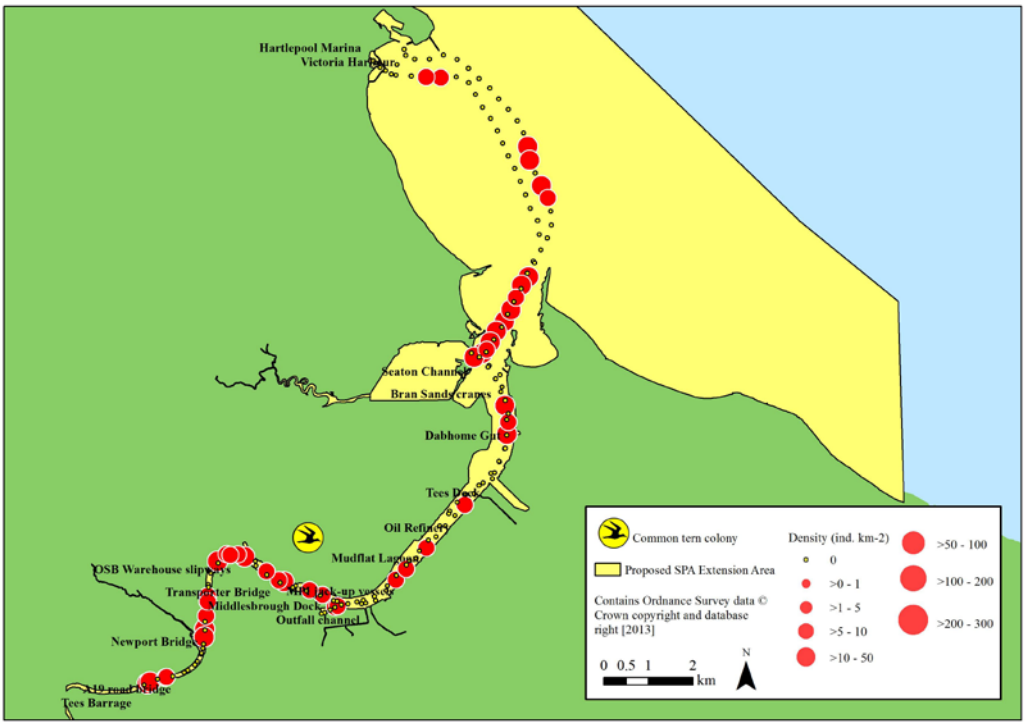


Figure 21. Density (ind. km^{-2}) of Common Tern from snapshots at 300 m intervals along the boat-based transect route from Hartlepool to Tees Barrage on 2nd July 2015.

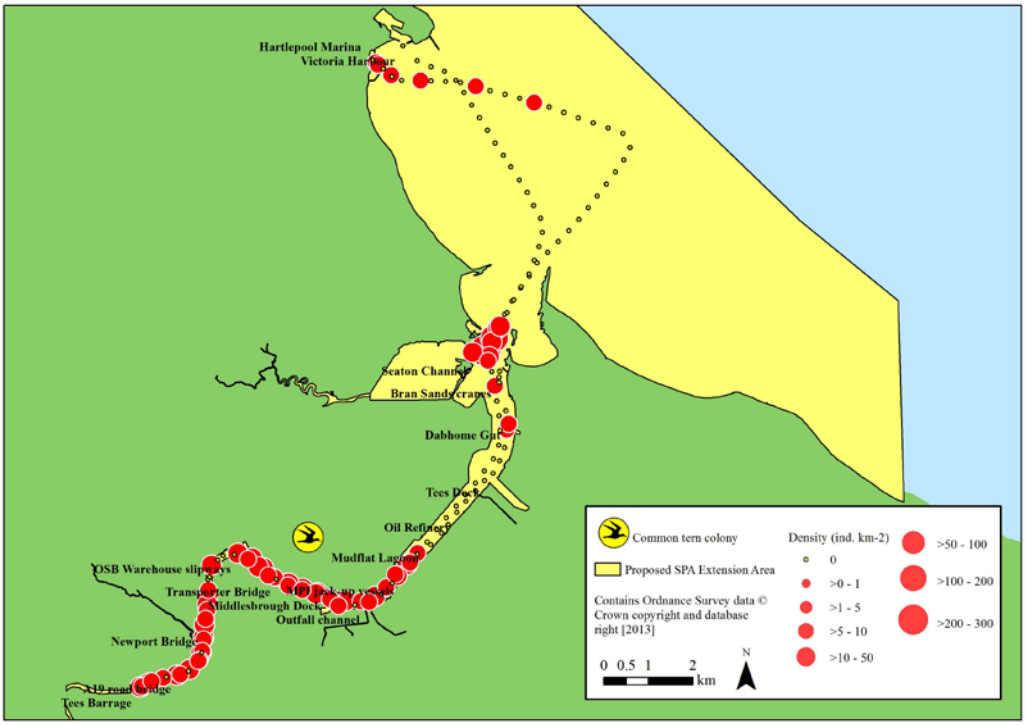


Figure 22. Density (ind. km^{-2}) of Common Tern from snapshots at 300 m intervals along the boat-based transect route from Hartlepool to Tees Barrage on 22nd July 2015.

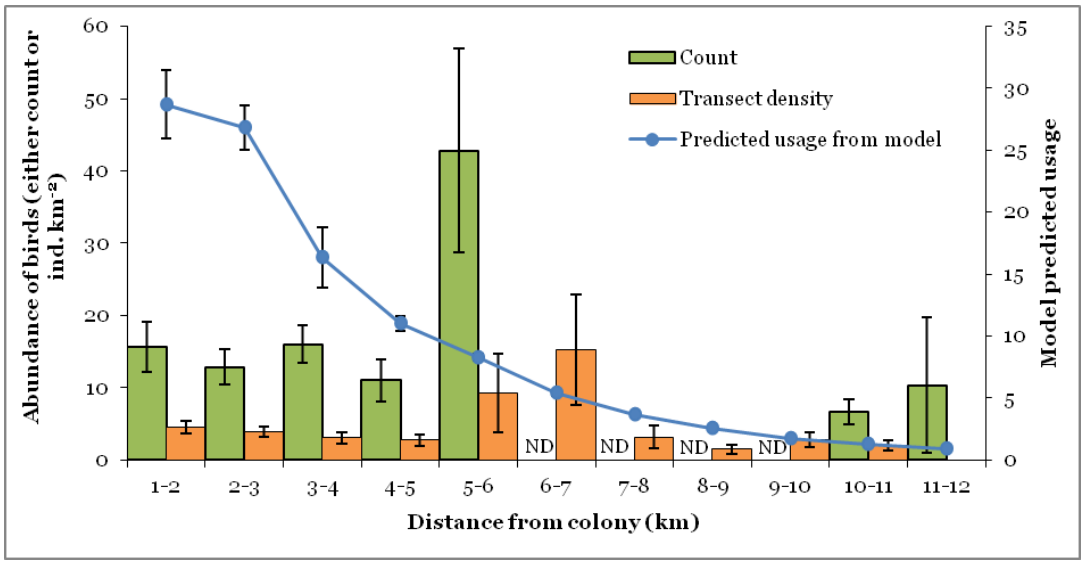


Figure 23. Relationship between the predicted Common Tern usage of cells at increasing distance from the colony according to the generic JNCC model, compared to measures of abundance of Common Tern from the current surveys including timed counts and density (ind. km^{-2}) from snapshots along the boat-based survey transect. ND = no data for some of the distance intervals from the colony relating to the timed counts.

Despite the fine-scale differences between the results of the current surveys and the predicted model usage at particular distances from the colony, at the broader scale the use of the river, estuary and Hartlepool Bay all fitted within the categories of moderate to high use predicted by the model and thus the boundary of important foraging areas suggested (Figure 24). In other words, the model encapsulates the potential for Common Terns to form hotspots of activity at reasonable distance from the colony observed during the current surveys.

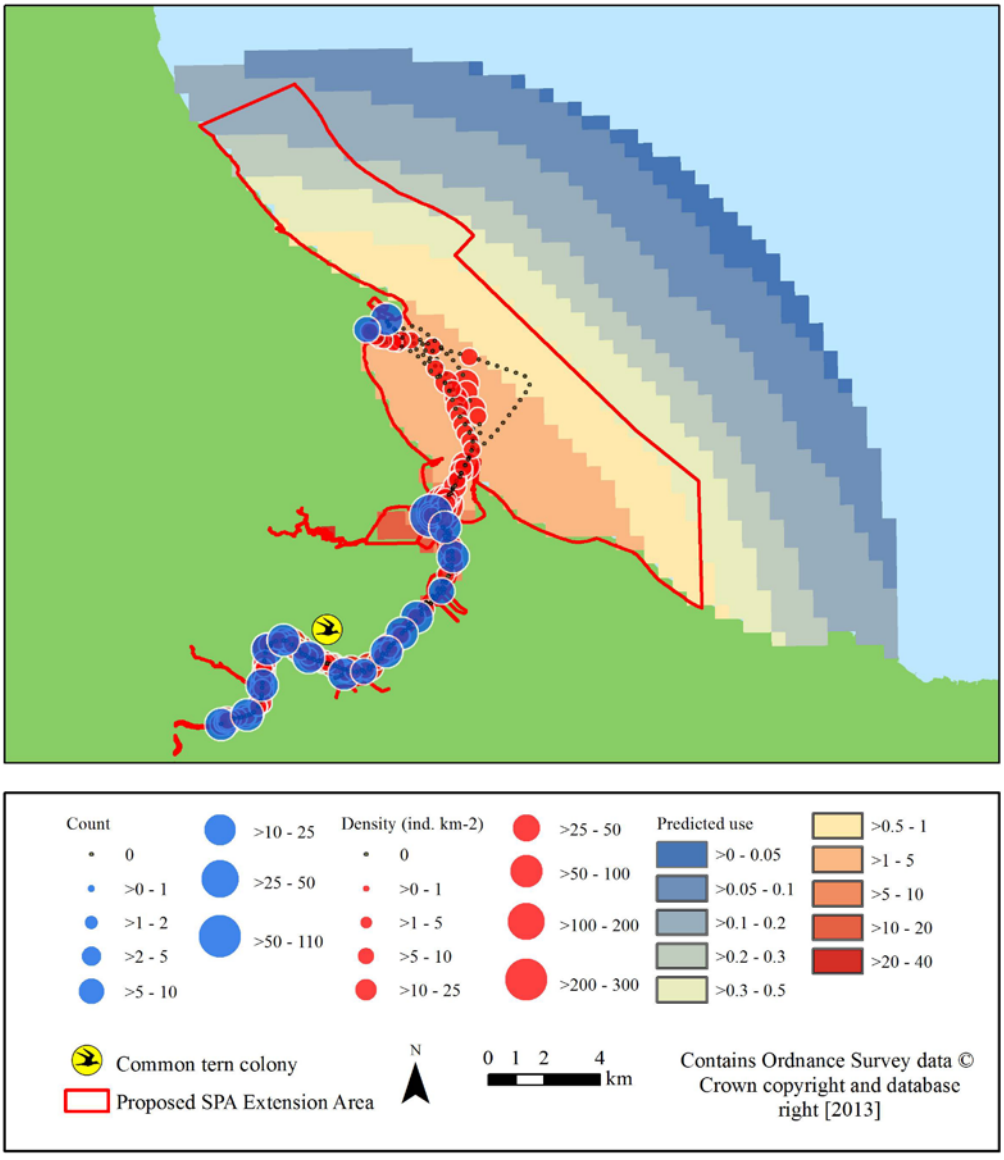


Figure 24. Comparison between the JNCC generic model-based output of relative usage and the boundary of important foraging areas for Common Tern from Salthome, relative to records of Common Terns in mean timed counts and density delivered from snapshots during boat-based transects from the three survey occasions in 2015.

The revised SPA boundary proposed by NE (Natural England 2015b, Figure 25) incorporates both the important foraging area for Common Tern from Salthome and the purported foraging range of Little Tern from Crimdon Dene as determined by Parsons *et al.* (2015). As such, the proposed SPA incorporates a much larger area particular to the northwest beyond Hartlepool Bay, than that suggested for Common Tern alone.

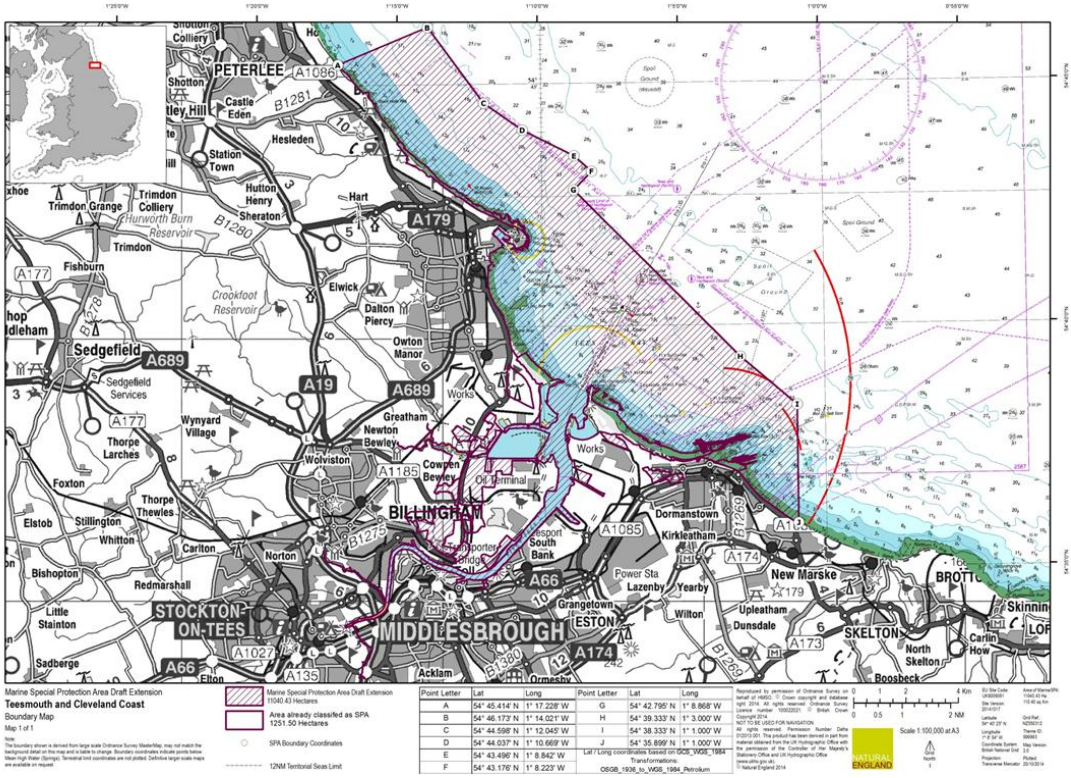


Figure 25. Possible Teesmouth & Cleveland Coast marine pSPA boundary proposed by Natural England (2015b) incorporating the interests of Common Terns breeding at RSPB Salthome and Little Terns breeding at Crimdon Dene.

Incorporation of the coastal waters to to the northwest of Hartlepool is valuable as previous boat-based surveys ECON that undertook for the JNCC in 2013 with the primary intention of informing the offshore extent of Little Terns from Crimdon Dene (see Parsons *et al.* 2013) also recorded Common Terns in this area (Figure 26). However, these surveys strongly suggested that the more important areas for Common Terns lay within Hartlepool Bay itself, where feeding aggregations were noted near Victoria Harbour in particular on occasion.

The tracking study of Perrow *et al.* (2010) also provided further information on the foraging range and activity of Common Terns originating from Salthome in relation to the proposed SPA. In particular, the study showed that although much foraging activity was recorded in the Tees estuary, 46% of the 107 Common Terns tracked reached the open sea and headed in all directions to produce a radiating fan-like pattern (Figure 26). A relatively small number (~10%) of the 107 Common Terns were also tracked beyond the suggested SPA boundary primarily offshore but also to

the south of Teesmouth. Perrow *et al.* (2010) suggested that Common Tern from Salthome undertook relatively long-distance movements compared to birds from other colonies. For example, at Salthome, mean (± 1SE) maximum distance from the colony was of 8.1 ± 0.3 km compared to 2.2 ± 0.4 km from 42 birds tracked at Blakeney Point on the North Norfolk Coast in 2008. Robertson *et al.* (2014) recorded a mean median value of 3.6 km from 7 birds tracked at Coquet Island. Generally longer foraging movements from the Salthome colony may explain any discrepancy with the outputs of a generic model.

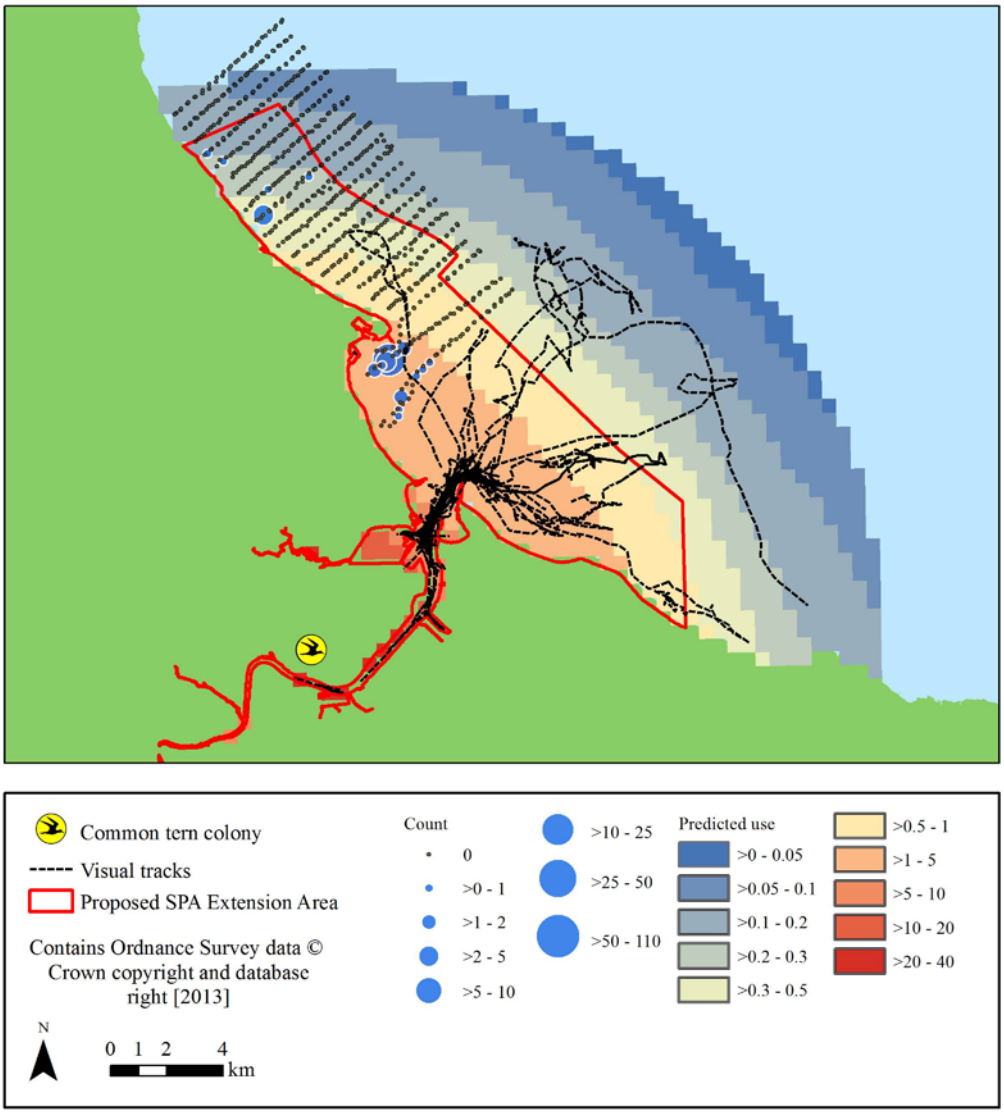


Figure 26. Comparison between the JNCC generic model-based output of relative usage and the boundary of important foraging areas for Common Tern from Salthome, relative to tracklines of 107 Common Terns on foraging flights Salthome in 2009 as determined by visual tracking (Perrow *et al.* 2010).

Furthermore, Perrow *et al.* (2010) also documented that Common Terns rarely chose to attempt to forage in the Tees itself upstream of the main dock area. But, as tracked birds were generally collected from the Seaton Channel after flying directly overland to reach the estuary, this could have introduced a bias to the data, as tracked birds may have been unlikely to turn back up the river to forage, perhaps unless the conditions in the estuary were unsuitable. Nevertheless, the flightlines of both outgoing and incoming birds from the colony both showed a strongly uni-directional pattern of movement, with some 77% of all outbound flights and 81% of all inbound flights following a bearing between 20° and 40°, a movement vector taking them directly to Seal Sands and the estuary beyond at the mouth of the Seaton Channel.

It would therefore appear that there are considerable differences in foraging patterns in 2009 and possibly 2013, compared to 2015, which are most likely to reflect differences in the spatio-temporal availability of key prey, which was demonstrated to be Sprat in 2009 (Perrow *et al.* 2010). Although a multitude of factors may have influenced the availability of prey for Common Terns in recent years, it may be more than coincidental that the use of the estuary and the open sea appears to have declined following the construction of the Teesside offshore wind farm (OWF) in 2013. Pile-driving is known to have the potential for considerable impact on hearing-sensitive species such as clupeids, including Sprat. As demonstrated by Perrow *et al.* (2011b) for Little Tern in relation to Scroby Sands OWF, such effects may not be as short-lived as is often suggested in Environmental Impact Assessments. Impacts may readily extend into the medium to long-term should the adult stock of fish be seriously affected.

We have no knowledge of any available fisheries data for Teesside OWF and even if some becomes available, it may be this targets benthic fishes rather than pelagic schooling species such as Sprat. Anecdotal information from local fishermen strongly suggests that fish stocks were very low in the summer of 2013 during pile-driving activity, with some recovery suggested thereafter. However, the fishermen do not target Sprat.

But if the effect upon prey fish was dramatic, this should be detectable in the performance of Common Terns at Salthome. Conversations with RSPB staff have revealed however that the intensity of monitoring of the Common Tern colony is modest at best, with only an estimate of the number of pairs available for each year (Figure 27). The available data appears to show that whilst there is fluctuation in the number of pairs in each year, there is concern that the population is in decline as the current population is at its lowest in the recording period. The current total of 258 pairs is some 36% lower than typically attributed to the area (~400 pairs). It may be no coincidence that two of the three lowest totals in the 9-year period have occurred since 2013 when the wind farm was constructed.

Unfortunately, it appears that there is virtually no information on the performance of the colony in terms of the chicks produced. It is understood that the Teesmouth Bird Club routinely rings chicks on an annual basis, but this is based on a timed effort to reduce disturbance at the site. As a result, there does not appear to any data on the number of fledglings produced at the colony in each year. It is possible

however that data on the condition (weight at various stages of development) of any chicks ringed could be available.

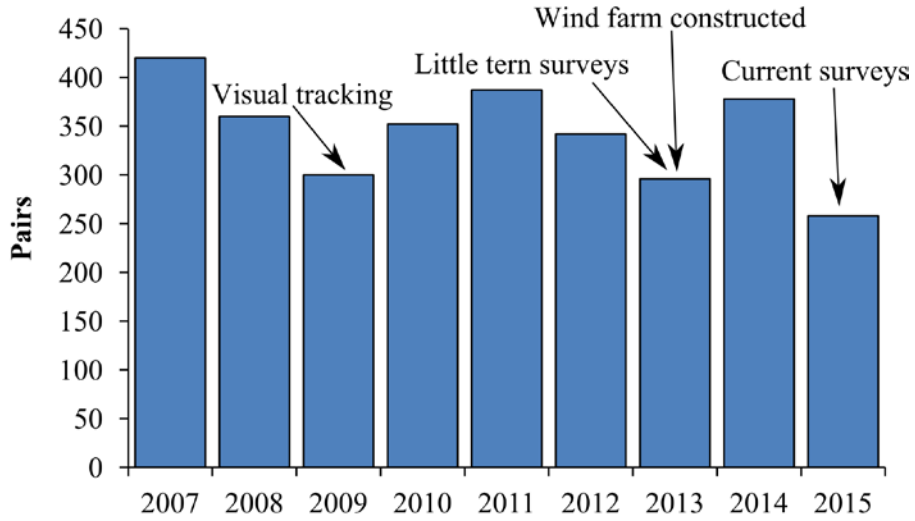


Figure 27. Estimates of the number of pairs of Common Terns at RSPB Salthome from 2007-2015 (from Dean Hewett RSPB *pers comm*.)

5.3 Northumberland

5.3.1 Spatio-temporal abundance

Of the four tern species nesting in Northumberland, only Sandwich and Common Terns were seen in any number on the surveys. Only two Roseate Terns were recorded with two consorting individuals flying into and then out of Amble Harbour on 7th July. No Arctic Terns were seen.

Sandwich Tern was the most abundant tern species recorded, with 400 individuals, (Table 8.3.1 in Appendix 8.3) with all of these recorded within the survey locations consistently surveyed over all occasions. Relatively few birds were seen on the first survey in mid June (81 ind.) with over twice as many in late June with a peak count of 182. ind. Numbers then declined somewhat by early July (137 ind.), although this was still higher than earlier in the season. The peak could coincide with an increase in foraging range of birds attempting to provision chicks. Alternatively, it could also represent breakdown of the colony with birds no longer tied to central-place foraging. Unfortunately, no information on the breeding success and timing of key events for Sandwich Terns breeding on Coquet Island, is available as yet, although it is known that >100 pairs Roseate Terns attempted to nest.

Sandwich Tern was recorded in all river catchments with potential connectivity to birds breeding on Coquet Island, as well as at Seahouses Harbour near the Farne Islands. Similar distribution and abundance patterns were suggested by timed counts and the mean snapshot density derived from those counts (Figure 28).

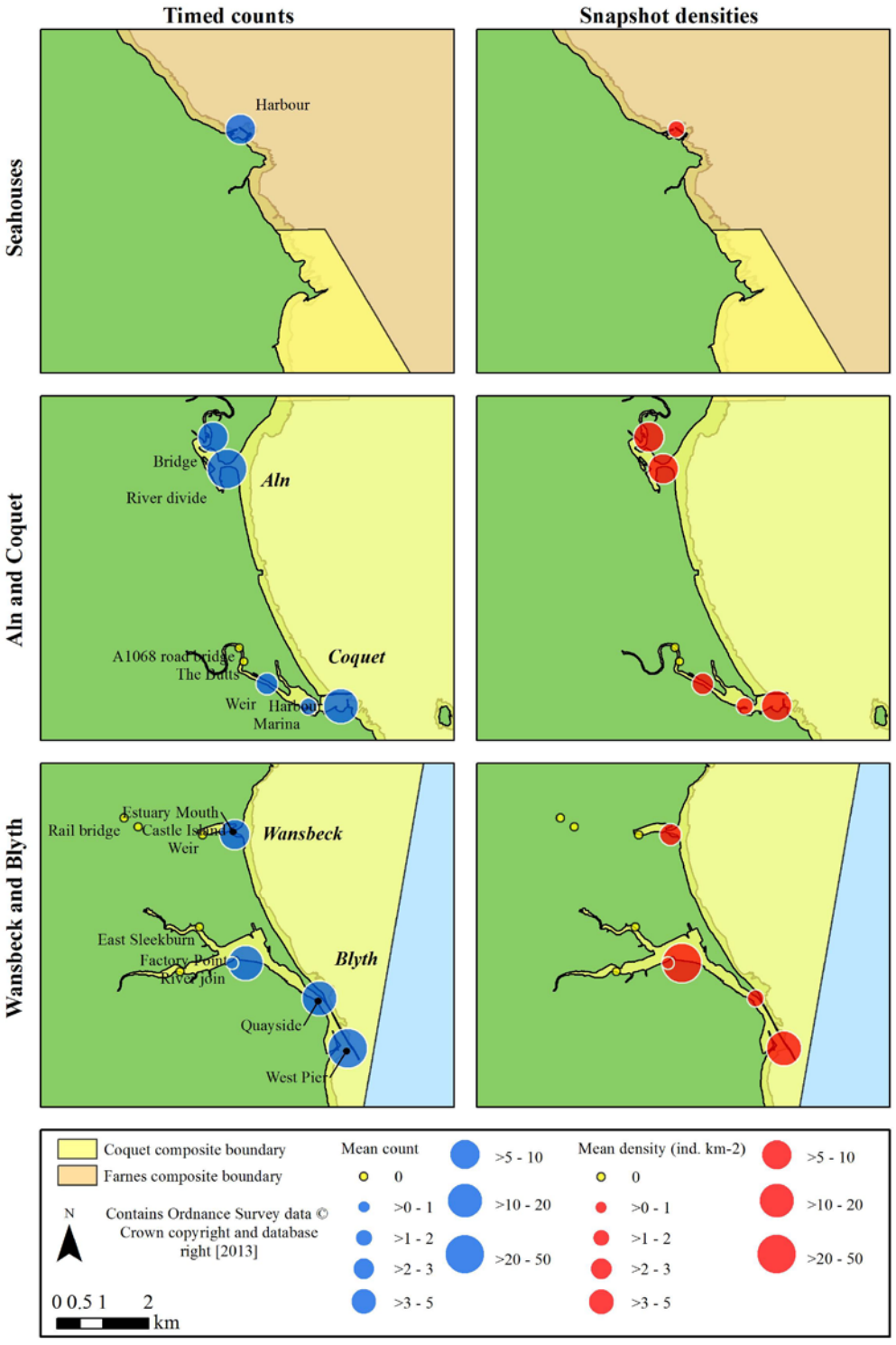


Figure 28. Abundance and distribution of Sandwich Terns at the various river estuaries in Northumberland as shown by timed counts and density (ind. km^{-2}) derived from snapshots within the timed count at the different survey locations in each of the sampling occasions in 2015.

At all key sites, Sandwich Tern was most numerous in late June. Overall, it was most abundant in the Aln estuary where 147 ind. (37% of all birds) were recorded in the estuary mouth. Relatively few (36 ind.) were recorded in Amble Harbour nearest to Coquet Island, particularly compared to the more distant Blyth estuary. Here, 65 ind. were recorded at the mouth of the estuary, but also occurred in reasonable numbers further upstream with 38 ind. recorded at Factory Point, although this is still very close to the sea as the tern flies (Figure 7). Elsewhere, Sandwich Tern also occurred further upstream in the Aln and Coquet although in reduced numbers compared to the estuaries, and only in the Wansbeck did it appear to be limited to the most seaward survey location. Importantly, the surveys appeared to be generally successful in defining the likely upstream limit of Sandwich Terns, with the absence of birds at the more upstream survey locations in the Coquet, Wansbeck and Blyth.

An overall total of 311 Common Terns were recorded over the three surveys (Table 8.3.2 in Appendix 8.3) with 286 of these recorded within the survey locations consistently surveyed over all occasions. As with Sandwich Tern, relatively few Common Terns were seen on the first survey in mid June (36 ind.) with reasonably similar numbers thereafter in late June (136 ind.) and early July (114 ind.). The increase in the number of Common Terns at this time is thought to be most likely linked to the failure of birds that had attempted to breed at Coquet (see 5.3.2 below).

Common Tern was recorded in all river catchments potentially connected to birds breeding on Coquet Island, as well as at Seahouses Harbour near the Farne Islands (Figure 29). The occurrence of Common Terns in the Wansbeck was at the limit suggested by modelling, with occurrence in the Blyth beyond that predicted (see 5.3.3 below). Similar distribution and abundance patterns were suggested by the two survey techniques, although timed counts tended to record presence more effectively than snapshots as shown by the occurrence of Common Tern further upstream in the Wansbeck within timed counts (Figure 29).

Typically, Common Tern was recorded further upstream than Sandwich Tern, and in fact occurred as far upriver as the most upstream survey locations in the Aln, Coquet and Blyth. In other words, only in the Wansbeck was there potential for the upstream limit of Common Tern distribution to be defined.

The survey locations with the most Common Terns occurred in the Aln (54 ind. in the estuary mouth) and Coquet (59 ind. in the Harbour) nearest to Coquet Island, although an unexpected (i.e. further than suggested by tracking and modelling by the JNCC – Wilson *et al.* 2014) relatively high number of Common Terns were also recorded in the Blyth the furthest catchment from Coquet Island. These included a relatively high number of birds away from the estuary mouth at its junction with Sleek Burn (33 ind.) and nearby Factory Point (32 ind.). These birds were present throughout the survey period and do not therefore obviously represent just failed breeders and it remains possible that a small number of birds breed in this area, although this could not be confirmed during the surveys with birds only observed resting on the wooden quay headings. In combination, the four sites mentioned (29% of sites surveyed on all occasions) comprised 62% of Common Tern records.

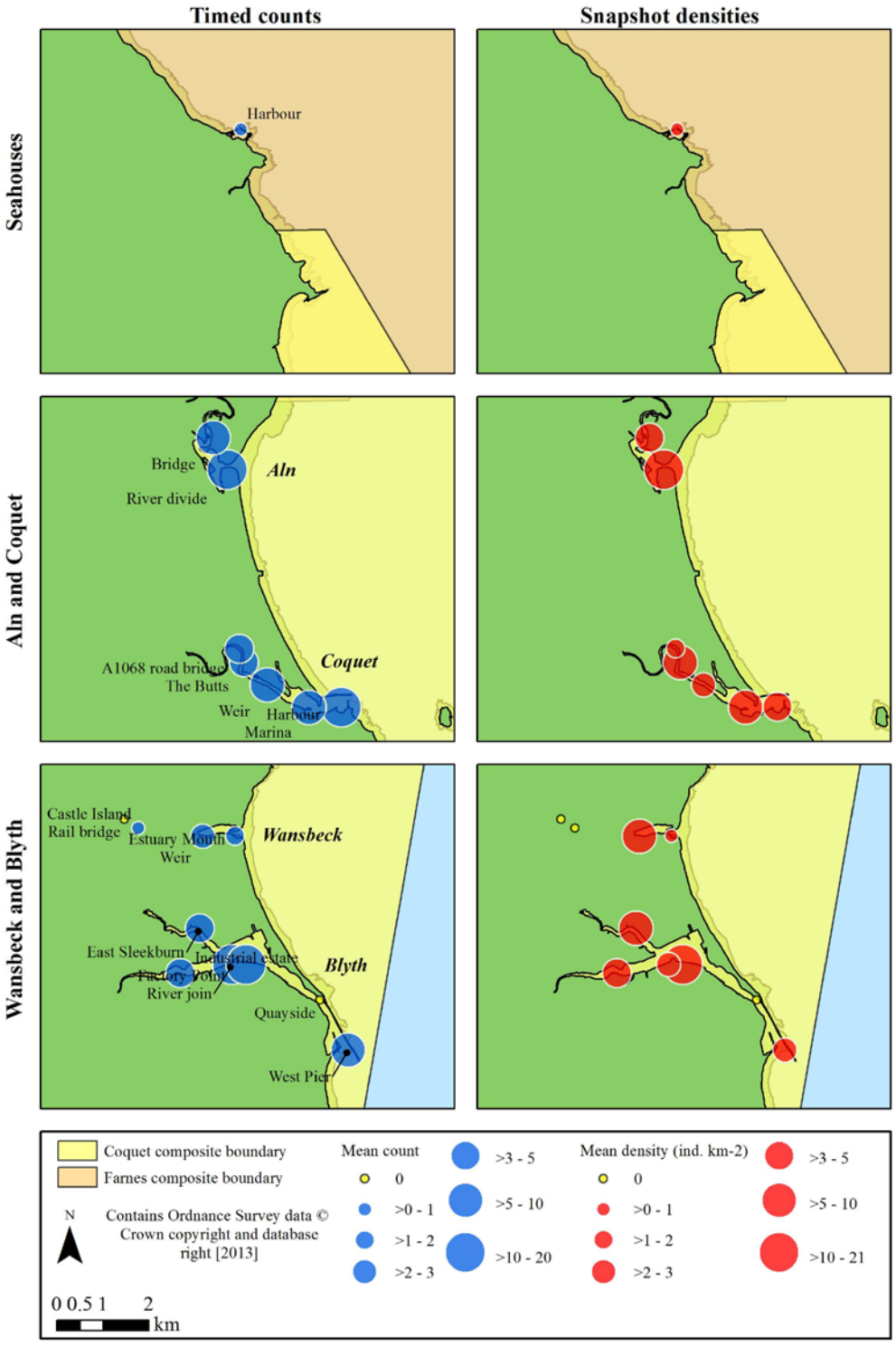


Figure 29. Abundance and distribution of Common Terns at the various river estuaries in Northumberland as shown by timed counts and density (ind. km^{-2}) derived from snapshots within the timed count at the different survey locations in each of the sampling occasions in 2015.

5.3.2 Patterns of activity

In the timed counts, relatively equal proportions of Sandwich Terns were recorded foraging (38%), resting (33%) or in directional flight (29%) (Table 8.3.1 in Appendix 8.3). The total of resting birds was however heavily influenced by a group 0f 84 ind. at the estuary mouth of the River Aln in late June. These resting birds were recorded beyond the maximum distance of 300 m from the observer and thus do not appear in snapshots from which activity patterns were determined (Figure 30). Nevertheless, Sandwich Terns were recorded as resting from observations of groups at various locations including the estuary mouth of the Aln and Factory Point in the Blyth where a group of up to 21 ind. was present in late June (Figure 30). Otherwise, birds were mainly recorded foraging without clear direction and rarely simply in directional flight.

Common Tern showed a different pattern with the highest proportion of birds in directional flight (49%) compared to foraging with no fixed direction (43%) with only a small proportion resting (7%). In contrast, resting birds were much more prevalent in the snapshots within the timed counts, particularly on the second survey occasion in late June (Figure 31). Common Terns were recorded resting in relatively large numbers alongside Sandwich Terns at Factory Point, as well as in small groups at most of the other sites in the Blyth and at isolated sites in all of the catchments. Particularly because such behaviour was occurring at sites some distance from the colony this would tend to indicate birds that are free from the constraints of provisioning chicks. In other words, relatively extensive resting behaviour at this time of the season and at this distance from the colony would tend to indicate failed rather than actively breeding birds.

5.3.3 Comparison with the proposed SPA

A series of site-specific models were produced by the JNCC for the four large tern species - Arctic, Common, Roseate and Sandwich - breeding on Coquet Island (Figure 32). The significantly greater foraging range of Sandwich Tern compared to the other species, coupled with its tendency to forage in close proximity to the coast means that the proposed limit of important foraging area derived from the species-specific model derived from the tracking of Sandwich Terns effectively determined the overall boundary relating to Coquet Island. The proposed boundary for Coquet Island was combined with predictions of the important foraging areas of terns breeding on the Farne Islands (Arctic, Common and Sandwich Terns), Little Tern and Arctic Tern breeding at Long Nanny and Little Tern breeding on Lindisfarne to produce the overall boundary for the Northumberland pSPA proposed by NE (Natural England 2014b, Figure 33).

The current surveys suggested that both Sandwich and Common Terns potentially breeding on the Farne Islands occasionally use Seahouses (North Sunderland) Harbour, although as this involves only a few birds on some occasions, this use does not appear to be of any particular significance, especially when compared to the survey locations at the range of river estuaries further south relating to the use of terns potentially originating from Coquet Island (Figures 28 & 29 for Sandwich and Common Terns respectively).

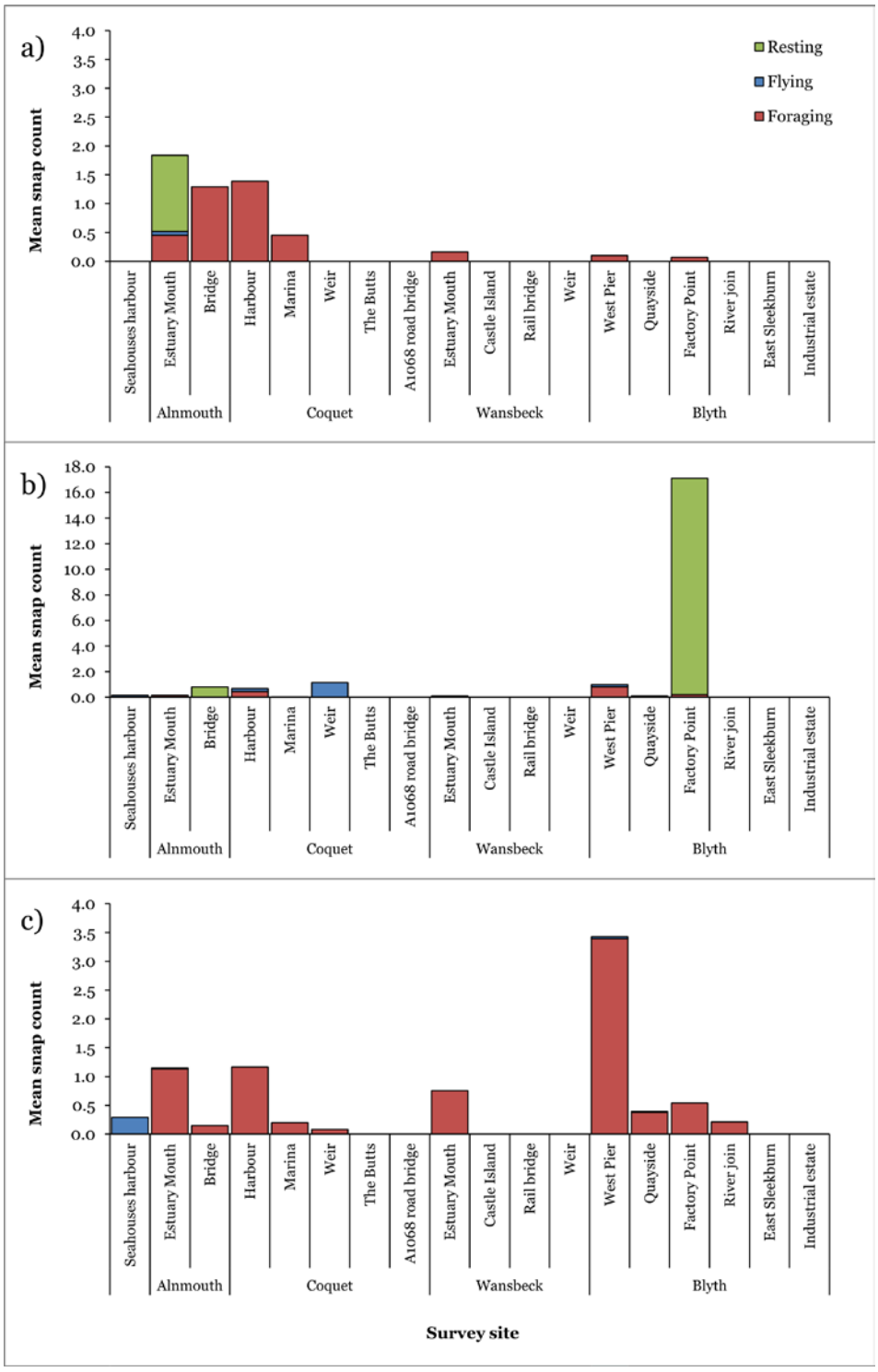


Figure 30. Activity patterns of Sandwich Terns derived from mean count in snapshots at the different survey locations on each survey occasion in Northumberland, represented by a) 10-12th June b) 24-26th June and c) 6-8th July. Note the considerable increase in scale in b).

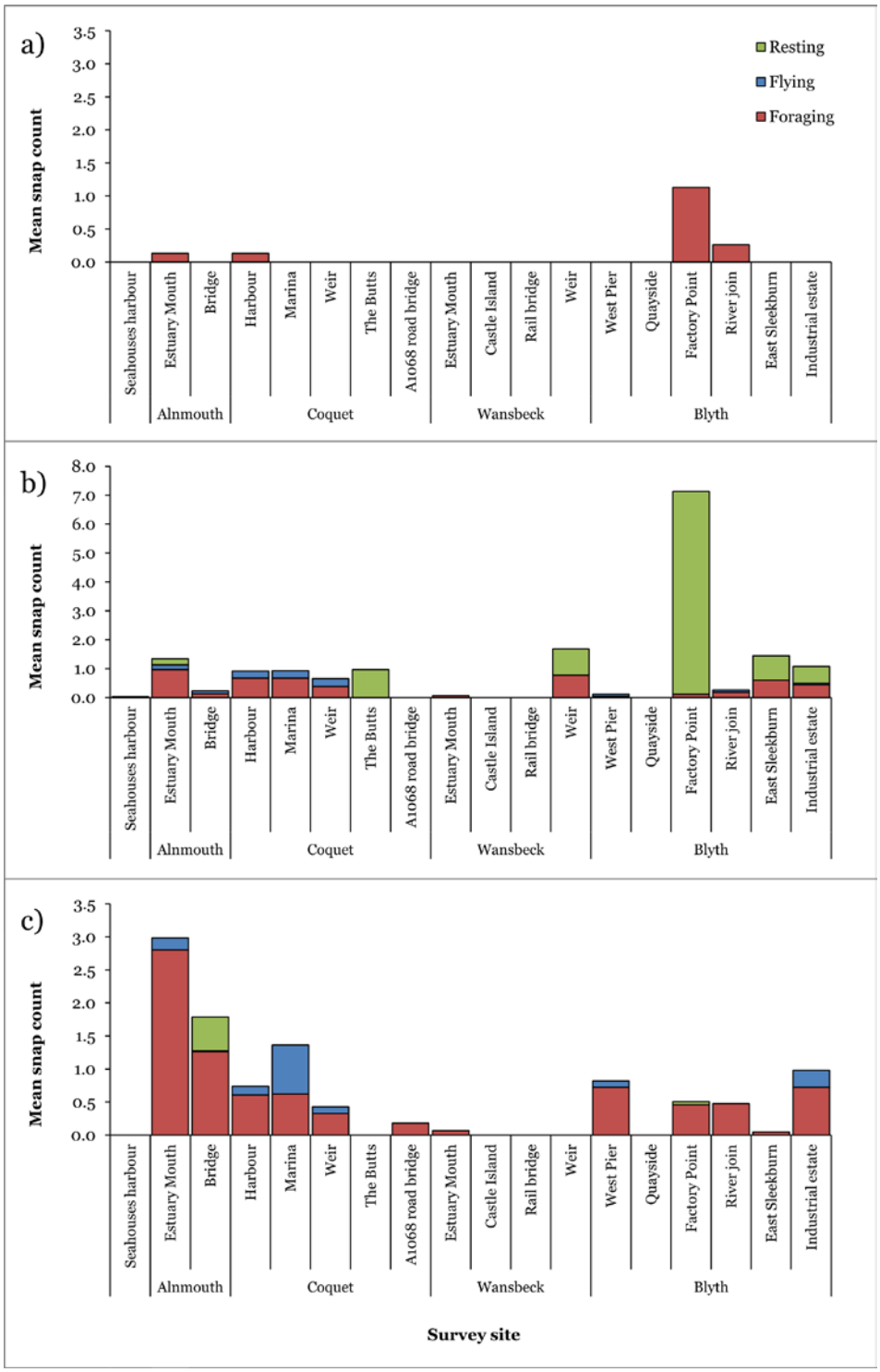


Figure 31. Activity patterns of Common Terns derived from mean count in snapshots at the different survey locations on each survey occasion in Northumberland, represented by a) 10-12th June b) 24-26th June and c) 6-8th July. Note the increase in scale in b).

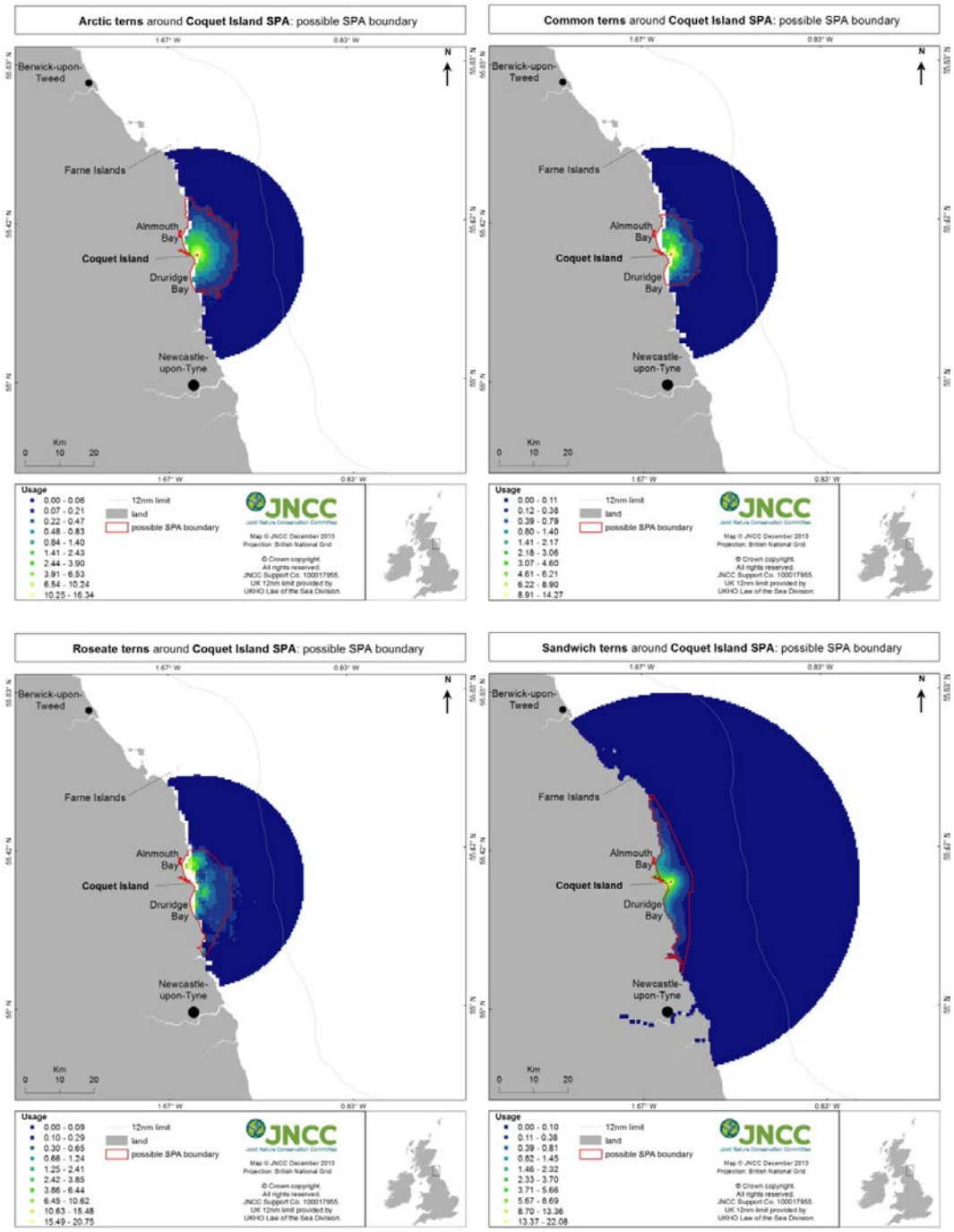


Figure 32. Outputs of species-specific habitat modelling by the JNCC for Arctic, Common, Roseate and Sandwich Terns breeding on Coquet Island, leading to proposals for relevant revised boundaries for Northumberland SPA.

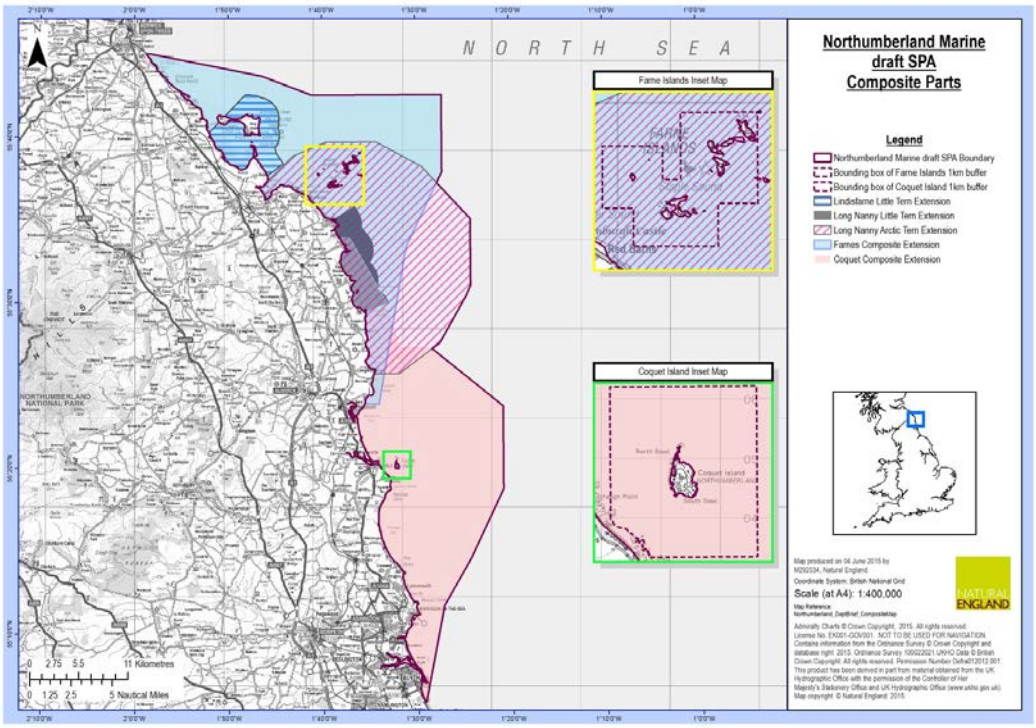


Figure 33. Possible Northumberland marine pSPA boundary proposed by Natural England (2014b) incorporating the combined interests of all five UK breeding tern species at a series of protected sites comprised of Coquet Island, Farne Islands, Long Nanny and Lindisfarne.

The modelled predicted use of the Aln, Coquet, Wansbeck and Blyth by Sandwich Terns was borne out by the surveys, with birds present in all catchments (Figure 34). In general, birds were distinctly estuarine in terms of abundance and distribution with birds recorded foraging as well as resting on available sandbanks and saltmarsh. Birds penetrate beyond the estuary mouth in the to ~1 km upstream in the Aln, ~1.6 km in the Coquet and ~3 km in the Blyth, although in all cases the contours of the river channel meant that the locations of the apparent upstream limits of the birds were only around 1 km or less from the sea as the tern flies.

Moreover, it is important to note that the number of survey locations was limited to just two in the Aln, with Sandwich Terns occurring at both and occasionally recorded flying upstream beyond the survey location furthest upstream (the road bridge). Sandwich Terns are therefore known to occur further upstream than documented in the current survey, although this seems unlikely to be of any particular importance.

Common Tern occurred in the lower reaches of the estuaries of the Wansbeck and Blyth as well as a few site sites further upstream in both sites and thus beyond the limit of the area of significant usage of this species generated by the model. It is of note that an individual Common Tern tracked by Wilson *et al.* (2004) did reach as far south as the mouth of the Wansbeck, although such outliers are of no importance in modelled data.

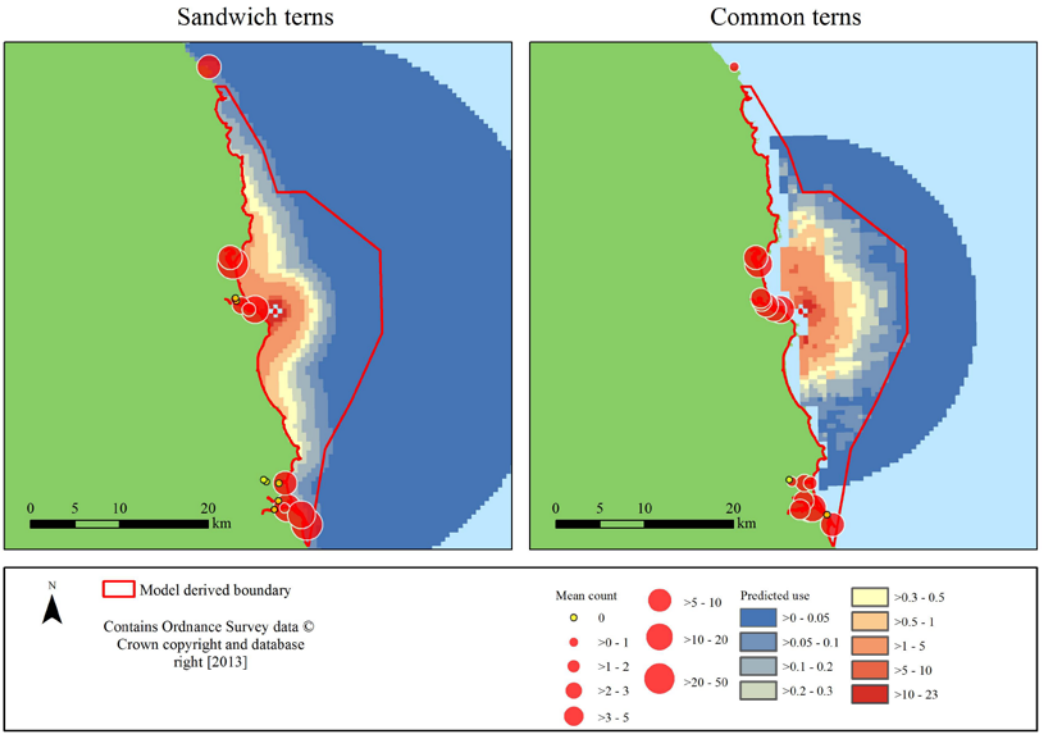


Figure 34. Comparison between the JNCC site-specific model-based relative usage and boundary (composite across species) of important foraging areas for Sandwich and Common Terns originating from Coquet Island relative to the species-specific mean timed counts at each site from the three survey occasions in 2015.

The distance from Coquet Island to the River Blyth represents a straight-line journey of ~21 km, which is well within the maximum foraging range of 30 km and close to the mean (± 1SE) maximum distance of 15.2 ± 11.2 km documented for Common Tern in the review of Thaxter *et al.* (2012). Only the mean (± 1SE) range of 4.5 ± 3.2 km is similar to median maximum distance of 3.6 km and total trip distance of 6 km recorded by Robertson *et al.* (2014) for a small number of visually tracked birds (*n* = 7) breeding at Coquet Island. It would thus appear that Common Terns breeding at Coquet Island could indeed use the Blyth estuary, although the bulk of foraging activity should occur closer to the colony.

5.4 Morecambe Bay & Duddon Estuary

5.4.1 Spatio-temporal abundance

A total of 45 Sandwich Terns were recorded in the single survey at Morecambe Bay & Duddon Estuary on 17th June (Table 8.4.1 in Appendix 8.4). All birds were recorded at Haverigg Point, the southernmost survey location closest to the colony at Hodbarrow Lagoon, where a maximum of 32 Sandwich Terns were seen with two AONs on the previous evening.

5.4.2 Patterns of activity

In the timed counts, the majority (67%) of Sandwich Terns were recorded as foraging with 33% resting (Table 8.4.1 in Appendix 8.4). The pattern was different in the instantaneous snapshot counts that allowed the separation of birds with apparent directional flight from those foraging with no clear direction, at least at the point of the snapshot. Thus, the most frequent activity was directional flight (43%), followed by foraging (32%), with 25% resting (Figure 35).

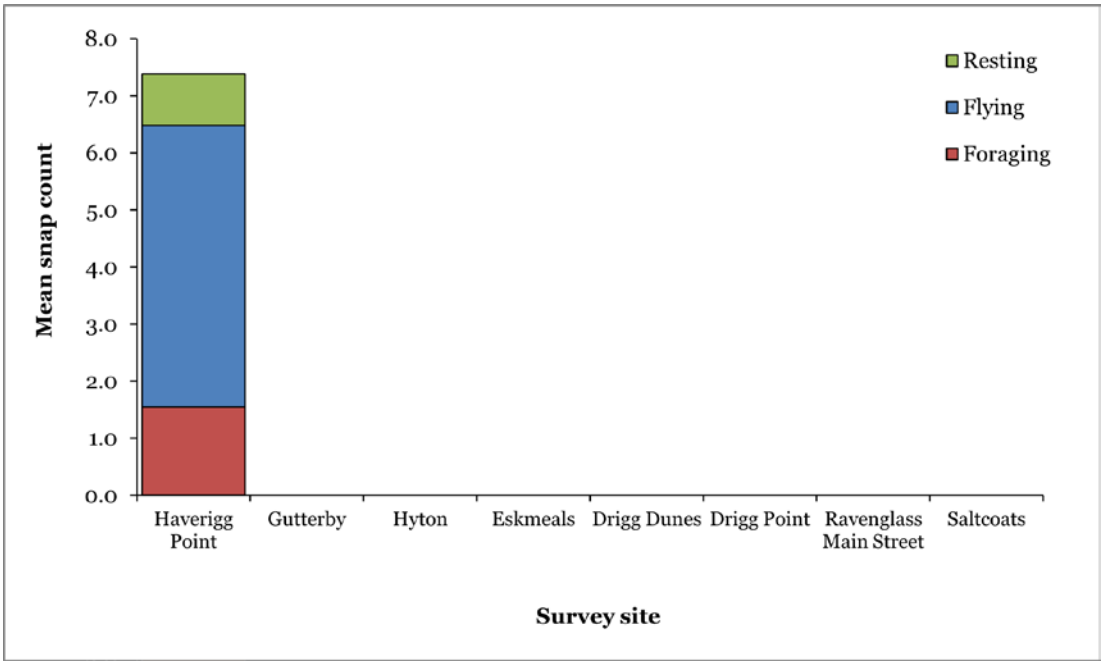


Figure 35. Activity patterns of Sandwich Terns derived from mean count in snapshots at the different survey locations on the single survey occasion (17th June) at Morecambe Bay & Duddon Estuary.

5.4.3 Comparison with the proposed SPA

The outputs of the generic JNCC Sandwich Tern model applied to the Duddon Estuary suggested a hotspot of activity within the Duddon Estuary itself (Figure 36). The sole cluster of observations of foraging Sandwich Terns at Haverigg Point at the northwestern extremity of the estuary at its junction with the Irish Sea concurs with the model output. At this juncture, it appears that few birds were actually nesting at Hodbarrow Lagoon and thus birds were not exactly tied to central-place foraging, although were likely to still have some connection with the colony. In some respects, the pattern may indicate good foraging opportunities within the Duddon Estuary compared to elsewhere along the coast, but whether or not birds would be likely to regularly range to the Esk estuary when breeding cannot be determined from the limited data gathered.

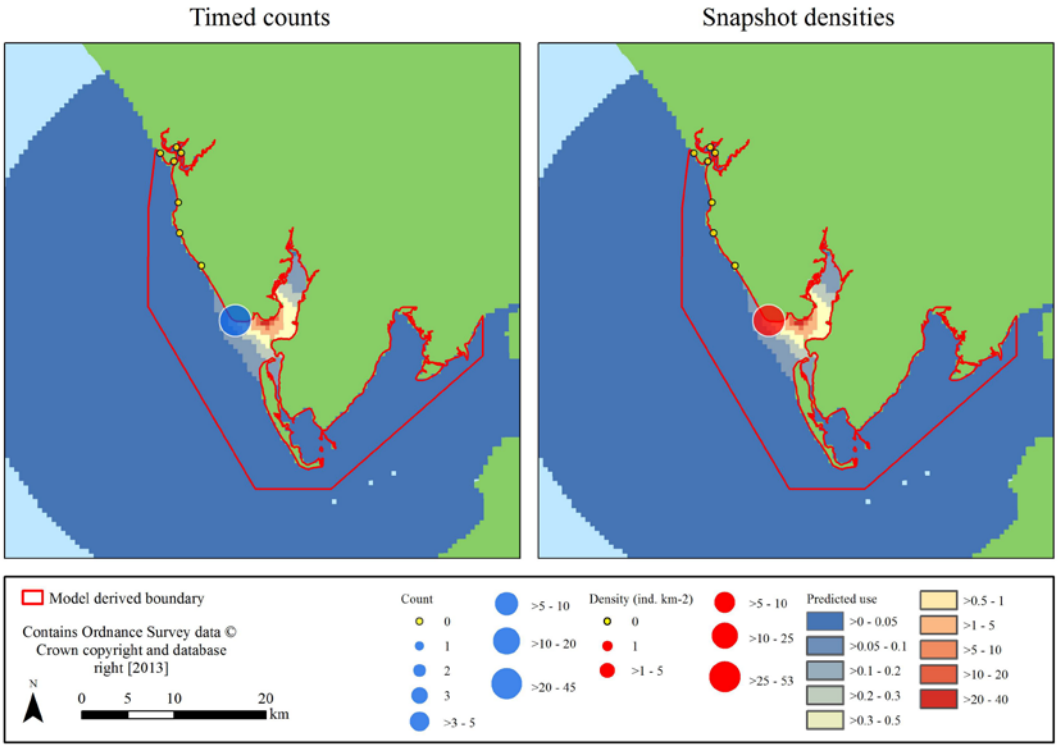


Figure 36. Comparison between the JNCC generic model-based relative usage and boundary of important foraging areas for Sandwich Terns originating from the Duddon estuary, relative to the mean timed counts and snapshot density derived at each site on the single survey occasion.

5.5 Liverpool Bay

5.5.1 Spatio-temporal abundance

A total of 309 Common Terns were recorded over the three surveys (Table 8.5.1 in Appendix 8.5) with the fewest birds (44 ind.) recorded on the second occasion in early July (1st) with a decline of 40% from the first survey with 73 ind. By far the largest number of birds (192 ind.) representing 62% of the total was seen just a few days later (9th). The overall proportion of records was concentrated at Seaforth (74%), with this contributing 80-81% on the first and last survey occasions. The low proportion of records at this site on the second occasion (34%) is inexplicable, especially as what could be an important factor, tidal state, was described as flooding at this site on both the second and third surveys.

Away from Seaforth, the proportion of records was relatively similar (4-8%) at Peel Dock, Tower Promenade, Huskinson Dock and Princes Jetty. No birds were recorded at all at Albert Dock or Rock Ferry at the furthest point upstream (Figure 37). A very small number of Common Terns were also only recorded at South Ferry the penultimate survey location before the upstream limit of the surveys, on the last survey occasion (Figure 37).

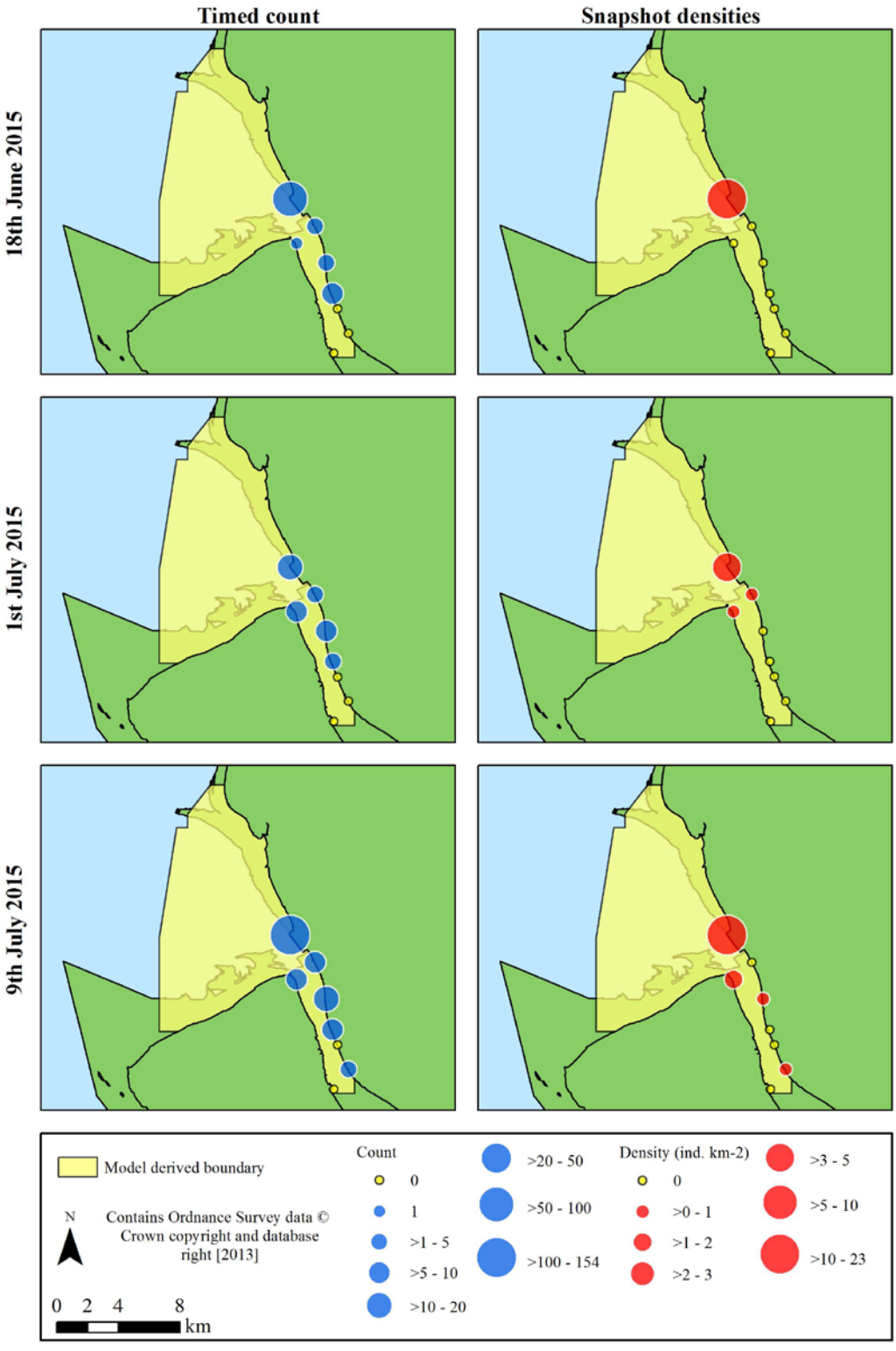


Figure 37. Abundance and distribution of Common Terns in the River Mersey within Liverpool Bay as shown by timed counts and density (ind. km^{-2}) derived from snapshots within the timed count at the different survey locations in each of the sampling occasions in 2015.

5.5.2 Patterns of activity

In the timed counts, Common Terns were overwhelmingly recorded in directional flight (83%) with some foraging (16%) with a very small proportion resting (<1%) (Table 8.5.1 in Appendix 8.5). Snapshots suggest a similar preponderance of directional flight (77% overall) compared to foraging (23%) with no resting birds recorded (Figure 38).

On the final occasion at Seaforth, 26 ind. (17% of records at this site on this occasion) were seen flying in from the open sea towards the colony carrying prey (fish primarily identified as clupeids from 1-2 bill lengths i.e. ~4-8 cm) invariably to provision developing chicks. Only 5 ind. had been noted returning with prey in such a fashion on 1st July, with none doing so on 18th June, presumably as birds were still incubating eggs at the colony at this point.

5.5.3 Comparison with the proposed SPA

The generic Common Tern model applied to Liverpool Bay predicted reasonable use of the Mersey upstream for ~8 km through the Mersey Narrows, that warranted inclusion of this part of the river within a proposed SPA boundary (Figure 39). NE adopted this proposal within their amendment to the wider Liverpool Bay marine pSPA (Figure 40). The predicted use of the lower part of the Mersey is a function of the location of the Seaforth colony at the mouth of the Mersey and the dominant 'distance to colony' model variable.

A cluster of activity of Common Terns around the colony and extending some 5 km into the Mersey was recorded during the surveys in keeping with the higher levels of use predicted by the model. This distance fits closely with the mean (± 1SE) foraging range of 4.5 ± 3.2 km documented by Thaxter *et al.* (2012) in their review of the literature of the foraging range of Common Tern (amongst other species of seabird).

The fact that no Common Terns were recorded at the upstream limit of the surveys and, no or very few Common Terns were recorded over the last 3 km of so of the surveyed stretch, suggests that it is unlikely that Common Terns on foraging trips from Seaforth generally penetrate further upstream than the length of river surveyed in this project. Put another way, on this evidence, the suggested boundary of the SPA may incorporate areas that are relatively rarely used by Common Terns.

However, to date, only a small number of surveys have been undertaken within a single breeding season. Even within the surveys conducted there was considerable variation in the numbers of birds returning with prey to the colony between surveys only a few days apart, which hints at the potential for considerable changes in the distribution and availability of prey to Common Terns in the estuary. In fact, there seems no obvious reason why prey may not become available within the lower part of the Mersey to the limit of the model boundary or even beyond, at some stage within the breeding season, perhaps linked to a particular tidal state. A mean (± 1SE) maximum foraging range of 15.2 ± 11.2 km, illustrates ample potential for Common Tern to exploit any prey further upstream in the Mersey.

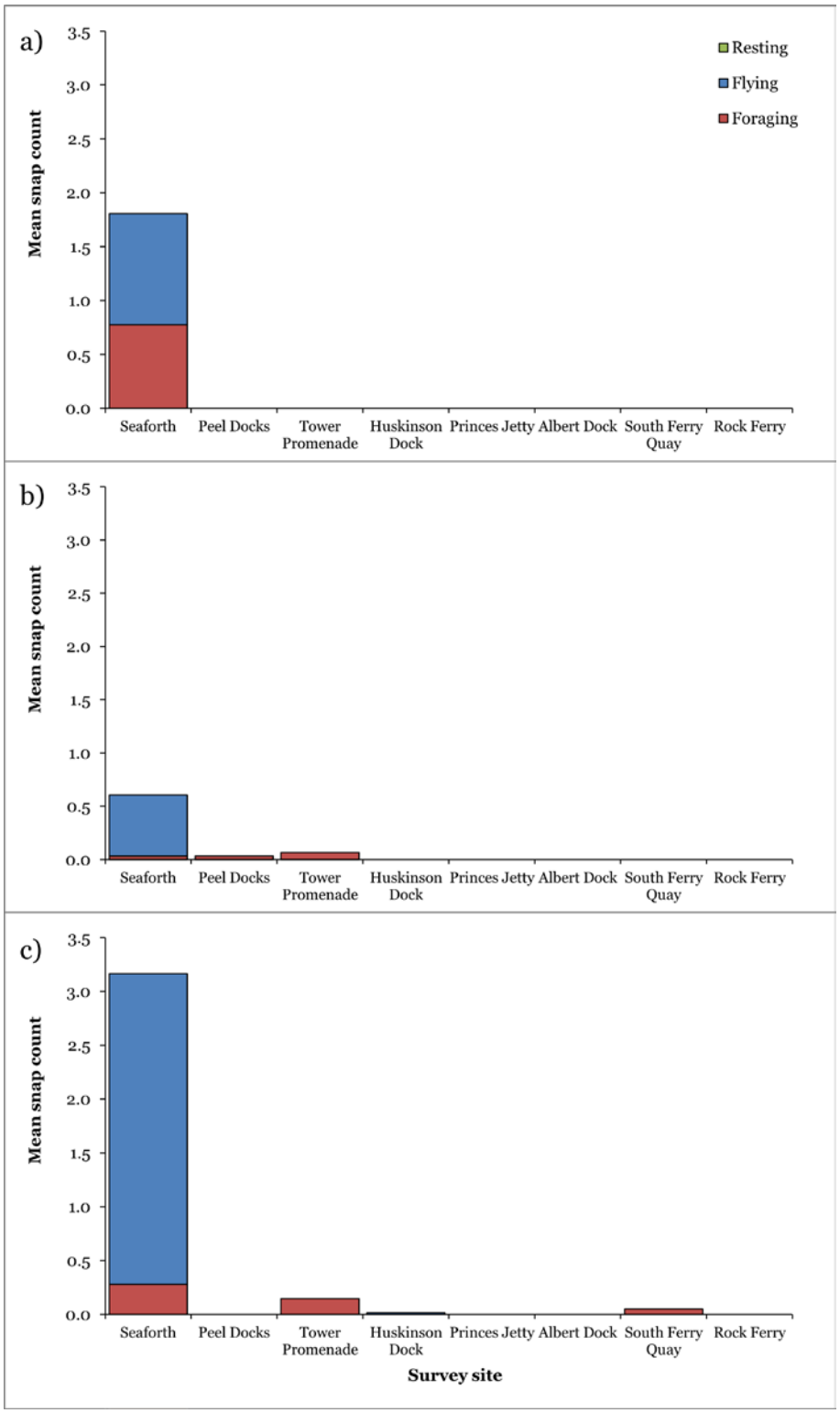


Figure 38. Activity patterns of Common Terns derived from mean count in snapshots at the different survey locations on each survey occasion in Liverpool Bay, represented by a) 18th June b) 1st July and c) 9th July.

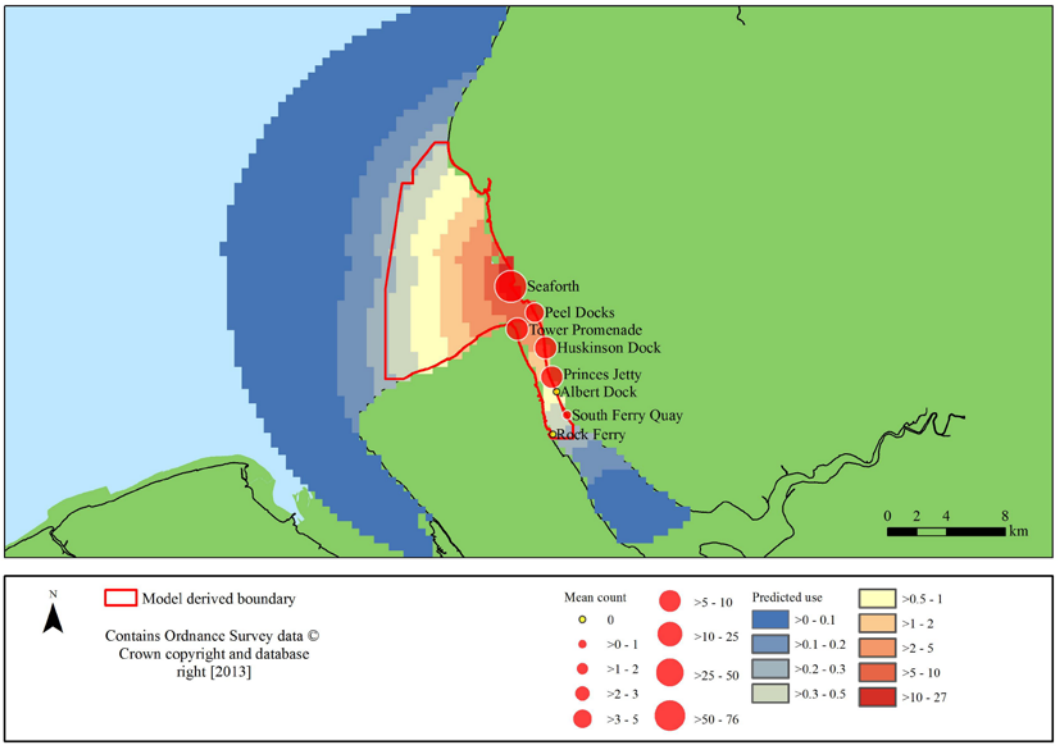


Figure 39. Comparison between the JNCC generic model-based relative usage and boundary of important foraging areas for Common Terns originating from the Liverpool Bay SPA, relative to the mean timed counts derived at each site from the three survey occasions in 2015.

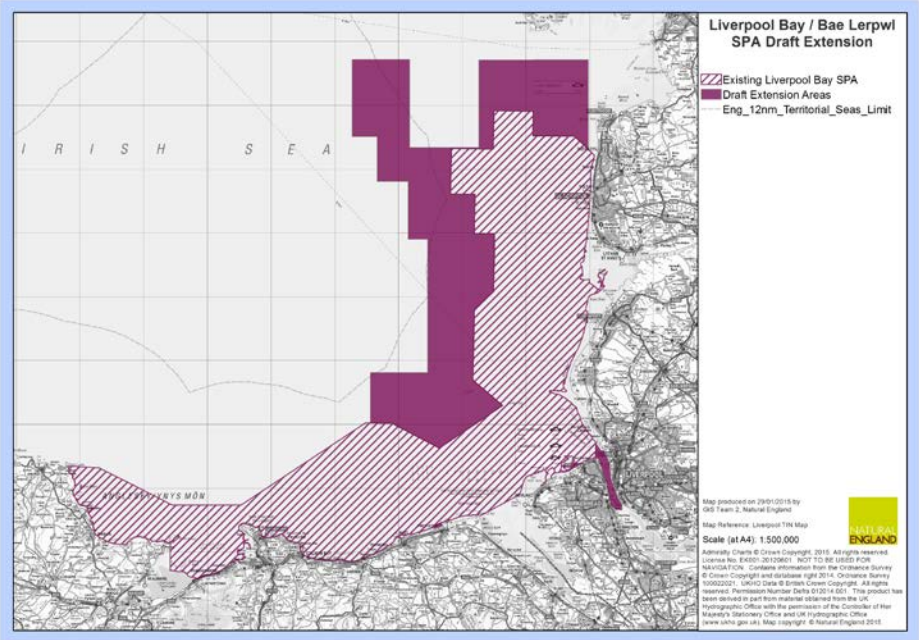


Figure 40. Possible Liverpool Bay marine pSPA boundary proposed by Natural England (2015c) incorporating the interests of breeding Common Tern at Seaforth Lancashire Wildlife Trust reserve.

Finally, the model and resultant SPA boundary is based on Common Terns nesting at Seaforth. The fact that Common Tern was discovered nesting on the quayside in Sandon Half Tide Dock (near Huskinson Dock) during this study illustrates the potential for small sub-colonies or enclaves of birds to form in similar industrial habitat further upstream in the tidal Mersey either now or in the future.

5.6 Poole Harbour

5.6.1 Spatio-temporal abundance

A total of 551 Sandwich Terns were seen over the course of all surveys (i.e. three surveys at 13 locations with one at another). According to Caldow (2015), 56% of the birds for which a direction was recorded were heading away from Poole Harbour whereas 44% were heading towards it. A high proportion of the total sightings (58%) were made at a single site: South Haven at the entrance to Poole Harbour (Figure 41). Far fewer birds were recorded at Studland Beach and Handfast Point, but with more within Swanage Bay and in particular at the southern edge of Swanage Bay at Peveril Ledges (Figure 41). Further west, low numbers of Sandwich Terns were seen at six of the eight survey stations including at Worbarrow Bay at the western most extremity of the proposed pSPA boundary and beyond that at Lulworth Cove and on the one *ad-hoc* visit to Osmington Mills (Figures 41). Overall, the distribution patterns were similar on all of the survey occasions.

A total of 204 Common Terns were seen over the course of all surveys. According to Caldow (2015), of the birds for which a direction was recorded, 48% were heading away from Poole Harbour and 52% were heading towards it. In marked contrast to Sandwich Tern, all except three Common Terns were seen at South Haven Point at the entrance to Poole Harbour (Figure 41), illustrating a restricted foraging range. There was some decline in the number of records within the timed count over the survey period, with the first survey at South Haven Point on 8th June yielding 51% of the total of all birds on all occasions, with the latter two surveys on 15th-21st June and 22nd June – 10th July providing 25% and 24% of the records respectively (Figure 42).

In addition, a total of 63 birds were unidentified with the great majority of these (56 ind. - 89%) seen at South Haven Point where tern traffic was heaviest and time to identify each individual shortest. No attempt was made to apportion any unidentified individuals to either tern species, and these records are thereby effectively ignored.

5.6.2 Patterns of activity

During the timed counts, of the 551 Sandwich Terns recorded, only 154 (28%) were recorded as actively searching or foraging with the remaining 397 (72%) being in direct flight. In the snapshots, the overall mean number of Sandwich Terns (averaged across all sites and dates) noted as actively searching or diving was 0.80 birds. This represented 82% of the mean number of Sandwich Terns seen on snapshot counts (averaged across all sites and dates) including all birds seen (0.96 birds).

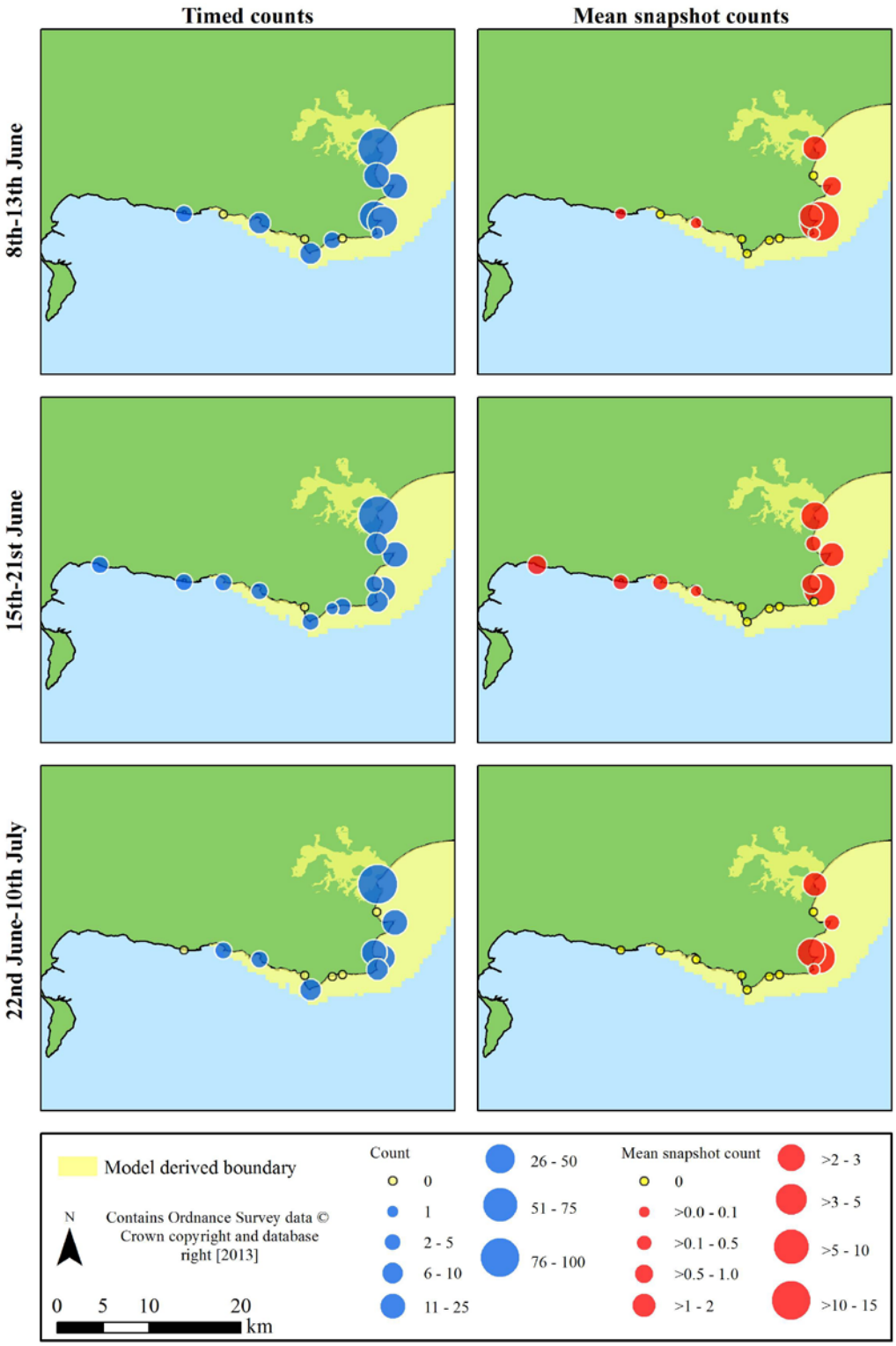


Figure 41. Abundance and distribution of Sandwich Terns along the Purbeck Coast as shown by timed counts and mean snapshot count within the timed count at the different survey locations on each of the sampling occasions in 2015.

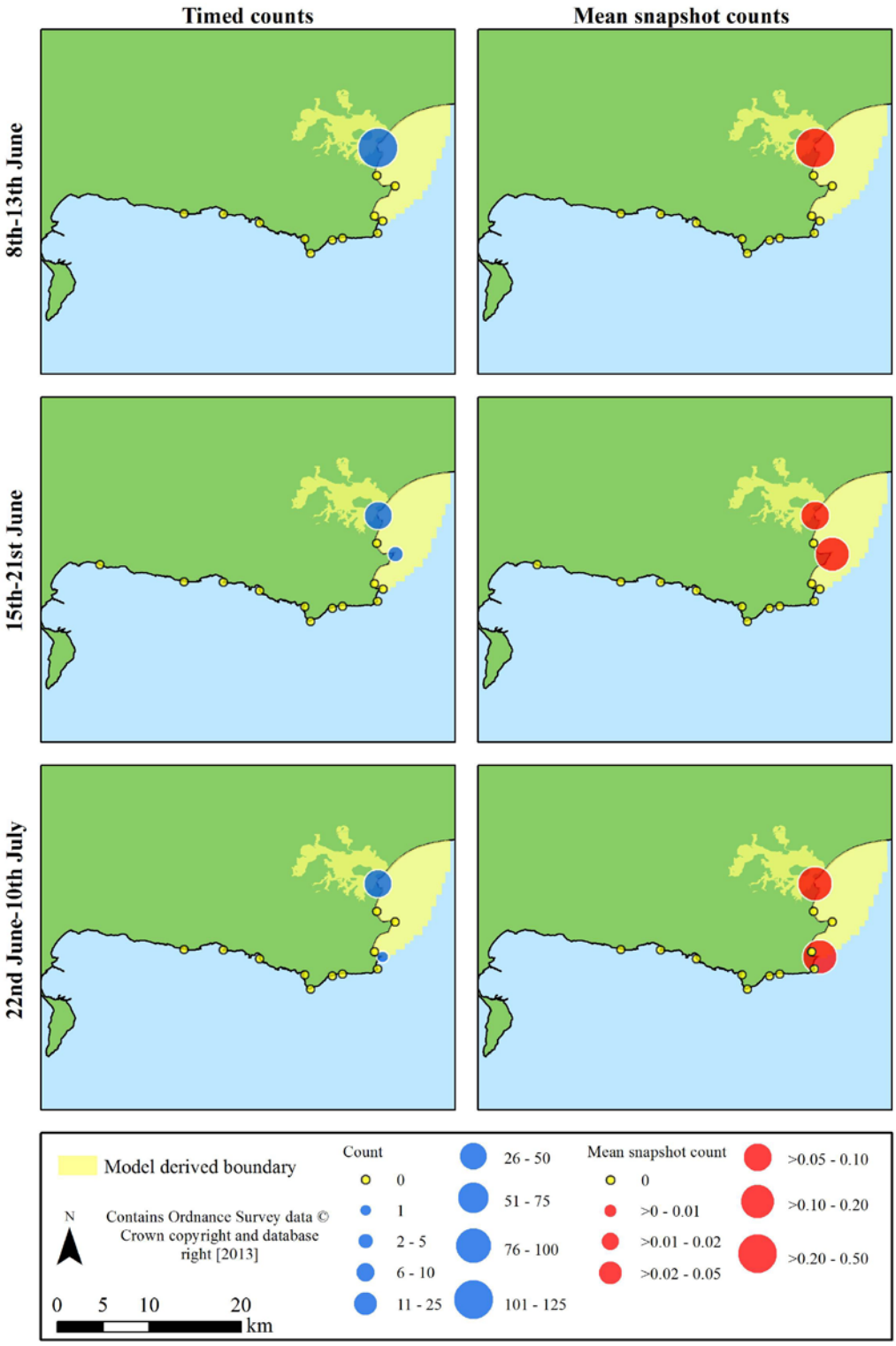


Figure 42. Abundance and distribution of Common Terns along the Purbeck Coast as shown by timed counts and mean snapshot count within the timed count at the different survey locations on each of the sampling occasions in 2015.

The difference between the timed counts and the snapshots could reflect the large numbers of birds seen leaving and returning to Poole Harbour at South Haven Point without obviously foraging in comparison to the very much smaller number of birds that remained and foraged close to the shore at this and other sites. In contrast, the relatively high mean snapshot count of Sandwich Terns at Peveril Ledges (Figure 41) all of which were recorded as actively foraging (Table 8.6.1 in Appendix 8.6) suggests that Peveril Ledges is a hotspot of foraging activity along the Purbeck coast at which either many birds forage or some birds forage over long periods. A lower level of foraging activity in snapshots was also recorded at each of the three stations between the entrance of Poole Harbour and Peveril Ledges. To the west of this, low numbers of actively foraging Sandwich terns were recorded at 5 of the 9 stations, including at Worbarrow Bay at the western most extremity of the proposed pSPA boundary and beyond that at Lulworth Cove and Osmington Mills (Figure 41).

A total of 67 Sandwich Terns were seen carrying fish (12.1% of all birds seen). Unsurprisingly, numbers were greatest at South Haven Point at the harbour entrance. Otherwise, birds carrying fish were seen only at four stations, all of which might be considered headlands i.e. Handfast Point, Peveril Ledges, Durlston Head and St Aldhelm's Head (see Figure 10). This suggests that birds returning to the colony with fish may take a relatively direct route back to the colony from headland to headland and pass across intervening stretches of coast and bays relatively far offshore and potentially beyond the observation range of this study.

During the timed counts, birds, only 20 (10%) Common Terns were recorded as actively searching or foraging, compared to 184 birds (90%) in directional flight. In the snapshots, the overall mean number (averaged across all sites and dates) of Common Terns noted as actively searching or diving was ~0.01 birds or 39% of the mean number of birds (~0.03) recorded in snapshots (Table 8.6.2 in Appendix 8.6). The number of foraging Common Terns was therefore over an order of magnitude lower than that recorded for Sandwich Terns.

Common Terns were recorded searching/diving in snapshots within the timed count at three survey locations: South Haven Point, Handfast Point and Peveril Ledges (Figure 42). Only the odd individual was recorded actively foraging at any of these locations illustrating that Common Terns do very little foraging along the Purbeck coastline. Only 14 Common Terns were seen carrying fish (6.9% of all birds seen), with all of these at South Haven Point.

5.6.3 Comparison with the proposed SPA

The overall Solent & Dorset Coast pSPA boundary proposed by the JNCC and adopted by NE for public consultation (Natural England 2015e) is a contiguous expression of predicted important foraging areas for a number of tern species (Common, Sandwich and Little Terns) originating from a number of adjoining SPAs (Poole Harbour, Solent & Southampton Water and Chichester & Langstone Harbour) of which Poole Harbour SPA is the westernmost (Figure 43).

The westernmost parts of the potential boundary of the Solent & Dorset Coast pSPA is derived on the basis of the predictions of the generic JNCC model for Sandwich Tern originating from Poole Harbour SPA, as this incorporated the output of the generic model available for the shorter ranging Common Tern breeding at the same locality (Figure 44).

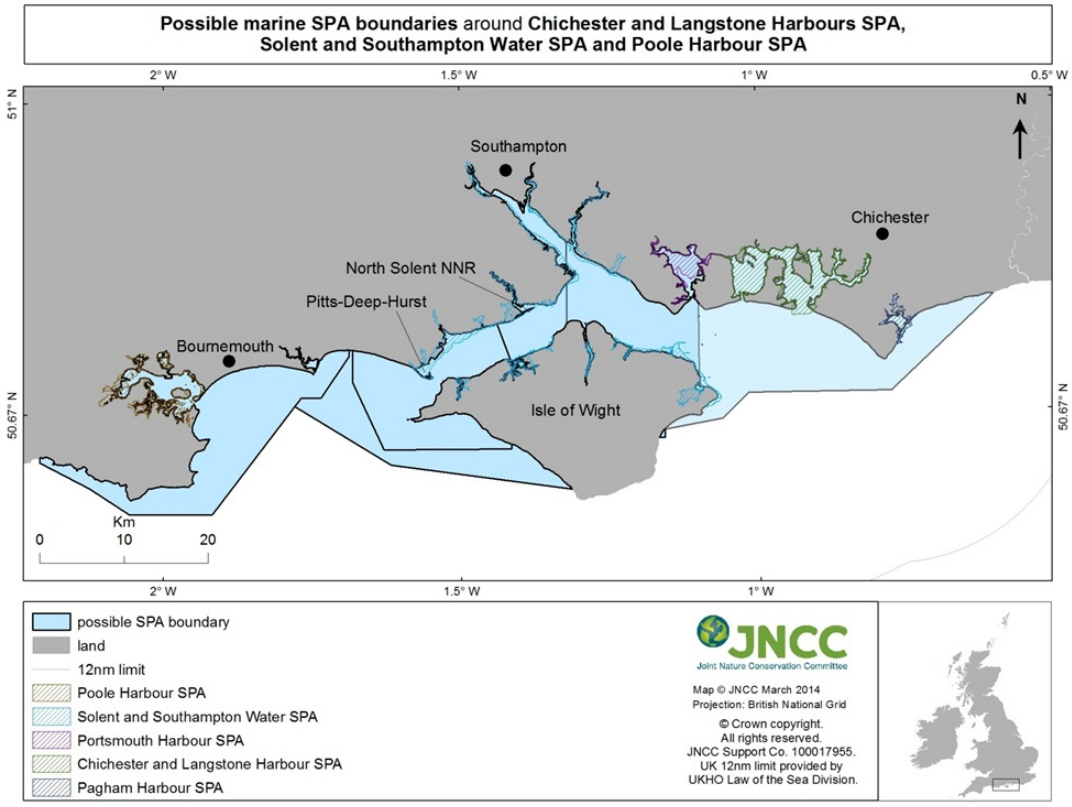


Figure 43. Possible Solent & Dorset Coast marine pSPA boundary proposed by Natural England (2015e) incorporating the interests of Common, Sandwich and Little Terns breeding at a number of locations within a series of protected sites comprised of Poole Harbour, Solent & Southampton Water and Chichester & Langstone Harbour.

The outputs of the species-specific but generic (i.e. not site-specific) JNCC models for both Sandwich and Common Terns breeding within Poole Harbour both suggested a hotspot of activity within the harbour itself (Figures 44 & 45), presumably simply because of the importance of the 'distance to colony' factor in the models. Moreover, there was a similar level of concentration close to the colony irrespective of the much greater range of Sandwich relative to Common Tern (the dark blue radius in Figure 44), presumably because of the use of a relative scale of usage within the results for each species. It is important to note however that this project did not seek to validate the location of any hotspots, as this was not considered to be a source of uncertainty in determining the boundary of the Solent & Dorset Coast pSPA. In addition, hotspots within Poole Harbour would already be contained within the Poole Harbour SPA.

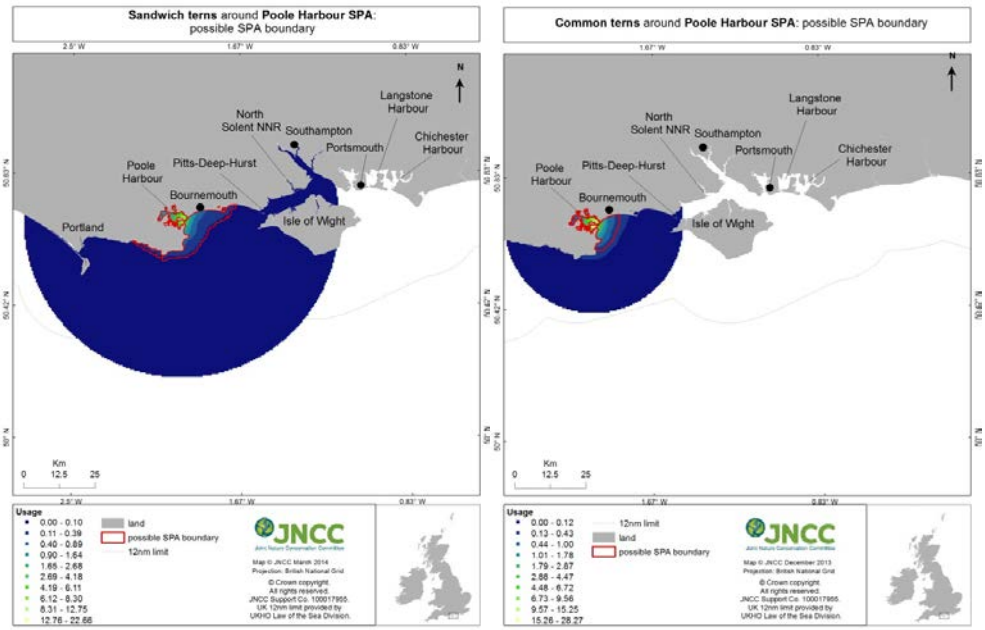


Figure 44. Outputs of species-specific habitat modelling by the JNCC for Sandwich and Common Terns breeding on Brownsea Island within Poole Harbour that underpins the definition of the westernmost extent of the Solent & Dorset Coast pSPA shown in Figure 43.

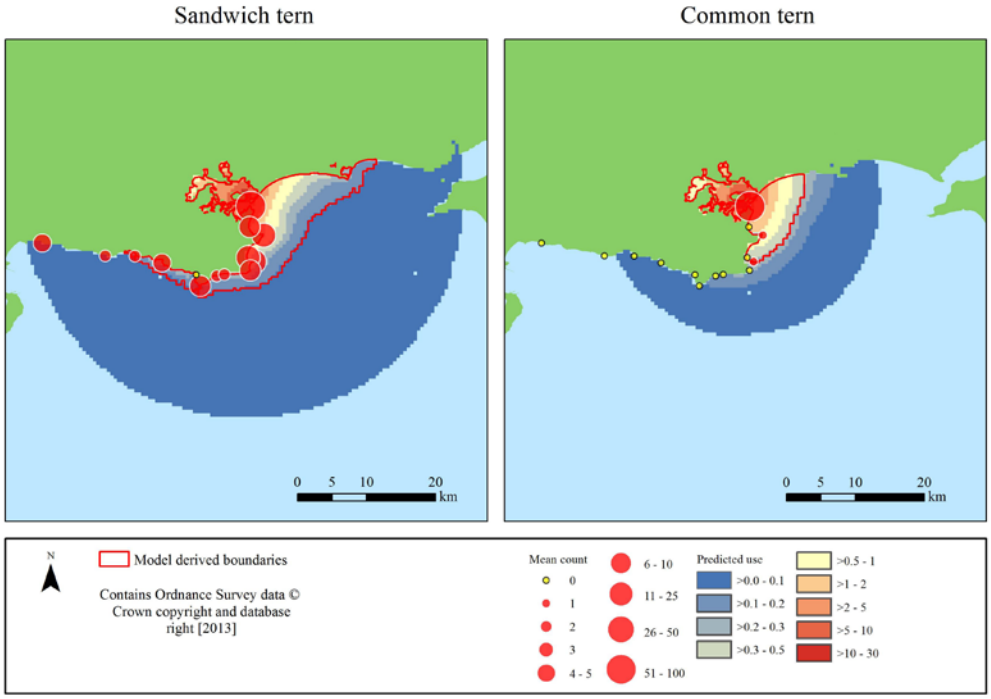


Figure 45. Comparison between the JNCC proposal for a revised boundary for Solent & Dorset Coast SPA based on the output of a specific habitat model for Sandwich Tern, relative to the model outputs for both Sandwich and Common Terns and the species-specific mean timed counts at each site from the three survey occasions (one in the case for the westernmost point).

Sandwich Tern occurred to the west of the colony in reasonable numbers as predicted by the generic model of relative usage. Some records were obtained beyond the boundary of the area of importance as suggested by maximum curvature analysis, although this is to be expected given that this does not intend to capture all use, but the most important use. A more direct comparison between the predictions of relative usage from the JNCC model and the occurrence of foraging birds in the surveys according to the distance from the colony illustrated reasonable agreement between the two sets of data, but that this was heavily influenced by high usage within a short distance from the colony within Poole Harbour (Figure 46).

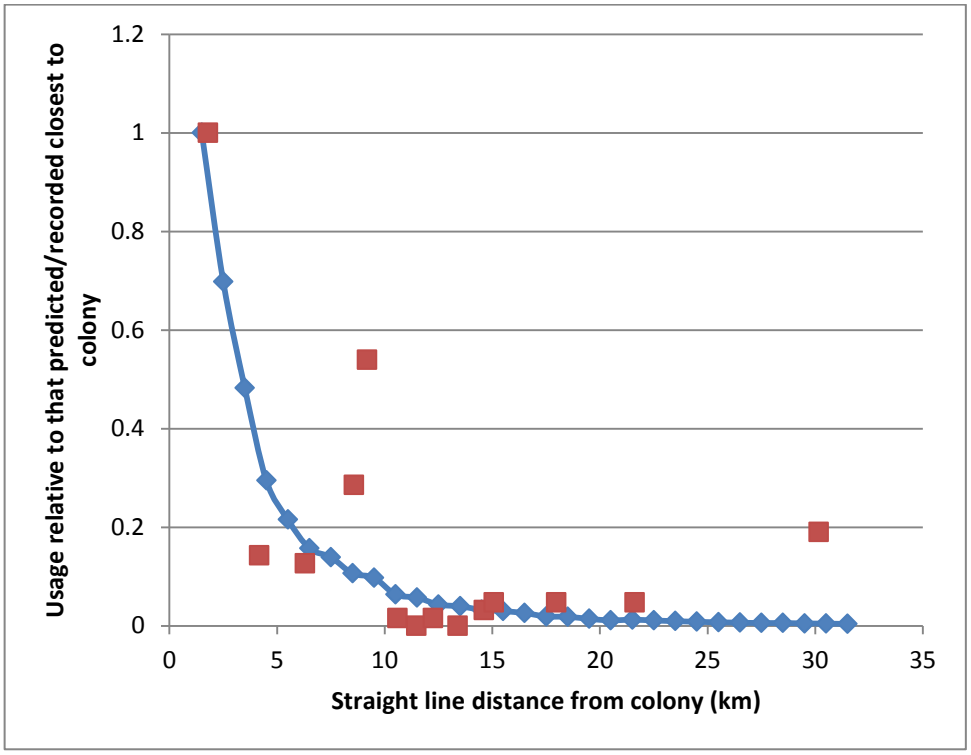


Figure 46. Comparison between the decline with increasing (straight line) distance from the colony of relative usage by actively searching Sandwich trens predicted by the JNCC generic model (blue diamonds and fitted line) and as recorded during surveys in 2015 (red squares). The predicted relative usage values generated by the JNCC model for each grid cell along the coastline from the Poole Harbour entrance were averaged across cells within 1 km distance bands expressed as a proportion of the average relative usage score within the distance band closest to the colony. The average number of Sandwich terns seen actively seaching per hour during timed counts at each station was also expressed as a proportion of the mean value recorded at South Haven Point and plotted at the relevant straight line distance of that location from the colony in Poole Harbour.

Otherwise, there was a preponderance of foraging birds at Peveril Ledges, at the southern limit to Swanage Bay some 9 km from the colony, assuming birds take the most direct route that stays at sea and do not cross a large expanse of land (Figures

45 & 46). Foraging Sandwich Terns also occurred much further to the west than this as evidenced by the following observations of birds: i) carrying fish eastwards past St Aldhelm's Head 14.6 km from the colony in a straight line, ii) actively searching as far west as Lulworth Cove, iii) in transit flight heading both west (outbound) and east (inbound) past Lulworth Cove at the westernmost limit of the pSPA boundary at 19 km from the colony, and iv) foraging at Osmington Mills, some 30 km from the colony by straight line flight and beyond the westernmost limit of the pSPA boundary (Figures 45 & 46).

The model output does however appear to capture the areas of relatively greater importance to Sandwich Terns as the suggested boundary limit of 19 km contains: i) all locations with records of birds returning with prey, ii) all locations (bar one) where the mean number seen actively searching per hour exceeded 1 bird i.e. at ~ 10 km, and iii) levels of active searching equivalent to 90% of that recorded overall (sum of mean birds actively foraging per hour in timed counts across all stations within the boundary = 90.5% of that across all stations) (Figure 47).

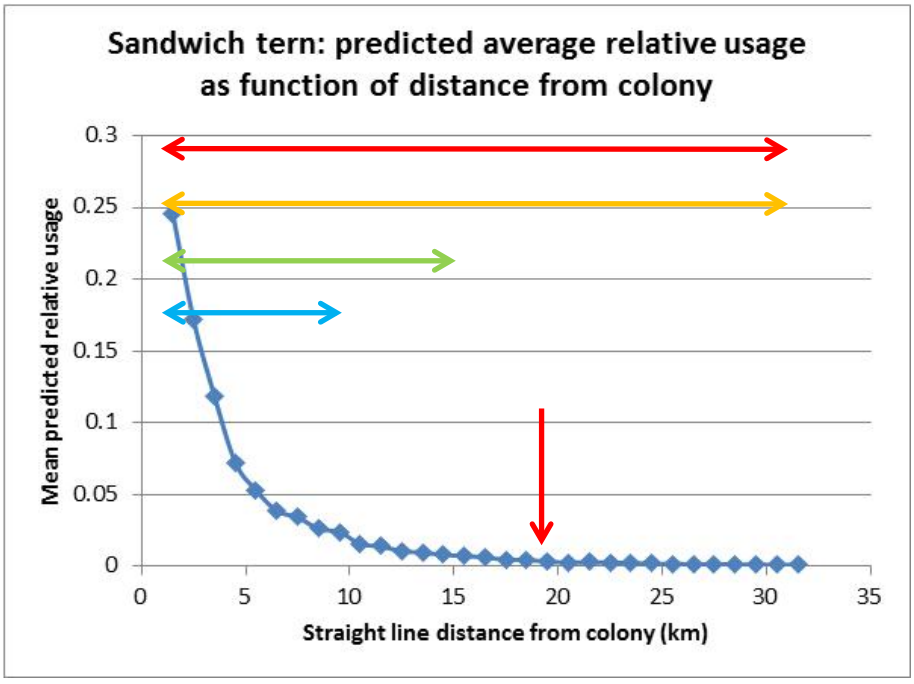


Figure 47. Model-predicted relative usage of Sandwich Terns in grid cells along the coast to the south and west of Poole Harbour as taken from Caldow (2015). The vertical red arrow denotes the straight-line distance of the westernmost limit of the area included within the red line boundary drawn around the modelled usage of Sandwich terns (Figure 44) and hence the pSPA boundary. Horizontal double-headed arrows denote the distance spanned by the survey locations at which the mean number of Sandwich Terns: i) present and actively searching was >0 in timed counts (red arrows); ii) actively searching per snapshot count was >0 (orange arrows); iii) carrying fish was >0 (green arrows), and iv) present and actively searching in timed counts was consistently and well above 0 (blue arrows).

The lack of sightings of Common Terns in this study at all sites except at the entrance to Poole Harbour, tends to confirm the bulk of foraging activity of Common Terns was contained either within the harbour, areas at sea immediately outside its mouth of the harbour, or perhaps areas to the east that were not sampled in this study. In accordance with the focus on the waters of Poole Harbour, the decline in the numbers of Common Terns at increasing distance from the colony is more rapid than would be expected (Figure 48). Nevertheless, all records were contained within the 9 km or so range predicted by the selected boundary (Figures 44 & 45).

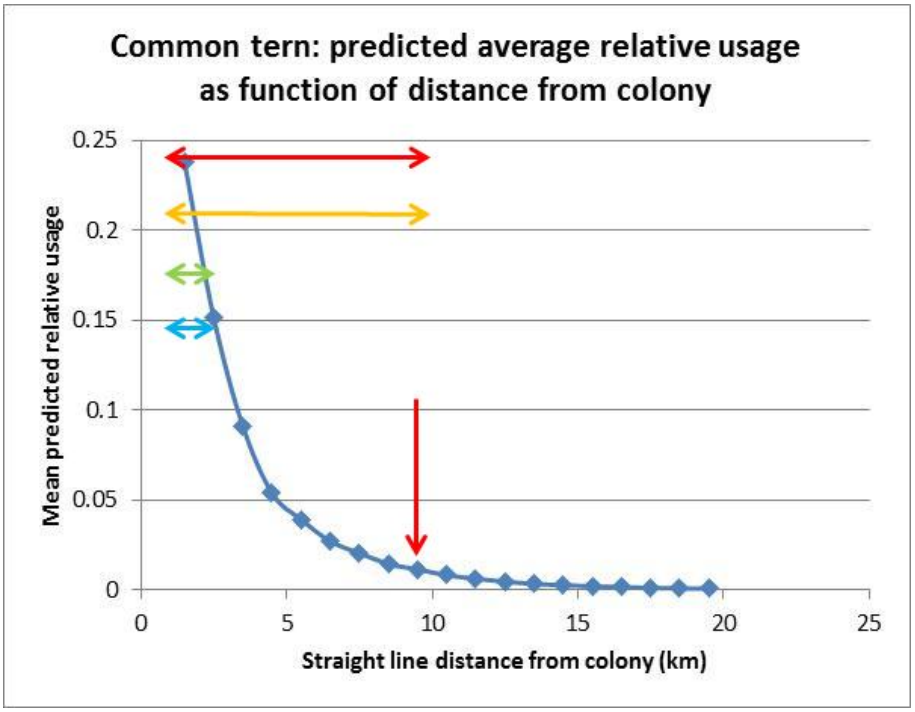


Figure 48. Model-predicted relative usage of Common Terns in grid cells along the coast to the south and west of Poole Harbour as taken from Caldow (2015). The vertical red arrow denotes the straight-line distance of the westernmost limit of the area included within the red line boundary drawn around the modelled usage of Common terns (Figure 44). Horizontal double-headed arrows denote the distance spanned by the survey locations at which the mean number of Common Terns: i) present and actively searching was >0 in timed counts (red arrows); ii) actively searching per snapshot count was >0 (orange arrows); iii) carrying fish was >0 (green arrows), and iv) present and actively searching in timed counts was consistently and well above 0 (blue arrows).

The foraging range of Common Tern along the Purbeck coast therefore appears to be extremely limited with almost all records obtained at South Haven Point at <2 km from the colony. This compares with a mean (± 1SE) maximum foraging range of 15.2 ± 11.2 km and a mean (± 1SE) foraging range of 4.5 ± 3.2 km from a range of studies reviewed by Thaxter *et al.* (2012), the mean (± 1SE) of 8.1 ± 0.3 km at Salthome (Perrow *et al.* 2010) and the median range of 3.6 km from Robertson *et al.* (2014) at Coquet Island. Only the mean (± 1SE) of 2.2 ± 0.4 km from 42 birds

tracked at Blakeney Point on the North Norfolk Coast by Perrow *et al.* (2010) is similar.

At the latter, Perrow *et al.* (2010) speculated that the limited range of Common Tern was linked to the occupancy of an 'inshore niche' targeting young-of-the-year fish (mainly clupeids) in the presence of significant numbers of sympatrically breeding Sandwich Terns, as is also the case in Poole Harbour. The provisions presented to Sandwich Tern chicks tend to be dominated by larger clupeids and sandeels (see Perrow *et al.* 2010, Cabot & Nisbet 2013 and Wilson *et al.* 2014 for reviews of a range of studies) and it may be that by specialising on small prey gathered in inshore waters, Common Tern may avoid or at least limit competition with Sandwich Tern. It should be noted that Little Tern would typically occupy this inshore niche in other circumstances.

6 Concluding remarks

6.1 Overview

The primary aims of this study were to identify foraging areas for terns originating from designated SPAs and in so doing to validate proposed limits to areas identified as potential marine pSPAs. The desire to conduct these verification surveys stemmed from the fact that many of the limits to proposed boundaries of marine pSPAs, and the inclusion within those boundaries of many small estuaries, river channels, creeks, inlets, harbours and docks etc. were based on either very limited site specific empirical data or even none at all, but rather on the predictions of generic models of tern usage patterns derived from studies at other colonies. It was entirely possible that this programme of surveys could have consistently failed to detect foraging terns in places which had been included within proposed site boundaries, and in particular in places that defined the site boundaries. The results of this project need to be considered in the context of this point.

A total of 3,181 terns were recorded during the surveys. The surveys were seen to be successful judging from the fact that the target species were seen on surveys (with the exception of Arctic Tern in relation to Northumberland) and often in relatively large numbers (e.g. 957 Common Terns were recorded in the boat-based surveys at Teesmouth & Cleveland Coast), and most importantly, the records could be used to verify the predictions of the site-specific and generic model outputs for the selected species of interest as well as confirming the occurrence of birds in particular locations of interest.

Notwithstanding the general success of the survey programme, a number of issues were noted. For example, the delayed award of the contract meant that the surveys did not start quite as early as intended, despite the rapid response of the survey team. This was most notable at Teesmouth & Cleveland Coast, which involved the additional logistics associated with a boat-based survey.

Furthermore, despite efforts to engage with the relevant staff on the ground including wardens wherever possible, this proved to be difficult, meaning that the surveys could not be matched with the timing of events at the relevant colonies. The lack of available resources to pursue retrospective information on the development and ultimate success of the colonies means that the results presented here cannot be couched within this colony-specific information, which may help explain particular spatio-temporal patterns. It is recommended that basic information for the colonies (number of pairs, date of first egg-laying and chick hatching and fledging, peak of number of nests, timing of any key events such as predation, number of chicks fledged and productivity etc) is compiled by relevant staff and compared against the results of this study as part of further work on the proposals for the relevant pSPAs.

The selection of survey sites was generally undertaken using the guidelines in the RFQ and using simple criteria (i.e. regular spacing within the constraints of access in some cases) although there was insufficient time to engage effectively with the site contacts to confirm the validity of any site selection process initially presented in our tender. In general, it appeared that an adequate number of sites were sampled, with the possible exception of the Aln in Northumberland where only two sites were sampled and thus the likely upstream limit of both Common and Sandwich Terns could not be confirmed in this case. Although a reasonable number of sites were sampled in the other rivers in this area (Coquet, Wansbeck and Blyth), yet more sites would be required to confirm the upstream limit of Common Tern.

The basic methodology adapted from that used by the JNCC to determine the alongshore extent of Little Terns from breeding colonies was relatively straightforward to undertake and generally fit for purpose in relation to this study. This is with the caveat that its basic design to determine the changing use of birds at increasing distance from the colony was only relevant to a few sites in this study such as Hamford Water for Little Terns and the Solent & Dorset Coast SPA for Sandwich and Common Terns breeding at Poole Harbour.

The methodology is therefore geared to situations where connectivity to a colony is readily established (i.e. by birds carrying fish in the direction consistent with the location of the colony). However, the likely provenance of the birds observed becomes more difficult where the survey locations are remote from the colony, and where birds may take a tortuous route whilst foraging along waterways. As such, even an indicative separation of breeding birds from non-breeding birds or failed breeders becomes impossible. In some cases, such as in Liverpool Bay and especially for a species like Common Tern, there is the possibility of the set-up of small satellite colonies away from the main colony, which may also confound interpretation of likely origin of the birds seen.

The primary focus of this study was to determine whether birds occurred at particular locations of interest, such as the series of docks at Teesmouth & Cleveland Coast. At this site, the addition of a boat-based transect route added considerably to the knowledge of the distribution and abundance of birds in the wider area relative to the particular survey locations of interest. Importantly, the additional methodology also provided quantitative estimates of density that also allows comparison with other sites if required.

An estimate of density could be determined from the snapshot methodology within the timed count once the field of view and area sampled had been determined. However, in many situations it was not possible to separate repeat observations of the same bird or birds from birds seen for the first time, and thus double-counting was likely at some survey locations. As such, we viewed the snapshot methodology as being the best source of behavioural data especially with respect to foraging activity. This is partly because it is easier to quantify behaviour in an instant rather than over a period of time where the behaviour illustrated may change rapidly leading to uncertainty in defining what the bird is actually doing.

In contrast, we saw the primary method of timed counts as geared towards providing a relative measure of abundance, although in some cases it could be used to generate a passage rate in the presence of an established directional movement especially when close to the colony. We were also less stringent about defining and limiting the area of field of view than was the case with snapshots. This is because it was more important to include birds that could be seen than to exclude them, bearing in mind a key objective was to record the presence or absence of birds at particular locations.

It is of note that the surveyors undertaking the surveys in relation to the Solent & Dorset Coast SPA (see Caldow 2015) treated the different methodologies in a different way, with greater reliance on the timed count to supply all information on relative abundance as well as foraging activity. Accordingly, the snapshots were seen to be less important and thus taken relatively infrequently at five minute, rather than one or two minute intervals. This illustrates that even a seemingly simple and relatively straightforward methodology may be applied rather differently in different hands.

As it stands, despite differences in methodology we are confident that all surveys supplied the basic information required on the likely distribution and abundance of breeding terns relative to the proposed boundaries for the six pSPAs investigated. Moreover, we would also conclude that no single issue or combination of issues was sufficient to impair the overriding value of any of the surveys conducted and therefore, that the conclusions reached for each site should be fit for purpose in relation to defining and ultimately designating robust SPAs for breeding terns as part of ongoing statutory commitment to the principles of the European Union Birds Directive.

6.2 Site-specific conclusions

6.2.1 Hamford Water

Records from the surveys conducted in 2015 verified the use of an area around site 5 (see Figure 1) some 5 km to the southeast of the colony, as previously indicated by boat-based survey data in 2013 (Figures 13 & 14). This area was encapsulated by a boundary derived from generic data for alongshore extent from several colonies proposed by the JNCC. However, the boundary adopted and submitted for public consultation by NE was derived from site-specific data for alongshore extent

including that from the boat-based survey as provided by the JNCC, falls short of site 5.

It should be clear that any proposed SPA would not necessarily be expected to include *all* use by Little Terns, and in fact site 5 only contributed some 2.6% of all records during the survey period in 2015. However, the site provided 10% of the records from the first survey in 2015 and the birds seen were involved in directional flight suggesting use of an area even beyond site 5. Moreover, Little Terns had been recorded in this vicinity in more than one year.

We conclude that the current proposed boundary for the marine SPA incorporating the interests of Little Terns at Hamford Water should be extended based on the latest site-specific data that will include the southernmost at-sea observations from the previous surveys. More specifically, the use of the JNCC recommended approach of using the maximum recorded alongshore distance recorded in site-specific data will see the extension of the proposed boundary to the southeast to incorporate site 5.

6.2.2 Teesmouth & Cleveland Coast

Common Terns from RSPB Salthome were consistently recorded using the entire length of the River Tees from the estuary as far upstream as Tees Barrage. It remains plausible, even likely, that use of the river extends even further upstream than this, although the terns would be obliged to take other, predominately freshwater fish species. Extensive use of the Tees was not recorded in previous tracking studies (in 2009) and the inter-annual frequency and extent of this use remains unclear, although it could indicate reduced fish availability in the estuary in some years and/or the possible increasing importance of the river as a foraging ground in recent years.

There is some potential for the involvement of the construction of the wind farm in fish distribution and abundance. As such, it would be valuable to repeat the tracking study undertaken in 2009 to determine any gross changes in distribution and abundance of foraging Common Terns and to determine if Common Terns use the wind farm itself, and if so, if they are at risk of collision. If so, this could represent a threat to the SPA colony, which undermines the attempt at its protection through establishment of a marine SPA.

The generic JNCC model did not accurately predict the relative levels of use of particular areas by Common Terns as a result of its use of distance from the colony as one of its primary predictor variables and the fact that the birds tend to aggregate at a variety of 'hotspots' especially at the Seaton Channel in the estuary (some 5-6 km from the colony), the Barrage in the river and various locations at sea within Hartlepool Bay and the Victoria Dock at Hartlepool. In the equivalent study to this one in Northern Ireland, Allen & Mellon Environmental Ltd. (2015) similarly showed that generic models could not always identify the precise locations of intense usage of terns, which was often at the mouths of loughs in their case. However, the proposed boundaries always succeeded in including these important areas.

This also proved to be the case at Teesmouth & Cleveland Coast as the SPA boundary generated by the application of the model generally encapsulated known hotspots of activity, bearing in mind that the survey effort at sea was relatively limited in the current and previous survey programmes, and Common Terns have previously been tracked on foraging trips much further out to sea and especially to the southeast along the coast. Notwithstanding the potential for Common Terns to range beyond the seaward boundary of the proposed SPA, the incorporation of the River Tees as far upstream as Tees Barrage within the proposed SPA could be verified by the current surveys.

6.2.3 Northumberland

No specific test of the performance of the species-specific models applied by the JNCC was undertaken as the surveys were focussed on simply confirming the use of specific rivers and their estuaries by terns, for which there was no site-specific empirical evidence base. Nevertheless, there were features of the distribution of birds in surveys that would not be expected from a model dependent on distance from colony as a principal predictor variable.

For example, the numbers of both Sandwich and Common terns recorded at more distant sites, such as the River Blyth and its estuary, was as high or higher than on the rivers Coquet & Aln, which lie much closer to the colony on Coquet Island. Moreover, Common Tern regularly occurred in good numbers beyond the point of predicted modelled use in the Blyth, although this is partly a feature of the 20 km cap of foraging range used in the model (see 4.4.1.), when it is known Common Tern can range further than this (Thaxter *et al.* 2012).

However, the proposed SPA boundary derived for all species breeding on Coquet Island (Sandwich Common, Arctic and Roseate) is effectively determined from the predicted use of the furthest ranging species, Sandwich Tern. The incorporation of the lower reaches and estuaries of the Rivers Aln, Coquet, Wansbeck and Blyth within the proposed SPA on the basis of model predicted use of these locations by foraging Common and Sandwich Terns was verified by the current surveys as a result of the consistent presence of both Sandwich and Common Terns in all catchments.

6.2.4 Morecambe Bay & Duddon Estuary

The failure of the Hodbarrow Sandwich Tern colony apparently just before the survey programme started precluded any verification of the distribution of birds foraging from the colony and whether the inclusion of the Esk estuary within the proposed SPA would be justified.

Nevertheless, the single survey undertaken recorded a cluster of observations of foraging Sandwich Terns at Haverigg Point at the northwestern extremity of the estuary at its junction with the Irish Sea. This concurs with the generic JNCC model output suggesting a hotspot of activity within the Duddon Estuary itself.

6.2.5 Liverpool Bay

Common Terns were particularly abundant around the Seaforth colony, with multiple observations of incoming birds carrying fish especially on the final survey, suggesting that the bulk of foraging activity occurs within the Mersey estuary. Nevertheless, Common Terns were consistently recorded in the River Mersey itself at up to around 5 km upstream of the colony.

However, the fact that no Common Terns were recorded at the upstream limit of the surveys and, very few birds were recorded over the last 3 km of so of the surveyed stretch, suggests that it is unlikely that Common Terns on foraging trips from Seaforth generally penetrate further upstream than the length of river surveyed in this project. Therefore, on this evidence, the suggested boundary of the SPA may incorporate areas that are relatively infrequently used by Common Terns. Conversely, the proposed SPA could be described as being very likely to incorporate *all* the use of the lower part of the Mersey through Mersey Narrows of birds from the Seaforth colony as well as possible small satellite colonies in other dock areas.

6.2.6 Solent & Dorset Coast

As predicted by the generic model, the abundance of Common Terns diminished rapidly with increasing distance along the Purbeck coastline to the south and west of the colony on Brownsea Island within Poole Harbour. Observations were virtually restricted to birds seen passing in and out of Poole Harbour itself, presumably, given the lack of sightings of birds further along the Purbeck coast, to feed off the mouth of the harbour or to the north-east along the seafront of Poole and Bournemouth. The restricted range of the species along the surveyed coastline matched exactly the limit to the important areas identified by JNCCs analyses of the model's predictions. A restricted foraging range of Common Tern in the presence of sympatrically breeding Sandwich Tern has been previously recorded within the UK (at Blakeney Point in Norfolk by Perrow *et al.* 2010), although this contrasts with the pattern at Coquet Island in Northumberland (see 6.2.3 above).

In contrast, Sandwich Terns were consistently recorded in virtually all survey locations westwards from the colony along the Purbeck coastline, although numbers diminished markedly with increasing distance from the colony. Nevertheless, there was a hotspot of activity at Peveril Ledges, at the southern limit to Swanage Bay some 9 km from the colony. Despite the occurrence of foraging birds at greater distance than predicted and the confounding effect of hotspots of foraging activity at some distance from the colony, the general performance of the JNCC generic model appeared to be reasonable.

Moreover, the modelled boundary of the proposed SPA derived from the wider-ranging Sandwich Tern included any hotspot areas and appeared to encapsulate the bulk of the alongshore westwards range of Sandwich Tern foraging from the colony. On the evidence from the surveys, the entire foraging range of Common Tern from the Brownsea Island colony will also be captured by the modelled boundary. As such, the surveys are seen as a clear verification of the westernmost limit of the proposed SPA boundary.

7 References

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8 Appendices

8.1 Hamford Water

Table 8.1.1 Numbers of Little Terns recorded during timed surveys and mean snapshot count (expressed as a mean) engaged in directional flight, foraging/feeding with no clear direction and resting/socialising at each survey location on each sampling occasion at Hamford Water. Note that mean snapshot count may be converted to mean density (individuals km^{-2}) by dividing by the area (0.141 km^2) contained within a single snapshot.

Survey location	Sampling occasion	Count from timed survey				Mean snapshot count			
		Directional flight	Foraging without direction	Resting	Total	Directional flight	Foraging without direction	Resting	Total
Colony	08/06/15	18	0	7	25	1.125	0.000	0.000	1.125
	22/06/15	0	5	8	13	0.000	0.313	0.000	0.313
	13/07/15	18	0	4	22	0.581	0.000	0.000	0.581
1	08/06/15	18	0	0	18	0.250	0.125	0.000	0.375
	22/06/15	12	7	0	19	0.063	0.563	0.000	0.625
	13/07/15	8	0	0	8	0.258	0.000	0.000	0.258
2	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	13/07/15	0	0	0	0	0.000	0.000	0.000	0.000
3	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	13/07/15	0	0	0	0	0.000	0.000	0.000	0.000
4	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	13/07/15	0	0	0	0	0.000	0.000	0.000	0.000

Survey location	Sampling occasion	Count from timed survey				Mean snapshot count			
		Directional flight	Foraging without direction	Resting	Total	Directional flight	Foraging without direction	Resting	Total
5	08/06/15	5	0	0	5	0.000	0.313	0.000	0.313
	22/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	13/07/15	0	0	0	0	0.000	0.000	0.000	0.000
6	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	13/07/15	0	0	0	0	0.000	0.000	0.000	0.000
7	08/06/15	1	1	0	2	0.000	0.063	0.000	0.063
	22/06/15	7	11	0	18	0.063	3.188	0.000	3.250
	13/07/15	0	31	0	31	0.000	8.613	0.000	8.613
8	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	0	2	0	2	0.000	0.125	0.000	0.125
	13/07/15	0	33	0	33	0.000	7.226	0.000	7.226
9	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	13/07/15	0	0	0	0	0.000	0.000	0.000	0.000
10	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	13/07/15	0	0	0	0	0.000	0.000	0.000	0.000
11	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	13/07/15	0	0	0	0	0.000	0.000	0.000	0.000
12	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	13/07/15	0	0	0	0	0.000	0.000	0.000	0.000

Table 8.1.2 Numbers of Common Terns recorded during timed surveys and snapshots (expressed as a mean) engaged in directional flight, foraging/feeding with no clear direction and resting/socialising at each survey location on each sampling occasion at Hamford Water. Note that mean snapshot count may be converted to mean density (individuals km^{-2}) by dividing by the area (0.141 km^2) contained within a single snapshot.

Survey location	Sampling occasion	Count from timed survey				Mean snapshot count			
		Directional flight	Foraging without direction	Resting	Total	Directional flight	Foraging without direction	Resting	Total
Colony	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	13/07/15	0	0	0	0	0.000	0.000	0.000	0.000
1	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	5	0	0	5	0.000	0.063	0.000	0.063
	13/07/15	2	1	0	3	0.032	0.323	0.000	0.355
2	08/06/15	19	0	0	19	0.000	0.500	0.000	0.500
	22/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	13/07/15	0	0	0	0	0.000	0.000	0.000	0.000
3	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	13/07/15	0	0	0	0	0.000	0.000	0.000	0.000
4	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	13/07/15	0	0	0	0	0.000	0.000	0.000	0.000
5	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	13/07/15	0	0	0	0	0.000	0.000	0.000	0.000

Survey location	Sampling occasion	Count from timed survey				Mean snapshot count			
		Directional flight	Foraging without direction	Resting	Total	Directional flight	Foraging without direction	Resting	Total
6	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	13/07/15	0	0	0	0	0.000	0.000	0.000	0.000
7	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	13/07/15	0	0	0	0	0.000	0.000	0.000	0.000
8	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	13/07/15	0	0	0	0	0.000	0.000	0.000	0.000
9	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	13/07/15	0	0	0	0	0.000	0.000	0.000	0.000
10	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	13/07/15	0	0	0	0	0.000	0.000	0.000	0.000
11	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	13/07/15	0	0	0	0	0.000	0.000	0.000	0.000
12	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	13/07/15	0	0	0	0	0.000	0.000	0.000	0.000

Table 8.1.3 Numbers of Sandwich Terns recorded during timed surveys and snapshots (expressed as a mean) engaged in directional flight, foraging/feeding with no clear direction and resting/socialising at each survey location on each sampling occasion at Hamford Water. Note that mean snapshot count may be converted to mean density (individuals km^{-2}) by dividing by the area (0.141 km^2) contained within a single snapshot.

Survey location	Sampling occasion	Count from timed survey				Mean snapshot count			
		Directional flight	Foraging without direction	Resting	Total	Directional flight	Foraging without direction	Resting	Total
Colony	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	13/07/15	0	0	0	0	0.000	0.000	0.000	0.000
1	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	13/07/15	3	0	0	3	0.000	0.097	0.000	0.097
2	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	3	0	0	3	0.000	0.000	0.000	0.000
	13/07/15	0	1	0	1	0.000	0.032	0.000	0.032
3	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	2	0	0	2	0.000	0.000	0.000	0.000
	13/07/15	8	0	0	8	0.129	0.065	0.000	0.194
4	08/06/15	2	0	0	2	0.125	0.000	0.000	0.125
	22/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	13/07/15	2	0	0	2	0.000	0.065	0.000	0.065
5	08/06/15	3	0	0	3	0.000	0.000	0.000	0.000
	22/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	13/07/15	0	0	0	0	0.000	0.000	0.000	0.000

Survey location	Sampling occasion	Count from timed survey				Mean snapshot count			
		Directional flight	Foraging without direction	Resting	Total	Directional flight	Foraging without direction	Resting	Total
6	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	13/07/15	0	0	0	0	0.000	0.000	0.000	0.000
7	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	0	1	0	1	0.000	0.063	0.000	0.063
	13/07/15	0	5	0	5	0.000	0.290	0.000	0.290
8	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	13/07/15	0	1	0	1	0.000	0.065	0.000	0.065
9	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	13/07/15	0	0	0	0	0.000	0.000	0.000	0.000
10	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	13/07/15	0	0	0	0	0.000	0.000	0.000	0.000
11	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	13/07/15	0	0	0	0	0.000	0.000	0.000	0.000
12	08/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	13/07/15	0	0	0	0	0.000	0.000	0.000	0.000

8.2 Teesmouth & Cleveland Coast

Table 8.2.1 Numbers of Common Terns recorded during timed surveys and snapshots (expressed as a mean) engaged in directional flight, foraging/feeding with no clear direction and resting/socialising at each survey location on each sampling occasion in the Teesmouth & Cleveland Coast area. Note that mean snapshot count may be converted to mean density (individuals km^{-2}) by dividing by the area (0.141 km^2) contained within a single snapshot.

Survey location	Sampling occasion	Count from timed survey				Mean snapshot count			
		Directional flight	Foraging without direction	Resting	Total	Directional flight	Foraging without direction	Resting	Total
Tees Barrage	18/06/15	20	3	0	23	0.355	0.774	0.000	1.129
	02/07/15	7	4	3	14	0.097	0.387	0.290	0.774
	22/07/15	12	26	0	38	0.000	3.774	0.000	3.774
A19 road bridge	18/06/15	16	0	0	16	0.097	0.097	0.000	0.194
	02/07/15	11	5	1	17	0.258	0.161	0.258	0.677
	22/07/15	15	8	0	23	0.290	0.129	0.000	0.419
Newport Bridge	18/06/15	12	2	0	14	0.097	0.290	0.000	0.387
	02/07/15	13	4	0	17	0.226	0.839	0.000	1.065
	22/07/15	3	8	0	11	0.097	0.645	0.000	0.742
Pinky & Perky towers	18/06/15	6	0	0	6	0.097	0.000	0.000	0.097
	02/07/15	17	5	0	22	0.516	0.097	0.000	0.613
	22/07/15	9	10	0	19	0.097	0.806	0.000	0.903
OSB Warehouse slipways	18/06/15	14	0	0	14	0.129	0.258	0.000	0.387
Transporter Bridge	18/06/15	8	2	0	10	0.000	0.161	0.000	0.161
	02/07/15	21	5	0	26	0.419	1.032	0.000	1.452
	22/07/15	12	11	0	23	0.226	0.613	0.000	0.839

Survey location	Sampling occasion	Count from timed survey				Mean snapshot count			
		Directional flight	Foraging without direction	Resting	Total	Directional flight	Foraging without direction	Resting	Total
Middlesborough Dock	18/06/15	6	0	0	6	0.000	0.000	0.000	0.000
	02/07/15	7	1	0	8	0.000	0.097	0.000	0.097
	22/07/15	15	14	2	31	0.097	1.742	0.484	2.323
Outfall channel	18/06/15	9	0	0	9	0.065	0.000	0.000	0.065
	02/07/15	7	0	0	7	0.000	0.129	0.000	0.129
MPI jack-up vessels	18/06/15	4	0	0	4	0.000	0.000	0.000	0.000
	02/07/15	5	0	0	5	0.065	0.032	0.000	0.097
	22/07/15	17	6	0	23	0.226	0.290	0.000	0.516
Mudflat lagoon	18/06/15	10	1	0	11	0.065	0.065	0.000	0.129
Oil Refinery	18/06/15	11	1	0	12	0.065	0.129	0.000	0.194
	02/07/15	11	0	0	11	0.065	0.000	0.000	0.065
	22/07/15	18	7	0	25	0.387	0.129	0.000	0.516
Tees Dock	18/06/15	1	0	0	1	0.000	0.032	0.000	0.032
	02/07/15	3	6	0	9	0.000	0.355	0.000	0.355
	22/07/15	4	8	0	12	0.065	0.194	0.000	0.258
Dabholme Gut	18/06/15	6	10	0	16	0.065	0.484	0.000	0.548
	02/07/15	9	11	0	20	0.129	0.226	0.097	0.452
	22/07/15	11	14	0	25	0.677	3.484	0.000	4.161
Bran Sands cranes	18/06/15	17	1	0	18	0.323	0.000	0.000	0.323
	02/07/15	4	5	0	9	0.032	0.097	0.000	0.129
	22/07/15	17	10	0	27	0.323	0.290	0.000	0.613
Seaton Channel	18/06/15	31	2	0	33	0.419	0.097	0.000	0.516
	02/07/15	96	49	0	145	1.194	2.226	0.000	3.419
	22/07/15	18	128	0	146	0.097	27.000	0.000	27.097

Survey location	Sampling occasion	Count from timed survey				Mean snapshot count			
		Directional flight	Foraging without direction	Resting	Total	Directional flight	Foraging without direction	Resting	Total
Victoria Harbour	18/06/15	2	0	0	2	0.000	0.032	0.000	0.032
	02/07/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/07/15	3	26	0	29	0.000	2.258	0.032	2.290
Hartlepool Marina	18/06/15	2	4	0	6	0.032	0.032	0.000	0.065
	02/07/15	4	0	0	4	0.161	0.032	0.194	0.387
	22/07/15	10	0	0	10	0.484	0.000	0.032	0.516

Table 8.2.2 Numbers of Sandwich Terns recorded during timed surveys and snapshots (expressed as a mean) engaged in directional flight, foraging/feeding with no clear direction and resting/socialising at each survey location on each sampling occasion in the Teesmouth & Cleveland Coast area. Note that mean snapshot count may be converted to mean density (individuals km^{-2}) by dividing by the area (0.141 km^2) contained within a single snapshot.

Survey location	Sampling occasion	Count from timed survey				Mean snapshot count			
		Directional flight	Foraging without direction	Resting	Total	Directional flight	Foraging without direction	Resting	Total
Tees Barrage	18/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	02/07/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/07/15	0	0	0	0	0.000	0.000	0.000	0.000
A19 road bridge	18/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	02/07/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/07/15	0	0	0	0	0.000	0.000	0.000	0.000
Newport Bridge	18/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	02/07/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/07/15	0	0	0	0	0.000	0.000	0.000	0.000
Pinky & Perky towers	18/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	02/07/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/07/15	0	0	0	0	0.000	0.000	0.000	0.000
OSB Warehouse slipways	18/06/15	0	0	0	0	0.000	0.000	0.000	0.000
Transporter Bridge	18/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	02/07/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/07/15	0	0	0	0	0.032	0.000	0.000	0.032
Middlesborough Dock	18/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	02/07/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/07/15	0	0	0	0	0.000	0.000	0.000	0.000

Survey location	Sampling occasion	Count from timed survey				Mean snapshot count			
		Directional flight	Foraging without direction	Resting	Total	Directional flight	Foraging without direction	Resting	Total
Outfall channel	18/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	02/07/15	0	0	0	0	0.000	0.000	0.000	0.000
MPI jack-up vessels	18/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	02/07/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/07/15	0	0	0	0	0.000	0.000	0.000	0.000
Mudflat lagoon	18/06/15	0	0	0	0	0.000	0.000	0.000	0.000
Oil Refinery	18/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	02/07/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/07/15	0	0	0	0	0.065	0.065	0.000	0.129
Tees Dock	18/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	02/07/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/07/15	0	0	0	0	0.000	0.000	0.000	0.000
Dabholme Gut	18/06/15	4	0	0	4	0.129	0.000	0.000	0.129
	02/07/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/07/15	0	0	0	0	0.000	0.000	0.000	0.000
Bran Sands cranes	18/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	02/07/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/07/15	2	13	0	15	0.226	1.032	0.000	1.258
Seaton Channel	18/06/15	5	3	0	8	0.032	0.097	0.000	0.129
	02/07/15	8	1	0	9	0.161	0.000	0.000	0.161
	22/07/15	0	11	84	95	3.290	0.323	0.000	3.613
Victoria Harbour	18/06/15	10	0	0	10	0.065	0.194	0.000	0.258
	02/07/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/07/15	0	7	0	7	0.000	0.484	0.000	0.484

Survey location	Sampling occasion	Count from timed survey				Mean snapshot count			
		Directional flight	Foraging without direction	Resting	Total	Directional flight	Foraging without direction	Resting	Total
Hartlepool Marina	18/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	02/07/15	0	0	0	0	0.000	0.000	0.000	0.000
	22/07/15	0	0	0	0	0.000	0.000	0.000	0.000

8.3 Northumberland

Table 8.3.1 Numbers of Sandwich Terns recorded during timed surveys and snapshots (expressed as a mean) engaged in directional flight, foraging/feeding with no clear direction and resting/socialising at each survey location on each sampling occasion in each of the locations in the Northumberland area. Note that mean snapshot count may be converted to mean density (individuals km^{-2}) by dividing by the area (0.141 km^2) contained within a single snapshot.

River	Observation point	Sampling occasion	Count from timed survey				Mean snapshot count			
			Directional flight	Foraging without direction	Resting	Total	Directional flight	Foraging without direction	Resting	Total
Aln	1 – River divide	11/06/15	13	12	3	28	0.065	0.452	1.323	1.839
		25/06/15	1	9	84	94	0.033	0.131	0.000	0.164
		07/07/15	1	8	16	25	0.016	1.131	0.000	1.148
	2 – Bridge	11/06/15	5	11	0	16	0.000	1.290	0.000	1.290
		25/06/15	0	0	1	1	0.000	0.000	0.803	0.803
		07/07/15	0	2	0	2	0.000	0.148	0.000	0.148
Coquet	1 – Harbour	11/06/15	7	5	0	12	0.000	1.387	0.000	1.387
		25/06/15	0	7	0	7	0.246	0.443	0.000	0.689
		07/07/15	0	17	0	17	0.000	1.164	0.000	1.164
	2 – Marina	11/06/15	3	1	0	4	0.000	0.452	0.000	0.452
		25/06/15	1	0	0	1	0.000	0.016	0.000	0.016
		07/07/15	1	0	0	1	0.000	0.197	0.000	0.197
	3 – Weir	11/06/15	2	0	0	2	0.000	0.000	0.000	0.000
		25/06/15	0	0	2	2	1.148	0.000	0.000	1.148
		07/07/15	0	3	0	3	0.000	0.082	0.000	0.082
	4 – The Butts	25/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	5 – A1068 road bridge	07/07/15	0	0	0	0	0.000	0.000	0.000	0.000

River	Observation point	Sampling occasion	Count from timed survey				Mean snapshot count			
			Directional flight	Foraging without direction	Resting	Total	Directional flight	Foraging without direction	Resting	Total
Wansbeck	1 – Estuary mouth	10/06/15	2	0	2	4	0.000	0.161	0.000	0.161
		24/06/15	2	2	0	4	0.000	0.097	0.000	0.097
		08/07/15	2	9	0	11	0.000	0.754	0.000	0.754
	2 – Castle Island	10/06/15	0	0	0	0	0.000	0.000	0.000	0.000
		24/06/15	0	0	0	0	0.000	0.000	0.000	0.000
		08/07/15	0	0	0	0	0.000	0.000	0.000	0.000
	3 – Rail bridge	10/06/15	0	0	0	0	0.000	0.000	0.000	0.000
		24/06/15	0	0	0	0	0.000	0.000	0.000	0.000
		08/07/15	0	0	0	0	0.000	0.000	0.000	0.000
	4 – Weir	24/06/15	0	0	0	0	0.000	0.000	0.000	0.000
		08/07/15	0	0	0	0	0.000	0.000	0.000	0.000
Blyth	1 – West Pier	11/06/15	3	1	0	4	0.000	0.097	0.000	0.097
		25/06/15	12	19	0	31	0.180	0.820	0.000	1.000
		07/07/15	0	30	0	30	0.033	3.393	0.000	3.426
	2 – Quayside	11/06/15	0	0	0	0	0.000	0.000	0.000	0.000
		25/06/15	10	0	0	10	0.049	0.049	0.000	0.098
		07/07/15	14	7	0	21	0.016	0.377	0.000	0.393
	3 – Factory point	11/06/15	1	1	7	9	0.000	0.065	0.000	0.065
		25/06/15	6	6	10	22	0.000	0.197	16.918	17.115
		07/07/15	0	1	6	7	0.000	0.541	0.000	0.541
	4 – River join	11/06/15	0	0	0	0	0.000	0.000	0.000	0.000
		25/06/15	0	0	0	0	0.000	0.000	0.000	0.000
		07/07/15	1	1	0	2	0.000	0.213	0.000	0.213
	5 – East Sleekburn	25/06/15	0	0	0	0	0.000	0.000	0.000	0.000
		07/07/15	0	0	0	0	0.000	0.000	0.000	0.000

River	Observation point	Sampling occasion	Count from timed survey				Mean snapshot count			
			Directional flight	Foraging without direction	Resting	Total	Directional flight	Foraging without direction	Resting	Total
	6 – Industrial estate	11/06/15	0	0	0	0	0.000	0.000	0.000	0.000
		25/06/15	0	0	0	0	0.000	0.000	0.000	0.000
		07/07/15	0	0	0	0	0.000	0.000	0.000	0.000
Seahouses	Harbour	12/06/15	2	0	0	2	0.000	0.000	0.000	0.000
		26/06/15	10	0	0	10	0.131	0.033	0.000	0.164
		06/07/15	18	0	0	18	0.295	0.000	0.000	0.295

Table 8.3.2 Numbers of Common Terns recorded during timed surveys and snapshots (expressed as a mean) engaged in directional flight, foraging/feeding with no clear direction and resting/socialising at each survey location on each sampling occasion in each of the locations in the Northumberland area. Note that mean snapshot count may be converted to mean density (individuals km^{-2}) by dividing by the area (0.141 km^2) contained within a single snapshot.

River	Survey location	Sampling occasion	Count from timed survey				Mean snapshot count			
			Directional flight	Foraging without direction	Resting	Total	Directional flight	Foraging without direction	Resting	Total
Aln	1 – River divide	11/06/15	4	2	0	6	0.000	0.129	0.000	0.129
		25/06/15	5	15	9	29	0.164	0.967	0.213	1.344
		07/07/15	2	17	0	19	0.180	2.803	0.000	2.984
	2 - Bridge	11/06/15	0	1	0	1	0.000	0.000	0.000	0.000
		25/06/15	11	0	0	11	0.098	0.131	0.000	0.230
		07/07/15	11	1	0	12	0.016	1.262	0.508	1.787
Coquet	1 – Harbour	11/06/15	4	4	0	8	0.000	0.129	0.000	0.129
		25/06/15	28	8	0	36	0.246	0.672	0.000	0.918
		07/07/15	0	15	0	15	0.131	0.607	0.000	0.738
	2 – Marina	11/06/15	0	0	0	0	0.000	0.000	0.000	0.000
		25/06/15	8	6	0	14	0.262	0.672	0.000	0.934
		07/07/15	14	0	0	14	0.738	0.623	0.000	1.361
	3 – Weir	11/06/15	0	0	0	0	0.000	0.000	0.000	0.000
		25/06/15	3	8	1	12	0.279	0.377	0.000	0.656
		07/07/15	2	3	0	5	0.098	0.328	0.000	0.426
	4 – The Butts	25/06/15	3	1	1	5	0.000	0.000	0.967	0.967
	5 – A1068 road bridge	07/07/15	3	1	0	4	0.000	0.180	0.000	0.180
Wansbeck	1 – Estuary mouth	10/06/15	0	0	0	0	0.000	0.000	0.000	0.000
		24/06/15	1	0	0	1	0.000	0.065	0.000	0.065
		08/07/15	2	2	0	4	0.000	0.066	0.000	0.066

River	Survey location	Sampling occasion	Count from timed survey				Mean snapshot count			
			Directional flight	Foraging without direction	Resting	Total	Directional flight	Foraging without direction	Resting	Total
	2 – Castle Island	10/06/15	0	0	0	0	0.000	0.000	0.000	0.000
		24/06/15	0	0	0	0	0.000	0.000	0.000	0.000
		08/07/15	0	0	2	2	0.000	0.000	0.000	0.000
	3 – Rail bridge	10/06/15	0	0	0	0	0.000	0.000	0.000	0.000
		24/06/15	0	0	0	0	0.000	0.000	0.000	0.000
		08/07/15	0	0	0	0	0.000	0.000	0.000	0.000
	4 – Weir	24/06/15	0	3	0	3	0.000	0.774	0.903	1.677
		08/07/15	3	0	0	3	0.000	0.000	0.000	0.000
Blyth	1 – West Pier	11/06/15	0	0	0	0	0.000	0.000	0.000	0.000
		25/06/15	0	3	0	3	0.066	0.049	0.000	0.115
		07/07/15	0	14	0	14	0.098	0.721	0.000	0.820
	2 – Quayside	11/06/15	0	0	0	0	0.000	0.000	0.000	0.000
		25/06/15	0	0	0	0	0.000	0.000	0.000	0.000
		07/07/15	0	0	0	0	0.000	0.000	0.000	0.000
	3 – Factory point	11/06/15	5	7	4	16	0.000	1.129	0.000	1.129
		25/06/15	8	2	0	10	0.000	0.115	7.016	7.131
		07/07/15	0	0	6	6	0.000	0.459	0.049	0.508
	4 – River join	11/06/15	2	3	0	5	0.000	0.258	0.000	0.258
		25/06/15	14	0	0	14	0.082	0.180	0.000	0.262
		07/07/15	6	8	0	14	0.000	0.475	0.000	0.475
	5 – East Sleekburn	25/06/15	9	0	0	9	0.000	0.590	0.852	1.443
		07/07/15	0	1	0	1	0.000	0.049	0.000	0.049
	6 – Industrial estate	11/06/15	0	0	0	0	0.000	0.000	0.000	0.000
		25/06/15	2	2	0	4	0.049	0.443	0.590	1.082
		07/07/15	0	9	0	9	0.262	0.721	0.000	0.984

River	Survey location	Sampling occasion	Count from timed survey				Mean snapshot count			
			Directional flight	Foraging without direction	Resting	Total	Directional flight	Foraging without direction	Resting	Total
Seahouses	Harbour	12/06/15	0	0	0	0	0.000	0.000	0.000	0.000
		26/06/15	2	0	0	2	0.033	0.000	0.000	0.033
		06/07/15	0	0	0	0	0.000	0.000	0.000	0.000

8.4 Morecambe Bay & Duddon Estuary

Table 8.4.1 Numbers of Sandwich Terns recorded during timed surveys and snapshots (expressed as a mean) engaged in directional flight, foraging/feeding with no clear direction and resting/socialising at each survey location during the single visit to the Morecambe Bay & Duddon Estuary sites on 17th June. Note that mean snapshot count may be converted to mean density (individuals km^{-2}) by dividing by the area (0.141 km^2) contained within a single snapshot.

Survey location	Count from timed survey				Mean snapshot count			
	Directional flight	Foraging without direction	Resting	Total	Directional flight	Foraging without direction	Resting	Total
1 – Haverigg Point	0	30	15	45	1.548	4.935	0.903	7.387
2 – Gutterby	0	0	0	0	0.000	0.000	0.000	0.000
3 – Hyton	0	0	0	0	0.000	0.000	0.000	0.000
4 – Eskmeals	0	0	0	0	0.000	0.000	0.000	0.000
5 – Drigg Dunes	0	0	0	0	0.000	0.000	0.000	0.000
6 – Drigg Point	0	0	0	0	0.000	0.000	0.000	0.000
7 – Ravenglass Main Street	0	0	0	0	0.000	0.000	0.000	0.000
8 – Saltcoats	0	0	0	0	0.000	0.000	0.000	0.000

8.5 Liverpool Bay

Table 8.5.1 Numbers of Common Terns recorded during timed surveys and snapshots (expressed as a mean) engaged in directional flight, foraging/feeding with no clear direction and resting/socialising at each survey location on each sampling occasion at Liverpool Bay. Note that mean snapshot count may be converted to mean density (individuals km^{-2}) by dividing by the area (0.141 km^2) contained within a single snapshot.

Survey location	Sampling occasion	Count from timed survey				Mean snapshot count			
		Directional flight	Foraging without direction	Resting	Total	Directional flight	Foraging without direction	Resting	Total
1 – Seaforth	18/06/15	57	2	0	59	1.032	0.774	0.000	1.806
	01/07/15	13	2	0	15	0.574	0.033	0.000	0.607
	09/07/15	148	6	0	154	2.885	0.279	0.000	3.164
2 – Peel Docks	18/06/15	2	0	0	2	0.000	0.000	0.000	0.000
	01/07/15	5	0	0	5	0.000	0.033	0.000	0.033
	09/07/15	6	0	0	6	0.000	0.000	0.000	0.000
3 – Tower Promenade	18/06/15	1	0	0	1	0.000	0.000	0.000	0.000
	01/07/15	10	0	0	10	0.000	0.066	0.000	0.066
	09/07/15	8	1	0	9	0.000	0.148	0.000	0.148
4 – Huskinson Dock	18/06/15	0	0	2	2	0.000	0.000	0.000	0.000
	01/07/15	0	9	0	9	0.000	0.000	0.000	0.000
	09/07/15	5	9	0	14	0.016	0.000	0.000	0.016
5 – Princes Jetty	18/06/15	1	8	0	9	0.000	0.000	0.000	0.000
	01/07/15	0	5	0	5	0.000	0.000	0.000	0.000
	09/07/15	0	7	0	7	0.000	0.000	0.000	0.000
6 – Albert Dock	18/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	01/07/15	0	0	0	0	0.000	0.000	0.000	0.000
	09/07/15	0	0	0	0	0.000	0.000	0.000	0.000

Survey location	Sampling occasion	Count from timed survey				Mean snapshot count			
		Directional flight	Foraging without direction	Resting	Total	Directional flight	Foraging without direction	Resting	Total
7 – South Ferry Quay	18/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	01/07/15	0	0	0	0	0.000	0.000	0.000	0.000
	09/07/15	2	0	0	2	0.000	0.049	0.000	0.049
8 – Rock Ferry	18/06/15	0	0	0	0	0.000	0.000	0.000	0.000
	01/07/15	0	0	0	0	0.000	0.000	0.000	0.000
	09/07/15	0	0	0	0	0.000	0.000	0.000	0.000

8.6 Solent & Dorset Coast

Table 8.6.1 Numbers of Sandwich Terns recorded during timed surveys and snapshots (expressed as a mean) engaged in directional flight and actively searching for prey on each sampling occasion to the west of Poole Harbour along the Purbeck coastline.

Survey location	Sampling occasion	Count from timed survey			Mean snapshot count	
		Directional flight	Active search	Total	All birds	Foraging only
1 – South Haven Point	08/06/15	67	27	94	1.83	1.67
	15/06/15	73	19	92	2.85	2.38
	22/06/15	77	22	99	1.07	0.56
2 – Studland Middle Beach	09/06/15	8	3	11	0.00	0.00
	17/06/15	0	6	6	0.42	0.42
	22/06/15	0	0	0	0.00	0.00
3 – Old Harry	08/06/15	7	4	11	1.00	0.42
	15/06/15	20	1	21	1.62	1.08
	22/06/15	15	3	18	0.46	0.15
4 – Swanage Beach	09/06/15	23	15	38	1.77	1.23
	16/06/15	3	2	5	0.92	0.69
	23/06/15	12	1	13	2.54	1.85
5 – Peveril Ledges	09/06/15	9	24	33	12.38	12.38
	16/06/15	8	7	15	5.00	4.92
	23/06/15	18	3	21	4.6	2.80
6 – Durlston Head	08/06/15	0	1	1	0.08	0.08
	16/06/15	8	0	8	0.00	0.00
	22/06/15	10	0	10	0.08	0.00
7 – Dancing Ledge	13/06/15	0	0	0	0.00	0.00
	15/06/15	4	0	4	0.00	0.00
	25/06/15	0	0	0	0.00	0.00

Survey location	Sampling occasion	Count from timed survey			Mean snapshot count	
		Directional flight	Active search	Total	All birds	Foraging only
8 – Seacombe	08/06/15	4	1	5	0.00	0.00
	15/06/15	1	0	1	0.00	0.00
	10/07/15	0	0	0	0.00	0.00
9 – St Aldhelm's Head	09/06/15	5	2	7	0.00	0.00
	16/06/15	3	0	3	0.00	0.00
	23/06/15	7	0	7	0.00	0.00
10 – Chapman's Pool	10/06/15	0	0	0	0.00	0.00
	17/06/15	0	0	0	0.00	0.00
	24/06/15	0	0	0	0.00	0.00
11 – Kimmeridge	08/06/15	5	3	8	0.08	0.08
	15/06/15	2	0	2	0.08	0.00
	06/07/15	2	0	2	0.00	0.00
12 – Worbarrow Tout	13/06/15	0	0	0	0.00	0.00
	21/06/15	0	3	3	0.27	0.27
	28/06/15	2	0	2	0.00	0.00
13 – Lulworth Cove	13/06/15	3	0	3	0.08	0.00
	21/06/15	0	3	3	0.23	0.23
	28/06/15	0	0	0	0.00	0.00
14 – Osmington Mills	21/06/15	1	4	5	0.54	0.54

Table 8.6.2 Numbers of Common Terns recorded during timed surveys and snapshots (expressed as a mean) engaged in directional flight and actively searching for prey, on each sampling occasion to the west of Poole Harbour along the Purbeck coastline.

Survey location	Sampling occasion	Count from timed survey			Mean snapshot count	
		Directional flight	Active search	Total	All birds	Foraging only
1 – South Haven Point	08/06/15	101	2	103	0.5	0.00
	15/06/15	40	10	50	0.08	0.00
	22/06/15	43	5	48	0.13	0.06
2 – Studland Middle Beach	09/06/15	0	0	0	0.00	0.00
	17/06/15	0	0	0	0.00	0.00
	22/06/15	0	0	0	0.00	0.00
3 – Old Harry	08/06/15	0	0	0	0.00	0.00
	15/06/15	0	2	2	0.15	0.15
	22/06/15	0	0	0	0.00	0.00
4 – Swanage Beach	09/06/15	0	0	0	0.00	0.00
	16/06/15	0	0	0	0.00	0.00
	23/06/15	0	0	0	0.00	0.00
5 – Peveril Ledges	09/06/15	0	0	0	0.00	0.00
	16/06/15	0	0	0	0.00	0.00
	23/06/15	0	1	1	0.2	0.2
6 – Durlston Head	08/06/15	0	0	0	0.00	0.00
	16/06/15	0	0	0	0.00	0.00
	22/06/15	0	0	0	0.00	0.00
7 – Dancing Ledge	13/06/15	0	0	0	0.00	0.00
	15/06/15	0	0	0	0.00	0.00
	25/06/15	0	0	0	0.00	0.00

Survey location	Sampling occasion	Count from timed survey			Mean snapshot count	
		Directional flight	Active search	Total	All birds	Foraging only
8 – Seacombe	08/06/15	0	0	0	0.00	0.00
	15/06/15	0	0	0	0.00	0.00
	10/07/15	0	0	0	0.00	0.00
9 – St Aldhelm's Head	09/06/15	0	0	0	0.00	0.00
	16/06/15	0	0	0	0.00	0.00
	23/06/15	0	0	0	0.00	0.00
10 – Chapman's Pool	10/06/15	0	0	0	0.00	0.00
	17/06/15	0	0	0	0.00	0.00
	24/06/15	0	0	0	0.00	0.00
11 – Kimmeridge	08/06/15	0	0	0	0.00	0.00
	15/06/15	0	0	0	0.00	0.00
	06/07/15	0	0	0	0.00	0.00
12 – Worbarrow Tout	13/06/15	0	0	0	0.00	0.00
	21/06/15	0	0	0	0.00	0.00
	28/06/15	0	0	0	0.00	0.00
13 – Lulworth Cove	13/06/15	0	0	0	0.00	0.00
	21/06/15	0	0	0	0.00	0.00
	28/06/15	0	0	0	0.00	0.00
14 – Osmington Mills	21/06/15	0	0	0	0.00	0.00