Colony habitat selection by Little Terns *Sternula albifrons* in East Anglia: implications for coastal management

Ratcliffe, N.[1]*, Schmitt, S.[2], Mayo, A.[2], Tratalos, J.[3] and Drewitt, A.[4]

**Correspondence author. Email: notc@bas.ac.uk*
[1] *RSPB, East Scotland Regional Office, 10 Albyn Terrace, Aberdeen AB10 1YP, UK (Current address: British Antarctic Survey, NERC, High Cross, Cambridge CB3 0ET, UK);* [2] *RSPB, The Lodge, Sandy, Bedfordshire SG19 2DL, UK;* [3] *University of East Anglia, Norwich NR4 7TJ, UK;* [4] *English Nature, Northminster House, Peterborough PE1 1UA, UK.*

Abstract

Little Terns *Sternula albifrons* are unusual among UK seabirds in that a large proportion of the population breed on mainland beaches in East Anglia. Relative sea-level rise means that such habitats are under threat in this region, and so we quantified colony habitat selection of beach nesting Little Terns in order to inform habitat restoration and creation initiatives. Random 1 km sections of beach were selected and the presence or absence of a Little Tern colony within each was related to physical (substrate type, height and width), biotic (vegetation cover, predator activity) and anthropogenic (disturbance) characteristics using logistic regression models. Little Terns positively selected for beaches with vegetation cover and negatively for those with high disturbance levels. They showed no selection according to width and height or Red Fox *Vulpes vulpes* presence, even though these are likely to affect flood and predation risk respectively. Red Foxes were found to be widespread on beaches irrespective of tern colony presence, and so movement of tern colonies will not always result in predator avoidance. Little Tern habitat creation needs to be integrated into coastal management plans in order to safeguard their population from the combined threats of relative sea-level rise, predation and disturbance.

Introduction

The population size and range of Little Terns *Sternula albifrons* in the UK have declined by 24% since the mid 1980s (Pickerell 2004), and qualifies it for inclusion on the Amber list based on a moderate rate of population decline (Gregory *et al*. 2002). It is also listed on Annex I of the Birds Directive (EC Directive on the conservation of wild birds 79/409/EEC) and 67% of the GB population lies within Special Protection Areas (Stroud *et al*. 2001). Little Tern distribution through the UK has been broadly stable since the 1960s, being wide and patchy with a stronghold in East Anglia where 69% of the population currently breed (Pickerell 2004). There is an absence of sandy offshore barrier islands in the UK, and so Little Terns nest mainly on low-lying shingle beaches, spits and estuarine islets, and here they face threats from disturbance by coastal tourism, predation and inundation by high tides or storms (Ratcliffe 2004). These threats are mitigated to varying extents by intensive colony protection schemes (Smart 2004) that currently cost conservation organisations tens of thousands of pounds per annum, and need to be run in perpetuity in order to maintain Little Tern populations. Furthermore, the colony habitat of Little Terns is under threat from relative sea level rise and increased storminess (Norris & Buisson 1994; Gill 2004), such that protection of existing colonies from disturbance and predation may be inadequate to conserve them in the future.

Rather than continuing to focus on colony site protection, a strategic approach to the management of Little Tern distribution relative to threats may result in more effective conservation. Little Terns require small areas of habitat that can be restored or created quickly and inexpensively, and these can be sited in areas where threats to breeding success are lower. For example, creation of dredge spoil islands offshore could reduce predation and disturbance without need for fencing and wardening (Parnell *et al*. 1986; Burgess & Hirons 1992; Erwin *et al*. 2001), and sediment recharge of eroded narrow beaches could mitigate loss of habitat or colony flooding risks (Charlton & Allcorn 2004). The characteristics of Little Tern colony sites need to be quantified and means of creation or restoration have to be tested in order to achieve this (Gill 2004).

Shoreline management plans are currently under review for East Anglia and decisions are being made that will affect coastal habitats in future decades. These decisions are mainly influenced by engineering and economic considerations at present, but it is important that conservation requirements are also included (Gill 2004). A strategic review of Little Tern habitat requirements would be timely in order to influence coastal planning decisions in a manner that is sympathetic towards Little Terns and to exploit opportunities that may arise as a by-product of managed realignment or coastal defence (Gill 2004).

This project examines colony habitat selection by Little Terns in relation to beach characteristics, including width, height, shoreward habitat type, substrate type, disturbance and predation risk. The implications of the results for habitat management and creation are discussed and recommendations for further research are made.

Study sites and methods

The entire length of beaches in Norfolk and Suffolk (east England) were divided into 1 km lengths using GIS, and these were used as the sampling unit for further data collection and analyses.

Beach habitat characteristics: Beach characteristics were studied in 68 randomly selected 1 km sample sections of beach in Norfolk and Suffolk, representing 33% of the entire beach length within these counties. Beach width from the landward limit of the beach to mean high water mark was extracted every 200 m from Ordnance Survey maps using GIS. Data on maximum beach height was extracted from Environment Agency beach profile databases. Substrate was quantified within 30 2.5 x 2.5 m quadrats placed randomly along the beach. The percentage cover of sand, shingle, rock, debris and vegetation was recorded in each. The values were averaged within each of the 1 km sample units. Fieldwork was conducted in April 2003 prior to the return of Little Terns to their colonies to avoid disturbance. The presence or absence of breeding Little Terns in each sample was determined by walking and scanning each section of coast three times during May and June 2003 when they would be incubating eggs.

Disturbance: Observations of disturbance within a subsample of 45 of the previous 68 beach sections were conducted, during May and June 2003, by walking each 1 km section of beach and counting the number of people and dogs. Each section was visited three times, with samples being taken at both weekdays and weekends to account for variation in disturbance owing to day of the week. Samples were only taken on fine days that were conducive to beach recreation to reduce variation owing to weather. These counts were averaged to provide an estimate of disturbance pressure within the sampled 1 km section.

Dummy nests were used to assess relative trampling risk in 40 sections of beach during late May and early June. Twenty Common Quail *Coturnix coturnix* eggs were each placed in separate artificial scrapes along the length of the beach section above the high tide line and were marked with a numbered peg. These were visited every 3–5 days over a period of 23 days to determine whether they were stepped upon by humans. Daily trampling rates for each section were obtained using the Mayfield method (Mayfield 1975).

Predation: Predation risk to Little Terns was determined during May and June 2003 by using sand traps and dummy nests. Sand traps were deployed at 30 sections of beach sampled from the previous 45, with five traps being set within each. These comprised 2.5 m^2 of smoothed-over sand with the perimeter marked with lines of pebbles to enable it to be relocated. A spoonful of cat food was placed in the centre of this. The traps were set in the evening and visited early in the morning and any footprints present were identified by reference to Bang & Dahlstrom (2001). Five traps were set on each of three nights in each sample section, with Red Foxes *Vulpes vulpes* being classed as present if footprints were found in a trap on one or more occasions.

Daily nest predation rates were assessed using the dummy egg experiment described above, except that the numbers of nests predated were analysed as opposed to numbers trampled.

Analysis: The presence or absence of Little Terns in a sample stretch of beach was related to the explanatory variables using logistic regression. We used presence or absence rather than number of breeding pairs as an index of suitability because we were interested in correlates of colony site selection rather than colony size. Moreover, abundance of Little Terns is more annually variable than site occupancy, and abundance in colonial birds is prone to non-independence (i.e. pairs selecting a site because of the presence of conspecifics, rather than owing to habitat characteristics).

A forward stepwise procedure was used to select the minimal adequate model, using a χ^2 alpha of 0.05 as the threshold for inclusion of an explanatory variable in the model. Chi-square statistics for each explanatory variable in the results are taken from the minimal adequate model. It was not possible to build a global model of all variables of interest since owing to the uneven sampling effort among parameters caused by manpower limitations (see sections above), and so separate models were fitted for each. Observed frequencies and model fits were plotted graphically according to Smart *et al*. (2004).

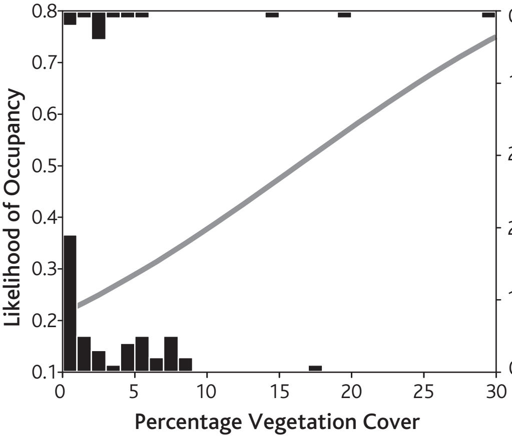
Results

Beach characteristics: Nineteen of the 68 samples were occupied by Little Tern colonies. The likelihood of a beach being used by breeding Little Terns increased significantly with percentage vegetation cover ($\chi^2_1 = 3.77$, $P = 0.05$). Occupancy likelihood was 23% in the absence of vegetation, but rose to 70% when coverage was 20% (Figure 1). Fitting the square of vegetation cover to the model did not significantly reduce the residual deviance, suggesting that there was no decline as vegetation became more dense within the range of cover observed. Fitting linear and quadratic models that included the variables beach height, beach width, the percentage cover of sand, gravel, rock or debris did not significantly reduce the residual deviance (all $P > 0.05$).

Disturbance: Occupancy likelihood declined significantly with the average number of people observed per km of beach ($\chi^2_1 = 4.5$, $P < 0.05$), but not with the number of dogs ($\chi^2_1 = 1.30$, $P > 0.2$). Occupancy likelihood was 47% in the absence of people but fell to zero when the average number of people exceeded 25 (Figure 2).

Daily nest trampling rates of dummy clutches were 1.33%, equating to a 26% survival rate over a 23-day incubation period, in the absence of other forms of loss. The likelihood of a site being occupied by Little Terns was not significantly affected by nest trampling rates of dummy clutches within sample sites ($\chi^2_1 = 2.6$, $P > 0.1$).

Predation risk: Sand traps revealed that foxes were present on 62% of beaches, but the likelihood of a beach being occupied by breeding Little Terns was not significantly affected by the presence of foxes ($\chi^2_1 = 0.03$, $P > 0.8$). Daily nest predation rates on dummy clutches were 1.08%, equating to a survival over a 23-day incubation period of 22%. Site occupancy was not explained by predation rates experienced by dummy clutches within the sampled stretches of beach ($\chi^2_1 = 0.00$, $P > 0.9$).



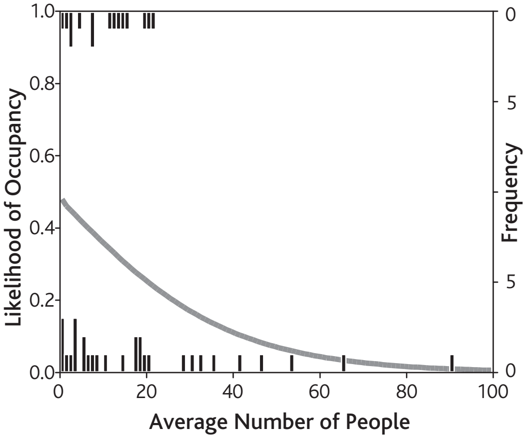


Figure 1 (left). The effect of percentage vegetation cover on the likelihood of a site being occupied by breeding Little Terns *Sternula albifrons*. The line represents the best fit line from the logistic regression model plotted on the left y axis , while the histograms show observed frequencies of presence (on the top x axis, which is inverted) and absence (on the bottom x axis) plotted against the right hand y axis (see Smart *et al*. 2004). **Figure 2 (right).** The effect of human disturbance pressure on the likelihood of a site being occupied by breeding Little Terns *Sternula albifrons*. See the legend of Figure 1 for details.

Discussion

While numbers of breeding pairs and breeding success within Little Tern colonies in East Anglia varies markedly among years, the locations of occupied sites has remained remarkably consistent since regular monitoring began in the 1960s (Pickerell 2004; Ratcliffe 2004). This suggests colony sites are selected consistently according to temporally stable habitat characteristics rather than selected at random or in response to previous breeding success. This is the first study to attempt to identify the physical factors driving colony site selection by Little Terns at a regional scale within the UK.

Of the physical beach habitat characteristics measured, only vegetation cover had a significant positive effect on colony site selection. Similarly, Goutner (1990) found Little Terns nested near low vegetation in Greece, and the closely related and ecologically similar Least Terns *S. antillarum* also selected sites with sparse vegetation cover (Kotliar & Burger 1986). However, thick vegetation cover greater than the 30% maximum found in this study might result in avoidance: Burger & Gochfeld (1990) found that Least Tern nests were closer to vegetation than random points where cover was sparse and further away where cover was dense.

Studies of Least Tern colony site selection in the USA (Thomas & Slack 1982; Gochfeld 1983; Kotliar & Burger 1986; Burger & Gochfeld 1990) have shown a preference for mixed sand and gravel or shell substrates (which aids camouflage of nests) and high, wide beaches (which reduce the risk of tidal inundation). However, in this study, substrate and beach height/width variables had no effect on colony site selection by Little Terns. This may have been because these factors are not selected for by Little Terns in East Anglia or that power to detect such effects was insufficient owing to sample size or co-linearity of explanatory variables. Alternatively, selection for beach characters may have been obscured by another factor that was not measured, with the most likely of these being food availability.

Little Terns have very short foraging ranges compared to most seabirds, with most food generally being obtained from within 5 km of the colony and 1 km of the shore (Davies 1981; Fasola & Bogliani 1990; Allcorn *et al*. 2003; Bertolero *et al*. 2005; Perrow *et al*. 2006). Consequently, Little Terns have to nest close to areas of high prey availability so that they can provision their chicks with sufficient food to maintain their growth and survival (Holloway 1993; Bertolero *et al*. 2005). Little Terns in the UK generally feed on small (30–40 mm) clupeids and sandeel (Davies 1981; Cramp 1985; Perrow *et al*. 2004), and on the east Norfolk coast selected sites where the availability of such prey was greatest (Perrow *et al*. 2004). As such, significant colony site selection according to beach characteristics might only be evident when controlling for offshore food availability. Collecting data on prey availability at the broad scales required to understand regional colony site selection is prohibitively expensive, but there may be potential to infer this from marine habitat variables such as turbidity (Perrow *et al*. 2004).

Little Terns showed a significant aversion to human disturbance, as noted elsewhere in Europe (Scarton *et al*. 1994; Catry *et al*. 2003), and for Least Terns in the USA (Thomas & Slack 1982; Gochfeld 1983; Kotliar & Burger 1986). Disturbance by humans and dogs has the potential to cause trampling or predation of eggs or chicks, or to disrupt courtship, incubation or brooding by parent birds, causing reduced breeding success and site abandonment (Thomas & Slack 1982; Gochfeld 1983; Kotliar & Burger 1986). Indeed, our dummy nest experiment showed that trampling on East Anglian beaches would destroy 74% of clutches over a 23-day incubation period in the absence of other sources of loss. Humans are active on beaches during both the day and the colony-prospecting period of Little Terns, and so birds are able to perceive this pressure and select sites accordingly. Continuing to maintain protective cordons around Little Tern colonies is therefore essential to prevent their extirpation, but there may also be potential to reduce disturbance in other areas that are deemed suitable to encourage colonisation. However, excluding tourists from popular areas of beach will be difficult and politically contentious, especially in the context of UK Government's objective to increase public access to the coast (Defra 2004).

Predation is among the most important causes of breeding failure at Little Tern colonies, with Red Foxes being the predator most frequently recorded to cause significant losses of both eggs and chicks (Ratcliffe 2004). Little Terns did not select colony sites according to the occurrence of Red Foxes or the rates of predation failure of dummy clutches, and so their ability to perceive, or scope to avoid, predation risks appeared to be poor. This is probably because the presence of nocturnal predators only becomes apparent to terns during the incubation or chick rearing stage when they have committed to breeding at a site.

Red Foxes were present on a large proportion of the beaches despite the fact that trapping effort was relatively low. Red Foxes have increased their range in East Anglia owing to reduced gamekeeping effort (Tapper 1992) and this has probably resulted in the reduced availability of predator-free colony sites for ground-nesting birds. Similarly, declines of beach-nesting terns in Virginia were associated with an increased occupancy of barrier islands by Red Foxes and Racoons *Procyon lotor* and a consequent reduction in available predator-free nesting sites (Erwin *et al*. 2001). Red Fox presence was not related to Little Tern presence or absence, suggesting that they are not venturing onto beaches solely to exploit tern prey. It is therefore likely that Red Foxes forage on most East Anglian beaches to feed on tide-line carrion and scraps dropped by tourists, and will opportunistically prey on tern colonies if they encounter them. This discredits the widely held belief that high predation rates are an indirect consequence of disturbance, which reduces habitat availability and hence the ability of birds to move to avoid predators. This assumes that Red Foxes only forage on beaches following a chance encounter with a tern colony, whereas the data presented in this study suggest they already occur along most stretches of beach and will opportunistically predate nests or chicks in any new colonies forming there.

The combined effects of disturbance avoidance and predation losses mean that intensive protection of mainland beach sites will be required in perpetuity if Little Tern populations are to be maintained on existing habitat. However, an alternative in the longer term is to create islets using dredge spoil which would enable Little Terns to nest in sites that are free from predators and people (Burgess & Hirons 1992; Krogh &

Schweitzer 1999). This method has been successfully employed the USA and now a large proportion of some regional tern populations nest on artificial islands (Parnell *et al*. 1986; Visser & Peterson 1994). In southern England, Little Terns typically breed on natural islets in saline lagoons or estuaries rather than beaches (Pickerell 2004), but such habitats are unavailable throughout much of East Anglia. Further research into colony habitat selection for islets is required to ensure new sites are designed appropriately. In particular, size is likely to be an important consideration, since larger islands are attractive to other species of tern and gulls, which can result in competitive exclusion of Little Terns (Fasola & Canova 1992; Scarton *et al*. 1994).

Correct location of the islets will be essential to ensure that they are colonised and to maximise breeding success. Positioning them within foraging range of concentrations of available prey will be essential, and studies of turbidity combined with surveys of prey availability using a fine-mesh, epipelagic trawl net (Perrow *et al*. 2004) would be required to achieve this. However, other factors have to be taken into account for practical and legal reasons. For example, construction of islets in some locations might be unfeasible as they might cause a hazard to navigation, suffer excessive erosion or contravene legislation protecting designated nature conservation sites (Harrison & Allcorn 2004). Conversely, offshore coastal defence structures or remnants of breached sea walls may present opportunities for site creation (Charlton & Allcorn 2004). Once islands of a suitable design are created in appropriate locations, Little Terns can be attracted to them using decoys and recordings of courtship calls (Kotliar & Burger 1984; Burger 1988; Jeffries & Brunton 2001; Colombé & Allcorn 2004), which will increase the likelihood of them being colonised.

Further work is required to develop an improved understanding of Little Tern habitat requirements and to assess how a network of colony sites can be delivered within the constraints and opportunities presented by wider coastal planning initiatives. While this work is in progress, it is essential that protection at existing sites is established and maintained in order to prevent their extirpation and further population declines.

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