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EDF Development Company Ltd

Sizewell

Little Tern Report

28 January 2011

Entec UK Limited

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Little Tern Report

28 January 2011

Entec UK Ltd

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Contents

1. Introduction

1.1 Purpose and Scope of this Report

Entec UK Ltd was commissioned by EDF Development Company Ltd (EDF) to complete a desk study and ornithological surveys in order to identify any potential impacts on little tern populations due to the development of a new nuclear facility at Sizewell, Suffolk. The information gathered will be used within both the Environmental Impact Assessment and Habitats Regulations Assessment processes as little tern are a qualifying feature of the Minsmere & Walberswick Special Protection Area (SPA).

Following the issue of a scoping report for the development by Royal Haskoning in March 2010 a response by the RSPB identified potential impacts on little tern. The potential impacts highlighted by the RSPB were;

- The potential for construction and operation of the new nuclear build and offshore facilities to disturb or displace foraging little terns (or their movements to and from breeding and foraging areas); and
- The effects of temperature increase caused by warm water emitted from the proposed outtake facility on the availability of little tern prey.

At the time of writing this report, the final location of the warm water outfall was not known, and therefore no modelling results showing the extent of the thermal plume were available. At the time of designing and undertaking the little tern survey programme (April-August 2010), results obtained from the initial options stages indicated that the discharge would drift to the south of Sizewell towards the shallow waters off Thorpeness. Subsequent to this, further modelling work (made available after the completion of the 2010 survey season) indicates that the cooling water discharge has the potential to extend as far south as Orford Ness.

1.2 Background

The Minsmere and Walberswick SPA qualifies under Article 4.1 of the Birds Directive by supporting a little tern population of European importance during the breeding season. The SPA qualifying population of 28 pairs (5 year mean, 1992-1996), represents at least 1.2% of the breeding population in Great Britain. Within the SPA there are currently two little tern colonies, located on Minsmere beach and on the beach between Dunwich and Walberswick. There are also further colonies located along the Suffolk coast to the north and south of the SPA.

Little tern is described as a common summer visitor and passage migrant in Suffolk (Piotrowski, 2003). Birds breed on sand and shingle beaches in a number of colonies located along the Suffolk coast, including at Minsmere beach and between Dunwich and Walberswick (referred to in this report as the Minsmere and Dingle colonies respectively). Both of these colonies are located on the upper reaches of shingle ridges, backed by reedbeds and lagoons that comprise the Minsmere and Dingle RSPB reserves respectively. However, these sites are not used every year and there is a considerable interchange of birds between colonies. Mason [ed] 2010 lists seven little tern colonies in Suffolk in 2009 as follows (with the approximate distance and direction from the Sizewell new build area in parenthesis):

- Minsmere (3km north): 1 pair present in 2009, but failed to breed;
- Dingle Marshes (9km north): 11 pairs present in 2009, outcome not reported;
- Dunwich beach (6km north, and also within the Minsmere and Walberswick SPA): 20 pairs present in 2009, raised 3 young;
- Kessingland (22km north): none present in 2009;
- Benacre (20km north): none present in 2009;
- Slaughden (8km south): none present in 2009;
- Languard (35km south): none present in 2009.

Breeding was attempted at three of these sites in 2009 (all within the SPA), and young were reported at one (Dunwich beach). In 2008, breeding was reported from three sites (Dingle, Minsmere and Kessingland) and was successful only at Minsmere (Mason [ed] 2009). Breeding has also been reported from other locations along the Suffolk coast between 2005 and 2008, including: Bawdsey (25km south of Sizewell), Havergate Island (16km south), Covehithe (19km north) and Trimley (33km south). The numbers breeding at each colony between these years varies considerably as colonies are established based on both habitat suitability and prey availability; individuals also oftenl move to another colony after a breeding failure to attempt nesting again within the same year.

Results from radio-tracking work on little terns in Norfolk by Perrow *et al.* (2005) found that the average home range of nesting birds was $4km^2$ (i.e. birds that were feeding chicks were primarily foraging within 2km of the colony). However, in 2004 the radio-tagged colony failed to breed primarily due to a shortage of food, after which the terns were recorded foraged up to 25km from the colony (Perrow *et al.*, 2005). Langston (2009) gives a foraging distance of 5km from the breeding colony for little tern and states that terns generally make numerous relatively short flights to catch fish for chicks. These data indicate that Sizewell is within the regular foraging range for little terns derived from the Minsmere colony (3km to the north) but is likely to be visited on a more occasional basis by birds from the Dingle and Dunwich colonies (respectively, 9km and 6km to the north of the SSA).

Figure 1.1 shows the approximate location of little tern colonies reported along the Suffolk coast between 2005 and 2009, and the likely main foraging area for birds derived from each colony (i.e. within 5km of the colony).

Key:

- Main foraging area
- SSA boundary
- # Location of little tern colony

0 km 10 km
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Sizewell Little Tern Report

Figure 1.1
Little Tern Colonies in Suffolk, 2005-2009

December 2010
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2. Methodology

In order to identify whether there are likely to be any impacts on little tern due to disturbance during construction of the new nuclear build and associated facilities, and/or from the cooling waters discharged from the outfall, a desk study exercise and programme of surveys was carried out, the details of which are provided below.

2.1 Desk Study

In order to provide some indication on how little terns might be affected by the cooling water discharge, it is firstly important to identify where the birds are foraging, or where they are likely to forage. It is also important to have an understanding of what the birds are likely to be feeding on in the Sizewell area, and how that prey might be affected by an increase in water temperature. To achieve this, a desk study exercise was undertaken that included:

- Use of bathymetry maps to identify obvious shallow areas within 10km of the Minsmere and Dingle breeding sites where little terns might forage. Consultation with local experts (Adam Rowlands at RSPB Minsmere and Alan Miller who co-ordinates the tern colony protection work at Dingle) was also carried out to identify potential places where little terns might be foraging;
- A literature search to identify the likely foraging distances and the main food sources of little tern and other behavioural and biological traits of the species and its prey; and
- A study to identify how an increase in water temperature might affect the abundance and distribution of the main prey species that little terns depend upon.

2.2 Surveys

In order to provide further information on where little terns from breeding colonies within the Minsmere & Walberswick SPA are feeding, a programme of surveys was undertaken in 2010. These surveys focussed on two broad areas:

- Colony surveys: to identify the direction of flight of little terns when leaving or returning to the two SPA colonies (Minsmere and Dingle) used on a regular basis (Dunwich beach was used in only one year between 2005-2009), and whether there was much feeding activity close inshore adjacent to the colonies; and
- Foraging surveys: to identify whether terns were foraging in the close inshore waters between the site for new nuclear build at Sizewell south to the shallow waters off Thorpeness.

At the time of designing and undertaking the little tern surveys, the initial options stages indicated that the discharge would drift to the south of Sizewell towards the shallow waters off Thorpeness. Thus the little tern foraging surveys were concentrated in the area between

Sizewell and Thorpeness. Details of the methods employed for the colony and foraging surveys are provided below:

2.2.1 Colony Surveys

Surveys for little terns were undertaken at two colonies, located on Minsmere beach (O.S Grid Reference TM 477 666) and Dingle marshes (O.S. Grid Reference TM 489 733). **Figure 2.1** shows the location of the two colonies. Agreement was reached with Alan Miller (SWT) and Adam Rowlands (RSPB) that 100 metres would be a suitable distance to watch the terns from to avoid disturbing them. The surveys involved watching little tern movements in and out of the colonies; recording the direction of incoming and outgoing flights. Birds leaving the colony were followed until out of sight, with the aid of a telescope. Details of the broad category of prey being returned to the colonies were noted (e.g. fish or invertebrates) and any foraging activity in inshore waters adjacent to the colonies was also recorded. Two hour watches were conducted at each colony site, approximately twice each week between early May and early August. It became apparent by the end of June that the Minsmere site was not going to be used by little tern for breeding, after which survey effort was concentrated at Dingle, with occasional visits made to Minsmere. The dates, time and weather conditions during the surveys are shown in **Table A1, Appendix A**.

The start and finish times of both surveys were varied over the course of the survey period to ensure that all aspects of the diurnal activity patterns of the species were covered (for example: foraging activity may be concentrated in the morning). The timing of the surveys was also varied to ensure that watches were undertaken through the full range of the tidal cycle.

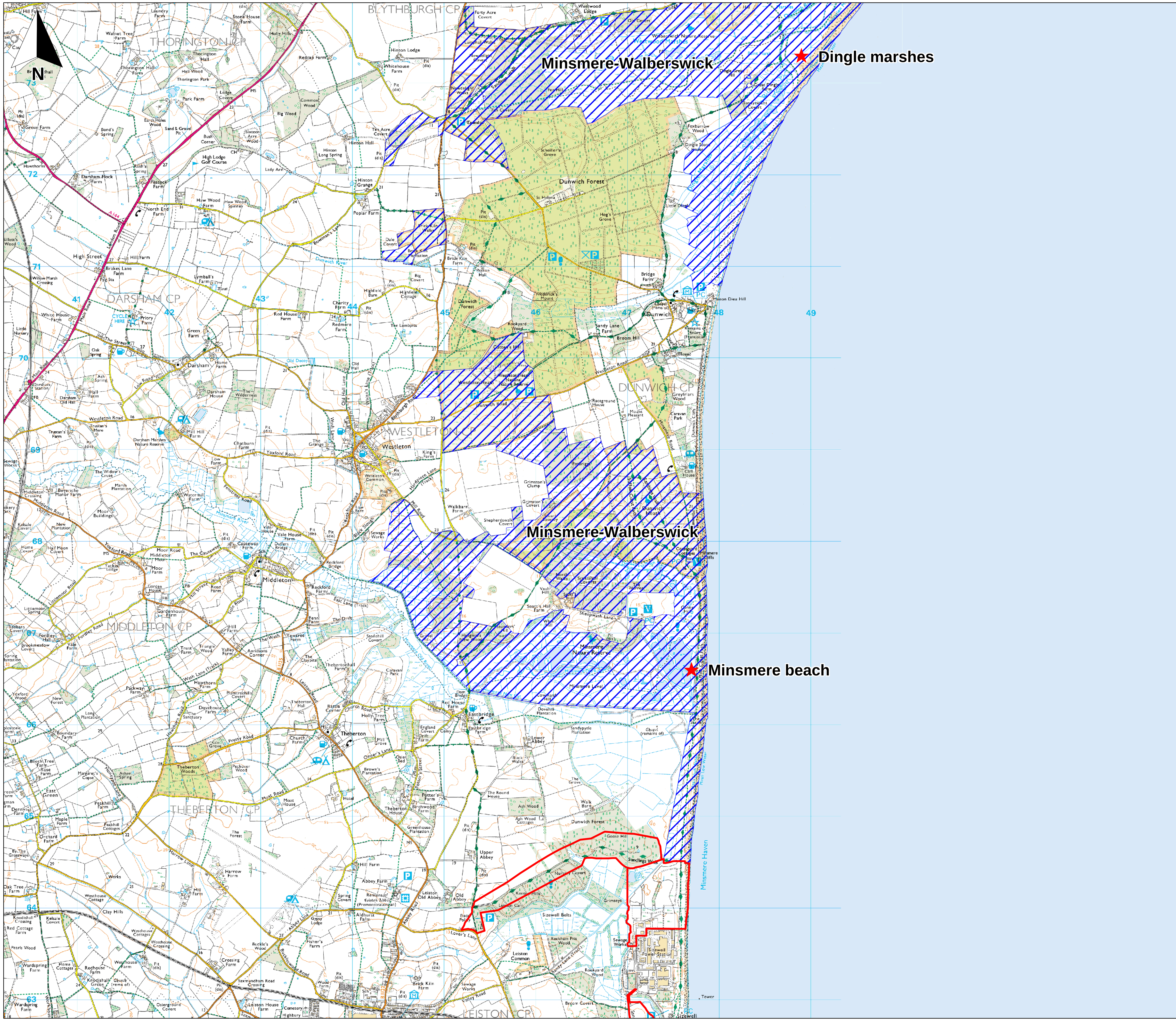
2.2.2 Foraging Surveys

Surveys of foraging little terns were carried out within a study area extending along the Sizewell coast from approximately 500m north of the proposed new build area, south to Thorpeness, where an area of shallow water extends offshore providing a potentially suitable foraging area. The study area also extended approximately 600m offshore (the likely maximum distance at which little terns could reliably be detected from the raised beach between Sizewell and Thorpeness).

A complete survey of the study area was undertaken (usually on one day) every fortnight between early May and late July. During each visit, a series of 45 minute watches was undertaken from six different locations (observation points) along the Sizewell to Thorpeness beach; each observation point being spaced approximately 1km apart. A suitable (minimum 15 minute) break was taken between each 45 minute watch to allow the surveyor to rest their eyes and move to the next observation point. Survey timings were varied during the survey period to ensure that as full a range of tidal states as possible were covered from each observation point. **Figure 2.2** shows the location of the study area and observation points. **Figure 2.3** shows the bathymetry within 5km of the Minsmere and Dingle colonies.

During each watch, details of any flight-lines or hunting activity of little terns were drawn onto maps. Details of the numbers and type of activity were also recorded, including the type of foraging activity (dives, surface feeding, etc) and any prey caught. The type of foraging activity can often determine what type of prey has been caught (e.g. diving for fish, surface pick-ups for invertebrates). Searches were also be made for little terns resting along the shoreline between

Sizewell and Thorpeness. The dates, time and weather conditions during the surveys are shown in **Table A2, Appendix A**.



Key

- Little tern colony locations
- SPA
- Sizewell SSA boundary

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Sizewell Little Tern Report

Figure 2.1

Little Tern Colony Locations

October 2010
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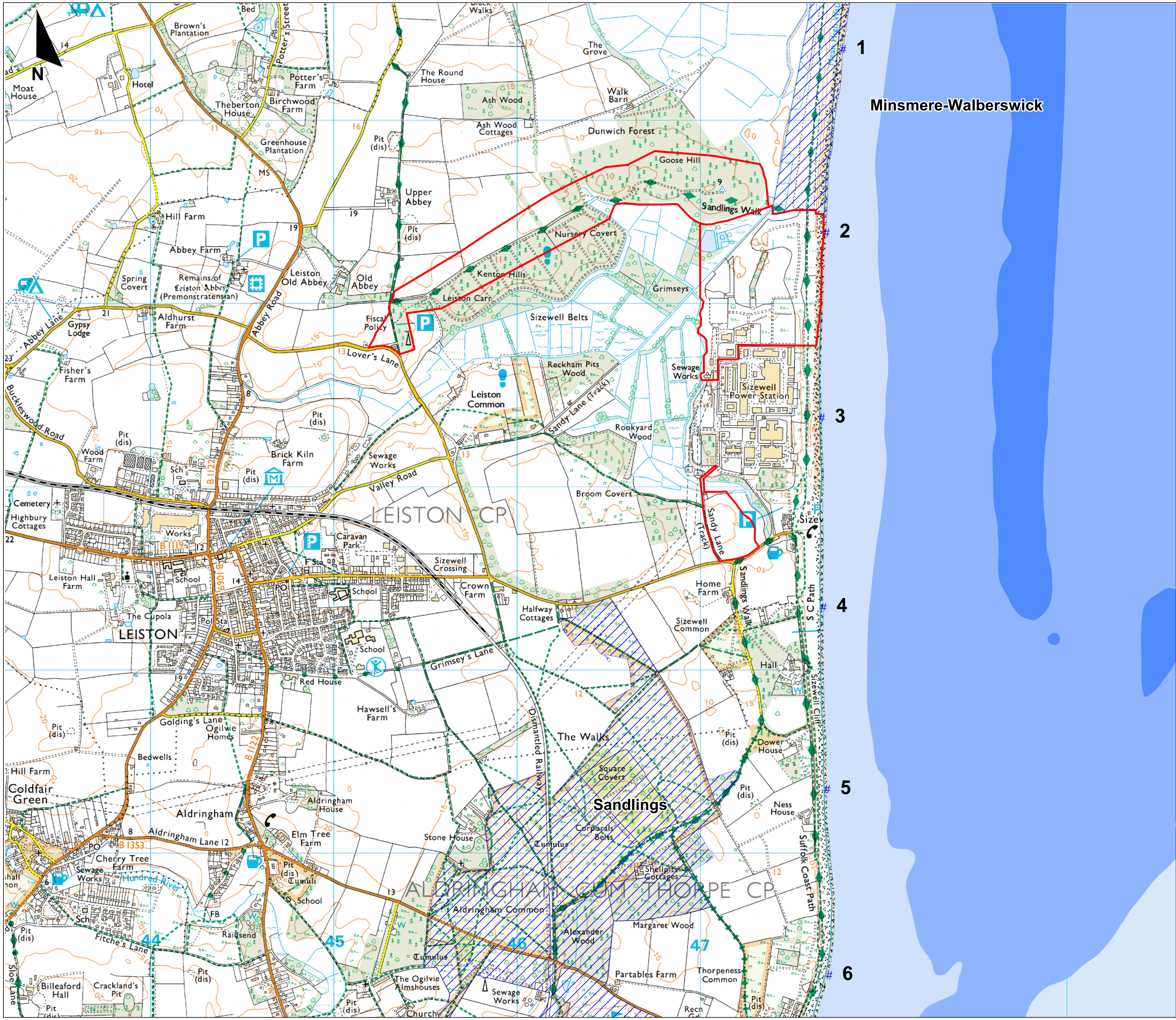

Key

1 # Vantage points

SPA

Sizewell SSA boundary

10m +

5 - 10m

0 - 5m

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Sizewell Little Tern Report

Figure 2.2

Little Tern Foraging Surveys, vantage-point locations

January 2011
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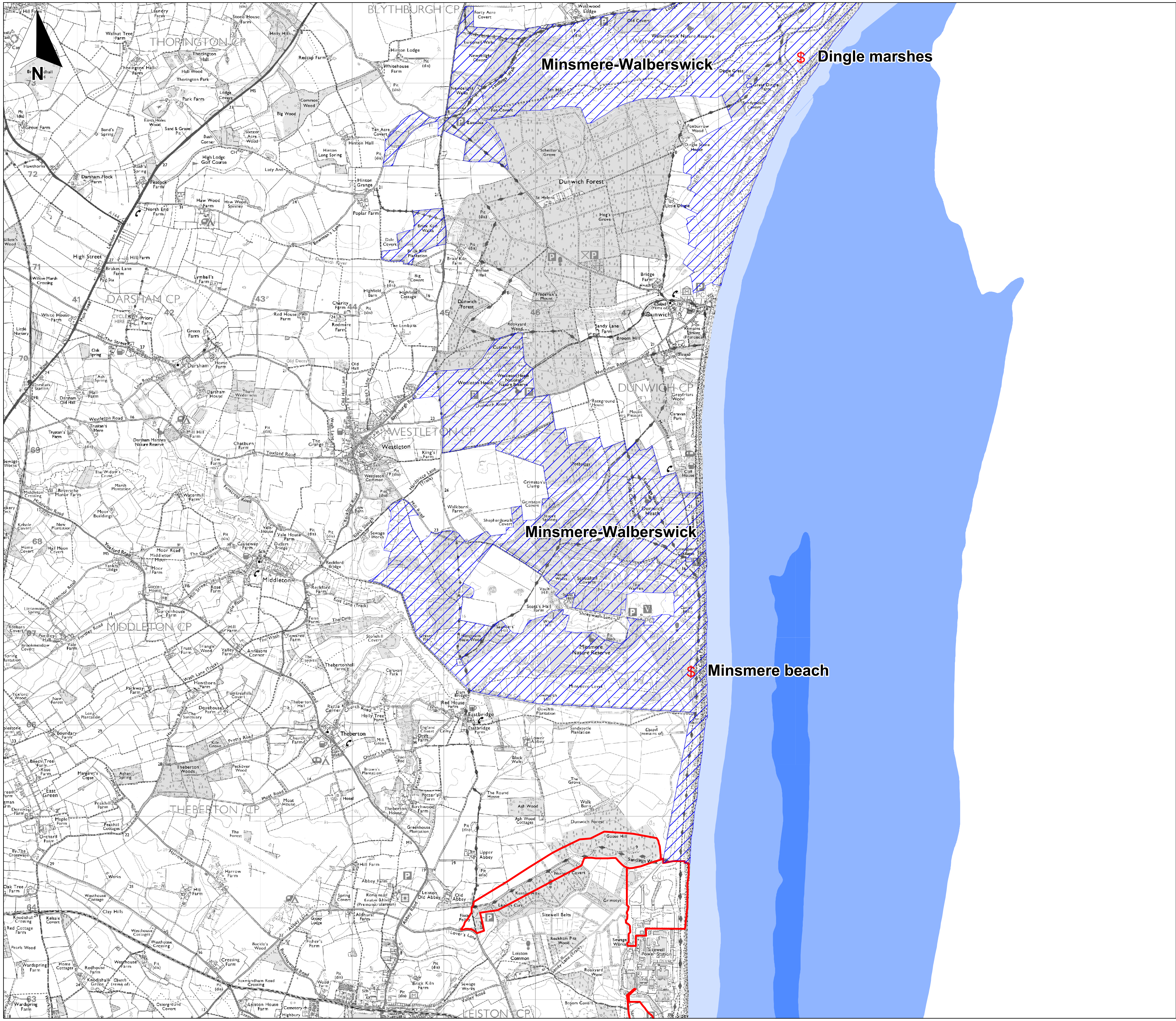

Key

- $ Little tern colony locations
- SPA
- Sizewell SSA boundary
- 10m +
- 5 - 10m
- 0 - 5m

0 m 2000 m

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Sizewell Little Tern Report

Figure 2.3

Bathymetry around the Minsmere and Dingle Little Tern Colonies

January 2011
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3. Results, Little Tern Prey Study

3.1 Introduction

The cooling water discharge from a proposed new nuclear development at Sizewell in Suffolk has the potential to impact the local little tern population through possible affects on their prey. Changes in water temperature could result in an alteration of the distribution of adult and juvenile fish and crustaceans on which the little terns feed. Additionally, changes in water temperature may also disrupt the spawning activity of these species.

The location of little tern colonies are closely tied to the location of suitable food sources (Perrow *et al.,* 2005), and hence a change in prey availability may lead to the demise or relocation of a colony. In addition, breeding timing and success are all known to be affected by prey availability (Perrow *et al.,* 2005).

According to Perrow *et al.* (2005) the most important prey species to little terns in this area of the North Sea are clupeids; namely Atlantic herring (*Clupea harengus*) and sprat (*Sprattus sprattus*). When these fish are scarce, the isopod crustacean *Idotea linearis* and the ghost shrimp *Schistomysis spiritus* are also important, particularly to adult little terns. Although little terns are not thought to be particularly fussy regarding their prey, the high energy, protein and fat content of the clupeid fish mean that they are likely to be the preferred food type. Young-of-the-Year (YOY or 0-group) clupeids are the dominant item in the chick's diet. Their use during courtship rituals and extravagant flight displays are suggested to act as visual signals to other little terns reflecting the quality of the foraging area and help initiate colony formation (Perrow *et al.,* 2005). Previous failures in herring recruitment events in this area of the North Sea have played a major part in the total loss of breeding success in little terns in those years (Perrow *et al.,* 2005).

3.1.1 The Proposed Development and Level of Warming Expected

At this stage there is very little information on the level of warming expected due to the operation of Sizewell C, however model outputs from similar modelling work undertaken for the Hinkley Nuclear Power station suggests that the immediate area around the outfall could warm by as much as 4^{o}C; although the greatest areas will probably be warmed by 1^{o}C or less. This assessment has therefore been based on the effect on the prey species of an increase in water temperature of between 1 and 4^{o}C.

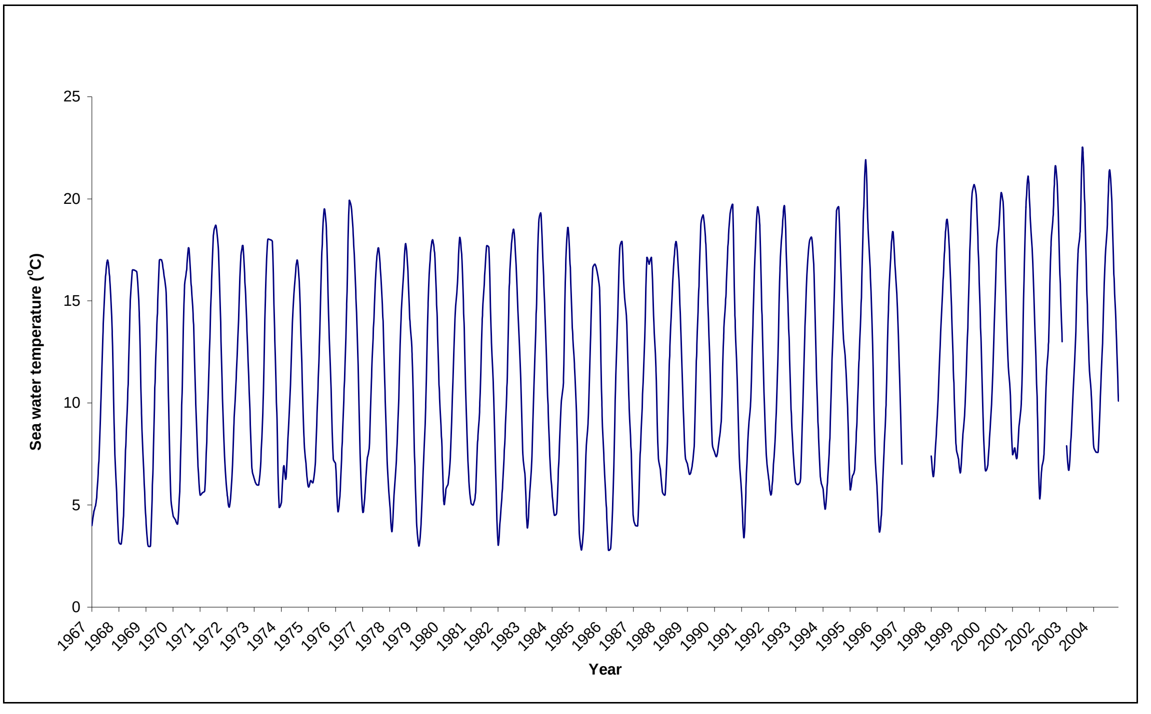
3.1.2 Current and Predicted Water Temperatures

In the North Sea, the sea surface temperature closely follows the air temperature, with the former having a mean 1-2°C above the latter (Lane and Paddle, 1994). The mean sea surface temperature has been monitored at Sizewell since 1967 through the coastal temperature network, ferry route programme and long-term temperature and salinity observations[1]. Mean

[1] http://www.cefas.co.uk/data/sea-temperature-and-salinity-trends/presentation-of-results/station-10-sizewell-ps.aspx

temperatures vary from 4.3°C in February to 18.2 in August, although in exceptional years the monthly average in August has been as high as 22.5°C (**Figure 3.1**). The high sea temperatures in summer 2003, coincided with no young being fledged from the Minsmere and Dingle colonies, and there was very poor breeding success at all colonies along the Suffolk coast in that year. However, human disturbance (rather than reduced food availability) was given as the main contributing factor to the failures at most Suffolk colonies at this time (Wright [ed], 2004).

Figure 3.1 Mean monthly sea surface water temperature from Sizewell 1967-2004

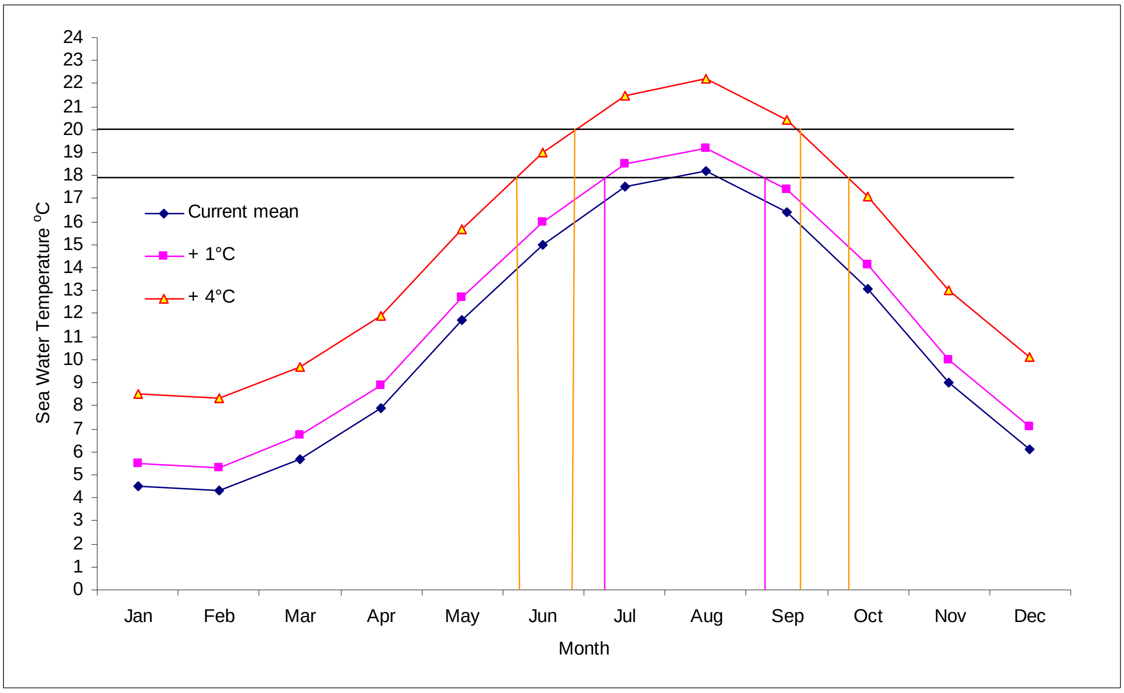


Sea water temperature declines with increasing depth, a process reinforced by thermal stratification that exists between March and October in deeper waters. Thermal stratification is however extremely unlikely in the shallow, well mixed waters off the Suffolk coast, where in water depths of less than 20m, sea bed water temperature is likely to be almost as high, if not the same, as surface water temperature.

With the exception of particularly hot years, mean monthly seawater temperature at Sizewell only exceeds 18°C in mid August (**Figure 3.2**). An increase of 1°C is likely to lead to the seawater in the vicinity of the outfall being over 18°C from early July to early September (**Figure 3.2**). An increase of 4°C is likely to increase the sea temperature in the immediate vicinity of the outfall to over 18°C from early June to early October and to over 20°C from late June to late September.

As previously stated, there is no current information on the size of the area likely to be affected by increased temperatures. This will depend on a multitude of factors (such as volume of water discharged, coastal currents, tidal dynamics etc) and would require complex plume dynamic modelling.

Figure 3.2 Potential sea temperature increases in vicinity of cooling water discharge



3.2 Little Terns

3.2.1 Life Cycle and Migratory Pattern

In order to assess the potential impact of temperature increase on both little terns and their prey, an appreciation of their life cycle and migratory patterns is required in order to assess if and when they will be in contact with the cooling water and its impacts.

Little terns are strongly migratory and arrive in Suffolk from late April (Anon, 2006). The timing of breeding is highly synchronised so that the period of peak prey demand (i.e. when raising chicks) coincides with the peak in density of 0-group clupeids in the surrounding waters (Perrow *et al.*, 2005). Nesting activity begins in mid to late May, with the peak in feeding activity (for the provisioning of chicks) generally occurring in early July (Allen Navarro *et al.*, 2004). Eggs are incubated for 18-22 days, with hatching in an average year usually starting around mid June. The chicks are fledged to maturity around 20 days later, hence are independent of their parents in terms of feeding by late July in an average year (Anon, 2006). Once the chicks are fledged, after a period of time they join the adults on the autumn migration back to West Africa which takes place between August and early October.

3.2.2 Prey

Little terns are present in Suffolk and dependant on the food resource in the area, only from April to October (primarily early May to early September). However, the impact of increased water temperatures on the various life history stages of the prey species throughout the whole year must be considered, as a failure in recruitment in a prey species will have obvious implications for little terns. Details of the life cycles of the four main prey items are provided below and summarised in **Table 3.1**.

Table 3.1 Summary of when cooling water may impact prey species at different life history stages

Species	Life history stage	Months when found inshore	Notes
Herring	Adult	Nov - Jan	Adults move into inshore waters to spawn
	Juveniles (0 – 2 years)	All year	Juveniles spend first 2 years of life in inshore nursery areas. May movie to deeper inshore waters in August when sea temperatures are higher in shallow waters.
	Larvae	All year	Larvae found inshore
	Eggs	Nov- Feb	Laid inshore
Sprat	Adult	Oct- Mar	Adult sprat migrate inshore in autumn and offshore in spring
	Juveniles (0- 2 years)	All year	Juveniles spend first 1-2 years in inshore nursery areas including along Suffolk coast
	Larvae	n/a	Larvae are offshore
	Eggs	n/a	Spawning grounds are offshore
Idotea linearis	All stage	All year	No eggs/planktonic phase, spends whole life in one place
Ghost shrimp	All stages	All year	No eggs/planktonic phase, spends whole life in one place

The four main prey items of little terns in Suffolk have a wide geographical distribution and are found in more southerly waters than those of the North Sea off Suffolk (see **Table 3.2**). However, in the case of herring and ghost shrimp, the mean summer temperatures experienced at Sizewell are already close to or exceed their stated upper temperature ranges.

Table 3.2 Prey species distribution and temperature tolerance

Species	Temperature range	Distribution
Atlantic herring	1 - 18°C (Whitehead, 1985)	Northern Bay of Biscay, Iceland, southern Greenland, Norway, Baltic Sea. (Whitehead, 1985)
Sprat	Not known	North east Atlantic, North sea, Baltic sea, Morocco, Mediterranean sea, Adriatic sea, Black Sea (Whitehead, 1985)
Idotea linearis	Not known	All UK waters, and the Mediterranean (Poore & Schotte, 2009)
Ghost shrimp	Will inhabit waters <18°C (Boscarino *et al.,* 2007). Upper lethal temp 20°C.	All UK coasts, the European coast of the North Sea and the Baltic Sea (WoRMS, 2009). The French Atlantic, Azores, Portuguese Atlantic (*Schistomysis* spp; Vasconcelos *et al*., 2004).

Within the marine environment predicting changes to populations as a result of environmental impacts on predators, prey or competitors are often difficult owing to the numerous life history stages of marine organisms. For example, cod are one of the main predators of sprat, whilst sprat also feed on cod eggs (Köster & Möllmann 2000). Hence a decline in the numbers of predators may not be an advantage as this will lead to a decrease in food availability for the prey.

Any assessment of competitors requires an understanding of the prey species favoured. The main sources of food for the four little tern prey items are shown in **Table 3.3**.

Table 3.3 Prey species food sources

Species	Food source
Atlantic herring	Zooplankton (Copepods)
Sprat	Zooplankton
Idotea linearis	Phytoplankton
Ghost shrimp	Detritus

In order to assess the impact of a 1-4^{o}C increase in water temperature on the prey species of little terns, several questions must be asked:

- Does the prey species occur in warmer waters than those found on the East England coast (e.g. in the Mediterranean) and if so, what is the temperature range in which the species occurs?
- Is spawning activity or viability of gametes likely to be impacted by warmer waters?
- Are warmer waters likely to attract more predators/competitors of the prey species and therefore displace them?
- Will the warming of the water impact upon the habitats and/or food chain on which each prey species depends?

These questions have been answered below in relation to each of the four main prey species of the little terns in this area of the North Sea, namely herring (*Clupea harengus*), sprat (*Sprattus sprattus*), the isopod *Idotea linearis*, and ghost shrimp (*Schistomysis spiritus*).

3.3 Herring

3.3.1 Life Cycle and Migratory Pattern

Adult herring are pelagic, occurring in large shoals and found mostly in continental shelf seas to depths of 200m (Whitehead, 1986). Maturing herring travel towards the spawning grounds between November and January as the milt and roe begin to develop, congregating in huge shoals in coastal waters. The North Sea stock is dominated by autumn spawning fish but there are also some small discrete groups of coastal spring spawning herring in areas such as The Wash and the Thames Estuary (Anon, 2009). The herring population around Sizewell are thought to be autumn spawners. UK nursery grounds in the southern North Sea are found around the Wash and also run south along the coast of Norfolk and Suffolk (see **Figure 3.3**).

Herring eggs are laid on the sea bed, usually in water 10-80 m deep, on hard ground covered with small stones, shells or seaweed to which the eggs can attach. The eggs incubate for 10-30 days depending on sea temperature, with 14-20 days being typical for the North Sea. Herring larvae are solitary and pelagic, drifting with the current. When the larvae reach a length of about 40mm, they begin to develop scales and move to inshore nursery grounds. Herring nursery grounds are found along the entire Suffolk coast. After spending their first two years in coastal nurseries the two-year old herring move offshore into deeper waters (Mackenzie, 1985) eventually joining the adult population in the feeding and spawning migrations offshore.

3.3.2 Predicted Impacts on Distribution in Relation to Water Temperature

According to the literature, Atlantic herring only inhabit waters between 1 and 18^{o}C. However, summer surface water temperatures in the Sizewell area regularly exceed 18^{o}C and can exceed 20^{o}C. During the summer months, adult herring migrate offshore (into cooler waters), although juveniles are known to inhabit inshore nursery areas throughout the summer until they are two years old. There is some evidence from catch data along the Norfolk coast that young herring may move into deeper and cooler waters within the nursery grounds during the warmer months. At Scroby Sands, Perrow *et al*. (2005) found that catch rates of young herring declined dramatically during August, which coincides with the warmest sea water temperatures in this area (above 18^{o}C). An increase in sea water temperature (as a result of the cooling water discharge) of just 1^{o}C could result in temperatures being elevated to over 18^{o}C from July to September (i.e. an extra six weeks of the year). This may result in young herring seeking deeper waters earlier in the year, thus making them unavailable to little terns as prey items for a substantial part of the breeding season.

3.3.3 Predicted Impacts on Spawning Activity or Gamete Viability

Herring spawn along the east coast of northern Suffolk between November and January (Coull *et al.,* 1998). Spawning events are correlated with water temperature. In the western Atlantic, spawning occurs in water temperatures ranging from 5-15^{o}C (Anderson & Karas, 1990). A study in the Baltic Sea of spawning activity of Atlantic herring in areas of cooling water discharge, noted that in areas of warmer water, spawning occurred up to a month earlier than in the reference sites (Anderson & Karas, 1990).

A 1^{o}C increase in water temperature (due to the cooling water discharge) would result in the waters in the affected area being above 5^{o}C throughout the winter. This could potentially lead to a change in the spawning periods in that instead of having discrete autumn and spring spawning periods, spawning might occur throughout the winter.

Development duration of herring eggs is inversely related to the temperature. Development takes 40 days to complete at 4-5^{o}C, 15 days at 6-8^{o}C, 11 days at 10-12^{o}C and 6-8 days at 14.4-16^{o}C (Reid *et al.,* 1999). In laboratory experiments, no development was observed in waters below 5^{o}C, and at temperatures greater than 20^{o}C, rapid development was followed by 100% mortality (Reid *et al.,* 1999). Because of the close relationship between development and temperature, a rise of only 1°C could cause herring eggs in the area to develop considerably faster.

In general, however, relatively small increases in seawater temperature may favour herring recruitment, speeding up their development and providing more zooplankton for food although mismatches in timing between the herring emergence and the increase in zooplankton can be very bad for recruitment. The failure of herring recruitment is most likely to be due to reduced egg survival and/or reduced population size of spawning individuals. There are naturally high levels of variability in these factors and therefore attributing recruitment failure to a single cause is often very difficult.

The International Council for the Exploration of the Sea (ICES) concluded that the poor recruitment of herring in 2002 (possibly due to high sea temperatures) had a knock on effect to recruitment in 2003-05. Other studies have suggested that low survivorship of the larvae is due to a general warming of the North Sea, causing the herring larvae to emerge at a time when food availability is not at its highest.

In addition, herring larvae which develop within the area of the cooling water discharge may be at increased risk of thermal shock once transported into the surrounding colder waters (Anderson & Karas, 1990). The risk of thermal shock may be increased due to the decreased development time which would occur in the warmer waters, causing larvae to emerge during the coldest months.

Studies in the Baltic Sea provide direct evidence of a negative effect on the spawning activity of Atlantic herring due to cooling water discharge. Large numbers of Atlantic herring spawned in a very restricted area in the vicinity of a cooling water discharge in the Baltic Sea, resulting in very thick egg layers (Anderson & Karas, 1990). The herring which spawned in the immediate vicinity of the outfall experienced high mortality through gas bubble disease caused by gas supersaturation of the water in this area (Anderson & Karas, 1990). In addition, egg mortality was higher in areas where egg layers were thick, and the overall recruitment from these areas of high spawning density was no greater than that from the reference sites (Anderson & Karas, 1990). This extreme situation is unlikely to arise at Sizewell as the outfall would be located on an open coast, as opposed to the restricted situation in the Baltic Sea study. In open coast situations, discharges are likely to be more quickly dispersed.

3.3.4 Predicted Predator/Competitor Changes

Atlantic herring is preyed upon by many species during all stages of its life history (see **Table 1.4**).

Table 1.4 Predators of the Atlantic herring during various stages of its life

Stage	**Predators**
Eggs	Eggs are utilised as a prey source by many species, including bottom dwelling flat fishes (e.g. Flounder *Platichthys flesus*), cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), dogfish (*Scyliorhinus caniculus*), and cannibalised by adult herring as well as many others. Eggs are also eaten by a number of mobile invertebrates including starfish and mysid shrimps.
Larvae	Atlantic herring larvae are solitary and pelagic and are thus vulnerable to a wide range of planktonic feeding species; this includes jellyfish, Chaetognaths (Arrow worms), larger copepods, Euphasids (Krill) and pelagic fishes.
Juvenile	Juvenile Atlantic herring are preyed upon by almost all pelagic predators including fishes, marine birds, cephalopods and marine mammals.
Adult	Adults are preyed upon by almost all pelagic predators including fishes, marine birds, cephalopods and marine mammals. Predation by other fish species is very intense during spawning.

Littoral mysid shrimps predate on Atlantic herring eggs and yolk sac larvae and will do so preferentially even when other food sources are available (Torniainen & Lehtiniemi, 2008). Studies have shown that mysid shrimps can have local effects on populations of Atlantic herring through heavy egg and larvae predation especially if large numbers are present within the spawning areas (Torniainen & Lehtiniemi, 2008). Increases in temperatures may lead to greater numbers of mysid shrimps which breed all year round producing greater numbers of offspring in the warmer months (Mauchline, 1967). Development is also faster in warmer waters (Winkler & Greeve, 2002).

The moon jellyfish *Aurelia aurita* acts as both predator (of larvae) and competitor (both feed on zooplankton) to Atlantic herring and can tolerate temperatures up to 31°C. The main predator of *Aurelia aurita* is the lion's mane jellyfish *Cyanea capillata,* which is a cold water species and will not tolerate warmer waters. In theory this could release populations of *Aurelia aurita* from predation pressure and subsequently negatively impact the Atlantic herring populations, however given the localised impact of this cooling water this would be unlikely to be significant.

Any increase in phytoplankton production as a result of warmer water (in the absence of chlorination) is likely to increase the abundance of zooplankton available for adult herring to eat in the vicinity of the outfall. However any increase in zooplankton may be accompanied by an increase in other zooplankton predators, which may consume herring larvae. Given that larvae have a wide distribution (inshore and offshore) this is unlikely to have an impact on their local population.

3.3.5 Conclusion

The shallow waters offshore of Suffolk support nursery grounds for young herring in the first two years of their life. These young herring are likely to provide a very important food resource for the provisioning of little tern chicks at colonies in Suffolk during much of the breeding season (June, July and early August). An increase in sea water temperature during this period may result in young herring seeking deeper waters earlier in the year, thus making them unavailable to little terns as prey items for a substantial part of the breeding season. An increase in sea temperature also has the potential to change the seasonal timing of herring spawning, which may result in young herring being present when their main food source is absent. This may ultimately lead to a failure in herring recruitment, which would also reduce the amount of food available to little terns at the SPA colonies (Minsmere and Dingle).

3.4 Sprat

3.4.1 Life Cycle and Migratory Pattern

It is generally assumed that sprat living in the North Sea undertake large seasonal migrations, migrating inshore in autumn and offshore in spring (Bailey, 1980). Sprats spawn offshore between May and August, with peak spawning occurring in May and June. In the autumn, the fish return to the inshore over-wintering areas, along with the incoming 0-group recruits (ICES, 1990).

Both the eggs and larvae of sprat are pelagic. Juveniles migrate inshore to nursery areas which are extensive and extend all along the North Sea coast including the Suffolk coast around Sizewell (**Figure 3.4**). The majority of sprat remain as juveniles until their second year, when they will migrate offshore and participate in their first spawning. Some sprat however can obtain adulthood after just one year (Peck & Mőllmann, 2008).

3.4.2 Predicted Impacts on Distribution in Relation to Water Temperature

No direct information has been found on the temperature tolerance of sprats, although it would appear that this species is capable of inhabiting water temperatures higher than those tolerated by herring, as they are found much further south than herring (e.g. the Mediterranean). Therefore elevated water temperatures could favour young sprat over herring. How this might affect the little terns in not known.

3.4.3 Predicted Impacts on Spawning Activity or Gamete Viability

Sprat spawn offshore, hence any change in sea water temperature as a result of this localised cooling water discharge is unlikely to affect spawning.

3.4.4 Predicted Predator/Competitor Changes

The jellyfish *Aurelia aurita* acts as both predator and competitor to sprat, as it does with herring, however given the localised impact of this cooling water any increased predation/competition is unlikely to significant affect the population.

Herring and sprat are known to compete for the same food resource, this is especially apparent in the Baltic Sea where food competition with Atlantic herring has lead to growth changes in both fish species (Möllmann *et al.,* 2005, Casini *et al.,* 2006). Competition in the waters off Suffolk will occur throughout the year with juveniles inhabiting the inshore waters all year round and both adult sprats and herrings migrating inshore in the winter months. Warmer water temperatures in the summer (+18^{o}C) around the vicinity of the cooling water discharge is likely drive juvenile herring into deeper cooler water, hence decreasing the competition for zooplankton for sprats.

3.4.5 Conclusion

Young sprat are found in the shallow waters off the Suffolk coast and are likely to provide an important food resource for the provisioning of little tern chicks during the breeding season. The evidence suggests that sprat are able to tolerate higher sea temperatures than herring and the two species are known to compete for the same food source. Therefore, higher sea temperatures due to the cooling water discharge could potentially lead to an increase in sprat if herring numbers in inshore waters decline.

3.5 Idotea Linearis

3.5.1 Life Cycle and Migratory Pattern

No specific life history information could be found for this species of isopod. Isopods however have no planktonic phase and the young are released as juveniles (mancas) which resemble the adults. Therefore the entire life history of this species is likely to occur within a very limited home range.

3.5.2 Predicted Impacts on Distribution in Relation to Water Temperature

Little information on temperature tolerances for this species was found. However, its southerly distribution (e.g. the Mediterranean) indicates its ability to tolerate increased water temperatures.

3.5.3 Predicted Impacts on Spawning Activity or Gamete Viability

Very little information was found on this species. However, reproductive activity in other temperate isopods is closely linked to temperature, with maximum reproductive effort occurring when water temperatures are between 5-12^{o}C (Leifsson, 1999). A 1^{o}C increase in temperature would lead to the water temperature exceeding 12^{o}C between the months of May and October, an extension of roughly two weeks over the current situation.

3.5.4 Predicted Predator/Competitor Changes

An increase in sea temperatures may lead to competition from another species of isopod, *Idotea metallica*. *I. metallica* is a warm water species of isopod which is occasionally found in the southern North Sea. It is not a resident species (it does not survive the winter) but individuals are introduced each year by currents from the Atlantic (Gutow & Franke, 2001). Warming seas are expected to contribute to a larger summer population of this species as the critical temperature for reproduction (13^{o}C) is exceeded for longer periods (Gutow & Franke, 2001). With even a small temperature increase of 1^{o}C the critical temperature will be exceeded for a further 3 weeks (mid May to late October). Therefore, a population of *Idotea metallica* will be able to breed for a longer period, contributing to a greater population. The impact of this on little terns however is likely to be minimal, as they are not thought to be particularly choosy in their prey selection, unless its behaviour makes catching it more difficult.

3.5.5 Conclusion

The isopod (*Idotea linearis*) is likely to form part of the food resource available to foraging adult little terns from the SPA colonies. Increased sea temperatures have the potential to increase the numbers of this isopod in the shallow waters offshore of Suffolk. However, other species of isopod (which compete with this species for food) may also increase in numbers due to the cooling water discharge. However, it is likely that the overall impact of any changes in the abundance of different isopod species on little terns at the SPA colonies will be minimal.

3.6 Ghost Shrimp

3.6.1 Life Cycle and Migratory Pattern

Ghost shrimps breed throughout the year (Mauchline, 1967). There is no larval stage, with early development taking place within the brood pouch (marsupium). Juveniles and adults commonly inhabit the same areas, and display similar habits (Makings, 1977).

3.6.2 Predicted Impacts on Distribution in Relation to Water Temperature

The ghost shrimp is only found within waters of 18°C and below and is likely to have an upper lethal temperature tolerance of 20°C and therefore may be susceptible to temperature increases. An increase in temperature of just 1°C could result in temperatures being elevated to above 18°C from July to September. This species is not migratory and is found throughout the year on the Norfolk coast. Therefore, this may indicate a greater tolerance to elevated temperatures than reported. However, given the species' upper lethal limit of only 20°C, it is likely that an increase in temperature would result in a decline in the population in the areas affected.

3.6.3 Predicted Impacts on Spawning Activity or Gamete Viability

In Scottish waters, spawning occurs year round, with differences in the timing of breeding events between separate ghost shrimp populations (Mauchline, 1967). Breeding is more intense during the warmer months, and the number of young is also greater at this time (Mauchline, 1967). Laboratory studies of other mysid shrimps have shown that egg incubation time is considerably reduced with higher temperatures, and incubation time was halved when the ambient temperature changed from 10 to 15°C (Winkler & Greeve, 2002). Winkler & Greeve (2002) also found that the minimum size of breeding females decreased with increasing temperature and the number of eggs per female also decreased with size. A 1°C increase in temperature, would lead to the water temperature exceeding 15°C between the months of June and October, an extension of roughly four weeks over the current situation.

3.6.4 Predicted Predator/Competitor Changes

Mysid shrimps such as the ghost shrimp are an important dietary component of many fish species. In UK waters the most important predator of mysid shrimps is likely to be the brown shrimp *Crangon crangon* (Hostens and Mees, 1999). This species has a similar temperature tolerance to mysid shrimps (Wear, 1974) and therefore *Crangon crangon* numbers are likely to decline along with ghost shrimp numbers in the vicinity of the cooling water discharge.

Clupeid fishes have also been known to feed on mysid shrimps, and therefore any increases in the abundance of sprat due to warmer temperatures is likely to result in an increase in predation pressure on this species (Moore & Moore, 1974; Casini *et al.,* 2004). However any increase in sprat is also likely to be accompanies by a decline in herring, hence predation pressure is likely to remain the same. It has also been suggested that top down control is a relatively minor factor in controlling abundance (Hostens & Mees, 1999), and therefore other factors (food availability, environmental suitability etc) may be the dominant forces controlling mysid numbers.

3.6.5 Conclusion

Ghost shrimps (*Schistomysis spiritus)* are likely to form part of the food resource available to foraging adult little terns from the SPA colonies. Sea water temperatures off Sizewell are near to the upper limit that this species can tolerate and therefore increased temperatures due to the cooling water discharge have the potential to result in a decline in the ghost shrimp population in the shallow waters offshore of Suffolk. How this might impact on the SPA populations of little tern is not known.

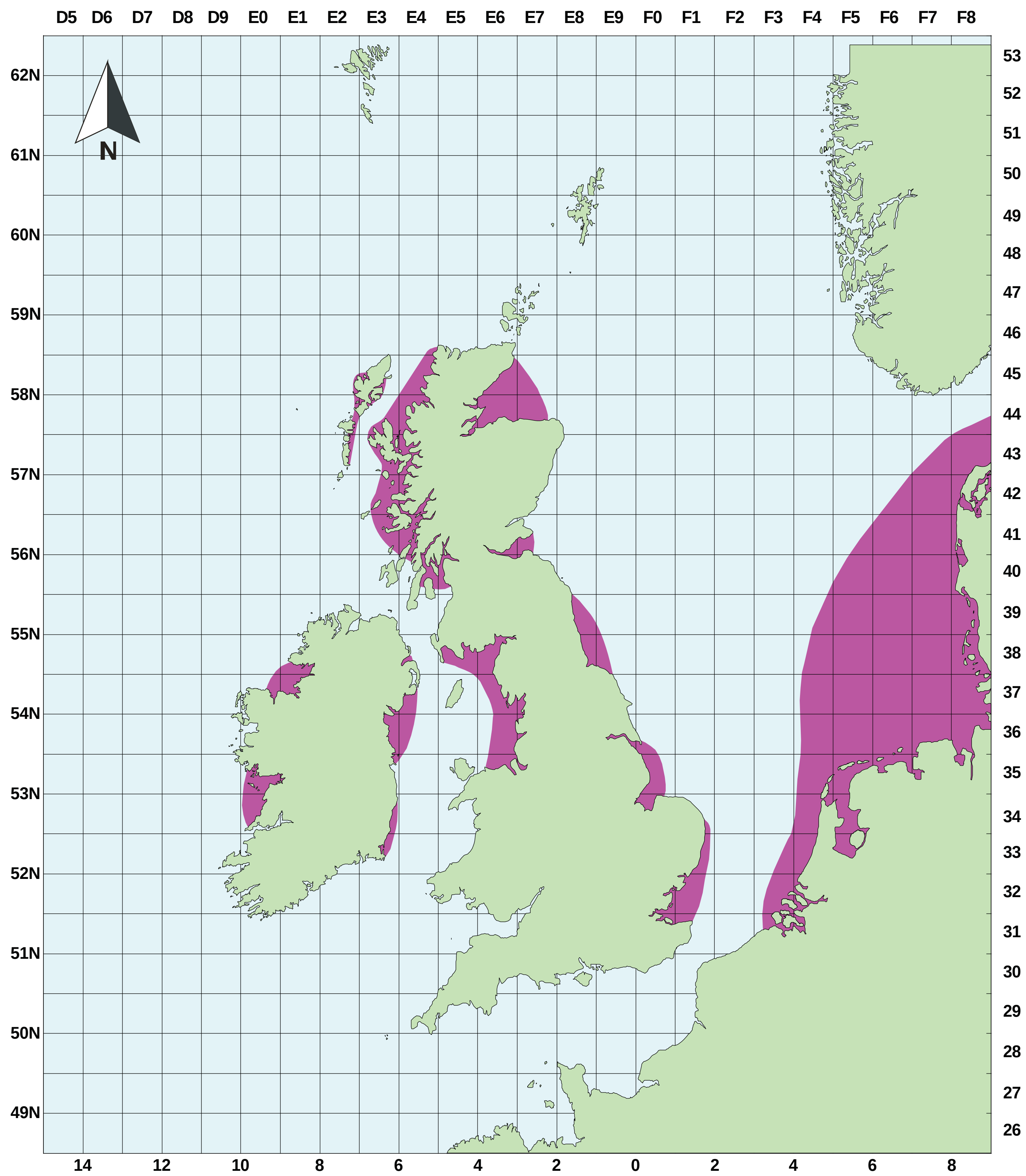
3.7 Predicted Impacts on Habitats and Food Chains of Prey Species

Herring, sprat and *Idotea linearis* all feed on plankton while the ghost shrimp feeds on detritus. Therefore the impact on the prey of these species by the cooling waters is not dependent on the effects on benthic (infauna and epifaunal) community. The main concern in terms of prey supply depends on the availability of plankton in the water column.

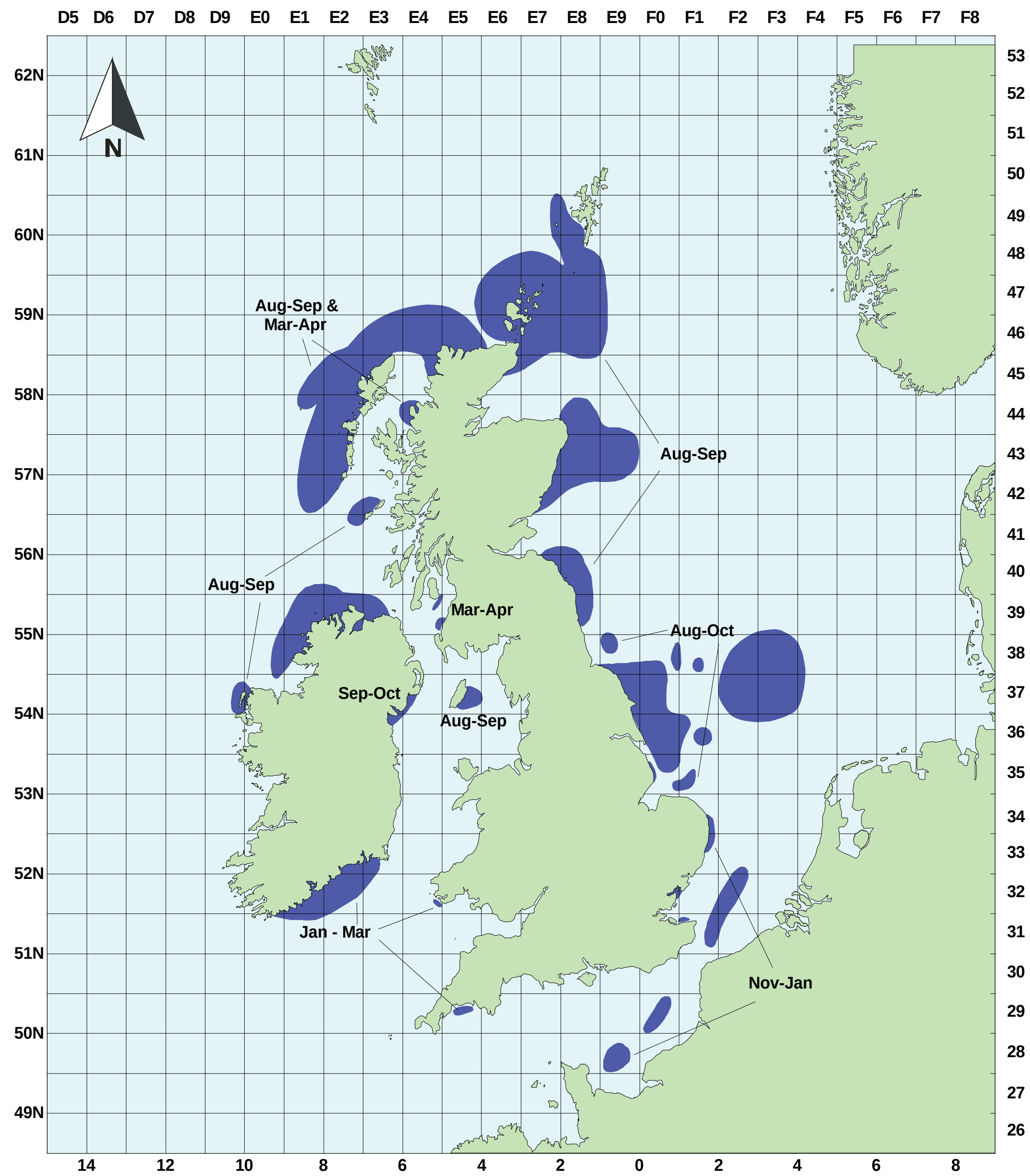
The extent to which cooling water discharge affects the plankton depends on whether the cooling water will be chlorinated, as phytoplankton production is negatively correlated with increasing chlorination of the water. Reduced phytoplankton production will also result in a subsequent decrease in zooplankton abundance (Poornima *et al.,* 2005; Chuang *et al*., 2009). This effect has been shown to be quite localised and that the overall coastal productivity is not significantly reduced (Poornima *et al.,* 2005; Chuang *et al*., 2009), however shifts in local abundances may occur.

In the absence of chlorination in temperate waters, localised warming will result in an increase in phytoplankton production, i.e. a longer season and greater production (Ilus & Keskitalo, 2008), and can result in the formation of algal blooms. These increases however, are limited by the nutrient availability in the system. Any increase in the phytoplankton biomass will allow a greater zooplankton production and thus greater food availability for herring, sprat and ghost shrimp.

Increases in phytoplankton biomass caused by localised warming will result in a greater zooplankton biomass and subsequently a greater level of detritus for organisms such as *Idotea linearis*.



Nursery Areas



Spawning Areas

Sizewell Little Tern Report

Figure 3.3
Known Spawning and Nursery Areas of Atlantic Herring Around the British Coast. Source, Coull et al., (1998)

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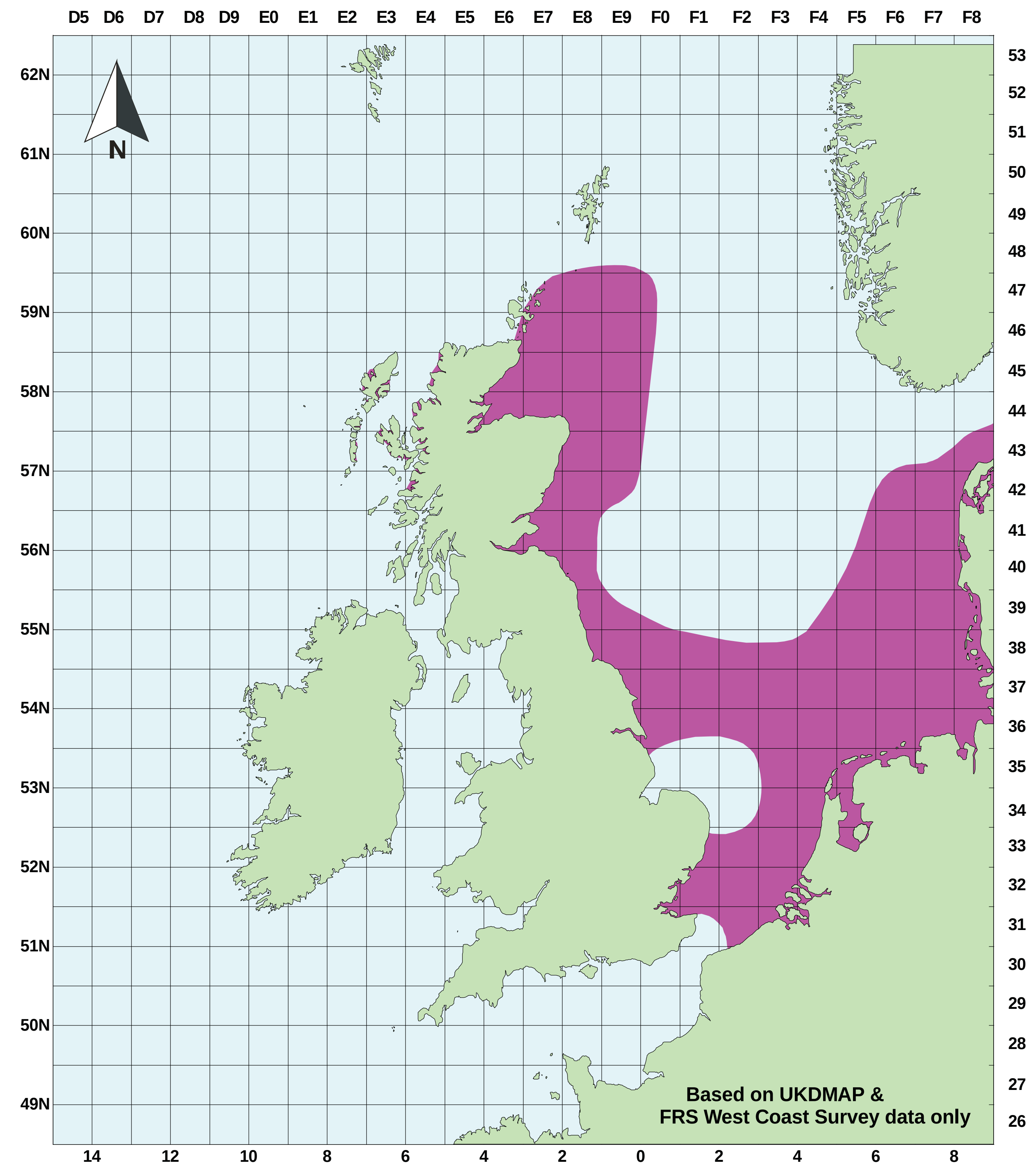
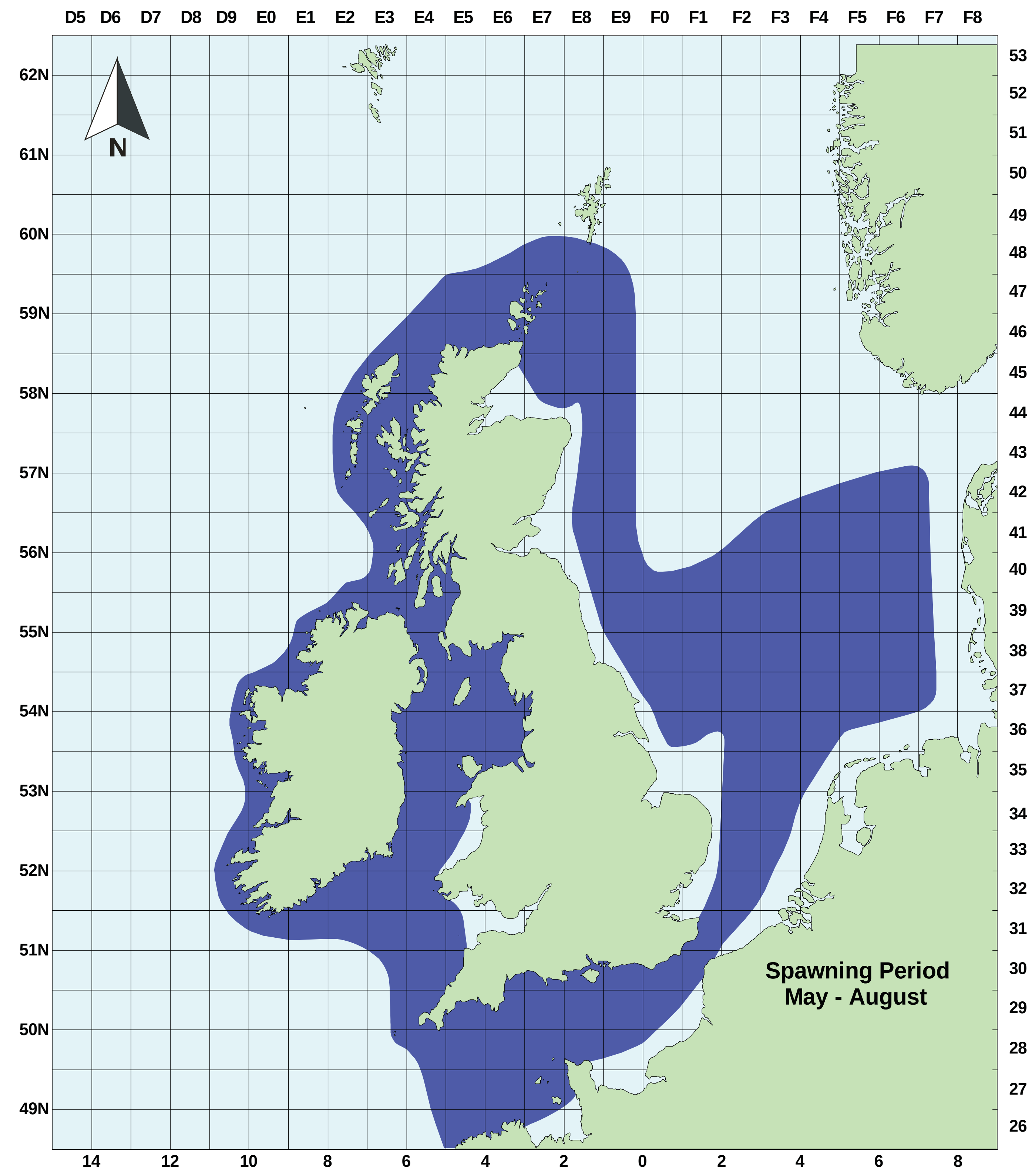


Nursery Areas



Spawning Areas

Sizewell Little Tern Report

Figure 3.4
Known Spawning and Nursery Areas of Sprat Around the British Coast. Source, Coull et al., (1998)

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4. Results, Little Tern Surveys

4.1 Little Tern Colony Surveys

A total of 17 and 31 two-hour watches were undertaken at the Minsmere and Dingle little tern colonies respectively, between 4 May and 6 August 2010. **Table 4.1** provides an overview of little tern activity at the two colonies on each survey date.

Table 4.1 Overview of tern activity at the Dingle and Minsmere Colonies

Date	Colony	Peak little tern count	Overview of activity
04-May	Dingle	0	None seen
04-May	Minsmere	1	Single bird commuting south
05-May	Dingle	3	Three birds roosting on the beach
05-May	Minsmere	5	A few birds on Minsmere wader scrape[2]
15-May	Dingle	8	A minimum of 8 birds catching fish close offshore
15-May	Minsmere	2	A minimum of 2 birds commuting south which then landed on wader scrape
16-May	Dingle	12	A minimum of 12 birds foraging close offshore and loafing on the beach, with courtship behaviour observed by at least 1 pair
16-May	Minsmere	7	A minimum of 7 birds foraging offshore, with 2 showing courtship activity in the tern sanctuary
20-May	Dingle	17	A flock of 17 birds commuting south distantly offshore. Also 1 pair showing courtship display with fish, seen on the beach.
20-May	Minsmere	6	A minimum of 6 birds foraging close offshore
24-May	Dingle	4	A minimum of 4 birds foraging close offshore
24-May	Minsmere	2	Two birds foraging offshore then onto wader scrape
29-May	Dingle	14	Fourteen birds on the shingle, including pairs tending nest scrapes, and courting
29-May	Minsmere	0	None seen
30-May	Dingle	12	Twelve birds in the colony on the shingle, including birds sitting on nest scrapes. Six birds were seen roosting on the beach and 1-4 foraging offshore.
30-May	Minsmere	2	One roosting on the scrape, and 1-2 birds foraging offshore

[2] The wader scrape refers to the complex of shallow lagoons within the Minsmere RSPB nature reserve, located immediately inland from Minsmere beach.

Table 4.1 (continued) Overview of tern activity at the Dingle and Minsmere Colonies

Date	Colony	Peak little tern count	Overview of activity
05-Jun	Dingle	2	Only two birds in the colony, and none seen on nest scrapes
05-Jun	Minsmere	3	Two birds loafing on the wader scrape and another foraging offshore. No breeding activity observed in the tern sanctuary area on the beach.
06-Jun	Dingle	16	Two nesting pairs and a further three courting pairs in the colony. Up to three birds foraging offshore.
06-Jun	Minsmere	3	Three birds loafing on the wader scrape, with some courtship behaviour observed, but no breeding
11-Jun	Dingle	9	Nine birds loafing on the beach. Several birds showing courtship behaviour and 1 pair on a nest scrape in the colony.
12-Jun	Dingle	4	Four birds loafing on beach, but none seen on nest scrapes in colony
12-Jun	Minsmere	6	Four birds commuting north and 2 birds loafing on the wader scrape
21-Jun	Dingle	14	Very few birds foraging offshore, but up to 14 birds loafing on beach or prospecting nest scrapes in the colony
21-Jun	Minsmere	0	None seen
22-Jun	Dingle	13	Very little foraging activity. Up to 13 birds loafing on beach, or showing courtship behaviour in the colony.
22-Jun	Minsmere	2	No foraging birds noted. Two birds flying over the beach.
29-Jun	Dingle	66i	An influx of birds to the area (presumably failed breeders from another colony). Many birds foraging within 500m of the shoreline or loafing on the beach.
29-Jun	Minsmere	2	Two birds foraging close offshore, which then flew onto the wader scrape
30-Jun	Dingle	100	A minimum of 100 birds foraging within 500m of the shoreline, or loafing on the beach. A few birds also prospecting in the colony.
05-Jul	Dingle	45	Large numbers of birds foraging within 700m offshore and loafing on the beach by the colony. Seven birds on nest scrapes in the colony.
05-Jul	Minsmere	2	Two birds foraging close offshore, which then flew onto the wader scrape
07-Jul	Dingle	70	Large numbers of birds foraging within 700m offshore and loafing on the beach by the colony. Ten birds on nest scrapes or loafing in the colony.
07-Jul	Minsmere	11	Eleven birds foraging 300m offshore from Minsmere Sluice
13-Jul	Dingle	75	Very little foraging activity, with at least 64 birds loafing on the beach. Four birds on nest scrapes in the colony, plus another 6 loafing nearby.
14-Jul	Dingle	10	The influx of birds had gone. Four birds on nest scrapes and a further 5 loafing in the colony. Very little foraging activity.
24-Jul	Dingle	7	Two pairs in the colony, plus another 4 birds loafing nearby. Very little foraging activity.

Table 4.1 (continued) Overview of tern activity at the Dingle and Minsmere Colonies

Date	Colony	Peak little tern count	Overview of activity
25-Jul	Dingle	8	Two pairs breeding in the colony, plus a further 2 birds loafing nearby. Very little foraging activity, involving 1-2 birds.
05-Aug	Dingle	1	Colony abandoned. One bird was seen foraging offshore from Dunwich beach car park.
06-Aug	Dingle	3	None in colony, and up to 3 birds foraging close offshore
06-Aug	Minsmere	0	None seen

Results from the colony surveys indicate that little tern did not breed at Minsmere in 2010, either on the wader scrape or the fenced off ‘tern sanctuary area’ on the beach. Some courtship behaviour was seen but no serious attempts at breeding were made. Between Dunwich beach and Walberswick, a small breeding colony of little terns was established on the upper reaches of the shingle beach adjacent to Dingle Marshes (located at national grid reference TM489733). Up to 7-8 pairs attempted to breed in the colony, with birds sat on nest scrapes by the end of May and present until the end of July. No successful breeding was observed (no young or fledged birds were seen).

Figures 4.1a-c show the flight lines of little terns recorded from the Dingle colony during May, June and July-August respectively, and **Figure 4.2** show the flight lines from Minsmere during the entire survey period. At Dingle, a large influx of little tern occurred between 22-29 June and birds were present until 13 July. At least 100 birds were present on 30 June, with birds foraging for fish close offshore (generally within 700m of the shoreline) or loafing on the shingle beach. It is likely that these birds were failed breeders from the Kessingland colony, located approximately 15km to the north of the Dingle colony (pers. comm. Robin Harvey, RSPB warden).

During the survey period, birds were seen heading south from both the Dingle and Minsmere colonies, although at both colonies, much of the foraging activity occurred in the shallow waters close offshore (generally within 700m of the shoreline). The pattern of movement at Dingle was primarily of birds moving between the shingle beach and breeding colony to waters close offshore. Birds were also seen commuting and feeding along the shoreline, moving in a north-south and south-north direction. Likewise at Minsmere, birds were seen (albeit in smaller numbers) commuting and foraging along the shoreline or close offshore, moving north and south. The flight line data indicates that birds were moving between Dingle and Minsmere, and were also heading further south along the shoreline and close inshore towards Sizewell. The flight line data provides no clear evidence that terns were heading further out to sea to forage on offshore sandbanks. Much of the foraging activity involved birds diving and catching small fish, with surface feeding also observed. Birds were seen to catch small fish in the close inshore waters off Dingle, and then return to the colony. Results from the surveys provided no evidence to suggest that little terns were experiencing problems in locating fish in the waters close to the Dingle colony, with numerous successful foraging attempts observed.

At Minsmere, some successful foraging activity was observed, both diving for fish and surface feeding for invertebrates, although generally, the level of activity was low compared to that at

Dingle due to the small number of individuals involved. Some courtship behaviour was seen on the wader scrape and beach during May and early June, but by the end of June occurrence had become sporadic with no serious attempts at breeding noted. Most of the sightings at Minsmere from mid-June to the end of July were of birds foraging briefly offshore, after which they would frequently fly onto the wader scrape on the reserve (South scrape) to rest.

4.2 Little Tern Foraging Surveys

A total of six 45 minute watches were undertaken from each VP between 10 May and 20 July 2010 (two watches each month). **Table 4.2** lists each record of little tern activity noted during the surveys. **Figure 4.3** shows the flight lines of little terns recorded during the surveys, and where foraging activity was observed.

Table 4.2 Flights of Little Terns during foraging surveys

Survey date	VP	Count of birds	Flight direction	Activity	Distance offshore(m)
27-May	2	4	South	Commuting	0-100
08-Jun	1	4		Foraging (diving)	200-400
08-Jun	1	2		Foraging (diving)	200-500
08-Jun	2	1		Foraging (diving)	0-100
08-Jun	2	1	South	Foraging (diving)	50-200
08-Jun	2	1	South	Commuting	0-100
08-Jun	3	1	North	Commuting	300-400
08-Jun	5	2		Foraging (diving)	0-50
08-Jun	6	3	South	Foraging (diving)	0-100
24-Jun	6	2	North	Foraging (diving)	0-200
05-Jul	2	3	North	Foraging (diving)	500
20-Jul	1	3		Foraging (diving)	0-200
20-Jul	1	1		Foraging (diving)	0-200
20-Jul	1	28	North	Foraging (diving & surface pickup)	500-700
20-Jul	1	6		Foraging (diving)	200-400
20-Jul	1	10	North	Foraging (diving)	0-100
20-Jul	1	2	North	Commuting	500
20-Jul	1	1		Foraging (diving)	400
20-Jul	1	6	North	Commuting	0-100
20-Jul	1	1		Foraging (diving)	0-50
20-Jul	1	2		Foraging (diving)	600-800

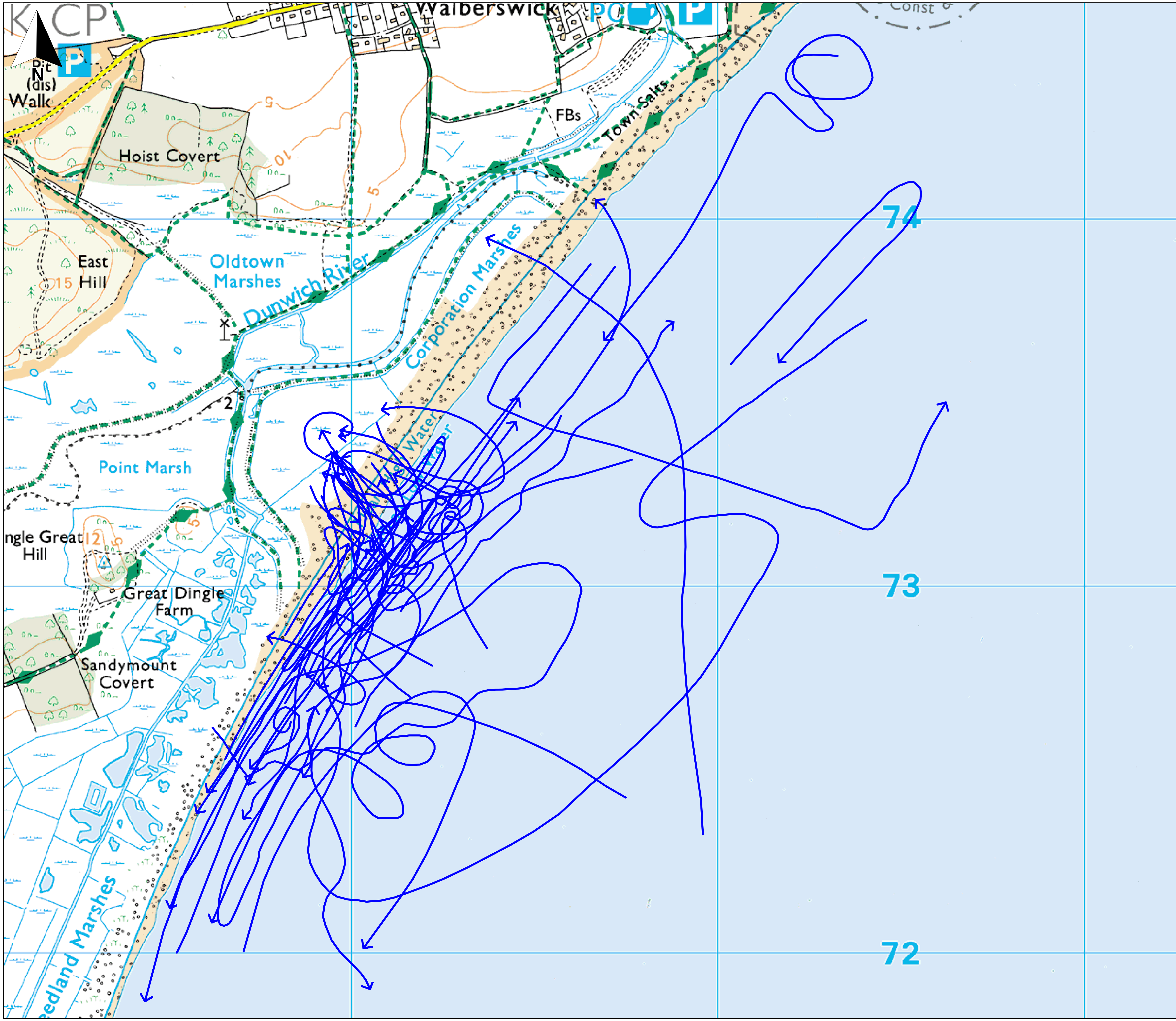
Table 4.2 (continued) Flights of Little Terns during foraging surveys

Survey date	VP	Count of birds	Flight direction	Activity	Distance offshore(m)
20-Jul	1	2		Foraging (diving)	300-400
20-Jul	1	3		Foraging (diving)	400-500
20-Jul	1	2		Foraging (diving)	600-800
20-Jul	2	1	North	Commuting	400-600
20-Jul	3	8	South	Commuting	400
20-Jul	6	2		Foraging (surface pickup)	500

The data presented in **Table 4.2** shows that much of the little tern activity was recorded on two survey dates: 8 June and 20 July. Most of the records of foraging terns were from VPs 1 and 2, located between Sizewell and Minsmere. The largest numbers of birds were recorded foraging offshore from VP1 on 20 July, including a peak count of 28 birds foraging and heading north towards Minsmere. Birds were also seen as far south as Thorpeness (VPs 5 and 6), although activity in this area was generally brief and involved small numbers of birds (2-3 birds seen on three survey dates). Apart from the activity noted on 20 July, very few birds were seen foraging offshore from Sizewell.

Much of the foraging activity between VPs 1 and 6 was in the shallows waters within 500m of the shore and involved birds diving to catch small fish. Results from the surveys provided no evidence to indicate that birds were flying further out to sea to forage. Figure 2.2 shows that potential feeding areas for little tern in the survey area and largely confined to shallow waters within 500m of the low water mark, apart from at Thorpeness, where a sand bank extends further offshore.

Sizewell B Power Station did however remain offline from 27 May until after the end of the survey period. As a consequence, fish numbers around the outfall were likely to be at much lower levels than normal (the warm water emitted from Sizewell B outfall attracts large numbers of fish to the area), and consequently the number of terns (particularly common tern) and gulls were likely to be much lower than normal. At least 15 common terns and 30 black-headed gulls were seen feeding around the outfall on 27 May (the last day it was operational during the survey period) after which very few were noted. Large numbers of common terns did however continue to forage offshore from Minsmere during June and early July.



Key

Flight line

0 m 500 m

Scale 1:10,000 @ A3

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Figure 4.1a

Flight lines of litte terns at the Dingle colony in May 2010

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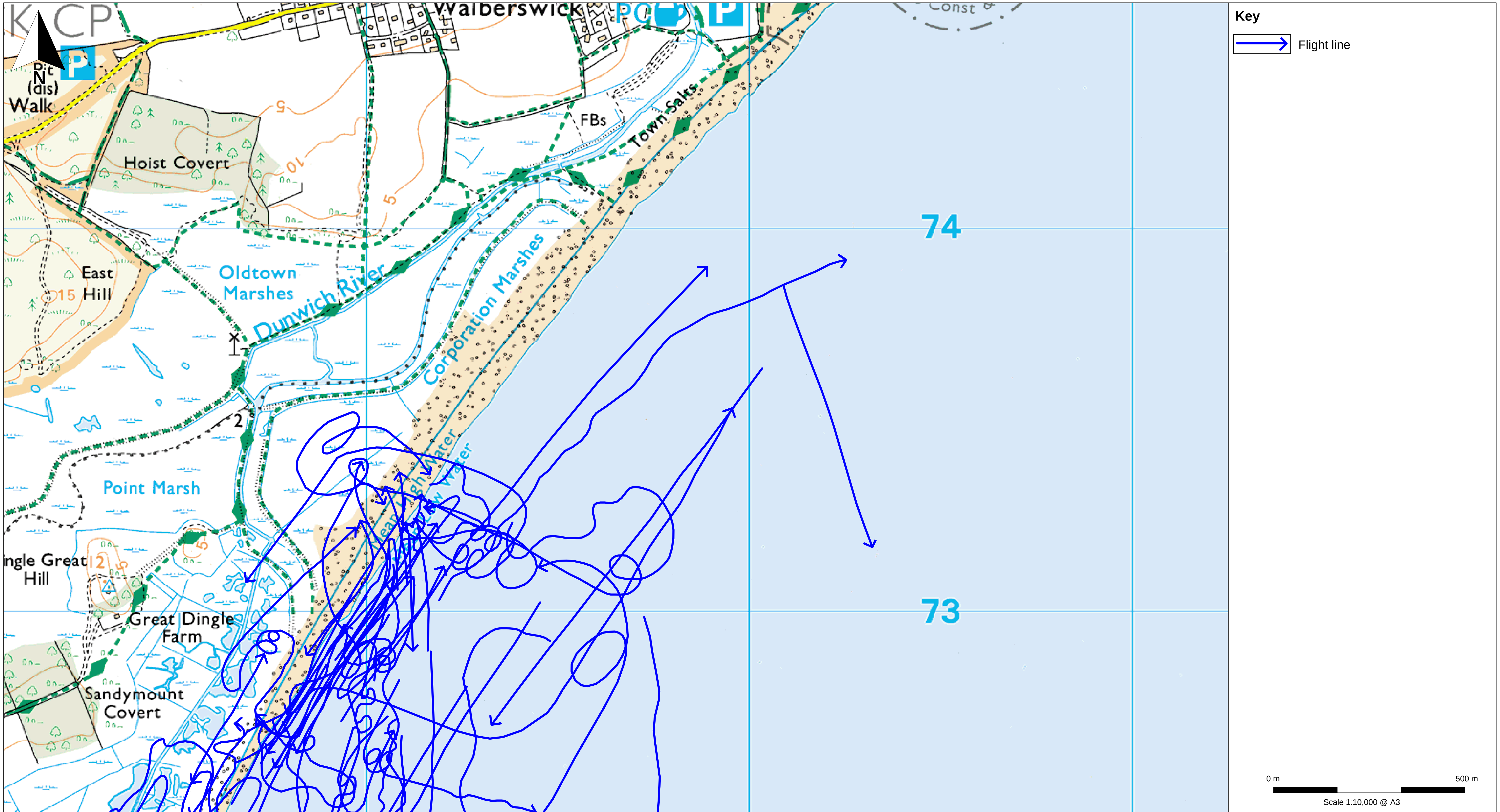

Sizewell Little Tern Report

Figure 4.1b

Flight lines of litte terns at the Dingle colony in June 2010

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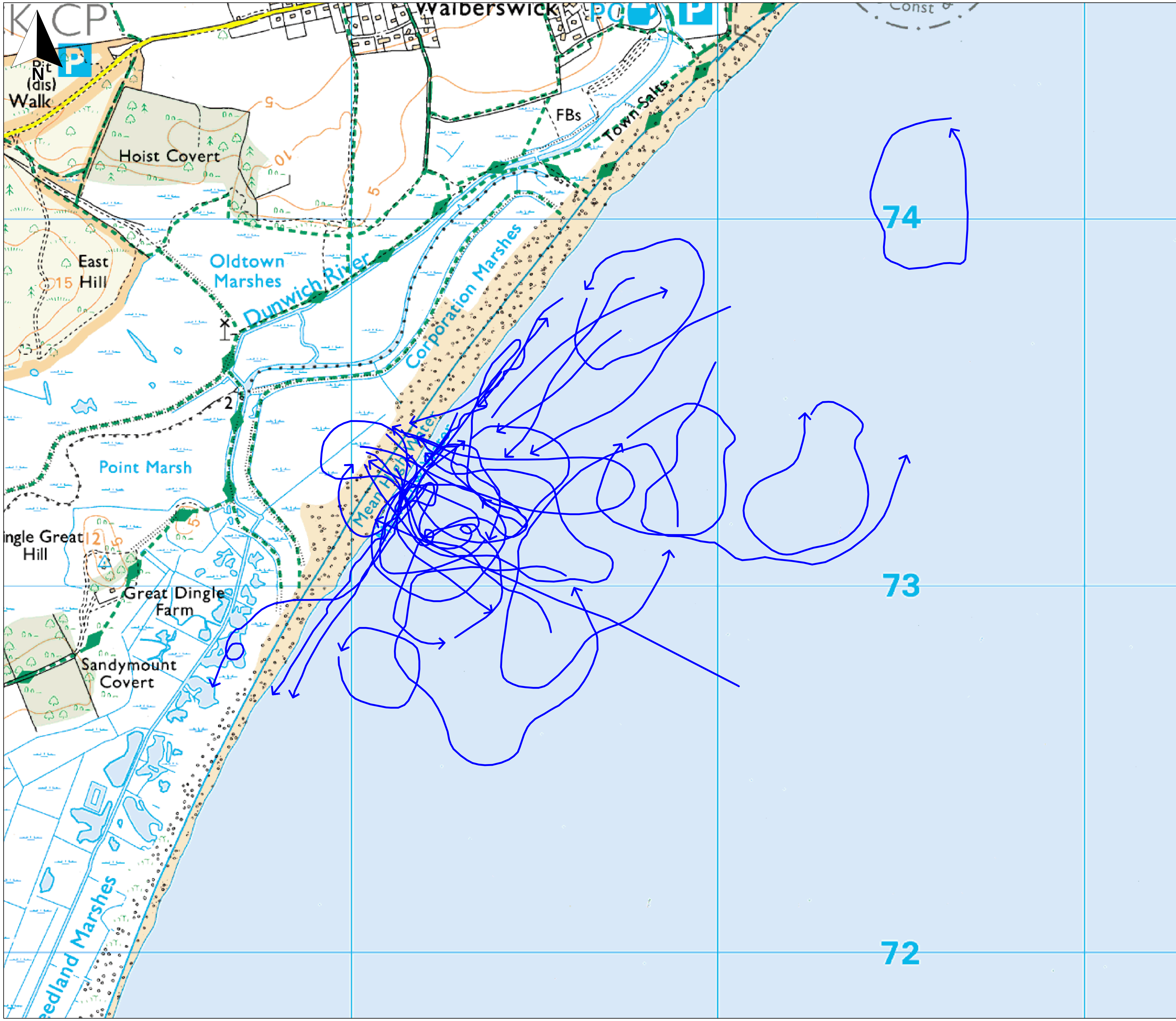

Key

Flight line

0 m 500 m

Scale 1:10,000 @ A3

Sizewell Little Tern Report

Figure 4.1c

Flight lines of litte terns at the Dingle colony in July and August 2010

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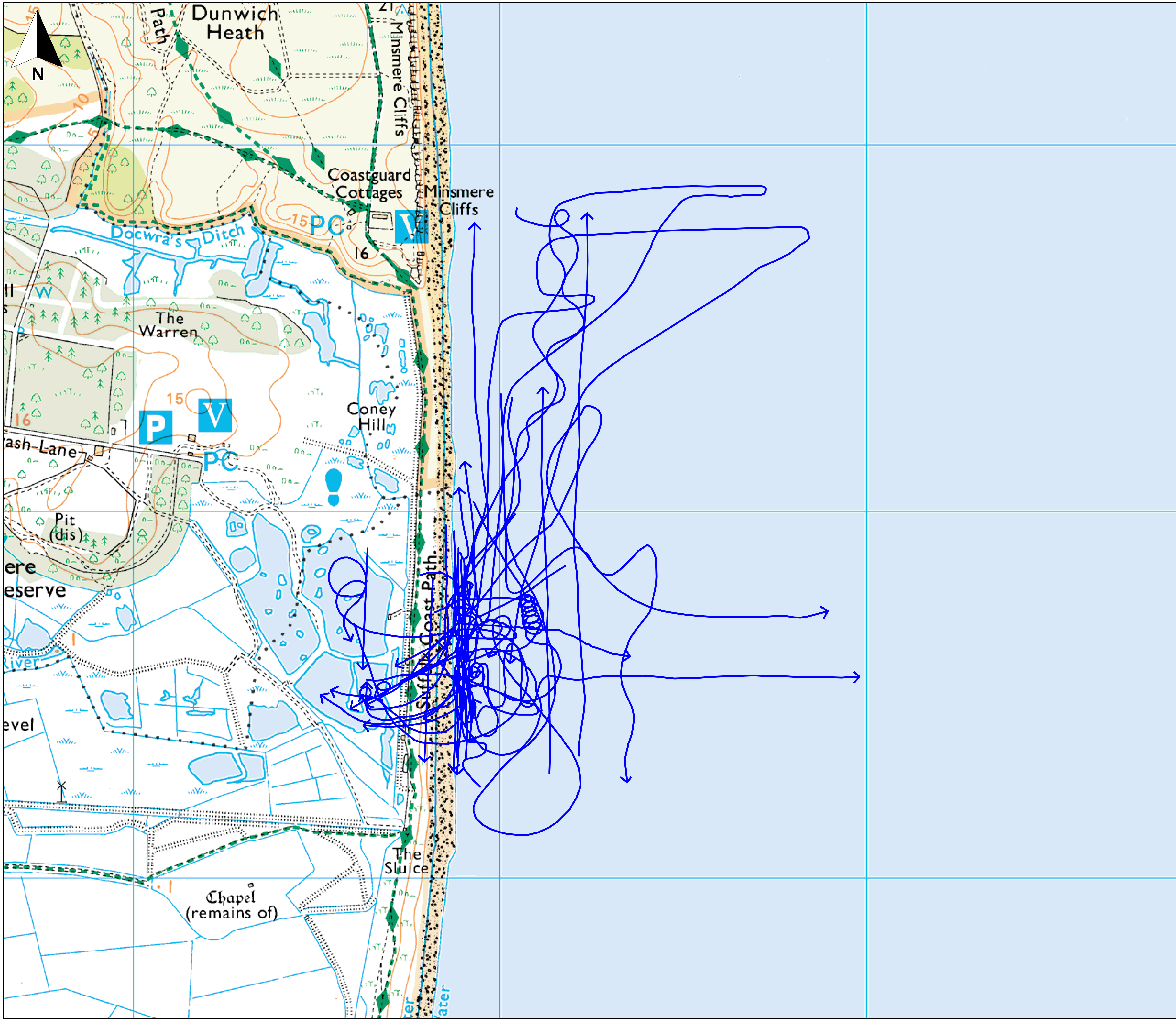


Key

Flight line

0 m 500 m

Scale 1:10,000 @ A3

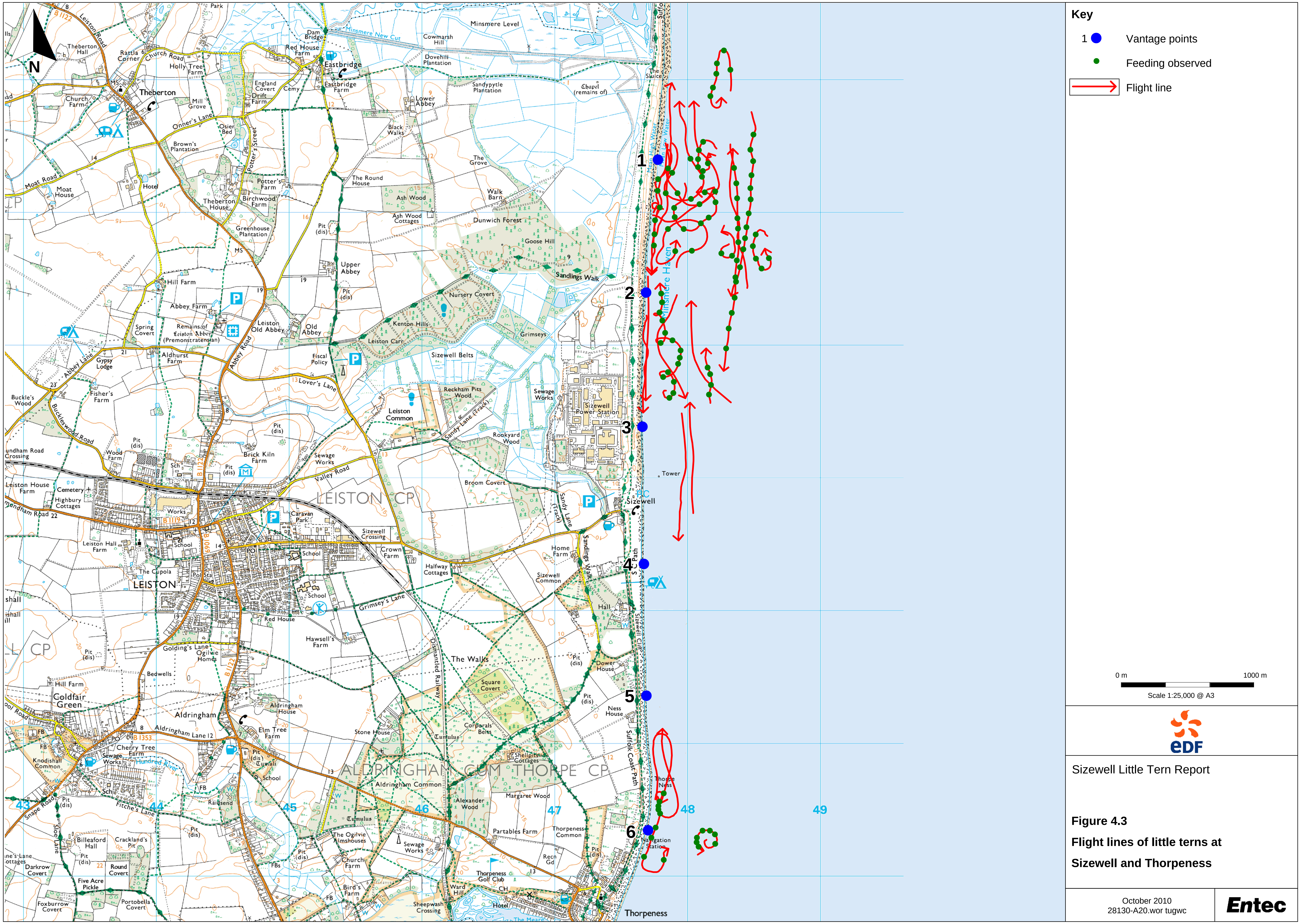
Sizewell Little Tern Report

Figure 4.2

Flight lines of litte terns at the Minsmere colony between May and August 2010

October 2010
28130-A17.wor tugwc

Entec



Sizewell Little Tern Report

Figure 4.3

Flight lines of little terns at Sizewell and Thorpeness

October 2010
28130-A20.wor tugwc

Entec

5. Discussion

5.1 Little Tern Prey Study

Before any conclusions can be reached regarding the likely impact of cooling water discharge on the main prey of little terns on the Suffolk coast, it must be emphasised that the potential area affected by water temperature increase is likely to be relatively small. In open coast conditions, such as those at Sizewell, the dispersal potential from any outfall is much greater than in a restricted bay. Prior to any assessment of impacts taking place, modelling of the plume would be required in order to evaluate the scale of the area which would be affected by waters of elevated temperatures. This would then need to be related to the size of the foraging area.

Despite uncertainties in the size of the area which would be affected, it is clear than even a 1^{o}C rise in temperature would take the ambient sea water temperatures above the range tolerated by both herring and ghost shrimps (18^{o}C) for a longer period of the year (up to 6 weeks more). Although juvenile herring inhabit inshore waters, there is evidence from further up the coast (Scroby Sands) that their numbers drastically decline in August (Perrow *et al.,* 2005), corresponding with water temperatures exceeding 18^{o}C. Juvenile herring remain in the inshore nursery areas for the first two years of their lives, and hence it would seem that they have simply moved to deeper waters within the nursery area where water temperatures would be lower. Juvenile herring are particularly important for little tern chicks, due to their high protein and fat content. Any decline in juvenile herring numbers, or movement into deeper water (thus making them unavailable to the little terns) earlier in the year may affect the breeding success of little terns.

Sprat, however, are tolerant of warmer water conditions, and compete with herring for the same food (zooplankton), hence any reduction in the number of herring may be accompanied by an increase in sprat. Little terns are known to be 'non-fussy' in their diet, and hence may simply switch to sprat instead of herring. However the juvenile sprat present during the summer months will be 1 year olds, as the young of the year (YOY) do not migrate to the inshore nursery grounds until autumn (ICES, 1990). One year old sprat are the same size, or smaller than 0-group herring, and therefore a switch to sprat should not present a problem to little terns, in terms of prey size. In terms of numbers, it is predicted that the majority of the sprat stock biomass is made up of 0-group individuals, so it is possible that there would be less food available to little terns (i.e. the one-year old sprat would provide a smaller quantity of food to little tern, than the 0-group herring). However, sprats are abundant in the southern North Sea, and their relative abundance in the waters around Scroby sands has been recorded as equal to or greater than that of herring over a number of years (Perrow *et al*., 2005). Another potential problem for little terns, is that if herring are not available and sprat have a bad year (as with herring, stock is annually variable), there would be fewer options to them in terms of prey.

Warmer sea temperature could also affect the spawning and reproductive success of some of the little tern prey species. Sprat spawn offshore, hence would not be affected by increased water temperatures along the coast. Herring on the other hand, spawn inshore and their spawning is temperature dependant (Anderson & Karas, 1990). One possible impact of elevated water temperatures would be to prolong the autumn spawning period into winter. The impact of an extended spawning period is not known, however given the small area that would be affected, compared to the size of herring spawning areas, is unlikely to impact the herring population as a whole.

Spawning in ghost shrimps and *Idotea linearis* are also dependant on temperature and an increase of ambient water temperature of just 1^oC would take the temperature over their optimum reproductive range for several extra weeks per year. As these crustacean species are none-migratory and have small home ranges, this affect could potentially impact their populations on a small spatial scale.

In terms of the potential for greater predation and/or competition with increased water temperatures, this is particularly difficult to assess in the marine environment owing to the numerous life history stages and complex food webs of marine organisms. Given the limited area likely to be affected by the cooling water, any changes in rates of predation or competition are unlikely to affect the populations of little tern prey species.

The extent to which the cooling water discharge will affect the habitat and food webs of the four prey species, primarily depends on whether the cooling water will be chlorinated. Herring, sprat and *Idotea linearis* all feed on zooplankton and the ghost shrimp feeds on detritus. Both these food sources ultimately depend on phytoplankton, the production of which is negatively affected by chlorination of the water.

In the absence of chlorination, localised warming may result in an increase in phytoplankton production, if sufficient nutrients are available. Any increase in the phytoplankton biomass will allow a greater zooplankton production and thus greater food availability for herring, sprat and ghost shrimp, and ultimately *Idotea linearis*. Hence these species may congregate to feed within the area of the cooling waters, so long as the maximum temperature they can tolerate is not exceeded.

5.2 Little Tern Surveys

Data provided by Alan Miller (SWT Warden) indicates that at least 3-4 pairs of little tern attempted to breed at Dingle in 2010, but failed to fledge any young. Nearby, at Dunwich, 10 pairs also attempted to breed but again failed to rear any young, due to predation by gulls. North of Dingle, birds at Kessingland also failed, but 30 pairs at Benacre managed to fledge 15 young. Results from the Entec colony surveys undertaken in 2010 support the findings from SWT in that there was no evidence of successful breeding at Dingle. Results from the Entec surveys indicated that breeding was not attempted at the Minsmere colony (3km north of Sizewell) in 2010. Breeding numbers at colonies along the Suffolk coast have varied considerably between years (see **Table 5.1**).

Table 5.1 Numbers of Little Tern at colonies in Suffolk (2005-08)[3]

Colony	Approx. Distance from Sizewell	2009	2008	2007	2006	2005
Bawdsey	25km south	0	0	0	0	4
Benacre	20km north	0	N/a	N/a	40	9
Covehithe	19km north	0	0	0	0	4
Dingle Marshes	9km north	11	2	2	2	1
Dunwich	6km north	20	0	0	0	0
Havergate Island	16km south	0	0	0	3	0
Kessingland	22km north	0	0	0	0	N/a
Minsmere	3km north	1	41	12	7	36
Slaughden	8km south	0	0	5	0	7
Trimley Marshes	33km south	0	0	0	0	10

Results from the foraging and colony surveys indicate that much of the foraging activity by little terns is concentrated close inshore (i.e. within 500-700m of the shoreline) around the colonies. Birds were however seen commuting along the shoreline and close inshore waters to forage further affield. Foraging activity was recorded off Sizewell beach and as far south as Thorpeness (12km south of the Dingle colony). Preliminary modelling work to assess where the cooling water discharge might flow (from a potentially suitable location for the new outfall facility), indicates that close inshore waters to the south of Sizewell will be potentially most effected (at least as far south as Thorpeness).

Sizewell is located 3km south of the Minsmere little tern colony and therefore is within the regular foraging range of 5km for this species (Langston, 2008). The cooling waters emitted from the proposed outfall at Sizewell will spread south and therefore away from the Minsmere (and Dingle and Dunwich) tern colony. Shallow waters that are suitable for foraging little tern that could be potentially effected by the cooling water discharge are located adjacent to the beach between Sizewell and Thorpeness. These foraging grounds are located 3-6km south of Minsmere and therefore are partly within the regular foraging range for little terns provisioning chicks with small fish. Perrow *et al*., (2005) found that most foraging activity for the provisioning of chicks around the Norfolk colonies at Winterton and Great Yarmouth occurred within approximately 2km of the breeding sites. Results from the colony surveys also indicate that much of the foraging activity around the Minsmere and Dingle colonies occurs close by (i.e. within 500-700m). Results from the foraging surveys between Sizewell and Thorpeness indicate that little terns also make occasional (albeit relatively infrequent) forays into the shallow waters south of Sizewell to hunt for fish. There was no evidence from either the colony or foraging surveys to indicate that little terns were routinely heading further out to sea to hunt over any offshore sandbanks.

[3] Data derived from Suffolk Birds 2005-2008 respectively

The Sizewell B outfall was not operational during much of the 2010 survey period (it remained offline from 27 May until after the end of the survey period), although little terns (unlike common terns) are not known to concentrate in this area for feeding (pers. Comm. Robin Harvey, Minsmere RSPB warden).

Overall, evidence from the desk study and 2010 surveys indicates that little tern foraging activity is likely to be concentrated in shallow waters close to the breeding colonies (see Figures 2.2 and 2.3), with occasional forays by birds further along the coast into the area potentially affected by the cooling water discharge. However, the situation in 2010 was complicated by the absence of operational Sizewell B outfall facility throughout much of the survey period, the lack of breeding at Minsmere and by the presence of large numbers of failed breeding birds (from a colony or colonies to the north of Dingle) during late June and early July. The increase in sightings of little tern foraging between Sizewell and Thorpeness on 20 July could also have been due to the presence of failed breeders from colonies outside Dingle/Minsmere. It is likely that the foraging grounds to the south of Sizewell are used occasionally by little terns from the Minsmere and Dingle colonies. The Dingle colony is however located 9-12km north of this area and is therefore well outside the usual foraging range for birds provisioning chicks (see Figure 1.1). Larger numbers of little terns may occur in this area, due to breeding failure at Dingle or Minsmere, but also from other colonies along the Suffolk and Norfolk coast.

6. Conclusions

The most likely and potentially significant affect is that warmer water temperatures (+18^{o}C) in summer (June – September) may prompt avoidance behaviour by herring and ghost shrimp. Sprat and *Idotea linearis* are more tolerant of warmer water conditions and may take advantage of the lack of competition and increase in numbers in this area. How this will affect little terns in unknown.

Results from the desk study and surveys undertaken at the Minsmere and Dingle colonies, and between Sizewell and Thorpeness indicate that much of the foraging activity (for the provisioning of chicks) is concentrated close (i.e. within 2km) to the colonies, and that the suitable foraging areas between Sizewell and Thorpeness that could be potentially effected by the cooling water discharge are not important hunting grounds for this species. This suggests that the proposed development at Sizewell is unlikely to adversely effect the Minsmere and Walberswick SPA little tern population.

However, breeding did not occur at Minsmere in 2010, a colony which is located within the regular foraging distance of the potentially effected feeding grounds south of Sizewell. During years when large numbers of little tern breed at Minsmere (for example, in 2008), greater use maybe made of foraging grounds around and to the south of Sizewell (i.e. those that might be potentially effected by the cooling water discharge). The interchange of birds between the Dingle and Minsmere colonies is most likely due to prey availability close to the colony locations, but also due to the suitability of the nesting habitat and colony site (Robin Harvey, RSPB warden, email dated 13 December 2010). Robin Harvey also notes that the beach at Minsmere has been eroded in the last two years to such an extent that it is now relatively narrow. As a consequence of this, the effects of disturbance by humans on nesting little terns have become greater. In contrast, the beach at Dingle is widening and becoming flatter, providing a greater area of suitable nesting ground for little tern. In the medium to long-term, Minsmere beach may cease to provide a suitable location for nesting little terns.

There also remain uncertainties about the extent of the plume of cooling water (i.e. how far it will extend along the coast), and the degree of warming predicted. Recent modelling work indicates that the plume may extend south of Thorpeness, as far south as Orfordness. If this were to happen, there would be the potential for the cooling waters to affect little terns breeding at Slaughden (part of the Alde-Ore Estuary SPA). A breeding population of little tern of European importance (48 pairs, Stroud *et al.*, 2001) is a qualifying feature for the Alde-Ore Estuary SPA, and therefore there is the potential for the development to effect the integrity of the SPA.

In light of these uncertainties, further work to determine where little terns are foraging along the coast may need to be undertaken. It is also recommended that once modelling work has been completed to determine where the plume is predicted to spread, the overlap between the plume and shallow waters is mapped, and the proportion of the Minsmere colony's foraging area (potentially lost) calculated.

7. References

Allen Navarro, K. Turtle, C., Clayton, E. & Smart, M. (2004). Great Yarmouth Little tern colony: Annual Report 2003. Royal Society for the Protection of Birds, Sandy, Beds, 27pp.

Anon. (2006). Birds of the Western Palearctic. Interactive DVD. v2 Birdguides ltd. 2002-2006.

Anon. (2009). Herring in the North Sea (ICES Division IV, VIId and IIIa). The Centre for Environment, Fisheries & Aquaculture Science Lowestoft. Available at: http://www.cefas.co.uk/media/31684/herringnorthsea.pdf

Andersson, J. & Karas, P. (1990). *Effects of cooling water discharges on spring spawning Baltic herring* (*Clupea harengus* L.). National Swedish Environmental Protection Agency, Marine section, Coastal Laboratory, Sweden.

Bailey, R.S. (1980). Problems in the management of short-lived pelagic fish as exemplified by North Sea sprat. *Rapp p-v Reun (Dan)***177**: 477-488.

Boscarino, B.T., Rudstam, L.G., Mata, S., Gal, G., Johannsson, O.E. & Mills, E.L. (2007). The effects of temperature and predator–prey interactions on the migration behaviour and vertical distribution of *Mysis relicta*. *Journal of Limnology and Oceanography*, **52**(4), 1599–1613.

Casini, M., Cardinale, M. & Hjelm, J. (2006). Inter-annual variation in herring, *Clupea harengus*, and sprat, *Sprattus sprattus*, condition in the central Baltic Sea: what gives the tune? *Oikos* **112,** 638–650.

Casini, M., Cardinale, M. & Arrhenius F. (2004). Feeding preferences of herring (*Clupea harengus*) and sprat (*Sprattus sprattus*) in the southern Baltic Sea. *ICES Journal of Marine Science*: *Journal du Conseil* **61**(8):1267-1277.

Chuang, Y., Yang, H. & Lin, H. (2009). Effects of a thermal discharge from a nuclear power plant on phytoplankton and periphyton in subtropical coastal waters. *Journal of Sea Research* **61** (4), pp 197-205

Coull, K.A., Johnstone, R., & Rogers, S.I. (1998). *Fisheries Sensitivity Maps in British Waters*. Published and distributed by UKOOA Ltd.

Gutow, L. & Franke, H.D. (2001). On the current and possible future status of the neustonic isopod *Idotea metallica* Bosc in the North Sea: a laboratory study. *Journal of Sea Research* **45** (1), 37-44

Hostens, K. & Mees, J. (1999). The mysid feeding guild of demersal fishes in the brackish zone of the westerschelde estuary. *Journal of fish biology* **55**, 704-719.

ICES (1990). Report of the Sprat Biology Workshop. *Cooperative Research Reports* No. 169, 16 pp.

Ilus E & Keskitalo, J. (2008). The response of phytoplankton to increased temperature in the Loviisa archipelago, Gulf of Finland. *Boreal environmental research*, **13**; 503-516

Köster, F.W., & Möllmann, C. (2000). Egg cannibalism in Baltic sprat *Sprattus sprattus*. *Marine Ecology Progress Series* **196**, 269–277.

Langston, R. (2008). Round 3 offshore wind farm developments and birds at sea. RSPB, Sandy.

Lane, A. & Prandle, D. (1996). Inter-annual variability in the temperature of the North Sea**.** *Continental Shelf Research*. Volume **16**, Issue 11, Pages 1489-1507

Leifsson, B.R., (1999). Life cycles, breeding periods and vertical distribution of *Idotea granulosa* Rathke and *I. pelagica* Leach (Crustacea, Isopoda) on Icelandic shores. *Sarsia*, **83**(1), 1-13.

MacKenzie, K. (1985). The use of parasites as biological tags in population studies of herring (Clupea harengus L.) in the North Sea and to the north and west of Scotland. *Journal du Conseil International pour l'Exploration de la Mer* **42**: 33-64.

Makings, P. (1977). A guide to the British coastal Mysidae. *Field Studies* **4,** 575-595

Mason, N. [ed] (2010). *Suffolk Birds 2009*. Suffolk Naturalists' Society.

Mason, N. [ed] (2009). *Suffolk Birds 2008*. Suffolk Naturalists' Society.

Mason, N. [ed] (2008). *Suffolk Birds 2007*. Suffolk Naturalists' Society.

Mauchline, J. (1967). The biology of *Schistomysis spiritus* [Crustacea, Mysidacea]. *Journal of the Marine Biological Association of the United Kingdom*, **47**, 383-396

Möllmann, C., Kornilovs, G., Fetter, M. and Köster, F. W. (2005). Climate, Zooplankton and pelagic fish growth in the Central Baltic Sea. *ICES Journal of Marine Science*, **62,** 1270-1280.

Moore J. W. & Moore, I.A. (1974). The basis of food selection in some estuarine fishes. Eels, *Anguilla anguilla* (L.), whiting, *Merlangius merlangus* (L.), sprat, Sprattus sprattus (L.) and stickleback, *Gasterosteus aculeatus* L. *Journal of Fish Biology* **9** (5), Pages 375 – 390.

Peck, M. A. & Mőllmann, C. (2008). *RECLAIM – resolving climatic impacts on fish stocks. Specific targeted research on "modernisation and sustainability of fisheries including aquaculture based production systems".* Institute of hydrobiology and fisheries research, University of Hamburg.

Perrow, M. R., Skeate, E. R. & Tomlinson, M. L. (2005). *Scroby Sands Ornithological Monitoring; Assessing the potential impact of the proposed wind farm upon Little tern Sterna albifrons: the construction phase 2004.* ECON

Piotrowski, S. (2003). *The Birds of Suffolk.* A & C Black Publishers Ltd, London.

Poore, G. & Schotte, M. (2009). *Idotea linearis* (Linnaeus, 1766). In: Schotte, M., Boyko, C.B, Bruce, N.L., Poore, G.C.B., Taiti, S., Wilson, G.D.F. (Eds) (2009). *World Marine, Freshwater and Terrestrial Isopod Crustaceans database*. Accessed through the World Register of Marine Species at http://www.marinespecies.org/aphia.php?p=taxdetails&id=119046 on 2010-06-23

Poornima, E.H., Rajadurai, M., Rao, T.S., Anupkumar, B., Rajamohan, R., Narasimhan, S.V., Rao V.N.R., and Venugopalan. V.P. (2005). Impact of thermal discharge from a tropical coastal power plant on phytoplankton. *Journal of Thermal Biology* **30** (4), pp 307-316

Reid, R. N., Cargnelli, L. M., Griesbach, S. J., Packer, D. B., Johnson, D. L., Zetlin, C. A., Morse, W. W., & Berrien, P. P. (1999). *Essential Fish Habitat Source Document: Atlantic Herring, Clupea harengus, Life History and Habitat Characteristics.* NOAA Technical Memorandum NMFS-NE-126.

Stroud, D.A., Chambers, D., Cook, S., Buxton, N., Fraser, B., Clement, P., Lewis, P., McLean, I., Baker, H. & Whitehead, S. (eds). 2001. *The UK SPA network: its scope and content.* JNCC, Peterborough.

Torniainen, J. & Lehtiniemi, M. (2008). Predation pressure of littoral mysids on herring eggs and yolk sac larvae. *Journal of Experimental Marine Biology and Ecology* **367**: 247–252.

Vasconcelos, R., Prista, N., Cabral, H. & Costa, M. J. (2004). Feeding ecology of the lesser weever, *Echiichthys vipera* (Cuvier, 1829), on the western coast of Portugal. *Journal of Applied Ichthyology* **20** (3), 211-216.

Wear, R. G. (1974). Incubation in British Decapod Crustacea and the Effects of Temperature on the Rate and Success of embryonic Development. *Journal of the Marine Biological Association of the United Kingdom.* **54**, 745-762 745

Whitehead, P.J.P. (1985). FAO species catalogue. Vol. 7. Clupeoid fishes of the world (suborder Clupeioidei). An annotated and illustrated catalogue of the herrings, sardines, pilchards, sprats, shads, anchovies and wolf-herrings. Part 1 - Chirocentridae, Clupeidae and Pristigasteridae. FAO Fish. Synop. 125(7/1):1-303.

Whitehead, P.J.P. (1986). Clupeidae. *In* Fishes of the North-eastern Atlantic and the Mediterranean Volume I (Whitehead, P.J.P., Bauchot, M.-L., Hureau, J.-C., Neilsen, J., and Tortonese, E., eds.) UNESCO, Paris, 268-281.

Winkler, G. & Greeve, W. (2002). Laboratory studies of the effect of temperature on growth, moulting and reproduction in the co-occurring mysids *Neomysis integer* and *Praunus flexuosus. Marine Ecology Progress series* **235**, 177-188

WoRMS (2009). *Schistomysis spiritus* (Norman, 1860). In: Deprez, T. & all (2005). NeMys. World Wide Web electronic publication. Accessed through the World Register of Marine Species at http://www.marinespecies.org/aphia.php?p=taxdetails&id=120206 on 2010-06-23.

Wright, M. [ed] (2004). *Suffolk Birds 2003*. Suffolk Naturalists' Society.

Appendix A
Survey Dates and Times

5 Pages

Table A1 Dates and time of Little Tern colony surveys

Date	Time (from)	Time (to)	Colony surveyed	Low tide	High tide	Wave height (cm)	Wind direction	Wind strength (Beaufort Scale)	Cloud cover (of 8)	Precipitation	Visibility
04-May-10	13:20	15:20	Minsmere	07:55	14:09	150	NE	5	8	Raining	Moderate to good
04-May-10	16:40	18:40	Dingle	07:55	14:09	120	NE	4	7	Light rain	Good
05-May-10	08:30	10:30	Dingle	08:37	14:56	50	S	3	4	None	Good
05-May-10	12:45	14:45	Minsmere	08:37	14:56	50	S	2-3	2	None	Good
15-May-10	11:45	13:45	Dingle	17:26	23:33	5	NE	1	3	None	Good
15-May-10	16:00	18:00	Minsmere	17:26	23:33	5	NE	1	7	None	Very good
16-May-10	11:25	13:25	Minsmere	05:40	11:53	5	W	1-4	8	None	Very good
16-May-10	16:15	18:15	Dingle	18:10	00:19	5	W	3	5	None	Very good
20-May-10	08:55	10:55	Minsmere	08:42	14:57	30	SW	2	4	None	Very good
20-May-10	12:00	14:00	Dingle	08:42	14:57	30	S	2-3	6	Light rain	Very good
24-May-10	11:20	13:20	Minsmere	13:22	19:17	10	SE	1	1	None	Very good
24-May-10	14:40	16:40	Dingle	13:22	19:17	10	SE	2	2	None	Very good
29-May-10	07:45	09:45	Minsmere	06:09	12:29	50	SE	3	7	Showers	Very good
29-May-10	10:50	12:50	Dingle	06:09	12:29	50	SE	3	8	None	Very good
30-May-10	10:25	12:25	Minsmere	06:51	13:09	10	W	3	7-3	Light rain	Very good
30-May-10	14:45	16:45	Dingle	13:09	19:08	10	W	3-5	4	None	Very good
05-Jun-10	15:45	17:45	Dingle	11:55	18:18	10	N-W	1-2	5-8	None	Very good

Table A1 (continued) Dates and time of Little Tern colony surveys

Date	Time (from)	Time (to)	Colony surveyed	Low tide	High tide	Wave height (cm)	Wind direction	Wind strength (Beaufort Scale)	Cloud cover (of 8)	Precipitation	Visibility
05-Jun-10	18:50	20:50	Minsmere	11:55	18:18	20	NNE	3	8	None	Moderate to good (fog offshore)
06-Jun-10	09:10	11:10	Dingle	07:12	13:01	20	NNE	3-4	8	None	Moderate to good (fog offshore)
06-Jun-10	12:40	14:40	Minsmere	13:01	19:13	20	NE	3	8	None	Good
11-Jun-10	12:00	14:00	Dingle	10:47	16:38	30	Variable	1	8	None	Good
11-Jun-10	15:40	17:40	Dingle	16:38	23:08	20	E	2	1	None	Very good
12-Jun-10	08:15	10:15	Dingle	05:07	11:32	10	W	2	8-5	None	Very good
12-Jun-10	12:25	14:25	Minsmere	11:32	17:30	20	W	2-3	4-2	None	Very good
21-Jun-10	13:45	15:45	Dingle	13:00	19:12	30	E	1-2	8-2	None	Very good
21-Jun-10	16:50	18:50	Minsmere	13:00	19:12	20	E	1	2	None	Very good
22-Jun-10	09:20	11:20	Minsmere	08:50	14:50	20	NE	2-3	0	None	Very good
22-Jun-10	13:45	15:45	Dingle	14:50	21:13	20	ENE	2	1	None	Very good
29-Jun-10	09:10	11:10	Minsmere	07:57	14:16	20	SE	3	3	None	Good
29-Jun-10	15:40	17:40	Dingle	14:16	20:25	50	SE	4-5	6	None, but heavy rain nearby	Good
30-Jun-10	09:15	11:15	Dingle	08:31	14:52	50	SE	3	4	None	Very good
30-Jun-10	16:00	18:00	Dingle	14:52	21:00	50	SE	3-4	6	None	Very good
05-Jul-10	07:50	09:50	Dingle	08:58	15:22	60	W	4	2	None	Very good
05-Jul-10	11:20	13:20	Minsmere	08:58	15:22	60	W	4	2	None	Very good

Table A1 (continued) **Dates and time of Little Tern colony surveys**

Date	Time (from)	Time (to)	Colony surveyed	Low tide	High tide	Wave height (cm)	Wind direction	Wind strength (Beaufort Scale)	Cloud cover (of 8)	Precipitation	Visibility
07-Jul-10	07:10	09:10	Dingle	00:00	06:48	120	S	6	7	None	Very good
07-Jul-10	10:40	12:40	Minsmere	12:18	18:36	80	S	6-4	8	Light rain	Good
13-Jul-10	12:35	14:35	Dingle	12:44	18:52	50	NE	3	8	None	Very good
13-Jul-10	15:30	17:30	Dingle	12:44	18:52	50	ENE	2	8	None	Very good
14-Jul-10	11:00	13:00	Dingle	07:12	13:31	50	SE	3	8	Light rain	Good
14-Jul-10	13:50	15:50	Dingle	13:50	15:50	50	S	3	8	Light rain	Good
24-Jul-10	16:30	18:30	Dingle	16:35	23:11	20	S-W	2-3	4	None	Good
24-Jul-10	19:00	21:00	Dingle	16:35	23:11	20	W	2	4	None	Good
25-Jul-10	08:00	10:00	Dingle	04:52	11:13	10	NW	2	8	Light rain	Good
25-Jul-10	11:15	13:15	Dingle	11:13	17:20	10	NW	2	8	Light rain	Good
05-Aug-10	16:15	18:15	Dingle	12:31	19:02	5	E	1	2	None	Good
05-Aug-10	19:00	20:30	Dingle	19:02	01:21	5	E	0-1	3	None	Good
06-Aug-10	10:20	12:20	Dingle	07:51	13:51	30	SE	4	0	None	Good
06-Aug-10	14:00	15:30	Minsmere	13:51	20:29	30	SE	4	0	None	Good

Table A2 Dates and times of Little Tern foraging surveys

Date	Time (from)	Time (to)	VP	Low tide	High tide	Wave height (cm)	Wind direction	Wind strength (Beaufort Scale)	Cloud cover (of 8)	Precipitation	Visibility
10-May-10	08:45	09:20	1	01:51	08:34	60	NNE	4-5	6	None	Very good
10-May-10	09:50	10:35	2	01:51	08:34	90	NNE	4-5	3	None	Very good
10-May-10	10:55	11:40	3	01:51	08:34	100	NNE	5	2	None	Very good
10-May-10	12:00	12:45	4	14:07	19:57	80	NNE	4-5	6	None	Very good
10-May-10	13:05	13:50	5	14:07	19:57	60	NE	4	6	None	Very good
10-May-10	14:35	15:20	6	14:07	19:57	90	NE	4	6	Light rain	Very good
27-May-10	15:10	15:55	1	16:06	22:07	80	SSE	5-6	4	Light rain	Very good
27-May-10	14:10	14:55	2	16:06	22:07	90	SSE	4-5	2	None	Good, light heat haze
27-May-10	13:10	13:55	3	16:06	22:07	60	SSE	3-4	8	Light rain	Misty
27-May-10	12:05	12:50	4	16:06	22:07	60	SE	2-3	8	Light rain	Very good
27-May-10	10:20	11:05	5	16:06	22:07	60	SE	2	8	None	Good, light heat haze
27-May-10	09:15	10:00	6	16:06	22:07	100	S	1	8	None	Moderate, some heat haze
08-Jun-10	08:15	09:00	3	00:59	07:40	90	ESE	5-6	8	None	Very good
08-Jun-10	09:15	10:00	2	00:59	07:40	100	SE	5	8	Light rain	Moderate, some mist
08-Jun-10	10:15	11:00	1	13:11	19:14	90	ESE	5	8	None	Misty offshore at 1.5km
08-Jun-10	11:55	12:40	4	13:11	19:14	60	SE	4	7	Showers	Misty offshore at 1km
08-Jun-10	13:40	14:25	6	13:11	19:14	100	SE	3-4	2	None	Very good
08-Jun-10	14:40	15:25	5	13:11	19:14	60	SE	3-4	4	None	Very good

Table A2 (continued) Dates and times of Little Tern foraging surveys

Date	Time (from)	Time (to)	VP	Low tide	High tide	Wave height (cm)	Wind direction	Wind strength (Beaufort Scale)	Cloud cover (of 8)	Precipitation	Visibility
24-Jun-10	20:15	21:00	1	15:05	21:11	20	N	3	3	None	Very good
24-Jun-10	19:15	20:00	2	15:05	21:11	20	NNW	3-4	7	None	Very good
24-Jun-10	18:15	19:00	3	15:05	21:11	30	NNW	4	8	None	Very good
24-Jun-10	17:15	18:00	4	15:05	21:11	20	NW	2	7	None	Very good
24-Jun-10	16:15	17:00	5	15:05	21:11	30	S	3	7	None	Good, a little heat haze
24-Jun-10	15:15	16:00	6	15:05	21:11	40	S	3	6	None	Very good
05-Jul-10	17:55	18:40	1	08:58	15:22	70	E	5-6	2	None	Very good
05-Jul-10	17:00	17:45	2	08:58	15:22	60	NE	5	5	None	Very good
05-Jul-10	15:55	16:40	3	08:58	15:22	40	SE	5-6	5	None	Very good
05-Jul-10	14:55	15:40	4	08:58	15:22	40	S	4-5	4	None	Very good
07-Jul-10	14:50	15:35	5	08:58	15:22	90	S	4-5	6	None	Very good
07-Jul-10	13:50	14:35	6	08:58	15:22	100	S	5	8	None	Very good
20-Jul-10	08:15	09:00	1	11:00	17:34	20	SE	3	7	None	Very good
20-Jul-10	09:55	10:40	2	11:00	17:34	15	SE	3	8	None	Very good
20-Jul-10	11:00	11:45	3	11:00	17:34	20	SE	3	7	None	Moderate heat haze
20-Jul-10	11:55	12:40	4	11:00	17:34	20	SE	3	8	None	Moderate heat haze
20-Jul-10	15:00	15:45	5	11:00	17:34	25	SE	4	8	None	Misty at 1km
20-Jul-10	14:00	14:45	6	11:00	17:34	15	SE	2	7	None	Moderate heat haze