A study of the biology of three species of terns on Foulney Island, Cumbria

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A STUDY OF THE BIOLOGY OF THREE SPECIES OF TERNS ON FOULNEY ISLAND, CUMBRIA

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CONTENTS

INTRODUCTION

The present study was concerned with the biology of three species of terns occurring in the same geographical region. Since all three species, the Sandwich Tern Sterna sandwicensis Lath, Common Tern S.hirundo L., and the Arctic Tern S.paradisaea Brunn, bred on the same island it was possible to study their breeding biology simultaneously, giving specific comparisons more validity.

The theory known variously as Gause's Law (hypothesis, theory) or Grinell's Axiom, which states that, "two species with similar ecology cannot live in the same region," (Lack 1946), has been a subject of much debate and controversy. There are many other variants of this hypothesis (see Gilbert, Reynoldson and Hobart 1952, Allee et al. 1949, Sperber 1947 and Udvardy 1951) which was derived from Gause's theoretical and experimental analysis (Gause 1934). The idea was first propounded by Darwin (1859) who said "As the species of the same genus usually have, though by no means invariably, much similarity in habits and constitution and always in structure, the struggle will generally be more severe between them, if they come into competition with each other, than between species of distinct genera." Mayr (1963) pointed out that it is erroneous to assume that because there is no physical combat there is no competition. Birch and Ehrlich (1967) have criticised the value of evolutionary ecology in interpreting present situations. They refute that present species divergence is explicable through past competition. However Lack (1944, 1945, 1947, 1954) has shown that closely related species tend to occupy different niches in the same habitat, and if one species was absent the related species often occupied the vacant niche. Also where two closely related species overlap in part of their range, they tend to differ markedly in this area, structurally, as well as in plumage, which suggests niche divergence, eg: Sittu neumayer and S.tephronata.

The ecology of closely related species has been examined in many cases (see Mayr 1963). Studies have been made on spiders Tretzel (1955), and psocids Broadhead (1958), amongst invertebrates, and on reptiles Carpenter (1952), Milstead (1957, 1961), and fish Nilsson (1955, 1960) amongst vertebrates. However most studies have dealt with closely related species of birds. Lack (1945, 1946, 1947) has examined the ecology of the Cormorant *Phalacrocorax carbo* L. and the Shag *P.aristotelis* L., various birds of prey, and species of ground finches *Geospiza* species. The biology of the Herring Gull *Larus argentatus* Pont. and the Lesser Black-backed Gull *L.fuscus* L. have been compared (Paludan 1957, Harris 1964, Brown 1967). Studies on closely related passerine species have been carried out by Hartley (1953) and MacArthur (1958).

Studies on the biology of terns prior to 1960 have been largely behavioural, and carried out on individual species. The Sandwich Tern has been studied by Desselberger (1929), Steinbacher (1931), Dicksen (1932) and Assen (1954a, 1954b). The Common Tern has had a more detailed treatment by Tinbergen (1931), Southern (1938), Palmer (1940, 1941) and Austin (1946b, 1947, 1949, 1951). The Arctic Tern being studied by Cullen (1956). The ecological studies are mostly confined to the Common Tern (Austin 1929) and Arctic Tern (Pettingill 1939, Bullough 1942, Hawksley 1950 and Grosshopf 1957).

Prior to 1960 comparative studies were limited to the general account by Marples and Marples (1934), and the study by Formosov who investigated the ecology of the Sandwich Tern, Common Tern, Gull-billed Tern *Sterna nilotica* G.M., and the Little Tern *S.albifrons* Pall., where, although no evidence was provided, it was stated that these four had distinct feeding niches, so that competition for food was avoided.

The last eighteen years has brought an increase in the number of comparative ecological studies. Cullen (1960a) relating to nesting adaptation in terns. Boecker (1967) comparing the Common and Arctic Terns found specific differences in respect to both nesting and feeding behaviour. Three major studies (Pearson 1964, Langham 1968 and Dunn 1972) have compared in detail the Sandwich, Common, Arctic and Roseate Terns on Coquet and the Farne Islands, Northumberland. Dunn and Pearson concentrated on the feeding ecology, whilst Langham took a more general approach. In all three cases it was found that resources were partitioned in varying degrees, thus avoiding or at least reducing competition.

The present study has set out to examine the breeding biology of the Sandwich, Common and Arctic Terns in respect to nesting behaviour, content and method of food acquisition, and breeding success, in order to determine whether competition for any resource was taking place.

STUDY AREAS

Morecambe Bay is noted for the large numbers of waders, which over-winter on the extensive mud-flats made available at low tide. During the summer the extreme Western region of the bay provides sites for a large gullery on the South end of Walney Island, and a tern colony on Foulney Island, Cumbria (grid reference S.D. 246642). The major part of this study was made on the latter island, which is situated at the South West end of Morecambe Bay. The study area also included areas of the adjoining coastline (Fig.1). Foulney is the last remaining breeding station of terns in Morecambe Bay. Apart from a few Little Terns and Common Terns at Millom c. 16.5 km. to the North, the nearest major colony is at Ravenglass c. 38 km. North.

Foulney Island lies 2 km. from the mainland and is connected by a foot causeway to the road embankment joining Roa Island to Rampside village. The island consists of a mildly undulating plateau with a maximum height of 3 m. above sea level. It has an area of c. 14 h.a. and is roughly diamond shape, with the long axis running in a N.N.W. to S.S.E. direction. The spit, which contains the tern colony, extends due N. (Fig.1). The island is covered by low lying vegetation (Appendix 1) and the distribution of the dominant species of the spit are shown in Fig. 2. The substratum is of boulder clay and sand, covered by shingle. The dominant feature of the area is the size of the littoral zone, which extends for up to 3½ km. from the mainland (Fig.3).

The surrounding coastline may be divided into: (a) Silt, sand substratum, although particle size and shore gradient varies in place and time. This general division, with its associated Spartina x townsendii (upper shore) and Zostera marina (mid shore) is characteristic of the study area east of Walney Island; (b) The Piel Channel, a deep water channel which extends from Barrow docks to the south end of Walney. This is prevented from "silting-up" by extensive dredging activity; (c) The mussel (*Mytilus edulis*) beds, the larger of which (c. 64 h.a.) lies to the South of Foulney, and the smaller at Head Scar North West of Roa Island (see Fig. 3). The mussel beds are commercially farmed, and these quite extensive areas withhold large volumes of water in shallow pools at low tide; (d) West of Walney Island the foreshore, which is exposed directly to the Irish Sea, has a lower silt content and steeper gradient than those described in (a).

In addition to the terns, Foulney Island supports a small colony of Black-headed Gulls *Larus ridibundus* L., 19 pairs of Eider Duck *Somateria mollissima* L., and one pair of Red-breasted Mergansers *Mergus serrator* L. Other species nesting in small numbers include Oystercatchers *Haematopus ostralegus* L. (c. 18 pairs), Ringed Plovers *Charadruis hiaticula* L. (c. 23 pairs), Redshanks *Tringa totanus* L. (3 pairs), Lapwings *Vanellus vanellus* L. (4 pairs), Skylarks *Alauda arvensis* L. (c. 15 pairs) and Meadow Pipits *Anthus pratensis* L. (c. 11 pairs).

The small mammal population is dominated by rabbits, breeding sites being present on the causeway and main island but absent from the spit, although foraging occurs in this area.

The brown rat *Rattus norvegicus* is believed to have been exterminated from the island. The effect of this species is dealt with further in the following section.

Anthropogenic factors are limited to the main island, entry to the spit being restricted between April 1st - August 15th.

Figure 1. Study Area

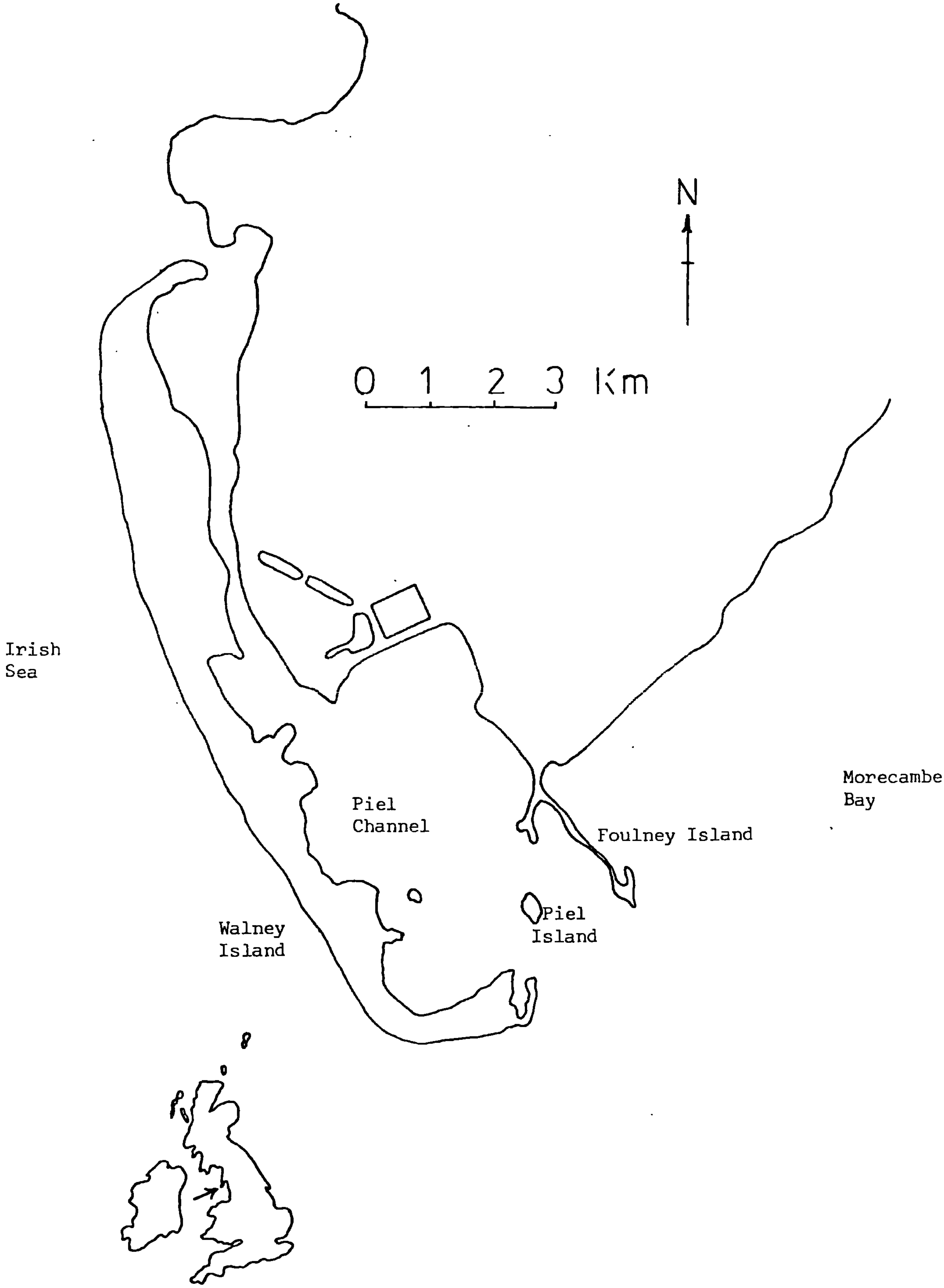


Fig. 2 Overlay, shows the nesting areas of all three Tern species.

= Arctic Tern

= Sandwich Tern

= Common Tern

Figure 2. Map of Slitch Ridge Showing Dominant Vegetational Areas

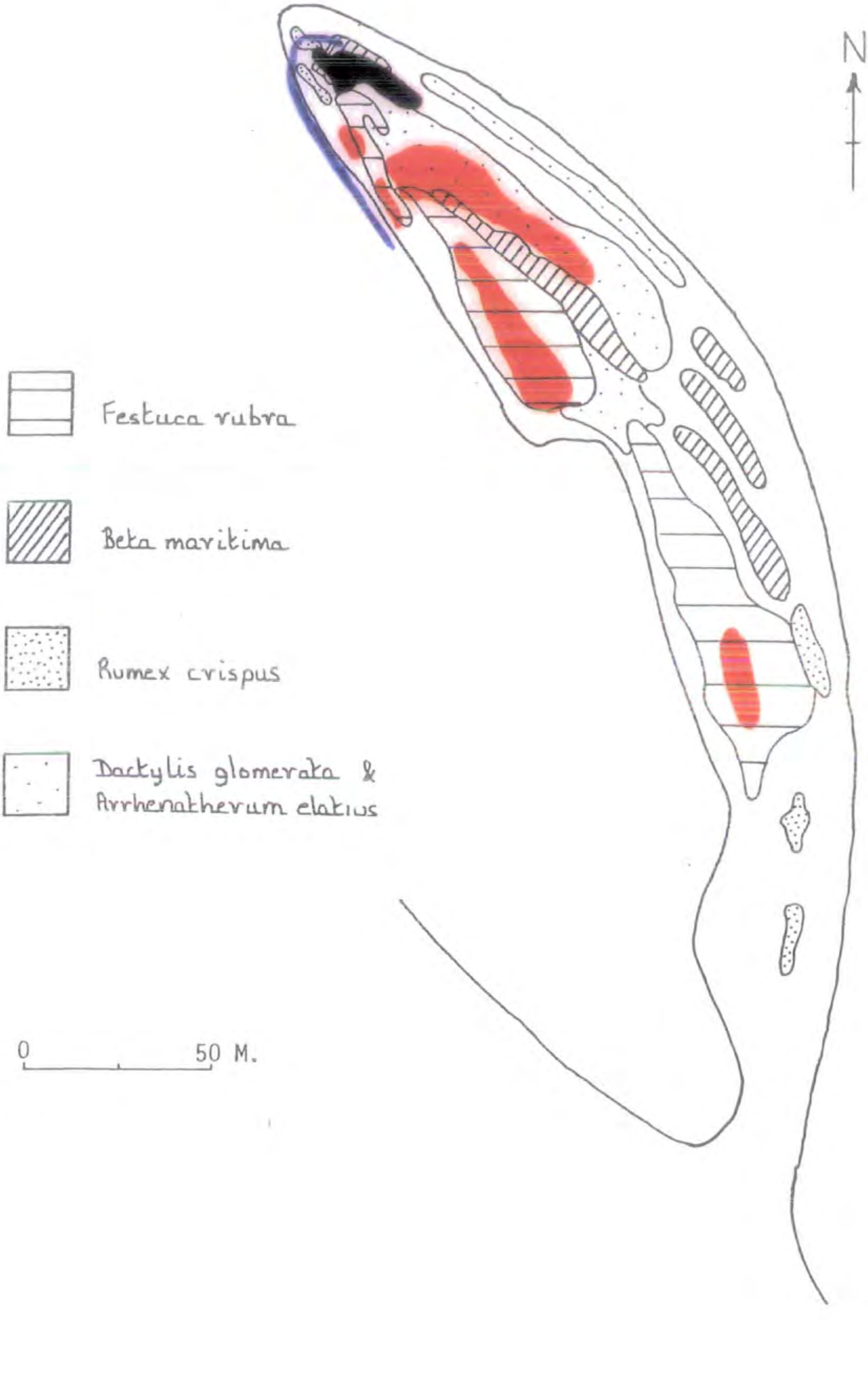
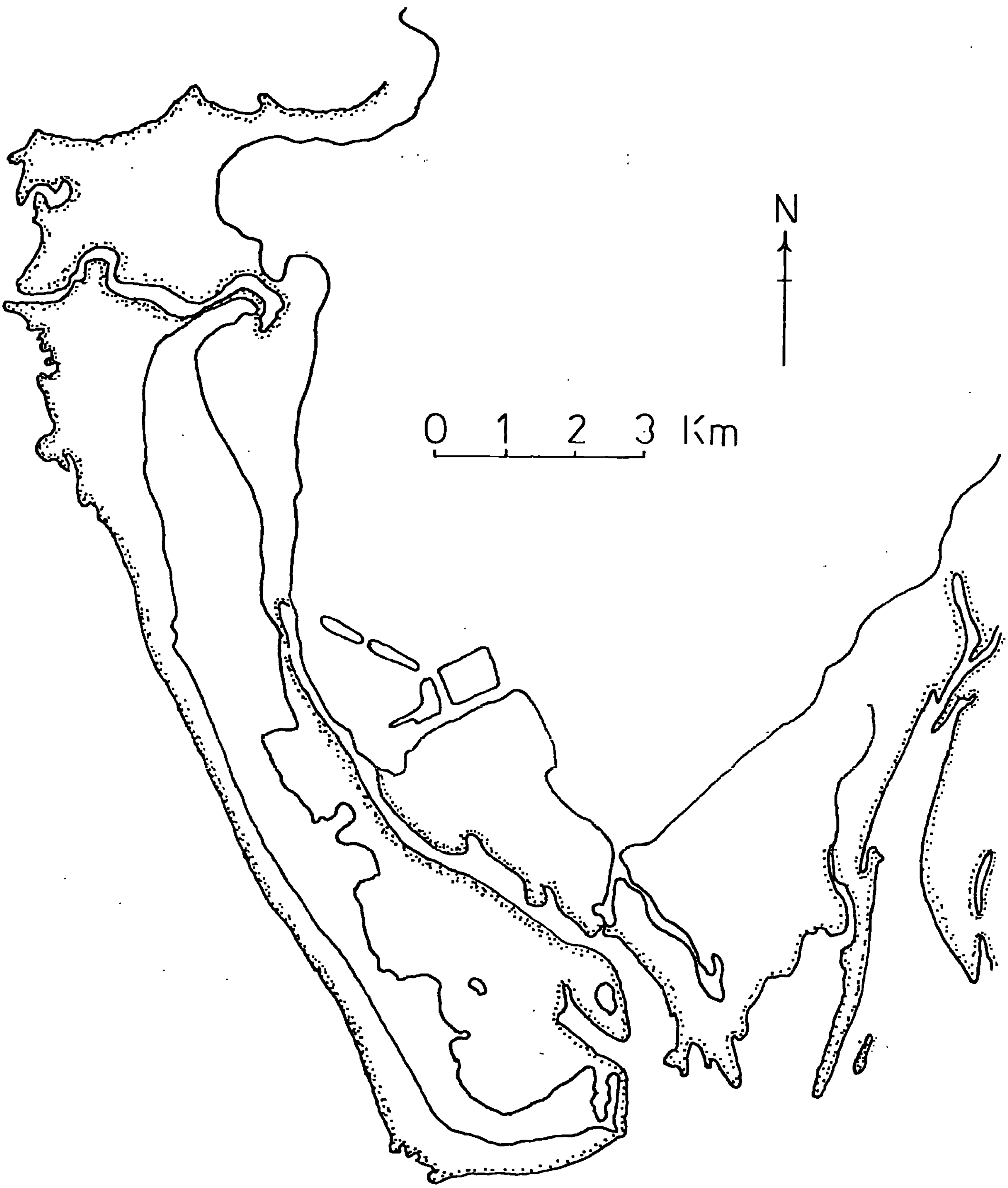


Figure 3. Study Area at Low Tide.



HISTORY OF TERN COLONIES ON FOULNEY ISLAND

The earliest available faunistic accounts collated by Mitchell (1885) indicate that terns were plentiful in the study area in 1840. The major, if not only, ternery in the area at this time was situated at the North end of Walney Island. Later reports note the presence of both Sandwich and Common Terns at this site from 1843-1889, when the Sandwich Terns moved to the Southern end of the island. This movement was followed two years later by the Common Terns. The new colony remained at low numbers until 1920, which was followed by 13 years of increasing numbers of both species, when "heavy predation of eggs" caused a movement of Sandwich Terns, probably to Ravenglass and Foulney Island. The Common Terns remained and continued to increase, 700 young were ringed in 1938, and 250 pairs were reported breeding in 1947 (Robinson 1950).

Foulney first enters the literature in 1933, and is next described as a flourishing ternery in 1946, in neither case are the numbers or species composition given. Sheldon (pers.comm.) noted the presence of Arctic Terns in the mid 1950's, although their presence on the island may well have a longer history. He also reported that Arctic Terns were greater in numbers than the Common Terns until 1960, when an influx of c. 600 pairs of Common Terns changed the species ratio. The Common Tern remained in these high numbers until 1963 when numbers dropped to c. 150 pairs, the Arctic Terns remained throughout this period at a little less than 100 pairs. From 1963-1970 numbers of both species remained approximately constant, but the breeding area fluctuated from Foulney to the South end of Walney.

Sandwich Terns during the 1950's and 1960's appear to have remained at about 100 pairs and to have bred spasmodically at either Foulney or Walney Islands. The other two species of maritime terns are even more poorly documented. Sheldon (op.cit.) reports low numbers of the Little Tern as being present continually, and that five pairs of Roseate Terns bred on Foulney Island in 1967 and 1968. A recent survey of tern numbers, in breeding pairs, for Foulney are presented in Table 1. Records were provided by Lloyd et.al. (1975) and the Cumbria Naturalist's Trust.

Table 1. Number of Breeding Pairs on Foulney Island

Species	1969	1970	1971	1972	1973	1974	1975
Common Tern	10	?	?	?	150	125	?
Arctic Tern	20	?	?	?	150	125	?
Sandwich Tern	10	0	0	0	20	170	?
Little Tern	?	?	?	?	?	1	1
Roseate Tern	0	0	0	0	0	0	0

It is difficult to assess the reasons for the fluctuations in numbers of the terns breeding on Foulney because the last 100 years has seen a number of alterations in the Island's status. In the 1870's Foulney Island was connected to the mainland by a foot causeway, which was constructed to protect the Piel Channel. This enabled the local inhabitants of Rampside village to graze their cattle on the main part of the Island, the area being fenced off from the spit. This practice had ceased by the 1920's. The subsequent 50 years has seen the Island eroded from the southern side, greatly reducing the available grazing areas.

The breeding success of the terns on Foulney Island has been very poor in the three years preceeding this study, this has been due to 2 factors:

(1) Predation by Gulls

The close proximity of the large gullery on Walney Island, and its steady population increase, Parslow (1973), increased the danger of predation. In 1973 the terns lost almost all of their eggs, apparently due to a mass invasion by Herring Gulls. Significant loss in 1975 was produced by the activities of a single Herring Gull, which consumed up to 12 chicks per day, Thom (pers.comm.).

(2) Predation by Rats

This occurrence is well documented on other terneries (Hagar 1937, Marples 1939). Their effect on Foulney Island in 1975 was such that only one Arctic Tern was fledged. This led the Cumbria Naturalist's Trust to implement a vigorous policy of rat control during the 1975-1976 winter, by means of Warfarin baits. This policy appeared to be successful, as no evidence of rats was noted during the summer of 1976.

NESTS AND NEST SITE PREFERENCES

The three species of terns breeding on Foulney Island provided an opportunity to examine their nesting site preferences. Prior to the studies by Boecker (1967) and Langham (1968) descriptions of the nesting situations have been general (Kirkman 1908, Bent 1921, Marples and Marples 1934). Boecker analysed vegetational height and density and found the Arctic Tern to be present in areas of low density with high vegetation, and the Common Tern choosing areas where the vegetation was both high and dense. The Arctic Tern nested in areas where either Agropyron junceum L. or Festuca rubra L. and Puccinellia maritima Huds. were the dominant plants. The Common Tern was found principally in areas dominated by Festuca rubra L. Langham (1968) on Coquet Island found the Common Tern to be restricted to areas dominated by Rumex acetosa L. and to a lesser extent Holcus lanatus L., both plants obtaining a height of 50-80 cm. The Arctic Tern showed a strong preference for the closely cropped Festuca ovina L. or the shingle beach, the latter being utilized by 25% of the population. Langham (1968) considered the vegetational preference of the Sandwich Tern to be secondary to its close proximity to the nesting Black-headed Gulls.

Method

Apart from three nests all the terns breeding on Foulney Island selected nest sites in the area known as Slitch Ridge. This area prior to the terns arrival had been subdivided by markers into 30 metre sections along the long axis of the spit. Following the first laying date, 19th May 1976, a detailed inspection was made at around 16 day intervals. The investigation consisted of transects at 2 metre intervals from the last high water mark across the breadth of the spit. Each nest was plotted for its position on the long axis of the spit, and its distance from the high water springs tide line (short axis). It was then possible to replot the positions on graph paper and measure the distances between nests without the disturbance direct measurements would have caused. The eggs were then counted, measured and marked. The presence of nest material and the degree of vegetational cover was recorded. Vegetational cover was recorded by estimating the ground cover in units of 20% in a metre quadrat in which the nest was centrally positioned. The overall vegetational survey was done during the third week of June, just after the maximum peak of egg laying, all vegetational dominance being designated as such subjectively.

The species responsible for the nest was determined by direct observation of the adult birds, with the exception of the Sandwich Terns where egg characteristics were used.

Results and Discussion

On Foulney Island the three tern species all showed distinct geographical and vegetational preferences, (Table 2 and Fig. 2).

Table 2. Vegetational Density of Nest Sites

Species	% Vegetational Cover					Total
	0-19	20-39	40-59	60-79	80-100	
Common Tern	11	24	34	48	21	138
Arctic Tern	69	2	1	0	0	72
Sandwich Tern	140	10	0	0	0	150

The Common Tern was found nesting in two distinct vegetational areas (Fig. 2). The first being dominated by *Festuca rubra* L. with a high density of ground cover (60-100%), but a low vegetational height (0-5 cm.) These areas were selected by 69 of the 138 nesting pairs. The second area was dominated by Arrhenatherum elatius L. and Dactylis glomerata L. here the vegetation attained the height of 50-100 cm. but with a density less than 60% ground cover.

The Arctic Terns nested almost exclusively just behind the extreme high water springs tide line, laying their eggs on the dead stalks of Spartina x townsendii Groves. Eleven of the seventy two clutches were laid lower on the bare shingle and were subsequently destroyed by tidal action. The nest sites (Fig. 2) were found, with three exceptions, on the western side of the spit where the shingle bank was of a lower gradient, and the shingle of smaller size than the eastern facing area which was more exposed to wave action.

The Sandwich Terns nested on top of the spit (Fig. 2) in an area of very low vegetational cover, only a few specimens of Beta maritima L. and Rumex crispus L. being present.

It was found that the three species of terns showed preferences for different vegetational height and densities. Statistical comparisons of the vegetational cover of Common and Arctic Terns nesting sites, using a t-test, showed a highly significant difference ($P<0.001$). The data from Foulney show the same trend as reported by Langham (1968) and Boecker (1967) but with a drift away from those areas containing a high and dense vegetation, the Common Terns laying (69 of the 138 pairs) in areas of dense vegetation with a low vegetational height, whilst the Arctic Tern nested in areas devoid of living vegetation.

Austin (1929) considered the site preferences of these two species to be due to the difference in tarsal length. The Common Tern,tarsal length 19-21 m.m., being suited more to walking in areas of vegetation than the Arctic Tern, tarsal length 15-17 m.m. There are many exceptions however, with the Arctic Terns in the Faroes nesting in areas of long vegetation (Fisher and Lockley, 1954), and Common Terns in Norfolk, in the absence of

Arctic Terns, are found to be nesting on sand and shingle.

The Sandwich Tern on Foulney nested on a flat area on top of the spit with very little vegetation, and in close proximity to a small colony of Black-headed Gulls (19 pairs), which had occupied the area prior to the terns' arrival. The association of Black-headed Gulls and Sandwich Terns has been recorded for many colonies. At Ravenglass in Cumbria Sandwich Terns nest amongst the large colony of Black-headed Gulls (pers. obs.) The association between these species on Foulney was very marked, the first scrapes of the Sandwich Terns started in close proximity to the existing nests of the Black-headed Gulls and later additions to the colony radiating out from this focal point. It would appear that the association is of the Sandwich Tern with the Black-headed Gull rather than vice versa, as the tendency is for the Black-headed Gulls to lay first. The benefit to the Sandwich Tern is one of protection, the more aggressive Black-headed Gull being important in deterring potential predators (Salmonsen 1943, Lind 1963). Observations on Foulney show that the Sandwich Terns suffer certain disadvantages from their association with the Black-headed Gulls. Assen (1954b) and Lind (1963) examined some of the disadvantages and concluded that losses due to predation on chicks and eggs were of minor importance. On Foulney Island there was no evidence of losses caused by Black-headed Gulls through predation, the major disadvantage of the association being caused by the Black-headed Gulls kleptoparasitising the adult Sandwich Terns returning to the colony. Rooth (1958) suggested this behaviour could lead to high chick mortality through starvation in inclement weather when food was in short supply. This did not appear to be of importance on Foulney Island as the proportion of Black-headed Gulls to Sandwich Terns was small and only a small number exhibited this feeding technique.

The nesting densities for the terns of Coquet Island was investigated by Langham (1968). It was found that nesting density decreased in the order Sandwich, Common and Arctic Terns which corresponded to the order of increasing aggression shown to intruders (Cullen 1960a).

The density of nest sites for the terns in this study was determined by the distance to the nearest neighbour. The Common Terns' density was analysed in two areas: (a) an area dominated by Dactylis glomerata L. and Arrhenatherum elatius L., as previously described, and (b) an area dominated by Festuca rubra. The mean distances between the nest sites were 3.46 $\pm$ 0.45 metres and 3.78 $\pm$ 0.91 metres respectively. Analysis using a t-test showed no significant difference between the nest site densities in the two areas ($P>0.1$, $t = 0.316$, 43 d.f.) Similar tests comparing the density of the Arctic Tern with Common Tern showed that the higher density of the Arctic Tern, mean distance 1.95 $\pm$ 0.25 metres, was significantly different ($P<0.001$).

It can be seen that the data obtained on Foulney Island do not completely correspond to that found by other workers on similar mixed colonies. The areas of difference are to be found in the nesting habitat and nest density of the Common and Arctic Terns.

Observations on Foulney Island indicated that the Arctic Terns were adapted to nesting on shingle, and their absence from the Festuca rubra areas was due to the Spartina x townsendii deposits, owing to their undulating nature, allowing a much higher nesting density than had previously been recorded. A similar situation of increased nesting density caused by vegetation between nests has been reported for the Sandwich Tern (Steinbacher 1931). Austin's consideration of the preference of site selection being due to tarsal length would not seem to be very significant on Foulney, as the Festuca rubra areas were cropped to a low level by rabbits producing a physical aspect similar to the cord grass deposits.

The Common Terns movement away from those areas of high vegetational height and density could be due to two factors. Firstly the availability of suitable shingle areas for the Arctic Terns made the areas of high density, low vegetational height available as nesting sites for the Common Terns. Secondly the low profile of Foulney Island has allowed a large amount of debris to be washed onto the spit which provides numerous sites for the chicks to hide. Observation on the colonisation showed that the Common Tern firstly occupied the low density Dactylis and Arrhenatherum dominated areas and the later nesting birds occupying the Festuca areas. The birds in the latter area tended to nest close to debris which provided suitable hiding places. The observations suggest that the optimum sites for the Common Terns are areas which provide suitable cover for the chicks without impeding their movement. The absence of the Arctic Tern on the Festuca areas is not considered to be the prime cause of this change in site selection, rather that the availability of suitable cover had provided conditions favourable to the Common Tern.

The site selection of the Sandwich Tern appears to be secondary to its association with the Black-headed Gulls. On Foulney the area selected was largely absent of vegetation, and this in conjunction with the white base colour of the eggs, and the guano deposits, made it difficult to distinguish the eggs and might act to reduce egg predation.

The study of site selection on Foulney Island has shown that the three species present have different site preferences which would tend to reduce, if not remove, competition.

FOOD AND FEEDING AREAS

Introduction

There is considerable evidence that closely related species can coexist by partitioning environmental resources, so that competition is avoided or at least relieved. The nature of interspecific variation in food selection has been described by Hinde (1959), who recognised that differences could occur in (a) feeding habitats, (b) location of feeding within a given habitat, (c) size of food taken, and (d) kinds of food taken.

Three studies in Northumberland, Pearson (1964), Langham (1968) and Dunn (1972), have examined the possibility of competition between terns during the breeding season and some of the factors which might prevent it. Pearson and Langham found considerable overlap in both the size and species of prey taken and in the distance of foraging trips, both concluded that food was superabundant in the breeding season and that competition for it was unlikely. Dunn further investigated these areas of overlap,showing feeding area preferences, the Arctic Tern being an offshore feeder, and the Sandwich Tern mainly inshore, whilst the Common Tern utilised both offshore and inshore areas.

The predominant prey species, in all three studies, were Ammodytidae and Clupeidae, Clupeidae being the more important in all the species, but the Arctic Tern differed by taking relatively more Ammodytidae. Langham in his study of prey size found the Sandwich Tern to take larger fish, but the differences between the other species were not considered to be biologically important.

Dunn's study showed that feeding techniques further divided the resources and suggested the possibility of vertical stratification of feeding layers.

The Foulney Island ternery offered a chance to study the feeding ecology of three species of terns simultaneously, as in the studies mentioned above, but in a different environment. The study may be divided into two broad sections. Firstly the areas in which the terns fed, and secondly the nature and method of acquisition of the prey.

Feeding Areas

The presence of three species in the same area allowed a study into whether there was any difference in the localities in which each species foraged. In order to determine if certain species showed any preference to particular areas a series of counts were made from vantage points on the island and neighbouring mainland. The study area was divided into six sections (see fig. 4), the parameters of which were determined by ease of view. Owing to the large areas exposed at low tide the sections displayed different characteristics depending on tide height, thus counts were taken at both high and low water. The counts were carried out during June and July, the method consisting of spot counts in which the numbers of terns of each species foraging in the area were recorded.

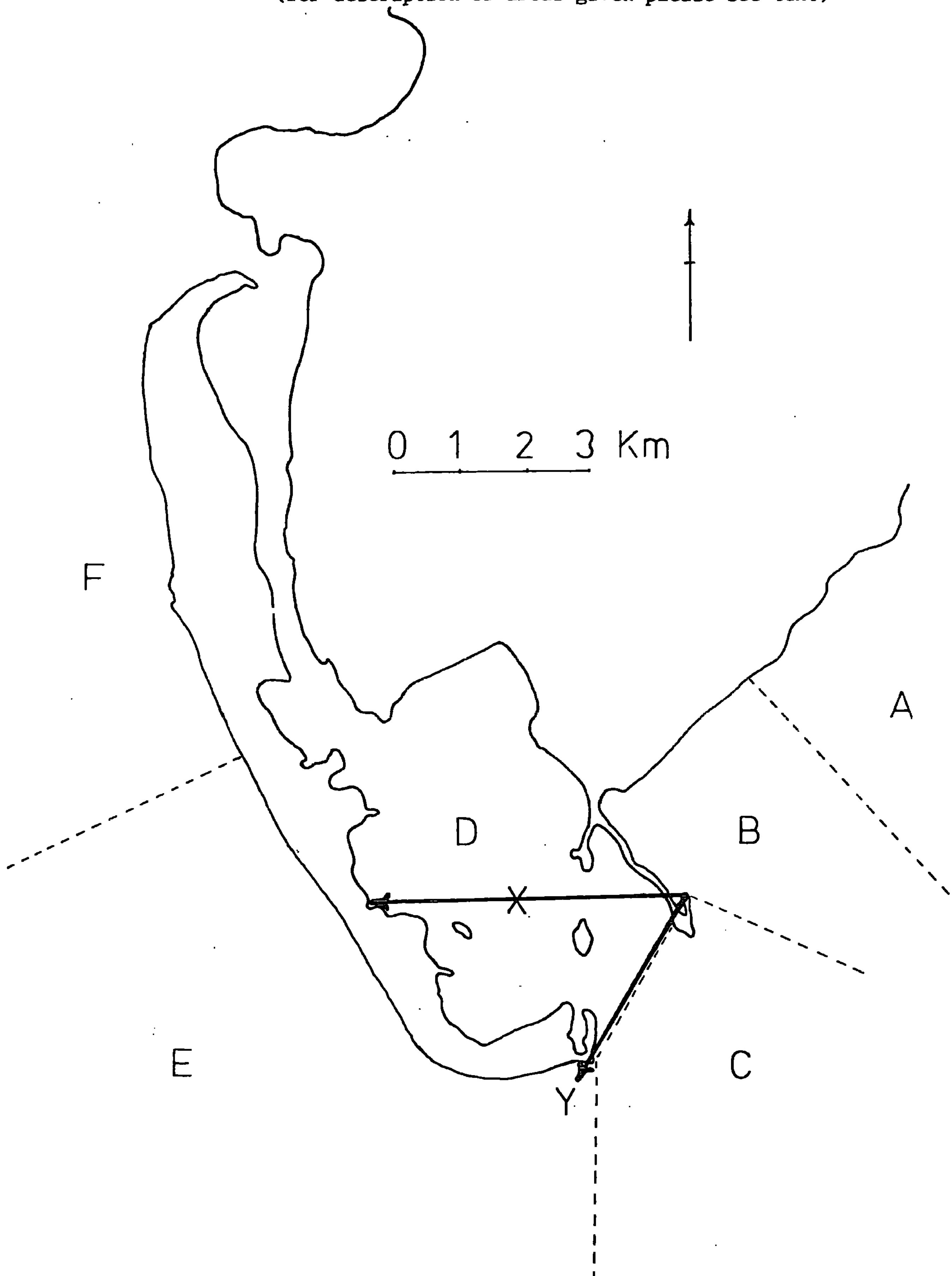
How were C. & A. Terns distinguished at a distance?

Table 3. Observed Distribution of the Terns Foraging in the Study Area with the Expect Numbers, Assuming a Random Distribution, Given in Brackets.

Area	Tide Height	Number of Terns: Common	Number of Terns: Arctic	Number of Terns: Sandwich	Number of Observation Days
A	High	1	0	0	3
	Low	0	0	0	4
B	High	16 (50.4)	115 (26.1)	0 (54.4)	8
	Low	0 (6.2)	16 (3.2)	0 (6.7)	8
C	High	5 (3.9)	3 (2.0)	2 (4.2)	5
	Low	2 (41.9)	107 (21.7)	0 (45.3)	6
D	High	53 (31.9)	29 (16.6)	1 (34.5)	8
	Low	59 (32.3)	19 (16.8)	6 (34.9)	9
E	High	0 (4.2)	0 (2.2)	11 (4.6)	3
	Low	1 (8.1)	0 (4.2)	20 (8.7)	3
F	High	0 (6.5)	0 (3.4)	17 (7.1)	3
	Low	0 (1.5)	0 (0.8)	4 (1.7)	3

Figure 4. Division of Study Area (A-F)

(for description of areas given please see text)



X & Y Flight lines of the Common & Sandwich Terns.

The status of the tern species in the sections is only meaningful in relation to the numbers which could have been present. It can be safely assumed that during June and July virtually all terns found in the area originated from the Foulney Island colony. Pearson (1968) calculated a maximum range for the Sandwich Terns of fifteen miles, and ranges smaller than this for the other tern species. Table 3 shows the observed numbers in each section and in brackets the expected numbers if the species were randomly spaced, assuming the expected ratio of Common, Arctic and Sandwich Terns is 2:1:2, the ratio being obtained from the number of nesting birds of each species.

It was found that the Arctic Terns were over-represented in sections B, C and D, those areas nearest to the colony, and were absent in all other areas. The presence of this species at low tide is of particular interest as, with the exception of section D, these areas were not covered by water. This is discussed in more detail later.

The Common Tern was found to be the species with the widest distribution, being recorded in all sections, with the exception of F, at some state of the tide. It was underrepresented in all areas except D where the difference from the expected numbers was not sufficient to explain its paucity in other areas.

The Sandwich Tern was almost totally absent from all areas except E and F where once again the numbers present were not sufficient to account for its underrepresentation in the remainder of the study area.

Observation on the flight paths of the Terns leaving and returning to the colony (fig. 4) showed movements of significant numbers of Common and Sandwich Terns to the West of Walney Island. Table 4 shows the numbers of these species returning to the colony.

Table 4. The Number of Terns returning to the Colony along Major Flight Paths.

Flight Line	Number of Terns Arctic	Common	Sandwich	Total observation time in minutes
X	1	79	65	240
Y	0	2	42	220

Investigation into the areas indicated by the flight paths failed to show the expected numbers, and would indicate that the terns were foraging at some distance from the shore line. One observation on the 4th August 1976 substantiated this hypothesis when 28 Sandwich Terns were observed feeding around five miles offshore in area F. The presence of two flight lines is due to the terns avoiding the large gullery on the South End of Walney Island, and their preference for flight over the sea, flight line X crosses Walney Island at its narrowest point, rather than indicating a distinction in foraging areas.

The status of the species on Foulney Island differs from that found at a mixed ternery on the Northumberland Coast by Dunn (1970). The Arctic Tern, considered as an offshore feeder by Dunn, is shown to be very much an inshore feeder in this study, and foraging to a considerable extent in areas devoid of complete water cover as shown by its presence in areas B and C at low tide. Conversely the Sandwich Tern, found to be an inshore feeder in Northumberland, foraged to a great extent offshore. The similarity between Dunn's results and that found on Foulney exists only in the status of the Common Tern, which at both sites was found to utilise both inshore and offshore areas. The difference in behaviour found on Foulney Island from other British sites closely resembles that exhibited by the Common and Arctic Terns on Wangerooge studied by Boecker (1968). This colony was also located in an estuarine environment and showed many features in common with the study area around Foulney Island, both having a large shore exposure dominated by mussel beds at low tide.

The presence of a tern species in a certain area may be due to its exclusion from other areas, or by possessing some adaptation which enables it to exploit a food resource found in that particular area. To investigate the second hypothesis a study into the diet and feeding technique of the terns was carried out.

The Food of the Terns

The food taken by terns may be studied in a number of ways, gut and regurgitation analysis, and direct observation are the most popular methods. In this study direct observation was used as it caused the least disturbance to the terns. The problem with this method is the inability to identify to species level the prey taken, and also small prey items may be overlooked. Additional information on the diet of the terns was obtained by collecting specimens of fish which had been dropped or discarded in the colony. The prey items were recorded as they were carried back to the colony, the observation point being constant and close to the colony so that no bias was introduced by terns arriving from any particular direction. The fish recorded were assigned to either the Ammodytidae (long slender fish) or to the Clupeidae (broad fish with a bifid tail). A number of small Mackerel *Scomber scombrus* L. were included with the Clupeidae, being broad fish sometimes caught in the area, and very small fish were difficult to categorise. A third category comprised of Crustacea, which consisted exclusively of the Common Shore Crab *Carcinus maenas* L. all five specimens collected, having been dropped by terns, were of this species.

Subsequent examination of all specimens collected on the ternery have shown the Clupeidae category to consist of Sprat *Clupea sprattus* L. (11 specimens) and Mackerel (3 specimens). The Ammodytidae retrieved from the colony were Ammodytes tobianus L. (2 specimens) and Ammodytes marinus L. (1 specimen), but the accuracy of classification is in doubt as distinguishing features are unreliable in juveniles (Reay 1970). Other specimens collected on the colony were small Plaice Pleuronectes platessa L. (5 specimens) and Flounder Platichthys flesus L. (9 specimens). The high frequency of these two species contrasts with the information obtained by direct observation. The flat fish were not an important constituent of the diet, and the high occurrence on the colony is caused by the inability of the chicks to swallow them. The Three-spined Stickleback Gasterosteus aculeatus L. produces similar problems on other colonies (Coulson pers.comm.) Table 5 presents the prey items taken by all three tern species.

Table 5. Prey Brought to the Colony by Tern Species

Species	Ammodytidae No.	Ammodytidae %	Clupeidae No.	Clupeidae %	Crustacea No.	Crustacea %	Total
Common Tern	240	31.4	525	68.6	0	0	765
Arctic Tern	0	0	209*	25.6	608	74.4	817
Sandwich Tern	1358	84.9	239	14.9	0	0	1599

* This figure for the Arctic Tern refers to three periods when shoals of Clupeidae were located between Foulney Island and the South End of Walney, and is not consistent with the general observations.

Table 5 shows that the tern species on Foulney exhibited a high degree of specificity in the prey taken. The Arctic Terns food being almost exclusively Carcinus maenas L., while the Sandwich and Common Terns were found to feed on Ammodytidae and Clupeidae. It was found however that the proportion of Ammodytidae to Clupeidae in the diet of tne Sandwich Tern was significantly larger than for that of the Common Tern ($X^2_1 = 20.54$ $P<0.001$).

Studies on the distribution of the terns showed the Common Tern tended to be in areas close to the colony more frequently at high than low tide.

A study to see whether this change in feeding area was reflected in the percentage of Ammodytidae to Clupeidae was carried out. Counts were made fifteen minutes either side of high, low and mid water, all observations being made during mid June to the end of July. The Sandwich and Common Terns observed returning with fish were noted, except on five occasions when only the Sandwich Terns were recorded. Table 6 shows the combined data for this study.

Table 6. The Proportion of Ammodytidae to Clupeidae Brought to the Colony in Relation to Tide Height

Species	Tide Height	Ammodytidae No.	Ammodytidae %	Clupeidae No.	Clupeidae %	No. of Counts
Common Tern	Low	97	45.3	117	54.7	7
Sandwich Tern	Low	310	81.5	70	18.4	7
Common Tern	Mid	85	26.5	235	67.3	9
Sandwich Tern	Mid	512	83.4	102	16.6	11
Common Tern	High	58	24.7	177	75.3	6
Sandwich Tern	High	578	89.5	68	10.5	9

Analysis showed that the tidal influences were not significant in effecting the proportion of Clupeidae to Ammodytidae in the Sandwich Terns, $X^2_2 = 0.41$ ($P>0.1$), but there were significantly more Ammodytidae taken at low tide than high tide in the case of the Common Tern, $X^2_2 = 127.8$ ($P<0.001$). The Sandwich Tern, a predominantly offshore feeder, was found to have a diet consisting of 80-90% Ammodytidae and the Common Tern was found to have a higher proportion of Ammodytidae during low tide, when it was generally absent from inshore areas.

Investigation into the distribution of Ammodytidae in the area by means of skin diving in areas B, C and D failed to locate any specimens and showed a general paucity in all fish species except Plaice and Flounder. The nearest location with an abundance of sand eels is between the Isle of Man and the Cumbria Coast (Reay pers.comm.), which corresponds to the direction of the flight lines, and is just within the range calculated for the Sandwich Tern by Pearson (1968).

The distribution of the Clupeidae is uncertain, evidence from diving indicated a paucity in areas close to the colony. Although local boatmen reported occasional shoals of "whitebait" (a general term used to describe all small fish except sand eels) in areas D and E.

All records of food items were taken after the end of May. Observations during the pair formation period showed all three species to be carrying both Ammodytidae and Clupeidae species during "fish flight" behaviour. The cessation of these species as a major item in the diet of the Arctic Tern corresponds with its period of egg laying. The change in diet could be due to a number of factors:

(a) A decrease in the availability of Clupeidae and Ammodytidae species, either by a decrease in numbers or a change in behaviour in the prey species;

(b) An abundance of an alternative food supply was made available;

(c) The time available for feeding was decreased by the breeding requirements thus reducing the feeding range.

Similar changes in diet were recorded at Wangerooge for Common and Arctic Terns, when both species reduced the amount of fish in their diet and crustaceans in the form of Shrimp *Crangon vulgaris* L. and Swimming Crab *Portunus depurator* L. became more important. Crustacea were found to make up between 60-80% of the Arctic Tern's diet and 25% in the Common Tern. Boecker considered this change to be due to an increase in the number of crustaceans, rather than a decrease in fish.

Reports by Langham (1968), Dunn (1970) and Pearson (1964) showed that the Arctic Tern took smaller fish than the Common and Sandwich Terns. It was postulated that a similar situation on Foulney Island in conjunction with the distance of the fishing areas could place this food source beyond the energy budget of the Arctic Tern.

The Size of Fish Taken by Each Species

The method employed for this investigation was similar to that carried out for the diet analysis. Fish size was estimated by comparison with length of the captor's bill, (Sandwich Tern 5 cm., Common Tern 4 cm. and Arctic Tern 3 cm.)

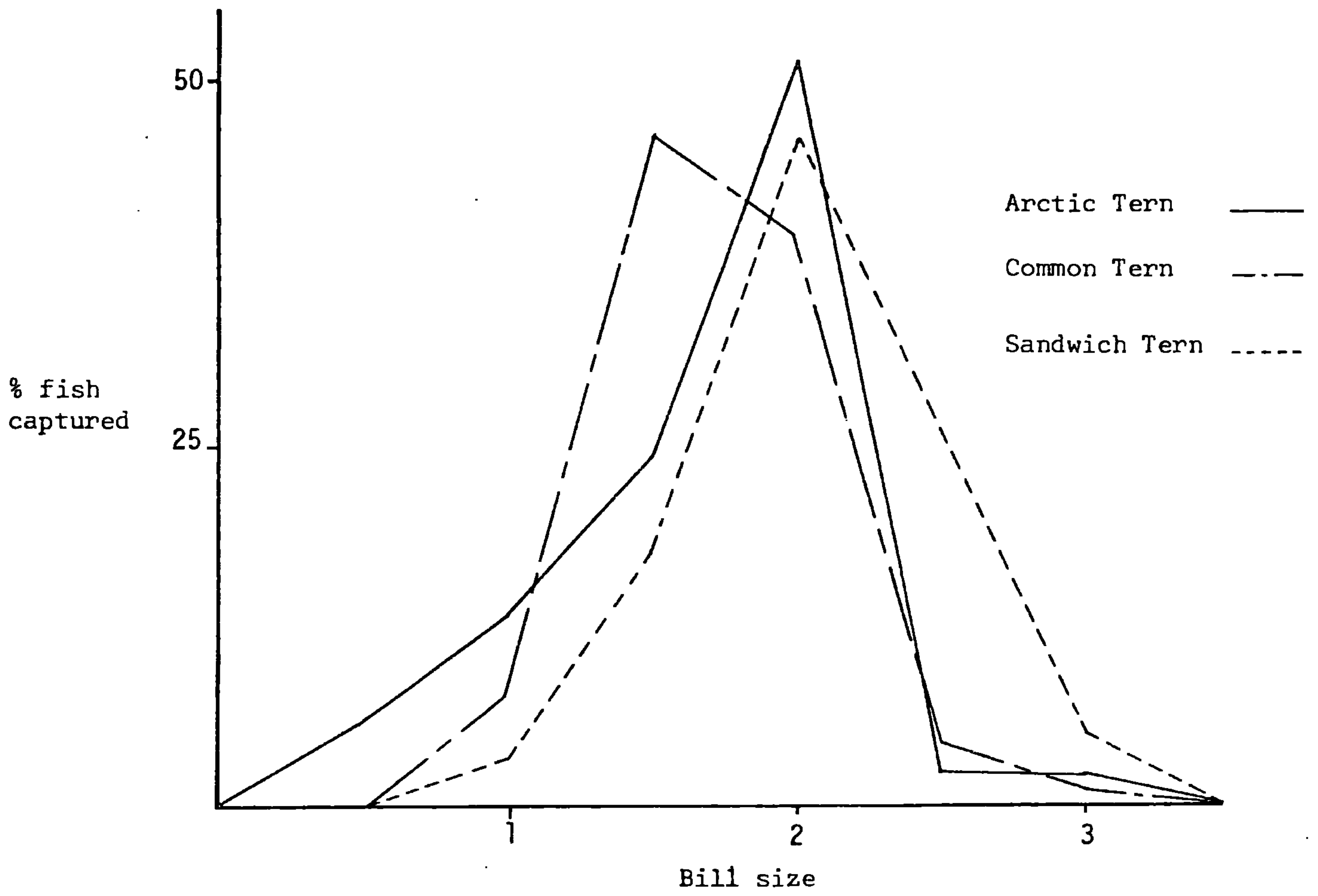
Table 7. Fish Size Taken by Each Species

Species	Sample Size	Mean Size in cm.	S.E.(cm.)
Common Tern	969	6.9	± 0.05
Arctic Tern	209	5.1	± 0.1
Sandwich Tern	1000	10.3	± 0.07

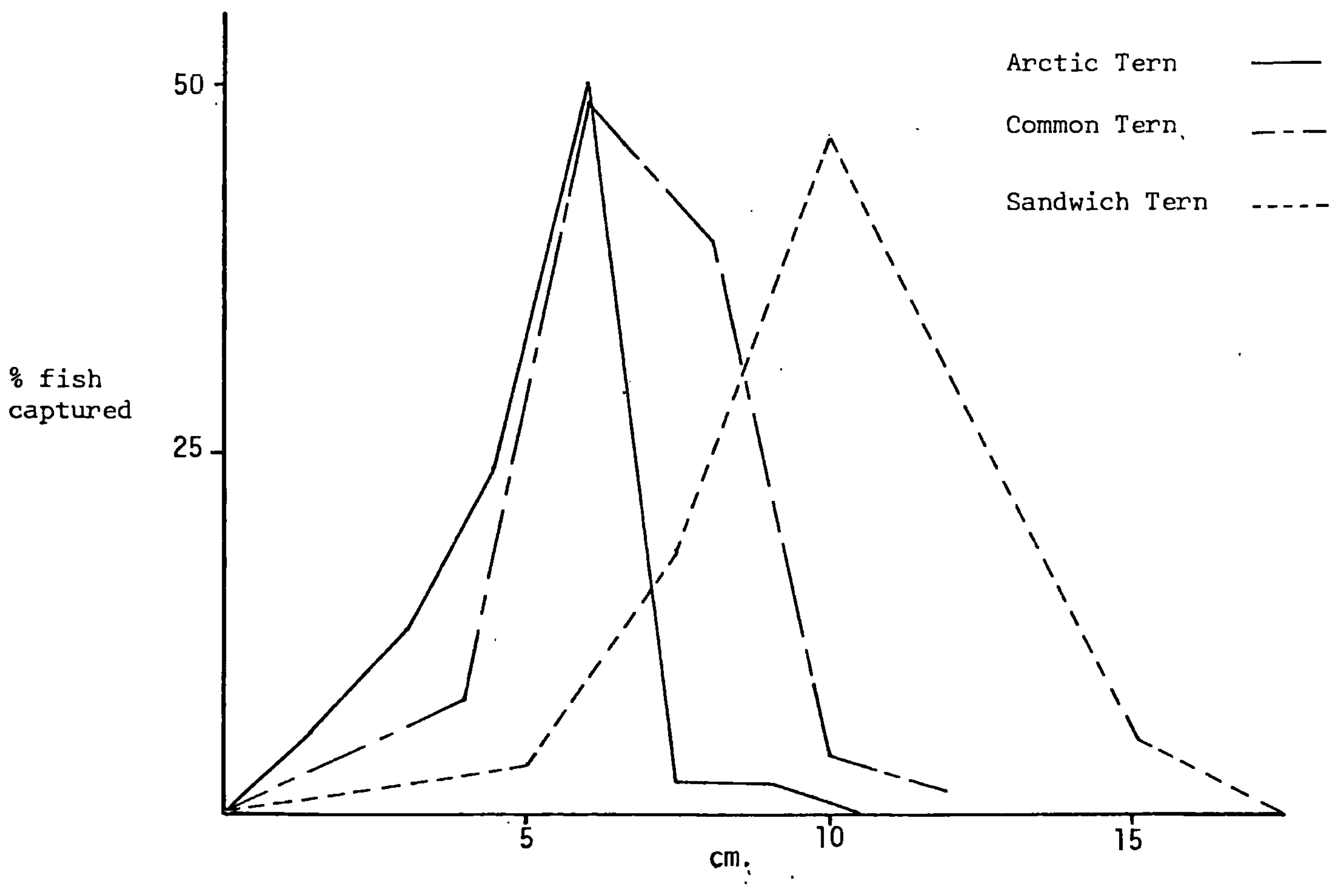
The size of fish taken by all three species was found to be significantly different ($P<0.001$) in all cases. Graphs (1) and (2) illustrate the percentage of fish returned to the colony in respect to (1) bill size, and (2) centimetre units for all three species.

The studies on the diet of the tern species showed that the Sandwich Terns were taking a higher proportion of sand eels to Clupeidae than the Common Tern. The sand eels were found to be on average longer than the Clupeidae, and to determine whether this influenced the overall fish size average an investigation was carried out into the size of these species returned to the colony.

Graph 1. Fish Size in Relation to bill length



Graph 2. % Fish Captured in cm. units



<u>The Size of Ammodytidae Captured by the Common and Sandwich Terns</u>

The method was as described for the previous study, readings for both species being taken simultaneously.

Table 8. Size of Ammodytidae Captured by the Common and Sandwich Terns.

Species	Sample Size	Mean Size of Ammodytidae in cm.	S.E.(cm.)
Common Tern	285	7.4	± 0.09
Sandwich Tern	316	9.6	± 0.12

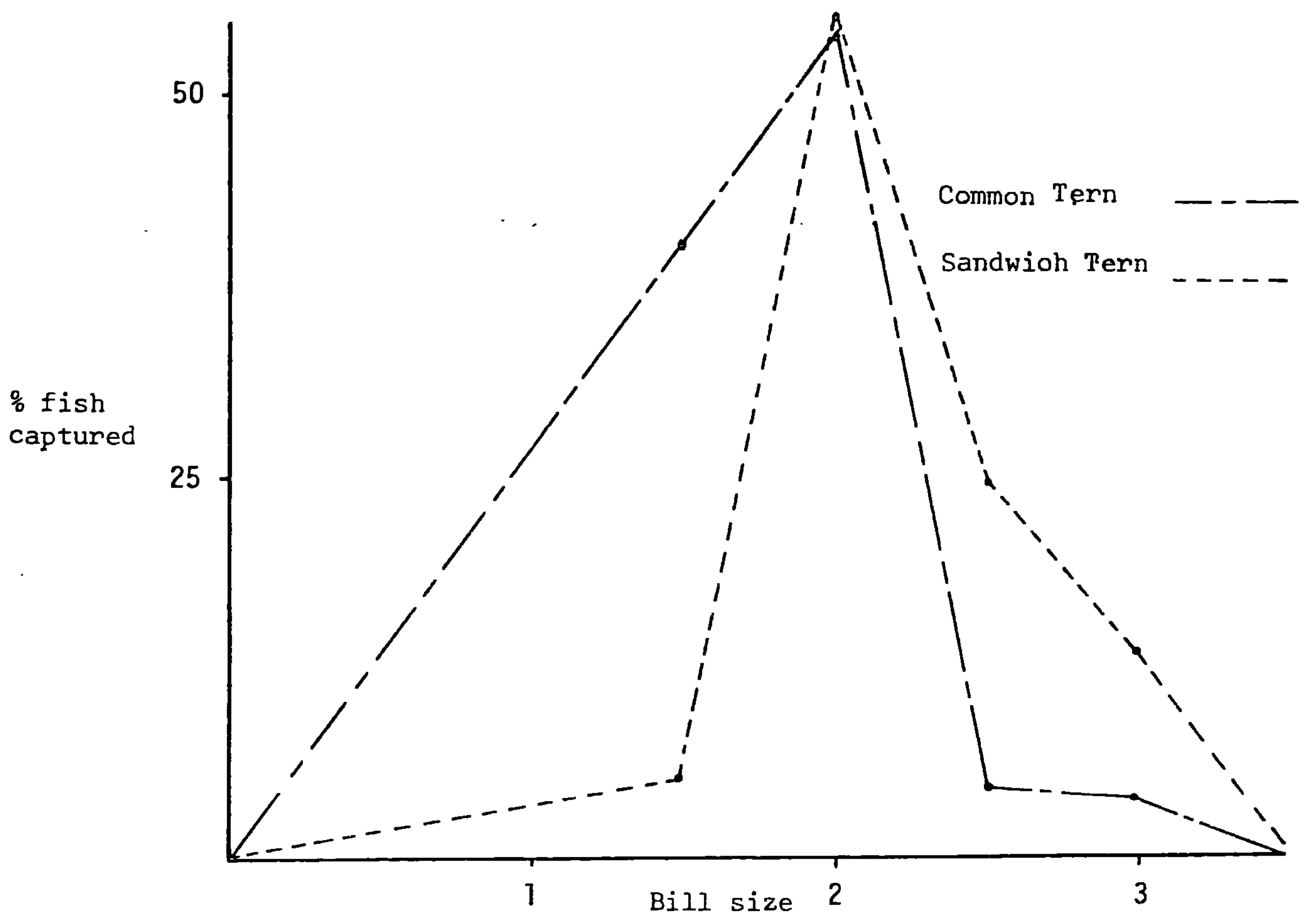
The data collected showed that the Sandwich Terns were returning to the colony with significantly larger sand eels than the Common Tern ($P<0.001$). Graphs 3 and 4 illustrate the percentage of Ammodytidae returned to the colony by Common and Sandwich Terns in respect to (a) bill size and (b) centimetre units.

In other investigations into the fish size taken by tern species it was concluded that the larger size and greater dive height of the Sandwich Tern enabled it to capture larger prey (Dunn 1970). The offshore distribution of the tern species feeding on fish prevented any investigation into the reasons for the difference in prey size.

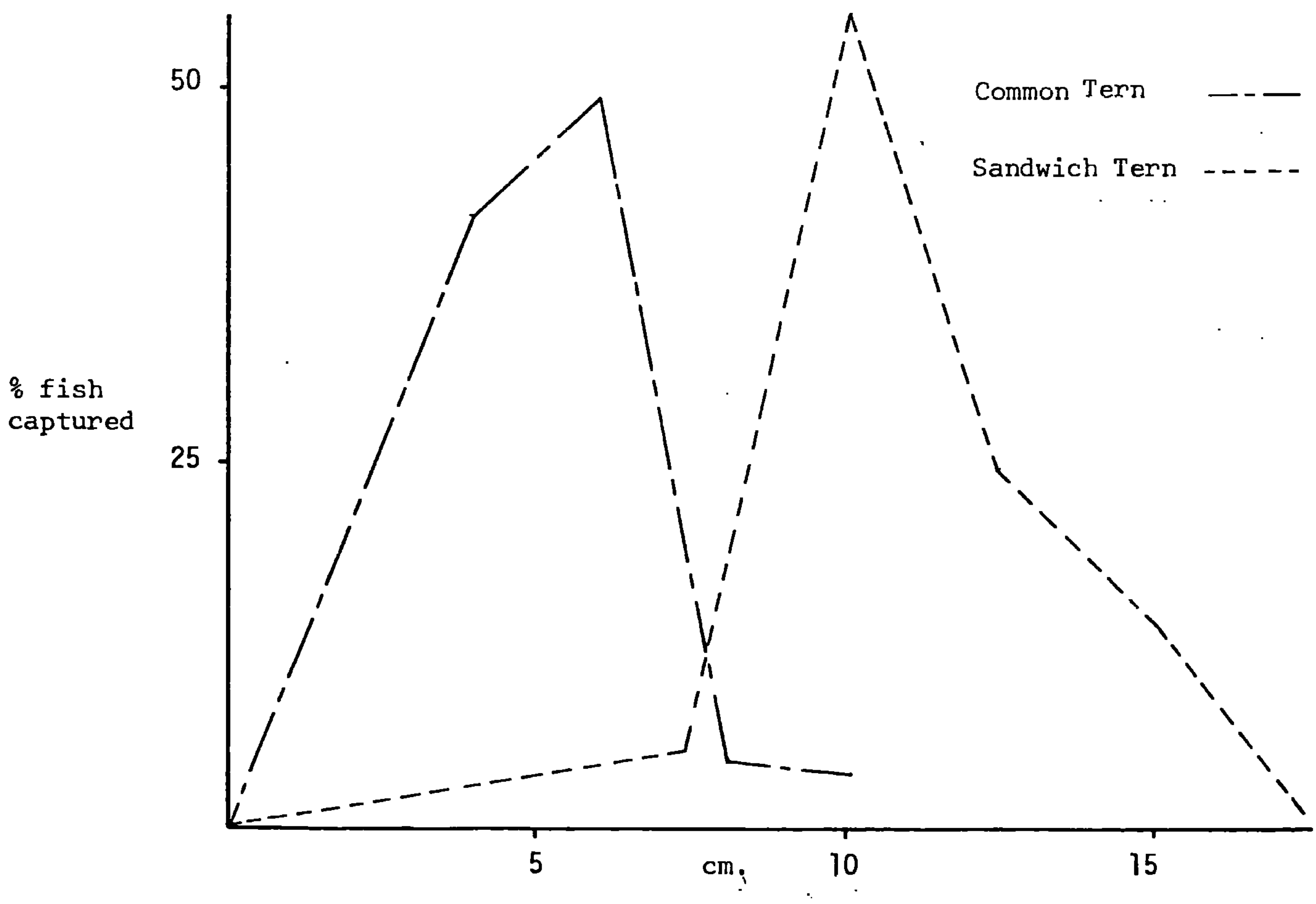
The hypothesis that the fish size captured by the Arctic Tern may prevent it feeding in "extreme" offshore areas does not receive much support from the investigation. Although the data for fish size in the Arctic Tern is limited, that obtained would not appear sufficiently different in size from that captured by the Common, to be consistent with the hypothesis.

The Arctic Tern has been shown to feed predominantly on the common

Graph 3. % of Sand Eels Captured in Relation to Bill Size



Graph 4. % of Sand Eels Captured in cm. units



shore crab at all states of the tide, specialisation on this prey has not previously been recorded, although other Crustacea were shown to be important at Wangerooge by Boecker (1968). Investigations into the feeding areas has shown that the Arctic Tern feeds close to the colony throughout the tide cycle. The major feeding area being the large shallow pools formed at low tide over the mussel beds in area C. These pools and other areas where the substratum has been partially stabilised, and allows some degree of cover, contain large numbers of crab which form a significant prey item for a number of bird species. Eider Duck, Herring and Lesser Black-backed Gulls were frequently observed feeding on crab. Crab was taken by the Arctic Tern, in addition to the area described above, in areas of mud-flats at low tide, and along the tide line in sections B and D at high tide.

Feeding Behaviour of the Arctic Tern

The Arctic Tern on Foulney had modified its feeding technique to exploit the abundance of crab. The plunge dive and dip feeding described by Dunn (1970) was observed occasionally throughout the study, but the major method of obtaining food was an intermediate form between these two methods. The Arctic Tern would hover at between 3-5 metres above the surface of the water, and the plunge descent was executed with outspread wings and legs, which allowed a slower descent and prevented the bird completely submerging.

Feeding Success of the Arctic Tern

An investigation into the feeding success by direct observation was carried out in Area C. An individual tern was observed for the period of time it remained close enough to determine whether a dive was successful. The time under observation was recorded by means of a stop-watch. All dives were recorded as either positive or negative depending on whether the tern secured a prey item. A dive was recorded only if the tern made contact with the water or substratum. The results are given in Table 9.

Table 9. Feeding Success of the Arctic Terns

No. of Dives	Success Positive No.	%	Negative No.	%	Total observation time in seconds
84	56	67	28	33	4590

The data show the dive rate to be one dive every 54.6 $\pm$ 6.7 seconds with a success rate of 67% for the total number of observations.

The Size of Crab Captured by the Arctic Tern

The size of crabs captured was studied by the same method applied to the study of fish size, but the smaller size and shape of the prey is thought to have reduced its accuracy. Arctic Terns were observed whilst feeding at high, low and mid tide in order to determine whether this influenced the prey size, the position of the tide having previously been seen to influence the feeding areas. Observations were carried out on the feeding grounds which enabled a reduction in observation distance, allowing a more accurate determination of prey size.

Table 10. Crab Size Captured in Relation to Tide Height

Tide State	Mean Size in cm.	S.E.(cm.)	No. of observations
Low Tide	1.29	$\pm$ 0.03	350
Mid Tide	1.24	$\pm$ 0.04	101
High Tide	1.29	$\pm$ 0.04	157

There was no significant difference in the size of crabs captured throughout the tidal cycle ($P>0.1$). The average crab size for all observations was 1.28 ± 0.02 cm., the size being estimated to be the width of the carapace. Specimens collected in the area show the relationship between carapace width and wet weight.

Table 11. Crab Size in Relation to Wet Weight

Carapace Width in cm.	Wet Weight in g.
2.2	4.5
1.8	2.0
1.4	1.5
1.3	1.5
1.3	1.5

The data from collected specimens indicate that the wet weight of the average crab size captured to be around 1.5 g. The calorific value of crustacea is less than of an equal wet weight of fish and this would require that the Arctic Tern captured proportionally more total weight of crab than fish to obtain the same calorific value.

Discussion

The studies above are not sufficient to determine the relative efficiencies of feeding behaviour for any of the tern species. It can be noted however that each species has been found to take sufficiently different food items, either by species content or size, to alleviate competition for food. On a number of occasions when shoals of Clupeidae were present in inshore areas all three tern species were observed feeding on fish of the same size and species. Similar situations have been recorded for predation on the vole Microtus arvalis L. by German Falconiformes and Strigiformes, where five species were found to prey on the vole in the same area. The vole was at most times superabundant, but in times of low numbers each predator changed to a different prey (Lack 1946). Lack also refers to seasonal abundance of caterpillars, fruits and seeds, where the abundant source may provide food for a number of different animals. Lack states that "the food in question are temporarily so much more abundant than the requirements of their consumers that the latter do not effectively compete with each other while eating them." Pearson (1968) considered that this situation of superabundance existed throughout the breeding season for the terns on the Farne Islands, and that differences in food and food size were the product of specific preferences, and subject to marked variation.

On Foulney Island the amount of fish food within the immediate vicinity of the colony did not appear to be abundant. The evidence obtained on the distribution of fish present in the diet of the terns showed the major areas containing these species existed offshore to the West of Walney Island. This correlates with the distribution of terns feeding on such species, causing a change in status of the Sandwich Tern from that recorded by workers on the Farne Islands, although the diet in both cases was predominantly Ammodytidae of comparable size, with the remaining items being Clupeidae.

The major difference from that found on the Farne Islands is in respect to the distribution and diet of the Arctic Tern. It was hypothesised that the low percentage of fish in the Arctic Tern diet was caused by the distance from the colony of suitable prey in conjunction with the smaller size of fish captured (Pearson 1968, Dunn 1970). The results obtained from studies on fish size however were not sufficient to substantiate the hypothesis. An investigation into the feeding behaviour of the Arctic Tern showed it to have adapted its feeding technique to exploit the superabundance of crab in the area. Other studies on feeding behaviour have shown the Arctic Tern to be more adaptable than other terns (Hawksley 1957). Boecker, however, considers this adaptation to be limited to shallow water and dry substrate feeding, pointing out that the Common Tern in similar circumstances continues to feed predominantly by plunge diving. The advantages for the Arctic Tern are speculative as no evidence is available to compare the energetics of each feeding method, however certain points may be noted. Boecker found that on Wangerooge, when an abundance of Crustacea and a paucity of fish food occurred, the breeding success of the Arctic Tern was greater than that of the Common Tern. On Foulney the influence of weather on feeding was reduced, the habitat of the crab was less subject to changes by wind than the open sea favoured by the other tern species, both of which were observed to forage more inshore when faced with strong prevailing winds. Other factors such as increased brooding time and the closer proximity of feeding areas for the newly fledged young would also seem to be favoured by the Arctic Tern's adaptation.

CLUTCH SIZE

The study of clutch size was undertaken on all three tern species. Identification of clutches by egg characteristics was possible only in the Sandwich Tern, and observation of the adult bird was required to determine the species responsible in the Common and Arctic Terns. Nineteen nest sites containing eggs were not allocated to any species but were described as "comic" nests (see Appendix 2), due to the lack of observation of adults to confirm identification. The nests were in the majority 1 egg clutches and 37% were found to have been deserted. The fate of the remainder was uncertain, the eggs were missing around the predicted time of hatching but no chicks were discovered. It was considered that these "comic" nests were in the main deserted incomplete clutches of the Common Tern.

The method for finding, plotting and identification of the eggs has previously been described. Eggs were marked with a Pentil felt tip pen, each egg being marked for the number in the nest and the date of discovery, each visit to the colony being allocated a marking code. An earlier attempt to determine accurate laying dates for each egg was abandoned as it required the complete colony to be searched at each visit, the resulting disturbance being unacceptably high. The marking method was ammended so that all areas were covered at least once every 16 days. This meant that no clutches which completed incubation were missed, but allowed for clutches to be laid and destroyed between visits.

The clutch size of the three tern species is presented in Table 12.

Table 12. The Clutch Size of the Terns on Foulney Island

Species	Clutch Size 1 Egg No.	1 Egg %	2 Eggs No.	2 Eggs %	3 Eggs No.	3 Eggs %	Mean Clutch Size	No. of Nests
Common Tern	2	1.5	34	25.2	99	73.3	2.72 $\pm$ 0.04	135
Arctic Tern	9	12.5	57	79.2	6	8.3	1.96 $\pm$ 0.05	72
Sandwich Tern	135	90.0	15	10.0	0	0	1.1 $\pm$ 0.02	150

The average number of eggs laid by each of the tern species was found to be significantly different (X^2_2 = 98.9 P<0.001), but as Lack (1954) stated "it is much harder to suggest reasons for the difference between species, as species differ from each other in so many ways. In general, the amount of food provided by the parent has probably been the basic factor determining evolution of clutch size." Lack (1947) recorded that published information on clutch size in terns failed to show any regional differences. Table 13 presents a summary of mean clutch size for colonies in European lattitudes, original data collated by Langham (loc.cit.)

Table 13. Mean Clutch Variation of Colonies in European Waters

Species	Range of Mean Clutch Size	No. of observations
Sandwich Tern	1.04 - 1.58	8
Common Tern	2.0 - 2.87	8
Arctic Tern	1.19 - 2.23	23

The data for Foulney Island show that the Common and Arctic Terns average clutch sizes are in the higher part of their range, whilst the opposite is found in the Sandwich Tern.

Factors influencing clutch size have been discussed by Lack (1947, 1948,1954). He considers the food requirements of the brood to be the ultimate factor where "clutch size evolved through natural selection to correspond with the largest number for which the parents on average can find food." This evolved number described by Lack has been shown to have a number of factors influencing its expression. The time of laying in the case of the Great Tit Parus major L. has been recorded to influence the clutch size, later clutches being smaller. This was considered due to the birds laying in anticipation of food availability for the young, and not that present at the point of laying (Perrins 1965). It has been found that the age of the bird influences the clutch size and to a lesser extent the individual egg volume (Coulson 1966, 1975).

Seasonal Variation

Studies on seasonal variation were limited to the Common Tern, where the later clutches in Area I allowed a comparison with the rest of the Common Tern population. All clutches in this area were completed between 27th June - 15th August. The results showed that clutches in Area I were smaller than the rest of the colony, 2.44 and 2.76 respectively, which was found to be significantly different ($X^2_1 = 5.91$ $P<0.002$). The reason for this decrease is not clear, but may be due to the area containing a higher proportion of younger birds, which have been found in the case of the Kittiwake Rissa tridactyla L. to have smaller clutches and a later laying date (Coulson 1958).

Egg Size

The length and breadth of all eggs of the Common and Arctic Terns on Foulney Island were measured to 1 mm. and the data were converted to volume using the relationship developed by Coulson (1963):

Volume (cc.) = breadth^2 x length x 0.000478 (where length and breadth are measured in mm.) The difference was found to be significant using a t-test ($P<0.01$). Results are presented in Table 14.

Table 14. Mean Egg Volume of Common and Arctic Terns

Species	Egg Volume in cc.	S.E. (cc.)	Sample Size
Common Tern	16.73	± 0.07	375
Arctic Tern	16.37	± 0.11	141

Variation of Egg Volume with Season in the Common Tern

The method applied to the comparison of mean egg volume in the Common and Arctic Tern was used to analyse the seasonal variation in the Common Tern, samples being the same as those used for the seasonal variation in clutch size. Results presented in Table 15 show no significant difference between the date of laying and the mean egg volume ($P>0.1$).

Table 15. Seasonal Egg Volume Variation in the Common Tern

Date of Laying	Mean Volume of eggs in cc.	S.E. (cc.)	Sample Size
Before 27th June	16.73	± 0.07	336
After 27th June	16.67	± 0.19	39

The studies on egg size have shown that the Arctic Tern lays smaller eggs than the Common Tern, however the smaller size of the Arctic Tern indicates that its eggs are larger in relation to its body mass than the Common Tern, but has a smaller clutch size.

The studies on seasonal changes in egg volume in the Common Tern found no significant variation. It is considered that the reduction of material put into egg production is expressed primarily in the clutch size, rather than through the size of individual eggs.

HATCHING SUCCESS

In estimating the hatching success (ie: the number of eggs that hatch of those laid, expressed as a percentage), the clutches of all three species were considered. The unidentified clutches which were thought to be deserted eggs of the Common Tern, and three late clutches of the Common Tern which had still to hatch at the end of the study, were omitted from the analysis. Table 16 presents the hatching success of the three species.

Table 16. Hatching Success of Tern Species on Foulney

Species	% Hatched	Sample Number
Common Tern	88.8	367
Arctic Tern	82.3	141
Sandwich Tern	85.5	165

X^2 tests show there to be no significant difference between the hatching success of the tern species ($X^2_2 = 3.6$ $P>0.1$). It is considered that the hatching success of the Common Tern is influenced by the removal from the sample of the "comic" nests, which were thought to be deserted Common Tern nests. The addition of these nests into the sample however would still give the Common Tern a hatching success of over 80%.

The circumstances producing egg failure in all three species are presented in Table 17.

Table 17. Circumstances of Egg Failure

Circumstances of Egg Failure	Arctic Tern No.	%	Common Tern No.	%	Sandwich Tern No.	%
Infertile Egg	4	16	17	41.5	13	54.2
Broken Egg	1	4	10	24.4	9	37.5
Died in Egg	0	0	10	24.4	0	0
Died Emerging	1	4	4	9.8	2	8.3
Washed Out	19	76	0	0	0	0
Total	25	100	41	100	24	100

The hatching success has been shown to be high on Foulney Island, and corresponds to other colonies absent of ground predators. Hatching success of around 80% has been found for terns by Pettingill (1939), Hawksley (1950) and Langham (1968).

Factors influencing hatching success have been mostly in the form of ground predators (Austin 1934), to which peninsula colonies are particularly subject. Predation of terns' eggs by Starlings Sturnus vulgaris L. (Coulson pers.comm.), Crows Corvus corone L. (Austin 1934) and Herring Gulls (Thom, pers.comm.) have also been recorded as producing a significant reduction in hatching success. Food shortage resulting in egg desertion has also been recorded for Common and Arctic Terns by Langham (loc.cit.)

CHICK MORTALITY

Studies on the chick mortality were carried out on all three species of terns. Identification difficulties between the Arctic and Common Tern chicks (see Appendix 4) required that the chicks were ringed in the nest soon after hatching to ensure correct identification. Ringing of older chicks occurred only if identification was confirmed by the chick being fed by an adult prior to capture. The marking of chicks consisted of attaching a coloured plastic ring to the leg. Individually marked rings used at the start of the study for recording growth rate were abandoned as the time between visits to the colony prevented any significant recovery rate. This method was replaced by white rings on the left leg, and red rings on the right leg for the Arctic and Common Terns respectively. Older chicks which were oaptured, but identification not confirmed, were individually marked with a felt tip pen on the emerging primary feathers and could be recognised if recaptured.

On capture all chicks were weighed, and measurements taken of tarsal and wing length (see Appendix 4). The Sandwich Tern chicks were not included in this part of the study. To estimate the chick mortality thorough searches were carried out on all areas of the colony at a maximum of ten day intervals, and to ensure no specimens were counted more than once all corpses were removed and buried. Searches were also carried out on the surrounding areas in case corpses had been removed by predators or tidal action.

The results of the study are presented in Table 18.

Table 18. Tern Chick Mortality on Foulney Island

Species	No. Hatched	No. Ringed No.	No. Ringed %	Ringed Dead No.	Ringed Dead %	Total Dead No.	Total Dead %
Arctic Tern	116	40	34.5	3	7.5	16	13.8
Common Tern	327	74	22.6	15	20.3	34	10.4
Sandwich Tern	141	-		-		8	5.7

The results show a low chick mortality, it does however make no allowance for predation on unidentified chicks and unobserved predation. The predation factor on Foulney was supplied by one Herring Gull which appeared to specialise on tern chicks. This gull on 14 occasions was observed to predate unidentified tern chicks, and on 4 other occasions to take 2 each of Arctic and Sandwich chicks, (the corpses being recovered.) The low chick mortality recorded was not considered due to the inefficiency of the searching technique, as most mortality occurs during the first few days after hatching (Langham 1968), at which time the chicks are close to the nest sites. Other errors produced by chicks being fully devoured whilst on the colony are not known, but there is no evidence to suggest this occurred. The data shown for the mortality of ringed and unringed chicks (Table 18) suggest that there may be an error in the identification of the latter. Appendix 3 gives details of the criteria applied to identification, and in all cases this was used in conjunction with the chicks position on the colony, which had previously been observed to be highly species specific.

Age at Mortality of Common and Arctic Tern Chicks

An investigation into the age at death of the chicks was complicated by the length of time between death and recovery, this prevented weight being used as a criterion for age. A method was devised using wing length, which was considered to be sufficiently accurate to place the chicks into three age categories, ie: 0-5 days, 6-10 days and older than 10 days. The method was based on results obtained from weight increase with age by Langham (loc.cit.) Thus by measuring the wing length to weight relationship on living chicks on Foulney Island, a scale of wing length to age was achieved, which could be applied to the dead chicks.

Table 19. Wing Length in Relation to Age for Common and Arctic Tern Chicks.

Species	Age in Days	Weight Range in g.	Mean Wing Length in cm.
Common Tern	5	36 - 49	3.28 ± 0.24
	10	64 - 82	6.0 ± 0.4
Arctic Tern	5	32 - 44	3.2 ± 0.2
	10	61 - 88	5.82 ± 0.56

Table 20. Age at Death of Recovered Arctic and Common Chicks

Species	Age in Days 0-5 No.	%	6-10 No.	%	>10 No.	%	Total
Arctic Tern	15	93.7	0	0	1	6.3	16
Common Tern	18	52.9	4	11.8	12	35.3	34

The results in Table 20 show that mortality is greatest in the first five days of life. There are four possible causes of chick mortality: (i) predation; (ii) adverse climatic factors; (iii) disease and (iv) starvation. Predation has previously been discussed and although a significant factor in the overall breeding success it did not contribute towards the deaths of the chicks found on the colony. Adverse climatic conditions such as heavy rain storms, low temperatures, etc. were not considered significant, the weather being uniformly hot and dry throughout June and July. There was no evidence of disease being responsible for the death of chicks, and dissection of five Common and one Arctic chick showed the gut to be empty, suggesting that starvation was the cause of death. The question as to why the risk of starvation is greater during the first five days of life is not clear. The volume to surface area relationship would suggest that during this period more energy must be placed into thermoregulation than when the chick is larger. However, Pearson (1963) found that for three species of sea-bird (Kittiwake, Herring Gull and Guillemot) the relationship between maintenance requirement and weight for chicks between 5 and 350 g. was a constant 29% (r = +0.986.) Langham (loc.cit.) has shown that larger clutch sizes tends to increase the brooding time and in times of adverse climatic conditions one parent is unable to obtain sufficient food for the clutch, and the weaker, later hatching chick tends to receive less food. This has been discussed by Lack (1954) in relation to other asynchromous hatching birds, and he concluded that this behaviour had evolved to ensure that when food was short it was not wasted by being fed to small chicks that would eventually die. The continual hot weather on Foulney during fledging reduced the time required for brooding and may be the significant factor in the low chick mortality.

BREEDING SUCCESS

Breeding success of the terns (ie: the number of birds fledged expressed as a percentage of the number of eggs laid) is not known as it was found to be impossible to achieve accurate counts of the numbers of terns fledged. It is considered however that by using the data on egg loss and chick mortality an estimate of the breeding success can be achieved for all three tern species. This estimate is complicated by the fact that the Common Tern had not completed its breeding season at the close of this study. The later breeding terns have been shown to have a much lower breeding success than those which laid earlier in the season, Coulson (pers.comm.), and consequently ommission of these data will artifically increase the overall breeding success. Also the lack of detailed observation on predation of the fledglings will further increase the breeding success. With these qualifications in mind the results are presented in Table 21.

Table 21. Estimation of Breeding Success of the Tern Species on Foulney.

Species	No. of Eggs	No. Hatched	No. of Dead Chicks	Breeding Success %	Young Raised Per Pair
Arctic Tern	141	116	16	70.9	1.4
Common Tern	375	327	34	78.1	2.2
Sandwich Tern	165	141	8	80.6	0.9

The results show that the number of chicks raised correlates with the clutch size, Common, Arctic, Sandwich, representing a decreasing order. This would be expected if hatching and fledging success were the same for all species. Evidence is available however to show that successes vary with species and season.

The hypothesis behind this present study on breeding success was that food paucity (fish food) indicated by diving surveys, and the evidence of local professional fishermen, in close vicinity to the colony would be reflected in the lower numbers of chicks raised by each species. Even allowing for an overestimation of the breeding success the data collected would appear to disprove this hypothesis. Breeding success is higher than reported for all previous workers. It is considered that the major factors producing this are as follows:

(i) Predation

Predation was extremely low, clutch loss due to predation was observed on only one occasion, when a Crow devoured one three egg clutch of a Common Tern. Predation of young was limited to the activities of one Herring Gull which, if observed predation was doubled, still accounted for less than 3% of the colony's young.

(ii) Climatic Conditions

The 1976 season was one of exceptional weather conditions, with extremely low rainfall and continual high temperatures. It is speculated that this allowed the terns to decrease the time spent on brooding and allowed a greater time for collecting food, which in the case of the Common Tern resulted in a reduction of mortality in the larger clutch sizes, which have been shown to be more heavily affected by adverse climatic factors (Langham loc.cit.) It is considered that the increase in feeding time allowed the Common and Sandwich Terns to extend their feeding range, negating the effect of fish food paucity in inshore waters.

(iii) Abundance of Alternative Food

This third factor is specific to the Arctic Terns which adapted their feeding technique to exploit the superabundance of crab in the immediate vicinity of the colony.

It is considered that these three positive factors were sufficient in combination to override the negative factor of fish paucity in the inshore waters.

CONCLUSION

The objective of this study, as mentioned in the introduction, was to determine whether three species of colonial nesting maritime terns present in the same geographical area at the same time, showed evidence of competition for any resource. Competition is used as given by Clements and Shelford (1939), "the process (of competition) may be defined inclusively as a more or less active demand in excess of the immediate supply of material or condition on the part of two or more organisms."

In this study three closely related species of terns have been examined. They all nest in close proximity to one another, and obtain the food for themselves and their young from the surrounding area. All three species are adapted for obtaining food by diving into the sea. There are size differences, Sandwich, Common and Arctic Tern representing a descending order in all aspects except that of wing length, which is similar in both Common and Arctic Terns. The morphological difference will influence movement in the air and on the ground.

The study may be conveniently divided into three sections:

1) Nest Site Selection

Previous research on nest site selection has shown that the Common Tern tends to nest in higher vegetation that the Arctic Tern, the nest site preference of the Sandwich Tern being largely subordinate to their association with Black-headed Gulls (Bent 1921, Boecker 1967).

Austin (1929) has related the preferences to be associated with tarsal lengths.

The situation on Foulney Island was similar and distinct geographical and vegetational preferences were recorded. It appears that the choice of distinctive nest sites avoids competition, as there was no evidence of active expulsion of one species by another. It can be seen that the Arctic Tern may find it difficult to nest in tall vegetation, but the Common Terns absence from the shingle areas is not understood, particularly as in colonies where either species is absent the species present tends to utilise both areas (Fisher and Lockley 1954, Marples and Marples 1934). On Foulney nest sites would appear to be abundant at the present population level for the Common and Sandwich Terns, but the carrying capacity for the Arctic Tern, with reference to their unexpectedly high density on the shingle,suggests it might be limiting. The washed out nests significantly reduced the overall breeding success of this species.

Austin's correlation with tarsal length and nest selection would appear to be substantiated on Foulney. However observation of the colour of the natal down, and predation avoidance behaviour of the Common and Arctic chicks, may be similarily used in an a priori statement, to be the "cause" of the differential selection of nest sites.

2) <u>Food and Feeding Areas</u>

Previous detailed studies of these tern species on food and feeding areas (Pearson 1963, Langham 1968, Dunn 1972), have found that partitioning existed to a large extent. In respect to feeding areas it was found by all three workers that the Common and Sandwich Terns were inshore feeders, and the Arctic Tern to be an offshore feeder. It was considered that for the duration of all the studies food was superabundant, and that areas of overlap were permissable without competition occurring. Dunn further studied these areas of overlap and concluded that the differences in height of dive and mass of the tern species would further alleviate competition.

The studies on diet showed the overlap in prey species was explicable on the non-competition hypothesis by the difference in prey size and by the superabundance of the prey. A similar situation has been reported for German Falconiformes and Strigiformes preying on a superabundance of the vole (Lack 1946).

On Foulney the terns were considered to have adapted to a paucity of fish food in the immediate vicinity of the colony. The Arctic Tern specialising on the Common Shore Crab along the shore line and in intertidal pools formed amongst the mussel beds. The Common and Sandwich Terns changing their status from predominantly inshore feeders (Pearson 1963, Dunn 1972), to feeding offshore and to have extended their range to include the areas abundant in sand eels in the Irish Sea (Reay 1970). The composition of diet between the two latter species is distinct, the Sandwich Tern taking larger numbers of sand eels than the Common Tern, and when prey species overlapped were significantly different in size to reduce competition. It was considered that the paucity of fish food in the immediate area did not produce interspecific competition, rather that each species changed its feeding behaviour according to specific preferences to cope with the situation. This was also found in German Falconiformes and Strigiformes when faced with a reduction in vole numbers (Lack <u>loc.cit.</u>)

3) <u>Breeding Success</u>

Studies on breeding successes of terns have shown that colonies are subject to marked variation. The previous two seasons on Foulney Island had produced no fledged young of any tern species due to the eggs and young being predated by rats (Thom <u>pers.comm.</u>) Prior to the 1976 season a rat control program throughout the winter had irradicated the rats. The present study estimating breeding success from the data on mortality of eggs and young found the breeding success of all three tern species to be high, the number fledged per pair correlating with the clutch size of the species. The high breeding success was considered to be caused by the low level of predation and favourable climatic conditions, the latter allowing a reduction in brooding time, and a consequent increase in time spent in collecting food. It is considered that in less favourable climatic conditions the success rate of the Common and Sandwich Terns, particularly the former, would be lowered to a greater extent that the Arctic Terns. This is based on the distance to the feeding areas in conjunction with the clutch size. It was found that the Common Terns had a lower breeding success than the Arctic Terns when faced with a similar situation on Wangerooge, which was considered to be due to the greater adaptation of the Arctic Tern.

Apart from indirect exclusion in nest site selection there is no evidence of competition between the three species of closely related terns studied during the breeding season in the vicinity of Foulney Island.

Appendix 1.

FLOWERING PLANTS OF FOULNEY ISLAND

Vernacular	Scientific
Sea Campion	Silene vulgaris
Bladder Campion	Cerastium arvense
Sea Sandwort	Honkenya peploides
Yellow Forget-me-not	Myosotis discolor
Groundsel	Senecio vulgaris
Daisy	Bellis perennis
Dandelion	Taraxacum officinale
Mouse-ear Hawkweed	Hieracium pilosella
Ribwort Plantain	Plantago lanceolata
Bulbous Buttercup	Ranunculus bulbosus
Birdsfoot Trefoil	Lotus corniculatus
Hop Trefoil	Trifolium campestre
Hairy Tare	Vicia hirsuta
Common Vetch	Vicia sativa
Spring Vetch	Vicia lathyroides
Sea Thrift	Armeria maritima
Meadow Saxifrage	Saxifraga granulata
Lambs Lettuce	Valerianella locusta
Germander Speedwell	Veronica chamaedrys
Hairy Bittercress	Cardamine hirsuta
Danish Scurvy-grass	Cochlearia danica
Thale Cress	Arabidopsis thaliana
Sea Kale	Crambe maritima
Herb Robert	Geranium robertianum
Dove's-foot Cranesbill	Geranium molle
Cow Parsley	Anthriscus sylvestris
Common Sorrel	Rumex acetosa
Sheep Sorrel	Rumex acetosella
Lady's Bedstraw	Galium verum
Sea Milkwort	Glaux maritima
Common Mallow	Malva sylvestris
Sea Spurrey	Spergularia marina
Curled Dock	Rumex crispus
Stinking Mayweed	Anthemis cotula
Common Catsear	Hypochaeris radicata
Yarrow	Achillea millefolium

Flowering Plants of Foulney Island, contd.

Vernacular	Scientific
Smooth Sow Thistle	Sonchus oleraceus
White Clover	Trifolium repens
Wild Thyme	Thymus serpyllum
Wall Pepper	Sedum acre
Wild Raddish	Rhaphanus raphanistrum
Sea Lavender	Limonium vulgare
Silverweed	Pontilla anserina
Yellow Horned Poppy	Glaucium flavum
Sea Beet	Beta vulgaris
Perennial Sow Thistle	Sonchus arvensis
Ragwort	Senecio jacobaea
Harebell	Campanula rotundifolia
Sea Purslane	Halimione portulacoides

Appendix 2.

Area = Subdivision of colony into 30 m. strips across the long axis. Areas were numbered alphabetically from North to South.

Location = Position of nest site within area, eg: 10 15 refers to the nest being 10 metres from the area marker along the long axis of the spit, and 15 metres in from the extreme high water springs line on the West side of the spit.

Vegetation Scale =

0 & 1	=	< 20%	ground cover
2	=	20-39%	ground cover
3	=	40-59%	ground cover
4	=	60-79%	ground cover
5	=	80-100%	ground cover.

APPENDIX 2.

ARCTIC TERNS' EGGS AND NESTS

Area	Number of Eggs	Egg Size in cm.	Location	Nest Lining	Vegetational Scale
A	2	4.0 3.0 4.1 2.9	2 0	+	0
A	2	4.0 3.0 4.1 2.9	4 0	+	0
A	2	4.1 2.9 4.0 3.0	12 0	+	0
A	2	4.1 3.0 4.0 3.0	14 0	+	0
A	3	4.1 2.9 4.0 2.9 3.9 2.8	16 0	+	0
A	2	4.0 3.1 4.1 2.9	16½ 0	+	0
A	2	4.2 2.9 4.0 3.0	18 0	+	0
A	2	4.1 3.0 4.1 3.0	20 0	+	0
A	2	4.2 3.1 4.0 2.9	21 0	+	0
A	2	4.1 3.0 4.0 2.9	22 0	+	0
A	2	4.0 3.0 4.1 3.0	22½ 0	+	0
A	3	4.1 3.0 4.0 2.9 4.0 2.9	25 0	+	0
A	2	4.1 3.0 4.0 3.0	26½ 0	-	0
A	2	4.2 3.0 4.0 2.9	28 0	-	0
A	3	4.2 2.9 3.8 2.9 3.8 2.9	36 0	+	0

Arctic Terns' eggs and nests, contd.

Area	Number of Eggs	Egg Size in cm.	Location	Nest Lining	Vegetational Scale
B	2	4.0 3.0 4.0 3.0	3½ 0	-	0
B	2	4.2 2.8 4.0 2.8	8 -2	+	0
B	2	4.1 2.9 4.0 2.8	11½ 0	+	0
B	2	3.9 2.8 3.9 2.8	17 -1	+	0
B	3	4.2 2.8 4.0 2.8 4.1 2.8	19 0	+	0
B	2	3.9 2.9 4.0 3.0	6 -2	+	0
B	2	3.9 2.8 3.9 2.8	6 0	-	0
B	2	3.9 2.9 4.0 3.0	1 +2	+	0
B	2	4.1 2.8 4.0 2.8	22 -1	+	0
B	2	4.0 2.9 4.2 3.0	23 -2	-	0
B	2	3.9 2.9 3.9 2.9	3 0	-	0
B	1	4.0 2.9	20½ 0	-	0
B	2	4.2 2.9 4.1 2.9	29 0	+	0
C	2	4.1 2.9 3.9 2.9	15 0	+	0
C	2	4.2 2.9 4.2 2.9	20 0	+	0
C	2	4.2 3.0 3.9 3.0	25 0	+	0

Arctic Terns' eggs and nests, contd.

Area	Number of Eggs	Egg Size in cm.	Location	Nest Lining	Vegetational Scale
A	1	4.0 2.8	34 0	-	0
A	2	4.4 2.7 4.2 2.7	18 2	+	2
A	1	4.2 2.9	15 4		0
A	2	4.0 2.9 3.9 2.9	15½ 6	+	0
A	3	4.0 2.8 3.9 3.1 3.6 3.0	43 0	-	0
B	2	4.0 2.8 4.0 2.9	5 0	+	0
B	2	4.2 3.1 4.3 3.1	7 0	+	0
B	2	3.9 3.0 4.1 3.0	8 0	+	0
B	2	3.7 2.9 3.8 2.9	10 0	+	0
B	3	3.8 2.6 3.8 2.7 3.9 2.7	20 0	+	0
B	2	3.8 2.8 3.9 2.9	26 0	-	0
B	2	4.0 3.1 4.0 3.1	27 0	+	0
B	2	3.9 2.8 4.0 2.8	28 0	+	0
B	1	3.9 2.8	28½ 0	+	0
B	2	4.1 2.9 4.0 2.8	25 0	-	0
B	2	4.1 3.0 3.8 2.9	30 -1	+	0
B	2	4.2 3.0 3.9 3.0	1 0	+	0

Arctic Terns' eggs and nests, contd.

Area	Number of Eggs	Egg Size in cm.	Location	Nest Lining	Vegetational Scale
C	2	3.8 2.8 3.9 2.9	-	-	0*
C	1	4.0 3.0	-	+	0*
C	2	4.2 2.9 4.0 2.9	-	-	0*
C	2	4.0 3.1 4.0 3.0	-	+	0*
C	2	4.1 2.8 4.0 2.8	-	+	0*
C	2	4.1 3.0 4.0 2.9	-	+	0*
C	2	4.1 3.0 4.1 3.0	-	+	0*
C	2	4.0 2.9 3.9 2.9	4 0	+	0
C	2	4.0 2.8 3.9 2.8	15 4	+	0
C	2	4.3 3.0 4.1 2.9	20 -	+	0*
C	2	3.8 2.8 4.1 3.0	28 23	+	2
C	2	4.2 3.0 4.0 3.0	8 36	+	2
C	2	4.0 3.0 4.0 3.0	10 37	+	1
F	2	4.3 2.9 4.0 2.8	13 45	+	0
G	1	3.7 2.9	26 43	+	0
G	1	4.4 2.9	2 -2	+	0*
G	2	4.1 2.9 3.9 2.9	10 0	+	0

Arctic Terns' eggs and nests, contd.

Area	Number of Eggs	Egg Size in cm.	Location	Nest Lining	Vegetational Scale
G	2	4.1 2.9 4.0 2.9	20 1	-	1
H	2	4.4 2.9 4.2 2.9	6 22	+	1
I	2	4.2 3.0 4.0 3.1	0 20	+	0
Main Island	1	4.2 2.9		-	0+
Main Island	2	3.7 3.1 3.7 3.1		-	0
Main Island	1	4.0 2.9		-	0*
Main Island	2	4.1 3.0 4.2 2.9		-	0*

* Washed out.

\+ Robbed

COMMON TERNS' EGGS AND NESTS

Area	Number of Eggs	Egg Size in cm.	Location	Nest Lining	Vegetational Scale
A	3	4.3 3.1 3.9 3.0 4.3 3.0	2 1	+	2
B	3	4.0 3.0 4.0 2.8 4.0 2.8		+	
B	3	3.8 2.6 3.8 2.7 3.8 2.8		+	
B	3	4.0 2.9 4.0 2.8 4.1 3.0		+	
B	3	4.0 2.8 4.0 2.8 4.0 2.8		+	
B	3	3.6 3.0 3.7 2.9 3.8 2.8		+	
B	3	4.1 3.0 4.1 3.0 4.1 3.0	15 0	+	1
B	3	4.2 3.0 4.0 3.0 3.9 3.1	2 26	+	1
B	3	3.9 2.9 4.0 3.0 3.9 3.0	2 22	+	2
B	3	3.9 3.0 3.9 3.0 3.9 2.9	4 22	+	3
B	3	4.1 3.0 4.1 3.0 4.1 3.0	6 22	+	2
B	3	4.1 2.9 4.0 3.0 4.0 3.0	8 4	+	1

Common Terns' eggs and nests, contd.

Area	Number of Eggs	Egg Size in cm.	Location	Nest Lining	Vegetational Scale
B	3	3.9 3.1 3.8 3.0 3.8 2.7	10 18	+	3
B	3	4.2 2.9 4.0 2.8 4.0 2.8	12 7	+	2
B	3	4.1 3.0 4.0 2.9 4.2 2.9	15 2½	+	3
B	3	3.8 3.0 3.9 3.1 3.8 3.0	19 12	+	3
B	3	3.9 3.1 4.0 3.0 4.0 3.0	20 2	+	2
B	3	3.8 3.1 3.8 3.1 3.8 3.1	22 3	+	2
B	2	4.0 3.0 4.0 3.0	24 3½	+	3
B	3	4.3 3.0 4.2 3.0 4.2 2.9	25 3½	+	2
B	3	4.2 3.0 4.3 3.0 4.1 3.1	26 3	+	1
B	3	3.9 3.0 3.9 3.0 4.1 2.9	27 2	+	2
B	3	4.0 2.9 4.1 2.9 4.0 2.9	28 2½	+	1
B	3	4.1 2.9 4.0 2.8 4.0 2.9	29 1½	+	2
B	2	4.1 3.0 4.1 3.0	25 5	-	3

Common Terns' eggs and nests, contd.

Area	Number of Eggs	Egg Size in cm.	Location	Nest Lining	Vegetational Scale
C	3	3.9 2.9 3.9 2.9 3.9 2.9		+	
C	3	4.1 2.9 4.0 2.9 4.0 2.9	7 32	+	3
C	3	3.9 2.9 3.8 2.9 4.2 2.9	13 4	+	3
C	2	4.0 3.1 3.9 3.2	14 29	+	3
C	3	3.7 3.0 3.5 3.1 3.5 3.0	14½ 30	+	3
C	3	4.2 2.9 4.0 2.9 4.0 2.9	19 28	+	4
C	3	3.8 3.0 4.0 3.0 3.9 3.0	23 12	+	4
C	3	4.0 3.0 4.0 3.0 4.2 3.0	23 30	+	3
C	3	3.9 3.0 4.0 3.1 4.0 3.0	17 29	+	3
C	3	4.1 2.8 3.9 2.9 3.9 2.9	23 16	+	4
C	3	4.0 3.0 3.9 3.0 3.9 3.0	25½ 15½	+	4
C	3	4.3 3.0 4.6 3.0 4.1 3.1	27 17	+	4
C	3	3.9 3.0 3.9 3.0 3.9 3.0	28 18	+	3

Common Terns' eggs and nests, contd.

Area	Number of Eggs	Egg Size in cm.	Location	Nest Lining	Vegetational Scale
C	3	3.9 2.9 4.0 2.9 3.9 2.9	24 21	+	3
C	2	4.2 2.9 4.0 2.9	28 20	+	3
C	3	4.1 3.0 4.2 3.0 3.9 3.0	24 1	+	2
C	3	4.0 3.0 4.0 3.0 4.0 2.9	29½ 20	+	3
C	3	4.0 3.0 3.9 2.9 3.9 2.9	29 22	+	3
C	3	4.1 3.0 4.1 2.8 4.0 2.8	18 30	+	2
C	3	4.0 3.0 3.9 2.9 4.0 3.0	3 36	+	2
C	2	4.1 3.0 4.1 3.0	28 2	-	2
C	3	3.8 2.8 3.9 2.9 3.8 3.1	1 40	+	1
C	2	3.9 2.9 4.0 3.0	2½ 39	+	2
C	2	4.2 3.0 4.2 2.9	22 22	+	1
C	3	4.0 3.1 4.1 3.0 4.0 3.0	4½ 39	+	3
C	3	4.0 3.2 4.2 3.0 4.1 3.0	12 32	+	4

Common Terns' eggs and nests, contd.

Area	Number of Eggs	Egg Size in cm.	Location	Nest Lining	Vegetational Scale
C	3	4.1 2.9 4.2 3.0 4.2 2.9	20 26	+	4
C	2	4.2 2.9 4.1 2.9	22 25	+	3
C	3	4.2 3.0 4.0 3.0 3.8 2.9	29 25	+	3
C	2	4.0 3.0 3.9 3.0	20 15	+	5
C	2	4.1 3.0 4.0 3.0	10 20	+	5
C	3	3.7 2.8 3.6 2.8 3.6 2.8	28 21	+	5
D	3	4.0 2.9 4.2 2.9 3.9 2.9	3 18	+	3
D	3	4.1 3.0 4.0 3.1 4.2 3.1	0 20	-	4
D	3	3.9 3.1 4.1 3.1 4.0 3.0	5 24½	-	3
D	3	4.2 3.0 4.0 2.9 3.9 2.9	3 22	+	4
D	3	4.1 3.0 4.1 2.9 4.1 2.9	6 10	+	4
D	2	4.2 3.0 4.2 2.9	7 11½	+	4
D	3	3.8 2.8 3.7 2.8 3.9 2.9	8 26	+	4
D	3	4.4 2.9 4.3 3.0 4.2 2.9	12 22	+	4

Common Terns' eggs and nests, contd.

Area	Number of Eggs	Egg Size in cm.	Location	Nest Lining	Vegetational Scale
D	3	3.9 2.9 4.0 3.0 4.1 2.8	15 21	+	4
D	2	3.9 2.9 3.8 2.8	15 20½	+	4
D	3	4.0 3.1 4.1 3.0 4.1 3.0	15 5	+	4
D	3	4.2 3.0 4.0 2.9 4.4 3.0	18 11	+	3
D	2	4.0 3.1 4.2 3.0	18 17	+	4
D	3	4.1 3.0 3.8 3.1 4.0 3.1	19 22	+	4
D	3	4.0 2.9 4.0 2.8 3.9 2.8	29½ 6	+	4
D	2	4.3 2.9 4.3 2.9	26 21	+	4
D	3	4.0 3.1 4.0 3.0 3.8 3.2	27 21	-	4
D	3	4.0 3.0 4.0 2.9 3.8 3.0	13 9	+	4
D	3	4.0 3.0 4.0 3.0 4.2 3.0	16 18	+	3
D	3	3.8 3.0 4.0 2.8 3.8 3.1	23 37	+	1
D	3	3.8 2.8 3.7 2.9 3.8 2.8	29 38	+	1

Common Terns' eggs and nests, contd.

Area	Number of Eggs	Egg Size in cm.	Location	Nest Lining	Vegetational Scale
D	2	4.3 3.1 4.0 3.0	15 22	+	5
E	2	4.0 2.9 4.0 2.9	26 4	+	5
E	3	4.0 2.9 4.1 3.0 3.9 2.9	2 12	+	3
E	3	4.0 3.0 4.2 3.0 4.2 2.9	½ 12½	+	3
E	3	4.0 2.9 4.0 2.9 4.0 3.0	4½ 12	+	3
E	3	4.1 2.8 4.2 3.0 4.2 2.8	12 8	+	5
E	3	4.1 3.0 4.0 2.9 4.1 2.9	14½ 12	+	4
E	3	3.9 2.8 3.8 2.8 3.8 2.8	12½ 12½	+	4
E	2	4.2 2.9 4.1 3.0	17 6½	-	4
E	2	4.3 3.0 4.2 3.0	16 11	+	4
E	3	3.9 3.0 3.8 3.2 3.8 3.0	16½ 12	+	4
E	3	4.2 2.8 4.0 2.9 4.1 2.8	17½ 12	+	4
E	2	4.2 3.0 4.2 3.0	18 21	+	3

Common Terns' eggs and nests, contd.

Area	Number of Eggs	Egg Size in cm.	Location	Nest Lining	Vegetational Scale
E	3	4.0 2.8 3.9 2.9 4.0 3.0	23½ 21	+	4
E	3	4.2 2.8 4.0 2.9 4.1 3.0	25 13	+	4
E	3	3.9 2.9 4.0 2.8 4.1 2.8	23 11	+	4
E	1	4.1 3.0	22½ 10½	+	4
E	2	4.2 3.0 4.3 2.9	23½ 7½	+	4
E	3	4.1 3.0 3.9 2.9 3.9 2.8	28 12	+	5
E	3	4.0 2.9 3.9 2.9 4.0 2.9	28½ 11	+	5
E	3	4.2 2.9 4.1 2.9 4.0 3.0	12 47	+	1
E	3	4.0 3.0 4.1 3.0 4.1 3.1	20 48	+	0
E	3	4.0 2.9 3.9 2.9 4.0 2.9	12 17½	+	4
E	3	4.0 3.0 4.0 3.1 3.9 2.9	24 18	+	5
E	3	3.9 2.9 3.9 2.9 3.8 3.0	24 17½	+	5
E	3	4.0 2.9 3.9 3.0 3.9 2.9	24 26	+	5

Common Terns' eggs and nests, contd.

Area	Number of Eggs	Egg Size in cm.	Location	Nest Lining	Vegetational Scale
E	3	4.0 3.0 4.0 3.1 4.0 2.9	28 18	+	4
E	3	4.0 2.9 4.0 2.9 4.0 2.9	20 17	+	0
E	3	4.0 3.0 4.0 3.0 4.0 3.0	10 21	+	4
E	3	4.0 2.9 4.0 3.0 4.1 2.9	3 20	+	3
E	2	4.1 2.9 3.9 2.8	20 19	+	5
E	2	3.9 3.0 4.0 3.0	10 32	+	4
F	3	4.3 3.1 4.2 3.1 4.0 3.1	21 9	+	
F	2	4.0 3.0 4.0 3.0	20 10	+	5
F	3	4.3 2.8 4.5 2.8 4.2 2.8	28 10	+	5
F	3	4.0 3.0 4.0 3.0 4.1 3.0	30 8	+	4
F	2	4.3 2.8 4.1 2.8	10 8½	+	5
F	3	4.2 2.8 4.1 2.8 4.2 2.8	29 18	+	4
G	1	4.0 2.9	18 6	+	5

Common Terns' eggs and nests, contd.

Area	Number of Eggs	Egg Size in cm.	Location	Nest Lining	Vegetational Scale
G	3	4.3 3.0 4.4 3.1 4.4 3.1	10 15	+	4
H	2	4.3 3.1 4.2 3.1	2 12	+	4
I	3	4.0 3.0 4.1 3.0 3.9 2.9	26 5	-	3
I	2	4.0 2.9 4.0 2.9	26 10	+	5
I	3	4.0 2.9 3.9 2.8 4.0 2.9	29 11½	+	3
I	3	3.8 3.0 3.8 3.0 3.8 3.1	14 12	+	3
I	3	4.2 3.1 3.9 2.9 3.9 3.0	23 12	+	3
I	2	4.3 3.1 4.2 3.1	18 12	+	5
I	3	4.2 2.7 4.1 2.9 3.9 2.9	25 5½	+	5
I	3	4.0 2.9 3.8 2.9 3.8 2.9	25 10	+	4
I	2	3.8 2.9 3.9 2.8	7 ½	+	5
I	2	4.1 3.0 4.1 3.0	12 20	+	4
I	2	4.1 3.0 4.1 3.0	20 13	+	4
I	2	4.2 2.9 4.3 2.9	22 13	+	4

Common Terns' eggs and nests, contd.

Area	Number of Eggs	Egg Size in cm.	Location	Nest Lining	Vegetational Scale
I	3	4.4 3.0 4.1 3.0 4.2 3.0	22½ 14	+	4
I	2	4.1 2.9 4.1 2.8	29 10	-	5
I	2	4.1 2.9 3.9 2.9	28 20	+	1
I	2	4.2 2.9 3.9 2.9	18 14	+	4

COMIC TERNS' EGGS AND NESTS

Area	Number of Eggs	Egg Size in cm.	Location	Nest Lining	Vegetational Scale
B	1	4.0 2.8	5 22	+	2
B	1	4.2 3.0	6½ 22½	+	3
B	1	4.0 3.0	11 17	+	3
B	2	4.0 3.0 4.0 3.0	14 2	+	1
B	1	4.0 2.9	15 4	+	2
C	2	4.0 2.9 3.9 3.0	18 28	+	3
C	1	4.1 2.8	1 37	+	2
C	2	3.9 2.8 3.8 2.9	18 33	-	1
D	1	3.9 2.8	9 18	+	3
D	1	4.0 3.0	27 4	+	4
D	3	4.1 3.0 4.1 3.1 4.0 3.0	13 37	+	5
D	2	4.3 3.0 4.3 3.0	17 39	+	0
E	2	3.8 2.9 4.0 2.9	4½ 29	+	3
E	1	4.0 2.9	5½ 12½	+	4
F	1	4.0 3.0	24 8	+	5
F	1	3.8 2.7	24 5	+	5
G	2	3.8 3.1 3.8 2.9	19½ 15	+	4
G	1	4.2 2.9	5 20	+	4
H	2	4.2 2.9 4.2 2.9	3 8	-	5

Appendix 3.

OBSERVATIONS ON ARCTIC AND COMMON TERN CHICKS

A number of observations on characteristics of the young of the Common and Arctic Terns have been noted which are of use in identifying these species. The problems generally found by workers in identification of the adults are increased when dealing with the unfledged birds.

Natal Down

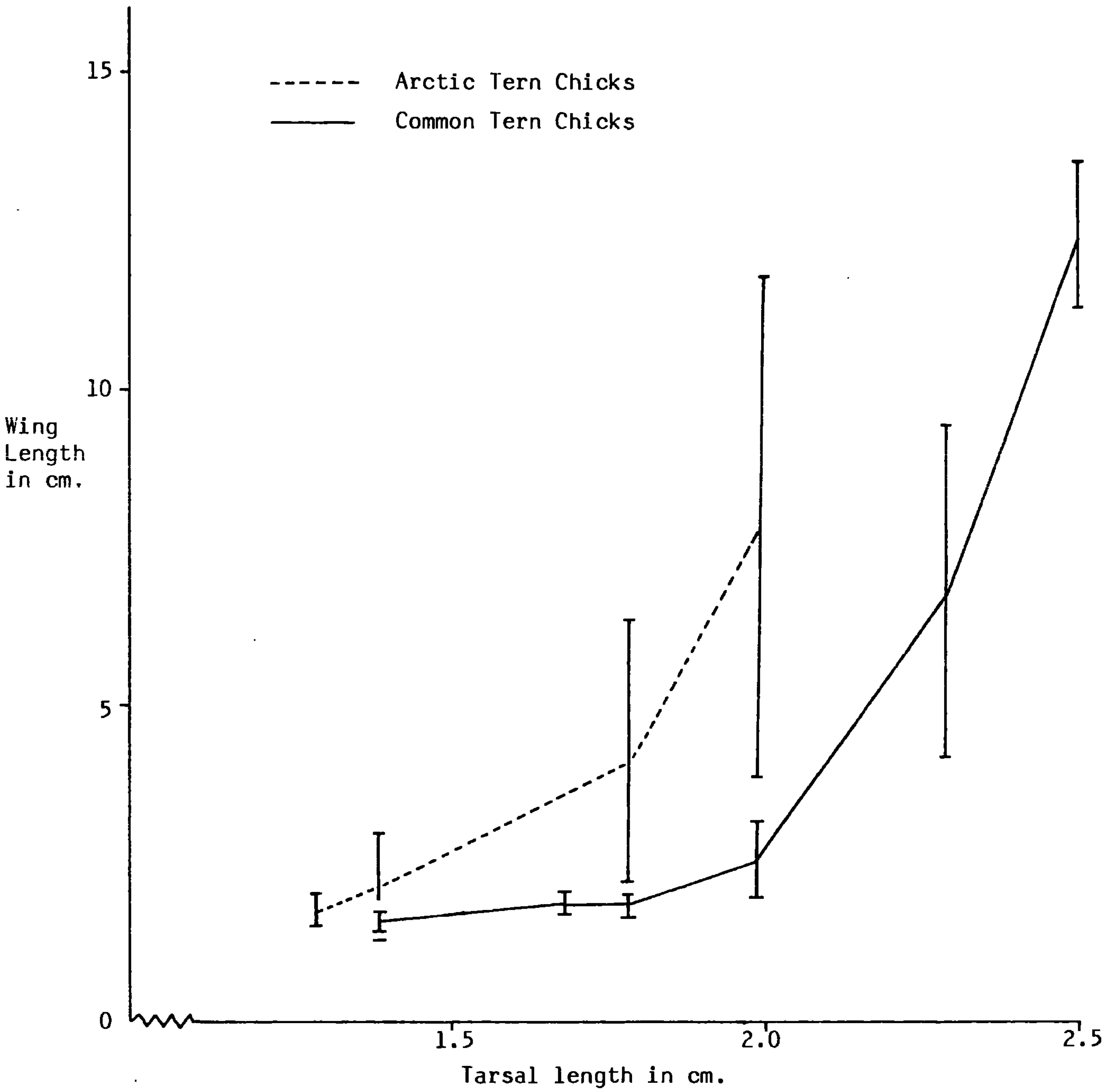
Observations on the colour of the natal down in the Arctic and Common Tern chicks showed that of the chicks captured prior to leaving the nest, (when identification could be confirmed with adult identification) 37% of the Arctic Tern chicks were noted to have a grey natal down. The remaining 63% had a natal down which was predominantly brown with flecks of black, a colour which was found to occur 100% in the Common Tern chicks.

Tarsus and Wing Length

One of the most reliable ways of discerning between the adults of the Common and Arctic Terns (given favourable conditions) is the relative tarsal lengths of the birds. Witherby et al. (1946) gives a variation of 15-17 mm. for the Arctic Tern, and 19-21 mm. for the Common Tern. It was found that in the absence of plumage characteristics, tarsal length in relation to wing length formed a fairly reliable method of identification of chicks. The details of wing length to tarsal length for both species are presented in Graph 5. It will be noted that the tarsal lengths supplied in the data exceed those given by Witherby, this was due to the method of measuring which entailed the inclusion of the joints above and below the tarsus.

The method described is not considered to be in anyway definitive, but it is a method which could, with further investigation, form a reliable technique for identification.

Graph 5. Relationship of Wing Length to Tarsal Length in Common and Arctic Tern Chicks (Confidence Limits Calculated to 95%).



COMMON TERN CHICKS

Colour	Tarsal Length cm.	Wing Length cm.	Ring Colour	Primary Colour	Weight g.	Comments
Brown	2.3	4.1	R.		48	
Brown	1.7	1.9	BRB.		18	
Brown	2.0	2.5	YPY.		28	
Brown	1.7	1.5	BY.		15	
Brown	1.4	1.5	R.		17	
Brown	1.4	1.7	R.		21	
Brown	1.7	1.9	R.		21	
Brown	1.6	1.4	R.		20	
Brown	1.4	1.5	R.		13	
Brown	1.8	2.1	R.		24	
Brown	1.8	1.6	R.		18	
Brown	1.6	1.6	R.		14	
Brown	1.8	1.7	R.		17	
Brown	1.6	1.3	R.		12	
Brown	2.3	8.0	R.		100+	
Brown	1.8	1.9	R.		14	
Brown	1.7	1.7	R.		22	
Brown	1.8	1.7	R.		17	
Brown	1.6	1.7			13	
Brown	1.8	2.0			16	
Brown	1.6	1.7	R.		15	
Brown	1.7	1.5	R.		13	
Brown	1.7	1.8	R.		17	
	2.3	12.0		RW 1Y	100+	
Brown	1.7	1.6			11	Dead
Brown	1.6	1.6			11	Dead
Brown	1.3	1.5				Dead
Brown	1.6	1.6	R.		13	
Brown	1.7	1.5	R.		18	
Brown	1.7	1.8	R.		20	
Brown	1.8	1.6	R.		16	

Common Tern Chicks, contd.

Colour	Tarsal Length cm	Wing Length cm.	Ring Colour	Primary Colour	Weight g.	Comments
Brown	1.7	1.6	R.		18	
Brown	1.6	1.7			10	Dead
Brown	1.8	1.5	R.		17	
Brown	1.8	1.8	R.		23	
Brown	1.7	1.8	R.		18	
Brown	1.9	1.9	R.		24	
Brown	1.8	1.8	R.		18	
Brown	1.8	1.8	R.		13	
Brown	1.8	1.7	R.		13	
"F.P."	2.5	11.0		RW 2Y	100+	
Brown	2.0	2.3	R.		28	
Brown	1.8	1.8	R.		16	
Brown	1.7	2.2	R.			Rec Dead
Brown	1.8	1.8	R.			Rec Dead
Brown	1.7	1.7	R.		23	
"F.P."	2.4	13.0			100+	
Brown	1.8	1.8	R.			Rec Dead
Brown	1.7	1.9	R.		18	
Brown	1.7	1.7				Dead
Brown	2.1	2.6	R.		40	
Brown	1.9	1.9	R.		19	
Brown	2.2	2.5	R.		46	
Brown	1.8	2.0	R.		18	
Brown	2.1	3.1	R.		38	
Brown	2.5	16.1	R.		100+	
Brown	1.8	1.7				
Brown	1.7	1.9	R.		20	
Brown	1.6	1.6				Dead
Brown	2.3	6.2	R.		100+	
Brown	2.1	9.0				Dead
Brown	1.9	2.1	R.		14	
Brown	1.9	1.9				Dead
Brown	2.5	13.0	R.		100+	
Brown	1.7	1.6	R.		17	

Common Tern Chicks, contd.

Colour	Tarsal Length cm.	Wing Length cm.	Ring Colour	Primary Colour	Weight g.	Comments
Brown	2.5	10.1		R RIP	53	
Brown	1.7	1.6	R.		16	
Brown	1.8	1.9	R.		20	
-	2.4	11.0				Dead
-	2.3	6.8				Dead
Brown	2.4	10.1	R.		100+	
Brown	2.3	3.8	R.		50	
Brown	2.0	3.6	R.		43	
Brown	1.7	1.5	R.		16	
Brown	1.8	1.8	R.		16	
Brown	1.8	1.9	R.		18	
Brown	1.8	1.8	R.		18	
Brown	1.5	1.5	R.		13	
"F.P."	2.6	10.5		R RIP		Rec Dead
"F.P."	2.7	14.5	R.	LR 2P	100+	
Brown	1.7	1.7	R.		13	
Brown	1.8	1.6	R.		18	
"F.P."	2.3	13.2				
"F.P."	2.4	15.4	R.			
Brown	1.9	1.9	R.			Rec Dead
Brown	1.5	1.5	R.		11	
-	2.1	4.4	R.			Rec Dead
Brown	2.0	1.9	R.		19	
Brown	1.8	2.1	R.		20	
Brown	1.6	1.6				Dead
Brown	1.8	1.8	R.		18	
Brown	2.1	2.8	R.		36	
Brown	2.1	3.8	R.			Rec Dead
Brown	2.5	5.5	R.		76	
Brown	1.6	1.6				
"F.P."	2.7	17.3	R.		100+	
Brown	1.6	1.6	R.			Rec Dead
Brown	1.8	2.2	R.		23	Rec Dead

Common Tern Chicks, contd.

Colour	Tarsal Length cm.	Wing Length cm.	Ring Colour	Primary Colour	Weight g.	Comments
Brown	1.7	1.9				Dead
-	2.2	3.8				Dead
-	2.4	7.0				Dead
Brown	1.8	1.6				Same Nest Dead
Brown	1.8	1.8				
-	2.4	8.9				Dead
-	2.5	22.5				Dead
-	2.3	9.0				Dead
-	2.5	14.6	R.		98	Rec Dead
-	2.2	5.6	R.		38	Rec Dead
-	2.3	7.3	R.		45	Rec Dead
-	2.2	6.8	R.			Rec Dead
-	2.6	17.0	R.			Rec Dead
Brown	1.9	2.1				Dead

ARCTIC TERN CHICKS

Colour	Tarsal Length cm.	Wing Length cm.	Ring Colour	Primary Colour	Weight g.	Comments
Grey	1.4	2.0				Dead
Grey	1.7	11.0	Y.		100+	
Grey	1.2	1.4	BWB.		13	
Grey	1.3	2.1	WYW		14	
Grey	2.0	3.3	YB.		43	
Brown	1.8	2.2	RY.		23	
Brown	1.8	2.2	RB.		28	
Grey	2.2	4.1	BYB.		63	
Brown	1.6	1.8	RYR.		18	
Brown	1.8	1.4	YRY		15	
Grey	2.0	8.0	BY.		100+	
Brown	1.8	2.6	RW.		32	
Brown	1.3	1.4				Dead
Brown	1.4	2.6				Dead
Grey	1.8	12.0	RB.		100+	
Brown	2.2	5.5	PW.		70	
Brown	1.9	5.5	WPW.		63	
Brown	1.9	3.0	RPR.		33	
Brown	1.6	1.8	PR.		14	
Brown	1.8	12.6	G.		100+	
Brown	2.0	8.0	B.		87	
Brown	2.1	8.9	BY.		100+	
Brown	1.6	2.4	PY.		13	
Brown	2.1	6.9	GWG.		100+	
Brown	1.4	1.5				Dead
Grey	1.3	2.5				Dead
Brown	1.1	1.5				Dead
Brown	1.3	1.5				Dead
Brown	1.3	1.4				Dead
Grey	1.3	1.5				Dead
Brown	1.3	1.3				Dead
Brown	1.4	1.6				Dead
Grey	1.6	2.1	PRP.		17	
Brown	1.8	1.8	BPB.		20	

Artic Tern Chicks, contd.

Colour	Tarsal Length cm.	Wing Length cm.	Ring Colour	Primary Colour	Weight g.	Comments
Grey	2.0	4.5	PR.		100+	
Brown	1.7	2.3	PBP.		28	
Brown	1.9	3.2	PYP.		40	
Brown	1.8	1.8	W.		15	
Brown	1.8	2.2	W.		23	
Brown	1.8	2.5	W.		19	
Grey	2.0	15.5	G.		100+	
Brown	1.5	1.8				Dead
Brown	1.3	1.5	W.		18	
Brown	2.2	12.0	W.		100+	
Grey	1.4	1.6	W.		16	
Brown	1.3	1.5	W.		11	
Brown	1.7	2.4	W.		33	
Grey	1.4	2.0				Dead
Grey	1.3	1.4	BWB.			Rec Dead
Grey	2.1	16.0			100+	Dead
Brown	1.4	1.6	W.		12	
Grey	1.4	1.7	Y.		18	
Grey	1.6	6.0	W.		60	
Grey	1.4	3.5	W.		33	
Grey	1.7	6.1	W.			Rec Dead
Brown	1.6	1.6	W.		13	
Brown	1.7	3.8	W.		38	
Brown	1.3	1.8			14	
Brown	1.4	1.9	W.			Rec Dead

SANDWICH TERN CHICKS

Colour	Tarsal Length cm.	Wing Length cm.	Ring Colour	Primary Colour	Weight g.	Comments
-	2.3	2.1				Dead
-	2.2	3.9				Dead
-	3.9	5.2				Dead
-	1.8	2.1				Dead
-	1.8	2.1				Dead
-	1.9	2.0				Dead

APPENDIX 5.

SANDWICH TERN DIET ANALYSIS

Low Tide

Ammodytidae No.	Ammodytidae %	Clupeidae No.	Clupeidae %	Total
37	75.5	12	24.5	49
53	96.4	2	3.6	55
60	86.9	9	13.0	69
42	100	0	0	42
69	93.2	5	6.8	74
17	29.8	40	70.2	57
32	94.1	2	5.9	34
310	81.5	70	18.4	380

Mid Tide

Ammodytidae No.	Ammodytidae %	Clupeidae No.	Clupeidae %	Total
64	88.9	8	11.1	72
16	80	4	20	20
90	100	0	0	90
42	87.5	6	12.5	48
71	100	0	0	71
19	23.5	62	76.5	81
53	96.4	2	3.6	55
49	80.3	12	19.7	61
12	100	0	0	12
67	93	5	7	72
29	90.6	3	9.4	32
512	83.4	102	16.6	614

High Tide

Ammodytidae No.	Ammodytidae %	Clupeidae No.	Clupeidae %	Total
84	100	0	0	84
72	100	0	0	72
12	19.7	49	80.3	61
92	97.9	2	2.1	94
76	95	4	5	80
54	100	0	0	54
76	100	0	0	76
39	90.7	4	9.3	43
73	89	9	11	82
578	89.5	68	10.5	646

COMMON TERN DIET ANALYSIS

Low Tide

Ammodytidae No.	Ammodytidae %	Clupeidae No.	Clupeidae %	Total
13	61.9	8	38.1	21
12	27.3	32	72.7	44
17	80.9	4	19.1	21
24	60	16	40	40
11	100	0	0	11
4	7.1	52	82.9	56
16	76	5	24	21
97	45.3	117	54.7	214

Mid Tide

Ammodytidae No.	Ammodytidae %	Clupeidae No.	Clupeidae %	Total
2	7.7	24	92.3	26
12	28.6	30	71.4	42
6	33.3	18	66.7	24
12	38.7	19	61.3	31
3	33.3	6	66.7	9
12	24.5	37	75.5	49
17	27.4	45	72.5	62
5	17.8	23	82.1	28
16	32.7	33	67.3	49
85	26.5	235	73.4	320

High Tide

Ammodytidae No.	Ammodytidae %	Clupeidae No.	Clupeidae %	Total
2	5.9	32	94.1	34
7	13.2	46	86.8	53
16	45.7	19	54.3	35
5	10.9	41	89.1	46
24	72.7	9	27.3	33
4	11.8	30	88.2	34
58	24.7	177	75.3	235

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