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CONTENTS

Cover vignette of Manx Shearwater by B. Zonfrillo

The population size of Manx Shearwater *Puffinus puffinus* on 'The Neck' of Skomer Island: a comparison of methods

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INTRODUCTION

Skomer Island, off the Pembrokeshire coast of Wales, contains one of the world's largest Manx Shearwater *Puffinus puffinus* colonies (Brooke 1990, Lloyd *et al.* 1991). In 1971 Corkhill (1973) estimated the number of Manx Shearwaters breeding on 'The Neck' of Skomer, a small promontory attached to the main island by a narrow isthmus, using the method of chick mark and recapture developed by Perrins (1967) for Skomer's neighbouring island, Skokholm. The estimate was 10,500 pairs and, given that The Neck constitutes about 11% of the area of Skomer, Corkhill (1973) derived an all-island estimate of 95,000 pairs on the assumption that densities on The Neck were representative of Skomer as a whole.

The chick mark-recapture census of The Neck, which was repeated in 1978 (and hinted at a slight increase; Alexander & Perrins 1980), 1989 and 1994 (Walsh *et al.* 1995a), relies upon the habit of maturing shearwater chicks emerging from their burrows at night to exercise and orientate themselves (Brooke 1990). The method used is as follows. During the first two weeks of August as many chicks as possible are removed from their burrows, ringed and replaced. From the third week of August until mid-September, up to 15 people systematically scour The Neck at night catching chicks on the surface, counting those that are ringed and those that are not, and ringing the latter so they are not recorded twice. The population of young shearwaters, and thus successful breeding pairs (as pairs only lay a single egg) on The Neck, is then calculated as (No. ringed in burrows) x ([No. caught on the surface at night]/[No. caught at night which had been ringed in burrows]). To convert this estimate to the total number of breeding pairs it is divided by the mean colony breeding success (chicks fledged per breeding pair) for that year. The results for 1994 serve as an example. The mark-recapture census yielded an estimate of *ca* 10,800 to 11,300 fledglings (Perrins 1994, Poole *et al.* 1996). In one intensively studied area of The Neck (the isthmus that joins it to the main island) a total of 22 chicks fledged from 47 burrows; the mean number of chicks fledged per pair was thus 0.468. The population of breeding pairs on The Neck in 1994 was thus estimated at *ca* 24,000 (Perrins 1997, but see *Discussion*).

It is unclear to what extent the apparently marked increase in shearwater numbers on The Neck since 1971 is real, a consequence of birds shifting distribution within Skomer, an artefact of subtle changes in the method (for example the number of nights over which the mark-recapture was undertaken) or a result of problems in the estimation of mean breeding success; certainly the final estimate is very sensitive to variation in the latter.

The mark-recapture method is very labour-intensive and requires fieldwork to be undertaken at night in potentially hazardous surroundings (Walsh *et al.* 1995b). An alternative tape playback census method exists. This was developed by James & Robertson (1985) and is based on the observations of Brooke (1978a & b). This method relies upon two observations. First, male Manx Shearwaters undertake slightly longer incubation stints than females (Brooke 1978a) and, as a consequence, the probability that a male will be in a burrow at any given time (0.55) is slightly greater than for a female (0.45; James & Robertson 1985). Second, when Brooke (1978b) played a male Manx Shearwater call at burrow entrances, most incubating males (23/25=0.92) responded while no females (0/26) did. Using these two pieces of information James & Robertson (1985)

calculated that the number of occupied burrows in a given area was C x the number of burrows from which a response to a tape of the male call was heard, where $C = (1/0.55) \times (1/0.92) = 1.98$. This method has the advantage of being quick and safe as fieldwork can be undertaken during the day. James & Robertson (1985) further showed that estimates of the number of occupied burrows in two quadrats on Skomer derived using the playback method compared favourably with those using the more traditional (and intrusive) technique of opening burrows. Brooke's response probabilities were, however, obtained at night rather than during the day, and although male diurnal response probabilities could not be much higher than at night, they could be lower thus leading to population underestimation.

Here, we report on a census of the Manx Shearwater population of The Neck of Skomer in 1995 using the playback method of James & Robertson (1985; see also Walsh *et al.* 1995b). We compare the results with those of the chick mark-recapture census of the previous year and comment on the advantages and disadvantages of each method.

METHODS

Timing of the census

The census took place over the five day period 18-22 June 1995. Brooke (1990) found that on Skokholm during the 1970s 95% of eggs were laid during 26 April-25 May and, given that incubation lasts an average of 51 days (Brooke 1990), most eggs will hatch during 16 June-15 July. The ideal census should probably be undertaken as soon as possible after all pairs have laid, i.e. last few days of May and first few days of June on Skokholm. Censuses earlier in the season would underestimate the population as some pairs would not have laid. Censuses later in the season would also underestimate the population, because some pairs will have started to fail at the egg stage. If the Skokholm dates are representative of Skomer, the 1995 census was probably two to three weeks late (two chicks were heard), and as a consequence the final population may have been underestimated because of failures at the egg stage. James & Robertson undertook their comparison during 9 & 10 June 1983.

All census work was undertaken during the day. This was advantageous for two reasons. First, the fieldwork was safer and more efficient. Second, it was hoped this would exclude as many non-breeders as possible, as these tend to inhabit burrows by night (Walsh *et al.* 1995b), though this is by no means universally true.

Stratification and sampling

A cursory examination of potential shearwater nesting burrows suggested that they were not distributed evenly across The Neck, rather they were grouped together in areas of high burrow density surrounded by larger areas of low density. To take this observed distribution into account and to attempt to improve the precision of the final estimate, The Neck was split into two separate categories (or 'strata') of high and low density, and fifteen randomly placed quadrats were surveyed within each. Although the total area of the low density stratum was nearly twice that of the high density stratum (see *Results*), the quadrat size used for sampling was twice as large in the low density stratum (see below) thus the overall sampling intensity within each stratum was similar (see *Results*).

In practice, the methods adopted were as follows. The Neck was mapped over a period of 1.5 days. This was done by placing a series of canes 50m apart in the form of a cross with its two arms orientated N-S and E-W. The location of this cross was marked on a large-scale (1:2,500) map of The Neck and, using it as a reference point, a grid of 25m x 25m was also marked on the map (Fig. 1). The boundaries of low and high density areas of burrows were overlaid on the grid on the map by systematically walking the entire Neck. The split into high and low density areas was fairly crude. Low density areas were those where it was straightforward to walk and few burrows were

encountered, high density areas those with numerous burrows within which walking was awkward and where it was difficult to avoid trampling burrows. Some areas of high burrow density were in Puffin *Fratercula arctica* colonies and as burrows in these areas are rarely occupied by shearwaters they were classified as low density.

The entire study site on The Neck (i.e. the total area occupied by both strata) covered an area of approximately 23ha (see *Results*). This was somewhat less than the total area of The Neck (generally estimated at *ca* 30.7ha; Perrins 1997) as some areas were entirely unsuitable for shearwaters (e.g. cliffs, rocks, shingle beaches and coastal slopes – the latter particularly along the southern fringes of The Neck).

Each intersection of the 25m x 25m grid was allocated to the stratum within which it fell, and each numbered uniquely on the map (high 1, high 2,...low 1, low 2.. etc.). Fifteen intersections were then randomly selected within each stratum. The location of each of these 30 intersections was determined on the ground using a tape and compass and the reference cross as a guide, and marked with a cane: each subsequently formed the centre of a sampling quadrat. Quadrats were circular in shape and their outer boundary determined by attaching a piece of string of either 4.4m (high density) or 6.2m (low density) in length to the marker cane and rotating the string – as though an arm of a clock – around it. Quadrats in high density areas were thus $60m^2$, and those in low density areas $120m^2$. Quadrat size differed between the two strata to ensure a reasonable sample of burrows in each.

On a few occasions when a random intersection had been located on the ground it became apparent that it had been allocated to the wrong stratum (i.e. what had been mapped as low density transpired to be high, and *vice versa*). This was due to inaccuracies in mapping the boundaries of the two different strata onto paper. On these occasions the nearest intersection in the intended stratum was selected instead; where there were several equidistant intersections, one was selected at random. All strata boundaries were subsequently rechecked on the ground to ensure that each intersection had been allocated to the correct stratum.

The area (m^2) of each stratum was calculated from the number of grid intersections that fell within it multiplied by 625 (the area covered by each 25m x 25m grid square).

Responses to playback

A recording of a male shearwater call was played at each burrow entrance in each quadrat for *ca* 15s (equivalent to 3-4 call 'cycles') at full volume (*ca* 90-100 decibels) and any response noted. Though most birds that responded to the tape were undoubtedly male as they replied with the characteristic male call of a combination of clear, vibrant notes and harsh notes (Brooke 1990), some responses contained only harsh notes more characteristic of females. Brooke's (1978b) observations, however, suggest that females never respond to the male call, and this is one of the most important assumptions underlying James & Robertson's (1985) method. To allow estimation of the population size it has been necessary to assume that all responses were from males. For completeness, however, we present analyses based on all responses and definite male responses, separately.

Population and confidence interval estimation

Using James & Robertson's (1985) correction factor (multiplying by 1.98) it was possible to estimate the number of pairs (=occupied burrows) in each quadrat and thus the mean number per unit area in each stratum. Knowing the total area of each stratum on The Neck, the total number of pairs in each was calculated and the total population of The Neck determined by summing the strata totals.

Because of the statistically non-normal distribution of the numbers of pairs in, particularly, the low density strata quadrats, 95% confidence intervals have been calculated by bootstrapping (see, e.g. Greenwood 1991). To do this 999 population estimates were calculated for each stratum. Each

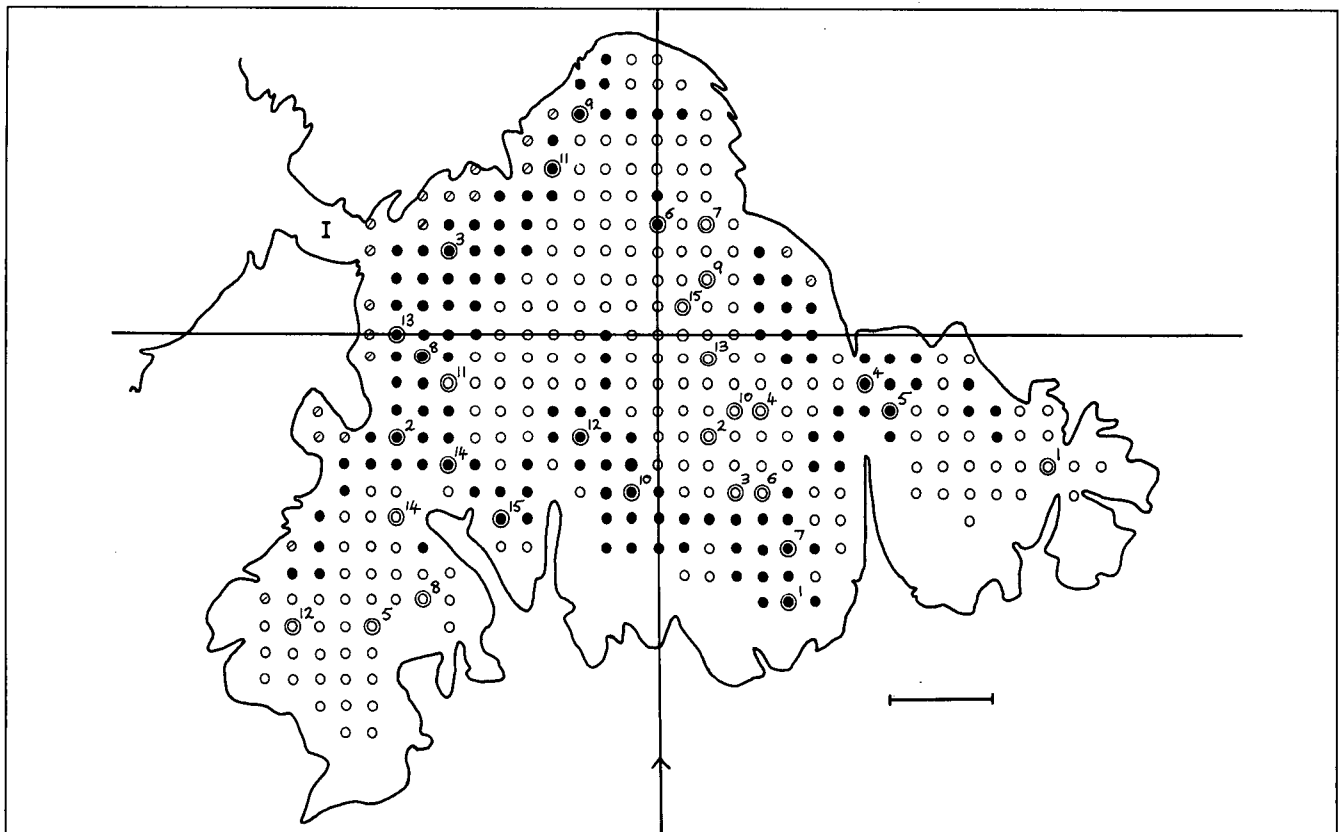

Figure 1. A map of The Neck of Skomer, showing the 25m x 25m grid, the central reference cross (based on magnetic north) and the high (filled circles) and low (open circles) burrow density areas. Sampled quadrats are ringed and their numbers cross-refer to those in Tables I and II. Areas of high burrow density in Puffin colonies are shown as open circles with diagonal lines. I = Isthmus. Horizontal scale bar represents 100m.

of these estimates was calculated by selecting at random, and with replacement, 15 values (i.e. equivalent to the number sampled) from the estimated number of pairs per quadrat, calculating a mean density from these 15 values and estimating the population as: (((mean density) x ([total area of the strata]-[total area of 15 quadrats])) + (observed total estimated across all 15 quadrats)). Nine hundred and ninety-nine estimates were then calculated for the total population of The Neck by summing one value taken, at random, from the 999 low strata estimates and one taken, again at random, from the 999 high strata estimates, and repeating this 999 times. These total population estimates were then sorted into numerical order and the 25th and 975th values taken as the lower and upper 95% confidence intervals, respectively.

Although including the 'observed total estimated across all 15 quadrats' in the calculation of each of the 999 population estimates for each stratum is statistically correct – as the population in these areas was actually measured and does not need to be estimated – the overall sampling intensity was so low (see *Results*) that each of the estimates could have been calculated approximately as [(mean density) x (total area of strata)].

RESULTS

Stratification and sampling intensity

The mean density of burrows in quadrats in the high density stratum (0.31/m^2, range 0.13-0.53, Table I) was approximately three times that in the low density stratum (0.10/m^2, range 0.02-0.19, Table II). A total of 136 and 226 grid intersections fell within the high and low density strata, respectively, thus their total areas were estimated as approximately 85,000m^2 and 141,000m^2. The percentage of the overall area of each stratum sampled was similar (900/85,000=1.06% for the high density stratum and 1,800/141,000=1.28% for the low density stratum) though in both cases representing a very low sampling intensity. Ideally, sampling intensities would have been much greater.

TABLE I. RESPONSES TO PLAYBACK OF MALE CALL IN HIGH DENSITY QUADRATS. ALL RESPONSES AND DEFINITE MALE RESPONSES ARE GIVEN SEPARATELY. ESTIMATED NUMBER OF PAIRS PER QUADRAT (FOLLOWING JAMES and ROBERTSON 1985) ARE GIVEN. [1]=ESTIMATE BASED ON ALL RESPONSES, [2]=ESTIMATE BASED ON DEFINITE MALE RESPONSES.

Quadrat	*No. of burrows*	*Burrows / m^2*	*No response*	*Response*	*Male response*	*Estimated pairs[1]*	*Estimated pairs[2]*
1	20	0.33	14	6	4	11.88	7.92
2	15	0.25	9	6	5	11.88	9.90
3	14	0.23	6	8	5	15.84	9.90
4	28	0.47	19	9	3	17.82	5.94
5	23	0.38	15	8	3	15.84	5.94
6	13	0.22	9	4	3	7.92	5.94
7	25	0.42	14	11	8	21.78	15.84
8	21	0.35	12	9	6	17.82	11.88
9	23	0.38	14	9	7	17.82	13.86
10	21	0.35	13	8	6	15.84	11.88
11	11	0.18	8	3	2	5.94	3.96
12	20	0.33	13	7	4	13.86	7.92
13	8	0.13	4	4	2	7.92	3.96
14	9	0.15	6	3	2	5.94	3.96
15	32	0.53	16	16	14	31.68	27.72
Total	283	0.31	172	111	74	219.78	146.52

TABLE II. RESPONSES TO PLAYBACK OF MALE CALL IN LOW DENSITY QUADRATS. OTHER DETAILS AS IN TABLE I.

Quadrat	*No. of burrows*	*Burrows / m²*	*No response*	*Response*	*Male response*	*Estimated pairs[1]*	*Estimated pairs[2]*
1	15	0.13	12	3	2	5.94	3.96
2	10	0.08	10	0	0	0	0
3	16	0.13	16	0	0	0	0
4	14	0.12	11	3	1	5.94	1.98
5	21	0.18	11	10	6	19.80	11.88
6	23	0.19	13	10	4	19.80	7.92
7	14	0.12	13	1	1	1.98	1.98
8	15	0.13	10	5	4	9.90	7.92
9	2	0.02	2	0	0	0	0
10	5	0.04	5	0	0	0	0
11	6	0.05	6	0	0	0	0
12	12	0.10	9	3	2	5.94	3.96
13	3	0.03	3	0	0	0	0
14	8	0.07	7	1	1	1.98	1.98
15	9	0.08	8	1	1	1.98	1.98
Total	173	0.10	136	37	22	73.26	43.56

Responses to tape playback

A total of 111 and 37 responses were noted from the high and low density quadrats, respectively, equivalent to approximately 220 and 73 pairs (Tables I & II). Seventy-eight and 42% of burrows were occupied in the high and low density quadrats, respectively, and, given the higher density of burrows in the high density quadrats, the mean density of occupied burrows in the high density areas (0.24/m²) was six times higher than in the low density areas (0.04/m²). By extrapolation, the total population of The Neck was estimated as 26,500 pairs (95% confidence intervals, 21,000-32,000, all values rounded to the nearest 250).

As outlined in the *Methods*, some responses to the tape could not be assigned unequivocally to males, even though Brooke (1978b) has demonstrated that all should have been. Using the definite male responses only, a population of 17,250 pairs was estimated for The Neck (95% confidence intervals, 12,250-22,500)

DISCUSSION

Comparison of methods of population estimation

The 1994 chick mark and recapture census estimated a population of approximately 24,000 pairs of Manx Shearwaters on The Neck of Skomer (Poole *et al.* 1996, Perrins 1997), the 1995 tape playback census reported here 26,500 pairs (95% confidence intervals, 21,000-32,000). Given that these estimates were arrived at by entirely independent means and in different years they are surprisingly similar. Both estimates, however, seem high compared to those from earlier years. Perrins (1997) has suggested that the measure of productivity (0.47 chicks per pair) used to obtain the final population estimate for the 1994 mark and recapture census was abnormally low and, as a consequence, the estimate too high. However, Poole *et al.* (1996) suggest that 1994 was the fourth in a series of years of poor breeding success. The data from individual years seem to confirm this: the number of fledglings produced per egg laid in the intensively studied plots on Skomer was 0.50, 0.38, 0.21 and 0.47 in 1991, 1992, 1993 and 1994, respectively (Walsh et al. 1992, 1993, 1994, 1995a); breeding success in 1995 was substantially higher (0.68; Poole *et al.* 1996).

Both forms of census have advantages and disadvantages. The chick mark-recapture census suffers from being very labour-intensive, with up to 15 people working over a period of several weeks, and is potentially dangerous for fieldworkers as much of the work is undertaken at night. It also involves a great deal of chick-handling. The method estimates the number of fledglings and thus successful pairs and the overall population size has to be calculated by taking annual breeding success into account and, on Skomer at least, this is based on a small (*ca* 45-70 burrows) non-random sample. The population of fledglings is itself sometimes difficult to estimate, as the final estimate arrived at depends on the number of nights of retrap data included in the final analyses. Finally, the method only works well in closed populations where chicks do not move out of, or into, the study area. The Neck of Skomer is, however, particularly suitable in this respect. The advantages of this method are three-fold. First, many chicks are ringed which ultimately yield valuable information on population dynamics. Second, the effective sampling intensity is high with (in 1994) about 35-37% of the estimated total number of fledglings actually caught and ringed (Walsh *et al.* 1995a, Poole *et al.* 1996). Third, the population has been estimated in this manner since the first census of The Neck in 1971 making comparisons of population change more straightforward, even though year-to-year variation in breeding success tends to remove this advantage.

The tape playback method is quick – the estimates arrived at here took 3.5 person-days – and safe as all fieldwork is undertaken during the day. The method does not involve handling of adults and chicks, though it is possible that adults may be disturbed by the playback. The method attempts to determine the number of breeding pairs, not fledglings, and does not need to be corrected by annual breeding success measures. However, the population may well be underestimated as the method estimates the number of pairs during incubation (in this case, quite late on in incubation). Even if the census was timed near-perfectly to coincide with the earliest possible date at which the great majority of birds had commenced incubation, some breeding pairs will already have failed at the egg stage. Ideally, the proportion of pairs that had already failed by the time of the census should be estimated from sample plots. The method also relies heavily on Brooke's (1978a & b) observations on response probabilities and the share of incubation by the sexes, neither of which have been investigated fully by other workers in other colonies. Though there are no reasons to doubt Brooke's figures it would be surprising if there was no diurnal, annual, seasonal or geographical variation in these parameters. In particular, Brooke's estimates of response probability were obtained at night rather than during the day, and the share of incubation by the sexes may well vary during the season, especially shortly after the peak of laying when incubation will be male biassed as males take the first incubation shift. In addition, response probabilities could be affected by eggs being unattended between incubation shifts or eggs being attended by both adults (James & Robertson, 1985). Furthermore, though the method is relatively quick, it would become much more labour-intensive were the colony sampled at a higher intensity in order to increase the precision of the estimate; here the sample was a mere 1%. Despite the problems associated with tape playback, this method seems to be a useful technique when compared to chick mark and recapture, a conclusion implicit in the recommendations of Walsh *et al.* (1995b).

One potential complication highlighted during this study was the type of response to the playback of the male call; some appeared to be from females even though Brooke's results (1978b) suggest that this should not have happened. Unfortunately the sex of birds that responded during this study will never be known with certainty. Future research on sex-specific response probabilities is clearly required and may allow further analyses of these data.

Stratification and sampling intensity

The stratification of The Neck into high and low shearwater burrow density areas was done very quickly (over 1.5 days) and very crudely. In addition, the overall sampling intensity was very low.

Had more time been available then the stratification could have been done in a more quantitative manner and a larger number of quadrats censussed in each stratum. Both of these measures would have led to a more precise final estimate. In addition, there would have been no cases of misallocation of grid intersections (and thus sample plots) to strata which added an undesirable level of complexity to the survey design.

The size of the grid (25m x 25m) used to locate the centres of the sampling quadrats combined with the size of those quadrats (4.4 or 6.2m radii) meant that large areas of The Neck could not be selected for sampling. This could have been a problem if there were any regular geographical patterns in burrow density such that areas of particular density (e.g. higher than average) tended to fall in those areas which were not available for sampling (Walsh *et al.* 1995b). Such regular patterning, however, is both theoretically unlikely and not evident from Fig. 1. Though this potential problem could have been removed altogether by decreasing the grid size or increasing the quadrat size, this would have increased the amount of work substantially (particularly increasing the quadrat size).

Burrow densities in high density stratum quadrats were about three times those in low density quadrats, though occupied burrow densities were six times higher. It is unclear why the proportion of burrows occupied in low density quadrats was half that in high density ones.

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SUMMARY

The population of Manx Shearwaters breeding on 'The Neck' of the island of Skomer off the coast of Wales in 1995 was estimated using tape playback during incubation. The entire Neck was stratified into areas of high and low densities of potential shearwater nesting burrows, and 15 randomly placed quadrats surveyed in each. A recording of a male shearwater call was played at all burrow entrances in each quadrat and any response noted. The number of occupied burrows in each quadrat was estimated using the method of James & Robertson (1985) and, knowing the area of each quadrat and the total area of each stratum, the total population of shearwaters on The Neck estimated as 26,500 pairs (95% confidence intervals, 21,000-32,000). This estimate was similar to that of *ca* 24,000 pairs estimated the previous year by chick mark and recapture. The relative merits of the two census methods are compared.

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The status of breeding Storm Petrels *Hydrobates pelagicus* on Skokholm Island in 1995

Denbeigh Vaughan and David W. Gibbons

INTRODUCTION

The breeding range of the Storm Petrel *Hydrobates pelagicus* is almost entirely restricted to north-west Europe where the ten most important breeding areas are in the Faroes, Iceland, and the Republic of Ireland (Tucker & Heath 1994). Although less significant numerically, the United Kingdom holds a sizeable population (20,000 - 150,000 pairs, Lloyd *et al.* 1991). Together, these countries are home to over 90% of the world population. The remaining 10% are found in Norway and European countries with a Mediterranean coastline.

The island of Skokholm off the Pembrokeshire coast of Wales holds one of the largest colonies of this species in the UK with an estimated 5,000-7,000 breeding pairs (Scott 1970). The much smaller population of Storm Petrels on Skomer has apparently declined markedly over the last 25 years (Dyfed Wildlife Trust, unpublished reports) and it is possible that this decline may have been underway since the turn of the century (Lockley 1983). As a consequence, there have been fears that the population on Skokholm may have suffered the same fate since the last complete census by Scott in the late 1960s. In 1992 Betts censused the dry-stone wall breeding population on Skokholm (Betts 1992) and found an apparent decline in numbers in this habitat since Scott's census.

In order to ascertain the magnitude of any overall decline, an all-island census of the population of Storm Petrels on Skokholm was undertaken in 1995; this census is reported here. Although the main aim was to obtain a population estimate to allow comparison with that of Scott (1970), it was realised at the outset that some of the methods used by Scott were either rather ill-defined or unacceptable (e.g. ringing and mist-netting, originally used by Scott, are currently banned on Skokholm) such that any direct comparison would be difficult.

For this reason the work had a secondary aim; to develop monitoring methods for this notoriously difficult species. Storm Petrels visit their colonies at night and nest underground in areas of rock-fall, scree, boulder-beach and earth burrow as well as in dry-stone walls. Furthermore, most colonies are found on remote or inaccessible islands. Because of these inherent difficulties the status of the Storm Petrel in the UK is poorly known and, as a consequence, its UK population estimate has a very broad range. Indeed, the range of this estimate is so great that any change in the Storm Petrel's status will remain obscured unless a reliable census method can be found. The methods used here were developed from those of Suddaby (1991-94) and Betts (1989, 1992-95); see Ratcliffe *et al.* (1996) for a review.

METHODS

Along with several other species of Procellaridae, Storm Petrels are very vocal at their breeding colonies and are sexually dimorphic in voice. Both sexes utter a 'flight' call ('terr-chick') while the male has a song (the 'purr' call), usually produced from within a burrow (James 1984). During incubation, playback of the male purr call will elicit a response from a proportion of birds present (James 1984). James and Robertson (1985) proposed the use of playback of conspecific calls as a method of censussing nocturnal burrow-nesting petrels.

On Mousa, Suddaby (1991-94) calculated the probability of response to playback of the purr call in an area where the absolute population size was known. This response probability was then

applied to the entire colony to estimate its population size. Here we report on a similar approach to censussing Storm Petrels on Skokholm in 1995 in which a response probability was calculated from several sample areas of known population size and was subsequently used to estimate the island's total population. Similar methods have been used more recently on several Scottish islands (Mainwood *et al.* 1997, Gilbert *et al.* 1998, Ratcliffe *et al.* 1998 & *in press*).

Calculating a response probability

The dry-stone walls that surround the island's buildings were chosen as the main study area. This was for two reasons: first, this area was used by Scott (1970) thus allowing a direct comparison and, second, it was unsafe to work in other habitats at night.

The number of occupied burrows in the study area was determined from four nocturnal visits early in the breeding season to each of ten randomly selected 50m sample lengths of the study area walls. The visits were undertaken between the hours of 2300 and 0300 during 1 June-7 July. The total length of wall covered represented a large proportion (38%) of the study area; this was necessary because of the patchy distribution of birds in the walls (Betts 1992). Fieldwork was undertaken at night because birds call readily at this time and silent birds can be stimulated to call more at night than during the day (Betts 1994).

Every metre along each section of wall, 10-15s of a recording of the male's purr call was played at full volume (*ca* 90-100 decibels) on a battery-operated tape recorder. All walls were at least 1m thick, so the process was repeated along both sides. The location and number of responses were noted and any newly located burrows marked. To exclude the possibility of temporal bias, both the time and direction that the wall was walked was changed on every visit.

By repeatedly visiting the same sites and eliciting calls the locations of all likely burrows were mapped. Though there was initially some concern that four visits would be insufficient to locate all occupied burrows (see Ratcliffe *et al.* 1996), this proved unfounded (see *Results*). This was probably helped by using playback, by restricting it to early in the season at night when birds were establishing their territories, and by playing the tape very frequently along the lengths of wall.

Once the total number of burrows in each length of wall was known, each was revisited twice during the day generally later in the season (4 and 13 July), and the number of birds that responded to playback noted. These later visits were undertaken during the day to allow calculation of a diurnal response probability so that future work could be conducted during the day. This was possible at this stage of the season as most pairs would have laid, and one member of each pair would have been incubating during the day.

From these repeated visits nocturnal and diurnal response probabilities (i.e. the number of burrows from which a response was heard divided by the total number of apparently occupied burrows – AOBs – present) were calculated for each wall section on each visit. Only those sections with Storm Petrels present could be included. Because the number of sections sampled was low and the response probabilities highly variable, mean response probabilities (+/- 95% CIs) were calculated by bootstrapping (Greenwood 1990). To do this 999 values of mean response probability were calculated for the nocturnal and diurnal visits separately. Each of these was generated by selecting at random, and with replacement, a number of response probability values equivalent to that sampled from among the measured values. The mean of these 999 bootstrapped samples was taken as the mean response probability, and the 25th and 975th values (once sorted numerically) were taken as the lower and upper 95% confidence intervals respectively.

The total length of suitable dry-stone walls in the study area and on the island as a whole was measured on the ground.

Censussing the island's natural habitats

Sub-colonies of Storm Petrels occur all round the island's coast (sparsely so on the north-west coast) and can be found at all levels from high water to the tops of the cliffs (Scott 1970, Betts

1989). Though they breed in a variety of natural habitats, these were classified into two major types, namely 'rockfall' (rockfall/scree and boulder beaches) and 'rockburrow' (earth burrows under large rock slabs or purely earth burrows).

Using the maps of Scott (1970; see Fig. 1) and Betts (1989) as a guide, all sub-colonies and their approximate boundaries within each habitat type were located at night (wherever possible) by listening for calls, eliciting calls with a tape and by direct observation of flighting adults, often with a hand-held light intensifier. Defining boundaries of sub-colonies in rockfall habitat was generally easy as these areas were visually distinct and bounded by unsuitable habitat. This was not always the case in areas of rockburrow, however, and it was necessary to make additional daytime searches for suitable nest sites. The task was made more difficult by the fact that Storm Petrel density in these areas was very low (see *Results*). There was insufficient time for these searches to be exhaustive so it is possible that some sub-colonies were missed.

The approximate area of each sub-colony was subsequently measured on the ground during the day. Access to a few sub-colonies was restricted due to fragility of the ground, danger to the observer or potential disturbance to other species; the areas of these sub-colonies were estimated using the earlier distribution maps and local knowledge. The total area of all sub-colonies in both the rockfall and rockburrow habitats was calculated by summation of the areas of their individual sub-colonies.

Some sub-colonies were too large to be censussed in their entirety; these were divided into quadrats whose size was fixed within each sub-colony but varied between them depending on expected burrow density (from 25m^2 in densely populated areas to more than 100m^2 in sparsely populated areas) and local topography. The remaining sub-colonies were too small to be split into quadrats. Each quadrat (where sub-colonies were large) or entire sub-colonies (where small) was uniquely numbered within its habitat type. Fifteen of the rockburrow quadrats/sub-colonies were randomly selected for censussing, with slightly more (17) in the rockfall habitat. Ideally, more quadrats/sub-colonies would have been selected and censussed; the number chosen was limited by the time available for the work. Due to its large size a substantial proportion of the rockfall quadrats fell in the 'Quarry' – a rockfall site at the SW of the island known to hold large numbers of birds (Scott 1970, Betts 1994). Where restricted areas were chosen by the random selection procedure an alternative was taken, again at random.

Between the 7 and 12 July, each sample site was visited once during the day to count the number and type of responses to playback. The tape was played at all locations that could contain a burrow and care was taken not to play to any location twice. Where suitable locations were grouped close together, the tape was played once per m^2 unless the local topography prevented this.

Population estimation

The number of AOBs per metre in each of the ten sample lengths of wall was known from the nocturnal visits. Nine-hundred and ninety-nine estimates of mean AOBs/m were generated by bootstrapping (as outlined above) and 999 estimates of the total wall population were calculated as (([mean AOBs/m] x [length of unsampled walls]) + (number of AOBs in sampled walls)). The mean of these values was taken as the best estimate of the population size of Storm Petrels in the island's dry stone walls, with the 25th and 975th values (once sorted numerically) taken as the lower and upper 95% confidence intervals, respectively. In practice, the best estimate could have been generated from the sample mean, rather than the bootstrapped mean, as these proved to be near identical; the same was true for the other habitats.

The population sizes in rockfall and rockburrow were calculated slightly differently. For each habitat, the number of responses/m^2 was calculated for each quadrat/sub-colony and 999 estimates of the mean number of repsonses/m^2 calculated by bootstrapping. Nine-hundred and nintey-nine estimates of the population were then calculated by taking, for each, one of these values at random, dividing this by one value of diurnal response probability calculated from the wall sample sites

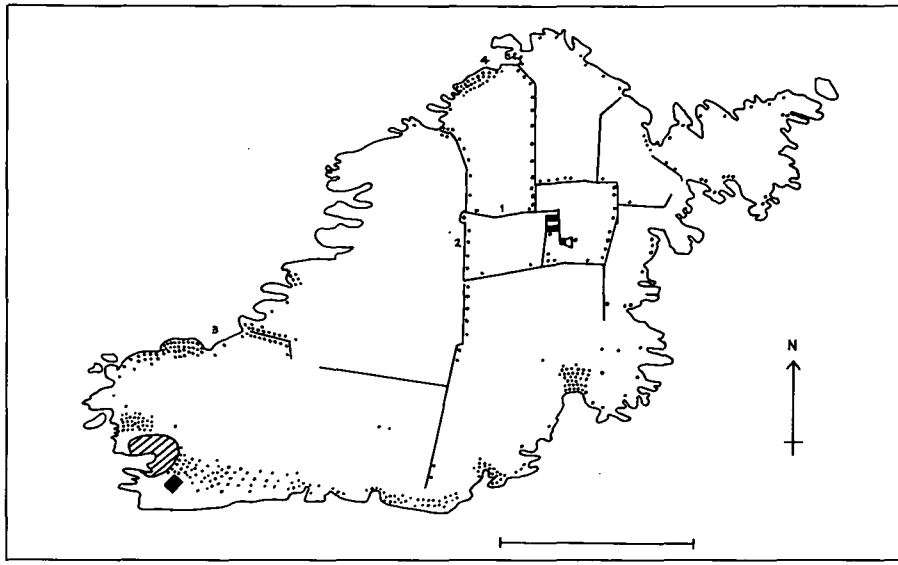

Figure 1. The approximate distribution of Storm Petrel burrows on Skokholm in the late 1960s (taken from Scott 1970). Each dot represents 10 burrows. The Quarry (hatched) was estimated to contain 2,000 pairs. Locations referred to in the text are: 1, North Pond Wall; 2, Half-way Wall; 3, Wallsend; 4, Little Bay. The horizontal scale bar represents 500m.

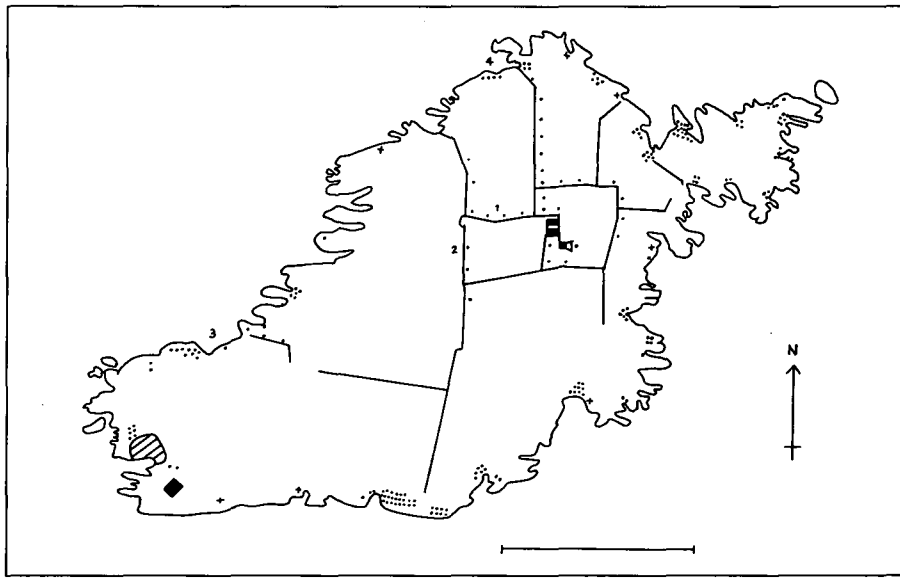

Figure 2. The approximate distribution of Storm Petrel sub-colonies and burrows on Skokholm in 1995. Each dot represents 10 burrows; crosses represent <10 burrows. The Quarry (hatched) was estimated to contain 1,600 pairs (95% CIs 1,000-2,550). Locations are as in Fig. 1

(again taken at random from among its 999 estimates) and multiplying by the total area of the habitat on the island. The best estimate of the population in each habitat (+/- 95% CIs) was calculated from these values as outlined for the wall population above.

The total population of Storm Petrels on Skokholm was calculated by summing the rockfall, rockburrow and wall populations. To calculate the confidence intervals of the all-island estimate, 999 estimates of the all-island population were generated by taking one value, at random, from each of the 999 rockfall, rockburrow and wall estimates and repeating this 999 times. These total population estimates were, again, sorted into numerical order and the 25th and 975th values taken as the lower and upper 95% confidence intervals, respectively.

More complete details of the methods, including locations, names and areas of all sub-colonies, locations of the sample plots, locations of burrows within the wall sample sites, dates of playback, and details of responses are given in Vaughan & Gibbons (1996).

RESULTS

Response probabilities

Table I shows the number of AOBs recorded in each wall sample site on each nocturnal visit. Because it sometimes proved difficult to distinguish between individual burrows, a range is given for the number found in each section of wall on each visit. The mean of this range was used in all subsequent calculations (see *Discussion*). The total number of AOBs recorded across all sections of wall was reasonably consistent between visits, with a mean of 45.1 recorded on each visit.

The cumulative number of AOBs recorded over successive visits reached an asymptote on the fourth visit, with only 3.5% of the total contributed by the fourth visit (Table I). The cumulative total number of AOBs recorded by the fourth visit to each section was thus taken to be the absolute population size for that section.

The results of the diurnal visits and summary results from the nocturnal visits to the sample sites are presented in Table II. The bootstrapped mean nocturnal and diurnal response probabilities were 0.60 (95% CIs 0.50-0.69) and 0.34 (95% CIs 0.23-0.45) respectively; the bootstrapped means were very similar to the sample means. The difference between the nocturnal and diurnal response probabilities may not be explained solely by differences in time of day, as the nocturnal playbacks were undertaken earlier in the season.

TABLE I. THE NUMBER OF APPARENTLY OCCUPIED BURROWS (MIN-MAX) RECORDED DURING EACH NOCTURNAL VISIT TO EACH OF THE WALL SAMPLE SITES. THE CUMULATIVE MEAN NUMBER OF AOBS RECORDED ON EACH VISIT IS ALSO GIVEN.

Wall section	*visit 1*	*visit 2*	*visit 3*	*visit 4*
1	10-12	6	14	12
2	0	0	0	0
3	0	0	1	0
4	2	2	1	4
5	0	0	0	0
6	4-5	6	8	7
7	0	0	0	0
8	5	5	6-7	6
9	8-10	11	11	9
10	10-11	11-13	8	9
Total	39-45	41-43	49-50	47
Cumulative	42	55	68	70.5

TABLE II. TOTAL NUMBERS AND DENSITIES OF APPARENTLY OCCUPIED BURROWS IN, AND NUMBERS OF DIURNAL RESPONSES FROM, THE WALL SAMPLE SITES.

Wall section	*Total AOBs (min-max)*	*AOBs/m (mean)*	*No. responses on 1st diurnal visit*	*No. responses 2nd diurnal visit*
1	18-20	0.38	3	4
2	0	0	0	0
3	1	0.02	0	0
4	4	0.08	3	1
5	0	0	0	0
6	8-9	0.17	5	4
7	0	0	0	0
8	7-8	0.15	3	3
9	14-16	0.30	5	7
10	14-17	0.31	6	4
Total	66-75	-	25	23

Size of the dry-stone wall population

The bootstrapped mean number of AOBs/m in the randomly selected lengths of walls in the study area was 0.14 (95% CIs 0.06-0.23). The 1316m of walls in the study area thus contained an estimated 185 AOBs (95% CIs 115-230). The total length of suitable wall on Skokholm was estimated at 2070m, so assuming that mean densities in the study walls and in walls elsewhere were the same, there were an estimated 290 AOBs (95% CIs 160-430) in Skokholm's dry-stone walls in 1995.

Comparison with Scott's (1970) estimate of the wall population is not simple. Scott did not provide an estimate for each year of his study, rather over a period of four years he located 230 Storm Petrel burrows in the walls of the study area. This was equivalent to 0.17 AOBs/m. The total length of suitable wall found by Scott was 2130m, slightly greater than that estimated in 1995, so the estimated total wall population for 1970 was 370 AOBs. From mist-net catches Scott considered this an underestimate and suggested that the true population in his study area was probably nearer 400 AOBs and thus 650 AOBs in the entire wall population. Whichever estimate is used a population decline of 22-55% (from either 370 or 650 AOBs to a mean of 290 AOBs) over a 25-year period is suggested. Unfortunately it is difficult to determine the significance of this decline as Scott was unable to provide confidence intervals around his population estimates; certainly the decline in the number of burrows located in the walls was not significant as the 1970 estimates fall within the confidence intervals of the 1995 estimates.

The all-island population estimate

Figure 2 shows the approximate distribution of Storm Petrel sub-colonies and burrows located on Skokholm in 1995. Table III gives the areas of, and total number of responses from, each sampled sub-colony/quadrat within the rockfall and rockburrow habitats. Table IV summarises this information and gives population estimates for each habitat on Skokholm and for the island as a whole. 'Response densities' (responses/m^2) and estimated numbers of AOBs/m^2 were about ten times greater in rockfall than in rockburrow.

There were an estimated 4,400 AOBs (95% CIs 2,900-6,600) on Skokholm in 1995; 3,400 (95% CIs 2,050-5,350) of these were in rockfall. The Quarry held 36% of the island total while the dry-stone walls held a mere 7%.

TABLE III. AREAS OF, AND NUMBER OF DIURNAL RESPONSES FROM, ROCKFALL AND ROCKBURROW SUB-COLONIES. *=RANDOM QUADRAT WITHIN SUB-COLONY. SUPERSCRIPTS REFER TO QUADRATS WITHIN THE SAME SUB-COLONY. [1]='QUARRY'.

Rockfall site	*Area / m²*	*Responses*	*Rockburrow*	*Area / m²*	*Responses*
1	30	1	1*[2]	100	2
2	25	8-10	2*[2]	100	5
3	90	23-27	3*[2]	100	4
4	70	1	4*[2]	145	1
5	30	3-4	5*[3]	100	2
6*	50	8-9	6*[3]	100	15-17
7*	75	6-8	7*[3]	100	4
8*[1]	25	5	8*[3]	100	1
9*[1]	25	19-22	9*[3]	100	1
10*[1]	25	2	10*	190	4
11*[1]	25	9	11*	135	2
12*[1]	25	8-9	12*[4]	95	3
13*[1]	25	10-12	13*[4]	100	1
14*[1]	25	6	14*[4]	110	4
15*[1]	25	8-10	15*	740	1-2
16*[1]	25	12			
17*[1]	25	9-11			
Total	620	138-158		2315	50-53

TABLE IV. POPULATION ESTIMATES (PAIRS) FOR EACH HABITAT AND FOR THE WHOLE ISLAND. AN ESTIMATE FOR THE QUARRY IS GIVEN SEPARATELY, THOUGH IT IS PART OF THE ROCKFALL HABITAT. TOTAL AREAS OR LENGTHS OF HABITATS WERE: ROCKFALL, 3960M²; QUARRY, 1425M²; ROCKBURROW, 7100M²; WALLS, 2070M. POPULATIONS OF 500 AND ABOVE ROUNDED TO NEAREST 50; POPULATIONS BELOW 500 ROUNDED TO NEAREST 10.

Habitat (or location)	*Parameter*	*Mean*	*Lower 95% CI*	*Upper 95% CI*
Rockfall	Responses/m²	0.28	0.20	0.38
Rockfall	Estimated AOBs/m²	0.87	0.52	1.35
Rockfall	Estimated population	3400	2050	5350
Quarry	Estimated population	1600	1000	2550
Rockburrow	Responses/m²	0.03	0.02	0.05
Rockburrow	Estimated AOBs/m²	0.10	0.05	0.18
Rockburrow	Estimated population	700	350	1250
Walls	AOBs/m	0.14	0.06	0.23
Walls	Estimated population	290	160	430
Island total	Estimated population	4,400	2,900	6,600

DISCUSSION

Using repeat visits to estimate absolute population size

An apparent asymptote in the number of AOBs recorded was reached by the fourth nocturnal visit with only a small proportion of the total number being recorded on the last visit. Assuming that all

pairs had begun territory establishment by this stage of the season and that no pair remained silent during all four visits, then the cumulative number of AOBs found by the fourth visit should represent the absolute number of territorial pairs at the start of the season. Betts (1994) failed to find such an asymptote. This may have been because Betts did not elicit calls with playback or because his sampling took place so late into the season that non-breeders may have provided a constant input of new records (Ratcliffe *et al.* 1996). However, due to the broad range of laying dates of Storm Petrels and the presence of at least some prospectors (Scott 1970), there will always be an element of error in any attempt to achieve an asymptote.

A decline in numbers on Scott's study site?

Though Scott's (1970) methods and those used here were different and cannot be compared statistically, the apparent decline of 22-55% over the intervening 25-year period is worrying. However, it must be borne in mind that the dry-stone walls only contained 7% of the island's population and that Scott (1970) regarded this habitat as sub-optimal.

By comparison with Scott (1970), Betts (1992) found a big decline in numbers in one wall (Halfway Wall) and an increase in another (North Pond Wall). In 1995 Halfway Wall and others in the south and east were either in gull *Larus* spp. colonies, surrounded by bracken *Pteridium*, or Manx shearwater *Puffinus puffinus* burrows, or all three; none of which was the case in 1970 (Scott, pers. comm.).

Population estimation

One of the greatest sources of error in estimating the size of the island's population was that it was necessary to apply a response probability generated in one habitat (walls) to others that differed both in population density and topography. The probability of an individual Storm Petrel responding might depend upon the density of other birds in the immediate neighbourhood. Similarly, topography differed markedly between the three habitats and may have affected response probabilities. For example, up to 60 birds have been recorded singing in caves (Betts 1994, Mainwood *et al.* 1997) and response probabilities in these situations will probably be very different to that in a dry-stone wall. In addition, the tape playback may be more easily heard in some habitat types than others.

The confidence intervals generated here are inevitably slightly tighter than is realistic. This was because where there was any uncertainty about the number of AOBs (in walls sections) or responses (in quadrats elsewhere) mean values were used in all subsequent calculations. This uncertainty arose because it was not always possible to determine whether two or more responses to the tape were from the same or different burrows.

The overall diurnal response probability found here (*ca* 34%) was about half that found on Mousa (Suddaby 1993, Ratcliffe *et al.* 1996, 1998 & *in press*). There are several possible reasons for this discrepancy. First, Suddaby's work was undertaken later in the season. Second, dry-stone walls on Mousa are narrower and more open than those on Skokholm, thus sound (both of the playback and the response) probably penetrates further in Mousa's walls. Third, Suddaby estimated response probabilities on the same day(s) as he ascertained the population size. On Skokholm, population size was estimated during territorial establishment, while responses were elicited during incubation. The (apparently) low response probability may thus have been because the population size was overestimated early in the season if, for example, individual males sang from a number of burrows or some males failed to get a mate. Finally, though a burrow may have been used as a nest site, it is possible that neither member of the pair were in attendance. Because burrows in dry-stone walls on Mousa were accessible, Suddaby knew whether birds were present or not and his response probabilities were the proportion of birds known to be in attendance that responded. Other recent studies have found similarly variable response rates (Mainwood *et al.* 1997, Gilbert *et al.* 1998, Ratcliffe *et al.* 1998 & *in press*).

The population of Storm Petrels on Skokholm in 1995 was estimated at 4,400 pairs (95% CIs 2,900-6,600), somewhat less than Scott's estimate of 6,200 pairs (5,000-7,000). Only a small proportion of this loss can be attributed to losses in the dry-stone walls. The remainder, if real, must have been lost from rockfall and rockburrow habitats.

Nearly 50% of the rockfall population occurs in the Quarry (Table IV). Betts (1994) estimated the size of a proportion of the Quarry population by recording unelicited calling birds within a 25m x 25m quadrat subdivided into 16 cells, each of 6.25m x 6.25m. Aerial photography (Betts 1995) showed that this quadrat covered about 40% of the entire area of the Quarry, though was not placed at random within it. A total of 347 calling birds were recorded in the quadrat, thus Betts estimated a population of 900 pairs in the entire Quarry though he considered this to be only 50% of the actual population size. All estimates of the size of the Quarry population are sufficiently similar (Scott 1970, 2000 pairs; Betts 1995, 900-1,800; this study, 1,600, 95% CIs 1,000-2,550) to suggest that this sub-colony is not undergoing any large changes in population size.

Figure 1, taken from Scott (1970), shows the distribution of Storm Petrels on Skokholm in the late 1960s. Comparing this with Fig. 2, which shows a similar map for 1995, there seems to have been a substantial decline in some areas, notably the south coast, Little Bay and Wallsend. These are all areas of predominantly rockburrow habitat which now contain very low densities of burrows. The lack of birds in these areas was confirmed in 1995 by several nocturnal visits in late May and late June with an image intensifier; only isolated singles and small groups of aerial birds were ever seen where Scott mapped hundreds. Despite these exhaustive searches, however, it is possible that some burrows or sub-colonies in the rockburrow habitat may have been overlooked. Birds in these areas probably breed in shearwater or rabbit burrows at low densities, and may easily be missed as their responses to a tape may be lost against the background of other species' calls. Scott inferred the presence of Storm Petrels in these habitats from mist-netting, rather than locating burrows; this method was not available in 1995.

Though all censuses of Storm Petrels on Skokholm have differed to varying degrees, it is likely that since the late 1960s there has been a modest decline in the island's Storm Petrel population and this has occurred predominantly in the rockburrow habitat. The extent of this decline will probably remain an unknown quantity until Scott's mark and recapture work with mist-nets is repeated. Though the methods used in 1995 were highly repeatable and will be invaluable for future monitoring, further work is required on understanding the causes of variability in response probabilities between different surveys, habitats, sites and parts of the season.

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SUMMARY

The size of the Storm Petrel *Hydrobates pelagicus* population on the island of Skokholm off the SW coast of Wales was estimated using tape playback. Storm Petrels on Skokholm breed in dry-stone walls, in areas of rockfall and boulder beach ('rockfall') and in earth burrows, predominantly under rocks ('rockburrow'). Absolute population sizes of ten random lengths of dry-stone wall were determined from four nocturnal visits using tape playback during territory establishment /early incubation; during each visit responses were noted from *ca.* 60% of burrows. Each site was subsequently re-visited during the day later in the season, the call played, and the proportion of pairs that responded calculated (*ca.* 34%). A further 32 randomly allocated rockfall and

rockburrow sites were visited during the day, the call played and the number of responses noted. Knowing the mean number of responses per unit area of each habitat type, the mean diurnal response probability calculated from the wall sample plots, and the area/length of each habitat type the population of Skokholm was estimated at 4,400 pairs (95% CIs 2,900-6,600), an apparent reduction from Scott's (1970) estimate of 6,200 pairs (5,000-7,000). The 'Quarry' – an area of rockfall at the SW of the island – held 36% of the island total while the dry-stone walls held a mere 7%.

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The diet of Shags *Phalacrocorax aristotelis* in the Cantabrian Sea, northern Spain, during the breeding season

David Álvarez

INTRODUCTION

The Shag *Phalacrocorax aristotelis* is found mainly along marine rocky coasts with shallow waters from the Kola Peninsula in Russia to North Africa. The breeding population in the Cantabrian Sea in northern Spain (Fig.1), is estimated at approximately 500 pairs (Coordinadora Ornitolóxica de Asturies 1990; unpublished data). The numbers of Shags in the main colony at La Caladoria and at other colonies along on the Cantabrian coast fell dramatically in the 1960s, due apparently to high hunting pressure and illegal egg collection.

Shags are large marine birds, adults weigh approximately 1800 g. The species feeds primarily on fish which live in intermediate water layers or close to the sea bottom (Cramp & Simmons 1977), and the average daily food consumption of an individual has been estimated at 16-24 % of body mass (Barrett *et al.* 1990; Johnstone *et al.* 1990). Several studies have reported on the feeding ecology of the Shag in northern Europe (Lumsden & Haddow 1945; Pearson 1968; Furness & Barrett 1985; Barrett *et al.* 1990; Barrett 1991; Harris & Wanless 1993; Wanless *et al.* 1993), but fewer data are available for southern populations (e.g. Noval 1982).

The aim of the present study was to assess the diet of Shags during the breeding season in a colony on the north coast of Spain using remains found in regurgitated pellets, and to make a preliminary estimate of the daily food intake of these birds.

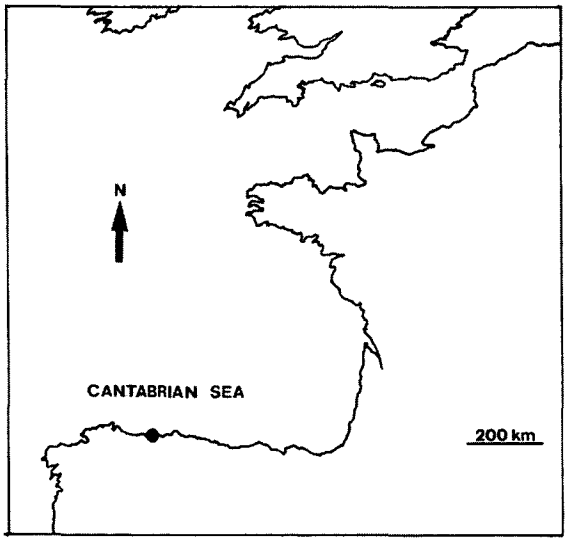

Figure 1: Location of the study area. The black point indicates the breeding colony at La Caladoria

MATERIAL AND METHODS

The study was carried out in the breeding colony at La Caladoria (43° 34' N, 06° 17' W), in the mid-west of Asturies, north of Spain (Fig. 1). This area is characterized by ca. 80 m high siliceous rocky cliffs and small and medium sized rocky islets. The sea floor is predominantly rocky, with some isolated sandbanks (Flor 1981).

Since the early 1980s, at La Caladoria numbers have increased gradually from 10 pairs in 1984 to 37 breeding pairs in 1996 and currently make up aproximately 8% of the Cantabrian population (Alvarez Fernández *et al.* 1995; unpublished data).

The breeding season at La Caladoria begins between mid-January and late February, eggs are laid between February and April, and chicks are found in the nest until June or July. Throughout most of its breeding range, Shags winter outside the breeding area (Galbraith *et al.* 1986), but the Cantabrian population is sedentary with few birds moving away after the breeding season, and few birds moving from other breeding areas (Alvarez Fernández *et al.* 1995).

Pellets regurgitated by incubating or brooding Shags were collected at nest sites between March and May 1995, and in January and between March and June 1996. The pellets were collected in different nests once each month, in an attempt to produce independent samples.

Fish were identified to the lowest possible taxon using sagital otoliths and pharangeal teeth (Härkönen 1986; unpublished data). I estimated the number of fish in a single pellet as half of the total number of otoliths in that pellet (Barrett *et al.*1990; Casaux & Barrera-Oro 1993). To identify and estimate lengths of Wrasse (Labridae) I used the lower pharangeal teeth rather than otoliths. The pharangeal teeth suffer less damage after digestion than do otoliths, and show greater interspecific variability, giving a higher reliability to the identification (unpublished data). To avoid the duplication of results, all the wrasse otoliths were excluded from the analysis, assuming one lower pharangeal tooth represented one fish. I present the data in two forms: (i) numerical frequency of each taxon (proportion of individuals of each taxon within a sample) and (ii) frequency of occurrence of each taxon (proportion of pellets containing each taxon; Hartley 1948; Barrett *et al.* 1990).

I back-calculated fish length and mass from regression equations of these variables on the measurements of otoliths and pharangeal teeth of the more common fish species found. To obtain these equations I determined the total length (± 0.5 cm) and mass (± 0.01g) in samples of intact fish of different species. The heads of these fishes were then cut off and the otoliths (or pharangeal teeth of wrasse) were dissected out. The otoliths were measured using a calibrated ocular grid in the microscope (± 0.01mm) and the pharangeal teeth were measured with vernier calipers (± 0.05 mm) (Fig.2). These measurements were used to produce a series of regression equations relating

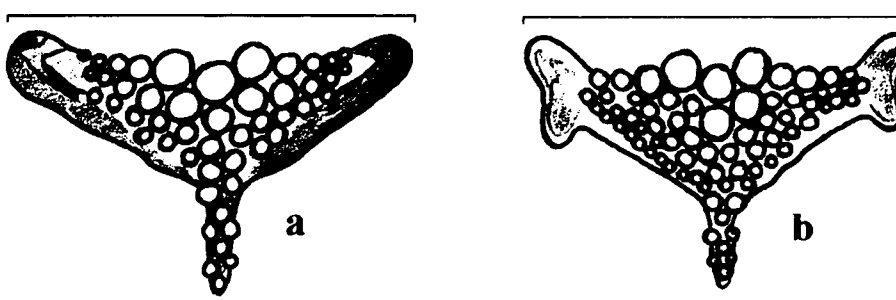

Figure 2: Pharangeal teeth and the measurements used to determine the original length of two species of the Labridae family: a) ballan wrasse *Labrus bergylta*, b) corkwing wrasse *Crenilabrus melops*.

TABLE I. REGRESSION EQUATIONS OF TOTAL BODY LENGTH (TL, CM) AND TOTAL BODY WEIGHT (W, G) AGAINST PHARANGEAL TOOTH LENGTH (PTL, MM) OR OTOLITH LENGTH (OL, MM) FOR THE COMMONEST FISH SPECIES FOUND IN THE SHAG PELLETS COLLECTED AT LA CALADORIA COLONY.

Species	*Equation*	r^2	*Range (cm)*	*Sample size*	*Authority*
Labrus bergylta	TL= 3.9819 + 1.0707 × PTL	0.99	8 - 43	23	present work
	W = -161.92 + 20.26 × PTL	0.98			
Crenilabrus melops	TL = 4.5362 + 0.9609 × PTL	0.91	6 - 25	48	present work
	W = -63.64 + 11.31× PTL	0.95			
Pollachius pollachius	TL = 13.2 × $OL^{1.329}$	0.99	8.3 - 61.4		Härkönen 1986
	W = 0.01192 × $OL^{4.205}$	0.99			
Atherina presbyter	TL = -1.296 + 3.053 × OL	0.91	4 -21	61	present work
	W = -24.102 + 8.37× OL	0.95			

fish length and weight to otolith length or pharangeal tooth length (Table I). In the case of pollack *Pollachius pollachius*, Härkönen's (1986) equation was used. To calculate the original length and mass of each prey item, only the undamaged bony pieces were used.

The total mass of all the fish represented in a pellet was estimated for each pellet in which I could determine the mass corresponding to all prey items. These results were used to estimate the biomass of prey consumed daily by Shags, assuming that each bird produces only one pellet each day (Johnstone *et al.* 1990; Marteijn & Dirksen 1991). There is a growing consensus that although pellets provide useful information on diet they should not be used as a basis for estimating daily food intake (Harris and Wanless 1993; Carss *et al.* in press; S. Wanless pers. com.). Such data are included here because no previous estimates for food intake have been published for Shags in the Cantabrian Sea. The results should nevertheless be considered as approximations only.

Statistical analysis

One-way analysis of variance was used to test for differences in sizes of prey during the breeding season. In this case, I chose corkwing wrasse *Crenilabrus melops*, because it appeared regularly throughout the study. One-way analysis of variance was used to test for differences in the number of prey items per pellet during the study, log transformed to achieve normality. For all the tests, the significance level was set at P = 0.05.

RESULTS

Only six (0.74%) of the 1003 bony fish remains isolated from 71 Shag pellets, were too eroded to enable the species from which they came to be identified. Remains of small benthic invertebrates, eg. polychaetes (mainly *Nereis* sp.), molluscs and crustaceans were also present. I assumed that these invertebrates were not eaten directly by Shags, but their remains had been present in the digestive systems of the fish (e.g. Lumsden & Haddow 1946; Barrett *et al.* 1990; Blackwell & Sinclair 1995).

Diet composition

A total of 13 species of fish, from seven families, were identified from the remains in pellets (Table II). Two families: Labridae and Atherinidae, comprised about 87 % of the total number of identified prey items. The two most frequently recorded species, both by numerical abundance and

TABLE II. NUMERICAL FREQUENCY (N.F.) AND FREQUENCY OF OCCURRENCE (F. OC.) OF PREY FISHES RECORDED IN SHAG PELLETS (N = 71) AT LA CALADORIA COLONY.

	n	*N.f. (%)*	*F. oc. (%)*
BELONIDAE	3	0.4	
Belone belone	3	0.4	2.8
GADIDAE	72	10.6	
Micromesistius poutassou	14	2.1	7.0
Pollachius pollachius	51	7.5	29.6
Trisopterus sp	5	0.7	7.0
Gaidropsarus mediterraneus	2	0.3	1.4
CARANGIDAE	1	0.2	
Trachurus trachurus	1	0.2	1.4
SPARIDAE	1	0.2	
Diplodus sargus	1	0.2	1.4
LABRIDAE	351	52	
Labrus bergylta	67	9.9	50.7
Crenilabrus melops	254	37.6	84.5
Coris julis	4	0.7	5.6
Unidentified Labridae	26	3.8	23.9
MUGILIDAE	3	0.4	
Unidentified Mugilidae	3	0.4	4.2
ATHERINIDAE	239	35.4	
Atherina presbiter	239	35.4	42.2
Unidentified fish	5	0.8	
TOTAL	675	100	

frequency of occurrence were the corkwing wrasse *Crenilabrus melops* and sand smelt *Atherina presbyter*. These and pollack *Pollachius pollachius* and *Labrus bergylta* accounted for 90.5% of all items recorded (Table II). Full details of the diet composition are presented in Appendix 1.

Monthly sample sizes were too small for statistical analysis but the data suggest that the relative importance (both in terms of numerical frequency and frequency of occurrence) of the main prey species differed in the two years with corkwing wrasse being the most frequent item in the diet in most months in 1995, while sand smelt were generally predominant in 1996. Clearly more data are needed to investigate these annual differences further.

Size of fish eaten

The estimated lengths of the prey items taken varied from 4 to 34 cm, with a mean size (± SD) of 13 ± 4 cm (n = 645). Although the size range of fish eaten by Shags was quite wide, most were within the range from 8 to 20 cm. The mean length and mass of the four most commonly recorded fishes in Shag pellets are given in Table III.

The length-frequency distribution was unimodal for all the main species recorded except *Labrus bergylta* (Fig. 3). In this species, a clear bimodal length-frequency distribution was observed. The length-frequency distribution for *C. melops* and *A. presbyter* were very similar, although their weight-frequency distributions differed with *C. melops* being much heavier for any given body length (Fig. 3).

TABLE III. MEAN LENGTHS AND MASS OF THE MOST COMMON SPECIES OF FISHES IN THE PELLETS OF SHAGS IN LA CALADORIA COLONY. IN THE CASE OF *LABRUS BERGYLTA* I ESTIMATE THE TWO MODES OF LENGTH AND WEIGHT BECAUSE IN THIS SPECIES A CLEAR BIMODAL SIZE-FREQUENCY AND MASS-FREQUENCY WAS OBSERVED.

Species	*Total length (cm)* *mean ± SD*	*Mass (g)* *mean ± SD*	*n*
Crenilabrus melops	14.70 ± 2.19	58.83 ± 23.22	104[a]
Atherina presbyter	10.77 ± 1.21	8.96 ± 3.33	222[b]
Pollachius pollachius	17.26 ± 1.99	54.43 ± 19.85	51[b]
	modes	modes	n
Labrus bergylta	12, 26	20, 270	48[a]

a: pharangeal teeth; b: otoliths

Daily food intake

The average daily food consumption of a Shag was calculated to be 287 g (range 100-666 g, n = 18 pellets, 223 prey items). Only 18 pellets were used in these estimates because it was impossible to determine the individual weight of all the prey items in the remaining 53. The estimated daily food consumption was approximately 16% of the body mass of an adult Shag, and is broadly similar to previous estimates (Mills 1969 and Rae 1969 in Cramp & Simmons 1977, Barrett *et al.* 1990, Wanless *et al.* 1993).

Number of prey items per pellet

The number of prey items per pellet varied from 1 to 64 with a mean (± SD) of 9.7 ± 10.6 (mode = 4). There were significant differences between months in 1996 (ANOVA: $F_{4,40} = 3.421$, P=0.016) (log transformed to achieve normality), with the number of items/pellet being higher in April and May. In May 1996 the mean number of prey per pellet was 18.0 ± 17.5 (n = 10 pellets), and one pellet containing 126 otoliths of *Atherina presbyter*. Numbers of prey per pellet were lowest in June 1996 (5.0 ± 5.5 prey/pellet; n= 11 pellets).

DISCUSSION

This study represents the first attempt to assess the diet of Shags in Northern Spain. The results suggest that, during the breeding season, birds from the colony at La Caladoria feed mainly on fish from two families: Labridae and Atherinidae, with the main species taken being *C. melops* and *A. presbiter*. Large spawning shoals of *A. presbiter* are known to occur close inshore during April and May, and it is likely that those are exploited by Shags breeding in colonies along the coast of the Cantabrian Sea. However, preliminary data from this study suggest that the importance of this prey species may show marked annual variations.

Another remarkable feature of La Caladoria colony which can be inferred from our data, when compared to those on other similar studies, is the unusual prey size range recorded. Both the lengths and weights of many of the items in this study were considerably greater than those recorded in other colonies of northern Europe, for example on the Isle of May, southeast Scotland (Harris & Wanless 1991). From this it follows that the number of prey items per pellet is also smaller than elsewhere. On the Isle of May, the number of otoliths per pellet decreased during the breeding season, so that the highest values with several hundred otoliths present per pellet, were obtained at the start of the breeding season (Harris & Wanless 1991), and the lowest ones during the chick rearing period. In the present study, by contrast, there was a slight, but consistent

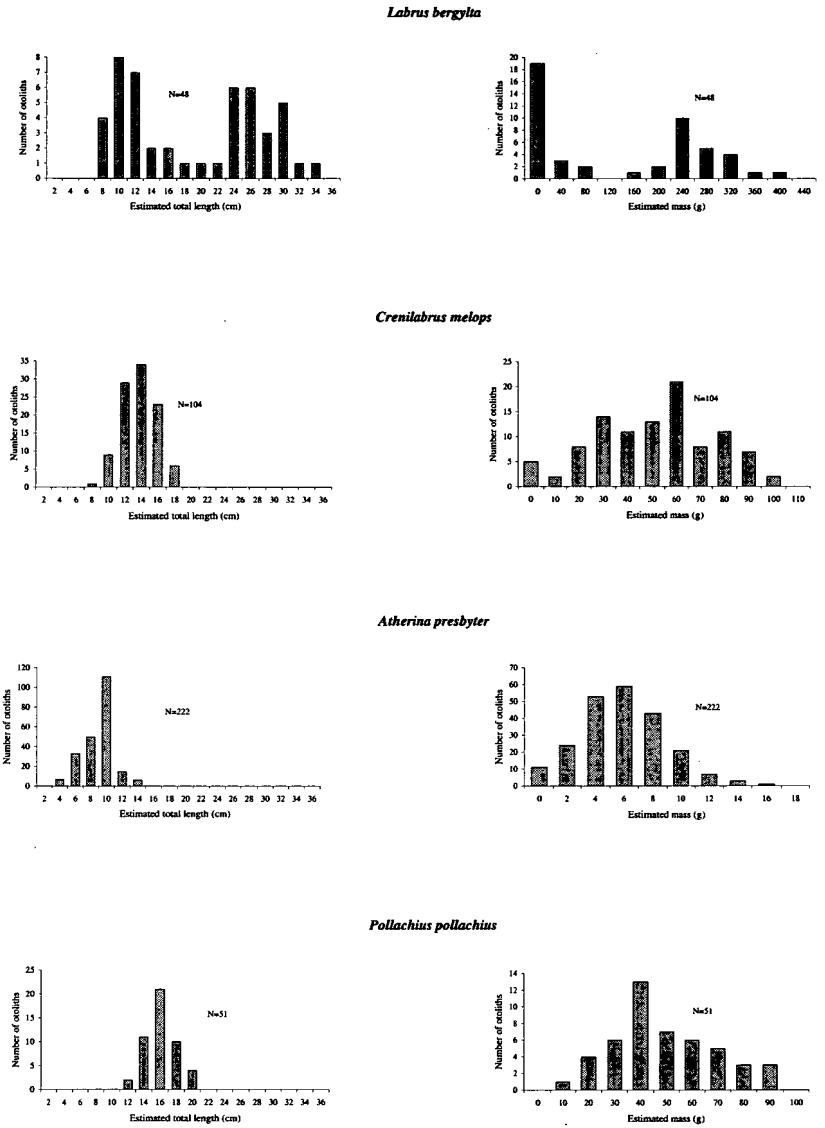

Figure 3: Frequency distribution of estimated length and masses of the four most commonly recorded fish species in the Shag pellets.

seasonal pattern showing the opposite trend, with numbers tending to be higher in April and May, in the main chick rearing period. This trend held in a year when *C. melops* main prey and when *A. presbiter* was predominant.

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SUMMARY

The diet of Shags *Phalacrocorax aristotelis* was studied in a breeding colony in the Cantabrian Sea in northern Spain by examining items in regurgitated pellets. All diet remains were from fish, mostly wrasses (Labridae) and sand-smelts (Atherinidae). Invertebrates found in the pellets had probably been eaten by the fish. The mean number of prey per pellet (± SD) was 9.7 ± 10.6, but significant differences between months were found. The overall mean length of fish caught size was 13.4 ± 4.4 cm, with most within the range 8 to 20 cm. The estimated mean daily food consumption was 287 g, approximately 17 % of the adult body mass of a Shag.

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APPENDIX. FISH SPECIES IDENTIFIED FROM REMAINS FOUND IN SHAG PELLETS AT LA CALADORIA COLONY. F.oc. = FREQUENCY OF OCCURRENCE; N.f. = NUMERICAL FREQUENCY OF ABUNDANCE

Date	*Mar-95*			*Apr-95*			*May-95*			*Jan-96*			*Mar-96*			*Apr-96*			*May-96*			*Jun-96*		
No. pellets	*4*			*11*			*9*			*12*			*5*			*9*			*10*			*11*		
	n	*N.f.*	*F.oc.*	*n*	*N.f.*	*F.oc.*	*n*	*N.f.*	*F.oc.*	*n*	*N.f.*	*F.oc.*	*n*	*N.f.*	*F.oc.*	*n*	*N.f.*	*F.oc.*	*n*	*N.f.*	*F.oc.*	*n*	*N.f.*	*F.oc.*
BELONIDAE																								
Belone belone	-	-	-	-	-	-	-	-	-	3	3.7	16.7	-	-	-	-	-	-	-	-	-	-	-	-
GADIDAE																								
Micromesistius poutassou	-	-	-	2	1.5	9.1	12	11.8	44.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pollachius pollachius	-	-	-	4	3.1	18.2	1	1.0	11.1	32	39.5	8.3	-	-	-	9	10.1	33.3	4	2.3	40	1	1.8	9.1
Trisopterus sp.	-	-	-	1	0.8	9.1	-	-	-	2	2.5	16.7	-	-	-	-	-	-	1	0.6	10	1	1.8	9.1
Gaidropsarus mediterraneus	2	11.6	25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CARANGIDAE																								
Trachurus trachurus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.6	10	-	-	-
SPARIDAE																								
Diplodus sargus	-	-	-	1	0.8	9.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LABRIDAE																								
Labrus bergylta	-	-	-	24	17.7	63.6	11	10.8	66.7	4	4.9	25	7	25.9	80	11	12.4	77.8	6	3.4	50	4	7.3	36.4
Crenilabrus melops	14	82.3	100	76	59.3	100	75	73.5	88.9	19	23.5	83.3	16	59.3	100	19	21.3	77.8	17	9.7	60	18	32.7	81.8
Coris julis	1	5.9	25	1	0.8	9.1	1	1.0	11.1	1	1.2	8.3	-	-	-	-	-	-	-	-	-	-	-	-
Labridae unidentified	-	-	-	-	-	-	-	-	-	4	4.9	33.3	3	11.1	60	12	13.5	55.5	5	2.8	40	2	3.6	18.2
MUGILIDAE																								
Mugilidae unidentified	-	-	-	2	1.6	18.2	-	-	-	-	-	-	1	3.7	20	-	-	-	-	-	-	-	-	-
ATHERINIDAE																								
Atherina presbyter	-	-	-	17	13.3	54.5	2	1.9	11.1	15	18.5	58.3	-	-	-	37	41.6	44.4	142	80.7	80	26	47.3	36.3
Unidentified fish	-	-	-	-	-	-	-	-	-	1	1.2	-	-	-	-	1	1.1	11.1	-	-	-	3	5.4	27.3
TOTAL	17	100		128	100		102	100		81	100		27	100		89	100		176	100		55	100	
Mean number prey/pellet ± SD	5.6 ± 4.8			11.6 ± 8.7			11.4 ± 9.4			8.1 ± 4.5			5.6 ± 3.0			11.2 ± 10.6			18.0 ± 17.5			5.0 ± 5.5		

Prey of Yellow-Legged Gull, RoseateTern and Common Tern in the Azores

Jaime A. Ramos, Encarnacion Solá, Filipe M. Porteiro and Luís R. Monteiro

INTRODUCTION

A knowledge of seabird diet is essential in order to understand their ecological relationships with the marine environment. Diets of Herring Gull *Larus argentatus* (Hunt & Hunt 1973, Gotmark 1984, Noordhuis & Spaans 1992; for a review see Furness & Monaghan 1987), Common Tern *Sterna hirundo* (Langham 1968, Frank 1992) and Roseate Tern *Sterna dougallii* (Langham 1968, Richards & Schew 1989, Safina *et al.* 1990) have been described in Europe and North America. Gulls are opportunistic feeders and their diets include marine and freshwater fish species, marine invertebrates, earthworms *Lumbricus* spp, bird eggs and chicks, and domestic refuse. Most gull species have changed their diets since the 1960s due to anthropogenic influences and presently some populations may rely largely on fishery waste (Furness *et al.* 1992) and domestic refuse (Furness & Monaghan 1987). Common Terns feed on marine, brackish and freshwater fish species. Roseate Terns feed on marine fish. The diets and prey items of gull and tern species in other parts of the world, especially oceanic islands, are poorly known.

Available information suggests that prey items of Yellow-legged Gull *Larus cachinnans atlantis* (Hamer *et al.* 1994), Common Tern (Granadeiro *et al.* 1995) and Roseate Tern chicks (Ramos *et al.* in press) in the Azores are more diverse than those in Europe and North America. In addition, prey items of Roseate Tern chicks may show seasonal variations (Ramos *et al.* in press). In this work we used pellets (for Yellow-legged Gull, Roseate Tern and Common Tern), and prey items dropped around nests (Roseate Tern chicks) to describe some seasonal and annual variations in diet on several colonies of the Azores in 1995 and 1996. This information is also of interest to fishery science because these birds may feed on the young of exploited fish species

METHODS

Descriptions of the colonies, size of populations and breeding is presented by del Nevo *et al.* (1993), Ramos & del Nevo (1995) and Monteiro *et al.* (1996a, 1996b). Gull pellets were collected in Baixo Islet, offshore Graciosa Island, prior to egg laying (4-6 March 1995) and when feeding chicks (6 June 1995), and Mistério da Prainha, Pico Island, during incubation (18 May 1996). Tern pellets were collected in Vila Islet, offshore Santa Maria Island, in the end of the breeeding season (Roseate Tern: 20-30 July; Common Tern: 18-25 August). The whole area of the colonies were searched but most pellets were found in several rocky areas where birds roosted. Roseate Terns nested in one dense group in the eastern side of the colony and led their half-grown chicks to nearby rocks to hide in crevices and cracks. Roseate Tern pellets were collected in the centre of this rocky area, where virtually no Common Tern fledglings were found. Common Tern pellets were collected in the western side of the colony, where no Roseate Terns were present. Pellets were preserved in individual plastic bags for examination in the laboratory. During the course of other work, items captured by foraging birds were also noted.

Prey dropped by Roseate Terns at nests and feeding areas were collected during the chick feeding period in the following colonies: Vila Islet (Santa Maria, 14 June-22 July 1995, 17 June-5 July 1996), Lagoinhas Islet (Santa Maria, 3 July 1996), Capelinhos, (Faial, 22 May-7 July 1996), Contendas Islet, (Terceira, 4 June 1996), and Baixa do Moínho Islet (Flores, 22 May and 22 July

1996). Apart from Capelinhos, which is a mixed sand and boulder beach with some soft boulders from a recent landslide, all other colonies are essentially rocky with Vila, Baixo and Lagoinhas having well vegetated plateaus. On Vila (1995) and Capelinhos (1996) prey dropped were collected throughout the breeding season at regular intervals. During each visit the same area of the colony was searched systematically and all dropped prey items were collected.

Pellets provide information on prey of adults and independent juveniles whereas prey dropped around nests by Roseate Terns provide information on prey delivered or intended for chicks. Prey items dropped at nests and feeding sites were found mostly under vegetation or in cracks, possibly dropped by chicks and impossible to retrieve by parents. Prey items dropped were identified using Whitehead *et al.* (1984). Sagital otoliths (Jobling & Breiby 1986, Smale *et al.* 1995), scales and characteristic bones from these and other specimens were used to prepare reference collections, which were used to identify remains of fish species found in pellets. Dropped specimens of *Scomberesox saurus* and *Nanichthys simulans* (family Scomberesocidae) could not be distinguished and numbers were grouped. Nomenclature of fish families is given after Nelson (1994) and fish species after Whitehead *et al.* (1989) . The results of pellet analyses are expressed as the percentage of pellets containing a particular prey type.

In terms of habitat and depth of prey species the following classification (after Whitehead *et al.* 1989) was used: Littoral (rocky and littoral zone), Epipelagic (0 - 200 m), Mesopelagic (200 - 1000 m), Bathypelagic (> 1000 m) and Benthic (associated to the bottom at any depth).

RESULTS

Pellets of Yellow-legged Herring Gull

The main prey types present in the various colonies are shown in Table I. On Mistério da Prainha, the proportion of fish in the pellets was significantly higher than on Baixo for both March (χ^2_1 = 48.41) and June (χ^2_1 = 112.64, both $p < 0.001$, with Yates correction). In 1995, on the colony of Baixo, the proportion of bird-pellets in March was significantly lower than that in June (χ^2_1 = 10.56, $p < 0.001$, with Yates correction). Earthworms were observed to be taken along pasture and heathland on Flores Island in March 1996. In late May 1996 marine gastropod shells were found near nests in the gull colony of Maria Vaz Islet, offshore Flores Island.

Appendix I presents a list of prey fish families and species found in this study and by Hamer *et al.* (1994). It is noteworthy that in March (prior to egg laying) and May (incubation), fish was the main prey type, with *Capros aper* being the most important species (Table II). The proportion of *Trachurus picturatus* in the diet of gulls on Baixo Islet increased significantly from March to June (χ^2_1 = 60.08, $p < 0.001$, with Yates correction). At this colony mesopelagic fish were not recorded in March but comprised about 25% of the fish prey items in June (Table II).

Pellets of Common Tern and Roseate Tern

Appendix 1 presents a list of prey fish families and species found in this study. Pellets indicated that in 1995 *Macroramphosus scolopax* was the main prey fish for both tern species (Table III). The major difference between the diet of Roseate Tern and Common Tern is a greater proportion of Myctophidae for the former: 30.6% of the pellets produced by Roseate Terns had remains of Myctophidae whereas for Common Terns the value was only 14.5%. This difference was highly significant (χ^2_1 = 11.67, $p < 0.001$, with Yates correction).

Prey dropped by Roseate Tern

In 1995 *Macroramphosus scolopax* comprised 68% of the fish species found on Vila Islet but, in 1996, *Trachurus picturatus* (38%) was the most abundant; the latter was also found in other colonies throughout the archipelago, where values ranged from 14% on Capelinhos to 48% on Baixa do Moínho (Table IV). No *Trachurus picturatus* were found on Contendas, but this colony was visited only once, early in the chick feeding period, and only a few samples were collected

TABLE I. THE NUMBER AND PERCENTAGE OF PELLETS OF DIFFERENT TYPES PRODUCED BY ADULT YELLOW-LEGGED HERRING GULLS IN THREE COLONIES OF THE AZORES.

	Baixo Islet (4-6 March 1995) N = 171		*Baixo Islet (6 June 1995) N = 172*		*Mistério da Prainha (18 May 1996) N = 155*	
	No. pellets	*%*	*No. pellets*	*%*	*No. pellets*	*%*
Pellet type						
Fish[1]	94	55.0	74	43.0	147	94.8
Vegetable[2]	21	12.3	18	10.5	4	2.6
Goose-barnacle	19	11.1	13	7.6		
Birds[3]	13	7.6	35	20.3		
Refuse[4]	11	6.4	10	5.8		
Mammals[5]	3	1.8	22	12.8	3	2.0
Mixed	10	5.9			1	0.6

[1] Some fish-pellets had also a few feathers and algae but were, nevertheless, classified as fish.
[2] Leaves and seeds of grasses and remains of insects
[3] Starling *Sturnus vulgaris granti*, Canary *Serinus canarius canarius*, Grey Wagtail *Motacilla cinerea* Robin *Erithaculus rubecula*, Pigeon *Columba* sp, Madeiran Storm-petrel *Oceanodroma castro* and Little Shearwater *Puffinus assimilis*.
[4] Mainly plastic, strings, chicken legs, glass and bones
[5] Rats, rabbits and some undetermined

TABLE II. THE NUMBER AND PERCENTAGE OF DIFFERENT FISH SPECIES IDENTIFIED IN PELLETS PRODUCED BY ADULT YELLOW-LEGGED HERRING GULLS ON THREE COLONIES OF THE AZORES. (L) DENOTES LITTORAL, (E) EPIPELAGIC, (M) MESOPELAGIC, (BP) BENTHO-PELAGIC AND (BE) BENTHIC SPECIES.

	Baixo Islet (4-6 March 1995) N = 94		*Baixo Islet (6 June 1995) N = 74*		*Mistério da Prainha (18 May 1996) N = 147*	
	No. pellets	*%*	*No. pellets*	*%*	*No. pellets*	*%*
Fish species						
Capros aper (E/M)	88	93.6	51	68.9	145	98.6
Trachurus picturatus (E)	3	3.2	43	58.1	4	2.7
Macroramphosus scolopax (E)	10	10.6	4	5.4	4	2.7
Electrona rissoi(M)			10	13.5		
Unidentified Myctophidae (M)			8	10.8		
Coelorhynchus choelorhynchus (BP)	2	2.2			3	2.0
Apogon (Apogon) imberbis (L, BE)					5	3.4
Abudefduf luridus (L, BE)					2	1.4
Undetermined	13	13.8	14	18.9	13	8.8

TABLE III. COMPARISON BETWEEN THE NUMBER AND PERCENTAGE OF DIFFERENT FISH SPECIES PRESENT IN PELLETS OF ROSEATE TERN AND COMMON TERN AT VILA ISLET 1995. (E) DENOTES EPIPELAGIC AND (M) MESOPELAGIC SPECIES.

	Roseate Tern *20-30 July 1995* *N = 362*		*Common Tern* *18-25 August 1995* *N = 208*	
	No. pellets	*%*	*No. pellets*	*%*
Fish species				
Macroramphosus scolopax (E)	362	100.0	208	100.0
Electrona rissoi (M)	75	20.7	8	3.8
Ceratoscopelus maderensis (M)	5	1.4	2	1.0
Diaphus metopoclampus (M)	3	0.8		
Myctophum punctatum (M)	1	0.3		
Unidentified Myctophidae (M)	27	7.4	20	9.7
Trachurus picturatus (E)	15	4.1	1	0.5
Capros aper (E/M)	3	0.8	8	3.8
Undetermined	8	2.2	9	4.3

(Table IV). Two individual squid (sub-order Oegopsidae) were also found on Capelinhos. More fish species were found on Capelinhos than in other colonies. This could be a result of a higher collecting effort in this colony, spread across the breeding season.

Prey dropped around nests were collected throughout the breeding season in both Vila islet (1995) and Capelinhos (1996), enabling a crude analysis of seasonal variation in prey items brought to the colony. The proportion of Myctophidae dropped around nests by Roseate Terns chicks on Vila in 1995, increased seasonally from 6% for the period 14-25 June to 12% and 11% for the following two collecting periods, whereas the proportion of *S. saurus* and *N. simulans* decreased from 6% to <1% and 2% (Table V). In 1996, the most abundant fish species *T. picturatus* increased through the breeding season ($r_s = 0.89$, ns), whereas *M. scolopax* ($r_s = -0.72$, ns), *S. saurus* and *N. simulans* ($r_s = -0.83$, ns), and Myctophidae ($r_s = -0.24$, ns) decreased, though all correlations were not significant. Squid was present only early in the season, and *Diretmus argenteus* later in the season (Table VI).

List of prey fish

A list of fish species identified during this study and from Hamer *et al.* (1994) is shown in Appendix 1. Twenty-seven families, 34 genera and at least 35 species were identified: 17, 34 and 21 genera/species for Yellow-legged Gull, Roseate Tern and Common Tern, respectively. The species *Howella sherboni*, found in the tern colonies, constitutes the first reference for the Azores. Other species such as *Lychonus brachycolus* have rarely been sampled previously.

Of the 27 families represented, five are families of littoral species, nine are families of predominantly epipelagic species, nine are families of predominantly mesopelagic and bathypelagic species, and four are families of benthic species. More than half of the identified genera/species (53%) occurred less than four times in either pellets or fish remains dropped by Roseate Terns. This may indicate that Roseate Terns tend to capture whatever prey is available to them. The majority of the occurrences (> 10% at any given colony), however, came only from seven species, which may be the most consistently abundant and available.

TABLE IV. THE PERCENTAGE OF DIFFERENT PREY ITEMS DROPPED BY ROSEATE TERNS IN SEVERAL COLONIES OF THE AZORES. (E) DENOTES EPIPELAGIC AND (M) MESOPELAGIC SPECIES.

Colony (island)	*Vila (S.Maria)*	*Vila (S.Maria)*	*Lagoinhas (S.Maria)*	*Capelinhos (Faial)*	*Contendas (Terceira)*	*Baixa do Moínho (Flores)*
	N = 680	*N = 61*	*N = 38*	*N = 637*	*N = 20*	*N = 23*
	14 June-22 July 1995	*17 June-5 July 1996*	*3 July 1996*	*22 May-7 July 1996*	*4 June 1996*	*22 May & 22 July 1996*
Prey species						
Macroramphosus scolopax (E)	68	19	15	15	53	9
Trachurus picturatus (E)	5	38	37	14		48
Scomberesox saurus and *Nanichthys simulans* (E)	5	10	3	22	<1	13
Capros aper (E/M)	10	26	37	7	26	4
Belone belone gracilis (E)	2		5			17
Myctophidae (M)	9	2		11	5	
Phycidae postlarva (E)				6		
Sternoptyx sp (M)				5		
Diretmus argenteus (M)				8		
Cubiceps gracilis, juveniles (E)		5		2		9
Squid (Oegopsidae)				2		
Others and undetermined	1		3	8	16	

DISCUSSION

Our data provides an assessment of prey items in the diet of Yellow-legged Herring Gull, Roseate Tern and Common Tern in the Azores archipelago. Analysis of pellets will underestimate the importance of items that produce little indigestible remains (Johnstone *et al.* 1990). Although some pellets may remain intact for a considerable period, collection from a site at the end of the breeding season should underestimate the importance of prey that result in unstable pellets. Long and thinner species of the family Scomberesocidae and other fine-boned species could well be under-represented if their pellets were less stable than those produced from wide-bodied species. Besides, no pellets were found on nest sites occupied by Roseate Tern chicks, suggesting that, like in Shags *Phalacrocorax aristotelis* (Russell *et al.* 1995), Roseate Tern nestlings do not produce pellets. This behaviour may contribute to explain the lack of fish species such as *Belone belone gracilis*, *Scomberesox saurus* and *Nanichthys simulans* in pellets, because these species are consumed primarily by Roseate Terns nestlings (Ramos *et al.* in press).

The greater frequency of birds in the diet of gulls on Baixo in June than in March may reflect the breeding season of passerines (i.e. fledglings which are easily caught). The fact that birds comprised more of the gull diet on Baixo Islet than on Mistério da Prainha could be related to differences in the availability of birds between these two locations: (1) The colony on Mistério da Prainha is surrounded by native forest (where passerines should be more difficult to capture) whereas Baixo Islet and the nearby Graciosa Island are covered with pasture. (2) Baixo is a mixed Procellariiform colony, with several small petrel species (Monteiro *et al.* 1996 b), whereas on Mistério da Prainha only Little Shearwater *Puffinus assimilis* were heard in the surrounding cliffs. Analyses of pellets showed Azores gulls to be opportunistic feeders, like those in mainland Europe

TABLE V. SEASONAL VARIATION IN THE PERCENTAGE OF ROSEATE TERN CHICK PREY ITEM (PREY DROPPED AROUND NESTS) ON ILHÉU DA VILA, OFFSHORE SANTA MARIA ISLAND, IN 1995. (E) DENOTES EPIPELAGIC AND (M) MESOPELAGIC SPECIES.

	14-25 June *N = 430*	*26 June - 5 July* *N = 139*	*22 July* *N = 111*
Prey species			
Macroramphosus scolopax (E)	68	63	73
Scomberesox saurus and *Nanichthys simulans* (E)	6	<1	2
Trachurus picturatus (E)	5	12	4
Belone belone gracilis (E)	<1	2	4
Myctophidae (M)	6	12	11
Capros aper (E/M)	12	6	3
Naucrates ductor (E)	<1	1	1
Others and undetermined	2	4	1

TABLE VI. SEASONAL VARIATION IN THE PERCENTAGE OF PREY ITEMS (PREY DROPPED AROUND NESTS) OF ROSEATE TERN CHICKS ON CAPELINHOS, FAIAL ISLAND, IN 1996. (E) DENOTES EPIPELAGIC AND (M) MESOPELAGIC SPECIES.

	22 May-2 June *N = 109*	*9-10 June* *N = 125*	*13-15 June* *N = 31*	*20-24 June* *N = 157*	*28-30 June* *N = 130*	*3-7 July* *N = 85*
Prey item						
Trachurus picturatus (E)	3	4	13	8	32	24
Macroramphosus scolopax (E)	14	34	19	10	5	9
Capros aper (E/M)	2	9	10	11	8	2
Scomberesox saurus and *Nanichthys simulans* (E)	32	23	20	24	16	14
Myctophidae (M)	11	14	13	20	5	11
Cubiceps gracilis (E)	1	5	6	3		1
Phycidae postlarva (E)	26	4	3		3	
Sternoptyx sp (M)	4	2	6	8	2	11
Squid (Oegopsidae)	3	2	3	2		
Diretmus argenteus (M)				5	17	20
Others and undetermined	4	3	7	9	12	8

(Furness *et al.* 1992, Noordhuis & Spaans 1992). Vegetable pellets found in our study may reflect the consumption of earthworms (Noordhuis & Spaans 1992). Fish is, however, more important in the Azores than in colonies of mainland Europe (Furness & Monaghan 1987). Around 50% of gull-pellets found on Baixo were composed of fish; on Mistério da Prainha the figure was 95%, although part of the fish could be scavenged (see later). The true proportion of fish in the gulls' diet may be even larger since fish-pellets are less durable and less easily visible than pellets containing remains of molluscs, refuse, mammals and birds (Hamer *et al.* 1994). Foraging situations such as domestic refuse should be less available in the Azores than in mainland Europe.

Fish dropped at nests gives a biased view of Roseate Tern chick diet because broad bodied species such as *C. aper* (which cannot be swallowed by young chicks) will be over-represented (Ramos *et al.*, in press). However, important dietary components of Roseate Tern chicks can be assessed using fish dropped at nests (Ramos *et al.* in press). This is also suggested in this study if the data from pellets are compared with those from fish dropped at nests.

The relative frequency of common fish prey species of Roseate Terns seem to vary more from year to year and through the breeding season, than by location within a particular breeding season. These data suggest major annual variations in the abundance and availability of prey stocks as well as some seasonal variations. In particular, variations within a breeding season might be explained by the fact that terns foraged on abundant fish schools as they move across the archipelago. A full assessment of tern and gull diets in relation to changes in the abundance of fish stocks deserves a detailed study.

Some species found in this study have rarely or never been recorded previously for the Azores. The family Batrachoididae mentioned by Hamer *et al.* (1994) is the only reference ever for the Azores. Clearly, this area needs further fish sampling.

Yellow-legged Herring Gulls, Common Terns and Roseate Terns feed mainly on epipelagic fishes, like Laridae in other parts of the world (Langham 1968, Randall & Randall 1978, Safina *et al.* 1990, Hensley & Hensley 1995) although mesopelagic prey were quite important. As pointed out by Hamer *et al.* (1994), gulls and terns may feed regularly in association with underwater predators, which may drive some mesopelagic species to the surface (Ashmole & Ashmole 1967, Au & Pitman 1988). However, some of the mesopelagic and bathypelagic species recorded in this study are reported to live at depths of 500-1000 m and over; therefore, it is unlikely that they are driven to the surface by marine predators.

Mesopelagic prey migrate vertically to surface waters during the night and some are caught by seabirds feeding nocturnally, such as Sooty terns *Sterna fuscata* (Bruyns & Voous 1965). Clearly, this is not the case in our study because we observed mesopelagic prey being delivered throughout the day, particularly around noon. Perhaps only a major and exceptional upwelling event can concentrate mesopelagic fish in high numbers at the surface (Merrett, pers. comm.). Mesopelagic species may die during the vertical migration and float to the surface, where they are scavenged. Large numbers of dead *C. aper* and a few specimens of *Coelorhynchus coelorhynchus*, *Abudefduf luridus* and *Apogon (Apogon) imberbis* were observed ashore throughout the winter of 1996 and should be readily available food. The very high proportion of fish species in the diet of gulls of the colony Mistério da Prainha coincided approximately with the time when many dead fish were found along the seashore. However, it remains unclear how terns include in their diet non-nocturnally migrating species such as *Sternoptyx* sp and *Opisthoproctus grimaldii*. Although unexpected deep mesopelagic, non-migratory species with gas-filled swimbladders such as *S. diaphana* and *S. pseudobscura* may feed on shallow epipelagic, even neustonic, zooplankton (Hopkins et al. 1996).

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SUMMARY

We used pellets and prey remains dropped around nests to assess seasonal and annual variation in the prey of Yellow-legged Gull, Roseate Tern and Common Tern at several colonies of the Azores archipelago. Yellow-legged Gull was an opportunistic feeder. Fish was the basis of the diet but pellets included vegetable material, birds, refuse and mammals. The three Laridae species feed mainly on epipelagic fishes but mesopelagic prey were also important and their occurrence is stressed. A list of prey fish is presented. Some mesopelagic fish constitute the first reference for the Azores. Roseate Tern prey varied greatly between years and across the

breeding season; overall, *Macroramphosus scolopax* was the main prey type in 1995, and *Trachurus picturatus* the main prey type in 1996. Thinner prey fish such as *Scomberesox saurus* and *Nanichthys simulans* were found more often early in the Roseate Tern breeding season. The data suggest major annual and seasonal variation in the abundance and availability of prey stocks across the whole archipelago.

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APPENDIX I. LIST OF FISH PREY SPECIES OF YELLOW-LEGGED GULL (FROM ADULT PELLETS), ROSEATE TERN (FROM ADULT PELLETS AND PREY REMAINS COLLECTED AROUND NESTS) AND COMMON TERN (FROM ADULT PELLETS AND PREY REMAINS COLLECTED AROUND NESTS) IN THE AZORES. WE CONCENTRATED OUR PREY COLLECTION AROUND NESTS OF ROSEATE TERNS. SOME OF THE PREY FISH TAKEN BY ROSEATE TERNS WERE ALSO BELIEVED TO BE TAKEN BY COMMON TERNS, THUS X? INDICATES A PROBABLE PREY FISH OF COMMON TERN. THE HABITAT IS INDICATED BY L - LITTORAL, E - EPIPELAGIC, M - MESOPELAGIC, B - BATHYPELAGIC AND BE - BENTHIC (SEE METHODS FOR DEFINITIONS).

Identification	*Habitat*	*Yellow-legged Gull*	*Roseate Tern*	*Common Tern*
Opisthoproctidae				
Opisthoproctus grimaldii	M	x[1]		
Alepocephalidae	M/B		x	
Sternoptychidae				
Argyropelecus aculeatus	M		x	x
Sternoptyx diaphana	M		x	
Sternoptyx sp	M		x	
Myctophidae				
Protomyctophum (Hierops) articum	M	x[1]		
Ceratoscopelus maderensis	M		x	x
Diaphus metopoclampus	M		x	
Diaphus rafinesquei	M		x	
Diaphus taaningi	M		x	
Electrona rissoi	M	x	x	x
Lampanyctus festivus	M		x	x?
Myctophum punctatum	M		x	
Myctophum sp	M	x[1]		
Notoscopelus resplendens	M		x	
Notoscopelus sp	M	x[1]		
Symbolophorus sp	M	x[1]		
Macrouridae				
Coelorhynchus coelorhynchus	BE	x		
Coelorhynchus sp	BE	x[1]		
Nezumia sclerorhynchus	BE		x	
Nezumia aequalis	BE	x[1]		
Phycidae (postlarval stage)	E		x	
Merlucciidae				
Lychonus brachycolus	E/BE		x	
Batrachoididae	BE	x[1]		
Atherinidae				
Atherina (Hepsetia) presbyter	L		x	x
Belonidae				
Belone belone gracilis	E		x	x

Identification	*Habitat*	*Yellow-legged Gull*	*Roseate Tern*	*Common Tern*
Scomberesocidae				
Nanichthys simulans	E		x	x
Scomberesox saurus	E		x	x
Exocoetidae				
larval stage	E		x	x?
Melamphaidae	M		x	x?
Diretmidae				
Diretmus argenteus	M	x[1]	x	
Trachichthyidae	E/M/BE	x[1]		
Berycidae				
Beryx sp	M/BE	x[1]		
Caproidae				
Capros aper	E/M	x	x	x
Macroramphosidae				
Macroramphosus scolopax	E	x	x	x
Acropomatidae				
Howella sherboni (juvenile)	E		x	
Polyprion americanus	E		x	x?
Apogonidae				
Apogon (Apogon) imberbis	L/BE	x		
Carangidae				
Naucrates ductor	E		x	x?
Trachinotus ovatus	E		x	x
Trachurus picturatus	E		x	x
Sparidae				
Boops boops	L			x
Diplodus sargus	L		x	x?
Pagellus bogaraveo	L		x	x
Pomacentridae				
Abudefduf luridus	L/BE			
Blenidae	L		x	
Gobiidae	BE	x[1]		
Scombridae				
Scomber japonicus	E		x	x?
Nomeidae				
Cubiceps gracilis (juvenile)	E		x	x

[1] source: Hamer *et al.* (1994)

Predation of Arctic Tern chicks by rabbits in northeast England

J.A. Robinson and K.C. Hamer

INTRODUCTION

Recent attention has focused on the impacts of introduced predators on populations of ground-nesting seabirds (Fitzgerald & Veitch 1985; Uttley *et al.* 1989; Ashmole *et al.* 1994; Burger & Gochfeld 1994; Craik 1995) but considerably less attention has focused on impacts of other introduced species. Both domestic sheep *Ovis* and red deer *Cervus elaphus* have been recorded to prey upon nestlings of a variety of species including Arctic Skua *Stercorarius parasiticus*, Arctic Tern *Sterna paradisaea* and Manx Shearwater *Puffinus puffinus* (Wormell 1969; Furness 1988a,b) but to our knowledge there are no records of such predation by other species of herbivore. In this note we describe the likely predation of Arctic Tern chicks by rabbits *Oryctolagus cunniculus* at Coquet Island, Northumberland, northeast England, and assess the likely impact of this predation upon productivity at the colony.

LOCALITY AND METHODS

Coquet Island (55° 20'N, 1° 32'W) is a small low-lying island situated off the coast of Northumberland, northeast England. About 750 pairs of Arctic Terns nest on the island annually, in grassy areas with a mixed sward including sow-thistle *Sonchus* spp., bugloss *Lycopsis arvenis*, stinging nettle *Urtica dioica* and annual nettle *Urtica urens* that provide cover for chicks after hatching. There are also colonies of other ground-nesting seabirds on the island, including Common Tern *S. hirundo*, Sandwich Tern *S. sandwicensis* and Black-headed Gull *Larus ridibundus*. Rabbits feed in close proximity to nests of all these species, sometimes provoking aggressive responses from breeding adults.

The breeding ecology of Arctic Terns on Coquet Island is monitored annually. In particular, breeding productivity is monitored each year at a sample of *ca.* 130 nests within a walled enclosure attached to the island's lighthouse. Shortly after the onset of hatching in 1997, for the first time tern chicks within this enclosure were noticed which had been attacked in a particularly characteristic manner strongly resembling that recorded at colonies in Shetland by Furness (1988a) as a result of predation by sheep. We therefore made careful searches of the entire tern colony throughout the chick-rearing period and recorded all cases of live or dead chicks showing these mutilations, along with all cases of dead chicks that were not mutilated. We also made observations from a suitable vantage point within the lighthouse complex and recorded the presence of any putative predators within the colony. The ages of chicks showing mutilations were determined where possible from measurements of wing or tarsus length calibrated against growth in chicks of known age (J.A. Robinson & K.C. Hamer unpublished data).

RESULTS AND DISCUSSION

Chicks that had been attacked (n = 15) had between one and four limbs cleanly severed. In most cases one or both legs had been removed, whilst severed wings were less common. Chicks did not survive these attacks, although in six cases where one leg had been severed when the chick was

first encountered, death occurred several days after the injuries were first recorded. There was no further damage to the body except in two cases where the beak had been severed. The chicks attacked were all newly hatched (1-5 days old) and attacks always coincided with occasions when one or more rabbits had been observed feeding in close proximity to the nest, although we were not able to observe predation events directly.

In total 229 eggs were laid at 130 Arctic Tern nests in the enclosure in 1997. Hatching success was 97%, producing 222 chicks. None of the failed eggs were eaten by rabbits. Fledging success was 46.9% (104 chicks) and of the 118 chicks that died before fledging, 15 (12.7%) had injuries indicative of attack by rabbits. Such injuries were not observed at Arctic Tern nests elsewhere on the island and no other tern or gull species were affected in this way.

There are no sheep or deer at Coquet Island and mammalian predators such as mink *Mustela vison*, otters *Lutra lutra* and hedgehogs *Erinaceus europaeus* are also absent, as are small rodents. Moreover the injuries inflicted on chicks were quite different from those caused by these predators or by predatory birds (e.g. see Craik 1995). The only putative predators observed feeding in the colony were rabbits and the injuries to the terns were highly characteristic of those caused by herbivores at other colonies (Furness 1988a, b). It is therefore highly probable that the injuries inflicted on chicks were caused by rabbits.

The parts of chicks that were removed were those with high bone content but little flesh, skin or feathers, and the method used to extract these parts was very precise and remarkably similar to that adopted by sheep and deer at seabird colonies elsewhere (Furness 1988a, b). The proportion of chicks killed by rabbits was small compared to total chick mortality prior to fledging. However, fledging success was unusually low in 1997 due to a severe and prolonged storm during the second half of the chick-rearing period. Fledging success of Arctic Terns at Coquet is usually around 70% (Uttley *et al.* 1989) and in these circumstances predation by rabbits at the level observed in 1997 would represent a substantial proportion of overall chick mortality. Nonetheless only 6.5% of chicks within the walled enclosure were killed by rabbits in 1997 and no such predation was observed anywhere else on the island. This intensity of predation is unlikely to have a large effect on annual productivity at the colony, although it may influence the choice of nest site by terns in future years.

The fact that predation by rabbits was recorded only within the walled enclosure suggests that at most a few individual rabbits were involved, although instances of such predation may have been overlooked elsewhere on the island where longer vegetation made dead or injured chicks harder to locate. The mineral status of rabbits at Coquet has not been investigated but it seems probable that the attacks on chicks were carried out in order to obtain calcium. Coquet is formed of sandstone and most of the dominant plant species are characteristic of poor quality light soils, indicating that calcium levels in the vegetation may be low compared to those in plants growing on more calcium-rich soil. Sheep and deer that prey upon seabird chicks also appear to use them as a source of calcium (Furness 1988b; Uttley *et al.* 1989) and other herbivores have also been observed to eat animals in order to obtain nutrients not available from plants in nutrient-poor habitats (Wallisdevries 1996).

To our knowledge, killing of birds by rabbits has not been previously documented. This suggests that it is likely to be a rare phenomenon, occurring only in unusual circumstances where rabbits are feeding on mineral-deficient vegetation in proximity to seabirds nesting at high density. Moreover, no chicks were apparently attacked beyond the first week post-hatching, suggesting that older individuals can successfully deter or avoid attack. The same is likely to be true of larger species of seabird. The fact that predation by rabbits at Coquet was apparently confined to a small part of the colony and has not been previously observed there suggests that it may be a novel habit involving only a small number of individual rabbits. Nonetheless rabbits breed sympatrically with terns at many colonies and the possibility of such predation occurring elsewhere should not be overlooked.

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SUMMARY

In 1997, Arctic Tern chicks at Coquet Island, northeast England were observed with injuries that were highly characteristic and very similar to those inflicted elsewhere by sheep. Observations at the colony indicated that only chicks 1-5 days old were attacked and that the animals responsible were rabbits, which were probably making up nutrient deficiencies by eating chicks. All attacks eventually proved fatal but losses were low compared to other causes of mortality. We suggest that at Coquet Island, predation of tern chicks by rabbits may be a novel habit involving only a small number of individuals. Nonetheless rabbits breed sympatrically with terns at many colonies and the possibility of such predation occurring elsewhere should not be overlooked.

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A remote-controlled net trap for ground-nesting cormorants

D. Grémillet and R. P. Wilson

INTRODUCTION

Cormorants *Phalacrocorax carbo* are shy seabirds which normally cannot be approached easily, even in remote places and within their entire distribution range (Johnsgard 1993). This is probably partly due to the traditional persecution of this piscivorous bird by humans (van Dobben 1952) because Cormorants are often considered to be direct competitors with man for fish resources (Suter 1991). This same potential competition has fuelled the interest of scientists, nature conservationists and politicians in the feeding ecology of these birds (Kirby *et al.* 1996, Carss *et al.* in press). The question as to the extent to which Cormorants are actually detrimental to fish stocks exploited by man has yet to be fully resolved, because these birds are pursuit divers which swallow most prey items underwater or at least out of sight of land-based observers. Thus collection of data on the foraging behaviour of Cormorants is often linked to the use of electronic devices with which the animals have to be equipped (Grémillet *et al.* 1997). An effective capture mechanism is consequently a most important piece of equipment for field studies on the feeding ecology of free-ranging Cormorants.

In this paper, we present the design of a remote-controlled net trap for ground-nesting Cormorants which was deployed during a three-year breeding study.

METHODS

The study was conducted at the Chausey Islands (French Channel Islands, 48° 55' N, 01° 45' W) between April and June 1994, 1995 and 1996. Cormorants at this location typically breed in groups of up to 100 nests on different unhabited islets of the Chausey archipelago and fly off as soon as humans set foot ashore.

The trap itself consisted of two metal framed quadrats (1m x 1m) connected on one side by two door springs (150mm length, Fridavo, Fritz Dannert, Postfach 4046, 58256 Ennepetal, Germany) (see Fig. 1A). When the trap was set, both frames were closed together virtually in parallel and nearly touching each other. At this time the two frames were held together at the non-spring end by a thin braid cord (1mm thick). Prior to activation, the double frame system was placed, folded flat, on the ground with the spring coiled and the quadrats held against each other by the nylon cord. When the nylon was cut, the spring caused one edge of the upper quadrat (that furthest away from the spring) to move quickly up and away from the adjacent parallel edge of the lower quadrat until it had described a hemi-sphere and both quadrats lay adjacent and parallel in the same plane. The lower quadrat, which did not move during the operation, was built of stainless steel tubing (21mm cross section) so that the construction was stable even in strong winds. The upper quadrat was built of aluminium (15mm x 15mm) so as to be as light as possible to increase the closure speed. Due to substantial tension within the set system, this quadrat tended to distort, so the edges of the quadrat were additionally re-enforced. The upper quadrat was mounted with a $4m^2$ net (2m x 2m; mesh width 30mm; cord thickness 1mm) using a 1mm nylon line. The complete trap weighed *ca.* 6 kg.

The remote-controlled release mechanism was built using a radio-control system for model boats or airplanes (Graupner D4, SSM), a water tight box (20mm x 12mm x 80mm), a PVC piping (100mm length, 15mm cross-section), two small metal arms (80mm x 10mm x 2mm) and a scalpel blade (Fig. 1B). The system was adapted from a remote-controlled syringe used by Wilson and Wilson (1989) to capture nesting birds. The radio-control receiver and the rotating wheel used as a driver were positioned on the bottom of the housing using polyurethane foam. The first metal arm was screwed onto the rotating wheel and connected to a second metal arm carrying the scalpel

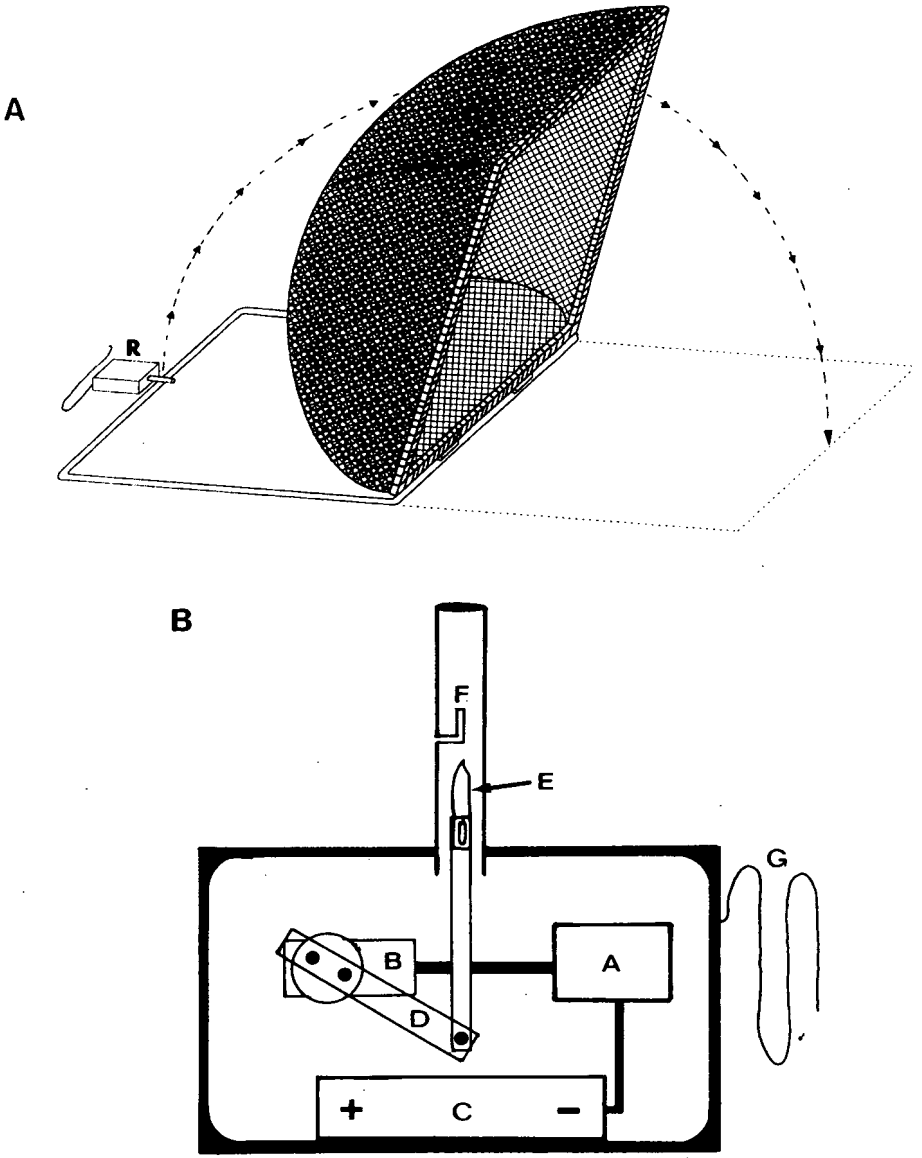
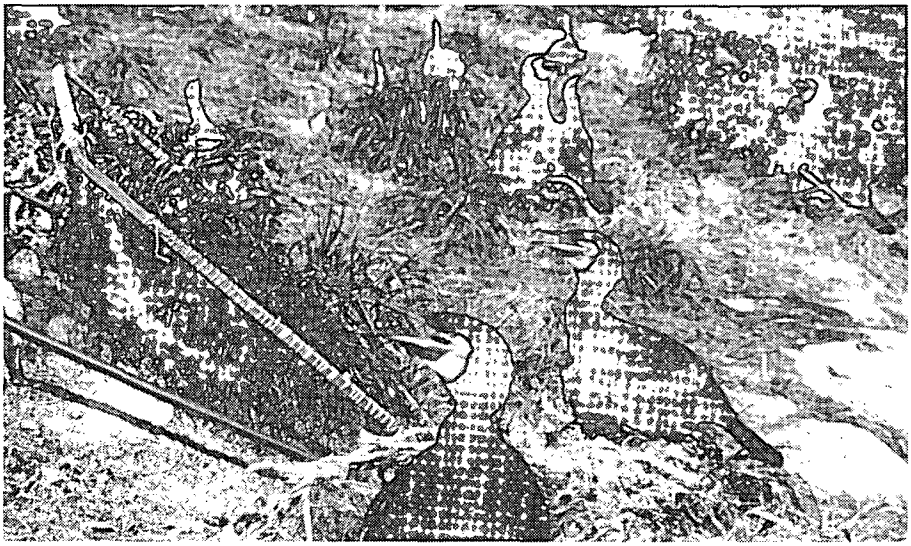


Figure 1: General assembly drawing of the Cormorant net trap (A) (R: release unit). Cross-section of the remote-controlled release unit of the net trap (B) (A: receiver, B: rotating unit, C: battery-pack, D: metal arm, E: scalpel blade, F: groove cut for the nylon string, G: Aerial.

Figure 2: Position of the remote-controlled net trap near a Cormorant nest.



blade. The rotating movement of the wheel pushed the blade along the PVC piping which protruded from the housing. The deployment of the transmitter thus caused the metal arm and the scalpel blade to move forwards or backwards within the PVC-piping. The nylon string used to connect the two quadrats of the set trap was placed in a groove cut into the piping. In the loaded position, the string passed through the tubing with the scalpel blade situated a few centimetres further down the tube. When the transmitter was activated, the blade was driven forwards by the radio-control receiver, which cut the string and released the trap.

In the field, trapping sessions were only conducted in the absence of rain and at air temperatures between *ca.* 10°C and 20°C. These precautions were taken because highly altricial Cormorant chicks cannot regulate their body temperature during the first ten days after hatching (Dunn 1976) and are thus sensitive to cold, moisture or high insolation when they are not brooded by their parents, i.e. during the deployment of the trap and before one of the adults comes back to the nest. The set trap was deployed as far as possible near nests which were built on a flat area (Fig. 2). The trap was opened by hand over the nest to ensure that, after deployment, the complete nest structure would be covered by the aluminium quadrat and the net, and that the aluminium frame would touch the ground on all sides around the nest. Furthermore, all nest material in which the net could get entangled (preventing the trap from opening correctly) was removed. Subsequently, the remote-controlled releasing unit was connected to the string linking the two frames of the trap. The nest was then observed continuously at a distance of at least 300 m (Leica APO-Televid 77; 20x - 60x) until one of the birds was back on the nest and sitting quietly. While an observer watched the bird, the breeding colony was approached as closely as possible by a worker in an inflatable motor boat before the trap was sprung (the trap could be sprung at a maximum unimpeded straight line distance of *ca.* 1400 m between transmitter and receiver). Following this, the nest site was reached as quickly as possible and the bird removed from the net to be equipped with devices.

RESULTS AND DISCUSSION

A total of 54 trapping sessions involving 38 birds was conducted during 3 consecutive breeding seasons. None of the birds was touched or injured by the frame when the trap was released (the trap closes in 0.8 to 1 s, as assessed from video). Birds usually leapt off the nest just after the frame

moved over their heads, which led them falling into a pouch of the net in which they got rapidly entangled. Three birds managed to escape after the trap was successfully released by crawling underneath the aluminium frame because it was not completely flush to the ground. In six cases, the release unit did not work properly which resulted in additional disturbance of the breeding colony. However, the consequently postponed trapping was, in all six cases, successful. In 2 cases, the trap was released sooner than planned, probably by gulls *Larus* spp juvenile Cormorants and Shags *P.aristotelis* which were often attracted by the release unit and "handled" it until the sharp edges of the PVC piping cut the cord. Here, the trapping was none-the-less successful although the birds remained in the net longer than usual. A total of 16 birds could be caught twice within the same week.

Unfortunately, the time needed by individual birds to come back to the nest where the trap was deployed was not systematically recorded. However, general field notes show that the average return time tended to be bi-modal: The majority of the birds were back on the nest in less than 15 minutes after the trap had been installed, but several individuals were wary of the trap and remained at some distance for at least 30 min before moving back to the nest. All trapped birds (which were equipped with different electronic devices) were still breeding successfully at the end of the experiments except for one nest. In this case, the chick's death occurred several days after the trapping session and thus cannot be directly attributed to this disturbance. The only directly detrimental impact of the trapping sessions was the occasional predation of eggs and chicks by Herring Gulls (*Larus argentatus*) and Great Black-backed Gulls (*Larus marinus*) at the study site. This could be minimized by covering nest contents with nest material or grass which was removed when the associated adult returned.

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SUMMARY

We present a portable remote-controlled net trap designed to capture ground-nesting Cormorants. The trap enabled us to catch 38 Cormorants in three field seasons, of which 16 were caught twice within one week with little or no detrimental effect.

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SEABIRD 20: 48-49

Some confusing errors of translation in Borodulina (1966)

J.C.A.Craik

Most seabird biologists will have come across three Russian authors whose names begin with the letter B : Bianki (1977), Belopol'skii (1961) and Borodulina (1966). Each of these books gives useful insights into parts of the vast expanse of the former USSR and the seabirds that are found there.

Many will encounter these three works through the excellent English language translations that were published by IPST (Israel Program for Scientific Translations). I recently had to consult both the Russian and English versions of Borodulina. Here I would like to record some errors of translation that are present in the English version, mostly involving confusion of the English names of some common seabird species. All page, line and figure numbers given below refer to the 1966 English version.

Borodulina's book is in two parts. The first part, "The Biology of the Laridae", describes six species of gulls and eight species of terns, each species having a section to itself. One of these species is the Black-headed Gull *Larus ridibundus*.

The second part of the book discusses comparative aspects of the ecology, morphology and economic importance of these gulls and terns. Although Black-headed Gull is always translated correctly in the first part of the book, in the second part it is sometimes, but not always, mistranslated. It is mistranslated as "common tern" on page 91 (line 19) and as "common gull" on pp 80 (line 8), 91 (7 and 17), 92 (35), 93 (legend to Fig. 47), 95 (in Fig. 48), 100 (26) and 122(6).

The Common Gull *Larus canus* is an uncommon species in the region and is not mentioned in the first part of the book. It is rarely mentioned in the second part and is always correctly translated ["common gull" on pp 97 (label in Fig. 51), 98 (label in Fig. 52), 99 (line 11), 100 (31,33 and 36) and 114 (bottom line)].

On p.74 the legend to Fig.31 has been mistranslated: the sequence of gull eggs in the upper row should be Herring, Common, Black-headed and Little, rather than Herring, Laughing, Common and Little. (Laughing Gull is occasionally used in the book as an alternative English name for Black-headed Gull, as is made clear on p.17).

The mistranslation of Black-headed Gull as "common gull" may have arisen because there are three Russian names for the Black-headed Gull: Ozernaya Chaika (literally "lake gull"), Rechnaya Chaika ("river gull") and Obiknovennaya Chaika ("common" or "usual gull"). Translating the last of these names literally into English carries the obvious risk of confusion with Common Gull (*Larus canus*). However, it is difficult to see why this should have happened in this case since, throughout the Russian version, Borodulina always uses the first of these three Russian names, which carries no such risk of ambiguity.

Since most people will read the Summary, a confusing misprint there is important: on p.117 (line 8), "nests" should be "nets".

ACKNOWLEDGEMENTS

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BOOK REVIEW

FORAGE FISHES IN MARINE ECOSYSTEMS: Proceedings of the International Symposium on the Role of Forage Fishes in Marine Ecosystems. Alaska Sea Grant College Program Report No. 9701. University of Alaska Fairbanks, 1997, pp 816 ISBN 1-56612-049-7. Price $40 in USA, $60 elsewhere, from Alaska Sea Grant College Program, Univ. of Alaska, P O Box 755040, Fairbanks, AK 99775-5040, USA.

"And well you might ask what a forage fish really is. 'Forage fish' is a concept that many people [mainly Americans, I guess] have come to understand because of the context it is used in, but for which we lack a concrete definition. The term embodies a peculiar combination of ambiguity and precision .....Sandeel is a quintessential forage fish." This comes from Alan Springer and Suzann Speckman's summary of a symposium held in November 1996 whose 56 papers are printed in this extremely well-produced book. The papers are of variable length, some are substantial reviews, others just extended summaries of talks presented. None of the contributions have been reviewed which is unfortunate but at least the production of the volume has been commendably swift.

Although many of the papers are very fish-orientated, virtually all offer some insight into seabird ecology. It is an extremely good and productive browse. Nobody with an interest will not gain by skimming this volume, the biology of sandeels, the swimming speeds of pelagic fish and macroplankton, the use of halibut stomachs to assess the fish available to seabirds, etc. Maybe 12 papers concentrate on birds. Many of these refer to Alaska but two are very specific to the northeast Atlantic.

R.W. Furness and M.L. Tasker contribute a paper 'Seabird consumption in sand lance [= sandeels] MSVPA Models for the North Sea, and the impact of Industrial fishing on seabird population dynamics'. The industrial fishery for the sand eel, *Ammodytes marinus,* is the largest single-species fishery in the North sea, with about 1 million tons harvested each year. Assessment of interactions between seabirds, sandeel stocks, and the industrial fishery in the North Sea has been a major recent concern of an International Council for the Exploration of the Sea working group. From estimates of breeding population and dietary data the quantities of sandeels consumed by seabirds were estimated by seasons and regions. Seabirds consumed an estimated 200,000 tons of sandeel, predominantly in summer, with consumption greatest in the northwestern North Sea. These data permit refinement of sandeel multispecies virtual population analyses and indicate that exploitation of sandeel by seabirds and the fishery are spatially segregated due to constraints imposed by the distribution of seabird breeding sites and by sandy substrates for fishing.

Consumption of sandeels by seabirds can be high in the vicinity of major seabird colonies, such as around Shetland and Orkney, but is low in central regions of the North Sea and averages overall only about 4% of the North Sea stock. Thus the potential for the fishery to affect seabirds is much greater than the converse. The extent to which seabirds may suffer reductions in food supply as a consequence of this fishery depends especially on whether recruitment varies in relation to prevailing levels of spawning stock biomass, but also on the age classes of fish selected by birds. Recent major changes in sandeel abundance at Shetland permit the authors to analyze the shape of functional responses of breeding seabirds to variations in food supply over the period 1974-1995. This case study indicates the critical importance of a minimum abundance of lipid-rich fish for breeding seabirds, but also the complexity of seabird-fish interactions, with different seabird species at the same colony responding in different ways to changes in food supply.

A paper 'Long- and short-term responses to seabirds in the Norwegian and Barents Seas to changes in stocks of prey fish' by T. Anker-Nilson, R.T. Barrett and J.V. Krasnov updates the fortunes of seabirds in northern Norway. The numbers of Puffins, Kittiwakes, and Guillemots have changed dramatically over the last 30-40 years. While some local populations of the Kittiwake west of the North Cape have increased or been fairly stable, those of the Puffin and Guillemots have decreased. For example, the Puffin population at Røst, Lofoten Islands, decreased from about 1.4 million pairs in 1979 to only 500,000-600,000 pairs during the last few years. At Røst, the decrease in the Puffin population and in part that of the Common Guillemot was due to long-term failures in chick production through starvation. For Puffins this was caused by the collapse in the Norwegian herring stock in the late 1960s.

East of the North Cape, the Kittiwake and Common Guillemot populations have increased since about 1960, probably as a result of an increased availability of capelin. Guillemot numbers continue to increase today but experienced a collapse of about 80% in their numbers in 1985-1987. This collapse

was the result of an extraordinary high adult mortality during the winter which was associated with the collapse of the Barents Sea capelin stock. The capelin stock is now low and Kittiwake numbers are showing signs of a decrease. Short-term responses on Røst and colonies in East Finnmark and the Kola Peninsula are characterised by close correlations between choice of chick food and/or breeding success and indices of the abundance of the main prey fish. This paper presents details of these and other seabird-fish interactions in these waters.

All serious seabird ecologists should read this volume.

M. P. Harris

THE SEABIRD GROUP 1998

The Seabird Group was founded in 1966 to circulate news of work in progress on seabirds and to promote research. It is run by an elected Executive Committee and maintains close links with the three major British national ornithological bodies – the British Ornithologist's Union, the British Trust for Ornithology, and the Royal Society for the Protection of Birds. Membership (£10 per annum, £9 if paid by banker's order, £5 for students) is open to all with an interest in seabirds; for details please contact the Membership Secretary (address below) – payment by banker's order helps the Group.

Current Executive Committee The present Committee comprises: Chair S. Wanless, Secretary J. Uttley, Treasurer J.C. Davies, Membership Secretary S. Russell, Editor of *Seabird* J.B. Reid, Newsletter Editor M. Tasker, also A. Douse, J.D. Okill, E.K. Dunn and S. Sutcliffe.

Newsletters and Meetings Three Newsletters are circulated to members each year. They contain all sorts of items including reports on seabird conservation issues and research projects, news from seabird groups in other countries, book reviews, details of meetings, etc. The Newsletter Editor (address below) welcomes contributions from members. The usual venue for the Group's annual meeting is the BTO Ringing and Migration Conference at Swanwick, except when the Group holds its own conference, in which case the meeting is combined with that. Our conferences draw seabird workers from many countries to join in a forum of topical interest. In keeping with our desire to promote work in the field, practical manuals and guidelines evolve from the workshop sessions which cater for specialist topics within the conference theme.

Seabird Group Grants Each year the Group has some money available to help fund research conducted by members. All grant applications should be submitted to the Secretary by the end of February, and will be considered by the Executive Committee by the end of March. Successful applicants are required to submit a typed report, not exceeding 500 words, by the end of October of the same year for inclusion in the Newsletter. A full typed report (in triplicate) must be submitted by the end of the year.

Seabird Colony Register The Seabird Group has always sought to organise and implement national schemes involving the active participation of its membership, now standing at 350 members. The Group membership played a major role in the national Operation Seafarer survey whose results were published in 'The Seabirds of Britain and Ireland' (1974). The Group completed the Seabird Colony Register fieldwork in 1988, in cooperation with the Nature Conservancy Council, and the results were published in the book: 'The Status of Seabirds in Britain and Ireland' in 1991. This register was begun in 1985 to gather together all existing data on breeding seabird numbers in the British Isles, to bring our knowledge of their status up to date by detailed field surveys and to establish a computerised database which can be easily updated in the future. Although this round of survey work has been completed, it is important to continue monitoring of seabird breeding numbers: anyone eager to conduct counts on a regular basis should contact Kate Thompson, JNCC, Seabirds and Cetaceans Branch, Dunnet House, 7 Thistle Place, Aberdeen AB10 1UZ, UK.

Seabird Journal In January 1998 the Group agreed to merge *Seabird* with *Sula*, the journal of the Dutch Seabird Group. The new journal, *Atlantic Seabirds*, will be published four times a year from 1999, and will maintain the high standards set by *Seabird* and *Sula*. *Atlantic Seabirds* will be edited by Jim Reid on behalf of the Seabird Group, and Kees Camphuysen on behalf of the Dutch Seabird Group. Offers of papers for the new journal should be addressed to either editor (see Guidelines for Contributors and addresses below). Members of the Seabird Group and the Dutch Seabird Group will receive *Atlantic Seabirds* free. Back issues of *Seabird 11 - 19* are available at £5 + 50p postage per copy. There are no cost concessions for multiple orders of *Seabird* and postal charges are additive.

Who to write to While the Seabird Group maintains an accommodation address (c/o RSPB, The Lodge, Sandy, Bedfordshire SG19 2DL, UK), the following can be contacted directly, as appropriate. Please help the Group by enclosing a stamped addressed envelope for reply.

Secretary (general enquiries about the Group, seabird conservation matters, grants, etc.): John Uttley, SNH, 2-4 Alexandra Buildings, The Esplanade, Lerwick, Shetland ZE1 0LL, UK.

Membership Secretary (membership renewals, applications and enquiries): Sheila Russell, Clober Farm, Craigton Road, Milngavie, Glasgow G62 7HW, UK.

Treasurer (subscriptions, donations, etc.): John Davies, 31 Easter Warriston, Edinburgh EH7 4QX, UK.

Editor of Seabird: Dr Jim Reid, JNCC, Dunnet House, 7 Thistle Place, Aberdeen AB10 1UZ, UK.

Newsletter Editor: Mark Tasker, JNCC, Dunnet House, 7 Thistle Place, Aberdeen AB10 1UZ, UK.

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GUIDELINES FOR CONTRIBUTORS TO ATLANTIC SEABIRDS

Atlantic Seabirds is the quarterly journal of the Seabird Group and the Dutch Seabird Group, and is the continuance of their respective former journals, Seabird and Sula.

Atlantic Seabirds will publish papers and short communications on any aspect of seabird biology. They will be peer-reviewed. The geographical focus of the journal is the Atlantic Ocean and adjacent seas at all latitudes, but contributions are also welcome from other parts of the world provided they are of general interest. *Atlantic Seabirds* is indexed in the Aquatic Sciences and Fisheries abstracts, Ecology Abstracts and Animal Behaviour Abstracts of Cambridge Scientific Abstracts databases and journals.

Copyright is retained by the Seabird Group and the Dutch Seabird Group and written permission must be sought from the editors before any figure, table or plate, or extensive part of the text is reproduced. Such permission will not be denied unreasonably but will be granted only after consultation with the relevant author(s).

The following are guidelines only, but they should be observed when submitting manuscripts for publication in *Atlantic Seabirds.* Authors should refer to *Seabird* for appropriate conventions and general presentation of contributions but detailed instructions for authors are available from the editors (addresses below).

Contributions, of which three copies should be submitted, should usually be written in English. Full length papers must be accompanied by summaries in English and one other European language. All papers will have Dutch summaries and subtitles, which will be provided by the editors for those not mastering that language. Text should be double-spaced on one side of the paper with large margins. Each Table and Figure must be on a separate page and have its correct number and the author's name written in pencil on the reverse. The approximate position of Tables and Figures within the text should be indicated in pencil in the margin. Spelling must conform with the preferred, i.e. first cited, spelling of the Shorter Oxford Dictionary for English, or spelling of the 12th edition of the Groot Woordenboek der Nederlandse Taal for Dutch.

On first mention, a species should be referred to by its vernacular name, followed by its systematic binomial in italics; authority and date need only be cited in taxonomic papers. Thereafter, only one name should be used, preferably the vernacular. Trinomials should be used only if subspecific nomenclature is relevant to the topic of discussion. Capitals should be used for the initial letters of all single words and hyphenated vernacular names of species (e.g. Great Black-backed Gull, White-bellied Storm Petrel) but not for group names (e.g. shearwaters, penguins). Foreign words, other than those that have been adopted into English, should be italicised. Underlining should be used for phonetic rendering of bird vocalizations.

Measurements must be given in SI units (International System of Units). However, if the original measurements were made in non-SI units, the actual values and units should be presented with SI equivalents indicated in parentheses.

Figures and diagrams should be prepared using black ink or good quality lettering on white board or paper. Software-generated figures must be of good contrast and quality; those produced on dot matrix printers are not acceptable. Scales should be labelled clearly and symbols must be legible and of an adequate size. Ideally, photographs should be prints of good contrast. Tables must have appropriate titles and all figure captions should be gathered together on a separate page. Authors are asked to consider the page-size and shape of *Atlantic Seabirds* (A5; identical to *Seabird*) when designing Figures and diagrams; originals should preferably be 1-1½ times final size. The submission of figures and diagrams on diskette in a format acceptable for MS Word 7.0 is strongly recommended.

In the text, references should be quoted in the format indicated by the following examples: Garthe 1980; Hagemeijer & Blair 1997; del Hoyo et al. 1995. References at the end of a paper or short communication should follow the following style:

Dijk A.J. van, Hustings F., Sierdsema H. & Meijer R. 1997. Kolonievogels en zeldzame broedvogels in Nederland in 1995. SOVON Monitoringrapport 1997/06, SOVON, Beek-Ubbergen, 63pp.

Evans P.G.H. & Nettleship D.N. 1985. Conservation of the Atlantic Alcidae. In: Nettleship D.N. & T.R. Birkhead (eds) The Atlantic Alcidae: 428-488. Academic Press, London.

Götmark F. 1990. A test of the information centre hypothesis in a colony of Sandwich Terns Sterna sandvicensis. Anim. Behav. 39: 487-495.

Hand J.L., Southern W.E. & Vermeer K. 1987. Ecology and behavior of Gulls. Stud. Avian Biol. No. 10, Cooper Orn. Soc., San Diego, 140pp.

Sibley C.G. & Ahlquist J.E. 1995. Phylogeny and classification of birds. Second edition. Yale University Press, New Haven.

Authors' names should be given below the title of the paper with addresses.

Authors should submit revisions of their contributions on disk in a common word processing format such as Word or Wordperfect. Poorly prepared manuscripts will be returned to the author.

Twenty-five offprints of each original contribution will be provided free to the author(s).

For further details and submission of papers contact the Editors:

Jim Reid, c/o Seabirds and Cetaceans, JNCC, Dunnet House, 7 Thistle Place, Aberdeen AB10 1UZ, Scotland. Email reid_j@jncc.gov.uk.

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