INVESTIGATIONS INTO THE CAUSES OF THE DECLINE OF THE BLACK-HEADED GULL (Larus ridibundus) COLONY AT RAVENGLASS, CUMBRIA

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By

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INVESTIGATIONS INTO THE CAUSES OF THE DECLINE OF THE BLACK-HEADED GULL (Larus ridibundus) COLONY AT RAVENGLASS, CUMBRIA.

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A thesis presented in candidature for the degree of Master of Science in the University of Durham, 1990

I certify that all material in this thesis which is not my own work has been identified and that no material is included for which a degree has previously been conferred upon me.

FOR M.A., R.A. AND A.R.A.

ACKNOWLEDGEMENTS

This research was carried out at the University of Durham and I thank Professor K. Bowler for the facilities provided in the Department of Zoology. The research was supported by grants from Cumbria County Council and the Department of the Environment.

I would like to thank the Cumbria Trust for Nature Conservation and the National Trust for permission to carry out research at the study colonies. I would like to thank all the people in Cumbria who helped and supported my research; Chris Johnson, Paul Baker, David Bailey, Howard Avery, Chris Rowley, Pat Lowe, Gareth Egarr and Gordon and Sally Steele. I am especially grateful to Dave and Ceri Simpson, without whose support, encouragement and friendship I would have followed the gulls and left Ravenglass in 1985.

My thanks are also due to my colleagues at Durham University, especially those who helped with gull-catching, model-making and putting up the electric fence; Digger Jackson, Chris Thomas, John Uttley, David Baines, Murray Grant, Stuart Gregory and John Richardson.

I would like to thank my parents and Hilary for their moral support and encouragement throughout this research. Special thanks to my mother for her invaluable help with typing the manuscript and tables. Finally, I would like to thank Andrea for just being there.

ABSTRACT

In the late 1970's, declines were noticed in the breeding populations of Black-headed Gulls and various tern species on the Ravenglass Local Nature Reserve, Cumbria. By 1983, terns were extinct as breeding species and Black-headed Gull numbers had fallen from 10,000 breeding pairs in 1976 to only 2,290.

The annual cycle of Black-headed Gulls was examined and a number of hypotheses constructed as to possible causes of the declines. These hypotheses were tested using historical information and field data collected at Ravenglass and a number of other Cumbrian Black-headed Gull colonies.

Historical data from Ravenglass suggest that Black-headed Gull breeding success was poor in a number of years. The reasons for this poor breeding success are not known but disturbance, predation and food shortage caused by agricultural change, vegetation change or weather factors appear to have been important. In 1984 the 1,514 pairs of gulls that settled at Ravenglass produced no young, probably as a result of predation by foxes on eggs and small chicks. No gulls settled to breed at Ravenglass in 1985 and none have done so since.

Studies at other Cumbrian colonies since 1985 revealed different causes of reduced breeding success at different sites in different years. This may have been important in reducing the number of potential recruits to Ravenglass from other colonies. Other ground-nesting birds breeding at Ravenglass (except Shelduck which breed in rabbit burrows) suffered fox predation in 1984-87.

Gulls from both inland and coastal gulleries fed predominantly inland. Levels of heavy metal and radionuclide contaminants in gulls are below those recorded to be harmful.

It is concluded that the decline was probably caused by a combination of a number of factors (see above). A number of changes in the colonial behaviour of Black-headed Gulls at Ravenglass were noted in the later stages of the decline suggesting ways in which the gulls responded to the reduction in colony size.

SUMMARY

1. Ravenglass Local Nature Reserve has long been famous for its breeding bird populations. These included Common, Arctic, Little and Sandwich Terns but most famous was the colony of Black-headed Gulls on the site. At one time this gullery was the largest in Europe (10,000 pairs). In recent years, however, declines to extinction have occurred in the populations of terns and at the start of this study (1983) the gullery numbered only 2,290 pairs.

2. A consideration of the gulls' annual cycle at Ravenglass suggested areas in which the cause of the decline could have acted. From these, a number of more specific hypotheses were proposed. These were tested by consideration of historical records and aspects of the breeding cycle of Black-headed Gulls at Ravenglass and other colonies in Cumbria.

3. The decline in the gull population at Ravenglass has not been paralleled on a National scale.

4. The decline in the Ravenglass gullery cannot be accounted for merely in terms of gulls moving elsewhere to breed in Cumbria.

5. The populations of Terns which bred at Ravenglass appear to have moved to other nearby sites.

6. A model is proposed suggesting that the overall observed decline can be explained if recruitment equalled emigration and annual adult mortality was 80.5% (calculated from ringing recoveries).

7. Predation and disturbance by predators and humans are implicated in reducing breeding success of Black-headed Gulls at Ravenglass in recent years.

8. Changes in agricultural practices around the Ravenglass estuary are unlikely to have reduced the availability of foodstuffs to Black-headed Gulls breeding at Ravenglass. The influence of weather factors on food availability is not known but may have been important in reducing breeding success of Black-headed Gulls at Ravenglass in certain years.

9. Many aspects of the breeding cycle at Ravenglass in 1984 differed from those described previously. The date of laying of the first egg was among the latest recorded and nesting overall was significantly less synchronous than recorded in the early 1960's. There was no significant difference in nest-spacing or nearest neighbour distance between 1984 and 1962/63. The recorded clutch size was significantly smaller than previously recorded. Survival of eggs to hatching was only 43.7% (Mayfield method). The mean survival time of chicks was 9.25 ($\pm$ 2.01 S.E.) days and no chicks fledged. Fox predation and disturbance appeared to be the main causes of this breeding failure.

10. The size and breeding success of Cumbrian Black-headed Gull colonies varied from year to year between 1985 and 1987. Birds did not settle to breed at Ravenglass in any of the three years but gulls marked at Ravenglass were recorded breeding at other sites. This suggests that some redistribution of birds has occurred since the extinction of the Ravenglass gullery. Data on clutch size, egg survival, egg volume and breeding success of Black-headed Gulls were recorded at a number of Cumbrian colonies and comparisons made. Breeding success varied amongst colonies in a particular year as did the factors influencing it, causes of breeding failure varied from flooding (Rockcliffe), predation by neighbouring gulls (Wastwater), to botulism (Foulney). Numbers of fledged young per pair have not been consistently sufficient to replace normal adult mortality at any one colony in all three years.

11. Ringed Plover and Oystercatcher breeding success was recorded at Ravenglass from 1985 to 1987. Oystercatcher nests were predated heavily by foxes in all three years with no eggs surviving to hatching in any year. Ringed Plover suffered a similar fate in 1985 and 1986 but produced fledged young in 1987. Shelduck, however, produced young in all three seasons. This suggests that hole-nesting species are more protected from predation than ground-nesters. Also, as Shelduck feed in the estuary the possibility of pollution effects from radionuclide contamination of estuarine food-items seems unlikely.

12. Black-headed Gulls breeding at Cumbrian colonies feed predominantly on food from inland sources despite having easy access to large estuarine areas. This suggests that even if estuarine invertebrate populations have declined or become contaminated by radionuclide pollution then gulls are unlikely to have been affected via their foodstuffs.

13. Densities of invertebrates in the Ravenglass estuary compare favourably with those recorded elsewhere. This suggests that there is sufficient food for Black-headed Gulls and that gulls have not switched to inland feeding sites as a response to reductions in estuarine prey populations.

14. Radiation doses acquired by Black-headed Gulls and other species breeding at Ravenglass are up to 10 x background, mainly as a result of contamination of sediments by radionuclides derived from the Sellafield Nuclear Reprocessing Plant. These levels, however, are still below those at which detrimental effects on survival or breeding success would be expected.

15. The implications of changes in colonial behaviour by Black-headed Gulls from the Ravenglass gull decline are discussed.

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INTRODUCTION

Black-headed Gulls (Larus ridibundus) are common breeding birds throughout much of Europe (Cramp & Simmons 1983). The species has greatly extended its breeding range this century e.g. Black-headed Gulls first bred in Iceland in 1911 (Gudmundsson 1951) on the North Sea coast of West Germany in 1931 and Italy and Spain in 1960. As well as these new breeding areas, populations in other European countries have increased rapidly e.g. in Ireland, France, Belgium, the Netherlands, parts of W. Germany, Sweden, Finland, Austria, Switzerland and the Baltic States of the USSR. These range and population expansions were considered to be due to a number of factors (Cramp and Simmons 1983) including climatic amelioration (allowing range extensions in the north), reduced persecution and increased food availability (including scavenging in parks and other urban areas, feeding by the public and greater use of agricultural land).

In the British Isles during the 19th century, Black-headed Gull numbers declined to such an extent that it was feared the species would disappear as a British breeding bird (Gurney 1919). After 1884 however, the population recovered and the subsequent increase has continued this century. Surveys of Black-headed Gull colonies in England and Wales were carried out in 1938, 1958 and 1973. In 1938 there were 41,000 pairs breeding in England and Wales (Hollom 1940, Marchant 1952). In 1958 an increase in numbers was noted with an estimated 46,000 - 51,450 pairs breeding that year (Gribble 1962) an annual average increase of 1.1%. In 1973 an estimated 100,000 - 110,000 pairs of Black-headed Gulls bred in England and Wales (Gribble 1976) an annual average increase of 5.2% since 1958.

For individual colonies of Black-headed Gulls, however, the situation is different. Between 1938 and 1958, despite the increase in the British breeding population and the establishment of many new colonies, some 104 (59%) of the colonies recorded in 1938 were abandoned. The majority of these sites held fewer than 1,000 breeding pairs of Black-headed Gulls and were deserted due to changes in water level (Gribble 1962). Five colony sites of between 1,000 and 10,000 breeding pairs were deserted in this period, these sites, together with reasons for their declines are shown in table 1.1. Other large gullery sites remained constant or increased through all these surveys.

TABLE 1.1

BLACK-HEADED GULL COLONIES OF BETWEEN 1,000 AND 10,000 PAIRS IN 1938 WHICH WERE DESERTED BY 1958 (from Gribble 1976).

SITE	REASON FOR DESERTION
Newton Reigny Bog, Cumbria	Drainage
Walney Island, Lancashire	Egg-collecting & inter-specific competition.
Scawby Gull Ponds, Lincolnshire	Egg-collecting.
Scoulton Mere, Norfolk	Inter-specific competition.
Poole Harbour, Dorset	Military Intervention.

The Black-headed Gull colony at Ravenglass Local Nature Reserve (LNR) near Whitehaven in Cumbria for example was the largest recorded in both the 1938 and 1958 censuses. (It was, however, overtaken by the Needs Oar Point gullery in Hampshire in 1973). Ravenglass LNR has long been famous for its colonies of breeding birds, most notably Black-headed Gulls and was at one time the largest in Europe (Gribble 1976). The gullery has been studied for at least a century. Macpherson and Duckworth (1886) describe a visit to the "teeming gullery" on Drigg Point. Since then, estimates of colony size have been made in some years (appendix 1) but it was not until 1969 that accurate counts were made on a yearly basis. These counts (presented as a log plot in figure 1.1) show that although numbers fluctuated in the early 1970's an unprecedented decline took placed recently from 10,000 pairs in 1976 to 0 in 1985. Similar declines occurred in the populations of terns breeding on the reserve. It can be seen from figure 1.1 that the rates of decline between 1975 and 1978 and 1980 to 1984 were similar. However, the rate between 1978 and 1980 was noticeably greater suggesting the time period of the decline.

Concern about these declines was expressed in the local and national press, mainly because of the possible link with radionuclide pollution from the nearby Sellafield Nuclear Reprocessing Plant. Research was commissioned by Cumbria County Council (CCC) and Department of the Environment (DOE) to investigate the decline. This thesis reports on the results of this research, the ecological factors influencing the gulls during the decline and attempts to put their behaviour into a biological context. For any animal population in a prescribed area, the numbers will change if births and immigration do not balance deaths and emigration. The annual cycle of Black-headed Gulls breeding at Ravenglass (figure 1.2) can be divided into two major parts; the breeding and non-breeding seasons. During the breeding season, from mid-March to early-August, Black-headed Gulls are present on the Ravenglass estuary in large numbers. During the non-breeding season gulls disperse and the number around the estuary decreases. Hence immigration and emigration for this species can refer to adults as well as young birds. Svardson, 1958 suggested that adult Black-headed Gulls showed site fidelity and that young birds recruited to their natal colony to breed. This was also suggested for Herring Gulls (<u>Larus argentatus</u>), Tinbergen 1961, Vermeer 1963; Silver Gulls (<u>Larus novohollandeae</u>), Murray and Carrick 1964; Glaucous-winged Gull (<u>Larus glaucescens</u>), Vermeer 1963 and it was assumed that gulls in general showed natal philopatry and site fidelity. More recently, however, a number of workers have shown considerable evidence of site infidelity and of young birds recruiting to colonies other than their natal one (for Herring

FIGURE 1.1

COUNTS OF BREEDING PAIRS OF BLACK-HEADED GULLS ON THE RAVENGLASS L.N.R. 1969-1985.

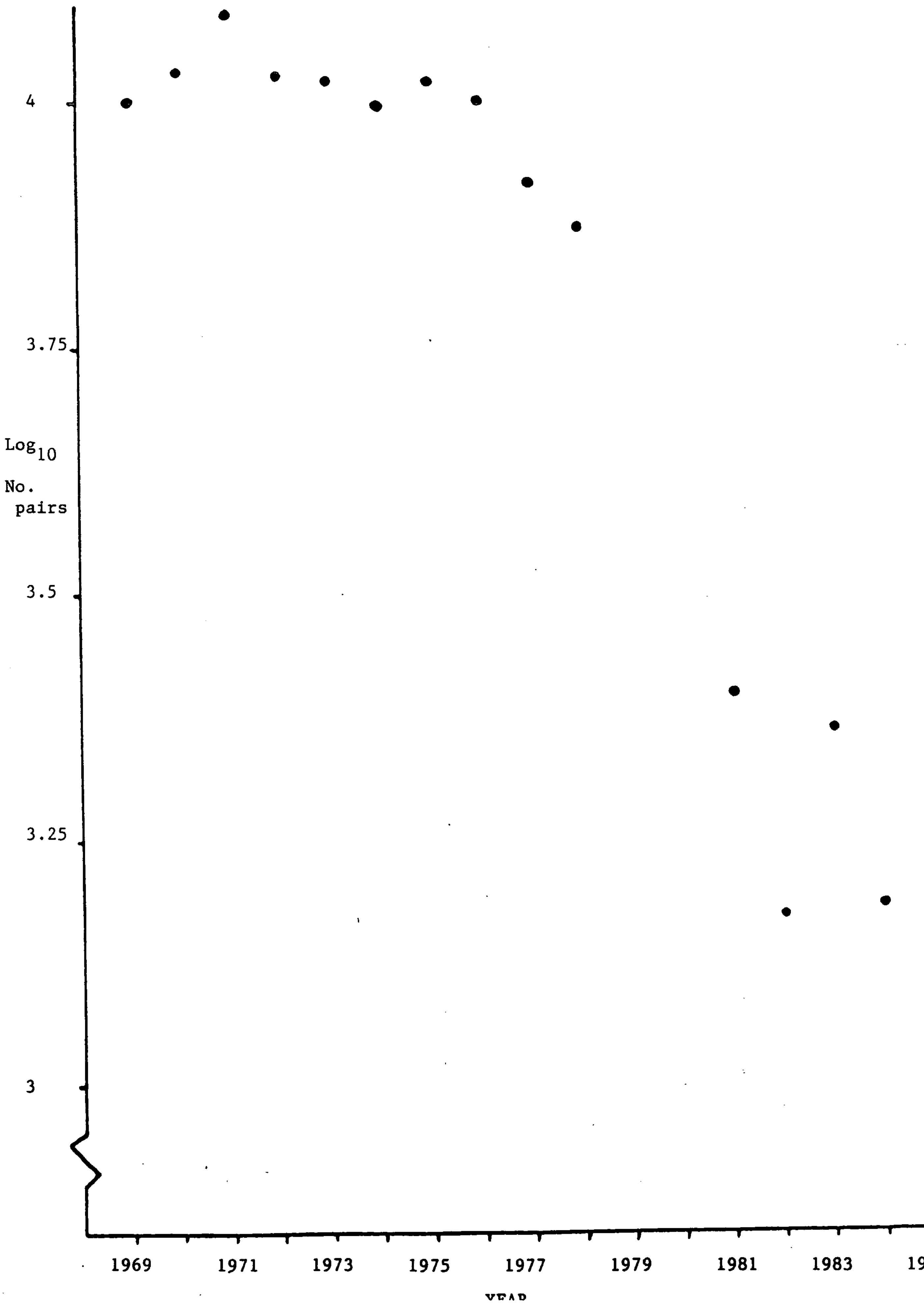
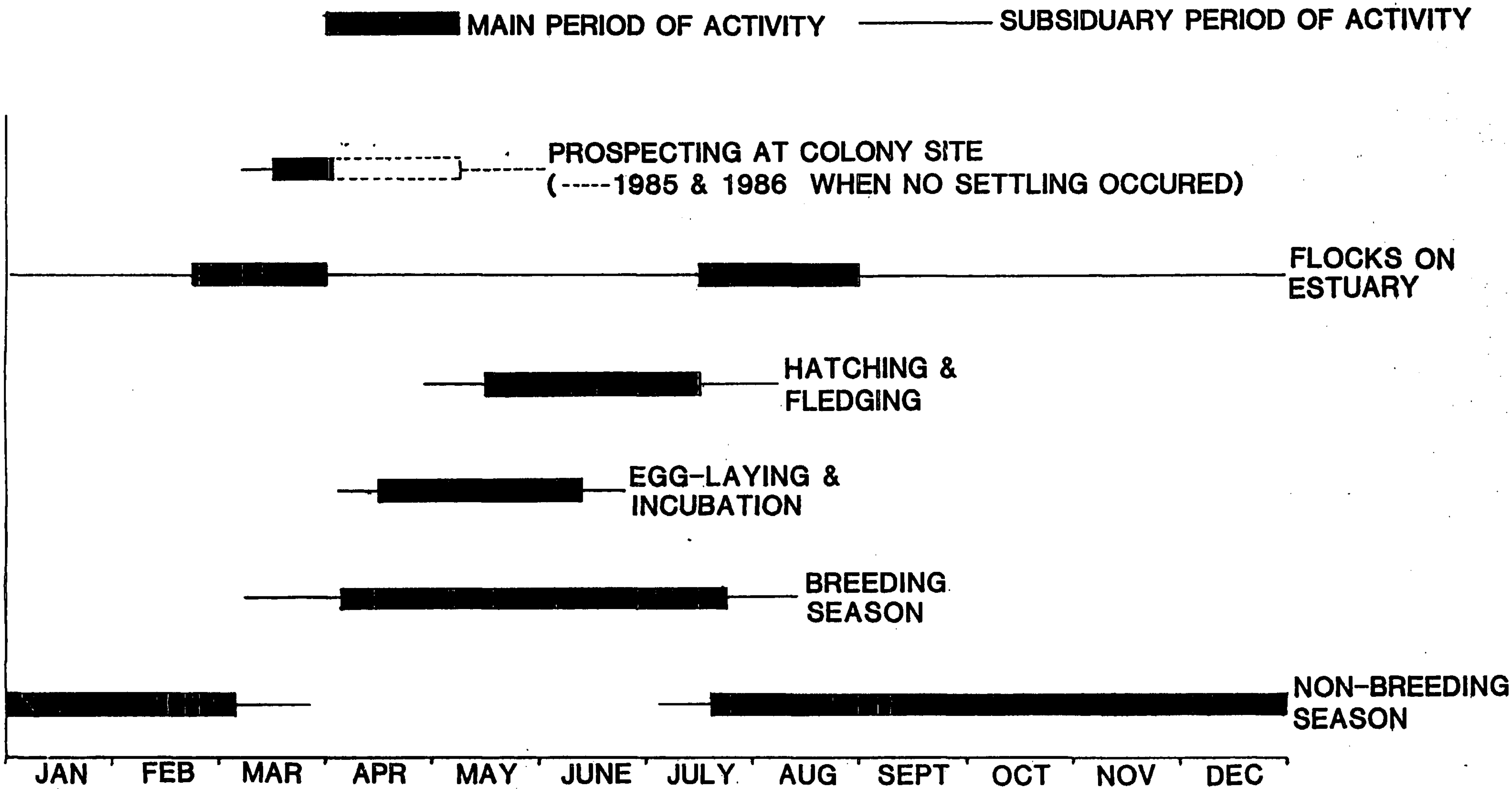


FIGURE 1.2

ANNUAL CYCLE OF BLACK-HEADED GULLS AT RAVENGLASS



Gulls, Chabrzyk and Coulson 1976, Duncan and Monaghan 1977; for Kittiwakes (Rissa tridactyla) Coulson and Wooller 1976, Wooller and Coulson 1977, Coulson and Porter 1985). Coulson (pers. comm.) also has evidence of Black-headed Gulls breeding for the first-time recruiting to colonies other than where they were fledged. It must be assumed, therefore, that Black-headed Gulls show some degree of site infidelity and young reared at Ravenglass do not all recruit there.

For Black-headed Gulls at Ravenglass, whatever the cause or causes of the decline they must have led to one or more of four main possible outcomes:-

i) A number of poor breeding seasons at Ravenglass or other colonies resulting in the number of young birds available to recruit to Ravenglass being insufficient to balance adult mortality.

ii) Increased mortality of Ravenglass breeding adults away from the colony so reducing the numbers returning to breed in subsequent years. (If the assumption that a proportion of young Black-headed Gulls recruit to their natal colony is true then increased mortality away from the colony site of young produced at Ravenglass would also reduce colony size).

iii) Increased mortality of adults at Ravenglass itself, also reducing the population available for breeding in later years.

iv) Adults and juveniles failing to settle at the Ravenglass colony site after returning in Spring so reducing the breeding population at Ravenglass.

From this broad framework, more specific hypotheses can be proposed for the decline:-

a) Poor breeding success may have occurred at Ravenglass due to predation by foxes (Vulpes vulpes), Mink (Mustella vison) or by egg-collecting and disturbance by humans. Predation by foxes on the Ravenglass reserve was found to be very severe by Kruuk (1964) and Patterson (1965). Indeed, Patterson considered that "replacement of adult losses (by new recruits) was well below that required to maintain numbers" mainly due to poor chick production caused by heavy fox predation. In recent years the incidence of Mink on the estuary has increased (N. Porter pers. comm.) possibly as the result of a release from a mink farm in

Eskdale in the early 1970's (H. Falkus pers. comm.). Such an increase might be expected to increase predation on the eggs and chicks. Disturbance or egg-collecting by humans would be expected to have a similar effect on breeding success.

b) Adverse weather conditions during the breeding period could have resulted in poor breeding success (in terms of chicks reared to fledging) by gulls at Ravenglass. In the late 1970's there were a number of dry springs which may have reduced the food supply of gulls so reducing clutch size, hatching success or fledging success, hence reducing overall production of fledged chicks. In the early 1980's the late-spring/early summer periods were cold and wet so it is possible that breeding failures occurred in these years as a result of egg-chilling or exposure amongst chicks. The abnormality of these weather conditions must first be identified.

c) Gulls may have become contaminated by radionuclides from the nearby Sellafield Nuclear Reprocessing Plant. Such contamination, possibly through food-chain pathways, could cause mortality amongst adults and/or chicks, sub-lethal doses could impair breeding success.

d) The area of the Ravenglass gullery may have become less attractive to gulls. Food resources may have declined due to habitat change, local changes in agricultural policy, contamination by radionuclides (resulting in death) or, (in the case of estuarine food sources), silting up of the estuary. A large reduction in the quantity of available food might have prevented adults attaining breeding condition or supplying food for large numbers of chicks. Habitat changes in the immediate vicinity of the colony may have increased accessibility to predators or humans, so reducing breeding success.

e. Gulls from Ravenglass may have been involved in mortality or pollution incidents away from the Ravenglass estuary. This could either reduce the number of gulls returning to breed the following year or reduce the breeding success of gulls due to sub-lethal pollution effects.

f. Adult gulls were killed by predators at the colony site. This would affect colony size directly as well as lowering breeding success so reducing both the number of gulls breeding at the site as well as the number of new recruits.

g. There has been some reduction in site-faithfulness and/or immigration rates of adults or new recruits. If the degree of fidelity or immigration of adults or first time breeders is reduced e.g. as a result of poor breeding success in a number of years deterring birds from settling then the population breeding at the site would drop.

Initially, a desk study was carried out using existing information to investigate and evaluate these hypotheses and to attempt to narrow down the timing of the agents of the decline in the gulls annual cycle. Field-studies were then carried-out, based on the results of the desk study to further investigate the possible causes of the decline and how these affected gull numbers.

STUDY AREAS

Ravenglass LNR was set up in 1954 and was Britain's first local nature reserve on a site without previous official status. The reserve, consisting of a coastal sand-dune ecosystem with associated habitats is situated at the tip of a penninsula on the north side of the estuary formed by the rivers Irt, Mite and Esk (figure 2.1). The origin of this estuary complex is not fully understood. What little evidence there is suggests that the River Irt assumed its current course in fairly recent times (Steers 1964). Certain features of the dunes suggest episodic southerly expansions of the spit known as Drigg Point with a series of cuspate spits visible as ridges in the dunes and also reflected to a certain extent in the vegetation (Dargie 1976). This has important consequences for the establishment and survival of the breeding colonies of gulls and terns as it is possible that the original breeding site was on an estuarine island or sand-bank and that the actual area surrounding the gullery and terneries has changed considerably since they were established. The gradual extension of Drigg Point as a series of sand or pebble bars may help to explain the occurrence of a Black-headed Gull colony in such a seemingly unusual site. This gull normally nests in colonies on freshwater and salt-marshes, hill lochs, moorland, shingle banks, coastal lagoons, sewage farms and gravel pits (Cramp et.al. 1974, Burger 1977).

The vegetation of the reserve has been described in detail by Dargie (1971,1976) and is summarised in figure 2.2. Since Dargie's last survey in 1976, much of the open sand area has been colonised by Ammophila arenaria (especially in the south and east of the reserve) and the vegetation as a whole has tended to stabilise. Most of the unstable yellow dune turf has become stable and there appear to be fewer open and wet dune slack areas than previously. The area to the north of the reserve, as far as Drigg Shore Road (5km.), has been declared a site of special scientific interest (S.S.S.I.) by the Nature Conservancy Council, mainly because of the plant communities it contains. There are large areas of dune heath (characterised by Erica cinerea and Calluna vulgaris) which have spread southwards and overtaken some of the grey dune turf found by Dargie at the northern extreme of the reserve. To summarise the changes since Dargie's survey: the vegetation of the dune system as a whole appears to have become more stable and, with less apparent sand-blow occurring, the vegetated part of the reserve is spreading south-east.

FIGURE 2.1 MAP OF THE RAVENGLASS ESTUARY

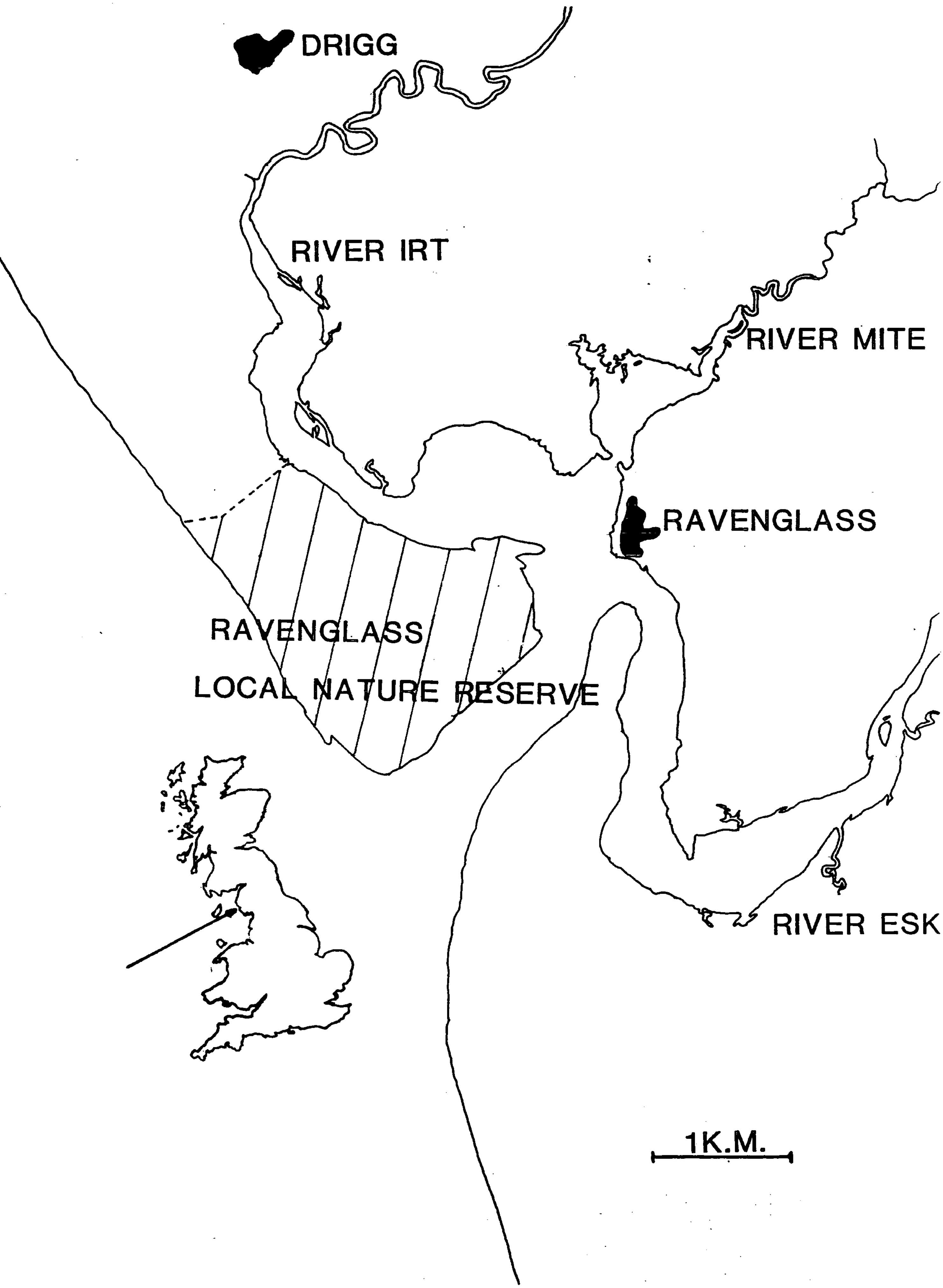


FIGURE 2.2 MAP OF RAVENGLASS LNR SHOWING

MAJOR VEGETATION TYPES

(FROM DARGIE 1976)

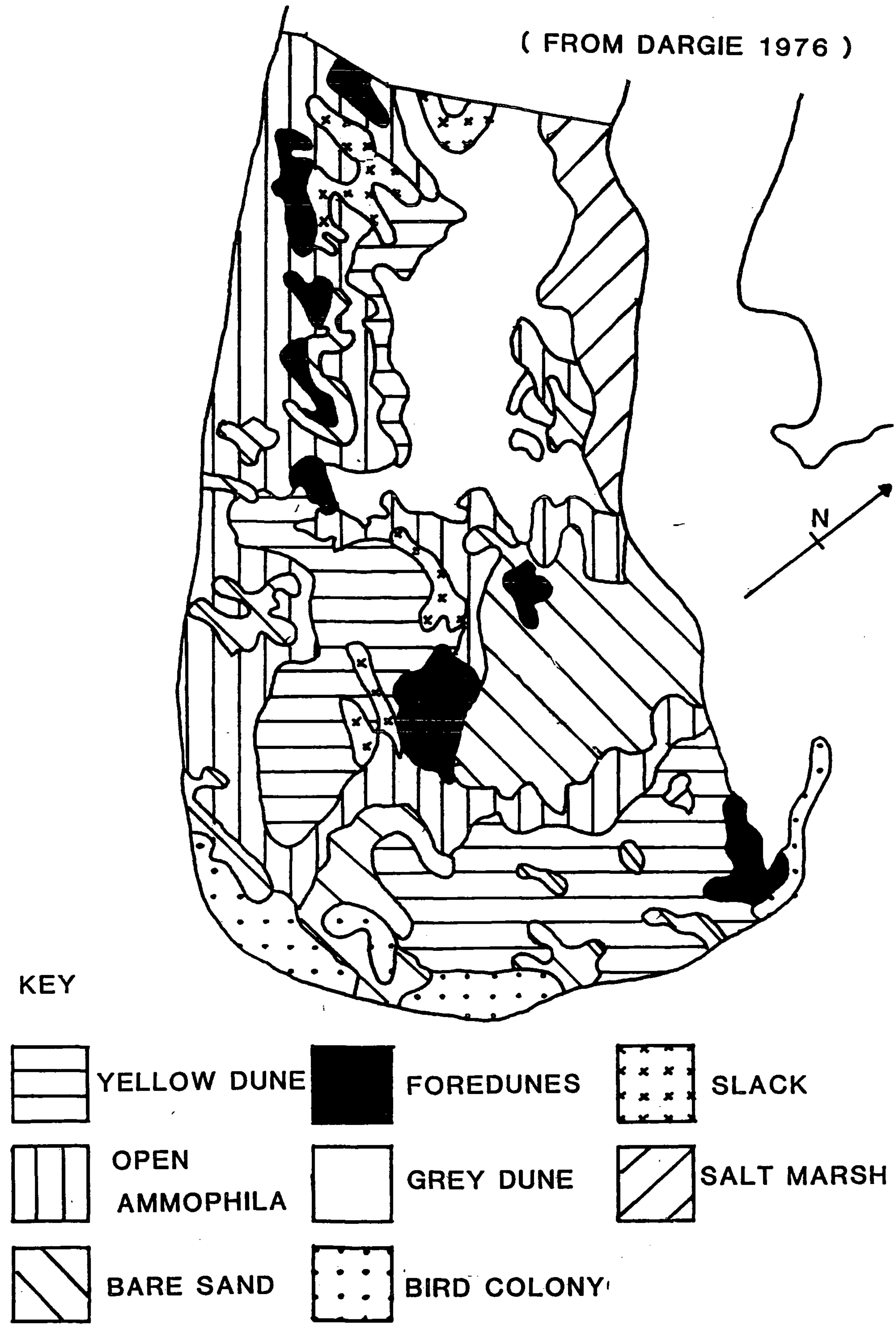
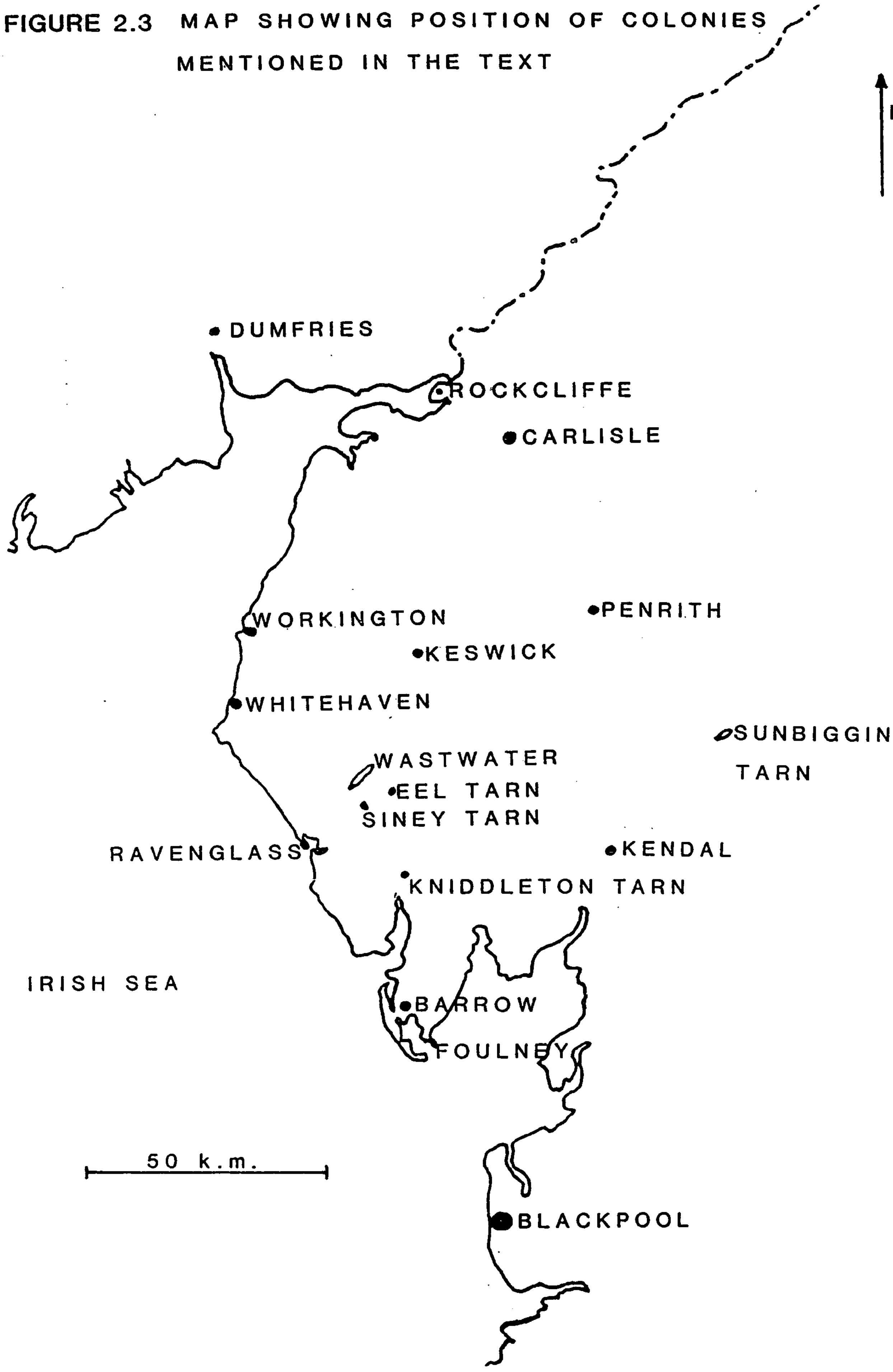


FIGURE 2.3 MAP SHOWING POSITION OF COLONIES MENTIONED IN THE TEXT



In the 1960's the reserve was used extensively for research on bird behaviour, mostly focussed on Black-headed Gulls (Moynihan 1955, Patterson 1965, Tinbergen et.al. 1962a, 1962b, 1962c, 1967, Beer 1961, 1962, 1963a, 1963b, 1966) although other studies were undertaken of predation on ground-nesting birds (Kruuk 1964) and of Skylarks (Alauda arvensis) (Delius 1965). Since then, little work has been carried out on the reserve except by Burger (1976, 1977) on gulls and vegetation and Banks and Beebee (1986a, 1986b) on Natterjack Toads (Bufo calamita). The large amount of data collected by the Oxford group concerning the behaviour and breeding-cycle of Black-headed Gulls at Ravenglass was useful as it suggested a number of areas in which the agents of the gull and tern declines could have acted. The lack of data collection since that time, however, means that little hard information is available concerning processes during the actual period of the decline.

Cumbria County Council have largely followed a "hands off" management policy as far as the reserve is concerned. There has been some control of Rosebay Willowherb (Epilobium angustifolium) and grazing animals have been excluded from certain of the more sensitive plant communities; however, little predator control or habitat management for birds has been carried out. The population of Natterjack Toads on the reserve and associated S.S.S.I. areas is of national importance (Beebee 1985) and some ponds and shallow "scrapes" have been dug to accommodate more toads. Apart from these few items the reserve has been left largely to its own devices.

In addition to the Ravenglass L.N.R., a number of other Cumbrian Black-headed Gull colonies were studied for comparison. These sites are indicated in figure 2.3. Four were chosen for intensive study, for the following reasons:-

ROCKCLIFFE MARSH and FOULNEY ISLAND - two large coastal gulleries comparable to Ravenglass in terms of food and feeding areas available to the gulls.

WASTWATER and SINEY TARN - two small inland colonies, chosen for comparison with the coastal sites and because their recent history suggested links with the Ravenglass gullery.

These other sites are described briefly below:-

Rockcliffe Marsh is a Cumbria Trust for Nature Conservation (C.T.N.C.) reserve situated on the Solway coast to the north of Carlisle. The reserve is a large area of heavily grazed saltmarsh crossed by many tidal creeks, the sides of which are not accessible to the cattle grazing the marsh.

Foulney Island is a C.T.N.C. reserve, situated to the south of Barrow-in-Furness. The bird colonies are situated at the end of a hook-shaped shingle spit. The major plant cover is provided by Sea kale (Crambe maritima) which has spread in recent years (C. Johnston pers.comm.) and has produced quite dense vegetation in some parts of the colony. Like Rockcliffe Marsh the site is wardened every summer.

Wastwater Black-headed Gull colony is situated on a small, rocky island at the western end of the lake. Siney Tarn is on moorland above Dalegarth Station in Eskdale. The tarn contains islands of floating vegetation which are used as nest sites by the gulls. Neither of these colonies is wardened but their positions restrict access to a minimum.

HISTORICAL DATA

As suggested in Chapter 1 some of the hypotheses proposed for the decline of the Ravenglass gullery and terneries should be site specific whereas others would result in declines at other sites, especially those nearby in Cumbria. There is no recent evidence that the Black-headed Gull is declining as a breeding species in Britain as a whole. Thus the decline at Ravenglass has not been paralleled on a national scale; however, if local or regional factors have been involved then the decline is likely to have been shown by other nearby colonies subject to similar external factors.

To investigate this the population levels of gulls, terns and other ground nesting shorebirds at Ravenglass were compared with those at other Cumbrian colonies. Information was obtained from the literature, unpublished reports and interviews with local farmers and naturalists for the sites indicated in figure 2.3. In addition to Ravenglass, the four colony sites described previously were studied intensively. Data were also obtained for some other inland colonies although these were often incomplete. Where possible, data for bird species other than Black-headed Gulls were collected if appropriate to species breeding at Ravenglass. Some information on breeding success was also obtained. This is presented below, but discussed more fully later.

Information concerning the larger colonies was fairly easy to obtain, either from published papers or nature reserve wardens' records. For the smaller sites, however, data were scarce and records built up through interviews with farmers and local naturalists. For completeness data are given (where available) for all years to 1987; for a full discussion of the breeding seasons from 1984 to 1987 see Chapters 7 and 8.

3.1 COUNTING METHODS

In order to make direct comparisons between colony size at different sites the methods of counting numbers of breeding pairs must give reliable results based on the same assumptions. Information from past records suggests that although counting methods were usually consistent from year to year at one particular site they did differ between sites. Two main counting methods were used:-

i) DIRECT NEST COUNTS. Where possible, marking nests directly (usually with a split cane marker) was the preferred method. This gives an accurate figure for the number of nests active at the time of the count. If continued through the season this method gives good data on the total number of nesting attempts. If an individual number is attached to the nest marker then repeated visits to the colony site allows data on re-laying, predation and hatching success to be recorded. This method was used at Ravenglass, Rockcliffe and Wastwater so the data from these sites is directly comparable. At other sites, however, topography, disturbance and time constraints made direct counting impossible so other methods were used.

ii) ESTIMATES FROM COUNTS OF ADULTS. Where it was not possible to mark nests directly colony size was estimated by making counts of the number of adults visible at a colony site and of those apparently sitting on eggs. Counts were made at each visit to the colony site (bi-weekly at Siney Tarn, weekly at Foulney Island). Obviously this method has limitations. However, Tinbergen (in Patterson 1965) suggested that during incubation an average of 1.57 adults per nest were visible at any one time. Dividing the counts of adults by this figure gives an estimate of the number of nests in the colony. If this method is used at the same colony in subsequent years then any trends in colony size will be visible.

Because of the inaccuracies inherent in these methods (especially the latter), direct comparisons are avoided unless the same method was used in both instances. The following discussion concentrates on comparing population trends rather than absolute numbers.

3.2 SITE ACCOUNTS

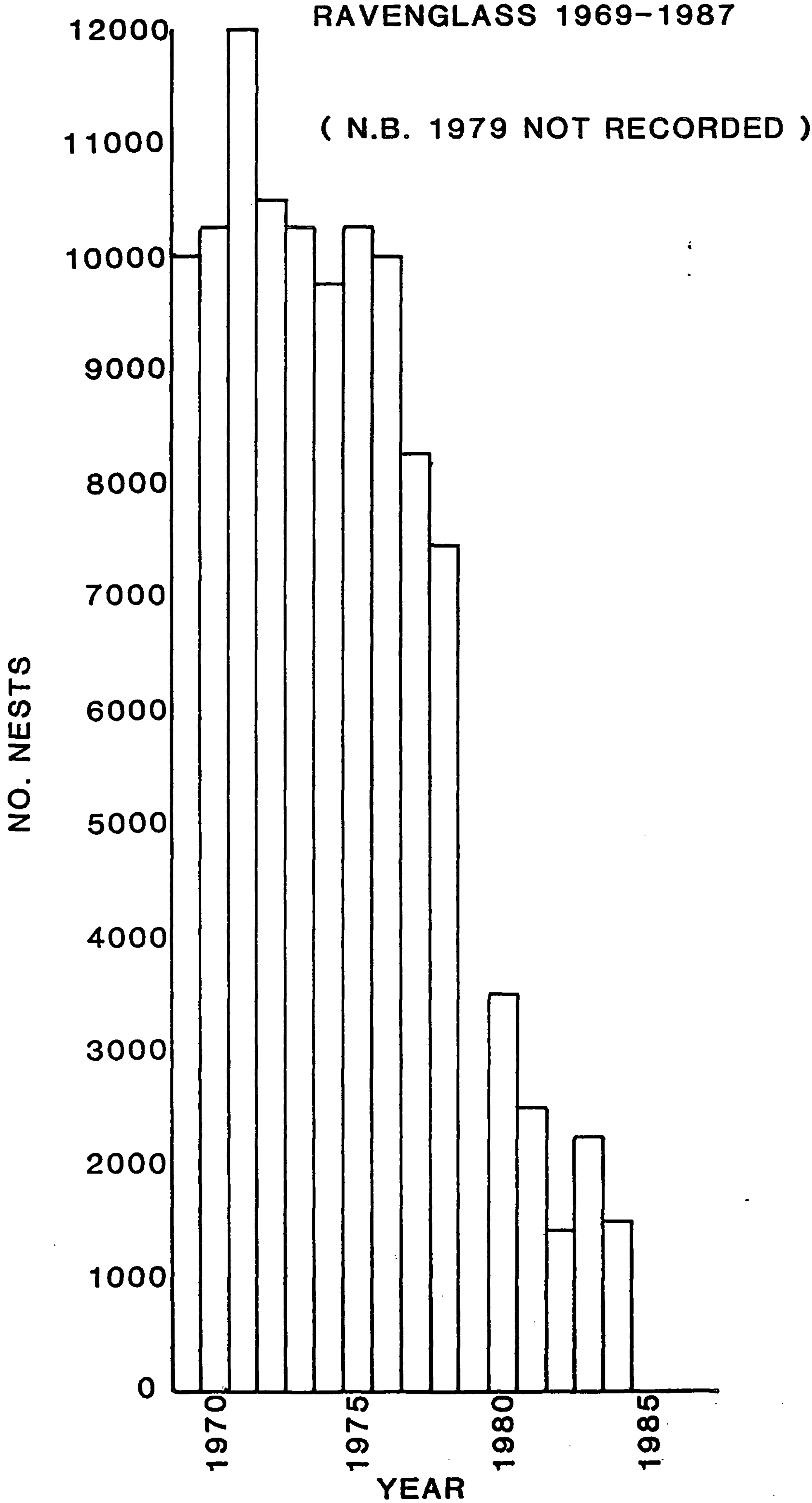
3.2.1 RAVENGLASS

Black-headed Gull

Before 1969 the size of the Black-headed Gull colony at Ravenglass was estimated from counts of adults (appendix 1). There was, however,

FIGURE 3.1

CENSUS COUNTS OF BLACK-HEADED GULL NESTS AT RAVENGLASS 1969-1987



little consistency in the method used. Tinbergen (in Gribble 1962) counted colony size in 1958 by photographing the colony, finding the ratio of birds to nests and then applying this figure to counts on the ground (see above), whereas Patterson (1965) used an aerial photographic survey in conjunction with counts of nests in marked areas. For this reason only those counts made after 1969 when nest-marking using split cane markers commenced are used here. This has been done every year since, except for 1979 and 1980 when no nest counts were made. An estimate for 1980 was made from observations of gulls at the colony site (C.E. Beer, F. Downton pers.comms.). These recent counts are summarised in figure 3.1.

As can be seen, the colony peaked at around 12,000 pairs in 1971. Numbers then remained fairly stable at around 10,000 pairs through the early 1970's but began to drop in 1976. Without even an estimate in 1979 it is impossible to say whether there was a sudden drop from 1978 or a gradual decline to the 1981 level of 2,200 breeding pairs. The colony declined further to 1,400 pairs in 1982 but increased slightly in 1983 then dropped to 1,514 pairs in 1984. Black-headed Gulls returned to the colony site in 1985 but none bred and none did so in 1986 or 1987.

Some data on breeding success are available (appendix 2). The figures from Patterson (1965) indicate that success was too low to maintain colony size (assuming 38% survival from fledging to first breeding (Lack 1943) and 15% annual adult mortality (Coulson in Patterson 1965). In 1975, the "northern gullery" (a sub-area of 600 pairs situated on the west side of Drigg Point 1k.m. from the southerly tip) produced no fledged young. The same occurred in 1980, but in this year the entire gullery was unsuccessful. The stage of the breeding cycle at which these failures occurred and their causes were not recorded. In 1981 the reserve warden found that the breeding success was even lower than that recorded by Patterson (1965) with most of the losses occurring before hatching. For 1983, an estimate of 0.5 juveniles reared per pair was obtained from counts of the ratio of adults to recently fledged juveniles on the beach at Ravenglass in July (D.E. Simpson pers. comm.). The maximum count of juveniles was, however, only 220 which from 2,200 nests implies that overall, as few as 0.1 chicks may have fledged per nest and that most nests failed to produce any young whatsoever.

FIGURE 3.2

CENSUS COUNTS OF SANDWICH TERNS AT RAVENGLASS (N/R NOT RECORDED)

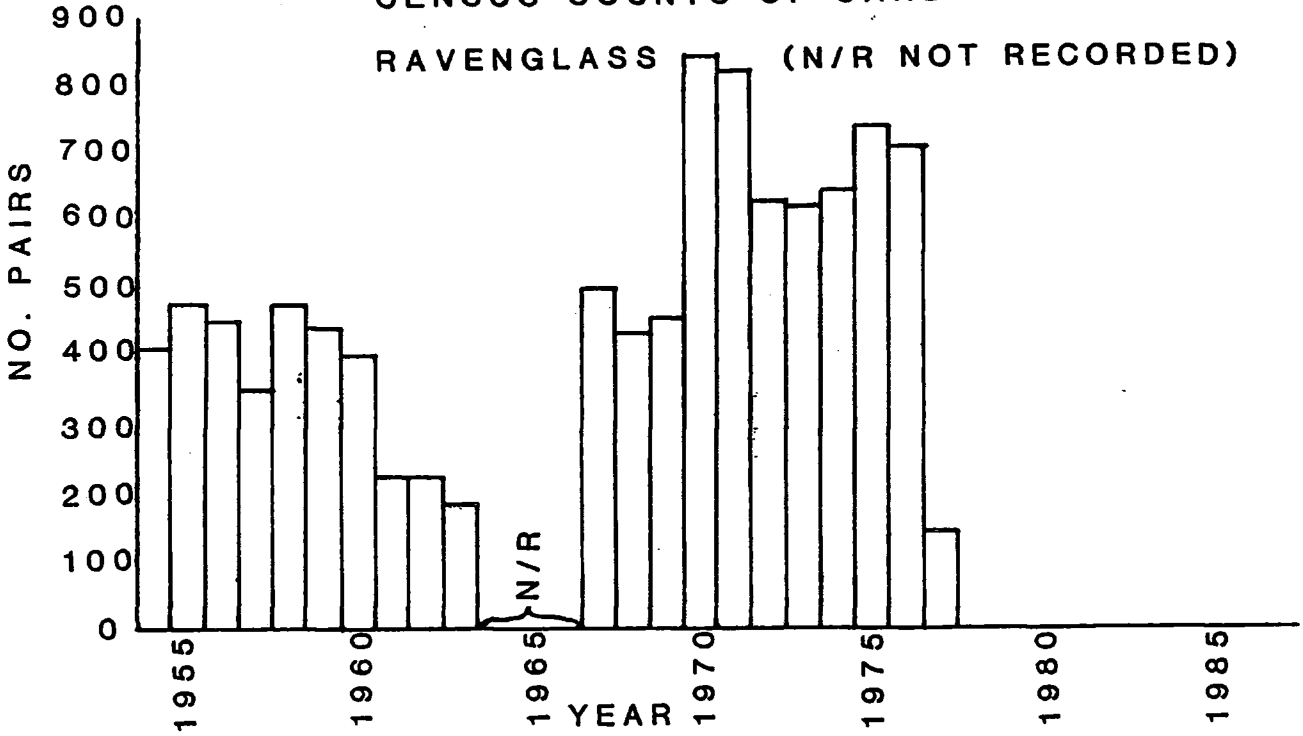


FIGURE 3.3

CENSUS COUNTS OF COMMON/ARCTIC TERNS AT RAVENGLASS

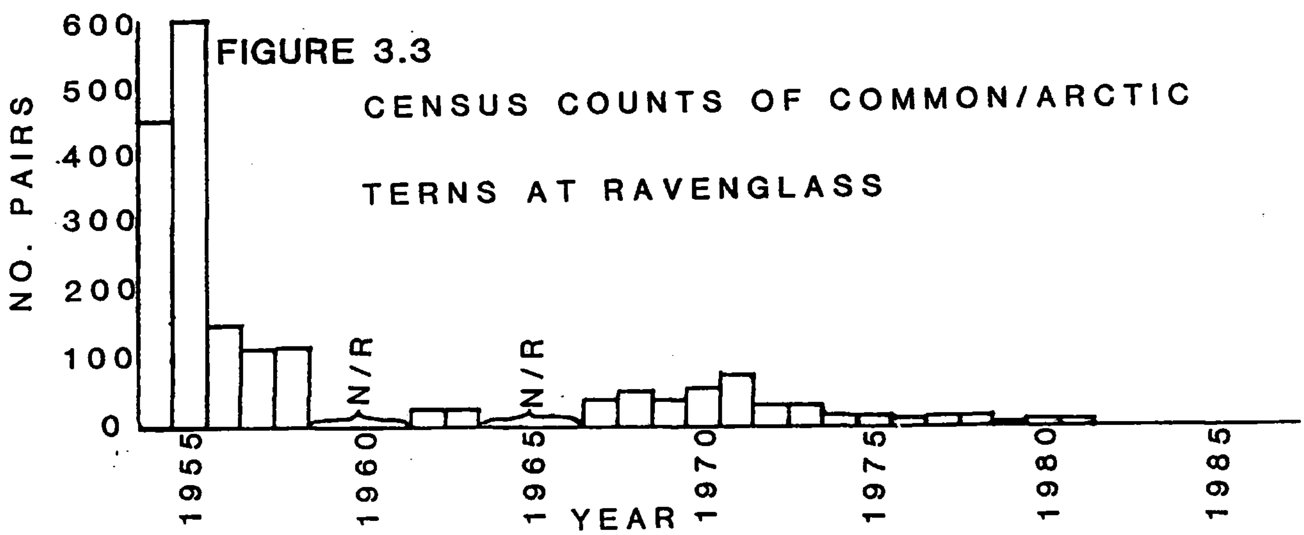
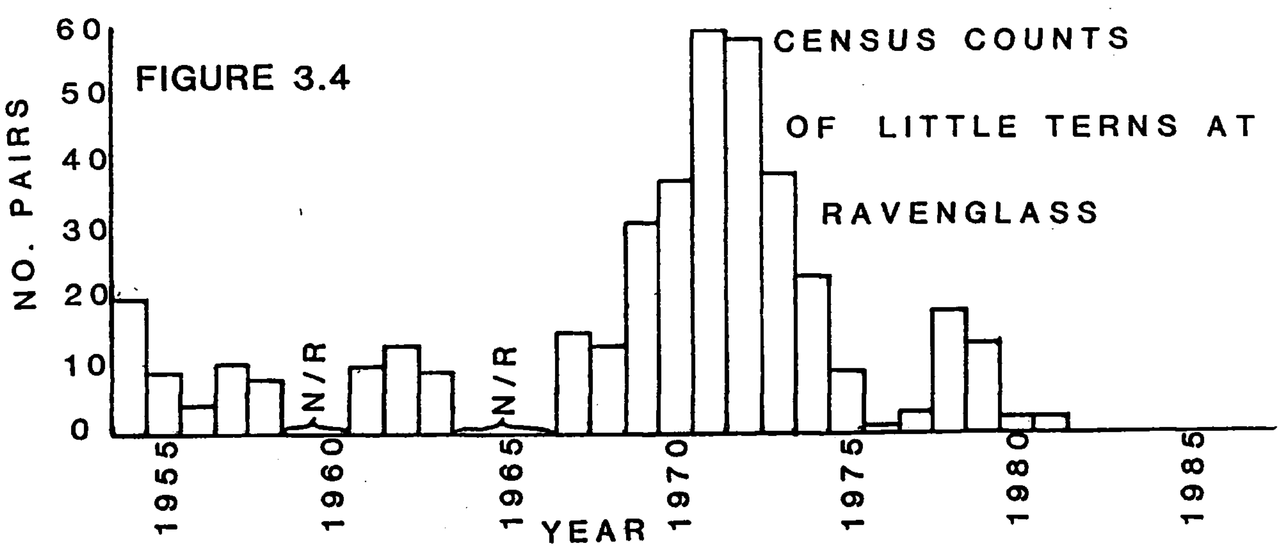


FIGURE 3.4

CENSUS COUNTS OF LITTLE TERNS AT RAVENGLASS



Sandwich Tern (Sterna sandvicensis)

Counts of colony size, made by direct marking, are shown in figure 3.2. The breeding population was stable at around 400 pairs in the early 1950's then dropped slightly before rising to a peak in the early 1970's. The colony failed to establish in 1978 and no birds have bred at Ravenglass since, although small numbers of Sandwich Terns assemble on Drigg Point every spring. Some data are available on clutch size of Sandwich Terns at Drigg (appendix 3) however, no standard errors are available so it is impossible to calculate the significance of the observed fall from 1971 to later years. However, with the exception of 1971 the data does fit into the range of 1.05 to 1.5 found by Dunn (1972) for colonies of Sandwich Terns in Northumberland.

Common Tern and Arctic Terns (Sterna paradisaea)

Counts, again made by direct marking are given in figure 3.3. Numbers peaked at around 500 pairs in the 1950's then dropped and remained stable at around 50 pairs until 1983 when no pairs nested.

Little Tern (Sterna albifrons)

Breeding population size was measured by direct marking methods (figure 3.4). Colony size peaked in the early 1970's but dropped to nothing later that decade.

Other Species.

There are no accurate counts available for Oystercatcher (Haematopus ostralegus), Ringed Plover (Charadrius hiaticula) or Red-breasted Merganser (Mergus serrator) although breeding has been attempted in all years. For Shelduck (Tadorna tadorna) however, counts of the maximum number of young on the estuary have been made in most years (appendix 4). As with the gulls and terns the peak production of young was in the early 1970's, however, in the absence of any data on the number of pairs attempting to breed the actual production per pair cannot be calculated.

3.2.2 FOULNEY ISLAND

Counts of breeding birds made by Cumbria Trust for Nature Conservation Wardens were available for all years from 1975 to 1983. Before that time there was considerable predation on the colonies by rats. This resulted in the bird populations being reduced to near extinction in 1974. The rats were exterminated in early 1974 and the bird colonies re-established themselves.

Counts of numbers of pairs of Black-headed Gulls were estimated from counts of adults whereas counts for other species were made by direct marking of nests. Species are treated separately below.

Black-headed Gull

Count data are shown in figure 3.5. As can be seen, the breeding population increased rapidly following the cessation of rat predation in 1975 and reached a peak of 1,200 pairs in 1983. Since then the gullery has been controlled by egg-taking to protect the terneries from excessive gull predation.

Estimates of breeding success are available for some years (appendix 5). The low levels of breeding success in 1980 and 1981 were ascribed to outbreaks of botulism amongst chicks causing high mortality between hatching and fledging. Figures for the mid-1980's suggest a better success rate followed by a decline, possibly due to the egg-taking described above.

Sandwich Tern

Population size is shown in figure 3.6. The number of breeding pairs varied erratically from year to year with a maximum of 1,500 pairs present in 1984. Some estimates of breeding success are available (appendix 6). As with Black-headed Gulls, success varied from year to year.

Common and Arctic Terns (figure 3.7).

Numbers of breeding pairs were stable at around 250 pairs in the late 1970's but have declined more recently in the early 1980's.

Other species

Little Terns have nested in most years but always in small numbers. Counts of numbers of nests of Oystercatcher and Ringed Plover are available for some years but these seem to reflect the enthusiasm of the warden rather than the actual number of pairs breeding.

3.2.3 ROCKCLIFFE MARSH

Nests of all species are marked individually in all years.

Black-headed Gull

These gulls nest chiefly on the edges of the many creeks which cross the marsh. The nests are susceptible to flooding by spring tides which reduces

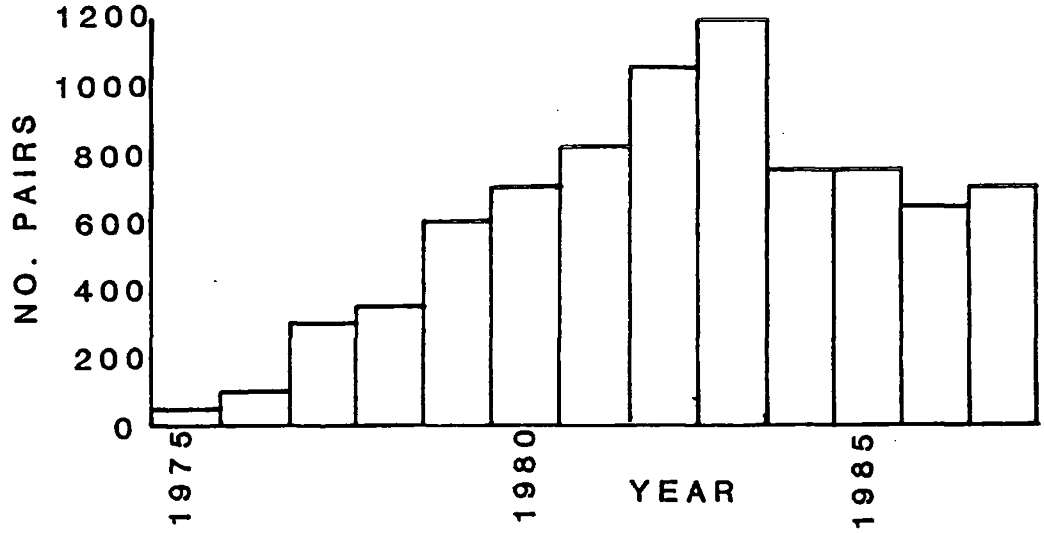


FIGURE 3.5

CENSUS COUNTS OF OF BLACK-HEADED GULLS AT FOULNEY

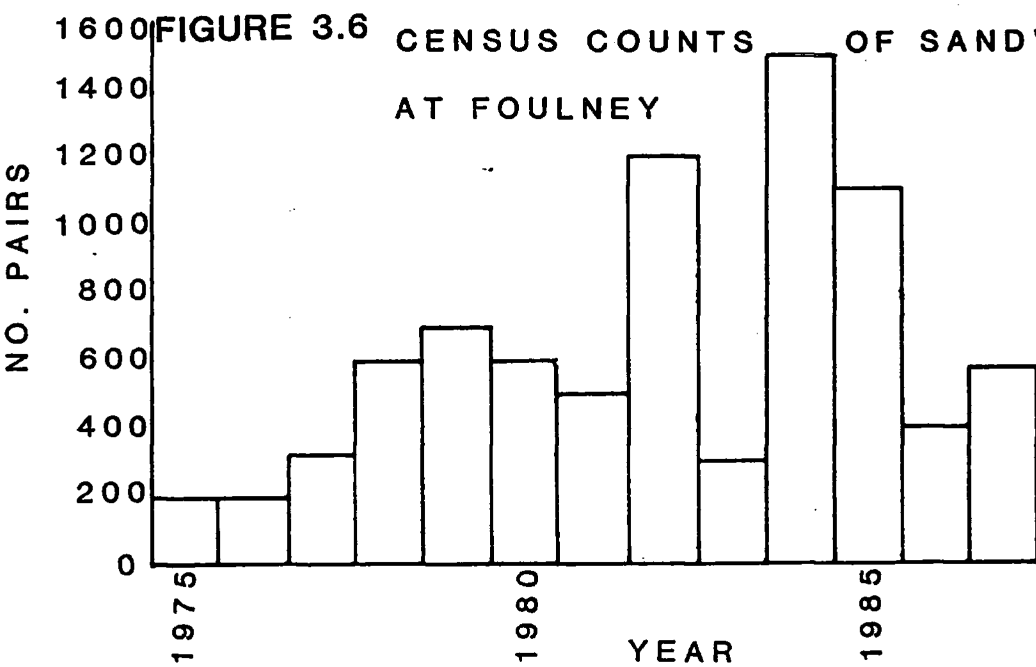


FIGURE 3.6 CENSUS COUNTS OF SANDWICH TERNS AT FOULNEY

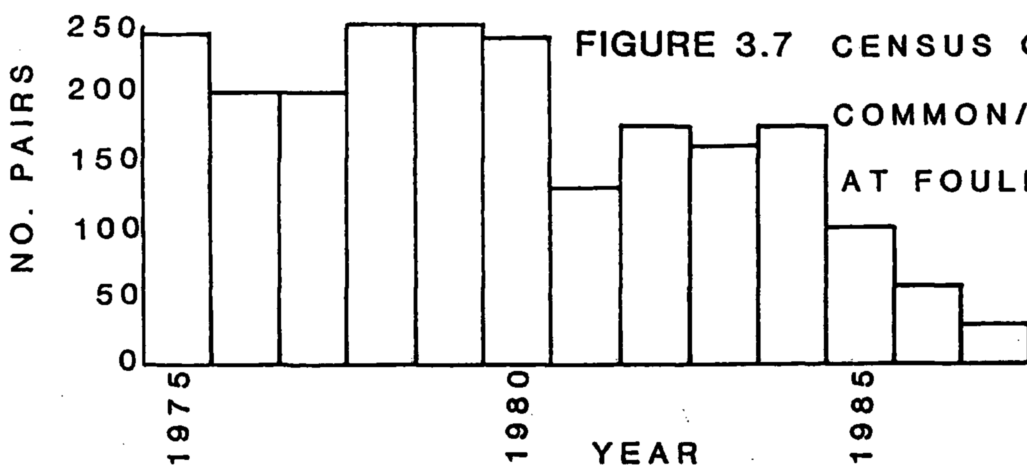


FIGURE 3.7 CENSUS COUNTS OF COMMON/ARCTIC TERNS AT FOULNEY

breeding success in some years. Yearly counts of population size are shown in figure 3.8. The number of pairs rose from around 800 in 1970 to a peak of 2,657 in 1976. Numbers then dwindled in the early 1980's but have increased in recent years.

Other Species

A very few pairs of Common Terns nest in most years but no figures are available. Some data are available for Oystercatcher and Ringed Plover (figures 3.9 and 3.10). Numbers of both these species have increased slightly since the early 1970's.

3.2.4 WASTWATER

Black-headed Gulls have nested at Wastwater since 1970. Originally the colony established itself on a small marsh on the north side of the lake about 2 k.m. from the western end. No accurate counts were available, however, the area supported about 50 pairs in most years but was prone to drying out which allowed access to people to take eggs. In 1984 egg-taking was so severe that the gulls deserted the site. In 1985 no gulls nested on the marsh but some pairs nested on a small rocky island in the lake about 1 k.m. from the western end; a total of 49 pairs nested that year. The colony numbered 109 pairs in 1986 and 147 in 1987. No other species of interest nests at this site.

3.2.5 SINEY TARN

A Black-headed Gull colony is situated amongst floating vegetation on this small tarn above Dalegarth Station in Eskdale. Little is known of the history of this site, except that there were around 50 pairs in 1970. The colony increased to 150-200 pairs in 1985 and remained at around that level in 1986 and 1987.

3.2.6 SUNBIGGIN TARN

This tarn is situated in the east of Cumbria, near Kirkby Stephen. As at Siney Tarn, Black-headed Gulls nest here on floating vegetation. Unfortunately, no accurate series of counts is available but it is estimated that the population had increased from c.2,000 pairs in 1975 to c.6,000 pairs in 1987 (D Baines pers.comm.).

FIGURE 3.8 CENSUS COUNTS OF BLACK-HEADED GULLS AT ROCKCLIFFE

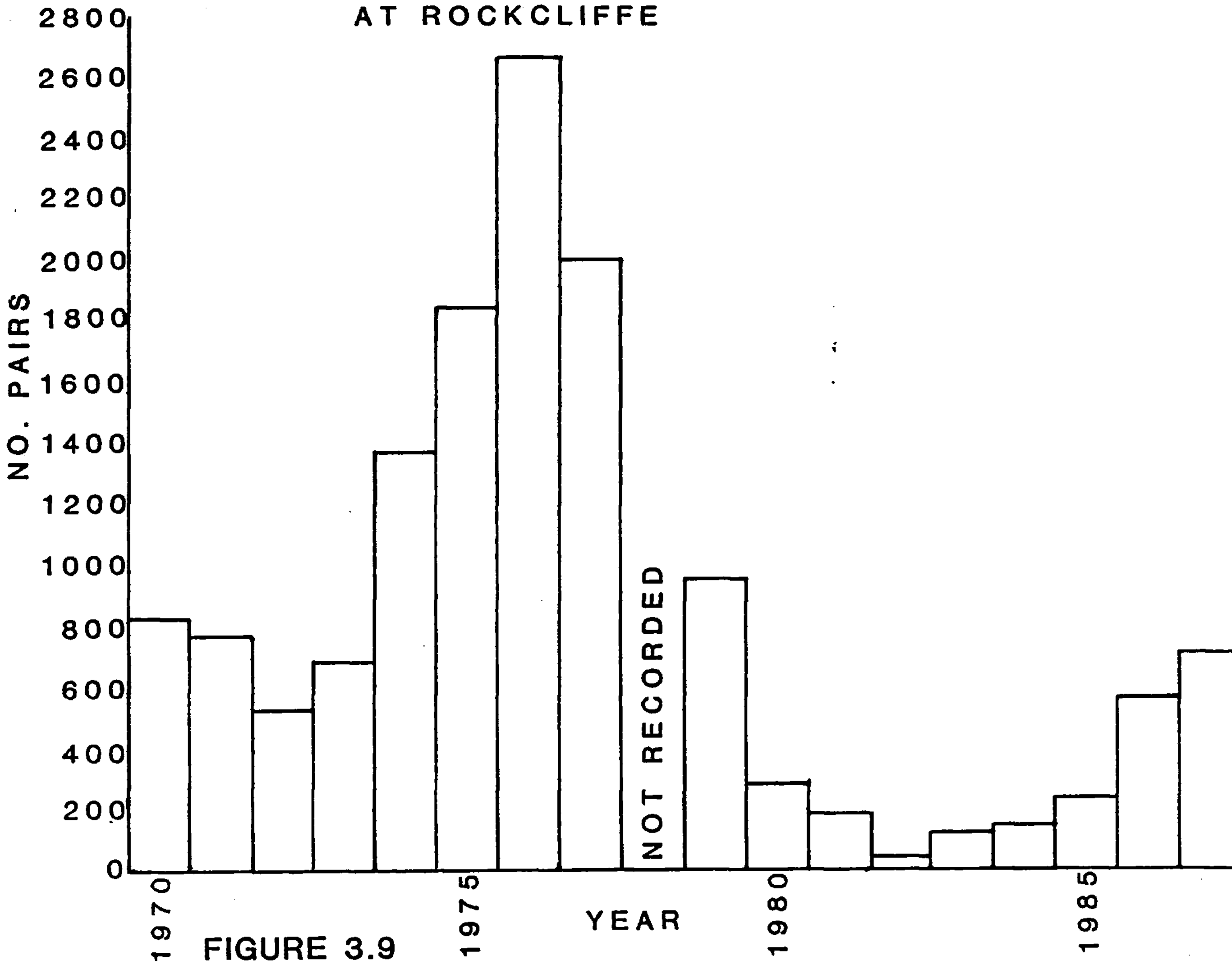


FIGURE 3.9 CENSUS COUNTS OF OYSTERCATCHERS AT ROCKCLIFFE

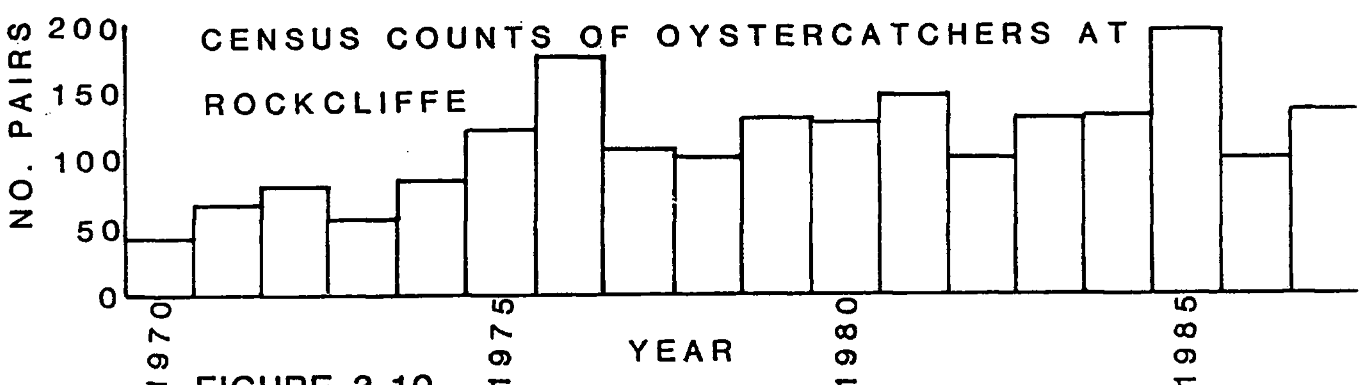
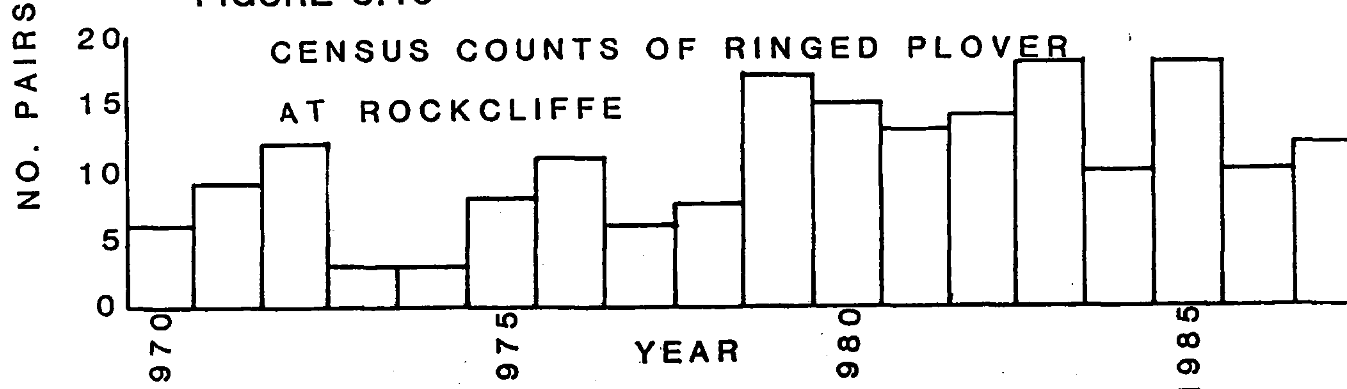


FIGURE 3.10 CENSUS COUNTS OF RINGED PLOVER AT ROCKCLIFFE



As can be seen, the sizes of Black-headed Gull colonies in Cumbria have not fluctuated in parallel in the past twenty years. Both the Ravenglass and Rockcliffe colonies suffered declines in the early 1980's. The Ravenglass colony declined to extinction, however, the Rockcliffe gullery is now increasing again. Over a similar time period the large colonies at Sunbiggin Tarn and Foulney Island increased consistently whilst the smaller colonies at Wastwater and Siney Tarn have fluctuated in numbers but increased recently. These increases have occurred coincidently with the cessation of breeding at Ravenglass.

The decline of the Ravenglass gullery was not paralleled at other inland Cumbrian colonies. However, another coastal colony at Rockcliffe Marsh showed a similar decline, although Rockcliffe appears to have recovered. This suggested that the cause of the Ravenglass Gull decline could have been due to a common factor acting on coastal breeding sites e.g. dry springs reducing the availability of terrestial food or marine pollution reducing the density of or contaminating marine food-stuffs. This was investigated in more detail (see Chapter 6).

The decrease in the Ravenglass gullery involved the disappearance of nearly 8,000 pairs of gulls between 1976 and 1981. During the same period, the colony at Rockcliffe Marsh decreased in size by some 2,000 pairs. Although the Foulney Island colony increased by about 1,000 pairs in the same time period and Sunbiggin Tarn grew by c.4,000 pairs in a period twice as long it is clear that the substantial losses from the two large coastal colonies cannot be accounted for merely in terms of changes of breeding location within Cumbria. Either adult mortality has increased to above normal levels, adults have moved to breed outside the county and/or failure to recruit young birds to the colony must have occurred. Even in the 1960's when the Ravenglass colony was not declining, output of fledged young was less than required to balance adult mortality (Patterson 1965), so that immigration must have been necessary to maintain the colony size then. Therefore, reproductive failures in the late 1970's at sites other than Ravenglass could have contributed to the decline in the Drigg gullery. Population dynamics of Black-headed Gulls were considered in more detail (Chapter 4).

The tern colonies at Ravenglass have also disappeared. It seems probable that the Sandwich Terns moved to Foulney as that colony appeared during the years birds first failed to settle at Ravenglass (1977 and 1978). During the early 1970's when bird populations at Foulney were low due to rat predation the population of Sandwich Terns at Ravenglass was high, suggesting that numbers on the whole Cumbrian coast have remained stable but the population has moved from site to site. Indeed the very recent decline in the breeding population of Sandwich Terns on Foulney has been paralleled by an increase in the number of pairs breeding at Walney Island (also near Barrow-in-Furness) and at Hodbarrow near Millom. This recent move from Foulney appears to be due to vegetation encroaching on to the colony site, forcing the terns, which nest in open areas, to move to new sites. No increases have occurred in the populations of Common, Arctic or Little Terns elsewhere in Cumbria in conjunction with the decrease at Ravenglass. For Little Terns at least this appears to be part of a general decline of breeding pairs in Cumbria as a whole (P. Baker pers. comm.). It seems likely that the causes of the decline of the Black-headed Gull colony at Ravenglass has also contributed to the fall in tern numbers there and eventually to their extinction as all these species nest in a similar open-ground habitat.

There does not, however, appear to have been corresponding fall in the populations of Shelduck at Ravenglass. This hole-nesting species is the only other for which reasonably quantitative data is available. The apparently healthy population of Shelduck suggests that whatever the cause of the Ravenglass gull and tern declines it has affected ground-nesting species more than hole-nesters (unless the difference in foods between gulls, terns and shelduck is critical).

It seems, therefore, that the cause or causes of the Ravenglass bird population decline was affecting species nesting in open ground habitat in coastal sites. This suggested a common link between the declines at Ravenglass and Rockcliffe Marsh. Before investigating further any definite hypotheses, however, available information was used to model the changes in population dynamics which could have occurred at Ravenglass in order to look for changes in mortality, emigration etc. which could pinpoint the time of the gulls annual cycle where the decline occurred.

MODELLING POPULATION CHANGES OF BLACK-HEADED GULLS AT RAVENGLASS

In order to propose and test possible hypotheses as to the actual causes of the Ravenglass gull decline it is necessary to pinpoint the times in the gulls' annual cycle when the agent or agents of the decline could have acted. One way to approach this is through modelling population processes concerning the gullery. As previously stated (Chapter 1) a population in a prescribed area will only remain stable if:-

$$\text{BIRTHS} + \text{IMMIGRATION} = \text{DEATHS} + \text{EMIGRATION} \qquad (1)$$

This equation contains a number of parameters which affect colony stability; on the left of the equation:-

"Birth" rate - Refers to Black-headed gulls breeding for the first time.
Breeding success will affect stability by increasing or reducing the number of young available to recruit and breed at the colony. An increase in the emigration rate of young birds to other colonies would have a similar effect.

Immigration - the number of birds coming into the colony to breed will also affect stability. In this case immigration refers to recruitment of young birds to Ravenglass from other colonies as well as adults from elsewhere.

On the right of the equation:-

"Death" rate - adult mortality rates would affect colony size by reducing or increasing the number of birds available to breed in subsequent years.

Emigration - the number of adult birds breeding at Ravenglass one year then moving to other colonies in later years will affect colony size and stability.

Using the above it is possible to model the population processes of Black-headed Gulls at Ravenglass under various conditions and to suggest areas in which changes in one or more of the above parameters could have resulted in the observed decline.

Data on survival rate, fledging success etc. for Black-headed Gulls are available from a number of sources; from elsewhere in Mackinnon 1986, Botkin & Miller 1974, Flegg and Cox 1975, Weidmann 1956, Greenhalgh 1975 and for Ravenglass in particular, Patterson 1965.

4.1 EVIDENCE FOR EMIGRATION AND SITE INFIDELITY

Using records of ringing recoveries from Ravenglass it was possible to investigate site-fidelity of adults and young which could have occurred during the decline.

4.1.1 METHODS

Black-headed Gulls are assumed to breed at the beginning of their third year so recruitment refers to birds recovered in their third and subsequent years. Data were divided into recoveries during the breeding season (April to July) and those outside (August - March). Birds recovered at the Ravenglass colony site or within a 10 km. radius of the colony were assumed to be breeding there.

4.1.2 RESULTS AND DISCUSSION

Table 4.1 shows the number of adult Black-headed Gulls recovered during the breeding season at Ravenglass and those recovered elsewhere for all years for which data are available. Data for gulls in their first year of breeding are given in table 4.2. For adults, roughly half of all recoveries, and for first-time breeders almost 60% of recoveries, were at places away from Ravenglass. There are however biases in these data; it is not known how likely it was that gulls would be recovered at Ravenglass or elsewhere; it was not known if birds recovered away from Ravenglass in the breeding season were breeding at other colonies and the methods of recovery of birds were not always comparable. It may be that the closed-season at Ravenglass, preventing access by humans to the gullery, reduced the number of recoveries of Black-headed Gulls there during the breeding season so reducing the number of gulls remaining faithful to Ravenglass. It is thus not possible to quantify the fidelity of adults and first-time breeders to the Ravenglass colony, however, some infidelity did occur.

RECOVERIES OF ADULT BLACK-HEADED GULLS (>3 YEARS OLD) RINGED AS CHICKS AT RAVENGLASS AND RECOVERED DURING THE BREEDING SEASON (APRIL TO JULY).

YEAR OF RECOVERY	TOTAL NO. RECOVERIES	NO. RECOVERED AT RAVENGLASS	NO. RECOVERED AWAY FROM RAVENGLASS
1913	2	0	2
1914	2	1	1
1916	4	2	2
1917	3	3	0
1920	1	1	0
1923	1	1	0
1930	1	1	0
1952	1	0	1
1954	2	0	2
1955	4	1	3
1956	8	2	6
1957	12	7	5
1959	7	5	2
1960	3	2	1
1961	9	6	3
1963	6	4	2
1964	4	2	2
1966	2	0	2
1980	1	0	1
TOTAL	73	38	35

TABLE 4.2

RECOVERIES OF FIRST-TIME BREEDING BLACK-HEADED GULLS (2 YRS OLD) RINGED AS CHICKS AT RAVENGLASS AND RECOVERED DURING THE BREEDING SEASON (APRIL-JULY).

YEAR OF RECOVERY	TOTAL NO. RECOVERIES	NO. RECOVERED AT RAVENGLASS	NO. RECOVERED AWAY FROM RAVENGLASS
1912	1	1	0
1913	1	0	1
1914	2	1	1
1915	3	0	3
1952	4	3	1
1953	5	1	4
1954	4	0	4
1955	1	1	0
1959	1	1	0
1963	11	7	4
1964	2	0	2
TOTAL	35	15	20

4.2 MODELLING

As previously stated, for a population of birds in a given area to remain stable then;

BIRTHS + IMMIGRATION = DEATHS + EMIGRATION

Certain of the parameters in this equation have been calculated above. Using the equation it is possible to construct a simple model which attempts to explain the observed decline of Black-headed Gulls at Ravenglass. This approach may identify more precisely the parts of the gulls annual cycle (figure 1.2) at which the agents of the decline acted.

From equation (1), and assuming adult Black-headed Gulls show complete site fidelity at Ravenglass, colony size in year X is given by:-

$$C_X = C_{X-1}.S_A + P_{X-2}.S_j.R \qquad (2)$$

where C_X = colony size in year X

C_{X-1} = colony size in year X-1

S_A = annual adult survival rate (0.805 Mackinnon 1986)

P_{X-2} = production of young in year X-2

S_j = survival rate from fledging to first breeding

R - recruitment rate of first-time breeders

To keep the model simple it is assumed that no young birds were produced or recruited at Ravenglass i.e. R in (2) is equal to zero. This means that colony size in year X is given by:-

$$C_X = C_{X-1} . 0.805 \qquad (3)$$

Figure 4.1 shows the predicted colony size, together with actual data from nest counts for the Ravenglass gull decline from 1975. As can be seen, the model fits well to the overall decline from 1975 to 1984; the overall slope

of the predicted line is -log 0.805 (as expected from equation (3)) whereas the slope of the actual overall decline is -log 0.807. Thus, the overall decline in the Black-headed Gull colony at Ravenglass between 1975 and 1984 can be explained by a simple model assuming no recruitment of young birds, complete adult site-fidelity and 80.5% annual adult survival.
This model gives a good, overall "fit", however, there are two differences:-

i) The actual decline appeared to occur in three "phases":-

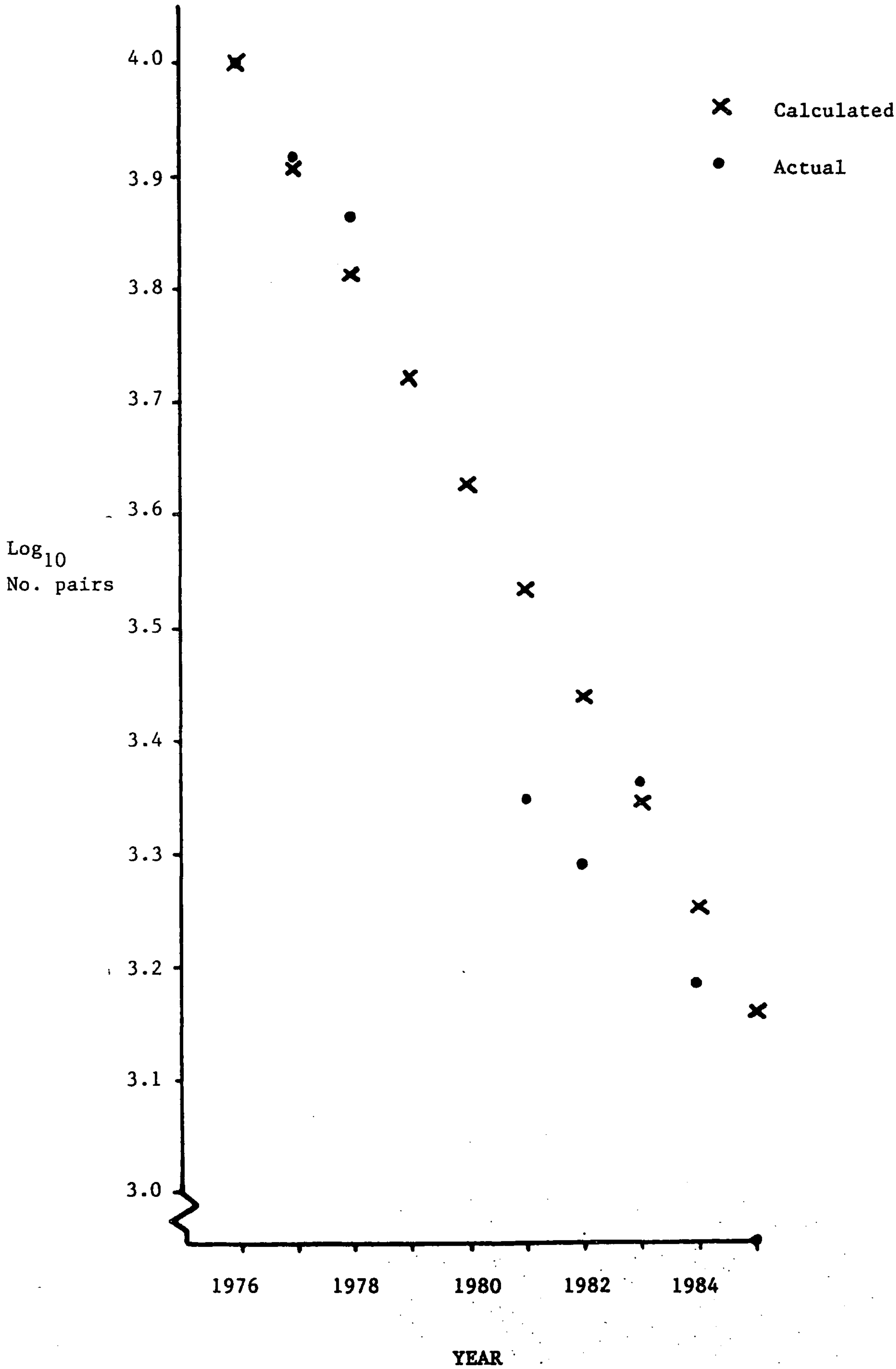
a) 1975 to 1978, the decline had a slope of -log 0.887.

b) 1978 to 1981, the slope was -log 0.671.

c) 1981 to 1984 with a slope of -log 0.863.

FIGURE 4.1

COLONY SIZE AT RAVENGLASS BLACK-HEADED GULLERY 1976-1985 BASED ON EQUATION 4.1 ASSUMING NO PRODUCTION OF YOUNG AND A STARTING POPULATION OF 10,011 PAIRS IN 1976.



A problem here is the lack of accurate counts in 1979 and 1980 but, returning to the model, the overall drop between 1978 and 1981 requires a decrease in adult survival to 67.1%. Without information for colony size in this period, however, it is impossible to speculate other than to suggest that a decrease in adult site-fidelity occurred in this period.

ii) The observed decline drops to 0 pairs in 1985 whereas in the model there is still expected to be 1,200 pairs of gulls.

To refine the model slightly it is possible to introduce more accurate information on production of young and emigration of adult birds. In 1980 and 1984 the colony suffered a complete breeding failure, however, in all other years fledged young were produced. If it is assumed that the production of young was equal to the emigration rate of adult birds then the rate of decline is equal to that shown in figure 4.1 but takes into account production of young birds and movements of adult birds to other colonies. There is still the problem of the model overestimating the colony size in 1985, however, this can be explained if adult birds moved away from Ravenglass in greater numbers in certain years i.e. the emigration rate increased periodically. It is possible, for example that more adult birds than usual failed to return to Ravenglass to breed following the breeding failures of 1980 and 1984 and consequently the pattern of decline was not a smooth fall as shown in figure 4.1 but rather a stepped decline with low rates of decrease interspersed with higher rates, as suggested by the actual pattern of decline (figure 1.1).

4.3 DISCUSSION

Evidence from Mackinnon (1986) suggest that there was no increase in annual adult mortality of Black-headed Gulls overall in Britain during the period of the Ravenglass decline. Thus it seems unlikely that the observed decline in the size of the Ravenglass gullery can be explained simply by an increase in the mortality rate of birds breeding there.

Ringing recoveries also show that there was infidelity to the Ravenglass colony by adult Black-headed Gulls and recruits. Various workers (Ludwig 1973, Chabrzyk and Coulson 1976, Duncan and Monaghan 1977) have studied lack of fidelity to the natal colony in Herring Gulls. Chabrzyk and Coulson found that no more than 40% of young gulls returned to their natal colony and inferred that large scale dispersion is the normal course of events and that female gulls showed a significantly greater tendency to disperse than did males. Duncan and Monaghan also found that significant numbers of Herring gulls from the colony on the Isle of May (Scotland) recruited to colonies other than the colony of birth. During the period of this research there was disturbance at the Isle of May colony site due to culling of birds.
However, Duncan and Monaghan's data suggest that lack of fidelity to the natal

colony occurred in the years prior to the cull beginning. It is possible, therefore, that there was a lack of fidelity to the natal colony amongst first-time breeders at Ravenglass. However, as before the data from ringing recoveries are few, do not cover the period of the decline, and have many biases.

The situation for adult Black-headed Gulls at Ravenglass, however, is not so clear. Duncan and Monaghan (1977), have no records of adult Herring Gulls leaving a colony once they have recruited to it although they consider it by no means improbable. Coulson and Wooller (1976) working on Kittiwakes found that breeding birds do not move between colonies. In the present study, however, the data from ringing recoveries, do suggest some lack of fidelity by both first-time breeders and adult birds. It is possible that the small size of the data set over-estimates the amount of infidelity to Ravenglass, possibly because searches for ringed birds at Ravenglass were not carried out as frequently as elsewhere.
Using a simple model it is possible to explain the observed decline in the number of pairs of Black-headed Gulls breeding at Ravenglass from a consideration of changes in the rate of adult mortality and/or emigration, the productivity of the colony, and the recruitment rate of first-time breeders to the colony.

The model proposed above thus suggests that the overall decline in the Ravenglass gullery can be explained, assuming a constant annual adult survival rate (80.5%), no emigration of adults and no production or recruitment of young (or that adult emigration balanced young recruitment). This implies that changes in rates of emigration or mortality amongst adults and/or changes in the productivity of the colony or recruitment of young-birds to the colony from Ravenglass or elsewhere could have influenced the observed decline.

HISTORICAL DATA ON PREDATION AND DISTURBANCE

The model proposed in Chapter 4 suggested that poor production or recruitment of young and increased emigration or mortality of adult birds from the Ravenglass gullery could be major factors accounting for the observed decline in the colony. Factors which affected the number of Black-headed Gulls coming into the Ravenglass area, prospecting at the colony site and subsequently staying to breed would be expected to alter colony size. Obviously, above average mortality of adults and juveniles in the previous winter period or above average mortality of adults and poor chick production during the previous breeding season (possibly due to predation), would reduce the number of gulls returning to the site in Spring (assuming there is not a compensatory increase in immigration). These would not be detectable, however, except by a process of elimination of other possibilities. Assuming that there are gulls returning to the Ravenglass area two main mechanisms could cause birds to move to other colonies to breed; food shortage and disturbance. Food shortage is discussed elsewhere but disturbance and predation are considered here.

If there is disturbance e.g. by predators or humans in the pre-breeding season then gulls, although present, may not settle on a colony site and subsequently breed. Various studies of non-gull species have shown that disturbance by humans can reduce the colony size and deter late-nesting birds from settling. Tremblay and Ellison (1979) working on Black-Crowned Night Herons (Nycticorax nycticorax) showed that visits to the colony shortly before laying caused abandonment of newly constructed nests and that frequent disturbance discouraged the settlement of late-nesting Night Herons. For Double-Crested Cormorants (Phalacrocorax auritus) frequent disturbance was also found to discourage late-nesting birds from settling in disturbed experimental colonies. (Ellison & Cleary 1978). If a similar behaviour is found in Black-headed Gulls at Ravenglass then there is a possibility that disturbance by humans or other agents (e.g. predators such as fox or mink) would cause desertion of the colony site prior to egg-laying or would prevent late-comers from nesting.

The effects of predation on the productivity of the colony and of predation and disturbance as agents affecting recruitment and failure to settle are considered separately.

5.1 HISTORICAL INFORMATION ON PREDATION AT RAVENGLASS

Despite the colony having been recorded for over 100 years there is little available information concerning production of young by Black-headed Gulls and factors affecting it at Ravenglass. Patterson (1965) studied breeding success in the early 1960's as part of his investigations into the timing and spacing of broods in the Black-headed Gull. He found that each pair in his study areas produced an average of 0.4, 0.2 and 0.3 chicks per year in 1961, 1962 and 1963 respectively. The main cause of this low breeding success was predation, by a variety of species, including Fox, Hedgehog (Erinaceus europaeus), Carrion Crow (Corvus corone), Herring Gull, Lesser Black-backed Gull (Larus fuscus) and other Black-headed Gulls. Patterson used published figures to investigate population turnover and concluded that "replacement of adult losses at the Ravenglass population was well below that required to maintain numbers, even allowing for the approximations in the data".

Kruuk (1964) studied the predators and anti-predator behaviour of the Black-headed Gull at Ravenglass. Kruuk investigated the responses of Black-headed Gulls to various predators and assessed the possible effect of each predator. His study period was the same as Patterson's and Kruuk considered that "the recruitment of fledglings was much less than it ought to have been for maintenance of the colony" and that this was "probably largely caused by fox predation".

Apart from these two published papers the remainder of the information concerning productivity and predation at Ravenglass is detailed in reports to Cumbria County Council from the reserve warden. These reports, however, contain little information concerning the number of fledged young produced by Black-headed Gulls at Ravenglass. Data exists for four years since 1969; in 1975 a sub-section of the colony holding 500 pairs of gulls suffered a complete breeding failure; in 1980 the whole colony suffered a breeding failure, (however, no count was done in that year so colony size is not known); in 1981 2,213 pairs raised an average of 0.06 chicks per pair

(Rose 1981); and in 1983 2,290 pairs had an average of 0.10 chicks per pair (Simpson 1983). The reasons for these poor seasons are unknown but Rose (1981) suggests that "a shortage of available food at a critical time in the reproductive cycle still seems to offer the best likely explanation of the breeding failure (in 1980)" however, he offers no evidence to support this claim.

During the early 1970's concern was expressed by the warden about the possible predation on eggs and chicks by larger gulls. There is a large colony of Herring, Lesser and Greater Black-backed Gulls at St. Bees Head to the North, and gulls were often observed flying down the coast. However, the amount of predation they caused appears to be small. Kruuk (1964) suggests that the anti-predator strategies of Black-headed Gulls are well adapted to preventing high levels of predation by these species. Rose (1975) however, suggests that Herring, Lesser and Greater Black-backed Gulls were responsible for much of the predation on the outlying parts of the Ravenglass gullery in 1975 and so were implicated in the breeding failure of part of the Black-headed Gull colony in that year. More important in terms of predation on the Ravenglass Black-headed Gull colonies was the build-up of a small colony of Herring, Lesser and Black-headed Gulls on the salt-marsh near the northern boundary of the reserve. Professor Tinbergen (C.J. Rowley pers. comm.) suggested in 1975 that this small gullery ought to be controlled to prevent it "exploding" and beginning to cause major predation problems for Black-headed Gulls at Ravenglass rather than the few "dash-and-grab" attacks which were occurring at that time. Following this advice, the larger gulls were prevented from nesting in subsequent years.

Kruuk (1964) and Patterson (1965) identified other species which were predators of Black-headed Gull eggs or chicks at Ravenglass or had the potential to do so. There is little information, however, concerning other predators although occasional mention is made of Hedgehogs or Carrion Crows (Corvus corone) taking chicks or eggs. (Rose 1971, 1974, 1975). Apart from foxes and the large gulls mentioned previously, the only predator which seems to have caused sufficient concern to be mentioned in the reports was a Badger (Meles meles) which occupied a set amongst the gulleries in the mid-1970's. This animal was recorded as taking Black-headed Gull eggs on a number of occasions (Rose 1974) but was not considered a major threat to the survival of the Black-headed Gull colonies.

Predation itself would have the effect of reducing the productivity of the gullery in a particular year not only through the direct losses of eggs, chicks or adults taken by predators but also through birds deserting the site during the breeding season in response to the disturbance caused by predation. Birds which deserted in one year may have bred elsewhere and failed to return to Ravenglass subsequently so increasing the emigration rate. The effects of predation as a disturbance to nesting or settling birds are impossible to obtain from the literature concerning Ravenglass. However, information does exist on other forms of disturbance experienced by Black-headed Gulls breeding at Ravenglass.

5.2 HISTORICAL INFORMATION ON DISTURBANCE AT RAVENGLASS

The gulleries at Ravenglass were, for a long time, "farmed" by local people as a source of eggs. No published evidence is available concerning the taking of eggs at Ravenglass, however, an outline of the scale of it was obtained from conversations with local people (P. Gordon-Duff-Penington, N. Porter et al. pers. comms.) Egg taking began in April and continued until the end of May and appears to have been strictly controlled by Muncaster Estates who sold the eggs. The principle behind the "close season" in June and July was to allow the gulls to raise young from second or even third clutches. Despite the considerable disturbance and, in effect, predation caused by the removal of eggs, Black-headed Gulls appeared to return to the site year after year and to produce young. There is no information available regarding the size of the colony during this period except estimates of numbers from Marchant (1952) (see Appendix 1). It seems likely that until egg-taking was stopped in 1954 this human predation was the only serious direct predation the colony suffered as other predators in the area were controlled to protect the valuable gull egg resource (P. Gordon-Duff-Penington pers. comm.).

Since the formation of Ravenglass L.N.R. no egg-taking has been allowed, but visitors to the gulleries have been allowed. The number of visitors to Ravenglass each year, for which data are available, are shown in table 5.1. Typically, the warden accompanied visitors on conducted tours of the reserve in large groups, often containing classes of school-children (C.J. Rowley pers. comm.). One of the highlights of the tours was a walk through the centre of the gull nesting area, during the high season. This could mean four half-hour long visits to the same area per day (N. Porter pers. comm.). As can be seen in table 5.1 the number of people visiting the reserve was over 1,000 from 1971 until 1980 when a "close season" was introduced preventing access to the gull colonies between 1 May and 30 June. Peak numbers of visitors occurred in 1971 and 1973 although the peak number of visiting

TABLE 5.1

NUMBER OF VISITORS TO RAVENGLASS L.N.R. (SOURCES, RESERVE REPORTS 1970-1987) (N/A - NOT AVAILABLE).

YEAR	NO. SCHOOL PARTIES	NO. ADULT PARTIES	TOTAL NO. VISITORS
1963	18	N/A	N/A
1970	16	3	910
1971	20	12	1,343
1972	16	11	1,076
1973	21	10	1,421
1974	19	7	1,080
1975	18	14	1,075
1976	21	8	1,230
1977	14	12	1,058
1978	10	22	1,023
1979	17	11	1,189
1980	22	8	774
1981	25	8	904
1982	12	8	471
1983	13	6	532
1984	9	6	382
1985	14	11	375
1986	5	4	251
1987	3	1	132

parties occurred in 1981. The number of period permits, allowing visiting at any time during the season, peaked between 1974 and 1977, whereas the number of photography permits, allowing access to hides in the gulleries was relatively constant from 1972 to 1979. In addition to authorised visitors, a number of trespassers were recorded at Ravenglass each year. These trespassers were often merely walkers unaware of the reserve but occasionally poachers or egg-collectors were caught. The peak years for trespassing were 1975 and 1976 when up to 380 people were apprehended.

It seems, therefore, that there were a large number of people present in the area of the gull colonies during the breeding season throughout the period of the gull decline in the late 1970's but that equally high numbers had been present in the early 1970's before any decline was noticeable. Numbers of visitors dropped-off in the early 1980's however, probably as a result of the cessation of walks through the gulleries and the reduction in size of the gulleries reducing the appeal of the reserve. It is not known what damage or disturbance was caused by the presence of so many people near to the nests, eggs and chicks of breeding Black-headed Gulls, however at the very least the fact that gulls would leave their nests to mob the visitors suggests that predators would have access to eggs and nests.

5.3 DISCUSSION

Despite the lack of quantifiable data concerning the effects of predation and disturbance on the gull colony at Ravenglass it can be suggested that, in the years for which data are available, predation and disturbance by predators were implicated strongly as causes of poor breeding success. Although the effects of disturbance on emigration and desertion rates were not quantified it can be suggested that one of the effects of the surplus killing of gulls by foxes described by Kruuk (1964) would be to cause disturbance and perhaps the chilling of eggs left unattended, especially in the early part of the season. Southern et al. (1985) studied the effects of nine years of fox predation on colonies of Ring-billed and Herring Gulls in Lake Michigan. They found that, in addition to the number of eggs taken directly by foxes, a major component of the total effect of fox predation was that eggs were knocked out of nests in the panic caused when a fox entered the gulleries. Kruuk (1964) describes a similar situation of panic at Ravenglass when a fox entered the colony at night. As the weather conditions favouring surplus killing were cold and wet, the eggs knocked out of nests would be likely to become chilled and inviable. This would further reduce the breeding success of the colony as a whole.

The effects of human disturbance on the Black-headed Gull colony at Ravenglass are unknown. Egg-collecting was practised for many years without seemingly causing a reduction in the size of the gullery. This may have been because management of the birds and their eggs as a valuable resource prevented extinction. It can, however, be suggested that the practice of taking parties of people through the centre of the gulleries on many occasions during the breeding season caused panic of a similar type to that caused by a fox and so resulted in a loss of eggs above that expected from predation. A piece of circumstantial evidence for this is that initially, parties were taken through the gullery to the north end of the spit which suffered a breeding failure in 1975 and was the first to disappear suggesting a tenuous link between human activity and the extinction.

It is impossible to identify links between predation and disturbance and rates of emigration amongst adult birds and rates of site infidelity amongst first-time breeders. Studies on other species (e.g. Tremblay & Ellison 1979 on Black-Crowned Night Herons; Ellison & Cleary 1978 on Double-crested Cormorants) suggest that disturbance can deter birds from nesting at a particular site but no direct evidence for this is available for Black-headed Gulls. Information does exist (Kruuk 1964, Beer 1963a) as to the settling pattern of Black-headed Gulls at the Ravenglass gullery and this was used as a comparison with field data collected at Ravenglass (Chapters 7 and 8) in order to investigate possible changes in settling at the colony site. Factors affecting productivity were also investigated in more detail during field-work.

HISTORICAL INFORMATION ON FOOD AVAILABILITY AND HABITAT CHANGES AT THE RAVENGLASS GULLERY

The model presented in Chapter 4 shows that the observed decline in the Ravenglass gullery can be explained in terms of poor production of young and adult mortality. Chapter 5 considered historical information on the effects of predation and disturbance on productivity and emigration. The availability of food is another factor which could influence the proportion of those birds arriving in an area that settled to breed there and subsequently the productivity of those birds.

If there is insufficient food to allow birds to attain breeding condition (food availability in staging areas between the wintering and breeding grounds may also be of importance here) then birds may either move to other colonies or defer breeding altogether in that season. Jones and Ward (1976) studied reserve protein level in the Red-billed Quelea (Quelea quelea) and concluded that the timing of the first, and any subsequent breeding attempts by any individual is regulated by the size of its protein reserve. They stress the importance of food supply as this is the major factor influencing an individual's body condition. Ashmole (1971) has similar views for control of timing of breeding attempts in tropical sea-birds. He states that "the date of laying in each pair may not be determined by any specially evolved timing mechanism involving response to proximate environmental factors, but instead may reflect mainly the date on which the members of the pair acquire energy reserves sufficient for the production of eggs and the commencement of incubation shifts". If the same holds true for Black-headed Gulls then if there is insufficient food for one or both members of a pair to acquire large enough protein/energy reserves to allow breeding to commence then the pair will not breed. This is supported by Drent and Daan (1980) who reviewed the literature on energetic adjustments in breeding and concluded that the decision to breed or not to breed is related to the body condition of the female, presumably because of the implications this has for survival of embryos and adult females. They also concluded that laying date and clutch size are under the influence of female body condition. Dijkstra et al. (in Drent and Daan) gave Kestrels (Falco tinnunculus) supplementary food and found that they laid larger and earlier clutches than control pairs.

The major factors which would be expected to influence food availability would be changes in the habitats where gulls fed resulting in changes in populations of prey items and weather factors which could influence the availability of prey items regardless of their abundance. In addition, habitat changes could affect nesting gulls directly by making the colony site more or less acceptable as a breeding site or making it easier for predators to gain access to the site. These are considered below.

6.1 FOOD SOURCES OF BLACK-HEADED GULLS AT RAVENGLASS

Much information is available on the food of Black-headed Gulls in general (e.g. Stamm in Cramp & Simmons (1983), Holyoak and Sager (1970), Vernon (1970), Isenman 1978, Florence 1912, 1914, 1915). This suggests that the diet of Black-headed Gulls is mainly animal material, particularly insects and earthworms but is commonly supplemented by plant material and household and industrial waste. Indeed, the rather catholic feeding habits of the Black-headed Gull are one of the reasons proposed for the species spread through Europe this century (see Chapter 1). During the breeding season earthworms and insects predominate in the diet (Florence 1912, 1914, 1915). The insect components of the diet are mainly ground-dwelling beetles and their larvae, tipulid fly larvae and aquatic insects and their larvae.

Less information is available concerning the specific diet of Black-headed Gulls breeding at Ravenglass although observations by Macpherson and Duckworth (1886) that "the downy young (at Ravenglass) are fed on earthworms and beetles" and Tinbergen (1962) that "gulls at Ravenglass eat earthworms by the thousand" suggest that the diet of Ravenglass breeding gulls is similar to that recorded elsewhere. Observations by the warden (Rose pers. comm.) suggest that Black-headed Gulls at Ravenglass fed in flocks inland on pasture fields during the early part of the season but were frequently seen hawking insects over the dunes later, especially in July. He considered that the Dune Cockchafer (Melolontha vulgaris) was an important food item at this time. Thus, to investigate changes in habitat which could have affected the availability of earthworms and beetles it is necessary to look at changes in the useage of agricultural land inland from Ravenglass.

One other interesting point concerning the diet of Black-headed Gulls at Ravenglass is the apparent lack of refuse site feeding. Until 1974 there was a domestic and industrial refuse tip at Drigg dump, site of the present low-level radiation dump. This site is situated less than 3k.m. from the gullery and would have been expected to have been used extensively by Black-headed Gulls. Rose (1974) comments on the large numbers, "up to 1,600" of large gulls using this food source however, Black-headed Gulls appear not to have utilised it (J Rose, N Porter, C J Rowley, R A Stamm pers. comms.). (The large numbers of gulls attracted into the area by the tip may have increased the level of predation on the gullery but no evidence is available).

6.2 CHANGES IN LAND-USE IN AREAS SURROUNDING THE RAVENGLASS RESERVE

Information on the diet of Black-headed Gulls at Ravenglass suggest that before laying season Black-headed Gulls feed on earthworms in flooded pasture fields and also behind the plough. Any change in the amount of timing of ploughing or the number of pasture fields would reduce the availability of food for adults and, if it occurred later in the season for chicks also.

6.2.1 METHODS

Information was obtained from the Agricultural and Dairy Advisory Service on the compositions of farms in the Cumbrian parishes surrounding the Ravenglass, Wastwater and Siney Tarn colonies. Unfortunately, these data were available only for the years 1970, 1975, 1980 and 1985. This does allow a preliminary investigation of the trends in agricultural change in the area of the Ravenglass gullery over the period in which the gullery declined.

6.2.2 RESULTS

Appendix 7 contains the details of the areas of crops grown in each parish in the years concerned. These data are summarised in table 6.1. The major changes are in the number of hectares of grassland and rough grazing with grassland increasing whilst rough grazing had decreased. There has also been a decrease in the number of hectares of cultivation of all crops except maize and barley which have increased by almost 200ha. in the period, mostly at the expense of oats.

6.2.3 DISCUSSION

The major change in land use in the Parishes surrounding the Ravenglass estuary has been the reclamation of rough grazing land and its transformation into permanent grassland. This has mainly occurred in the more upland

TABLE 6.1

NUMBER OF HECTARES OF CULTIVATION OF CROPS IN PARISHES AROUND THE RAVENGLASS ESTUARY

	Year				Change 1970-1985
CROP	1970	1975	1980	1985	(Ha)
WHEAT	0	0	0	0.1	+ 0.1
BARLEY (TOTAL)	284.8	515.6	444.7	484.4	+ 199.6
(SPRING)	N/R	N/R	405.4	457.6	N/R
(WINTER)	N/R	N/R	39.3	26.8	N/R
OATS	142.2	61.9	53.7	10.0	- 132.2
MIXED CORN	40.3	15.7	7.6	4.5	- 35.8
RYE	36.5	0.8	12.5	12.6	- 23.9
POTATOES (TOTAL)	55.6	32.8	23.9	42.2	- 13.4
(EARLY)	16.3	6.8	N/R	N/R	N/R
(MAIN)	39.3	26.0	N/R	N/R	N/R
MAIZE	0	4.4	7.8	6.5	+ 6.5
HORTICULTURE	9.0	2.8	2.5	1.7	- 7.3
TURNIP, SWEDE	69.8	83.1	31.2	38.0	- 31.8
KALE, CABBAGE AND RAPE	83.6	44.7	30.1	10.6	- 73.0
OTHER CROPS	10.5	23.4	13.8	0.2	- 10.3
BARE FALLOW	8.8	25.9	25.3	3.0	- 5.8
LUCERNE	10.2	5.2	0	0	- 10.2
GRASS (TOTAL)	7,757.6	7,887.4	9,306.4	9,044.2	+ 1,286.6
(PERMANENT)	5,455.4	6,265.0	7,622.2	7,419.8	+ 1,964.4
(TEMPORARY)	2,302.2	1,622.4	1,686.2	1,624.4	- 677.8
ROUGH-GRAZING	8,981.8	8,415.3	7,600.4	7,254.8	- 1,727
WOODLAND	71.6	106.7	181.8	233.7	+ 162.1
OTHER	12.0	19.5	70	75.8	+ 63.8
TOTAL AREA	17,575.8	17,245.2	17,813.7	17,222.3	- 353.3

parishes of Eskdale and Muncaster where fell land has been improved to provide better grazing for sheep. Also in these inland parishes there has been an increase in the number of hectares of woodland. In the lowland parishes closest to the Ravenglass reserve the major change in agricultural policy since 1970 appears to be the planting of spring barley in place of oats.

It is unlikely that any of these changes have significantly reduced the availability of earthworms to feeding flocks of Black-headed Gulls. The improvement of hill land would, if anything, be expected to increase the availability of earthworms as gulls would find it easier to feed. Evidence for this comes from Wasdale where gulls fed on pasture land at all times and were seen to feed on rough grazing areas only late in the breeding season following the beetle hatch. If drainage has occurred in lowland as well as upland areas then it is possible that the lowland pastures where flocks of gulls have been observed to feed, especially during the pre-breeding season, may be less liable to flooding so reducing the availability of earthworms. It is impossible to answer this question using the data presented above. However, the occurrence of large flocks of gulls in these flooded pasture fields in recent years (Chapter 7) suggests that the fields are still sufficiently wet to provide feeding sites.

The switch from oats to spring barley in the fields nearer the gullery site itself will not reduce the amount of ploughing (hence earthworm availability) as both crops are planted following spring ploughing (Halley 1982). Therefore, it seems unlikely that any changes in agricultural policy around the Ravenglass estuary can have reduced the food supply available to Black-headed Gulls sufficiently to cause gulls to leave the Ravenglass area to breed.

6.3 HABITAT CHANGES ON THE RAVENGLASS L.N.R.

Any change in the habitat in or immediately surrounding the Black-headed Gull nesting areas at Ravenglass could reduce the attractiveness of the site to breeding gulls. An increase in the height of the vegetation could prevent all round visibility by gulls on nests and allow predators to enter the gullery undetected. A change in the areas surrounding the gullery could make the gullery itself more accessible to predators which would consequently be able to prey on gulls or their nests.

6.3.1 METHODS

Information was collected from the literature concerning Ravenglass on the habitat surrounding and in the gullery. In addition, aerial photographs of the site were obtained from Oxford University and comparisons made between the vegetation present at the time of the photographs (1963) and other studies of vegetation.

6.3.2 RESULTS

6.3.2.1 ORIGINS OF THE COLONY SITE AT RAVENGLASS

Before considering habitat changes in detail it is interesting to consider how the gullery came to be at Ravenglass in the first place. The colony site at Ravenglass is atypical for Black-headed Gulls (Burger 1976, Cramp and Simmons 1983) as the species appears to prefer nesting on islands or floating vegetation in fresh or brackish water. The origins of the peninsula at Drigg are not known but Steers (1964) suggests it to be a relatively recent feature. P Gordon-Duff-Pennington (pers. comm.) considers that, until the late 1860's the River Irt flowed straight out into the Irish Sea and did not join the Mite and Esk. It is not clear whether the Irt changed its course abruptly or if it gradually moved southwards and took up its present course over a longer period. The presence of a series of raised "bars" towards the southern end of Drigg Point suggest the latter. These bars carry fertilised vegetation reminiscent of that found on the gullery site itself (Dargie 1971) so it is possible that gulls have nested on them in the past. This could have been for one of two reasons, i) the raised areas provide all round visibility to enable early detection and hence defence against predators or ii) the raised bars were sand or shingle islands, formed as the River Irt moved south and which were cut off from the mainland. These would have provided safe nest sites for gulls and terns. Whatever the actual timescale of the Irt's change of course it is possible that the bird colonies at Ravenglass originally formed on areas without easy access from mainland areas and were already large before the site became joined to the mainland as part of the Drigg peninsula. This suggests that the existence of mammalian predators in the gulleries may be a relatively recent phenomenon so the poor productivity of the colony recorded in Chapter 5 may also be recent.

Little information is available concerning the habitat preferences of breeding Black-headed Gulls. Burger (1976, 1977), however, looked at nest density of larid species in relation to the vegetation around their nest sites with particular reference to visibility. One of the species considered was the Black-headed Gull and work was carried out at Ravenglass and nearby at Siney Tarn (see figure 2.1).

At Ravenglass, Burger (1976) found that Black-headed Gulls preferred to nest in marram areas on the dunes as opposed to within areas of nettles. Marram areas, however, were replaced by nettles after a few years due to fertilisation by the birds' guano. She also found that movements between areas of the colony were almost always from areas of nettles to areas of marram and that after a few years the marram areas recovered so birds moved back into them. Burger suggested that natural selection might favour nesting in marram since these areas provided cover early in the season which would reduce predation on eggs and incubating adults. This is because nests in the marram have some cover early in the season whereas nettle areas are bare at the time of egg-laying so nests are completely exposed. Later in the season when nettles grow higher and denser than marram, they may provide cover for chicks. Patterson (1965) suggests that all chicks hide in the nettles as they are highly mobile.

Burger (1977) also showed that intra-specific hostility between pairs of gulls was greater in more open habitats and concluded that the lower densities of Black-headed Gulls in nettle areas (28 Ha^{-1}) than in marram areas (43 Ha^{-1}) may result from spacing being decided before nettle growth was advanced.

Although not giving complete coverage over the whole of the gullery areas the aerial photographs clearly support the work of Burger. The majority of birds were found to be nesting in areas of marram grass. This also supports the findings of Patterson (1965) who found areas of marram to be preferred over areas of nettles. It seems, therefore, that Black-headed Gulls at Ravenglass preferred to nest in areas of marram grass rather than nettles so any change in the vegetation on the colony sites would be of importance. Data were collected during the 1984 breeding season and is discussed in Chapter 7. Historical data are presented here.

Apart from the aerial photographs from 1963, little information is available on the vegetation of the gulls' breeding sites at Ravenglass. The only data available are from Dargie's (1971,1976) two surveys of the vegetation of Ravenglass L.N.R. Figure 2.2 summarises the findings of Dargie's 1976 survey. One feature is immediately apparent from figure 2.2. The areas described by Dargie as containing "bird colony vegetation" (i.e. nettles) are confined to the southern tip of the peninsula. This is interesting as until that year Black-headed Gulls had nested up the west side of the peninsula. There is no sign of the northern gullery area on Dargie's map. However, on the 1963 aerial photographs a dark area, presumably nettle vegetation, is visible on the site of the northern gullery on the western side of the reserve. This suggests that, as this sub-colony had declined to extinction in 1976 the nettle vegetation had returned to marram as less gulls fertilised the area.

Considering the vegetation of the reserve as a whole Dargie (1976) suggests that in the years since his previous survey in 1971 there was a tendency for vegetation to stabilise with less areas of open sand being present and more marram areas tending towards the more stable yellow dune turf.

6.3.3 DISCUSSION

Black-headed Gulls at Ravenglass appear to prefer nesting in areas of marram grass, however, use of these areas results in fertilisation by guano causing dense nettle growth to take over. These nettle areas are not as popular with nesting gulls as the more open marram areas but may be important for chicks as hiding places. Burger (1976, 1977) showed that Black-headed Gulls at Ravenglass moved from nettle areas to marram areas and that nettle areas reverted to marram in the absence of fertilisation by guano. This suggests that a decrease in the available area of open marram vegetation on the site could reduce the size of the nesting area available to gulls and consequently reduce colony size. Little information is, however, available except that Dargie (1976) considered the vegetation of the reserve as a whole to be stabilising and the total area of bare marram to be decreasing. Considering Dargie's map of vegetation (figure 2.2) however, there appeared to be large areas of open marram on the west of the reserve not being used as breeding areas by Black-headed Gulls.

In terms of the vegetation surrounding the gullery sites there appeared to have been stabilisation with areas of open sand colonised by marram and marram areas tending towards more stable yellow dune turf. It is possible that this increase in vegetation density in areas near the gullery reduced the visibility of birds in the gullery and so allowed predators easier access to the colony; or that gulls left the site as a response to this reduction in visibility. In addition to this stabilisation of vegetation there appears to have been a reduction in the level of the water table (J Rose pers. comm.) over the period 1971-1983 possibly as a result of an increase in ground level due to less sand being blown away from the area as the vegetation became thicker. J Rose, H Falkus and H Kruuk (pers. comms.) all remember the large dune valley at the southern end of the peninsula (immediately behind the main sub-colony area) as being much wetter in Spring in the 1960's than in later years. Indeed, film taken by H Falkus between 1963 and 1966 shows that this area was flooded in Spring giving the impression that the main gullery site was an island. It is possible that this is the way in which the spit built, and that, as the water table fell, the period during each summer when the gullery was protected by water from predator access gradually reduced until the flooding of the large dune valley became a rare occurrence and eventually the gullery was connected to the mainland at all times. Without more information it is impossible to speculate further as to the importance of the vegetation and water table in the selection of nest sites by Black-headed Gulls and their accessibility to predators. Work was carried out in the 1984 breeding season on the areas of the reserve favoured by nesting Black-headed Gulls and is reported in Chapter 7.

6.4 WEATHER

As Black-headed Gulls at Ravenglass appear to select earthworms as a food-source the influence of weather factors on the availability of worms is important. In addition, poor weather conditions such as low temperatures, rain or snow could adversely affect the viability of eggs, especially as not all clutches are incubated from the laying of the first egg especially early in the season (Beer 1962, Kruuk 1964).

6.4.1 METHODS

For the period 1971-1987

Weather records were available from Eskmeals Ministry of Defence weather recording station 1km. south of the Ravenglass estuary. Data were only available on a monthly basis and the following variables were recorded, for each month; mean maximum daily temperature, mean minimum daily temperature, mean daily temperature, maximum temperature, minimum temperature (all in ^{o}C), total monthly rainfall (mm).

Unfortunately, little information was available concerning the breeding success of Black-headed Gulls at Ravenglass during the period for which weather data were available so it was impossible to investigate the effect of weather in any detail. Correlations between weather conditions in February and March and the number of pairs of Black-headed Gulls settling to breed were made.

6.4.2 Results and Discussion

Data on weather factors for the breeding season months (Feb.-Aug.) is given in Appendix 8. There were no significant correlations between the size of the Ravenglass gullery and any of the recorded weather factors for February, March or April in the period 1971-1985. This suggests that weather conditions in the pre-breeding season at Ravenglass did not directly affect the number of Black-headed Gulls settling to breed at the colony site.

Thompson et al. (1985) studied the effects of weather conditions on the breeding performance of a population of Greenshanks (Tringa nebularia) in North-West Scotland. They concluded that a range of climatic and female-specific factors appear to shape breeding performance in Spring and Summer and specifically that Greenshanks laid heavier eggs and completed clutches earlier in years when early spring was warm. They suggested that this was influenced by energy supply and food requirements of female Greenshanks, however, birds had to breed early enough to provide fledglings and adults with sufficient time to build-up pre-migratory fat reserves (Evans and Pienkowski 1984). Thompson et al. results, therefore, suggested a balance between breeding earlier in order to have a longer period in which to build-up fat for migration and the need for females to build-up sufficient energy for egg-production. Warm periods in early Spring appeared to increase prey availability and produced an earlier clutch. If the same is true for Black-headed Gulls at Ravenglass then it would be expected that earthworms would be available in warm wet Springs and that laying date and clutch weight would be greater in such years. Unfortunately data are only available on laying date for one year; 1984. Rainfall figures for March, April and May 1984 were all lower than the ten-year average 1975-1984 and the media laying date was later than previously recorded (Chapter 7). It may be that weather has an effect on the breeding cycle of Black-headed Gulls at Ravenglass as this anecdotal example suggests. In the absence of any firm data, however, no conclusions can be drawn.

6.5 DISCUSSION

As with predation and disturbance, little quantifiable evidence exists concerning food availability and habitat change at the Ravenglass gullery. Available information suggests that Black-headed Gulls breeding at Ravenglass feed predominantly inland and mainly on earthworms (Macpherson and Duckworth 1886, Tinbergen 1962). This is interesting as there is, in the Ravenglass estuary, a large mud-flat area with apparently abundant food and Black-headed Gulls are known to feed on mudflats, especially in the Winter (e.g. Curtis et al. 1985, Crook 1953, Vernon 1970). As Black-headed Gulls from Ravenglass appear to feed on earthworms throughout the breeding season then factors affecting the abundance and availability of earthworms would be expected to affect the food supply of Black-headed Gulls and possibly affect breeding success in some years.

There have been changes in land-use on farms surrounding the Ravenglass estuary in recent years, however, these have been slight and unlikely to have reduced the food supply available to Black-headed Gulls at Ravenglass. The influence of weather factors on the availability of earthworms is not so clear. It would be expected that earthworms would be more available in wetter conditions as they tend to burrow deeper in dry times (Gerard 1967) and so the amount of rainfall during the season may have an important effect on the amount of available food and so breeding success of Black-headed Gulls at Ravenglass. Unfortunately, there is insufficient data to allow a comparison between aspects of the breeding cycle of Black-headed Gulls and weather variables so it is impossible to comment further.

It was also impossible to carry out an analysis of the effects of habitat change at the gullery itself on the colony of Black-headed Gulls. There is some evidence (Burger 1976, 1977) that gulls prefer nesting in marram grass rather than in nettles, however, little information is available concerning changes in the vegetation on the gullery site during the period of the gull decline so further speculation is unwise at this point.

Possible effects of food shortage and habitat change on the observed decline in the Ravenglass gullery cannot be ruled out and so must be considered as possible important agents in the decline.

1984 BREEDING SEASON AT RAVENGLASS

The model presented in Chapter 4 suggested that two of the major factors involved in the observed decline in the population of breeding Black-headed Gulls at Ravenglass were poor production of young birds leading to low recruitment and lack of fidelity to Ravenglass by surviving adult birds. Historical evidence (Chapters 5 and 6) suggests that production of young may have been affected by predation in certain years or by food shortage in years when the gulls' preferred foodstuff, earthworms, were in short supply, and that the accessibility of the colony to ground predators may have been affected by habitat changes in the vicinity of the colony site. In addition it was considered that the effects of predation, disturbance and perhaps vegetation change may have been to dissuade adult gulls or first-time breeders from settling to breed at Ravenglass or to abandon a breeding attempt in mid-season. Thus a number of possibilities as to the cause of the decline were suggested which all acted during the breeding season (see figure 1.2). To investigate which, if any, of these breeding season factors were likely to have affected the breeding population of Black-headed Gulls at Ravenglass the colony was studied in Summer 1984. The intention of this pilot project was to study the whole breeding season to narrow down the possible causes of breeding success perturbations and to concentrate on these in subsequent breeding season studies at Ravenglass.

The breeding season was divided into the following periods:-

i) The pre-laying period. This period included the build-up of pre-breeding flocks of Black-headed Gulls around the estuary, colony prospecting behaviour, settling at the colony, courtship, nest-building and copulation. The time taken for this period is roughly 4-5 weeks.

ii) The laying and incubation period. For each nest the incubation period is roughly 24 days (Cramp and Simmons 1983) however, for the whole colony asynchronous nesting meant that not all nests were in the same incubation state at the same time.

iii) The hatching and chick growth period. The fledging period for Black-headed Gulls is about 35 days (Cramp and Simmons 1983).

As previously stated, any factors affecting the number of Black-headed Gulls coming into the Ravenglass area, prospecting at the colony site and subsequently staying to breed would be expected to alter colony size. Modelling and a consideration of historical data concerning the Ravenglass gullery suggest that food shortage or disturbance could be important factors influencing the settlement patterns of adult Black-headed Gulls at Ravenglass. To study the possible effects of these, observations were made in the pre-breeding season both at and away from the Ravenglass colony area. (see Chapter 9).

7.1.1 METHODS

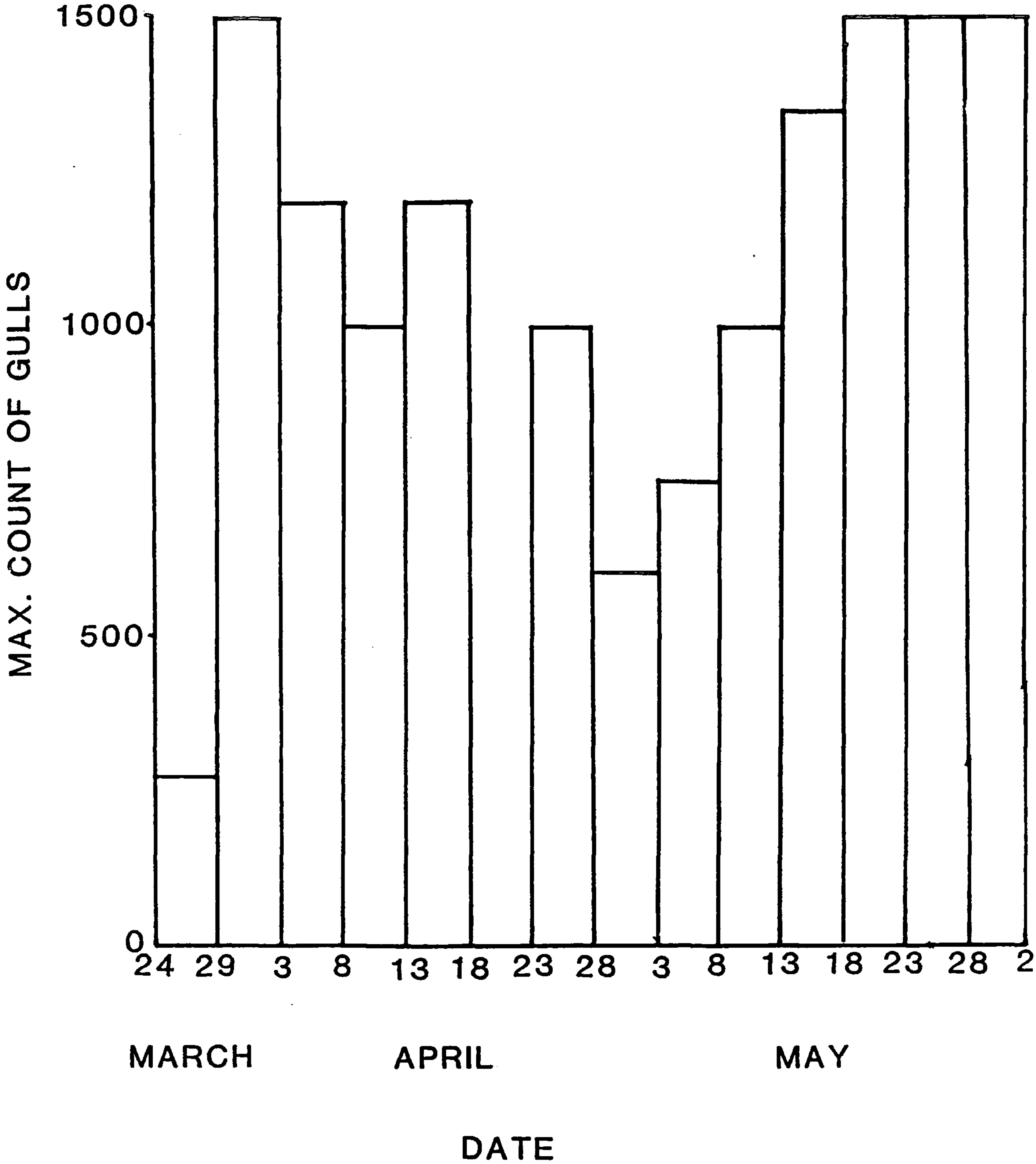
Counts of Black-headed Gulls were made at the colony site on two out of every five days from mid-March onwards. Watches were made in the early morning or evening to coincide with the peak in numbers of gulls visiting the colony site (Patterson 1965). Counts were made from a dune overlooking the colony site using 10x binoculars and a 30x telescope.

7.1.2 RESULTS AND DISCUSSION

The counts at the Ravenglass colony site (fig. 7.1) show that in 1984 the gullery was first occupied by small numbers of gulls, between the 24th and 29th of March. This was followed by an influx on 30th March when 1,500 gulls were counted on the site. Numbers then fell slightly but remained between 1,250 and 1,000 birds until mid-April. On 19th April the colony site was deserted. This occurred even though nest-building and courtship behaviour were well advanced. The weather at the time of colony desertion was thick fog with visibility as low as 50m. As the weather cleared slightly, the gulls became visible sitting on Eskmeals beach on the opposite side of the estuary. Investigation of the colony site revealed the presence of mink and fox footprints, although no dead gulls were found. It seems likely that the gulls deserted the colony site at this time in response to disturbance by potential predators in the gullery. During the time gulls sat on Eskmeals beach courtship behaviour and copulations were noted. The Ravenglass gullery was re-occupied on 21 April when the weather

FIGURE 7.1

COUNTS OF BLACK-HEADED GULLS AT THE RAVENGLASS COLONY SITE 1984



cleared. However, despite eggs being laid soon after this re-occupation, peak counts of gulls each day remained low until early-May.

7.2 THE LAYING AND INCUBATION PERIOD

Introduction

Any factor reducing either the number of eggs laid or hatched would be expected to lower the production of fledged chicks by a colony of gulls. If breeding success decreased in a number of years then the number of potential new recruits from Ravenglass would be reduced, perhaps even below that required to balance the mortality of breeding adults. Colony size would then decrease. Breeding success at other colonies may also be important in providing breeding recruits for Ravenglass.

To investigate possible causes of breeding failures a number of aspects were studied; timing of first egg, spread of laying dates, total nest counts, clutch sizes, causes of egg loss, egg volume and nest-spacing. In addition, information was collected on the densities of nests in different habitat types.

7.2.1 METHODS

Following the gulls' return to the colony site after the desertion on 19th April 1984 the colony site was visited at two day intervals to determine the dates of laying of first eggs. Thereafter nests were visited once every five days. In order to count colony size accurately all nests were marked using split cane markers. Of these markers 700 were individually numbered, this enabled a large sample of nests to be followed as not all nests were found on each visit. A nest was considered "initiated" if an egg was present on any visit to the colony.

Clutch size was taken as the maximum number of eggs in a nest through the season and was not corrected for egg loss between visits during laying. Survival and success of nests and eggs to the hatching stage were calculated using the "Mayfield method" (Mayfield 1961, 1975, Johnson 1979, Erwin and Custer 1982 : see Appendix 9) which takes into account nests which were not visited daily. Egg volume was calculated using the method of Coulson 1963 (Appendix 10). Observations were made to attempt to observe predation on eggs or adults. No equipment was available to enable nocturnal observations to be made. During visits to the colony observations were made of predation on eggs and where possible the cause of any predation was recorded. As previously stated it was not possible to use a hide in the colony area.

Nest-spacing was calculated at the end of the breeding season when the gulls had left the site, using the cane markers which were visible even though the vegetation had grown up on the colony site. Two measures of nest-spacing were recorded, nearest neighbour distance and the number of other nests within a 1m radius of the centre of the nest being considered. This allowed comparison with data collected at the same colony by Patterson (1965). The densities of nests in marram grass and nettle areas were recorded at the end of the breeding season.

7.2.2 TIME OF LAYING OF FIRST EGG

Table 7.1 summarises information from 1984 and earlier years. The date for 1984 is later than any previously recorded.

The slight delay in laying of the first egg of the first clutch at the colony in 1984 compared to previous years might have resulted from low food availability in the pre-laying period. However, data from subsequent years (Chapters 8 & 9) suggest that, unless the weather in the early part of the year is exceptionally dry, gulls will be able to find sufficient food to attain breeding condition by mid-April. Another possibility was that young birds formed the majority of the colony since Perrins (1970) and Coulson and White (1958, 1960) showed for a number of species that inexperienced breeders tend to lay later in the season. Unfortunately, no recoveries of ringed birds have been made at Ravenglass in recent years so it was impossible to check the age composition of the breeding population of Black-headed Gulls in 1984. Darling (1938) suggested that in social breeding birds, reproductive success is related to colony size and that below a certain threshold of numbers breeding may be totally unsuccessful. This "social stimulation" hypothesis was invoked by Goodbody (1955) to explain differences in laying date between two colonies of Black-headed Gulls in Aberdeenshire. However, at Ravenglass the first egg in 1970, when colony size was at its peak, was laid on 22 April, later than in subsequent years when colony size was smaller.

TABLE 7.1

DATES OF LAYING OF FIRST EGGS AT RAVENGLASS

YEAR	DATE OF FIRST EGG	SOURCE
1960-1963	12th-15th April	Kruuk 1964
1970	22nd April	Rose 1970
1977	22nd April	Rose 1977
1981	17th April	Rose 1981
1982	19th April	Rose 1982
1983	20th April	Rose 1983
1984	24th-26th April	This study

Figure 7.2 shows the spread of laying dates of first eggs in 1,514 nests at Ravenglass in 1984. Similar data for first clutches in 1962 (Patterson 1965) are presented in figure 7.3. As no birds were individually marked at Ravenglass in 1984 no information is available concerning possible replacement nests so all the data are included.

The median date of clutch initiation was significantly later in 1984 than in 1962 by two weeks (Median test (Siegel 1956); $X^2 = 214$ 1df $p \ll 0.001$). Using the 'mid-point method' of Gochfield (in Burger et.al. 1980) to examine synchrony (table 7.2) it was found that Black-headed Gulls nesting at Ravenglass in 1984 were significantly less synchronous in the date of clutch initiation than in 1962 (1984; mean date of clutch initiation was 18.2 $\pm$ 0.17(S.E.) days from the date of the first egg in the colony; 1962 mean date of clutch initiation was 8.75 $\pm$ 0.34 (S.E.) days from the date of the first egg in the colony; d test, $d = 25$, $p \ll 0.001$). Various workers have suggested that in species with a fairly vulnerable brood, synchronisation of egg-laying probably functions to reduce total egg predation by a swamping effect (Patterson 1965, Darling 1938, Ashmole 1962). For a number of passerine species e.g. Great Tit (Perrins 1963) the peak of laying occurs on different dates in different years and is correlated with variations in the date of the peak of the food supply. Patterson (1965) concluded that as the date of the first Black-headed Gull egg had varied at Ravenglass only within four days in the previous eight years the peak of earthworm abundance at Ravenglass either did not change from year to year or was unimportant in the regulation of breeding synchrony. It is possible that the changes in median dates of laying since 1962 have occurred as a result of changes in availability of food but this seems unlikely (Chapter 9) and the synchronisation of breeding among Black-headed Gulls at Ravenglass is likely to have an anti-predator function, as suggested by Patterson (1965). If Patterson was correct then any lengthening of the nesting period would be likely to increase susceptibility to predation and so reduce breeding success.

The cause of the increased spread of laying dates in 1984 is not clear. It is possible that the "social stimulation" mentioned earlier was lacking so birds were not synchronous in their breeding effort or that the supply of food in the area was not sufficient to enable all the females to attain breeding condition at a similar time. It is also possible that the observed disturbance of gulls during the pre-breeding period caused birds to desert the colony site or to delay breeding so leading to asynchronous laying.

FIGURE 7.2

SPREAD OF DATES OF CLUTCH INITIATIOI

RAVENGLASS 1984

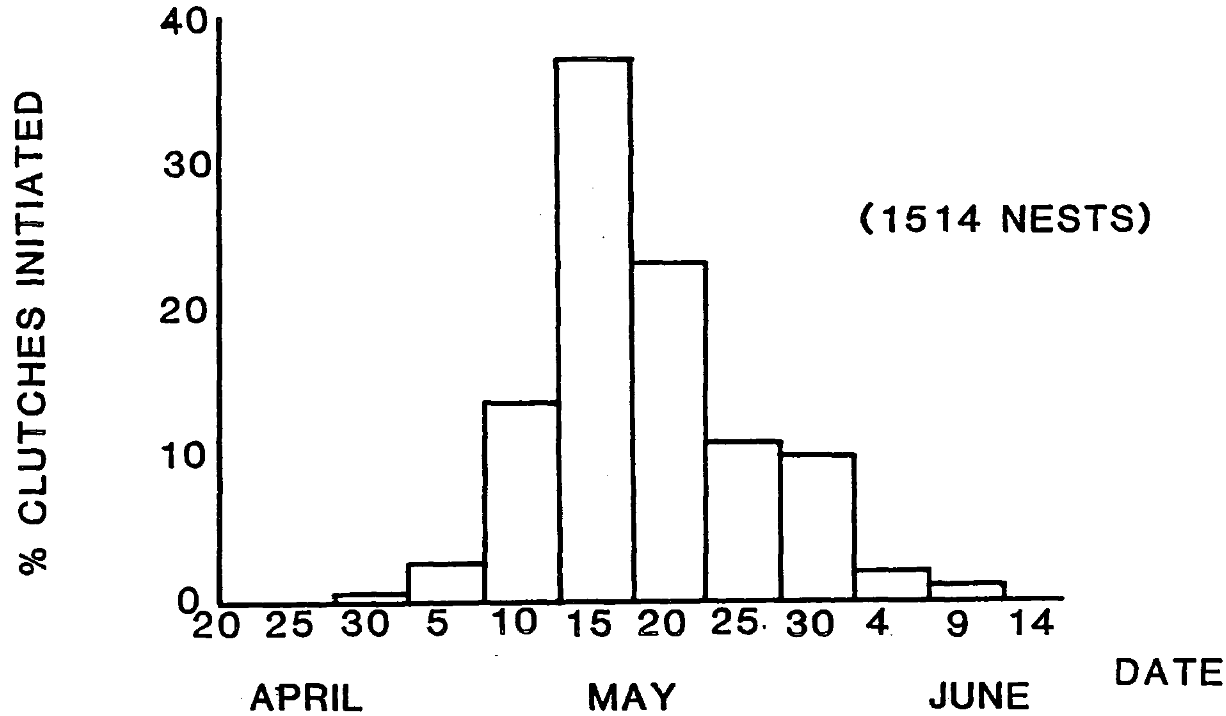


FIGURE 7.3

SPREAD OF DATES OF CLUTCH INITIATIO

RAVENGLASS 1962 (FROM PATTERSON 1965 :

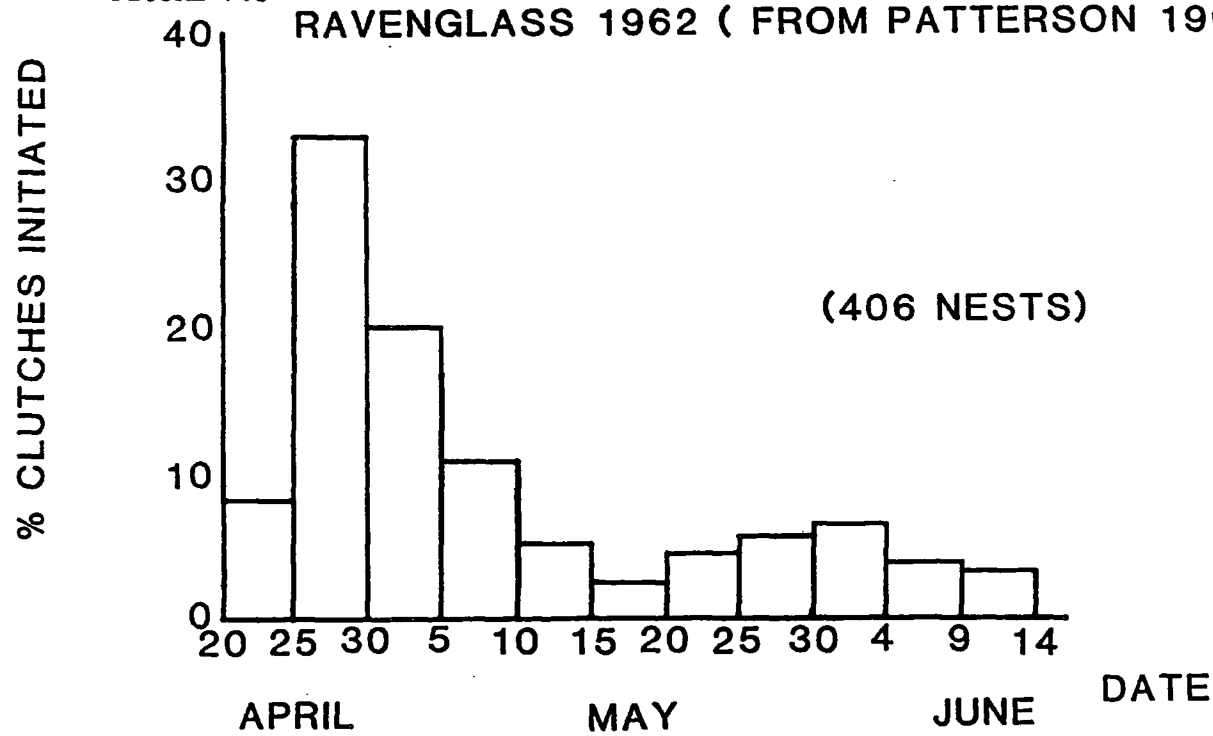


TABLE 7.2

SYNCHRONY OF NEST INITIATION AT RAVENGLASS IN 1984

DAYS FROM INITIATION OF FIRST NEST	NO. (%) OF NESTS INITIATED
0 - 4	4 (0.25)
5 - 9	39 (2.5)
10 - 14	205 (13.5)
15 - 19	563 (37.0)
20 -24	353 (23.25)
25 - 29	164 (10.75)
30 - 34	149 (9.75)
35 - 39	28 (1.75)
40 - 44	9 (0.05)
TOTAL	1,514

Tables 7.3 a) and b) show the results of the measurement of numbers of nests within 1m. and of nearest neighbour distances in 1984, together with those for 1962/63 (Patterson 1965). In order to minimise disturbance, measurements of inter-nest distances were carried out at the end of the breeding season; however, by this time some markers had been removed by gulls or hidden by nettles and only one area was found where all the markers were still in their places. There were no significant differences between the 1984 and 1962/3 results for either nearest neighbour distance ($d=0.698$, 498 df, $p>0.10$) or the number of nests within 1m of the chosen nest ($d=1.13$, 158 df, $p>0.10$). This suggests that the gulls breeding at Ravenglass were still spaced relative to each other in 1984 as they were during Patterson's study, although the size of the colony as a whole had decreased. Patterson (op. cit.) presented a formula to determine random distribution of nests in a colony and found that the distribution of Black-headed Gull nests in 1962/63 was more uniform than random (see appendix 11). This was true also in 1984 (X^2 Test; 2d.f. $X^2 = 37.09$ $p<0.001$). Also, Southern et al. (1985) found that for Ring-billed Gulls which were exposed to nine years of fox predation the distribution of nests remained clumped as the colony size decreased. However, the space occupied by each pair increased so birds spread out slightly when numbers of breeding pairs fell.

Patterson found no link between nest-spacing and breeding success. However, he considered that clustering of nests worked alongside breeding synchrony as an anti-predator system. It seems, therefore, that the nest distribution aspect of anti-predator behaviour in the Black-headed Gull colony at Ravenglass has not changed since the time of Patterson's study although the timing and synchrony of breeding have changed.

Because a number of nest markers had been destroyed or up-rooted by the end of the breeding season an accurate picture of habitat selection could not be obtained. From impressions gathered during the season, however, the earliest nests all appeared to be in areas of marram grass whereas later nests were also in the nettle areas. Areas of dense nettle growth were used by chicks as hiding places, making it difficult to locate them during many visits to the colony (see section 7.3.4).

TABLE 7.3

INTER-NEST DISTANCES IN THE RAVENGLASS BLACK-HEADED GULL COLONY

a) No. nests m^{-2}

YEAR	N	Mean no. nests m^{-2} ($\pm$S.E.)
1962/63	477	0.37 ($\pm$0.009)
1984	23	0.40 ($\pm$0.042)

b) Nearest Neighbour Distance

YEAR	N	Mean distance to nearest nest ($\pm$S.E.)
1962/63	137	1.27m ($\pm$0.059)
1984	23	1.42m ($\pm$0.117)

Table 7.4 summarises data from Ravenglass in 1984 and from earlier studies. The clutch size recorded at Ravenglass in 1984 was significantly smaller than in the other four studies. It is possible that Black-headed Gulls at Ravenglass experienced difficulties in obtaining food prior to the 1984 breeding season so laid smaller clutches; however this is unlikely (see Chapter 9). More likely, however, is that the observed reduction in clutch size at Ravenglass in 1984 came about as a result of the method of recording clutch size. In all the studies mentioned previously, workers took account of eggs predated during the laying period. However, to reduce disturbance, in 1984, nests were checked only every five days. Thus, any eggs lost during the laying period were not recorded except as a reduction in clutch size. Southern et al. (1985) recorded clutch size in the same way and found a decrease in both Ring-billed and Herring Gull clutch sizes when exposed to fox predation over a period of nine years.

The most likely explanation for the reduced clutch size among Black-headed Gulls at Ravenglass in 1984 is that eggs were lost during the laying period as a result of predation, probably by foxes (see later). The first eggs in fifteen early nests were marked individually using a marker pen. All disappeared in the five day period between marking and the next visit. Tracks in the sand surrounding the nests suggested foxes as the predators responsible. I was concerned that the marking of eggs was making them susceptible to predation so it was stopped, consequently a, b and c eggs could not be identified.

Southern et.al. (1985) also concluded that disturbance by nocturnal predators such as foxes resulted in panic flights by Herring Gulls (also recorded for Black-headed Gulls by Kruuk (1964). This caused up to 8% of eggs to be knocked out of nests and so lost. However, panic flights were not recorded at Ravenglass in 1984 and are not considered to be of importance in that year.

7.2.6 EGG VOLUME

A sample of 116 eggs had a mean egg volume (±SE) of 35.41 (± 0.30) cm. Little information is available in the literature concerning egg-volume in Black-headed Gulls (see Chapter 8).

TABLE 7.4

CLUTCH SIZES OF BLACK-HEADED GULLS AT RAVENGLASS (1984) AND OTHER SITES

Site	N	Mean Clutch Size (±S.E.)	Significance of difference in clutch size from that at Ravenglass
Ravenglass[1]	489	2.34 (±0.037)	
Norway[2]	421	2.90 (±0.021)	d = 13.16 $p<<0.001$
Norway[3]	100	2.62 (±0.043)	d = 4.94 $p<0.001$
Finland[4]	450	2.82 (±0.028)	d = 10.34 $p<<0.001$
England[5]	191	2.54 (±0.054)	d = 3.06 $p<0.01$

Sources

1. This study
2. Ytreberg 1956
3. Ytreberg 1960
4. Lundberg & Vaisainen 1975
5. Weidmann 1956

Few observations were made of predators actually taking eggs. At the end of the breeding season, a sample of 314 eggshells was inspected to discover whether chicks had hatched from them or they had been taken by predators, 251 (79.9%) showed signs of predation (tooth marks in the shell, remains of blood and yolk inside the shell, torn shell membrane). Although no foxes were observed to take eggs, footprints were noted in the colony on almost all nest-checking visits.

Predation was estimated using the "Mayfield" method (appendix 8). Very few eggs were lost singly from nests so predation was estimated as the proportion of nests which survived to hatching (table 7.5). In addition to this, the Mayfield estimator was calculated for nests commenced in a given time period to compare survival of nests through the season. The results of this are also given in table 7.5. As can be seen, the overall probability of a nest surviving from one day to the next was 96%, although this was not constant through the breeding season. The chances of a nest surviving from one day to the next varied according to the date on which it was initiated (Anova $F=23.4, f_1=8, f_2=4430 p<0.001$). Multiple range tests showed that nests started early or late were significantly less likely to survive than those started around the median laying date. As there were fewer nests in the early incubation stage at these times, the swamping effect suggested by Darling (1938) and others did not apply. In terms of nests surviving to hatching (24 days Cramp & Simmons 1983) it can also be seen that nests initiated early or late in the season had less chance of hatching eggs than those started in the main period. Overall, however, it was calculated that only 36% of the nests would be expected to hatch eggs successfully.

7.3 THE HATCHING AND CHICK GROWTH PERIOD

Attempts were made to investigate chick growth and survival rates at Ravenglass in 1984 and to estimate fledging success.

7.3.1 METHODS

Hatching was recorded as successful if either chicks were found in the nest or eggs were pipping during the visits to the colony site. During these visits,

TABLE 7.5

CALCULATION OF MAYFIELD ESTIMATORS BY DATE OF NEST INITIATION FOR RAVENGLASS 1984.

Date of nest initiation	N	No. failures	Total exposure (days)	S ± S.E. see App. 8	S^{24}
21/4-26/4	4	4	12	0.67 ± 0.140	6.0×10^{-5}
27/4-30/4	27	25	135	0.82 ± 0.33	7.4×10^{-3}
1/5 -5/5	127	87	1,404	0.94 ± 0.006	2.2×10^{-1}
6/5 -10/5	229	102	3,848	0.97 ± 0.003	5.2×10^{-1}
11.5-15/5	40	24	643	0.96 ± 0.007	4.1×10^{-1}
16/5-20/5	18	16	239	0.93 ± 0.016	1.9×10^{-1}
21/5-25/5	4	4	36	0.89 ± 0.052	6.1×10^{-2}
26/5-30/5	1	1	4	0.75 ± 0.217	1.0×10^{-3}
31/5-6/6	2	2	18	0.89 ± 0.074	6.1×10^{-2}
TOTAL		265	6,339	0.96 ± 0.003	3.6×10^{-1}

any chicks found were caught and marked. Up to 5 day old chicks were too small to ring with B.T.O. metal rings so were given numbered plastic rings designed to be replaced or to fall off as the chick grew (Parsons 1976). Chicks were also weighed and measured to estimate growth rates.

7.3.2 HATCHING SUCCESS

Only 171 chicks were known to have hatched from a total of 3,459 eggs laid i.e. 5%. This underestimates the true hatching success as some chicks that hatched between visits will not have been found in the dense nettle vegetation present on the colony site at this time. Even allowing for this, however, the hatching success of gull eggs at Ravenglass in 1984 was very low.

Southern et al. (1985) recorded lower than normal hatching success in Ring-billed and Herring-Gull colonies exposed to fox predation, with minimum hatching success rates as low as 10% for Herring Gulls and 15% for Ring-billed Gulls. In contrast, Ytreberg (1956), working on Black-headed Gulls in Norway for two years, found hatching success rates of 75.3% and 78.3%. In his study there was little or no predation on eggs so these figures are representative of actual hatching rates if there is no predation. Obviously the Mayfield calculated figure of 36% for Ravenglass is well below that for a colony with no predation and it is likely that the cause is predation, either on eggs as described earlier or newly hatched chicks which were taken between colony visits. Patterson (1965) found that Herring and Lesser Black-backed Gulls frequently took newly-hatched chicks. No evidence of gull predation was, however, found in 1984 at Ravenglass. Fox tracks were found during the hatching period and some young chicks were found with tooth marks in the breast muscle consistent with fox predation. Thus foxes were probably important agents in reducing hatching success.

7.3.3 PREDATION ON CHICKS

As with egg losses, most chicks just disappeared without trace. A total of 50 were found dead and examined. Of these, four had been killed by hedgehogs and the preen gland eaten, and fourteen had severe injuries, including missing heads and torn breast muscles. These injuries are consistent with fox predation (Patterson 1965). The remaining 32 chicks had no apparent injuries and the cause of their death is unknown. An examination of the stomach contents of chicks (Chapter 9) suggested that starvation was not an important factor in chick death.

7.3.4 CHICK GROWTH RATES

Although 69 chicks were marked with rings, none was caught more than once either because they died or hid in the thick vegetation on the colony site. No chicks ringed were older than c.4 days so calculation of even average growth rates was impossible. Twelve chicks were ringed immediately upon hatching and subsequently found freshly dead (from causes unknown). Their mean period of survival ($\pm$ S.E.) was only 9.25 ($\pm$ 2.01) days; the fledging period of Black-headed Gulls is c.35 days (Cramp and Simmons 1983).

7.3.5 FLEDGING SUCCESS

No chicks successfully fledged during the 1984 breeding season at Ravenglass and the colony site was deserted by early July.

The total lack of fledging success by 1,514 pairs of Black-headed Gulls breeding at Ravenglass in 1984 was mainly due to predation of eggs by foxes. A similar breeding failure occurred at the site in 1980 and among a sub-colony in 1975. The reasons for these failures are unknown (Rose 1980). Patterson (1965) calculated fledging rates of 15.2%, 5.8% and 11.0% from eggs laid in 1962, 1963 and 1964 respectively, and ascribed the low success to fox predation.

7.4 DISCUSSION

Several aspects of the breeding cycle of Black-headed Gulls at Ravenglass in 1984 differed from those described by previous workers (Patterson 1965, Kruuk 1964, Weidmann 1956). The date of laying of the first egg in the colony was among the latest recorded, the spread of nest initiation dates was significantly longer than recorded in the early 1960's (Patterson 1965) and the median date of nest initiation was also significantly later than in Patterson's study. However, there was no significant difference in nearest neighbour distance or nest spacing between 1984 and 1962/63 (Patterson 1965). The recorded clutch size was significantly smaller than in other published studies on Black-headed

Gulls (Ytreberg 1956, 1960, Weidman 1956, Lundberg and Vaisainen 1975). Survival of nests from initiation to egg-hatching (calculated using the "Mayfield method") (Mayfield 1961, 1975, Johnson 1979, Erwin and Custer 1982) was only 36%. The mean survival time of chicks from hatching to death was 9.25 ($\pm$ 2.01)(S.E.) days and no fledged young were produced by the colony.

Observations suggested that predation by foxes was an important factor influencing the observed reduction in clutch size, egg survival, hatching success and fledging success amongst Black-headed Gulls breeding at Ravenglass in 1984. Southern et al. (1985) studied the effects of nine years of fox predation on colonies of Ring-billed and Herring Gulls on Lake Michigan. They found very similar changes in the breeding cycle to those described above even to desertion of the colony site in the early part of the season if a predator was present there.

Similar declines to that at Ravenglass have been recorded in colonies of Lesser Black-backed and Herring Gulls in Dutch dune systems (Mulder 1982, Lucas and Wonders 1986, Vader 1984) and these have been linked to predation by foxes which escaped after being kept as pets in cities and are now breeding in the dunes.

Although it is possible that the delay in starting the breeding season and the increased spread of laying dates in 1984 were due in part to other unidentified causes e.g. food shortage in the pre-laying period, nevertheless the long drawn-out laying period facilitated fox predation. Patterson (1965) considered that the patterns of nest distribution and limited spread in laying dates seen in Black-headed Gull colonies function as anti-predator systems and that the most important is synchronisation of laying and the breeding attempt. Ryder and Ryder (1981) concluded the same for Ring-billed Gulls as did Birkhead (1977) for Guillemots (<u>Uria aalge</u>). For larger species of Laridae e.g. Western Gull (<u>Larus occidentalis</u>) (Hunt and Hunt 1975) and Glaucous-winged Gull (Hunt and Hunt 1976), where intra-specific predation is the greatest agent of chick mortality, spacing of nests in relation to nearest neighbour may be more important, especially in years of low food availability.

Evidence from 1984 suggests that, probably as a result of disturbance by predators in the early part of the season, as also recorded by Emlen et.al. (1966) for Ring-billed Gulls, breeding synchrony broke down. The effect of this was to lessen any swamping of predation (suggested as important by Kruuk 1964, Patterson 1965, Ytreberg 1956 and Weidman 1956) so that each individual nest was more susceptible. The observed lowered clutch size at Ravenglass in 1984 probably resulted from predation occurring during the laying period. Evidence from calculation of the "Mayfield" nest survival estimator for nests initiated on dates through the season suggests that nests started towards the middle of the overall laying period were less likely to be destroyed by predators, supporting work quoted above.

The effects of food shortage and disturbance on breeding success and on failure of Black-headed Gulls to settle at Ravenglass were still unclear so further work on these topics was planned for 1985 at Ravenglass and at other colonies.

BREEDING PERFORMANCE AT RAVENGLASS AND OTHER CUMBRIAN BLACK-HEADED GULL COLONIES 1985-1987.

Introduction

The total breeding failure experienced by Black-headed Gulls at the Ravenglass gullery in 1984 appeared most likely to have been caused largely by fox predation and disturbance. Work during the 1985 breeding season was planned to pin-point more precisely the part of the breeding cycle at which predation and disturbance were most damaging. The model proposed in Chapter 4 showed that the overall ten-year decline in size of the Ravenglass gullery between 1975 and 1984 could have resulted simply from the 19.5% annual adult mortality (calculated from ringing data) and no recruitment of young birds to the colony. (It could also have occurred if any recruitment was balanced by emigration of adults to other colonies). The detailed time-course of the decline was not identical to the model as there was a large drop in numbers between 1978 and 1981 which, if the model was to fit would have required the annual adult survival rate to drop to 67.1%. For Black-headed Gulls in Britain no increase in annual adult mortality rate occurred at this time period however. (Mackinnon 1986). Thus, either adult birds must have left the colony site and bred elsewhere and/or recruitment from Ravenglass or other colonies, of first-time breeders must have dropped, or both.

Both Southern (1977) and McNicholl (1975) suggest that colony site tenacity and fidelity are more likely to be shown among species nesting in stable habitats. More recently, Southern and Southern (1981) have suggested that Ring-billed Gulls respond to disturbance and predation in a number of ways including reduction in colony size, by emigration to other sites.
When working on stable Ring-billed Gull colonies Southern (1977) found a well developed tendancy of adults to return to the colony where they first bred. Thus the effect of disturbance and predation was to lessen colony site tenacity in this species. Confirmation of this came from Southern et al. (1985) who found further evidence of emigration amongst Ring-billed Gulls and also Herring Gulls following nine years of fox predation. If a similar mechanism of emigration exists as a response to breeding failure in Black-headed Gulls then birds would have been expected to move from Ravenglass as a result of the poor breeding seasons in 1980 and 1984.

In addition to work in 1985 at Ravenglass itself, studies were carried out on the breeding biology of Black-headed Gulls at other colonies in Cumbria to investigate the possibility that the Ravenglass decline was not site-specific but was linked to a more widespread decline and to compare the breeding success of gulls at other inland and coastal sites with those at Ravenglass. Other shorebird species breeding at Ravenglass were also studied to compare their breeding success with that of gulls. Unfortunately, no gulls settled to breed at Ravenglass in 1985 and none have done so since so work there was confined to the pre-breeding (gathering and settling) stages of the breeding cycle.

8.1 THE PRE-BREEDING SEASON AT RAVENGLASS 1985-87

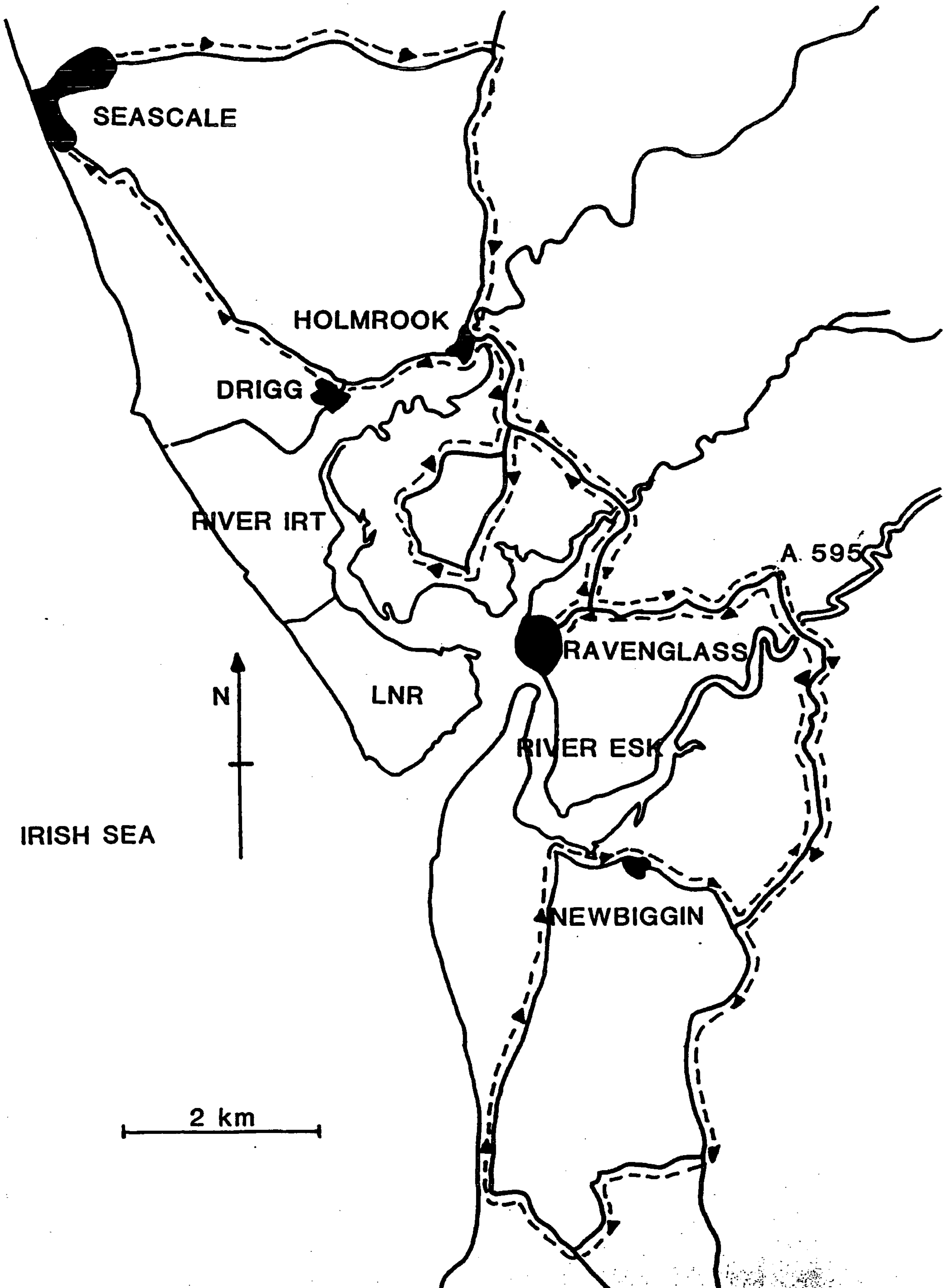
Counts of Black-headed Gulls on and around the Ravenglass estuary were made from February onwards. Counts were also made of the total number of Black-headed Gulls around the estuary complex at roughly weekly intervals through March and April, from a vehicle following a route south on the A595 (Whitehaven-Barrow road) from Seascale to Bootle then north to Waberthwaite via the coast road (figure 8.1). The number of birds feeding in different habitats were also recorded (these data are discussed in Chapter 9).

Counts of Black-headed Gulls prospecting at the colony site were made regularly through the early spring in all years. In February 1986 and early March 1987 an electric fox-proof fence was erected around the gullery site on the Drigg Dunes Reserve. This fence, 1,000m long, was intended to reduce disturbance and predation by foxes, to allow gulls to prospect unmolested. In 1987 tapes of Black-headed Gull calls were used at the colony site throughout April, together with 50 model gulls, in an attempt to attract gulls to settle within the electric fenced area.

In March of all three years a catch of gulls was made on the Drigg shore 3km north of the gullery site, using a cannon-net. In 1985, 68 birds were caught and fitted with a yellow plastic ring on each leg as well as a numbered metal B.T.O. ring; additionally, the 50 adults in the catch were dyed green (ciba-geigy green) on the tail. In 1986, 145 of the 149 birds caught were dyed green on the tail and fitted with yellow and black plastic rings (the latter incorporating a thermoluminescent dosimeter (TLD) to measure external radiation dose as part of a study undertaken by the Institute of Terrestial Ecology (ITE), Merlewood) and a numbered metal B.T.O. ring. In 1987 the

Figure 8.1

ROUTE OF COUNTS OF GULL FLOCKS IN THE RAVENGLASS AREA



catch was made chiefly to retrieve the black TLD rings used in 1986; 54 gulls were caught but only one carried a TLD ring. All individuals marked in 1987 were given a unique combination of coloured plastic rings and a metal B.T.O. ring. In all cases the birds were released unharmed. By means of the dye and the permanent coloured rings it was possible to identify birds from the Ravenglass estuary at other colonies without the need to recapture them. Adult gulls only were marked with dye so they could be spotted in feeding flocks or breeding colonies.

Results and Discussion

Low-water counts of Black-headed Gulls on the River Irt from 1985 to 1987 are shown in figures 8.2, 8.3 and 8.4. The seasonal pattern of numbers was similar in all three years, with birds arriving in the area through February to a peak in mid-March, after which some birds began to move elsewhere to breed. Gulls remaining on the estuary in June included a large proportion of first-summer birds which do not breed (Patterson 1965). Although the same pattern was evident in all three years, the peak number of birds involved decreased from 700 in 1985 to only 320 in 1987. This decrease is also shown by the counts for the whole Ravenglass estuary complex (figure 8.5) which follow a pattern similar to that on the Irt alone. For the whole estuary the maximum count of Black-headed Gulls fell from 2,500 in 1985 to only 420 in 1987.

Counts of Black-headed Gulls prospecting (before settling to breed) at the Ravenglass gullery are shown in figure 8.6. As on the Irt and the whole estuary complex, the total number of gulls prospecting at the colony site dropped considerably from 1985 to 1987 and in all years were lower than in 1984 (Chapter 7). This may be because there were fewer Black-headed Gulls in the area as a whole or was possibly a result of gulls not returning to Ravenglass following the breeding failure in 1984. In 1985 gulls actually settled on the colony site in early April but were disturbed, probably by a vixen which had an earth near the site. Tracks in the sand indicated considerable activity by foxes on the gullery site in 1985 and at least two adult gulls were killed whilst on the colony site in early April. Gulls did not attempt to resettle later in April at Ravenglass but some probably moved to other colonies (see below). In 1986, no birds visited the colony site until the end of April when a few terns prospected during a spell of fine weather. In 1987 the increased interest shown by the gulls (see below) in April coincided with the use of taped calls and model gulls at the colony site.

FIGURE 8.2

COUNTS OF BLACK-HEADED GULLS ON THE RIVER IRT 1985

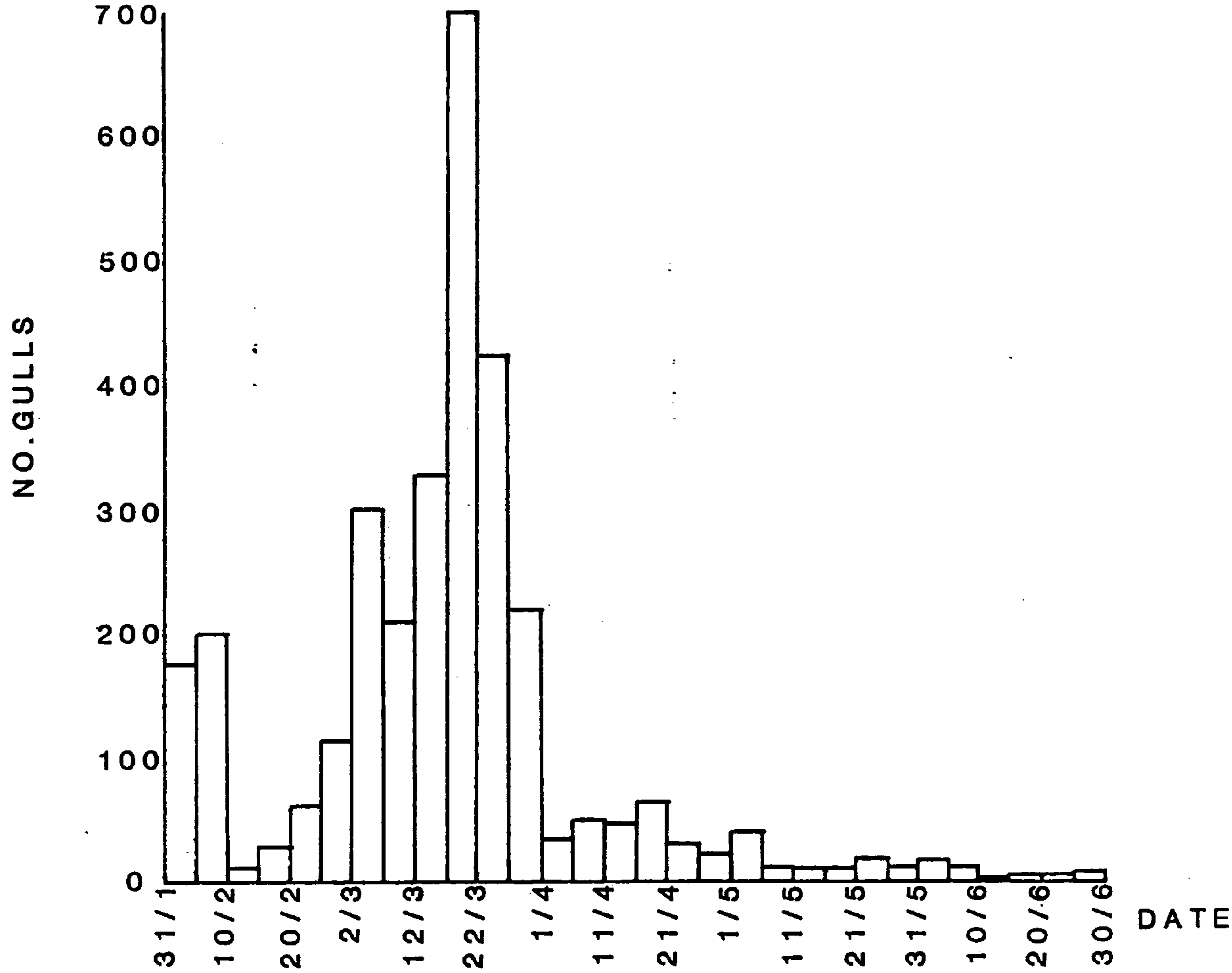


FIGURE 8.3

COUNTS OF BLACK-HEADED GULLS ON THE RIVER IRT 1986

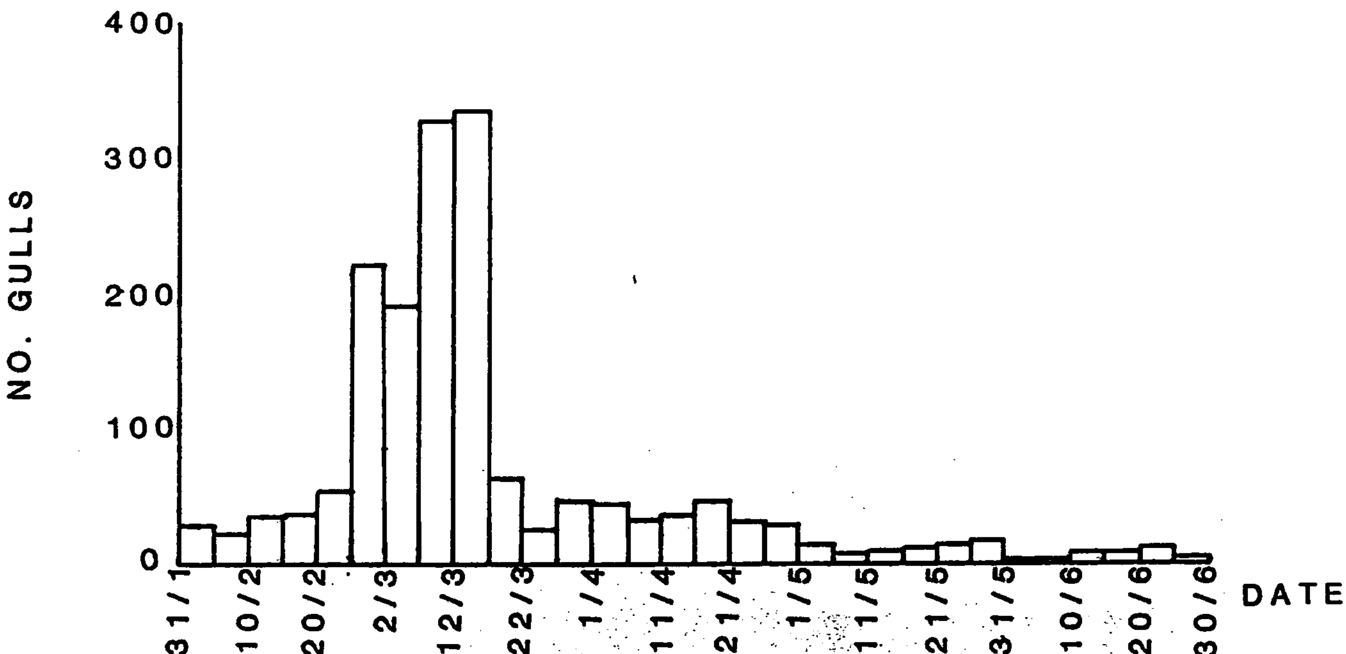


FIGURE 8.4

COUNTS OF BLACK-HEADED GULLS ON THE RIVER IRT 1987

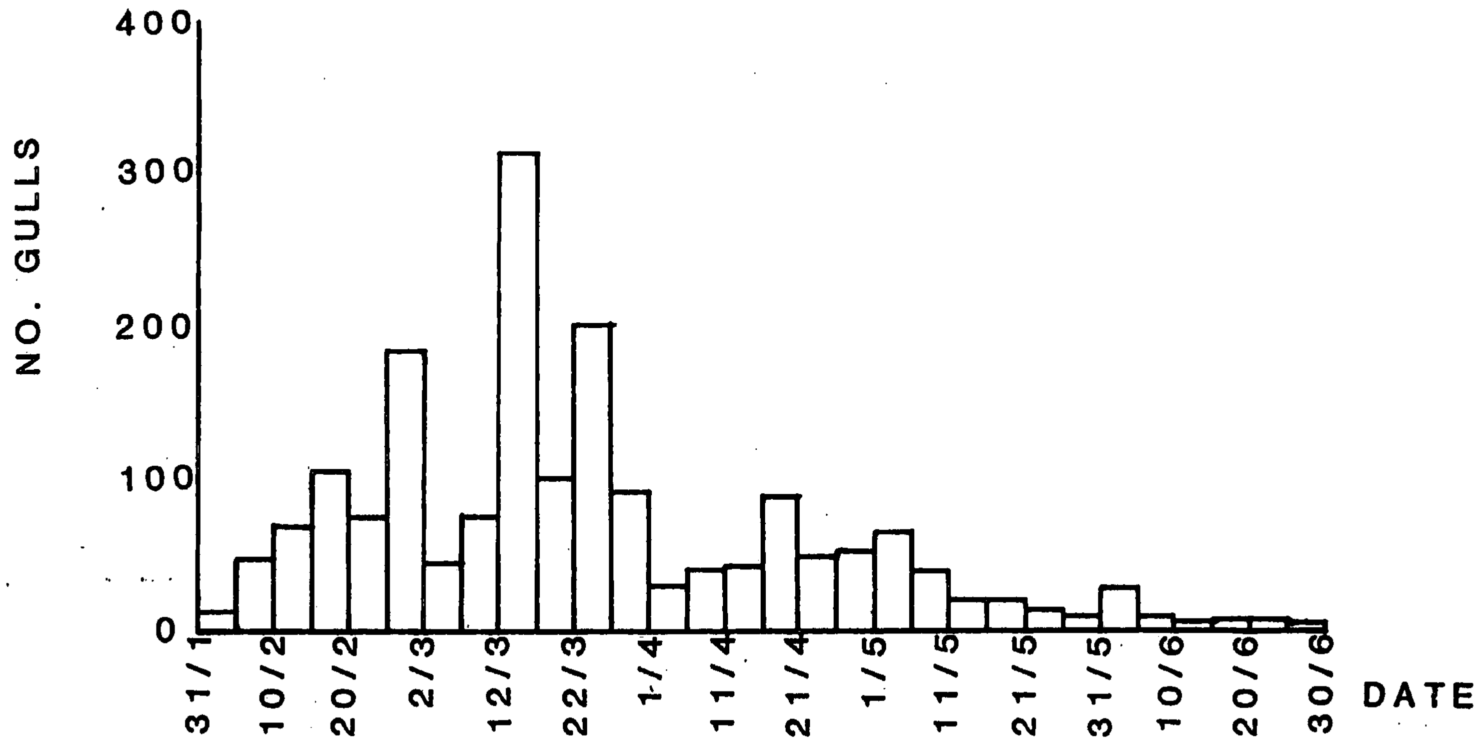


FIGURE 8.5

COUNTS OF BLACK-HEADED GULLS ON THE RAVENGLASS ESTUARY COMPLEX

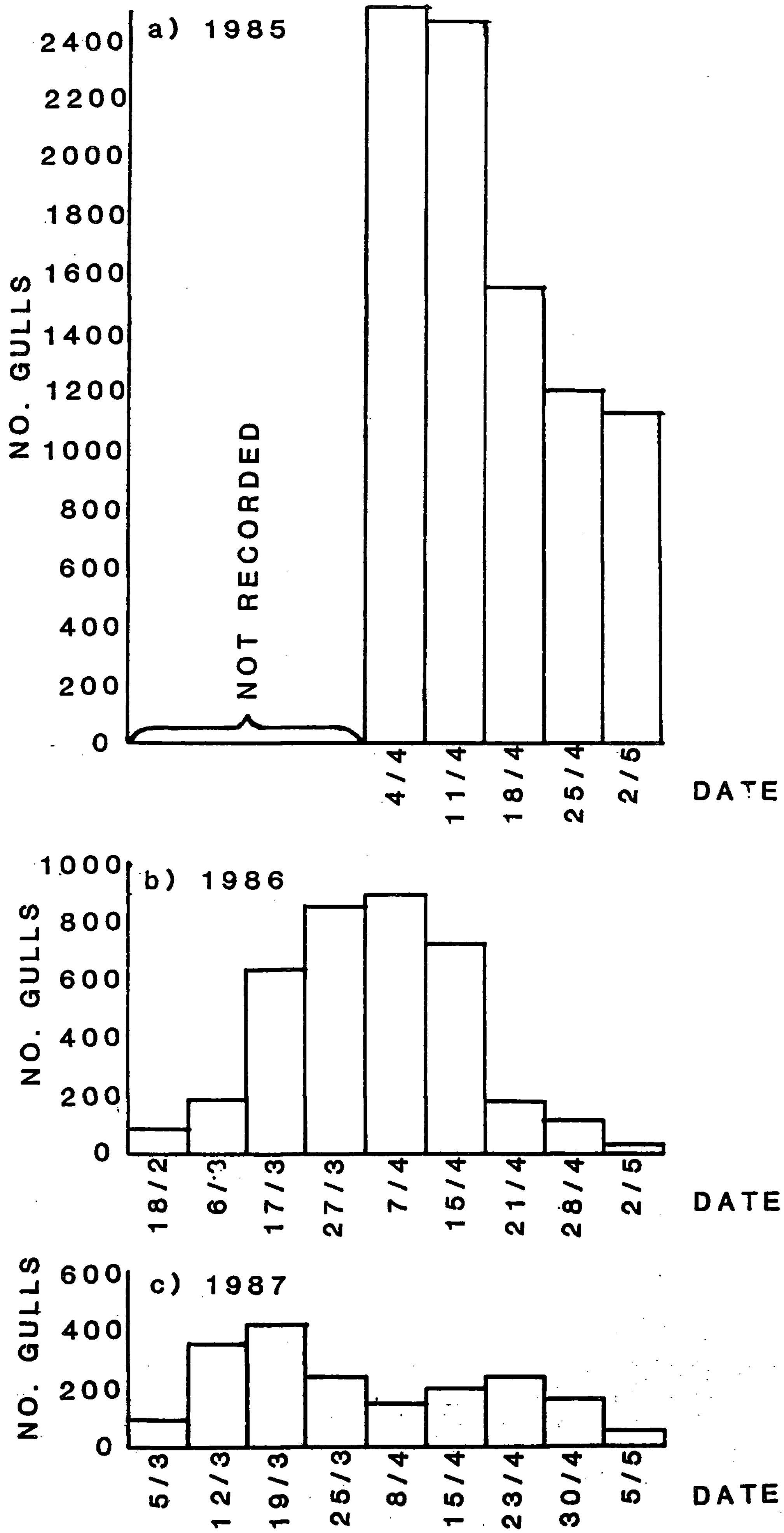
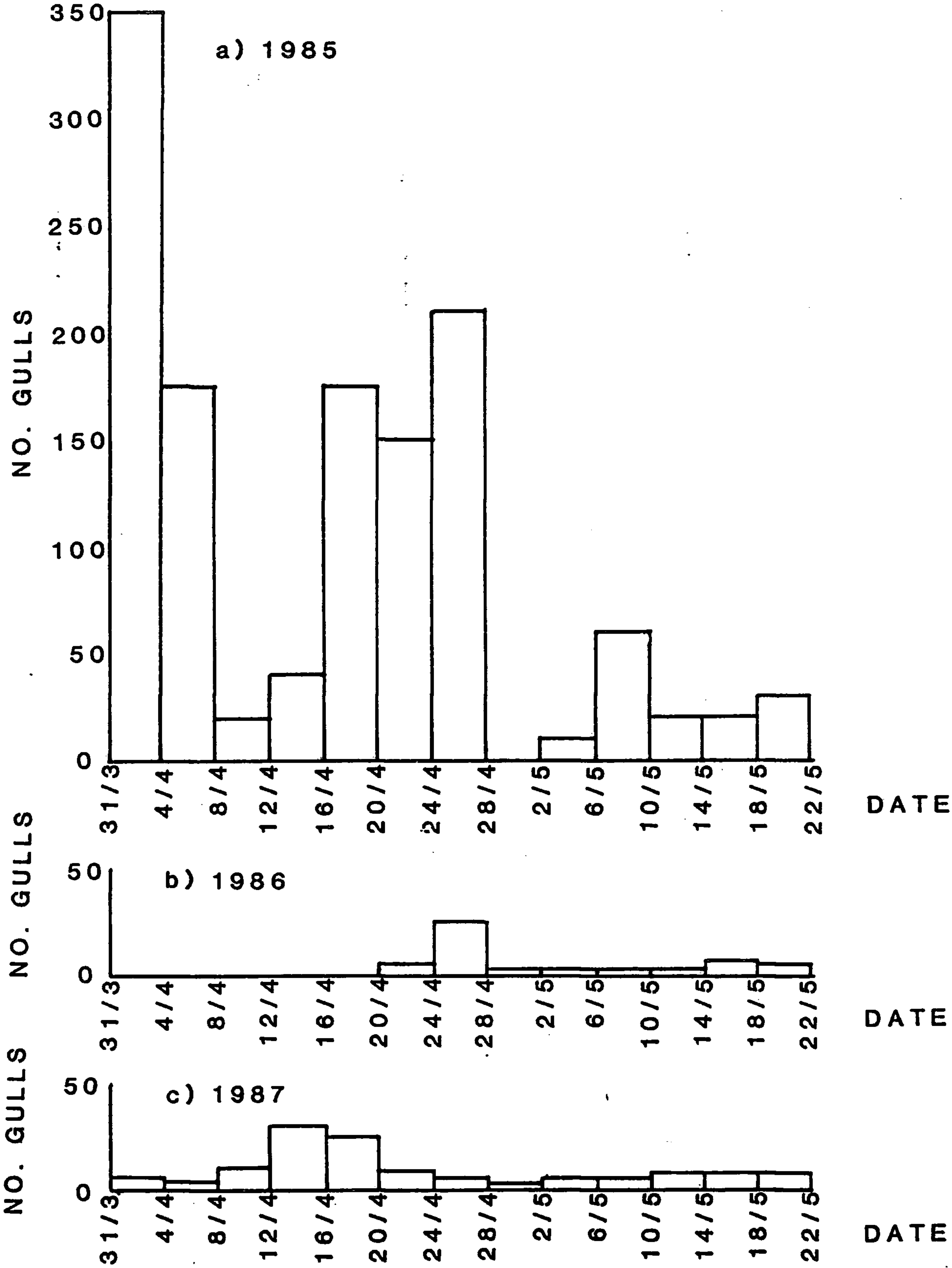


FIGURE 8.6 MAX. NO. BLACK-HEADED GULLS OVER COLONY SITE



The behaviour of gulls over the colony site differed between years. In 1985 and 1986, numbers built up at the estuary mouth around high tide; a few birds then flew high over the colony, circled once or twice and then returned to the water. This continued for up to two hours until there were more than five or six gulls involved in these "up flights". Then birds began to circle for longer periods often reducing altitude and calling loudly. This appears to be typical behaviour during the settling period (Kirkman 1937, Stamm in Cramp and Simmons 1983). These flights over the colony usually ended in a dread (i.e. all the birds in the air suddenly flying silently out to sea) a behaviour often seen at seabird, especially tern, colonies. In 1987, with the presence of the models and tape recordings, bird behaviour was different. Gulls appeared over the colony at all stages of the tide, especially when the wind was westerly, which made the tapes audible to gulls on the Saltcoats mud-flats. In addition to the usual circling flights, the birds showed the "swoop and soar" disply flights characteristic of the early breeding season in Black-headed Gull colonies (Beer 1963, Moynihan 1958, Stamm in Cramp and Simmons 1983).

As no gulls nested within the electric fence it was not possible to gauge its effectiveness against predation. Some anecdotal examples are available, however, in both 1986 and 1987 fox tracks were found in bare sand outside the fence, these often followed the line of the fence but on only one occasion were tracks found within the fence. In mid-March 1987, soon after the fence was switched on fox tracks were found following the fence line on the inside! An occupied earth was discovered within the fence area, the fence was switched off and chemical repellants and other methods were used to disturb the occupying vixen. The following morning tracks were found crossing the fence line, the fence was switched on again and tracks were subsequently found only outside the fence. The use of decoys and a tape lure thus produced a higher intensity of pre-breeding behaviour among Black-headed Gulls around the estuary. (It seems probable that if more gulls can be attracted to the estuary complex in future years this method may lead to at least a few pairs of Black-headed Gulls attempting to breed at Ravenglass again).

Following the failure of Black-headed Gulls to settle and breed at Ravenglass in 1985 work was concentrated on other shorebird species at Ravenglass and on Black-headed Gulls breeding elsewhere in Cumbria. The colonies chosen for study were those for which historical records were available (see Chapter 2 for descriptions and reasons for choice of study sites). Where possible, breeding performance parameters similar to those obtained at Ravenglass in 1984 were collected. In addition, observations were made of those gulls, marked near Ravenglass in March, that were found breeding at these other sites.

8.2.1 Foulney Island

Foulney Island is a Cumbria Trust for Nature Conservation (CTNC) reserve and only limited access was possible. Population estimates were derived from counts made by telescope so are not totally accurate; however, they are consistent among themselves (from year to year) so any trends are real. Counts of fledged young Black-headed Gulls on the shore at Foulney were made in July and used to estimate breeding success. Observations were made in all three seasons to check for gulls marked at Ravenglass. A sample of eggs was taken by the warden in 1987 during the gull control programme; these were used to calculate egg volume.

Table 8.1 shows the number of breeding pairs and breeding success at Foulney Island. As can be seen, the number of breeding pairs have remained fairly steady at around 700 despite "control measures" by the wardens who removed some nests and eggs in an attempt to protect the nearby Sandwich Tern colony.

In 1985 the colony produced a minimum of 1.6 chicks per pair, enough to balance normal adult mortality. In 1986, however, a large number of chicks were found dead, the warden considered the symptoms to be consistent with an outbreak of botulism. This reduced breeding success to a minimum of only 0.69 chicks fledged per pair. In 1987, a further out-break of suspected botulism occurred and once again reduced the breeding success. In 1987, a sample of 32 eggs was measured and used to calculate egg volume. The mean volume was 34.60 cm^3 ($\pm$ 0.39) (S.E.) and volumes ranged from 30.92 to 39.95; egg volume is discussed later.

TABLE 8.1

COLONY SIZE AND BREEDING SUCCESS OF BLACK-HEADED GULLS AT FOULNEY ISLAND

Year	No. of Pairs	Max. count of Young	Min. No. Young Reared/Pair	No. Marked Birds*
1985	750	1,200	1.60	1
1986	650	450	0.69	7
1987	700	450	0.64	0

* Marked at Ravenglass in March of the corresponding year.

TABLE 8.2

COLONY SIZE AND BREEDING SUCCESS OF BLACK-HEADED GULLS AT SINEY TARN

Year	No. of Pairs	Max. count of Young	Min. No. Young Reared/Pair
1985	175	80	0.46
1986	200	190	0.95
1987	125	75	0.60

TABLE 8.3

MARKED* BLACK-HEADED GULLS BREEDING AT SINEY TARN

Year	No. with 1985 mark	No. with 1986 mark	No. with 1987 mark	TOTAL
1985	6	-	-	6
1986	6	6	-	12
1987	5	5	2	12

* Marked at Ravenglass in Spring of corresponding year.

The number of Black-headed Gulls marked at Ravenglass but which subsequently bred at the Foulney gullery varied from 7 in 1986 to 0 in 1987 (despite careful checking of over 1,000 adults).

The Foulney gullery is relatively free from predation and due to careful wardening receives little disturbance from the public. The major cause of egg loss in the gullery is destruction by the warden to protect the tern colonies. The major cause of death among chicks in recent years appears to have been botulism. (C. Johnston pers.comm.).

8.2.2 Siney Tarn

Due to the nature of the site at Siney Tarn it was impossible to mark nests individually. Colony size was estimated by counts of adults sitting on nests, this probably gives an under-estimate. The vegetation surrounding the tarn grows up in mid-June so some birds, especially those re-nesting, will be missed. Fledged young congregated on a raised area of rocky moorland behind the tarn and could be counted easily. The accuracy of the estimates of fledging success depends on the synchrony of fledging so figures given represent minimum fledging success figures for the colony.

Colony size and estimated minimum fledging success are given in table 8.2. The number of breeding pairs fluctuated between 1985 and 1987. The water level was higher in 1987 than previously so a smaller area was available for nesting. This was associated with a decrease in the number of pairs breeding at the site. The main cause of the low breeding success, especially in 1985 and 1987, was heavy rain in mid-season, causing a rise in water level and a consequent loss of eggs and small chicks. In 1985 c.80 nests remained by the end of June; the nests which survived produced a fledging success of 1.0 chicks per pair.

As at Foulney Island, counts were made of marked birds breeding at Siney Tarn in all three years (table 8.3). Siney Tarn is closer to Ravenglass than Foulney and the number of gulls breeding at Siney which were marked at Ravenglass was greater than found at Foulney Island. It is not possible, however, to calculate accurately the percentage of Siney Tarn breeding birds using the Ravenglass estuary in Spring as a proportion of birds marked at Drigg were later found breeding on the continent.

8.2.3 Ravenglass Estuary

In 1985 a few pairs of Black-headed Gulls attempted to breed late in the season on raised areas of saltmarsh in the rivers Irt and Mite. These nests were marked individually and their fates recorded. A total of eighteen pairs of gulls nested on the saltmarshes, eight on the river Irt and ten on the River Mite. Data on clutch size and egg volume were collected (tables 8.4 and 8.5) although, to reduce disturbance, a, b and c eggs were not distinguished. Clutch size and egg volume are discussed later. All nests were flooded out by high tides in early June and no eggs hatched.

8.2.4 Wastwater

In all years counts of nests were made during visits to the colony on the island in the lake. The count for 1985 was made late in the season during chick ringing operations, consequently some nests may have been missed although all with signs of occupation were counted. In 1986 and 1987 regular visits were made to the colony throughout the breeding season. Due to the rocky nature of the island it was not possible to mark nests using split-cane markers as at Ravenglass in 1984. In 1986, therefore, plastic tags were tied to the nests but these were soon removed (or built into the nest) by adult gulls. In 1987 nest numbers were written on eggs using an indelible pen; this allowed nests to be identified until hatching.

TABLE 8.4

CLUTCH SIZES OF BLACK-HEADED GULLS BREEDING ON SALTMARSHES IN THE RAVENGLASS ESTUARY, 1985.

Site	N	Mean Clutch Size (± S.E.)
River Irt	8	1.75 (± 0.31)
River Mite	10	2.30 (± 0.26)

TABLE 8.5

EGG VOLUMES FOR BLACK-HEADED GULLS BREEDING ON SALTMARSHES IN THE RAVENGLASS ESTUARY, 1985.

Site	N	*Mean Egg Volume ($cm.^3$) (± S.E.)	Range
River Irt	4	32.29 (± 1.14)	29.13 - 34.49
River Mite	19	34.83 (± 3.31)	25.74 - 39.06

* See Appendix 9 for formula to calculate egg volume.

Chicks were ringed in all years. In 1986 as at Ravenglass, very small chicks were ringed with plastic numbered rings which were replaced later by metal B.T.O. rings whilst larger chicks were ringed with metal rings only. In both years, chicks were weighed on capture and measurements of head and bill, tarsus length, tarsus and toe length were made in an attempt to assess growth rates. It proved impossible, however, to recapture chicks more than one week old so little information on growth rates was obtained. Counts of fledged chicks were made at the end of the season and used to assess the total productivity of the colony.

Colony size and breeding success since 1985 are shown in table 8.6. The number of pairs breeding on the island has increased threefold since 1985. This was associated with good breeding performances in 1985 and 1986. In 1986 a sample of 44 nests visible from the observation point were followed from hatching to fledging. Their mean chick production was 1.67 $\pm$ 0.27 (S.E.) chicks per pair, slightly higher than the minimum average of 1.3 estimated for the whole colony by counts of young. It thus seems likely that the method of counting juveniles, even at colonies such as Wastwater where most of the colony can be seen clearly, gives an underestimate of the actual number produced. At the colonies studied, the disturbance covered by daily visits to obtain exact fledging success figures could well have directly reduced these figures by causing chick mortality and desertion. Daily visits were, therefore, avoided.

As at Ravenglass in 1984, the Mayfield method (Mayfield, 1961, 1975, Johnson 1979 see appendix 9) was used to calculate nest survival from laying to hatching in 1986 and 1987. The results are shown in table 8.7. As can be seen the probability of a nest surviving to hatching in 1986 was lower than in 1987 but there is no significant difference between daily survival (t-test $t=1.23$, $p>0.05$) or survival from laying to hatching in the two years. This suggests that the observed reduction in breeding success from 1986 to 1987 was caused by increased mortality of chicks prior to fledging which could have been a result of increased predation, chilling (Summer 1987 was wet and cold) or disease. No systematic observations were made on chick mortality but some dead chicks were noted to have head injuries consistent with predation by other Black-headed Gulls. It seems probable that as more gulls nested on the small island in Wastwater the distances between adjacent nests have been so reduced that chicks are within easy reach of neighbours' beaks. Patterson (1965) who studied nest spacing at Ravenglass suggested that the upper limit

TABLE 8.6

COLONY SIZE AND BREEDING SUCCESS OF BLACK-HEADED GULLS AT WASTWATER

Year	No. Pairs	Max. count of Young	Min. no. Young/Pair
1985	49	79	1.6
1986	109	140	1.3
1987	147	85	0.6

TABLE 8.7

NEST SURVIVAL AT WASTWATER 1986 AND 1987 CALCULATED USING THE MAYFIELD METHOD

Year	S (PROBABILITY A NEST WILL SURVIVE 1 DAY) ± S.E.	S^{24} (PROBABILITY A NEST WILL SURVIVE TO HATCHING) (95% C.I.)
1986	$0.981 \pm 5.57 \times 10^{-3}$	0.631 (0.484-0.835)
1987	$0.989 \pm 2.96 \times 10^{-3}$	0.772 (0.668-0.891)

of colony density is influenced by increased intra-specific predation on eggs and chicks at high densities. At the Wastwater gullery birds have chosen to nest closer to each other on the island rather than in more open conditions along the edge of the lake where chicks and eggs are more vulnerable to mammalian predation.

Mean clutch sizes for the Wastwater colony (table 8.8) show no significant differences between years (ANOVA). Table 8.9 shows mean egg volumes for the Wastwater gullery from 1985 to 1987. The results and those for clutch size are discussed again later. Birds marked during cannon-netting at Ravenglass in March of all three years were found breeding at Wastwater in each summer (table 8.10). In addition to these, two birds marked as chicks at Wastwater in 1985 are known to have bred there in 1987.

8.2.5 Rockcliffe Marsh

Data for 1985 were obtained from the reserve manager (D Bailey pers. comm.). Nests in 1986 and 1987 were marked with individually numbered pegs (as at Ravenglass in 1984). Chicks were ringed on hatching with numbered plastic rings, some of which were later replaced by metal B.T.O. rings. Because of the nature of the terrain it was impossible to relocate more than a small proportion of ringed chicks so no data were collected for chicks of over c.10 days old. Estimates of fledging success were obtained by counting the number of fledglings on the estuary in July although this procedure probably gave an underestimate because young fledged over several weeks and those early to fledge may have left the estuary before the last fledged.

Estimates of colony size and breeding success are shown in table 8.11. In 1985 the colony occupied the middle area of the marsh towards the River Esk (figure 8.7a). There is no quantitative information on fledging success, although some young birds were seen in late July. In 1986 gulls nested in a similar area, although there was an extension to the south west (figure 8.7b). In May 1986, however, high tides, coupled with gale force westerly winds and very low atmospheric pressure flooded the entire marsh causing the loss of all the Black-headed Gull nests. At least 362 pairs re-nested. However, the distribution of nesting areas was different to that found previously (figure 8.7c). Re-nesting gulls appeared to prefer the edges of the many creeks which bisect the marsh, in particular, those on the western (area 6) and southern edges (area 1) of the marsh. Those pairs which re-nested successfully produced young. In 1987 the pattern of nesting (fig.

TABLE 8.8

CLUTCH SIZES OF BLACK-HEADED GULLS AT WASTWATER 1985-87

Year	N	Mean Clutch Size (± 1 S.E)	Significance of Difference
1985	49	2.20 (± 0.12)	
			t_{100} = 1.78 p >0.05
1986	53	2.55 (± 0.11)	
			t_{127} = 0.63 p >0.05
1987	76	2.42 (± 0.09)	
			t_{113} = 1.33 p >0.05
(1985	49	2.20 (± 0.12))	

TABLE 8.9

EGG VOLUMES OF BLACK-HEADED GULLS BREEDING AT WASTWATER 1985-87

Year	N	Mean Egg Volume (± 1 S.E.) $cm.^3$	Range ($cm.^3$)
1985	24	36.13 (± 0.53)	32.95 - 42.07
1986	55	36.82 (± 0.44)	29.82 - 43.33
1987	49	34.57 (± 0.38)	30.45 - 39.86

TABLE 8.10

BLACK-HEADED GULLS MARKED NEAR RAVENGLASS BUT BREEDING AT WASTWATER

Year	No. Marked Near Ravenglass	No. Breeding at Wastwater with 1985 mark	with 1986 mark	with 1987 mark	Total
1985	68	3	-	-	3
1986	145	4	6	-	10
1987	54	5	3	1	9

FIGURE 8.7

NESTING AREAS USED BY BLACK-HEADED GULLS AT ROCKCLIFFE MARSH

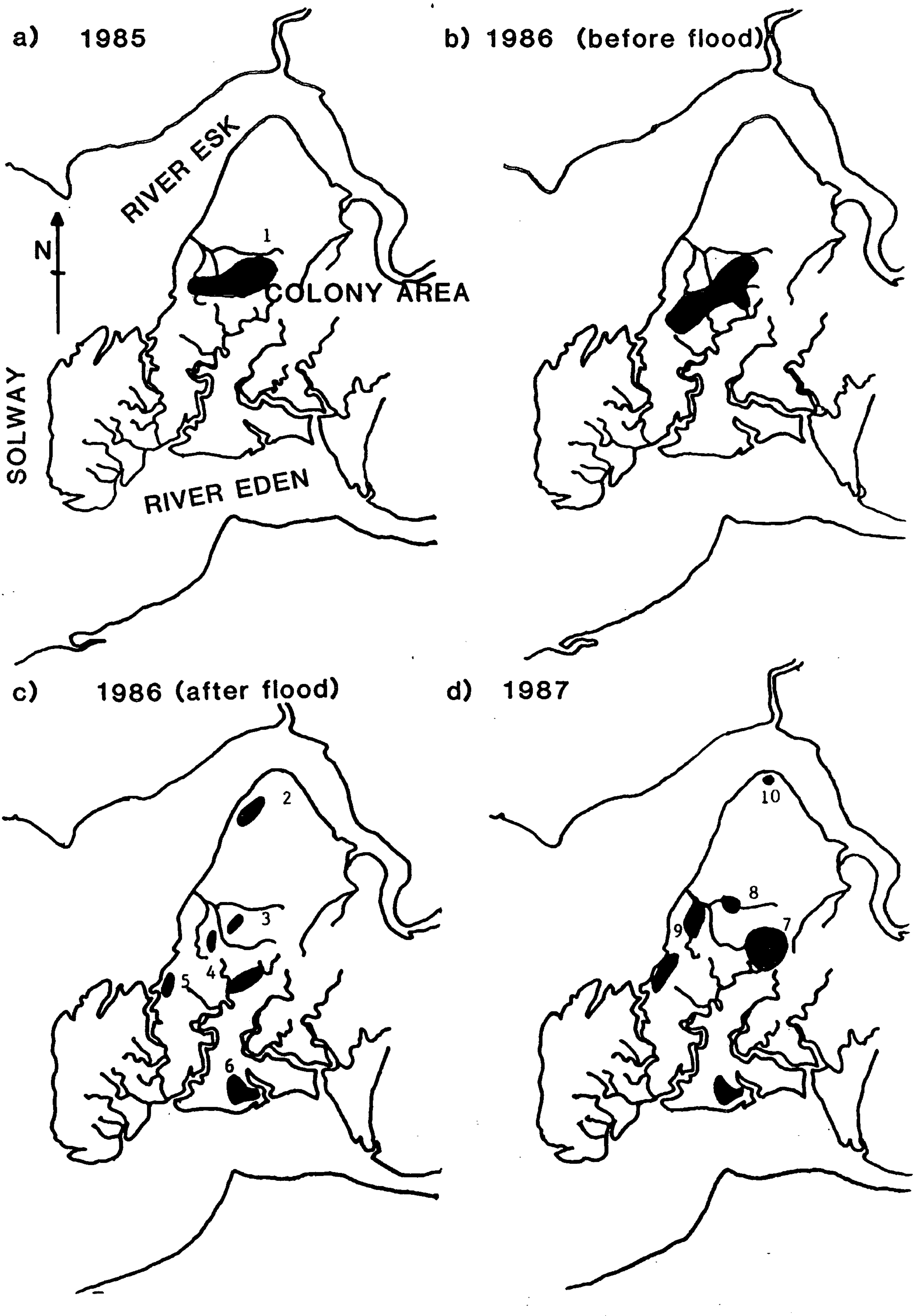


TABLE 8.11

COLONY SIZE AND BREEDING SUCCESS OF ROCKCLIFFE MARSH 1985-1987

Year		No. Nests	No. Young Reared/Nest
1985		271	N.R.
1986	1st Clutch	>562*	0
	2nd Clutch	364	0.18 - 1.3
1987		709	0.9

* Not all nests had been marked before the marsh was flooded in May.

8.7d) was similar to the second clutch in 1986 with gulls nesting along the edges of creeks and pairs were again successful in rearing young. The increase in numbers in 1987 probably accounts for the wider spread of nesting areas compared to 1986. It is possible that birds which re-nested successfully in 1986 returned to their nest-sites in 1987 whereas birds which left the area following the flood returned to the central area in 1987; hence the increase in use of that area (area 10). The most northerly of the 1986 areas (area 5) was not re-occupied in 1987 despite being successful in 1986. This was because of disturbance by turf-cutting activities in that area during 1987.

Clutch sizes for first and repeat layings at Rockcliffe in 1986 are shown in table 8.12. There were no significant differences between mean clutch sizes (ANOVA) in the three areas for which data were collected for the second clutch, so pooled results are used to show that the mean clutch size was not significantly different for the first and second layings. Clutch sizes for various areas in 1987 are shown in table 8.13. As in 1986 there were no significant differences between the clutch sizes recorded in the different areas (ANOVA) so again pooled results have been calculated. Clutch sizes are discussed further below. Egg volumes were also recorded at Rockcliffe in 1986 and 1987 (table 8.14). In 1986, first and second layings were considered separately. In 1987 there was no significant difference between egg volumes in two areas, so in further discussions pooled results only are considered.

In 1987 a sample of nests at each of three of the nesting areas was followed from initiation to hatching or loss (table 8.15). There were significant differences between the number of nests which did and did not hatch in the different areas ($X^2 = 21.1$, d.f = 2, $p<0.001$) and in areas away from creeks significantly more nests were lost to predation ($X^2 = 105.66$, d.f = 2, $p<0.001$).

The Mayfield method was used to estimate nest survival to hatching in the three areas considered above (table 8.16). Using t-tests there were no significant differences between the daily survival estimates for the three areas. When the whole incubation period is considered however, area 9, where a large proportion of nests were washed out, has a significantly lower probability of survival of nests from laying to hatching than does area 6 where the majority of nests were successful. Surprisingly however, there is no difference between area 10 and the others despite the large percentage of nests which were lost to predation. This seems to be because area 9 suffered from other sources of mortality which did not apply to area 10.

TABLE 8.12

CLUTCH SIZES AT ROCKCLIFFE IN 1986

	N	MEAN	S.E.
1st Laying	286	2.50	0.041
2nd Laying 1*	23	2.39	0.175
2nd Laying 5*	58	2.50	0.098
2nd Laying 6*	99	2.40	0.076
2nd Laying TOTAL	180	2.43	0.055

* See Figure 8.6

TABLE 8.13

CLUTCH SIZES AT ROCKCLIFFE IN 1987

AREA*	N	MEAN	S.E.
6	123	2.64	0.054
7	18	2.33	0.162
9	64	2.55	0.085
10	53	2.49	0.091
TOTAL	268	2.57	0.040

* See Figure 8.6

TABLE 8.14

EGG VOLUMES AT ROCKCLIFFE 1986 AND 1987

Year		N	Mean Egg Volume ($cm.^3$)(± S.E.)	Range ($cm.^3$)
1986	1st Laying	32	35.80 (± 0.61)	29.80-43.95
1986	2nd Laying	61	34.41 (± 0.50)	28.50-39.52
1987	Area 6	72	36.47 (± 0.25)	31.34-43.16
1987	Area 10	51	37.23 (± 0.34)	33.11-43.39
1987	Total	123	36.78 (± 0.20)	31.34-43.39

TABLE 8.15

FATE OF NESTS AT ROCKCLIFFE 1987

		FATE OF NESTS				
Area*	N	No. (%) Hatched	No. (%) Washed out	No. (%) Predated	No. (%) Trodden	No. (%) Unknown
6	133	90 (68%)	25 (19%)	1 (1%)	9 (7%)	8 (6%)
9	64	26 (41%)	37 (58%)	0	0	1 (2%)
10	53	19 (36%)	1 (2%)	33 (62%)	0	0
Total	250	135	63	34	9	9

* See Figure 5.8d

TABLE 8.16

NEST SURVIVAL IN THREE AREAS OF THE ROCKCLIFFE GULLERY IN 1987 (CALCULATED USING THE MAYFIELD METHOD*)

Year	S (PROBABILITY A NEST WILL SURVIVE 1 DAY) (± S.E.)	S^{24} (PROBABILITY A NEST WILL SURVIVE LAYING TO HATCHING (95% C.I.)
6	0.986 ± 0.0028	0.713 (0.670-0.768)
9	0.974 ± 0.0055	0.531 (0.463-0.607)
10	0.974 ± 0.0066	0.534 (0.386-0.737)

* See Appendix 8.

Very few gulls marked as adults at Ravenglass were recorded at Rockcliffe, 2 in 1986 and 1 in 1987. This does, however, imply that some birds have moved more than thirty miles from Ravenglass in late March or April to find a suitable nesting colony.

8.2.6 Discussion

The size and breeding success of the Black-headed Gull colonies studied in Cumbria between 1985 and 1987 varied considerably from year to year. In none of the three years did birds breed at Ravenglass and most birds present on the shore at Drigg in late March dispersed to breed elsewhere in April. Ringing and marking of samples of these birds showed that several moved to Wastwater to breed, others to Siney Tarn, a few to Foulney Island and three even as far as Rockcliffe. Other recoveries of marked birds during the breeding season, one from the isle of Man, two from colonies in Sweden and one from Finland show that not all gulls which gathered near Ravenglass in February and March are Cumbrian breeding birds.

Various breeding parameters were recorded at the Cumbrian colonies studied from 1984 to 1987. Mean clutch sizes recorded during the study, together with information from the literature are shown in table 8.17a). There are significant differences between the clutch sizes (ANOVA $F=23.4$, $f_1=12$, $f_2=2564$, $p<<0.01$). Table 8.17b) shows the results of multiple range testing on the pairs of clutch size estimates. As can be seen, the mean clutch sizes for the Ytreberg (1956) and Lundberg and Vaisainen (1975) studies were significantly higher than most whereas Ravenglass 1984 was significantly lower than all previously published studies. Three mean clutch sizes lay below that for Ravenglass, namely those for Wastwater 1985 (where the estimation of mean clutch size was made from one visit only) and the Irt and Mite Marsh "colonies" in 1985 when most nests were washed out before a full clutch was laid. Another complicating factor may be that, for the Wastwater colony in all years no distinction was made between first and second clutches. Weidmann (1956) and Witherby et.al (1941) suggest that for Black-headed Gulls, the second clutch is smaller than the first. However, data for first and second clutches at Rockcliffe in 1986 indicate no significant differences between those two clutch sizes.

TABLE 8.17

COMPARISON OF CLUTCH SIZE

a) Study		N	Mean Clutch Size	S.E.
NORWAY	1	421	2.90	0.021
NORWAY	2	100	2.62	0.043
FINLAND	3	450	2.82	0.028
ENGLAND	4	191	2.54	0.054
RAVENGLASS 1984		489	2.34	0.037
WASTWATER 1985		49	2.20	0.120
WASTWATER 1986		53	2.55	0.110
WASTWATER 1987		76	2.42	0.09
ROCKCLIFFE 1986	5	286	2.50	0.041
ROCKCLIFFE 1986	6	180	2.43	0.055
ROCKCLIFFE 1987		268	2.57	0.040
IRT MARSH 1985		4	1.75	0.31
MITE MARSH 1985		10	2.30	0.26

SOURCES

1. Ytreberg 1956
2. Ytreberg 1960
3. Lundberg and Vaisainen 1975
4. Weidmann 1956
5. 1st Laying
6. 2nd Laying

TABLE 8.17 (continued)

COMPARISON OF CLUTCH SIZE

b)

Multiple Range Tests
N.S. = Not Significant
* = Significant at 5% level

		NORWAY 1	NORWAY 2	FINLAND 3	ENGLAND 4	RAVENGLASS 1984	WASTWATER 1985	WASTWATER 1986	WASTWATER 1987	ROCKCLIFFE 1986 5	ROCKCLIFFE 1986 6	ROCKCLIFFE 1987	IRT MARSH 1985	MITE MARSH 1985
NORWAY	2	*												
FINLAND	3	NS	NS											
ENGLAND	4	*	NS	*										
RAVENGLASS 1984		*	*	*	*									
WASTWATER 1985		*	*	*	NS	NS								
WASTWATER 1986		*	NS	NS	NS	NS	NS							
WASTWATER 1987		*	NS	*	NS	NS	NS	NS						
ROCKCLIFFE 1986	5	*	NS	*	NS	NS	NS	NS	NS					
ROCKCLIFFE 1986	6	*	NS	*	NS	NS	NS	NS	NS	NS				
ROCKCLIFFE 1987		*	NS	*	NS	*	*	NS	NS	NS	NS			
IRT MARSH 1985		*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		
MITE MARSH 1985		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	

The smaller clutch size recorded at Ravenglass in 1984 than at most successful colonies was probably, as suggested previously (Chapter 7), a symptom of heavy fox predation. Coulson and Porter (1984) suggest that clutch size in Kittiwakes (Rissa tridactyla) indicates the condition of birds at laying, which results from a genetical component modified by environmental factors. However, they comment on the low predation rates on cliff-nesting Kittiwakes. Although predation may have been the cause of the reduced clutch size at Ravenglass, food availability is investigated later (Chapter 9). The influence of the age structure of the Ravenglass gullery in 1984 on clutch size is not known although Coulson (1968) showed that inexperienced Kitiwakes often had smaller clutches than experienced ones. In general, the pattern among the other sites considered is that mean clutch sizes recorded from British colonies were lower than those from colonies further North.

Comparisons of the Mayfield nest-survival estimates (tables 8.18a) and b)) show that the probability of a nest surviving from one day to the next at Ravenglass in 1984 was significantly lower than at Rockcliffe in 1987 or at Wastwater in 1986 or 1987. This again suggests that nest loss at Ravenglass in 1984 was exceptionally high, far more than at other colonies which produced fledged young. The value calculated for Rockcliffe in 1987 was significantly less than that recorded at Wastwater in the same year. This may also be due to fox predation, which was observed on one of the colony areas at Rockcliffe in 1987, acting in conjunction with the nest loss due to swamping by high tides at that site reducing nest survival.

Data for egg-volumes calculated for Cumbrian colonies are shown in table 8.19a). As with clutch sizes, there are significant differences between them (ANOVA; $F=5.39$, $N=9$, $N_2=505$, $p<0.05$). Table 8.19b) shows the results of multiple range tests between each pair of egg-volumes. The calculated egg-volumes for Rockcliffe 1987 and Wastwater 1986 were significantly larger than those from Wastwater 1987 and Rockcliffe 1986 (2nd clutch) but the majority of comparisons show no significant difference. Parsons (1976) and Nisbet and Welton (1984) found in the Herring Gull and Common Tern respectively, a strong positive correlation between egg-size and chick survival. Lundberg and Vaisainen (1979) also found a clear positive relationship between egg-size and chick survival at a Finnish Black-headed Gull colony. Egg size may indeed affect chick hatching weight and so chick survival. However, in the present study this effect was masked by other factors increasing egg or chick mortality e.g. predation, swamping by high tides or disease.

TABLE 8.18

MAYFIELD ESTIMATORS

a)

Site	S	S.E.
RAVENGLASS 1985	0.966	2.1×10^{-3}
WASTWATER 1986	0.981	5.6×10^{-3}
WASTWATER 1987	0.989	3.0×10^{-3}
ROCKCLIFFE 1987	0.980	2.4×10^{-3}

b) COMPARISON OF MAYFIELD ESTIMATORS

(d tests)

	RAVENGLASS 1984	WASTWATER 1986	WASTWATER 1987	ROCKCLIFFE 1987
WASTWATER 1986	2.51 **			
WASTWATER 1987	6.28 ***	1.26 N.S.		
ROCKCLIFFE 1987	4.39 ***	0.16 N.S.	2.34 *	

N.S. = Not significant
* = Significant at 5% level
** = Significant at 1% level
*** = Significant at 0.1% level

TABLE 8.19

EGG VOLUME COMPARISONS

SITE	N	MEAN EGG VOLUME (cm^3)	S.E.
RAVENGLASS 1984	116	35.41	0.30
FOULNEY 1987	32	34.60	0.39
IRT MARSH 1985	4	32.29	1.14
MITE MARSH 1985	19	34.83	0.76
WASTWATER 1985	24	36.13	0.53
WASTWATER 1986	55	36.82	0.44
WASTWATER 1987	49	34.57	0.38
ROCKCLIFFE 1986 [1]	32	35.80	0.61
ROCKCLIFFE 1986 [2]	61	34.41	0.55
ROCKCLIFFE 1987	123	36.78	0.20

1. 1st LAYING
2. 2nd LAYING

TABLE 8.19 (continued)

EGG VOLUME COMPARISONS

b)

	RAVENGLASS 1984	FOULNEY 1987	IRT MARSH 1985	MITE MARSH 1985	WASTWATER 1985	WASTWATER 1986	WASTWATER 1987	ROCKCLIFFE 1986[1]	ROCKCLIFFE 1986[2]	ROCKCLIFFE 1987
FOULNEY 1987	NS									
IRT MARSH 1985	NS	NS								
MITE MARSH 1985	NS	NS	NS							
WASTWATER 1985	NS	NS	NS	NS						
WASTWATER 1986	NS	NS	NS	NS	NS					
WASTWATER 1987	NS	NS	NS	NS	NS	*				
ROCKCLIFFE 1986[1]	NS	NS	NS	NS	NS	NS	NS			
ROCKCLIFFE 1986[2]	NS	NS	NS	NS	NS	*	NS	NS		
ROCKCLIFFE 1987	*	*	NS	NS	NS	NS	*	NS	*	

N.S. = Not Significant
* = Significant at 5% level

Breeding success varied amongst colonies in any one year. Causes of breeding losses or failures during 1985-1987 have been several; flooding by heavy rain (Siney Tarn) or exceptionally high tides (Rockcliffe); predation by neighbouring gulls (Wastwater) or foxes (part of the Rockcliffe colony); and suspected botulism (Foulney). Numbers of young fledged per pair have not been consistently sufficient to replace normal adult mortality at any one colony in all three years. The picture emerges of a highly dynamic population in which different colonies are successful to different degrees in different years. The extent to which adult birds move between colonies from year to year is unknown but variations in colony size suggest that some degree of mobility or difference in recruitment of first-time breeders is regular.

8.3 BREEDING SUCCESS OF SPECIES OTHER THAN BLACK-HEADED GULLS AT RAVENGLASS BETWEEN 1985 AND 1987.

In all three years the breeding success of Oystercatcher and Ringed Plover was recorded during twice-weekly (11 k.m.) walks of the beach from the Drigg Shore Road end, around Drigg Point to the end of the reserve track (figure 8.8) from early May onwards. All nests found were marked in such a way as to avoid drawing the attention of predators to them and their fate recorded. Shelduck nests were well hidden in the dunes and too time-consuming to find so breeding success was estimated by counts of the number of young on the estuary from July onwards.

Ringed Plover and Oystercatcher breeding attempts are summarised in tables 8.20 and 8.21. As can be seen, Oystercatcher have been unsuccessful in all years. Ringed Plover, however, fledged some young in 1987. Amongst nests whose fate was known, the major cause of loss in all years was fox predation, as indicated by observations of tracks on the beach. It is probable that a large proportion of the "unknown" nest losses were also due to predators, but because tracks are visible only in certain weather conditions they had gone unnoticed. In all years Oystercatchers fared worse than Ringed Plovers with few nests surviving beyond two weeks of incubation and only one (in 1987) beyond three weeks. It seems likely that in 1985, once the gull colony had disappeared, foxes preyed on other bird species nesting on the reserve as a food source. Harris (1967) found that mean clutch size for Oystercatchers on Skokholm, where there is no fox predation was 2.77 ± 0.03(S.E.). This value is significantly higher than any of the three values for Drigg (d-tests; 1985, $d=4.78$, $p<0.001$; 1986, $d=9.78$, $p<0.001$; 1987, $d=3.00$, $p<0.01$). As with Black-headed Gulls in 1984 the apparently lower clutch size was probably due

FIGURE 8.8

ROUTE TAKEN TO CENSUS OYSTERCATCHER AND RINGED PLOVER NESTS AT RAVENGLASS 1985–1987

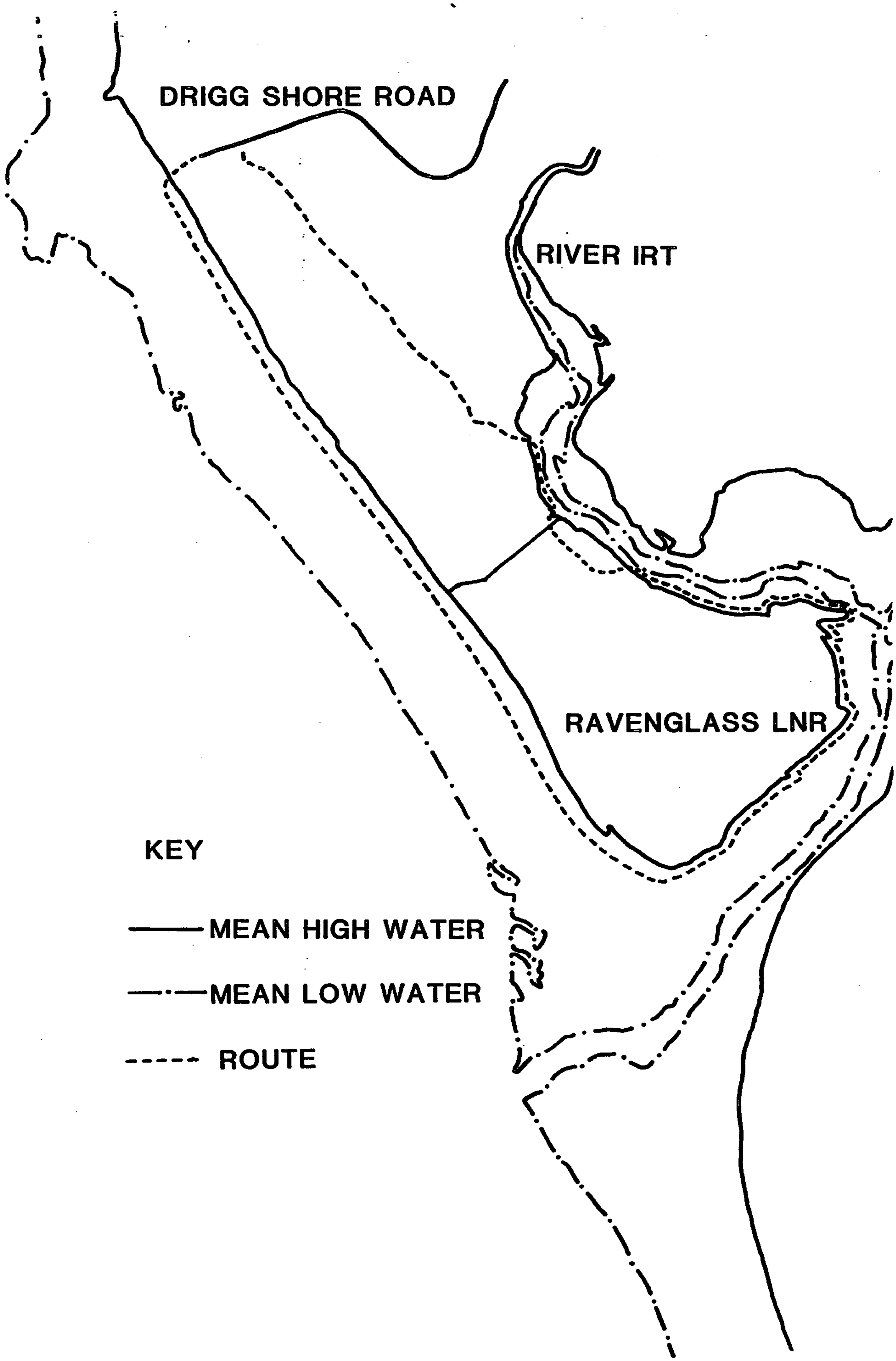


TABLE 8.20

BREEDING STATISTICS OF RINGED PLOVER NESTS AT DRIGG 1985-87

	YEAR		
	1985	1986	1987
No. nests found	4	8	17
No. nests successful	0	0	7 (41%)
No. washed out	0	0	1 (6%)
No. covered by sand	0	0	0
No. predated	1 (25%)	4 (50%)	7 (41%)
% predated by fox	100%	100%	100%
% predated by crow	0%	0%	0%
No. crushed by cows	0	1 (13%)	0
No. lost to unknown cause	3 (75%)	3 (37%)	2 (12%)
Mean clutch size (S.E.)	3.25(0.25)	3.63 (0.30)	3.58 (0.26)

TABLE 8.21

FATE OF OYSTERCATCHER NESTS AT DRIGG 1985-87

	YEAR		
	1985	1986	1987
No. nests found	18	34	47
No. successful	0	0	0
No. washed out	0	3 (9%)	2 (4%)
No. covered by sand	4 (22%)	2 (6%)	0
No. predated	9 (50%)	13 (38%)	33 (70%)
% predated by fox	100%	92%	82%
% predated by crows	0%	8%	18%
No. crushed by cows	0	3 (9%)	0
No. lost to unknown cause	5 (28%)	13 (38%)	12 (26%)
Mean clutch size (S.E.)	1.67 (0.20)	1.47 (0.11)	2.32 (0.12)

to predation of eggs by foxes before clutches were completed. Ringed Plover clutch sizes were not significantly different from published data (Pienkowski 1983a). However, Pienkowski's study population also suffered fox predation.

In 1987, foxes were less active on the beaches at Ravenglass than in previous years (fewer tracks were found in the sand) and this probably allowed Ringed Plover, which tend to nest earlier than Oystercatchers, enough time to rear young. It was not until May, when Oystercatchers were present in good numbers, that foxes began to visit the shore regularly and to predate nests.

Shelduck successfully produced young in all years (table 8.22). These maximum counts (D E Simpson pers. comm.) compare favourably with those from previous years (Chapter 2) and 1987 especially was a good year. The fact that Shelduck have produced young in all years is interesting for two reasons. Firstly they feed almost exclusively on estuarine invertebrates so would be expected to be one of the first species at risk if any pollutants had affected the inter-tidal fauna of the estuary and secondly they nest in burrows so are fairly well protected from fox predation. Thus they have managed to produce young even in years when predation on other bird species has been at a very high level.

8.4 SUMMARY

Following the breeding failure in 1984, Black-headed Gulls failed to settle at the Ravenglass colony in 1985 and have not attempted to breed there since. Various methods have been employed to persuade gulls to return but without success. Studies on breeding success at other gulleries in Cumbria indicate that it varies between years and between sites for a variety of reasons. Recoveries of adult gulls marked near Ravenglass but breeding at other colonies indicates emigration which may account for the increased rate of colony decline at Ravenglass above that expected if breeding failures had occurred in all years in the late 1970's and early 1980's.

Comparisons of breeding parameters between Ravenglass, other Cumbrian sites and published accounts show that egg survival at Ravenglass in 1984 was significantly less than elsewhere, clutch size at Ravenglass in 1984 was significantly less than at some successful colonies but that no clear pattern emerges from comparisons of egg volume measurements. These point to interference with breeding at Ravenglass itself as being important. Predation was again implicated as important, supported by evidence from other species breeding at Ravenglass which were badly affected probably by foxes. The importance of the effects of reduced food availability has not, however, been investigated, this is considered in Chapter 9.

TABLE 8.22

MAXIMUM COUNTS OF SHELDUCKLINGS ON THE RAVENGLASS ESTUARY SINCE 1985

Year	Maximum Count
1985	49
1986	62
1987	117

FEEDING AREAS AND DIETS OF BLACK-HEADED GULLS FROM CUMBRIAN COLONIES

Information collected during the 1984 breeding season at Ravenglass suggested that predation on eggs and chicks were the major causes of the observed breeding failure in that year. It is still possible, however, that in other years the availability of suitable foodstuffs may have affected the breeding success of Ravenglass Black-headed Gulls and perhaps more directly affected the number of gulls settling to breed at the colony site. The location and density of available foods for birds affect the ease with which they can obtain their nutritional requirements for breeding. Changes in food availability could affect breeding of Black-headed Gulls in several ways. A lack of food, for either adults or chicks, could reduce clutch size or fledging success; contamination of food by pollutants could result in contamination of adults, eggs etc. and also lead to poor breeding success.

If food species decline or disappear from an area then birds will either have to adapt to utilising other food resources or travel further to obtain their preferred foods. In the case of a large colony of Black-headed Gulls a lack of suitable food types close to the colony could affect either adults or chicks and reduce breeding success. Ankney and MacInnes (1978) found that the number of eggs laid by Lesser Snow Geese (Anser cenarulescens) and subsequent breeding success depended upon the nutrient reserves built up by the female prior to breeding. If food declined and Black-headed Gulls were not able to obtain sufficient before egg-laying then clutch size might have been reduced and hatching and fledging success could have been impaired. If insufficient food is available for adult gulls to feed their chicks then fledging success would be reduced if chicks were not fed at an adequate rate for their survival.

In the case of the Ravenglass Black-headed Gull colony, the most obvious contaminants that could affect birds are radionuclides discharged in effluents from the BNFplc. Sellafield Nuclear Reprocessing Plant situated on the coast 5km. north of Ravenglass. There are two main routes through which birds could be affected by radionuclides; i) externally, through doses derived from the external environment and ii) internally, through radionuclides taken into the body, usually as food. External doses are unlikely to affect the health of the individual unless very high levels occur. The major pathway of internal contamination is through foodstuffs and several workers have shown that the type of food taken is important e.g. Rickard et.al. (1976) at the USAEC Savannah River site in North Carolina found that Cs-137 levels in Blue Heron (Florida cearulea) nestlings were five times greater than in Green Herons (Butorides virescens). This was attributed to the two species taking different foods which had different levels of Cs contamination. They also showed that the levels of Cs-137 in herons generally were lower than those found in ducks. This was because ducks fed on plant material which was higher in radiocaesium levels than the animal prey taken by the herons. There is thus some evidence of a trophic level effect, with animals at the top of food chains acquiring less radionuclide contamination than those further down. This may, however, apply only to birds as they are known to accumulate lower levels of radiocaesium than other animals in a given contaminated environment; they also have a high turnover rate of radionuclides so that body burdens decrease rapidly following contamination (Danby and Macfarlane 1978). Radiation dose rates from internal and external sources are discussed more fully in Chapter 10.

In order to assess the risk from radionuclide contamination to breeding birds it is first necessary to identify their major foods and feeding areas. It was considered that estuarine food sources from the contaminated estuarine silts (Bradford et al. 1984) were the most likely source of contamination to gulls. The work described below was carried out to investigate whether or not Black-headed Gulls at Ravenglass and other Cumbrian colonies fed in estuarine habitats and so were at risk from contamination by radionuclides from inter-tidal invertebrates. In addition, the identification of food sources of Black-headed Gulls at Ravenglass and other Cumbrian colonies was necessary to confirm the findings of the literature review (Chapter 6) of the historical information on feeding by gulls at Ravenglass.

9.1 METHODS

Four methods were used to investigate the diets and feeding areas used by Black-headed Gulls from Ravenglass and other Cumbrian colonies. The methods used at a particular colony depended on time and topographical constraints. The colonies at which particular methods were used are detailed below.

This method was used especially around the Ravenglass estuary complex during the pre-breeding season. Counts were made of the number of gulls around the estuary at least weekly from March to May. The numbers of gulls feeding inland and in estuarine habitats were recorded as were the foodstuffs taken by the gulls. This method was also used during the breeding season if a feeding flock of adult gulls was noted near any of the study colonies.

9.1.2 OBSERVATIONS OF FEEDING OF CHICKS

At Siney Tarn and Wastwater it was possible, using a 30x telescope, to observe the foods which adult gulls regurgitated for chicks. At other colonies the terrain and vegetation in the colony prevented a clear view of chick feeding. This method was also used at these colonies in 1987 to investigate "courtship feeding" of the female by the male. This occurs in the early part of the season and is believed to strengthen the pair bond and to assist in the demands of egg-production.

9.1.3 CHICK REGURGITATE ANALYSIS

When Black-headed Gull chicks are handled e.g. during ringing operations, they often regurgitate their last meal. These regurgitates were collected, preserved in 70% alcohol, dissected, and their contents examined in the laboratory. This method could be used only at those colonies where chicks were handled i.e. Ravenglass, Rockcliffe, Wastwater and to a lesser extent Foulney.

9.1.4 STOMACH CONTENT ANALYSIS

Corpses of adults and chicks which had been killed by predators were collected during visits to colonies. Their alimentary canals were removed and preserved in 70% alcohol. The contents of the gut were removed and identified in the laboratory. This method was used at Ravenglass, Rockcliffe, Wastwater and Foulney.

Each colony is treated separately and the results are compared below.

9.2.1 RAVENGLASS

a) Observations of feeding flocks

The proportions of Black-headed Gulls using estuarine and inland sites during counts in the pre-breeding seasons from 1985 to 1987 are shown in figures 9.1, 9.2 and 9.3. In 1987, the gulls fed chiefly on the estuary on the days of observation whereas in 1985 the largest flocks were seen on pasture areas and in 1986 birds used both areas. The use of estuary or pasture varied from count-day to count-day. As all inland feeding flocks in the early part of the season were observed to be feeding on earthworms it is probable that differences in sites used between count-days were due to the effects of rainfall on the availability of earthworms in the pastures. The differences may also have resulted from variations in the tidal state at the time of the count. Whilst every effort was made to make the counts at a similar time in the tidal cycle from week to week, this was not always possible; obviously, at high tide the mud-flats are covered so birds cannot feed there.

During the 1984 breeding season only two feeding flocks were observed around the Ravenglass estuary. One was of 650 Black-headed Gulls feeding on earthworms behind a plough near Drigg Station in early June, the other was of 800 gulls hawking flying insects over the sand-dunes at Ravenglass in mid-June. No groups of more than seven gulls were seen on the estuary after the end of March 1984, despite a very dry Spring.

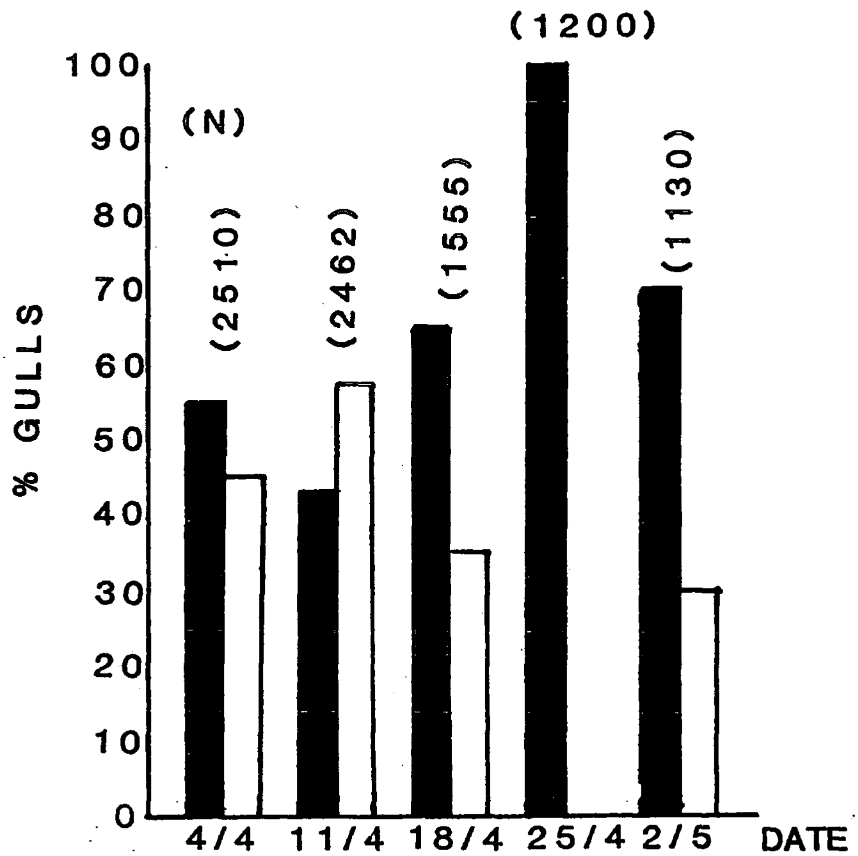
b) Analysis of Stomach Contents

The results of the stomach contents analysis of eight adult and seven chick Black-headed Gulls found dead at Ravenglass in 1984 are shown in table 9.1a. The samples were not all freshly dead so some decomposition may have occurred. It is probable that vegetation and stones were taken up whilst other food-items were obtained and were not selected as food; they are, therefore, not included in the following analyses. Beetles and earthworms were found most regularly in the stomachs (table 9.1b). The most interesting point is the predominance of food from inland sources. Of the 15 stomachs examined, significantly more contained food items from inland sources than

FIGURE 9.1

% GULLS FEEDING ON ESTUARY ■

AND PASTURE 1985



% GULLS FEEDING ON ESTUARY □

FIGURE 9.2

AND PASTURE 1986

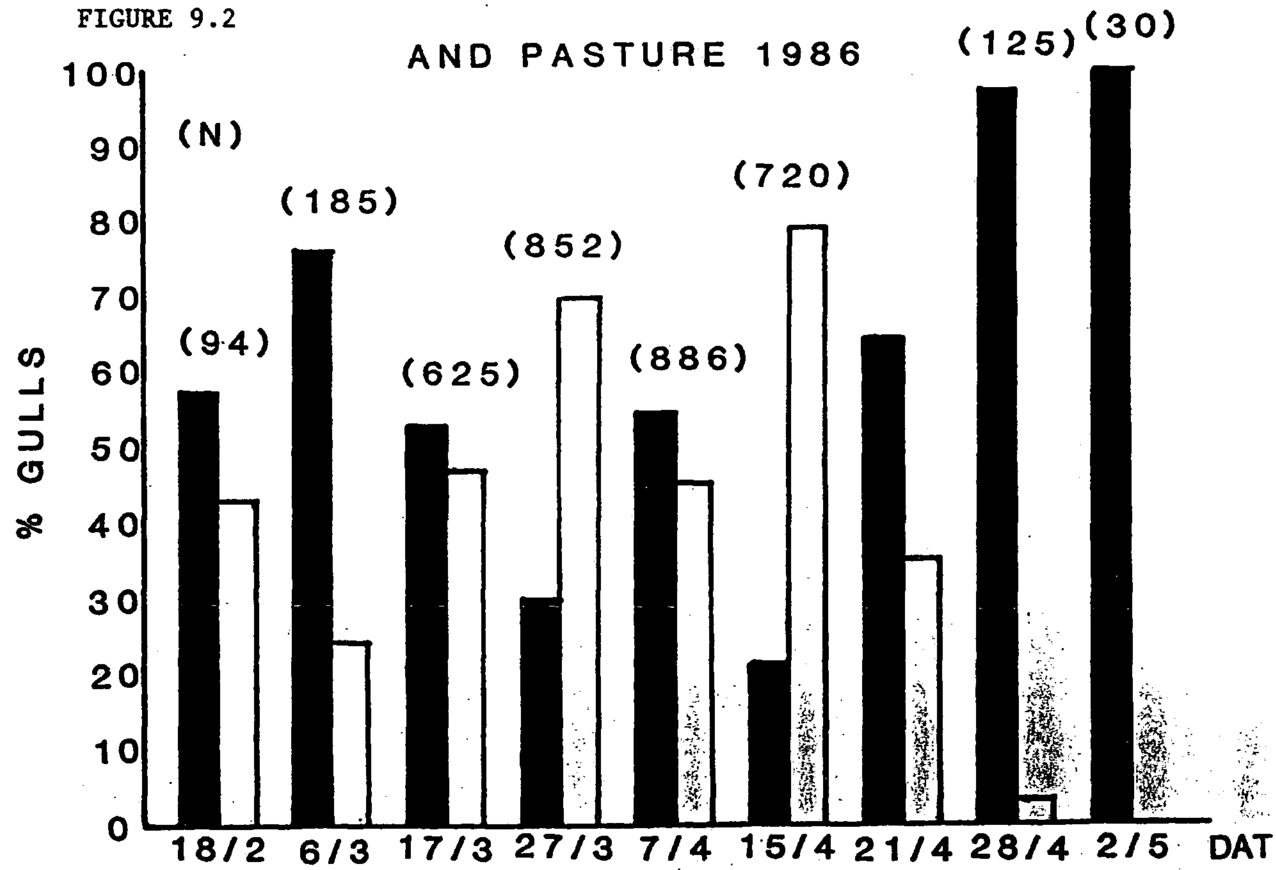
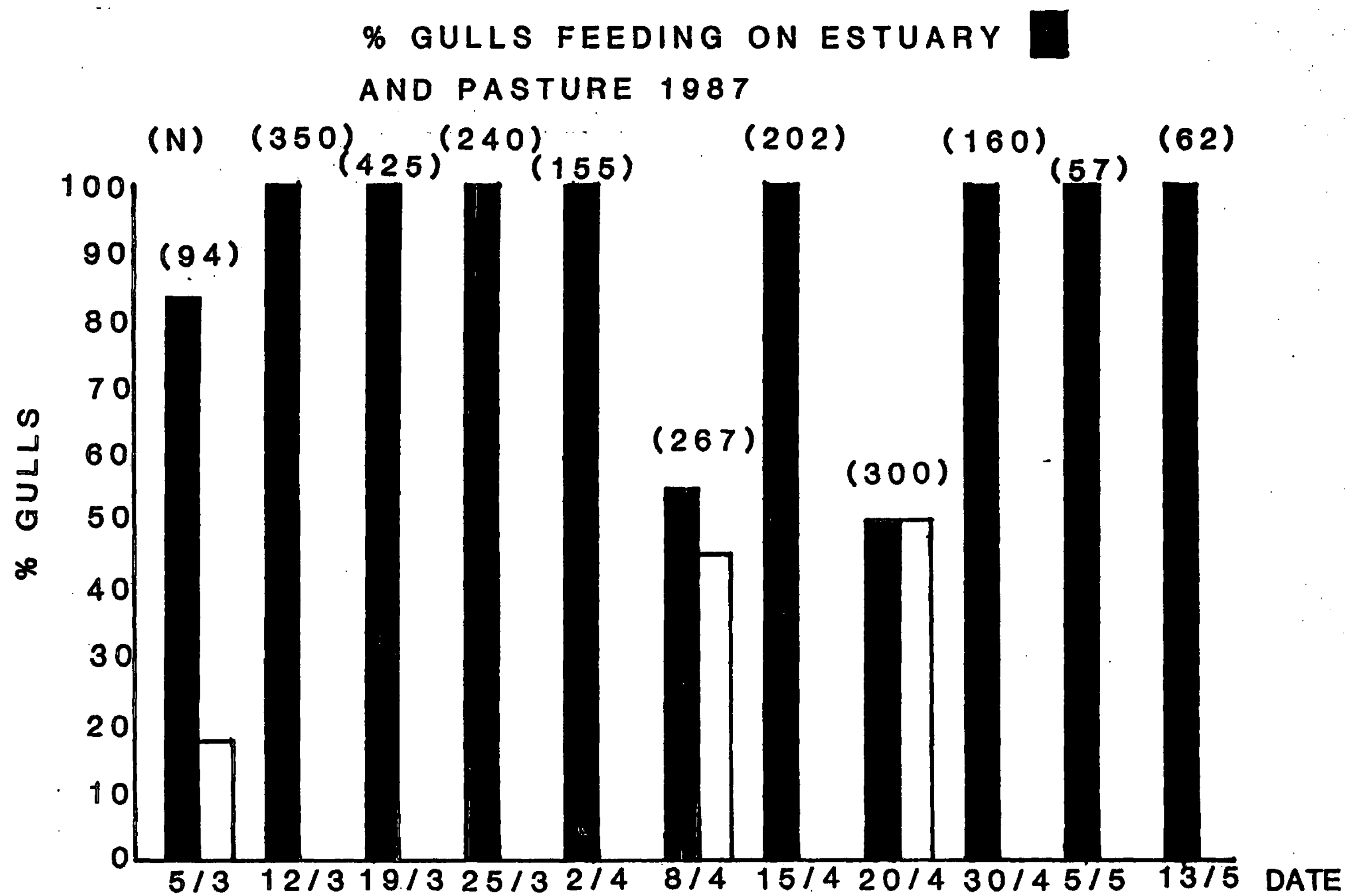


FIGURE 9.3



% GULLS FEEDING ON ESTUARY
AND PASTURE 1987
(N)
(94)
(350)
(425)
(240)
(155)
(267)
(202)
(300)
(160)
(57)
(62)
% GULLS
100
90
80
70
60
50
40
30
20
10
0
5/3
12/3
19/3
25/3
2/4
8/4
15/4
20/4
30/4
5/5
13/5
DATE

TABLE 9.1

a)

FOOD-ITEMS IN STOMACHS OF BLACK-HEADED GULLS COLLECTED AT RAVENGLASS DURING THE 1984 BREEDING SEASON.

	ADULTS		CHICKS		TOTAL	
FOOD ITEM	N	NO. (%) STOMACHS FOUND IN	N	NO. (%) STOMACHS FOUND IN	N	NO. (%) STOMACHS FOUND IN
Beetles	8	7(88%)	7	7(100%)	15	14(93%)
Earthworms	8	4(50%)	7	4(57%)	15	8(53%)
Leatherjackets	8	1(13%)	7	1(14%)	15	2(13%)
Vegetation	8	6(75%)	7	1(14%)	15	7(47%)
Hydrobia ulvae	8	1(13%)	7	0	15	1(7%)
Fish	8	1(13%)	7	0	15	1(7%)
(Stones)	8	1(13%)	7	0	15	1(7%)

b)

COMPARISON OF PROPORTIONS OF INLAND AND ESTUARINE FOOD ITEMS IN BLACK-HEADED GULL STOMACHS FROM RAVENGLASS 1984.

	N	NO. OCCURRENCES	SIGNIFICANCE OF DIFFERENCE (FISHER) EXACT PROBABILITY) TEST).
Inland items only	15	13	
			$p = 1.03 \times 10^{-7}$
Inland and estuarine items	15	1	
			$p = 0.50$
Estuarine items only	15	1	
			$p = 1.03 \times 10^{-7}$
(Inland items only	15	13)	

from estuarine sources or both (Fisher Exact Probability Test, table 9.1b), indicating that inland feeding areas were preferred. This is in accordance with the observations of Macpherson and Duckworth (1886) and Tinbergen (1953) who stated that "Black-headed Gulls at Ravenglass eat earthworms by the thousand".

9.2.2 FOULNEY ISLAND

a) **Analysis of Stomach Contents**

The results of gut content analysis of the three adult and three chick Black-headed Gulls found freshly dead at Foulney Island in June 1987 are given in table 9.2a. As at Ravenglass, few estuarine items were found despite the extensive mud and sand-flats surrounding the colony site at Foulney Island. Although there were no significant differences between the number of stomachs containing food items from inland or estuarine sources or both (Fisher Exact Probability Test, table 9.2b), the presence of earthworms and beetles suggests that, as at Ravenglass, the gulls tended to feed inland, at least during the breeding season. There is also indirect evidence for inland feeding from regular observations of flight lines from Foulney onto the fells to the north-east of Barrow-in-Furness.

b) **Chick Regurgitate Analysis**

During ringing operations in the Foulney Island colony in June 1987 a total of five regurgitate samples were collected from chicks of between 7 and 21 days old. These samples consisted entirely of earthworms, again suggesting that inland food sources were important to the Foulney Black-headed Gull colony even though there are rich estuarine and intertidal feeding areas available close at hand.

9.2.3 ROCKCLIFFE

a) **Analysis of Stomach Contents**

The results of the analysis of the guts of four adults and one chick collected in the Black-headed Gull colony at Rockcliffe in 1986 are shown in table 9.3a. There are no significant differences between the frequency of

TABLE 9.2

a)

FOOD-ITEMS IN STOMACHS OF BLACK-HEADED GULLS COLLECTED AT FOULNEY IN JUNE 1987.

	ADULTS		CHICKS*		TOTAL	
FOOD ITEM	N	NO. (%) STOMACHS FOUND IN	N	NO. (%) STOMACHS FOUND IN	N	NO. (%) STOMACHS FOUND IN
Beetles	3	3(100%)	3	3(100%)	6	6(100%)
Earthworm	3	2(67%)	3	1(33%)	6	3(50%)
Pygmy Shrew (*Sorex minutus*)	3	1(33%)	3	0	6	1(17%)
Vegetation	3	1(33%)	3	2(67%)	6	3(50%)
Macoma balthica	3	1(33%)	3	0	6	1(17%)
Crustacean sp.	3	0	3	1(33%)	6	1(17%)

*2 chick guts contained large numbers of parasites.

b)

COMPARISON OF PROPORTIONS OF INLAND AND ESTUARINE FOOD ITEMS IN BLACK-HEADED GULL STOMACHS FROM FOULNEY 1987.

	N	NO. OCCURRENCES	SIGNIFICANCE OF DIFFERENCE (FISHER EXACT PROBABILITY TEST).
Inland items only	6	3	
			p = 0.116
Inland and estuarine items	6	2	
			p = 0.455
Estuarine items only	6	0	
			p = 0.091
(Inland items only	6	3)	

TABLE 9.3

a)

FOOD-ITEMS IN STOMACHS OF BLACK-HEADED GULLS COLLECTED AT ROCKCLIFFE IN 1986.

	ADULTS		CHICKS		TOTAL	
FOOD-ITEM	N	NO. (%) STOMACHS FOUND IN	N	NO. (%) STOMACHS FOUND IN	N	NO. (%) STOMACHS FOUND IN
Anuran	4	1(25%)	1	0	5	1(20%)
Hydrobia ulvae	4	1(25%)	1	0	5	1(20%)
Macoma	4	1(25%)	1	0	5	1(20%)
Other	4	1(25%)	1	1	5	2(40%)
Earthworm	4	2(50%)	1	1	5	3(60%)
Beetle	4	2(50%)	1	1	5	3(60%)
Leatherjacket	4	0	1	1	5	1(20%)
Vegetation	4	1(25%)	1	1	5	2(40%)

b)

COMPARISON OF PROPORTIONS OF INLAND AND ESTUARINE FOOD ITEMS IN BLACK-HEADED GULL STOMACHS FROM ROCKCLIFFE 1986.

	N	NO. OCCURRENCES	SIGNIFICANCE OF DIFFERENCE (FISHER EXACT PROBABILITY TEST).
Inland items only	5	1	
			p = 0.778
Inland and estuarine items	5	1	
			p = 0.778
Estuarine items only	5	1	
			p = 0.778
(Inland items only	5	1)	

occurrence of inland or estuarine food items or both in the gulls' stomachs (Fisher Exact Probability Test, table 9.3b). However, food from inland sources was found most regularly, and estuarine food (Macoma) appeared only once.

b) **Chick Regurgitate Analysis**

Table 9.4 shows the contents of 7 chick regurgitate samples collected in 1986 and 6 collected in 1987. Once again, no estuarine food items were found, suggesting that, as at Foulney and Ravenglass the Rockcliffe Black-headed Gulls did not exploit estuarine foodstuffs to any large extent during the breeding season. Indeed, the stickleback remains found are likely to be from a freshwater species as estuarine species have thickened head plates (S. Carter pers. comm.).

9.2.4 WASTWATER

a) **Gut Content Analysis**

A total of 11 chick guts collected during the 1986 breeding season were examined (see table 9.5). As expected, only inland foodstuffs were found. Earthworms and beetles occurred most frequently.

b) **Chick Regurgitate Analysis**

Results of the analysis of 5 samples collected at the Wastwater colony in 1985 and 7 collected in 1986 are shown in table 9.6. Earthworms and beetles were again the main food items found, although leatherjackets (Tipulid larvae) were important in the 1986 sample.

c) **Feeding Observations**

The results of observations of chick feeding in 1986 and 1987 together with those of courtship feeding in 1987 are shown in figures 9.4 a) and b). Information on courtship feeding was not collected in 1986 as work was concentrated at Ravenglass that year. In both years earthworms were the major food items throughout the season, although they were slightly more important in 1987, the wet weather making them available even late in season. The amount of bread fed to chicks correlates with periods when large numbers of people were picknicking at Wastwater. Leather-jackets were taken

TABLE 9.4

COMPOSITION OF CHICK REGURGITATES FROM ROCKCLIFFE

	N	NO. OCCUR-RENCES	% OCCUR-RENCES	N	NO. OCCUR-RENCES	% OCCUR-RENCES	N	NO. OCCUR-RENCES	% OCCUR-RENCES
Earthworm	7	4	57	6	5	83	13	9	69
Beetle	7	1	14	6	3	50	13	4	31
Wireworm	7	1	14	6	-	-	13	1	8
Pygmy Shrew	7	1	14	6	-	-	13	1	8
Stickleback	7	1	14	6	-	-	13	1	8
Mosquito Larva	7	1	14	6	-	-	13	1	8
Leatherjacket	7	-	-	6	1	17	13	1	8

FIGURE 9.4

CONTENTS OF CHICK- AND COURTSHIP-FEEDS AT WASTWATER

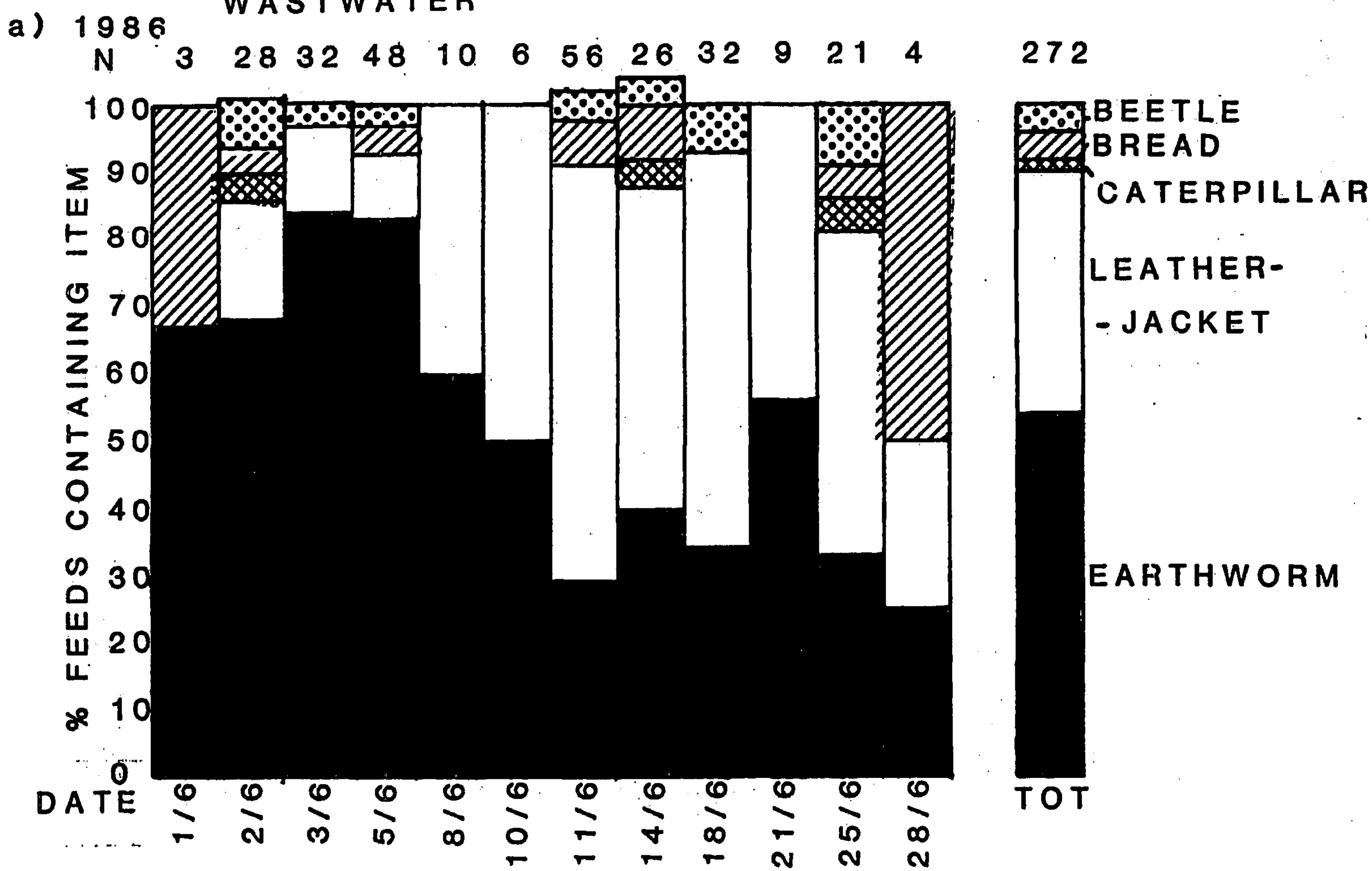


FIGURE 9.4

b) 1987

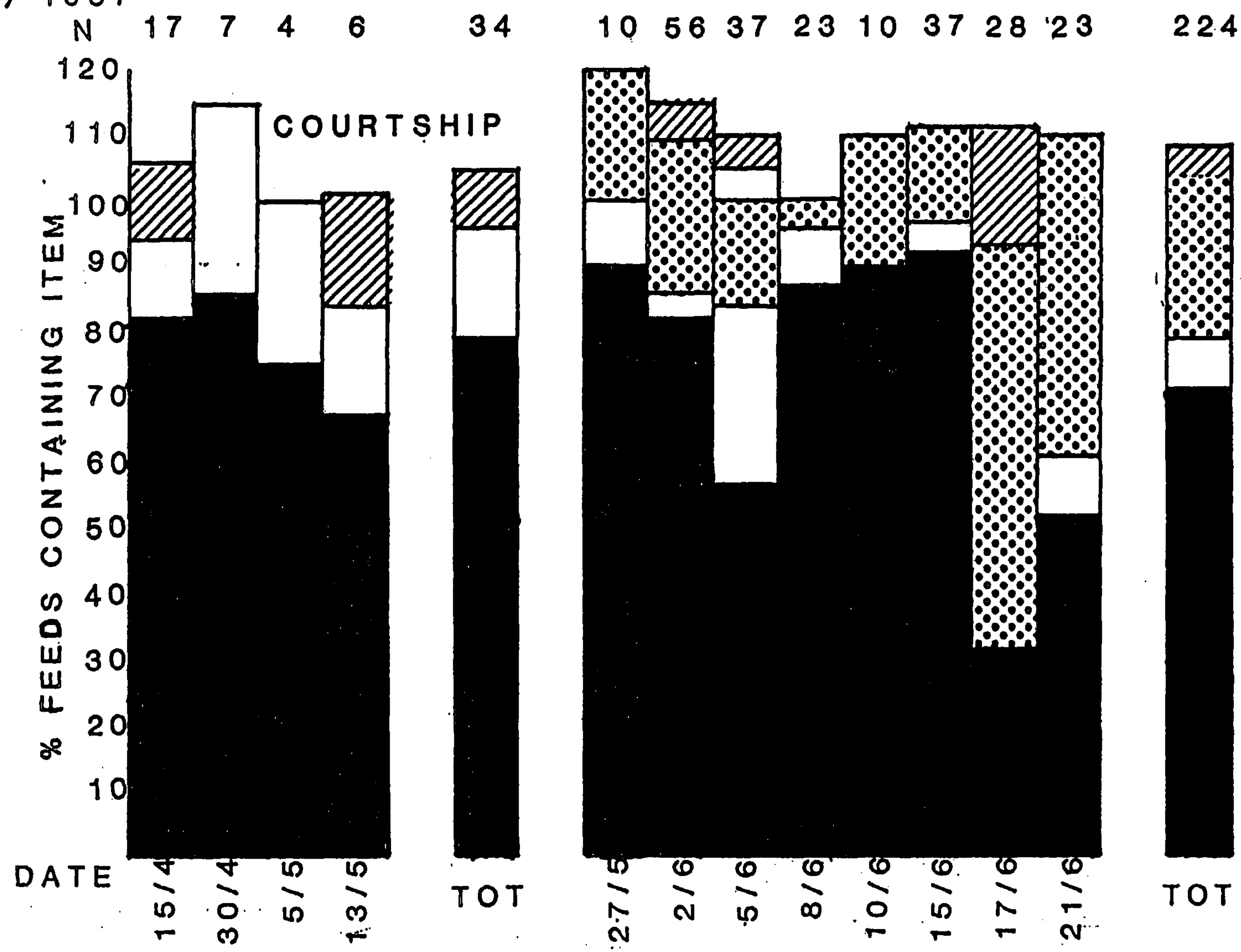


TABLE 9.5

FOOD ITEMS IN THE GUTS OF BLACK-HEADED GULL CHICKS FOUND DEAD AT WASTWATER IN 1986

	N	NO. OCCURRENCES	% OCCURRENCES
Earthworm	11	7	67
Beetle	11	11	100
Wireworm	11	3	27
Leatherjacket	11	2	18
Fly	11	1	9
Field Vole (*Microtus arvalis*)	11	1	9
Vegetation	11	6	55
Other	11	4	36

TABLE 9.6

COMPOSITION OF CHICK REGURGITATES FROM WASTWATER

	1985		1986		TOTAL	
	N	NO. (%) OCCUR-RENCES	N	NO. (%) OCCUR-RENCES	N	NO. (%) OCCUR-RENCES
Beetle	5	1(20%)	7	4(57%)	12	5(42%)
Earthworm	5	5(100%)	7	4(57%)	12	9(75%)
Leatherjacket	5	0	7	3(43%)	12	3(25%)
Fly	3	0	7	1(4%)	12	1(8%)

frequently in 1986 but were replaced to a large extent by beetles in 1987; this probably relates to differing amounts of rainfall with more earthworms available in wet years.

d) Comparison of Methods

As all three methods of estimating chick diet were used at Wastwater it is possible to compare them. All three methods were found to concur on the identities of foodstuffs taken most frequently (Kendall's coefficient of concordance $W=0.677$, $N=7$, $K=4$, $p<0.01$). This suggests that any one of the above methods would give a satisfactory picture of the food types which are most frequently fed to Black-headed Gull chicks during the breeding season. Care must be taken, however, when making deductions from observations on chick feeding as smaller items, such as beetles, may be missed. Beetles were found in all chick stomachs examined from 1986 whereas in the feeding observations they were rarely seen. It is likely that in 1986 beetles were given as food alongside larger items such as earthworms (and so missed in observations) whereas in 1987 a large number of feeds contained beetles only so the proportion recorded by direct observation was higher.

e) Courtship Feeding

In 1987, observations were also made of courtship feeding between pairs of Black-headed Gulls at Wastwater (figure 9.4b)). The predominant items were earthworms and leatherjackets although bread appeared on days when tourists were around the site. The lack of beetles recorded at this time may have been due to the observational method used but it seems more likely that other items were more easily accessible in this early part of the season as large areas of pasture land were still very wet following rain in early Spring.

f) Observations of Feeding Flocks

Some observations were also made of feeding flocks of adult Black-headed Gulls around Wastwater. The major concentrations of birds noted were in pasture fields at the beginning of the breeding season. Adults gradually moved further inland up the Irt valley as the weeks passed. Flocks originally appeared in the fields around Drigg, then Holmrook, and then gradually up to the pastures to the west of Wastwater itself. In all cases the gulls were seen to feed on earthworms. Later in the season (apart from flocks exploiting tourists) the major concentrations of feeding adults moved northwards to pastures nearer Gosforth, or in dry spells, onto the wetter moorland areas. When the weather became really dry, birds were seen to feed on beetles and other flying insects. Towards the end of the breeding season, hay cutting in Wasdale usually led to an assembly of a flock of gulls hawking the insects which were disturbed. No gulls were seen feeding in the lake itself at any time.

9.2.5 SINEY TARN

a) **Chick Feeding Observations**

Results of feeding observations at Siney Tarn in 1986 and 1987, together with those of courtship feeding in 1987 are shown in figures 9.5 a) and b). The diet of chicks at Siney Tarn was similar to that at Wastwater except that no bread was taken (few tourists visit the site). As at Wastwater the proportion of leatherjackets in the diet fell from 1986 to 1987.

b) **Observations of Feeding Flocks**

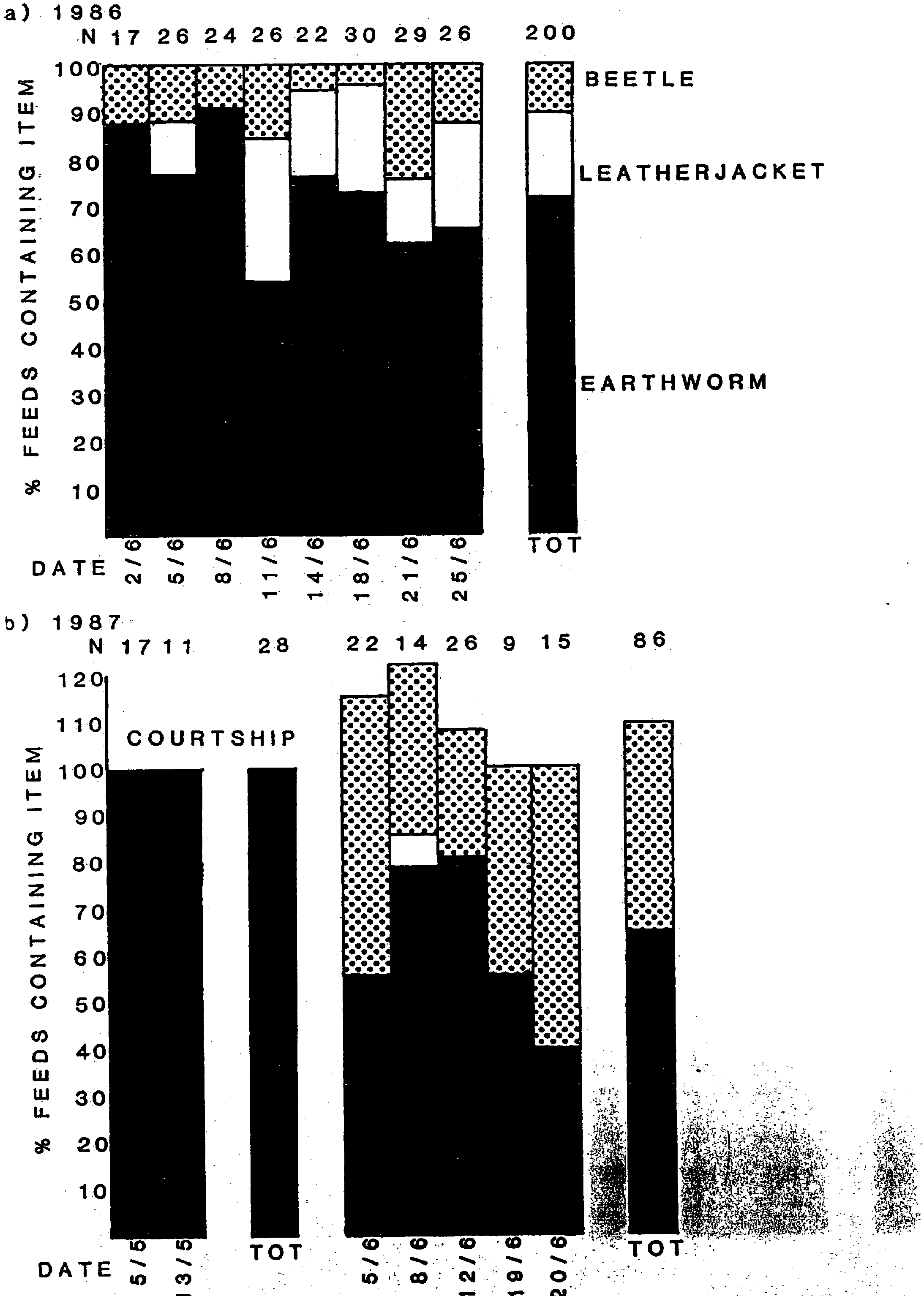
Flight lines to and from the Siney Tarn colony and any congregations of feeding gulls were noted. The major route out from the colony was north-west into Miterdale. Very few gulls were seen to feed in Eskdale until later in the season when flocks were seen hawking insects during hay-cutting activities around Boot Village at the eastern end of the valley.

9.2.6 DISCUSSION

The most interesting point emerging consistently from this work on feeding areas and food of Black-headed Gulls at Cumbrian colonies is the predominance of "inland" food-types taken, even at those colonies on the coast which have easy access to large estuarine feeding areas. Indeed, the three coastal colonies (Ravenglass table 9.1, Foulney Island table 9.2, Rockcliffe Marsh table 9.3) show considerable concordance as to food choice (Kendall's coefficient of concordance $W=0.478$, $N=11$, $K=8$, $p<0.01$) with earthworms and beetles being the major food items. This suggests that the observations of Macpherson and Duckworth (1886) that "the downy young (at Ravenglass) are fed on earthworms and beetles" and Tinbergen (1962) that

FIGURE 9.5

CONTENTS OF CHICK AND COURTSHIP FEEDS AT SINEY TARN



"gulls at Ravenglass eat earthworms by the thousand" hold true for other coastal colonies. This means that if those Black-headed Gulls which breed in coastal colonies feed on inland food sources every year then even if estuarine invertebrates are contaminated by radionuclides the gulls are unlikely to have been affected via their foodstuffs.

A comparison of the methods used to investigate the dietry preferences of Black-headed Gull chicks at Wastwater showed that although all three methods concurred on the most frequently taken foodstuffs, each method underestimated the importance of a particular group. Direct watching from a hide within the colony may have given a better picture of the overall diet and allowed concentration on one pair at a time so feeding rates could have been calculated. Also, the use of an emetic on chicks in a colony would have provided a larger sample size of chick regurgitates and avoided the possible bias that those chicks fed on e.g. earthworms, were more likely to have regurgitated on handling than were chicks fed on other foodstuffs. Obviously, one of these methods would have been preferable to those used, but time constraints would have prevented detailed work at more than one or two colonies. The range of methods used give an overview of the foods and feeding areas used by Black-headed Gulls from Cumbrian colonies but more detailed work would be necessary to investigate the preferences at any one colony more closely.

9.3 ESTUARINE INVERTEBRATE POPULATION SURVEY

It could be argued that gulls from Ravenglass feed predominantly on inland food items because the estuary has become so contaminated by radionuclides that the populations of invertebrates are too low to support a colony of gulls. This seems unlikely for several reasons:-

a) Macpherson and Duckworth (1886) recorded gulls from Ravenglass taking inland foods long before there was any possibility of radionuclide contamination in the estuary.

b) Black-headed Gulls from other coastal Cumbrian colonies also feed on inland food sources (see above), and

c) Other species which are known to feed on the estuary e.g. Shelduck, are producing young in good numbers so some food must be available.

As a check, however, the population levels of the most common invertebrates in the Ravenglass estuary were investigated by means of survey carried out in August 1986.

9.3.1 METHODS

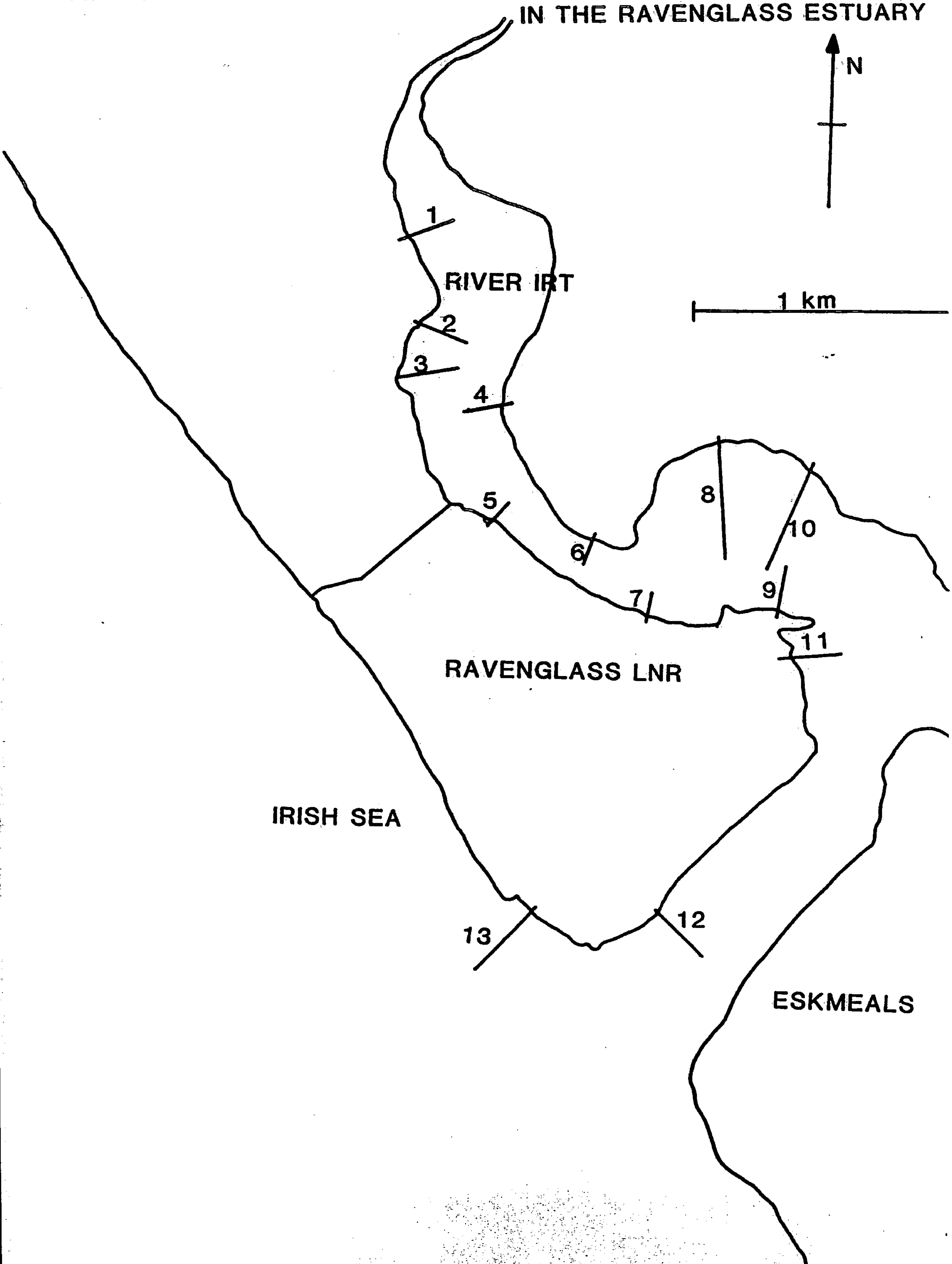
As time was not available to complete a large-scale invertebrate survey, it was decided to concentrate on species which are important as food for birds e.g. Nereis diversicolor, Hydrobia ulvae, Corophium volutator, Macoma balthica, Arenicola marina etc. (Prater 1972). The estuary of the River Irt was divided up into three sections by eye. In each of these sections sand and mud areas were distinguished and transects mapped out. The position of the transects are shown in figure 9.6. The number and length of transects on a particular area was determined by the size of the area and the distance from the back of the beach to a point roughly in the middle of the estuary channel. Sampling points were spaced according to the substrate and the transect length, usually 25m. apart but 12.5m. apart on very short transects and 50m. apart on the longer marine transects. Using a cylindrical corer, two samples were taken at each point, placed in plastic bags and labelled. Samples were sieved through a 1mm mesh seive. Animals were preserved in alcohol and identified in the laboratory. Lugworms (Arenicola marina) generally burrowed too deep to be caught in a 10cm. deep sample so numbers were estimated by taking the average counts of casts in four random 1m. quadrats at each sampling point. Mussels (Mytilus edulis) occurred in dense beds in some parts of the estuary. Where a transect line crossed such a bed density was estimated as for lugworm. Maximum figures were used as indicators of density, as too few samples were taken to give realiable mean values.

9.3.2 RESULTS

The results of the transect survey are given in Appendix 12. Species accounts for the major bird food items are given below:-

FIGURE 9.6

POSITION OF INVERTEBRATE SAMPLING TRANSECTS IN THE RAVENGLASS ESTUARY



a) Nereis diversicolor.

This errant polychaete worm occurred in nearly all transects. Anderson (1971) found that this species occurred mainly in the middle reaches of estuaries. This was the case in the Ravenglass estuary. As expected, N. diversicolor was found predominantly in the muddier sediments, particularly at Saltcoats and at Lake End (figure 9.7). The maximum density of $2033m^{-2}$ was within the range of published studies from other estuaries (table 9.7).

b) Corophium volutator.

This was the most abundant invertebrate in the intertidal sands in the estuary and an important food of waders e.g. Redshank (Goss-Custard 1970). As with Nereis diversicolor the maximum density recorded at Drigg was within the range found at other sites (table 9.7). Corophium was also found mainly in the muddier sediments in the estuary. This is consistent with Meadows' (1964) studies which concluded that Corophium prefers fine-grained sediments.

c) Hydrobia ulvae.

This small gastropod mollusc is an important food of estuarine birds, especially Shelduck (Cramp and Simmons 1983). It was found predominantly in the muddier areas as was Corophium volutator. This is as predicted by Anderson (1971) who found a positive correlation between the distributions of the two species. The maximum number of Hydrobia per m^2 was, however, below that found in other studies (table 9.7) and below the range of $5,000-9,000/m^2$ considered by Green (1968) as normal.

d) Macoma balthica.

The Baltic Tellin is another important food source for waders, especially Redshank (Prater 1972). It was found mainly in muddier areas with a maximum density of $891m^{-2}$ on the Saltcoats mud-flats. This density is low compared to that found in Morecambe Bay (Anderson 1971) but similar to that at Lindisfarne, Northumberland, and larger than that in the Tees estuary (Davidson 1980), (see table 9.7) and is in region of the $c.1,000m^{-2}$ recorded in the Solway Firth (Perkins and Williams 1966).

TABLE 9.7

MAXIMUM DENSITIES OF INTERTIDAL INVERTEBRATES FROM RAVENGLASS COMPARED WITH THOSE FROM THREE OTHER ESTUARIES

Species	Max. no/m^2				
	Drigg	*Morecambe Bay	**Tamer	***Towy	****Tees
Nereis diversicolor	2,033	750	3,000	1,212	1,200
Corophium volutator	15,276	c 1,300	11,000	17,136	1,500
Hydrobia ulvae	3,183	8,525	N/R	N/R	12,000
Macoma balthica	891	c 2,000	N/R	N/R	100

Sources :

- * Anderson 1971
- ** Spooner & Moore 1940
- *** Howells 1964
- **** Davidson 1980

e) Arenicola marina.

Arenicola was found mainly in sandier sediments, either nearer the estuary mouth or towards the bottom of the transects in muddier areas e.g. Lake End and Saltcoats. The maximum density of $117m^{-2}$ fits in well with the records of Anderson (1971) for Morecambe Bay where densities of between $20\text{-}100^{-2}$ were common and occasional figures of more than $100m^{-2}$ were recorded.

f) Other Species.

Several other species of intertidal invertebrates were found during the survey (Appendix 11), however of these, one only, a gammarid sp. was found in large enough numbers to be considered as an important possible food source for birds feeding in the estuary. No information was found to allow comparison of densities of these less common invertebrates from Ravenglass with those from other estuaries.

9.3.3 DISCUSSION

The maximum densities of the major food sources found in the Ravenglass estuary compare well with those found in other estuaries, especially the nearby Morecambe Bay. Hydrobia ulvae densities were, however, less than those found in Morecambe Bay (Anderson 1971) and below those considered by Green (1968) as normal in the Clyde estuary. Without any data on densities of Hydrobia in the Ravenglass estuary in previous years it is impossible to speculate as to whether there has been a decline in the population. It may simply be that the sediment in the estuary is unsuitable for large numbers of Hydrobia with fine sediments such as muds being present only in a limited area. It is interesting that Shelduck, whose main food source in several estuaries is Hydrobia (Olney 1965, Bryant and Leng 1975) but not in the Tees (Evans et al. 1979) have not apparently decreased in numbers in recent years and are now producing young in larger numbers than in most years previously recorded (see Chapter 3).

Coastal feeding areas preferred by Black-headed Gulls have been described by Vernon (1970) and Crook (1953). Both of these studies were conducted during the winter (non-breeding) period. Black-headed Gulls feeding on the shore tended to be found in areas of estuarine mudflats but the actual food items taken were not identified in any detail. Vernon (1970) and Curtis et al. (1985) consider that Nereis diversicolor are important as are intertidal crustaceans e.g. Corophium volutator. Both of these species were present in large enough quantities to provide a reasonable food source for Black-headed Gulls, at least comparable to other estuaries. Thus it seems unlikely that the densities of possible invertebrate prey items in the Ravenglass estuary are low enough to force Black-headed Gulls to stop feeding there and to switch to inland feeding sites and food items.

9.4 GENERAL DISCUSSION

The evidence presented concerning feeding by Black-headed Gulls during the breeding season shows that even those birds breeding in colonies near abundant estuarine food sources travel inland to feed, mainly on earthworms. This along with observations of gulls from the Ravenglass colony (Macpherson and Duckworth 1886, Tinbergen 1952, Anderson 1985) suggests that estuarine food sources are of little importance to Black-headed Gulls during the breeding season. It is unlikely, therefore, that gulls at Ravenglass obtained any radionuclide contamination via their foodstuffs. To test this further a sample of 8 thyroid glands, collected from adult gulls killed by foxes at Ravenglass in 1984, were sent to St. Bartholomew's Hospital for analysis. Boult (pers.comm.) found that I-131 was readily concentrated in the thyroid glands of sheep feeding in contaminated foodstuffs near Sellafield and also in humans and Mute Swans (Cygnus olor) exposed to radio-iodine from hospital sources which was released into water supplies in the Thames Valley. No detectable levels of iodine were recorded in the gull tissue, again suggesting that the gulls at Ravenglass are not exposed to radiation sources through their foodstuffs.

It has been suggested that Black-headed Gulls from Ravenglass feed inland because there is insufficient food for them in the estuary. Evidence from the breeding success of other species e.g. Shelduck, which feed entirely on estuarine food sources and the estuary survey detailed above, suggests that the population levels of intertidal invertebrates used as food by birds are comparable with those from other estuaries. It seems, therefore, that there are sufficient estuarine food-sources for gulls should they wish to feed on them.

Black-headed Gulls feeding in flocks on fields near Ravenglass in March and April appeared to have no difficulty in obtaining earthworms suggesting that a lack of food in the pre-breeding period was not responsible for the failure of birds to settle in 1985, 1986 or 1987. It was noticeable, however, that fewer gulls appeared in the feeding flocks in later years so the possibility that food resources in the area as a whole had declined sufficiently to limit the total number of gulls that could be supported cannot be ruled out. A detailed survey of the earthworm populations of the fields in which Black-headed Gulls fed at Ravenglass would have helped address this. However, such a study was impossible given the resources and time available.

It seems unlikely that Black-headed Gulls at Ravenglass have been affected to any great extent by radionuclides taken in through foodstuffs, however, the possible effects of doses of external radiation from contaminated substrates are not known; these are considered in Chapter 11. Also, from an investigation of the diet of gulls during the breeding season, it is impossible to tell if birds have been contaminated by pollution taken in during the non-breeding season in areas away from Ravenglass and this is considered in Chapter 10.

CONTAMINATION OF BLACK-HEADED GULLS BY HEAVY METALS

INTRODUCTION

All the hypotheses tested so far have assumed that the causes of the decline in the Ravenglass gullery operated at Ravenglass only during the breeding season. Hypothesis v) in Chapter 1 however, suggested that gulls from Ravenglass may have been involved in pollution incidents outside the breeding season away from the Ravenglass estuary which reduced the numbers of adult gulls returning to the colony the following year. Figure 1.2 summarised the annual cycle of Black-headed Gulls breeding at Ravenglass. As can be seen, the gulls are present at Ravenglass for only five months of the year. At the end of the breeding season most leave the area and the numbers present on the estuary are low until the following March. It is possible, therefore, that adult mortality increased at the time of the decline in the late-1970's through acquisition of pollutants in the birds' wintering areas.

An analysis of recoveries of gulls ringed as chicks at Ravenglass (see Chapter 4) and recovered as adults (older than 2 years) suggested that the main dispersal direction at the end of the breeding season was south-south-east. This makes it possible that gulls from Ravenglass were involved in the "Mersey bird kills" in the late-1970's. As a result of discharges of alkyl-lead compounds into the Mersey in the late summer several thousands of Black-headed gulls and shorebirds were killed there (Head et.al. 1980, Bull et.al. 1983). There is no direct evidence from ringing recoveries that Ravenglass birds were killed in these incidents; however, the deaths occurred 10-15 years after most birds had been marked at Ravenglass so few <u>ringed</u> birds would have been alive to be at risk then.

It is also possible that sub-lethal effects of contamination from the same sources could have led to the breeding failures at Ravenglass in 1980 and 1984. As lead was the main pollutant implicated in the Mersey bird kills (Head et al. 1980, Bull et.al. 1983) samples of gulls, and their eggs, were collected and analysed for contamination. In addition, samples were also analysed for cadmium, zinc and copper residues.

Black-headed Gulls were obtained from a variety of sources. At Ravenglass, 8 birds killed by foxes during the 1984 breeding season and 2 cannon-net casualties from 1986 were examined. Gulls found dead at Rockcliffe (4), Foulney Island (3), and Sunbiggin Tarn (3) during the 1985 and 1986 breeding seasons and, for comparison with birds from a known polluted area, 5 gulls collected around Teesmouth during the winter of 1985/86 were also analysed. In addition, a sample of eggs from Cumbrian Black-headed Gull colonies was taken in 1985 under licence from the Nature Conservancy Council. All samples were kept deep frozen until analysed.

After dissection, liver and kidney samples were removed from birds, dried at 60'C in a vacuum oven to constant weight, then oxidised and evaporated to dryness with nitric acid. Residues were dissolved in 1:1 hydrochloric acid and metal levels determined using a Pye-Unicam SP.9 Atomic Absorption Spectrophotometer (Evans and Moon 1981). Egg samples (contents only, not shells) were treated similarly.

10.2 RESULTS AND DISCUSSION

The results from the analyses of liver and kidney samples are shown in tables 10.1 and 10.2 respectively. Ravenglass was the only Cumbrian site at which heavy metal concentrations in the liver were elevated. Evans and Moon (1981) found that the mass of birds' liver decreases markedly if the bird has not fed for more than 6 hours. Unless heavy metal contaminants are lost at the same rate as other components (and this does not usually occur) then this reduction in liver mass will result in apparently elevated contaminant levels. It seems that, as the samples from Ravenglass were not as fresh as those from other sites, the lower liver mass (table 10.1) probably resulted from decomposition and resulted in elevated contaminant concentrations. It is probable that this also occurred at Teesmouth, as most of the birds sampled were cold-weather casualties, so were in poor, semi-starved condition. In comparison to other studies (Parslow et.al. 1972, Hutton 1981) the mean levels of all four metals in the liver are at the low end of known ranges and probably not high enough to cause any ill-effects to the birds. In fact, in only two cases from Teesmouth and two from Ravenglass does the figure for zinc for a single gull exceed the mean for the seabirds studied by Parslow et.al. The figures for cadmium found by Osborne et al. (1979) in seabirds are an order of magnitude greater than those found at any of the Black-headed Gull sites, whereas those for lead are similar for both studies.

TABLE 10.1

MEAN LIVER CONCENTRATIONS OF HEAVY METALS FROM BLACK-HEADED GULLS
(MEAN ± STANDARD ERROR, RANGE BELOW, SAMPLE SIZE IN PARENTHESES)

SOURCE OF SAMPLE	Zn^{2+} IN TISSUE mg/kg DRY WT.	Cu^{2+} IN TISSUE mg/kg DRY WT.	Pb^{2+} IN TISSUE mg/kg DRY WT.	Cd^{2+} IN TISSUE mg/kg DRY WT.	LIVER DRY MASS
RAVENGLASS	229.36±84.42(9) 58.82-698.28	13.38±4.10(9) 3.68-42.24	5.07±0.99(7) 0.36-9.26	1.37±0.40(9) 0.26-3.66	3.07±0.14(9) 2.32-3.46
FOULNEY	56.67±4.37(3) 48-62	3.68±0.05(3) 1.86-5.04	0.39±0.16(3) 0.13-0.68	0.31±0.09(3) 0.13-0.44	3.38±0.23(3) 2.96-3-77
ROCKCLIFFE	89.68±18.05(4) 43.33÷130.63	3.47±0.52(4) 2.53-4.95	0.53±0.13(4) 0.34-0.9	0.48±0.11(4) 0.28-0.72	3.44±0.20(4) 3.00-3.85
SUNBIGGIN	65.01±11.28(3) 45.45-84.53	3.36±0.71(3) 2.25-4.68	0.31±0.13(3) 0.66-0.45	0.62±0.12(3) 0.47-0.86	3.55±0.41(3) 2.78-4.18
TEESMOUTH	248.54±113.79(5) 43.75-590.16	11.61±5.36(5) 1.72-25.61	3.27±1.84(5) 0.26-9.84	1.52±0.71(5) 0.22-3.44	2.32±0.52(5) 1.04-3.80

TABLE 10.2 MEAN KIDNEY CONCENTRATIONS OF HEAVY METALS FROM BLACK-HEADED GULLS (MEAN + STANDARD ERROR, RANGE BELOW, SAMPLE SIZE IN PARENTHESES).

SOURCE OF SAMPLE	Zn^{2+} IN TISSUE mg/kg DRY WT.	Cu^{2+} IN TISSUE mg/kg DRY WT.	Pb^{2+} IN TISSUE mg/kg DRY WT.	Cd^{2+} IN TISSUE mg/kg DRY WT.
RAVENGLASS	155.14±38.98(10)	13.40±0.80(10)	4.48±0.54(10)	14.91±1.26(10)
	76.16-427.81	10.63-18.27	0.64-6.75	8.10-20.40
FOULNEY	446.06±139.18(3)	20.19±5.63(3)	6.07±1.83(3)	14.75±4.08(3)
	217.13-697.67	9.95-29.46	2.41-8.06	6.63-18.99
ROCKCLIFFE	475.14±22.99(4)	20.89±3.62(4)	7.05±0.70(4)	13.13±2.14(4)
	409.25-516.13	15.49-20.80	5.20-8.60	8.82-16.98
SUNBIGGIN	332.16±72.89(3)	14.66±3.84(3)	4.62±1.96(3)	14.96±5.72(3)
	196.85-446.81	8.19-26.38	2.21-8.51	8.19-26.38
TEESMOUTH	535.37±127.22(5)	22.65±5.08(5)	15.01±4.73(5)	14.08±6.54(5)
	194.73-961.54	8.02-39.66	3.44-31.25	5.01-39.42

Considering the more representative kidney samples, which are less susceptible to changes in mass related to starvation, the level of zinc found in the gulls were higher than those found in Oystercatcher, Herring Gull and Great Skua (Catharacta skua) by Hutton and in Curlew (Numenius arquata), Sanderling (Calidris alba), Redshank (Tringa totanus), Knot (Calidris canutus) and Dunlin by Evans and Moon (1981); but zinc is not a particularly toxic metal. Mean cadmium concentrations in the gull kidney samples were also slightly higher than found in the above species. Concentrations of cadmium in Oystercatchers and Great Skuas were found to increase with age (Hutton 1981), related to the long biological half-life of the metal - a consequence of the binding of cadmium to metallothionen and its subsequent retention in the kidney (Friberg et.al. 1974). It is, therefore, possible that, as all the birds sampled were adults, the elevated cadmium levels in the kidney are due to an age related accumulation. Higher levels of zinc, copper and lead were found in gulls collected at Teesmouth than in Cumbria; this is as expected, as the Teesmouth area is known to be seriously polluted by heavy metal residues (Porter 1973).

The data collected from the analysis of Black-headed Gull eggs are given in table 10.3. The levels of copper, lead and cadmium in the eggs are all significantly less than those found by Parslow et.al. (1972) for 5 Puffin (Fratercula arctica) eggs from St. Kilda. As with the livers and kidneys, these levels are lower than those thought to cause infertility.

It seems unlikely that the concentrations of those heavy metal contaminants analysed from Black-headed Gull corpses and eggs from Ravenglass and other Cumbrian colonies were large enough to have adversely affected breeding performance although there is some evidence of slightly elevated kidney cadmium levels, probably age-related and presumably picked-up on wintering sites. Unless organo-lead compounds are quickly excreted by birds, it would seem that Ravenglass birds were not involved in the pollution incidents on the Mersey in 1979/80, as they now carry relatively low levels of lead in their tissues. If Ravenglass Black-headed Gulls have not been affected by pollutants acquired outside the Ravenglass area then they may still have been contaminated by pollution on the Ravenglass estuary itself. The main possible source of pollution at Ravenglass is radionuclide waste from the Sellafield Nuclear Reprocessing Plant situated on the coast 5k.m. North of the reserve. This is considered in Chapter 11. It is, of course, possible that other heavy metals which were not analysed for e.g. mercury, were present in higher than normal concentrations in Ravenglass birds.

TABLE 10.3

HEAVY METAL CONCENTRATIONS IN BLACK-HEADED GULL EGGS (MEAN± STANDARD ERROR, RANGE BELOW, SAMPLE SIZE IN PARENTHESES)

SAMPLE SITE		Cu^{2+} IN EGG mg/kg DRY WT.	Pb^{2+} IN EGG mg/kg DRY WT.	Cd^{2+} IN EGG mg/kg DRY WT.
Ravenglass	1984	1.3±0.3(3) 1.0-2.0	3.0±0.76(3) 2.0-4.5	NOT DETECTABLE
River Mite	1985	2.5±0.87(3) 1.0-4.0	3.27±0.05(3) 2.30-4.00	NOT DETECTABLE

INTERNAL AND EXTERNAL RADIATION DOSE RATES RECEIVED BY BIRDS USING THE RAVENGLASS ESTUARY

INTRODUCTION

A number of workers have investigated the effects of radiation doses on wild birds and their young. Most have concentrated on external doses. Willard (1963) calculated that 50% of young Bluebirds (Sialia sialia) irradiated over a 16-day period would die from an absorbed dose of 21.7 Gy (see appendix 14 for an explanation of the units). Brisbin (1969) found that the highest level of irradiation that commercial broiler chicks could tolerate without a significant decrease in early growth rate was 2 Gy (delivered over two days at a rate of 0.08 Gy per minute). Zach and Mayoh (1984) showed that no ill-effects occurred in nestling Tree Swallows (Iridoprocne bicolor) acutely exposed to gamma-radiation doses of up to 4.5 Gy immediately after hatching, but that doses of 1.0 Gy per day induced retardation or stunting in growth. They concluded that "the relative sensitivities of embryo, nestling and adult birds suggest that hatching success is the best criterion for assessing radiological stress in wild birds". The same authors (1986) conducted similar experiments with House Wrens (Troglodytes aedon) which also showed dose-dependant growth depression induced by a dose of a similar magnitude.

Of more direct relevance to the Ravenglass situation, Miss L J Phillips (pers. comm.) found that a chronic dose of 10 Gy over 20 days was necessary to reduce full-term development and cause inviability among 50% of a sample of Black-headed Gull eggs collected from a colony in Norfolk. Woodhead (1986) used data collected by the Ministry of Agriculture, Fisheries and Food (MAFF) at Ravenglass in conjunction with equations derived from modelling radionuclide behaviour to calculate the external and internal doses received by Black-headed Gulls breeding at Ravenglass. Using data collected during this study, and a complimentary one by the Institute of Terrestrial Ecology (ITE), Merlewood it has been possible to up-date Woodhead's conclusions and to extrapolate calculations to other bird species breeding on the Ravenglass Reserve.

Data used in the dosimetry calculations were collected by ITE, Merlewood between 1980 and 1987 (Allen et.al. 1983, Lowe 1987), from Black-headed Gulls and other bird material by analyses of breast muscle, liver, alimentary tract and the remainder of the carcass. Samples of eggs were also analysed. MAFF provided data on gamma-ray dose rates measured at a height of 1m. over sand, silt and salt-marsh substrates at a number of sites in the Ravenglass estuary. Concentrations of radionuclides in potential food items were measured by ITE.

Before attempting dose-rate calculations a "worst case scenario" was developed. This identified the group of gulls which received the highest possible radiation doses from the environment, i.e. the "critical group" birds. The "critical group" concept is widely used in radiation protection as, if individuals receiving the highest possible dose are within recognised safety limits, it is reasonable to assume that the rest of the population is within these limits. Critical group birds were assumed to:-

1. Arrive on the Ravenglass estuary in early March and leave in late August. i.e. stay for the longest time of all breeding birds.

2. Spend 24 hours per day around the estuary complex, feeding or roosting on contaminated sediments. (Gulls actually fed inland most of the time, see Chapter 9).

3. Forage for themselves and feed chicks entirely on food derived from the estuary itself. Nereis diversicolor was chosen as the main food item as data are available for consumption during the breeding season at a German colony (Hartwig and Huppop 1982) and the ITE study (Lowe 1987) showed it to be amongst the most contaminated invertebrate species.

Calculations based on the above assumptions provide an upper estimate of the dose rate to Black-headed Gulls at Ravenglass. Similar assumptions were made for Oystercatcher and Shelduck.

The actual calculations were based on a MAFF radiation dosimetry model (Woodhead 1986). External and internal doses were treated separately as follows:-

i) EXTERNAL

Measurements of gamma-rays were made by MAFF at a height of 1m. above contaminated sediments. To model the situation for an egg or an adult on the nest this figure was multiplied by 2 and for an adult feeding or roosting by 1.5 (Woodhead 1986). To calculate external dose rates the time-budgets of "critical group" gulls at Ravenglass were estimated (after Woodhead 1986 - table 11.1) and the number of hours spent in each activity multiplied by the dose rate associated with that activity. These are added together then divided by 24 to give a mean dose rate in Greys per hour.

ii) INTERNAL

The calculations for doses from internal sources were based on the equations given in table 11.2. As the distribution of radionuclides in the gut is not uniform, Woodhead (1986) suggested that the values obtained from equation 1 should be increased by 25% to obtain gamma-dose rates from materials in the gut. For alpha and beta particles equations 2 and 3 are used with the equivalent whole body concentration replaced by equivalent gut concentration (Cg). Woodhead states that "as cells lining the gut are irradiated from one side only the values from equations 2 and 3 should be halved". I can see no justification for this so have left the values whole. Where possible, adult male, adult female and juvenile Black-headed Gulls were treated separately in calculations as their different food requirements cause differences in their dose rates, especially to the alimentary canal.

11.2 RESULTS AND DISCUSSION

The calculated dose rates for Black-headed Gulls are shown in table 11.3 and for Oystercatcher and Shelduck in table 11.4. In all cases the dose from external gamma-emitting radiation is the major contributor to the total dose received by both birds and eggs. For adults in all stages of the breeding cycle and chicks the highest dose component in the mean is that derived from activities over mud, silt or saltmarsh. If for example, an adult gull remained on estuarine mud for 24 hours then its mean external radiation dose rate would be 1.4×10^{-6} Gyh $^{-1}$. Natural background radiation gives a dose of around 1×10^{-7} Gy per hour (Woodhead 1986) so birds at Ravenglass are obtaining doses of approximately 10X background, whilst eggs receive around 4X background. Considering a greatest likelihood scenario where Black-headed

TABLE 11.1

ESTIMATIONS OF TIME-BUDGETS OF BLACK-HEADED GULLS AT RAVENGLASS FOR EXTERNAL RADIATION DOSE CALCULATIONS

A) ADULTS

i) Pre-laying period (42 days)

ACTIVITY	NO. HOURS PER DAY	ESTIMATED MEAN DOSE RATE (Gyh^{-1})
Feeding/roosting over saltmarsh	8	1.4×10^{-6}
Feeding over mud/silt	8	1.4×10^{-6}
Roosting on sand	5	3.0×10^{-7}
Courtship behaviour over sand	2	3.0×10^{-7}
Flying	1	0
Mean over 24 hours		1.0×10^{-6}

ii) Incubation period (24 days)

ACTIVITY	NO. HOURS PER DAY	ESTIMATED MEAN DOSE RATE (Gyh^{-1})
Incubating eggs on sand	12	4.0×10^{-7}
Feeding over mud/silt	8	1.4×10^{-6}
Feeding/roosting over saltmarsh	3	1.4×10^{-6}
Flying	1	0
Mean over 24 hours		8.4×10^{-7}

iii) Fledging period (35 days)

ACTIVITY	NO. HOURS PER DAY	ESTIMATED MEAN DOSE RATE (Gyh^{-1})
Incubating/brooding	9	4.0×10^{-7}
Feeding over mud/silt	8	1.4×10^{-6}
Feeding over saltmarsh	6	1.4×10^{-6}
Flying	1	0
Mean over 24 hours		9.7×10^{-7}

B) CHICKS

	ESTIMATED MEAN DOSE RATE (Gyh^{-1})
Fledging period (35 days)	1.1×10^{-6}

TABLE 11.2

EQUATIONS USED IN CALCULATIONS OF INTERNAL RADIATION DOSES

a) For gamma-rays

$D_\gamma = 576 \times 10^{-9}.\ n(E_\gamma)\ \phi\ (E_\gamma)\ E_\gamma\ C_{WB}\ Gy.h^{-1}$ 1

b) For alpha particles

$D_\alpha = 576 \times 10^{-9}.n(E_\alpha)\ E_\alpha\ C_{WB}\ Gy.h^{-1}$ 2

c) For beta particles

$D_\beta = 576 \times 10^{-9}.\ n(E_\beta)\ E_\beta\ C_{WB}\ Gy.h^{-1}$ 3

where:-

$n(E_{\gamma\ \alpha}$ or$_\beta)$ = the proportion of disintegrations resulting in the emission of a ray of energy $E_{\gamma\ \alpha}$ or $_\beta$ Obtained from ICRP (1983).

C_{WB} = the equivalent whole body concentration of the radionuclide in Bq. per gramme.

$\phi\ (E_\gamma)$ = the absorbed fraction of gamma-rays at every E . (Assumed to be 1 for α and β).

TABLE 11.3

CALCULATED RADIATION DOSE RATES RECEIVED BY BLACK-HEADED GULLS BREEDING AT RAVENGLASS

TARGET	SOURCE	DOSE RATE ($Gy.h^{-1}$) Adult Male	Adult Female	Chick
Whole Body	β/γ Emitters in whole body	1.3×10^{-9}	1.3×10^{-9}	1.3×10^{-9}
	β/γ Emitters in gut	6.2×10^{-9}	6.7×10^{-9}	4.3×10^{-9}
	α Emitters in whole body	7.2×10^{-9}	7.2×10^{-9}	7.2×10^{-9}
	External γ emitters	1.0×10^{-6}	1.0×10^{-6}	1.1×10^{-6}
	TOTAL	1.0×10^{-6}	1.0×10^{-6}	1.1×10^{-6}
Cells lining	β/γ Emitters in whole body	1.3×10^{-9}	1.3×10^{-9}	1.3×10^{-9}
Alimentary	β/γ Emitters in gut	9.6×10^{-8}	1.0×10^{-7}	6.7×10^{-8}
Tract	α Emitters in gut	3.2×10^{-8}	3.5×10^{-8}	2.3×10^{-8}
	External γ emitters	1.0×10^{-6}	1.0×10^{-6}	1.1×10^{-6}
	TOTAL	1.1×10^{-6}	1.1×10^{-6}	1.2×10^{-6}

TABLE 11.3 (continued)

		DOSE RATE ($Gy.h^{-1}$)
EGGS	Internal β/γ emitters	4.1×10^{-9}
	Internal γ emitters	2.1×10^{-10}
	External α emitters	4.0×10^{-7}
	TOTAL	4.0×10^{-7}

TABLE 11.4

CALCULATED RADIATION DOSE RATES RECEIVED BY OYSTERCATCHER AND SHELDUCK AT RAVENGLASS

TARGET	SOURCE	DOSE RATE (Gyh^{-1}) SHELDUCK	OYSTERCATCHER
Whole Body	β/γ Emitters in whole body	9.2×10^{-9}	1.7×10^{-8}
	β/γ Emitters in gut	2.1×10^{-8}	3.9×10^{-8}
	α Emitters in whole body	1.3×10^{-9}	8.5×10^{-8}
	External γ emitters	1.2×10^{-6}	1.1×10^{-6}
	TOTAL	1.2×10^{-6}	1.2×10^{-6}
Cells lining alimentary tract		Not recorded	Not recorded
Eggs	Internal β/γ Emitters	Not recorded	Not recorded
	External γ Emitters	4.0×10^{-7}	4.0×10^{-7}

Gulls are feeding on food from inland sources which is uncontaminated (Lowe 1987) then the overall dose rate is 1.0×10^{-6} Gyh^{-1} i.e. similar to the "critical group" because of the contribution of external radiation sources to the total.

Even the dose rates calculated for the "critical group" birds are considerably lower than those found to cause harm to other birds by Zach and Mayoh (1984, 1986), Willard (1963) and Brisbin (1969). Thus, unless Black-headed Gulls are considerably more susceptible to damage by radiation (for which there is no evidence) then the doses received by gulls at Ravenglass are unlikely to have caused chick growth problems or mortality. Also, the chronic dose for eggs over a 10-day period is only approximately 1×10^{-4} Gy, considerably less than the value of 10 Gy found by L J Phillips (pers. comm.) to be necessary to reduce full-term development among Black-headed Gull eggs. The radiation dose received by eggs at Ravenglass is unlikely, therefore, to have affected hatching success. The same appears to apply to Oystercatcher and Shelduck although no comparable figures are available for these two species.

Radiation has been claimed to affect breeding birds in other ways. Zach and Mayoh (1982) studied nest-site selection by Tree Swallows and House Wrens within a gradient of gamma-ray radiation ranging from background to 3.7×10^{14} Bq. They claimed that birds responded to radiation levels as low as 100X background and selectively used nest sites in areas of lower radioactivity. The mechanism of this apparent radiation detection is unclear. However, if Black-headed Gulls were able to detect radiation at Ravenglass then they might respond to it by moving to other sites to breed, so reducing the number of breeding birds using the traditional site. The maximum dose they received at Ravenglass, however, was only 10X background. Unless gulls can detect such small elevations of radiation levels, an order of magnitude lower than those detected by birds in Zach & Mayohs study, it seems unlikely that they left Ravenglass for that reason. In addition, other species such as Oystercatcher and Shelduck continue to attempt to breed at Ravenglass despite being subjected to the same radiation levels as Black-headed Gulls. Indeed, Shelduck were successful in producing young in all years (see Chapter 3). Although the relative radiation tolerances of all the bird species concerned are not known, on existing evidence the calculations presented above suggest that contamination by radionuclides is not important in affecting breeding success or settlement rates among bird species nesting at Ravenglass. Thus the conclusion of Woodhead (1986) that "the results indicate that the incremental exposure (of birds) could be significantly higher than that due to the natural background but below that at which detrimental effects would be observable" is still valid even when species other than Black-headed gulls are considered.

GENERAL DISCUSSION

The evidence presented above suggests that the main cause or causes of the decline to extinction of the Ravenglass Black-headed Gull colony have acted during the breeding period of the birds annual cycle (figure 1.2). In 1984, predation by foxes on eggs and young chicks prevented gulls from rearing any chicks to fledging there. In 1980, the gullery also suffered a total breeding failure, although the cause of this is not known. Assuming that Black-headed Gulls at Ravenglass recruited no young after 1974, had an annual adult survival rate of 80.5% (calculated from ringing recoveries), and showed total site fidelity then the overall ten-year decline between 1975 and 1984 can be modelled (figure 4.2). There are, however, differences in detail between the model and the actual time-course of the decline; i) the actual decrease occurred in three 'phases' with different rates of decline and ii) the observed fall to extinction in 1985 was not predicted by the model. Indeed 1,200 pairs of gulls were expected to breed that year. This implies that changes in rates of either emigration or mortality amongst adults and/or of changes in the productivity or recruitment of young birds to the colony could have influenced the observed decline. There is no evidence for a recent increase in adult mortality rates among Black-headed Gulls in Britain as a whole (Mackinnon 1986) so movements of adults from Ravenglass to other colonies or reduction in the recruitment of young birds to Ravenglass are probable.

An analysis of ringing recoveries of gulls ringed as chicks at Ravenglass (table 4.3) shows that there is some infidelity to the natal site for subsequent breeding but this was impossible to quantify because of the limitations in the data. This suggests that Black-headed Gulls reared at Ravenglass show some degree of infidelity to the colony site although it does not throw light on the amount of year-to-year faithfulness of adults to the site.

Southern (1977) found a well-developed tendency among adult Ring-billed Gulls breeding at a stable colony to return to the colony where they first bred. However, this site-fidelity decreased following prolonged exposure to disturbance and predation, in this case by foxes, Southern (1985), resulting in a decrease in the size of the breeding colony. The mechanism behind this response is unclear. It may simply be that some gulls do not return to an area if they have been unsuccessful in a breeding attempt there (for any reason). If so, how might they choose a new colony? Cerny and Stamm (in Cramp & Simmons 1983) consider that "ringing data suggest that pairs, siblings and perhaps also groups from one colony may remain together on migration and in winter quarters, possibly over more than one season". Thus, gulls from an unsuccessful colony could be able to identify groups of birds containing a high proportion of juveniles and follow adults from that group back to their colony site in the following spring. Radford (1962) however, shows that immature Black-headed Gulls disperse more widely than adults so ratios of immature to adult birds in wintering flocks may not give a good indication of the breeding success of a particular group of birds. A field study involving marking and observations of gulls in both summer and winter is needed to resolve this.

If the above occurred at Ravenglass, with adults not settling to breed at the colony site in years following poor breeding seasons then a drop in colony size would be expected in the years following the breeding failures in 1980 and 1984. In 1981 the colony numbered 2,290 pairs; however, there were no counts in 1979 or 1980 so the amount of decrease between then and 1981 is not known. The overall rate of decline during the period 1978-1981 was, however, greater than could have resulted simply from annual adult mortality so a drop may have occurred. In 1985, after the failure in 1984, no gulls settled to breed although some prospected at Ravenglass. There is, therefore, some circumstantial evidence that the colony declined more rapidly in years following total breeding failures and that this more rapid decline was due to a decrease in site-fidelity amongst adult gulls.

The causes of poor breeding success of Black-headed Gulls at Ravenglass are not completely known although there were a number of contributory factors.

Fox predation was important in the breeding failure in 1984 (an attempt to quantify fox-diet at Ravenglass was unsuccessful but summarised in appendix 13); food shortage caused by changes in agricultural practice or weather factors could not be totally ruled-out as agents of the decline; changes in vegetation may have deterred birds from nesting; egg-collecting and disturbance by visitors may have reduced breeding success in some years.

Further factors influencing breeding success were discovered during studies of other Black-headed Gull colonies in Cumbria and included high tides washing out nests (at Rockcliffe), suspected botulism outbreaks (Foulney Island), intra-specific predation (Wastwater) and rising water levels (Siney Tarn). It is impossible, therefore, to pin-point precisely the overall cause(s) of decline of the Ravenglass gullery. Probably a combination of many factors some being more important in certain years than others (e.g. in 1984 fox predation on eggs and young chicks).

The importance of recruitment of first-time breeders to Ravenglass from other colonies is not known. If young birds from elsewhere do recruit to Ravenglass then breeding success at other colonies will influence the number of potential recruits to Ravenglass.

Whatever the actual cause of the decline, a number of changes in the gulls nesting pattern occurred which have wider implications for colonially nesting birds. Colonial nesting has been explained in a number of ways. Four were proposed by Coulson and Dixon (1979) in a review of coloniality in sea-birds, especially Kittiwakes. These were:-

1) Defence against predators.

2) Social stimulation.

3) Population regulation.

4) "Information centre" for finding food.

The first two of these are well documented (e.g. Patterson 1965, Kruuk 1964, Coulson and White 1961, Parsons 1975, Frazer Darling 1938), whereas the others are unconfirmed hypotheses (Wynne Edwards 1962, Ward and Zahavi 1973). Whatever the underlying explanation behind colonial nesting in birds it can be assumed that there are advantages of nesting in a colony which outweigh the disadvantages. Also, colonial nesting birds have certain characteristics during the breeding season which are considered to aid survival and to increase the breeding output of the individual and ultimately to reinforce the colonial habit. Patterson (1965) investigated spacing of nests and timing of broods of Black-headed Gulls at Ravenglass. He suggested that both clustering and synchronisation of nesting functioned as anti-predator systems but that spacing of nests was caused by territorial aggression. The actual pattern of nesting was, therefore, determined by an interaction between spacing to avoid territorial aggression and clustering to avoid predation.

At Ravenglass in 1984, although the total colony size and area had decreased since Patterson's study, there was no change in the spacing of nests from 1962/63. Patterson concluded that nest-spacing did not influence breeding success and that the timing and synchrony of the breeding attempt was more important in affecting breeding success. Other workers have also stressed the importance of synchrony and timing of breeding, (Lack 1954, Perrins 1970, Murton & Westwood 1977, Perrins & Birkhead 1983, Thompson et.al. 1986) either as an anti-predator system or in order to time breeding so that young are in the nest during the period of maximum food availability. At Ravenglass in 1984, the median date of clutch initiation was two weeks later than in 1962 and the colony was less synchronous. It is just possible that the change in median laying date since 1962 was due to changes in the peak of earthworm (Black-headed Gulls preferred food at Ravenglass) availability. However, Patterson commented that as the date of the first Black-headed Gull egg at Ravenglass varied by only four days in the eight years prior to 1962 it is likely that earthworm availability varies little between years or is unimportant in the regulation of breeding synchrony. The effects of recent changes in agricultural practice on earthworm availability are not known but might cause the peak to occur later. However, few changes occurred in the part of Cumbria used by the birds just before breeding. (Chapter 9). Disturbance by predators, a breakdown in "social stimulation" due to the reduction in colony size, or a lack of food in the pre-laying period preventing females from attaining breeding condition at the same time are other possible causes of the reduction in breeding synchrony.

Regardless of the cause of the changes in the median date of clutch initiation and synchrony of breeding in 1984 the effect on the colony would be to increase the period over which eggs and young chicks were available to predators by reducing the number of nests at a given stage of incubation at a particular time. Kruuk (1964) suggested that concentration of Black-headed Gull nests into the shortest possible time would reduce total losses to predators over the season.

Another aspect of coloniality which changed in the case of the Ravenglass gullery between the 1960's and the 1980's would appear to be site fidelity by the adults.. In the absence of evidence for an increase in annual mortality rates amongst adult gulls at Ravenglass it seems that emigration rates must have increased during the period of the decline leading to the eventual extinction of the colony.

Regardless of the factors causing increased emigration rates (e.g. response to breeding failures) the fact that Black-headed Gulls at Ravenglass deviated from established colonial behaviour may be seen as an adoptive response to a particular problem. The gulls attempted to maximise their lifetime reproductive output by leaving an area where they failed to produce young in one or more years and moved to another area where they may have been able to produce young in subsequent years, i.e. gulls risked moving to an unfamiliar area to breed and balanced that with the probability of breeding successfully at a known site. The mechanism of "decision-making" is not known but the more years of breeding failure at one site the greater the benefits of moving elsewhere to try.

Little is known about the production of young Black-headed Gulls at Ravenglass during the years of the decline and even less about the amount of fidelity shown to their natal site by these birds. Again (Southern 1977 and McNicholl 1975) studies have shown that in colonial species young birds show considerable fidelity to their natal colony. There are exceptions, Duncan & Monaghan (1977) showed that young Herring Gulls recruited to colonies other than their natal ones, Coulson and his co-workers (Wooller & Coulson 1976, Coulson & Wooller 1976, Coulson & Porter 1985) working on Kittiwakes showed considerable infidelity to the natal colony by first-time breeders. Svardson (1958) showed natal colony fidelity amongst first-time breeding Black-headed Gulls. If some degree of natal colony fidelity was the case amongst gulls reared at Ravenglass then these birds could also increase their reproductive output by moving to other sites to breed if Ravenglass became unsuitable. If immigration of first-time breeders to Ravenglass from other colonies occurred then these birds could increase their reproductive output by recruiting to other colonies. Chabrzyk & Coulson (1976) suggest that for Herring Gulls the factor determining whether or not a bird recruits to a colony is breeding success at that colony in the year before recruitment. They propose that immature Herring Gulls visit colony sites in the breeding seasons prior to recruitment to a colony and recruit to that colony only if it is successful in producing young. If the same is true for Black-headed Gulls then young prospecting at Ravenglass in 1984 for recruitment in 1985 may have gone elsewhere in response to the breeding failures.

It is interesting that the number of Ringed Plover and Oystercatcher attempting to breed at Ravenglass has not decreased despite the heavy losses of eggs to fox predation. Neither species nests colonially and both rely on cryptic coloration of eggs for protection from predation so it may be that one beach area is as safe (or unsafe) as another and that local knowledge of an area in terms of food sources for chicks is important as found for Ringed Plover on South Uist (Jackson 1988). Thus it may be better for Oystercatcher and Ringed Plover to rely on camouflage to protect eggs and be able to nest near known good feeding areas than to move to sites where the risk of predation may be less but the food resources are unknown. Conversely, it may be that different pairs attempted to nest in different years. As no Ringed Plover or Oystercatcher are colour-marked it is impossible to know. Jackson (1988) showed strong site fidelity for Ringed Plover in different parts of South Uist so it seems unlikely that population turnover at Ravenglass is greater, however, there are no foxes on South Uist.

To summarise, I suggest that the decline in the number of pairs of Black-headed Gulls breeding on the Ravenglass L.N.R. can be explained as a combination of circumstances In the mid-1970's factors acted at Ravenglass (e.g. predation, decline of food sources, egg-collecting, disturbance by visitors) to reduce the breeding success at the colony site. Unsuccessful pairs probably did not return to the site to breed and colony size began to decrease. As colony size decreased so the "social stimulation" (Frazer Darling 1938) effect become less strong and various changes took place in the birds breeding cycle. The pattern of laying synchrony described by Patterson (1965) began to break down and the timing of breeding became later. The effects of this were to increase the susceptibility of nests to predation, increase the total losses of eggs and chicks to predators and possibly to put the peak hatching and chick growth phase out of synchrony with the peak of food availability for chicks. The lack of synchrony would further reduce breeding success which would in turn increase emigration rate. Reductions in food availability could also have acted directly on clutch size, egg size, laying date and chick survival. This spiralling decline continued until colony size was so small e.g. in 1984, that one factor alone (predation) produced a total breeding failure which further increased the emigration rate so that no pairs settled to breed in 1985 and none have done so since.

The effects of disturbance in the pre-breeding period (especially in the later stages of the decline) may have been to reinforce the tendency to emigrate. The amounts of "damage" caused by the various factors implicated as agents of the decline are not known. Had some monitoring of colony productivity and size been carried out in all years then the problem might have been diagnosed earlier and remedial steps carried out. The extinction of the Ravenglass gullery could, therefore, be used as an example of the need to adequately monitor populations of birds in order to detect any perturbations whatever the cause.

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APPENDIX 1

RECORDS OF NUMBER OF PAIRS OF BLACK-HEADED GULLS AT RAVENGLASS PRE-1969

YEAR	NO. PAIRS	NOTES	SOURCE
1621	?	Record of Gull chicks sent from Muncaster to Carlisle - possibly from Ravenglass	Gaythorpe (1913)
1884	?	"Colony on marsh near Ravenglass"	Gurney (1919)
1886	?	"Colony teeming"	Macpherson and Duckworth (1886)
1892	?	"Good numbers of large chicks"	Macpherson (1892)
1918	?	"Large colony among sandhills"	Gurney (1919)
1938	10,000	Corrected from estimate of 60,000	Marchant (1952)
1939	10,000		Gribble (1976)
1941	10,000	Calculated from records of egg-collecting	Marchant (1952)
1948	6,500	Observation	Marchant (1952)
1951	6,000	Observation	Marchant (1952)
1958	13-16,000	Calculated from ratio of sitting to flying Gulls	Gribble (1962)
1960	10,000+	Method unknown	Gribble (1976)
1961	10,000-	Method unknown	Gribble (1976)
1962	10,000-	Method unknown	Gribble (1976)
1963	8,000	From aerial photographs	Patterson (1965)
1965	8,000	Method unknown	Gribble (1976)
1967	6,000	Method unknown	Gribble (1976)
1968	6,000	Method unknown	Gribble (1976)

APPENDIX 2

ESTIMATES OF BREEDING SUCCESS OF BLACK-HEADED GULLS AT RAVENGLASS UP TO 1984

YEAR	% Eggs surviving to fledging	Mean no. chicks reared/pr.	Source
1961	15.2	* 0.44	Patterson 1965
1962	5.8	* 0.17	Patterson 1965
1963	11.0	* 0.33	Patterson 1965
1975	"Northern Gullery (500 prs.) produced no young.		C. J. Rowley pers. comm.
1980	0	0	C. J. Rowley pers. comm.
1981	2.4	x 0.06	Rose 1981
1983	N/R	+ 0.50	D.E. Simpson pers. comm.

* Calculated from Patterson's data assuming a mean clutch size of 2.89 (Ytreberg 1956, assumed by Patterson).

x Calculated from counts of juveniles on Drigg beach, 1981.

\+ Calculated from counts of adult:juvenile ratios on Drigg beach July 1983. The ratio of fledged juveniles to nests was only 0.10.

APPENDIX 3

ESTIMATES OF CLUTCH SIZE OF SANDWICH TERNS AT RAVENGLASS

YEAR	Mean Clutch Size (eggs/nest)
1971	1.61
1972	1.17
1973	1.11
1974	1.26
1975	1.19
1976	1.12
1977	1.18

Source : Wardens reports to Cumbria County Council 1971-1978.

APPENDIX 4

MAXIMUM COUNTS OF SHELDUCK YOUNG ON THE RIVER IRT, RAVENGLASS

YEAR	Maximum Count
1969	8
1970	14
1971	109
1972	27
1973	88
1974	70
1975	'present'
1976	'present'
1977	40
1978	19
1979	53
1980	'present'
1981	60
1982	38
1983	72
1984	40
1985	49
1986	60
1987	117

Sources : Reserve reports, A. Strand (pers. comm.), D. E. Simpson (pers. comm.).

APPENDIX 5

BREEDING SUCCESS OF BLACK-HEADED GULLS AT FOULNEY ISLAND, 1980-1987

YEAR	No. pairs	Max. Count of Fledged Young	Minimum No. Fledged per pair*
1980	700	300	0.43
1981	814	450	0.55
1982	1,050	'Predation by large gulls heavy, breeding success poor'	
1983	1,200	N/R	N/R
1984	750	1,000	1.33
1985	750	1,200	1.60
1986	650	450	0.69
1987	700	450	0.64

* Estimate based on maximum counts of fledglings on the beach at the end of the season, therefore minimum figures.

Sources : 1980-1984 Warden's reports to C.T.N.C.
1985-1987 This study (see Chapter 4)
(N/R = Not Recorded)

APPENDIX 6

BREEDING SUCCESS OF SANDWICH TERNS AT FOULNEY ISLAND 1980-1987

YEAR	No. pairs	Max. chick count	Minimum no. reared/pair
1980	600	300	0.50
1981	500	403	0.81
1982	1,200	1,120	0.93
1983	300	N/R	N/R
1984	1,500	1,000	0.67
1985	1,100	950	0.86
1986	400	400	1.00
1987	575	400	0.70

Source : Warden's reports to C.T.N.C. 1980-1987
(N/R = Not Recorded)

APPENDIX 7

DATA ON FIELD USAGE FOR PARISHES SURROUNDING RAVENGLASS

PARISH SEASCALE

CROP	NO. HECTARES OF CROP IN YEAR			
	1970	1975	1980	1985
WHEAT	0	0	0	0
BARLEY (TOTAL)	13.4	28.7	48.0	63
(SPRING)	-	-	48.0	63
(WINTER)	-	-	0	0
OATS	2.9	18.4	28.8	0
MIXED CORN	0	0	0	0
RYE	0	0	0	0
POTATOES (TOTAL)	1.3	0.3	0.1	0.2
(EARLY)	0	0	-	-
(MAIN)	1.3	0.3	-	-
MAIZE	0	0	0	0
HORTICULTURE	0	0	0.4	0
TURNIP, SWEDE	0.4	0.2	0	0
KALE, CABBAGE, RAPE	0.9	0.9	0	1.6
OTHER CROPS	0	0	0	0
BARE FALLOW	0.8	0	0	1.5
LUCERNE	0	0	0	0
GRASS (TEMPORARY)	70.9	71.0	77.1	90.3
(PERMANENT)	172.7	227.3	217.7	170.0
(TOTAL)	243.6	298.3	294.8	260.3
ROUGH-GRAZING	76.6	1.2	0	2.9
WOODLAND	0	0.8	0.8	0.8
OTHER	0	0	1.0	1.7
TOTAL	339.9	349.6	374.7	332.2

APPENDIX 7 (continued)

PARISH DRIGG & CARLETON

CROP	NO. HECTARES OF CROP IN YEAR			
	1970	1975	1980	1985
WHEAT	0	0	0	0
BARLEY (TOTAL)	47.1	40.6	50.4	62.6
(SPRING)	-	-	48.4	60.3
(WINTER)	-	-	2.0	2.3
OATS	10.2	9.9	2.8	2.8
MIXED CORN	0	3.2	0	0
RYE	0	0	0	0
POTATOES (TOTAL)	14.1	6.7	3.5	6.9
(EARLY)	4.8	1.6	-	-
(MAIN)	9.3	5.1	-	-
MAIZE	0	4.4	6.0	4.1
HORTICULTURE	1.0	0	0	0
TURNIP, SWEDE	11.3	7.1	3.1	2.3
KALE, CABBAGE, RAPE	6.1	0.6	2.0	0.8
OTHER CROPS	0	0	0	0
BARE FALLOW	0.1	4.4	3.3	1.5
LUCERNE	0	0	0	0
GRASS (TEMPORARY)	313.2	153.8	243.7	270.1
(PERMANENT)	431.8	595.2	539.6	561.9
(TOTAL)	745.0	749.0	783.3	832.0
ROUGH-GRAZING	482.2	289.0	284.0	281.5
WOODLAND	0.1	0.2	6.8	12.3
OTHER	0.9	0.8	2.5	5.0
TOTAL	1,318.1	1,115.9	1,148.3	1,211.8

APPENDIX 7 (continued)

PARISH MUNCASTER

CROP	NO. HECTARES OF CROP IN YEAR			
	1970	1975	1980	1985
WHEAT	0	0	0	0
BARLEY (TOTAL)	5.3	24.7	18.4	0
(SPRING)	-	-	18.4	0
(WINTER)	-	-	0	0
OATS	0	0	0	0
MIXED CORN	5.7	2.8	0	0
RYE	13.0	0	0	0
POTATOES (TOTAL)	0.3	0.1	0.2	0
(EARLY)	0	0	-	-
(MAIN)	0.3	0.1	-	-
MAIZE	0	0	0	0
HORTICULTURE	3.2	2.5	0	0
TURNIP, SWEDE	5.9	8.8	4.0	3.6
KALE, CABBAGE, RAPE	3.6	1.0	0	0
OTHER CROPS	0	0	0	0
BARE FALLOW	1.0	0.5	0	0
LUCERNE	0	0	0	0
GRASS (TEMPORARY)	241.6	78.7	47.6	177.5
(PERMANENT)	804.9	965.4	1,405.3	1,277.4
(TOTAL)	1,046.5	1,044.1	1,452.9	1,454.9
ROUGH-GRAZING	1,017.0	902.3	646.5	299.7
WOODLAND	3.6	16.9	33.9	30.9
OTHER	1.7	4.5	30.1	21.5
TOTAL	2,106.8	2,008.2	2,186.0	1,810.6

APPENDIX 7 (continued)

PARISH BOOTLE

CROP	NO. HECTARES OF CROP IN YEAR			
	1970	1975	1980	1985
WHEAT	0	0	0	0
BARLEY (TOTAL)	52.0	129.9	81.6	44.1
(SPRING)	-	-	53.3	44.1
(WINTER)	-	-	28.3	0
OATS	52.2	4.5	3.1	0
MIXED CORN	8.6	0	0	0
RYE	0	0	0	0
POTATOES (TOTAL)	3.2	1.0	0.9	0.8
(EARLY)	0	0.2	-	-
(MAIN)	3.2	0.8	-	-
MAIZE	0	0	0	0
HORTICULTURE	0	0	0	0
TURNIP, SWEDE	14.3	16.3	1.0	1.5
KALE, CABBAGE, RAPE	2.1	4.0	4.6	0
OTHER CROPS	7.3	20.2	4.5	0
BARE FALLOW	1.8	2.0	0	0
LUCERNE	0	0	0	0
GRASS (TEMPORARY)	326.3	198.7	319.5	299.0
(PERMANENT)	903.5	1,029.1	992.9	973.6
(TOTAL)	1,229.8	1,227.8	1,312.2	1,277.6
ROUGH-GRAZING	524.5	532.9	451.0	433.2
WOODLAND	1.5	13.1	7.6	7.8
OTHER	3.0	3.0	5.0	2.7
TOTAL	1,900.3	1,954.7	1,871.8	1,767,8

APPENDIX 7. (continued)

PARISH NETHER WASDALE

CROP	NO. HECTARES OF CROP IN YEAR			
	1970	1975	1980	1985
WHEAT	0	0	0	0
BARLEY (TOTAL)	1.2	7.2	10.5	0
(SPRING)	-	-	10.5	0
(WINTER)	-	-	0	0
OATS	9.7	6.2	0	0
MIXED CORN	0	0	0	0
RYE	0	0	0	0
POTATOES (TOTAL)	0.5	0.1	0.4	0.4
(EARLY)	0	0	-	-
(MAIN)	0.5	0.1	-	-
MAIZE	0	0	0	0
HORTICULTURE	0.1	0	0	0
TURNIP, SWEDE	5.4	7.4	3.1	3.5
KALE, CABBAGE, RAPE	0.4	3.6	0	0
OTHER CROPS	0	0	0	0
BARE FALLOW	0	0	0	0
LUCERNE	0	0	0	0
GRASS (TEMPORARY)	19.8	23.9	18.3	20.9
(PERMANENT)	399.1	369.0	1,056.1	418.7
(TOTAL)	418.9	392.9	1,074.4	439.6
ROUGH-GRAZING	2,946.9	2,975.2	2,302.4	2,951.5
WOODLAND	3.4	3.8	39.9	37.4
OTHER	0	0.5	6.6	2.9
TOTAL	3,386.5	3,396.9	3,437.3	3,435.3

APPENDIX 7 (continued)

PARISH ESKDALE

CROP	NO. HECTARES OF CROP IN YEAR			
	1970	1975	1980	1985
WHEAT	0	0	0	0.1
BARLEY (TOTAL)	0.8	0	41.8	51
(SPRING)	-	-	41.8	42
(WINTER)	-	-	0	9
OATS	0	0.8	0	0
MIXED CORN	0	0	0	0
RYE	0	0	0	0
POTATOES (TOTAL)	0.4	0.2	0	0
(EARLY)	0	0	-	-
(MAIN)	0.4	0.2	-	-
MAIZE	0	0	0	0
HORTICULTURE	0	0	0	0
TURNIP, SWEDE	0.6	0	0.3	0
KALE, CABBAGE, RAPE	0	1.1	0	0
OTHER CROPS	0	0	2.0	0.2
BARE FALLOW	0	0	0	0
LUCERNE	8.1	0	-	-
GRASS (TEMPORARY)	4.0	9.2	63.6	18.3
(PERMANENT)	443.3	541.0	727.3	1,017.2
(TOTAL)	447.3	550.2	790.9	1,035.5
ROUGH-GRAZING	2,540.1	2,513.7	2,881.0	2,370.8
WOODLAND	15.0	20.8	19.7	54.9
OTHER	0.6	0.6	3.0	10.5
TOTAL	3,012.9	3,087.6	3,738.8	3,523.0

APPENDIX 7 (continued)

PARISH WABERTHWAITE

CROP	NO. HECTARES OF CROP IN YEAR			
	1970	1975	1980	1985
WHEAT	0	0	0	0
BARLEY (TOTAL)	31.8	65.6	57.7	51.6
(SPRING)	-	-	51.5	51.6
(WINTER)	-	-	6.2	0
OATS	0	0	0	0
MIXED CORN	2.9	0	0	8.0
RYE	23.5	0.8	12.5	12.6
POTATOES (TOTAL)	0.4	0.2	0	0.1
(EARLY)	0	0	-	-
(MAIN)	0.4	0.2	-	-
MAIZE	0	0	0	0
HORTICULTURE	0	0	0	0
TURNIP, SWEDE	3.4	17.3	0	0.7
KALE, CABBAGE, RAPE	3.6	2.0	0	0
OTHER CROPS	0	0	2.8	0
BARE FALLOW	0	7.2	0	0
LUCERNE	0	0	0	0
GRASS (TEMPORARY)	282.8	313.9	231.8	195.0
(PERMANENT)	753.8	802.5	690.7	716.9
(TOTAL)	1,036.6	1,116.4	922.5	911.9
ROUGH-GRAZING	473.1	289.3	257.4	218.5
WOODLAND	2.0	10.4	9.3	15.7
OTHER	0	5.6	2.9	12.2
TOTAL	1,577.3	1,514.8	1,268.7	1,223.3

APPENDIX 7: (continued)

PARISH GOSFORTH

CROP	NO. HECTARES OF CROP IN YEAR			
	1970	1975	1980	1985
WHEAT	0	0	0	0
BARLEY (TOTAL)	78.2	113.4	77.5	101.2
(SPRING)	-	-	75.0	87.7
(WINTER)	-	-	2.5	13.5
OATS	48.3	12.0	11.8	3.2
MIXED CORN	23.1	9.7	4.5	4.5
RYE	0	0	0	0
POTATOES (TOTAL)	17.4	10.2	9.6	13.2
(EARLY)	6.5	3.8	-	-
(MAIN)	10.9	6.4	-	-
MAIZE	0	0	0	0
HORTICULTURE	2.2	0	0.5	0.5
TURNIP, SWEDE	15.5	17.6	12.0	23.3
KALE, CABBAGE, RAPE	37.7	13	7.2	5.2
OTHER CROPS	3.2	3.2	0	0
BARE FALLOW	0.8	8.3	0.6	0
LUCERNE	0	0	-	-
GRASS (TEMPORARY)	625.9	328.4	379.8	352.5
(PERMANENT)	744.6	1,016.2	1,095.0	1,177.6
(TOTAL)	1,370.5	1,344.6	1,474.8	1,530.1
ROUGH-GRAZING	520.2	646.4	524.8	477.5
WOODLAND	20.5	14.3	15.5	21.9
OTHER	0.5	3.6	9.9	10.9
TOTAL	2,138.1	2,196.5	2,150.6	2,191.5

APPENDIX 7 (continued)

PARISH IRTON WITH SANTON

CROP	NO. HECTARES OF CROP IN YEAR			
	1970	1975	1980	1985
WHEAT	0	0	0	0
BARLEY (TOTAL)	55.0	105.5	58.0	110.9
(SPRING)	-	-	58.0	108.9
(WINTER)	-	-	0	2
OATS	19.6	10.1	7.2	4.0
MIXED CORN	0	0	0	0
RYE	0	0	0	0
POTATOES (TOTAL)	18.3	14.0	9.2	20.6
(EARLY)	5.0	5.0	-	-
(MAIN)	13.3	9.0	-	-
MAIZE	0	0	1.8	2.4
HORTICULTURE	2.5	0.3	1.6	1.2
TURNIP, SWEDE	13.0	8.4	7.7	3.1
KALE, CABBAGE, RAPE	29.2	18.5	16.3	3.0
OTHER CROPS	0	0	4.9	0
BARE FALLOW	5.3	3.5	21.4	0
LUCERNE	2.1	5.2	-	-
GRASS (TEMPORARY)	417.7	444.8	304.8	200.8
(PERMANENT)	801.7	719.3	897.6	1,106.5
(TOTAL)	1,219.4	1,164.1	1,202.4	1,307.3
ROUGH-GRAZING	400.7	265.3	251.3	219.2
WOODLAND	25.5	26.4	48.3	52.0
OTHER	5.3	0.9	8.1	8.4
TOTAL	1,795.9	1,622.2	1,645.6	1,732.1

WEATHER DATA

FEBRUARY (NA - Not available)

YEAR	Mean Max. daily temp. (°C)	Mean Min. daily temp. (°C)	Mean daily temp. (°C)	Max. temp. (°C)	Min. temp. (°C)	TOTAL Rainfall (mm)
1971	NA	NA	NA	NA	NA	NA
1972	7.6	3.3	5.4	10.6	-4.6	78.5
1973	7.0	2.4	4.7	10.8	-3.8	54.3
1974	8.1	3.4	5.7	11.0	-0.4	94.8
1975	8.8	1.6	5.2	12.6	-2.3	38.4
1976	NA	NA	NA	NA	NA	NA
1977	5.1	0.8	2.9	8.6	-5.2	95.6
1978	5.7	0.5	3.1	9.8	-8.0	85.3
1980	8.2	2.5	5.3	13.0	-4.7	135.8
1981	4.9	-0.4	2.1	10.7	-6.5	58.0
1982	7.9	2.7	5.3	10.1	-2.4	77.9
1983	5.8	-0.3	2.7	10.9	-5.6	33.5
1984	6.5	1.1	3.8	8.6	-3.1	73.9
1985	6.1	0.5	3.3	13.3	-4.9	23.0
1986	3.6	-2.0	0.8	5.7	-9.0	0.8
1987	NA	NA	NA	NA	NA	NA

APPENDIX 8 (CONTINUED)

WEATHER DATA

MARCH (NA - Not available)

YEAR	Mean Max. daily temp. (°C)	Mean Min. daily temp. (°C)	Mean daily temp. (°C)	Max. temp. (°C)	Min. temp. (°C)	TOTAL Rainfall (mm)
1971	7.0	0.7	3.9	11.1	-5.9	84.6
1972	9.7	2.9	6.3	17.5	-3.1	86.4
1973	7.0	2.4	4.7	10.8	-3.8	54.3
1974	9.3	2.7	6.0	15.6	-0.8	52.8
1975	8.3	1.7	5.0	13.0	-2.0	42.1
1976	NA	NA	NA	NA	NA	NA
1977	8.6	2.8	5.7	12.2	-2.9	79.8
1978	8.5	4.3	6.4	12.9	-1.5	128.0
1979	6.8	2.1	4.5	10.0	-2.4	107.8
1980	7.5	0.8	4.1	10.3	-4.0	107.7
1981	9.5	3.5	6.5	15.9	-1.5	192.5
1982	8.4	2.8	5.6	12.0	-1.4	102.0
1983	8.3	3.4	5.9	10.3	-4.0	137.3
1984	7.5	2.2	4.9	11.1	-2.8	84.2
1985	7.8	1.4	4.6	10.7	-5.3	49.0
1986	7.5	1.9	4.7	11.1	-7.0	109.0
1987	6.9	1.6	4.3	9.8	-4.7	139.0

APPENDIX 8 (CONTINUED)

WEATHER DATA

APRIL (NA - Not available)

YEAR	Mean Max. daily temp. (°C)	Mean Min. daily temp. (°C)	Mean daily temp. (°C)	Max. temp. (°C)	Min. temp. (°C)	TOTAL Rainfall (mm)
1971	11.6	3.7	7.4	17.8	-1.1	34.5
1972	11.1	4.9	8.0	14.6	-0.2	98.2
1973	10.1	2.0	6.1	14.8	-4.1	64.0
1974	NA	NA	NA	NA	NA	NA
1975	NA	NA	NA	NA	NA	NA
1976	NA	NA	NA	NA	NA	NA
1977	9.4	3.1	6.2	12.4	-2.1	55.6
1978	11.3	4.1	7.7	16.2	-4.6	23.7
1979	10.1	4.7	7.4	19.5	-1.5	92.0
1980	12.8	4.6	8.7	19.0	0.2	7.6
1981	11.1	2.6	7.0	18.0	-1.3	55.1
1982	11.9	4.5	8.2	17.0	-2.0	22.1
1983	9.4	2.8	6.1	14.5	-1.2	73.5
1984	11.8	3.3	7.5	23.2	-4.0	29.2
1985	10.4	4.5	7.5	15.8	-4.3	106.0
1986	8.8	2.1	5.5	11.3	-3.1	105.0
1987	13.0	6.0	9.5	21.7	-1.7	50.0

APPENDIX 8 (CONTINUED)

WEATHER DATA

MAY (NA - Not available)

YEAR	Mean Max. daily temp. (°C)	Mean Min. daily temp. (°C)	Mean daily temp.(°C)	Max. temp.(°C)	Min. temp.(°C)	TOTAL Rainfall (mm)
1971	14.5	7.3	10.9	19.7	3.0	48.6
1972	13.7	7.7	10.7	18.0	5.5	80.4
1973	14.5	8.1	11.3	23.5	3.0	51.0
1974	NA	NA	NA	NA	NA	NA
1975	NA	NA	NA	NA	NA	NA
1976	NA	NA	NA	NA	NA	NA
1977	15.6	6.4	11.0	23.5	1.3	31.2
1978	15.8	7.9	11.9	26.2	5.0	8.6
1979	11.4	5.9	8.7	16.9	-0.5	92.0
1980	16.7	7.1	11.9	25.2	1.3	33.8
1981	15.1	6.3	11.1	23.2	-1.7	57.6
1982	14.7	7.2	10.9	24.0	0.5	42.0
1983	13.1	6.7	9.9	18.7	0.0	112.2
1984	14.1	4.8	9.5	19.1	-1.0	17.6
1985	14.2	7.1	10.7	18.7	0.3	44.0
1986	13.2	7.8	10.5	21.9	2.5	107.0
1987	13.6	5.6	9.6	19.4	-1.3	44.0

APPENDIX 8 (CONTINUED)

WEATHER DATA

JUNE (NA - Not available)

YEAR	Mean Max. daily temp. (°C)	Mean Min. daily temp. (°C)	Mean daily temp.(°C)	Max. temp.(°C)	Min. temp.(°C)	TOTAL Rainfall (mm)
1971	15.7	8.4	12.1	21.6	3.5	68.2
1972	14.1	8.1	11.1	18.7	5.0	92.8
1973	16.8	10.0	13.4	21.5	2.5	24.4
1974	NA	NA	NA	NA	NA	NA
1975	18.4	9.2	13.8	24.2	3.4	30.0
1976	NA	NA	NA	NA	NA	NA
1977	16.4	9.1	12.7	21.1	4.6	61.3
1978	17.2	10.2	13.7	28.0	6.1	54.8
1979	16.7	10.4	13.6	21.0	6.0	29.3
1980	16.5	10.4	13.5	24.3	6.0	98.0
1981	14.8	9.0	11.9	18.8	3.5	71.1
1982	17.9	11.1	14.5	26.5	6.0	60.3
1983	16.2	10.0	13.1	22.1	4.5	45.3
1984	16.4	9.5	12.9	23.0	4.9	72.6
1985	15.2	8.1	11.7	21.5	1.5	59.0
1986	NA	NA	NA	NA	NA	NA
1987	14.3	8.9	11.6	18.7	3.4	106.0

APPENDIX 8 (CONTINUED)

WEATHER DATA

JULY (NA - Not available)

YEAR	Mean Max. daily temp. (°C)	Mean Min. daily temp. (°C)	Mean daily temp. (°C)	Max. temp. (°C)	Min. temp. (°C)	TOTAL Rainfall (mm)
1971	19.7	11.2	15.4	27.5	5.5	105.3
1972	18.0	11.4	14.7	24.2	8.0	57.9
1973	17.7	11.4	14.5	21.0	6.6	91.5
1974	NA	NA	NA	NA	NA	NA
1975	18.9	12.6	15.7	22.1	8.5	90.9
1976	NA	NA	NA	NA	NA	NA
1977	19.2	12.9	15.9	27.8	7.0	47.7
1978	17.4	11.3	14.3	21.0	8.4	66.1
1979	16.8	11.0	13.9	22.0	8.2	71.2
1980	17.6	11.3	14.5	25.0	7.0	72.4
1981	16.7	11.2	13.9	19.2	7.5	80.0
1982	18.9	11.7	15.3	26.3	6.0	33.4
1983	20.9	12.5	16.7	26.8	6.3	26.2
1984	18.8	10.9	14.8	28.2	4.6	38.7
1985	17.6	12.3	14.9	26.2	7.8	106.0
1986	NA	NA	NA	NA	NA	NA
1987	18.0	12.1	15.0	21.8	7.6	144.0

APPENDIX 8 (CONTINUED)

WEATHER DATA

AUGUST (NA - Not available)

YEAR	Mean Max. daily temp. (°C)	Mean Min. daily temp. (°C)	Mean daily temp. (°C)	Max. temp. (°C)	Min. temp. (°C)	TOTAL Rainfall (mm)
1971	18.4	11.3	14.8	23.6	4.0	122.3
1972	17.0	10.4	13.7	20.1	6.2	46.7
1973	18.8	12.6	15.7	27.2	9.1	115.5
1974	NA	NA	NA	NA	NA	NA
1975	NA	NA	NA	NA	NA	NA
1976	21.9	12.4	17.1	27.4	6.5	7.4
1977	18.9	12.1	15.5	22.5	5.0	69.3
1978	17.6	11.7	14.6	21.7	6.4	143.5
1979	17.1	10.8	14.0	21.0	6.2	136.3
1980	NA	NA	NA	NA	NA	NA
1981	17.5	11.3	14.5	21.3	6.5	68.0
1982	17.6	11.9	14.3	25.5	5.5	112.1
1983	19.8	11.6	15.7	26.9	5.6	67.0
1984	20.3	12.3	16.3	28.9	7.9	59.0
1985	NA	NA	NA	NA	NA	NA
1986	NA	NA	NA	NA	NA	NA
1987	17.3	11.5	14.4	22.9	5.5	74.0

APPENDIX 9

CALCULATION OF EGG SURVIVAL TIMES USING THE MAYFIELD METHOD

The Mayfield Method (Mayfield 1961, 1975, Johnson 1979) was developed to calculate nesting success for nests which were not visited every day during the incubation and fledging periods. This is achieved by using the concept of nest-(or egg)- days which refers to the number of days a nest (or egg) was exposed to predation during the breeding period. Formulae were developed by Mayfield (1961,1975) and refined to include a measure of standard deviation by Johnson (1979). In this study the standard exposure unit used was the 'egg-day' and the following formulae were used:-

$$m = 1 - s = \frac{\text{NO. FAILURES}}{\text{TOTAL EXPOSURE}}$$

where m = daily mortality rate

s = daily survival rate

NO FAILURES = Number of eggs lost in time period t (= 24 days in this study).

TOTAL EXPOSURE = Total No. egg-days when eggs were vulnerable over time period t.

The variance of s (=S.E.^{2}) can be calculated using:-

$$\text{variance of } s = \left(\frac{-1}{\dfrac{-(\text{exposure})^3}{((\text{exposure-losses}) \times \text{losses})}}\right)$$

The survival rate for a time period t is obtained by raising the value of s to the power of t i.e. s^t, in this study t was taken as the length of incubation period (24 days).

APPENDIX 10

CALCULATION OF EGG-VOLUME

Egg volume was calculated using the following formula, obtained from Coulson (1963):-

$$v = K_v.LB^2$$

v = egg volume (cm^3)

K_v = shape constant (= 0.498 for Black-headed Gulls*)

L = length (cm)

B = breadth (cm)

*K_v is a constant for a particular species (Coulson 1963, Furness and Furness 1981). The value for Black-headed Gulls was not found in the literature so was calculated by measuring the volume of a number of eggs from the Durham University Zoology collection. The value for K_v was calculated as 0.498.

APPENDIX 11

CALCULATION OF THE RANDOM DISTRIBUTION OF INTER-NEST DISTANCES

The following formula (derived by Dr J M Cullen and Dr M Bulmer) was obtained from Patterson (1965) and allowed comparison of data collected in 1984 with that collected by Patterson in 1962 and 1963.

Given the same number of nests n, distributed randomly with respect to each other in the same area A. The number of nests having their nearest neighbour at a distance X is given by the expression:-

$$\exp[(-\pi n/A)(X-\tfrac{1}{2}a)^2] - \exp[(-\pi n/A)(X+\tfrac{1}{2}a)^2]$$

where a = the unit of measurement used.

APPENDIX 12

RESULTS FROM ESTUARINE INVERTEBRATE SURVEY

TRANSECT 1

		DISTANCE BELOW MEAN HIGH WATER SPRING (MHWS)									
		0	25m	50m	75m	100m	125m	150m	175m	200m	225m
Nereis diversicolor	no	16	8	13	2	20	15	9	5	14	5
	no/m^2	1,018	509	827	127	1,273	955	573	318	891	318
Hydrobia ulvae	no	50	1	0	0	0	0	0	0	0	0
	no/m^2	3,183	64	-	-	-	-	-	-	-	-
Corophium volutator	no	12	2	18	4	4	7	3	37	116	48
	no/m^2	764	127	1,146	255	255	446	191	2,355	7,384	3,055
Macoma balthica	no	2	0	0	0	0	0	0	0	0	0
	no/m^2	127	-	-	-	-	-	-	-	-	-
Arenicola marina	casts/m^2	0	0	2	2	0	0	0	0	0	0

APPENDIX 12 (continued)

RESULTS FROM ESTUARINE INVERTEBRATE SURVEY

TRANSECT 2

		DISTANCE BELOW MEAN HIGH WATER SPRING (MHWS)							
		0	25m	50m	75m	100m	125m	150m	175m
Nereis diversicolor	no	11	18	21	17	22	18	15	15
	no/m^2	700	1,146	1,337	1,082	1,400	1,146	955	955
Hydrobia ulvae	no	12	12	10	0	6	9	0	2
	no/m^2	764	764	637	-	382	573	-	127
Corophium volutator	no	15	32	17	35	36	20	40	177
	no/m^2	955	2,037	1,082	2,228	2,291	1,273	2,546	11,266
Gammarus sp.	no	0	0	0	0	6	0	0	0
	no/m^2	-	-	-	-	382	-	-	-

TRANSECT 3

		0	12.5m	25m	37.5m
Nereis diversicolor	no	0	4	6	7
	no/m^2	-	255	382	446
Corophium volutator	no	4	130	35	0
	no/m^2	255	8,275	2,228	-

APPENDIX 12 (continued)

RESULTS FROM ESTUARINE INVERTEBRATE SURVEY

TRANSECT 4

		DISTANCE BELOW MEAN HIGH WATER SPRING (MHWS)				
		0	25m	50m	75m	100m
Nereis diversicolor	no	2	32	32	20	29
	no/m^2	127	2,037	2,037	1,273	1,846
Corophium volutator	no	4	107	116	66	0
	no/m^2	255	6,811	7,383	4,201	-
Hydrobia ulvae	no	0	1	0	0	0
	no/m^2	-	64	-	-	-
Haustorius aurenarius	no	0	0	0	1	0
	no/m^2	-	-	-	64	-
Euridice pulchra	no	1	0	0	0	0
	no/m^2	64	-	-	-	-
Gammarus sp.	no	0	0	0	1	0
	no/m^2	-	-	-	64	-

APPENDIX 12 (continued)

RESULTS FROM ESTUARINE INVERTEBRATE SURVEY

TRANSECT 5

		DISTANCE BELOW MEAN HIGH WATER SPRING (MHWS)			
		0	25m	50m	75m
Nereis diversicolor	no	0	1	0	0
	no/m^2	-	64	-	-
Haustorius aurenarius	no	0	0	3	3
	no/m^2	-	-	191	191
Hydrobia ulvae	no	0	1	0	0
	no/m^2	-	64	-	-
Gammarus sp.	no	0	10	21	0
	no/m^2	-	640	1,337	-
Arenicola marina	casts/m^2	0	0	4	9

APPENDIX 12 (continued)

RESULTS FROM ESTUARINE INVERTEBRATE SURVEY

TRANSECT 6

		DISTANCE BELOW MEAN HIGH WATER SPRING (MHWS)										
		0	50m	100m	150m	200m	250m	300m	350m	400m	450m	500m
Nereis diversicolor	no	0	3	14	2	3	0	5	4	4	1	4
	no/m²	-	192	891	128	192	-	320	256	256	64	256
Corophium volutator	no	43	0	1	34	46	12	18	35	90	40	84
	no/m²	2,737	-	64	2,164	2,928	764	1,146	2,228	5,729	2,546	5,347
Hydrobia ulvae	no	0	0	30	9	0	3	2	0	1	0	0
	no/m²	-	-	1,910	573	-	192	128	-	64	-	-
Macoma balthica	no	0	0	2	0	0	0	1	8	14	3	0
	no/m²	-	-	128	-	-	-	64	509	891	192	-
Arenicola marina	casts/m²	0	0	0	0	0	0	7	18	32	42	78

(also recorded - Cardium edule, Littorina littoralis, Nerine cirratulus)

APPENDIX 12 (continued)

RESULTS FROM ESTUARINE INVERTEBRATE SURVEY

TRANSECT 7

		DISTANCE BELOW MEAN HIGH WATER SPRING (MHWS)								
		0	50m	100m	150m	200m	250m	300m	350m	400m
Nereis diversicolor	no	4	9	2	0	1	1	1	0	1
	no/m²	255	573	128	-	64	64	64	-	64
Corophium volutator	no	6	7	14	79	170	64	57	75	94
	no/m²	382	446	891	5,028	19,820	4,074	3,628	4,774	5,983
Hydrobia ulvae	no	0	6	3	2	1	0	0	0	0
	no/m²	-	382	192	128	64	-	-	-	-
Macoma balthica	no	0	0	0	0	0	1	2	4	0
	no/m²	-	-	-	-	-	64	128	255	-
Nerine cirratulus	no	0	0	0	1	0	3	1	5	0
	no/m²	-	-	-	64	-	192	64	320	-
Arenicola marina	casts/m²	0	0	2	0	0	114	0	94	49

(also recorded Nephthys hombergii, Cardium edule, Corcinus maenis, Lineas sp., Pilumnus hirtellus)

APPENDIX 12 (continued)

RESULTS FROM ESTUARINE INVERTEBRATE SURVEY

TRANSECT 8

		DISTANCE BELOW MEAN HIGH WATER SPRING (MHWS)				
		0	25m	50m	75m	100m
Nereis diversicolor	no	0	1	7	29	26
	no/m²	-	64	456	1,846	1,655
Corophium volutator	no	0	240	50	2	0
	no/m²	-	15,276	3,183	128	-

TRANSECT 9

		0	25m	50m	75m	100m	125m
Nereis diversicolor	no	0	2	1	0	4	0
	no/m²	-	128	64	-	256	-
Corophium volutator	no	0	0	0	12	20	2
	no/m²	-	-	-	764	1,273	128
Macoma balthica	no	0	2	0	0	0	0
	no/m²	-	128	-	-	-	-
Gammarus sp.	no	0	0	0	0	0	2
	no/m²	-	-	-	-	-	128

APPENDIX 12 (continued)

RESULTS FROM ESTUARINE INVERTEBRATE SURVEY

TRANSECT 10

		DISTANCE BELOW MEAN HIGH WATER SPRING (MHWS)								
		0	25m	50m	75m	100m	125m	150m	175m	200m
Nereis diversicolor	no	0	0	0	0	7	1	12	2	0
	no/m^2	-	-	-	-	446	64	764	128	-
Corophium volutator	no	0	0	0	120	26	90	24	120	0
	no/m^2	-	-	-	7,638	1,656	5,729	1,528	7,638	-
Macoma balthica	no	0	0	0	0	5	2	0	0	0
	no/m^2	-	-	-	-	318	128	-	-	-
Arenicola marina	casts/m^2	0	0	0	0	117	62	0	32	0

APPENDIX 12 (continued)

RESULTS FROM ESTUARINE INVERTEBRATE SURVEY

TRANSECT 11

		DISTANCE BELOW MEAN HIGH WATER SPRING (MHWS)											
		0	50m	100m	150m	200m	225m	250m	275m	300m	325m	350m	375m
Nereis diversicolor	no	0	0	0	0	0	0	0	0	0	0	0	3
	no/m²	-	-	-	-	-	-	-	-	-	-	-	192
Corophium volutator	no	0	0	0	0	0	0	1	0	0	0	0	2
	no/m²	-	-	-	-	-	-	64	-	-	-	-	128
Hydrobia ulvae	no	1	0	0	1	2	1	2	3	4	0	0	0
	no/m²	64	-	-	64	128	64	128	192	256	-	-	-
Macoma balthica	no	0	0	0	0	0	3	4	1	1	1	0	0
	no/m²	-	-	-	-	-	192	256	64	64	64	-	-
Nepthys hombergii	no	0	0	0	1	0	0	0	2	0	0	3	0
	no/m²	-	-	-	64	-	-	-	128	-	-	192	-
Euridice pulchra	no	0	0	0	0	2	2	0	1	0	0	0	0
	no/m²	-	-	-	-	128	128	-	64	-	-	-	-
Bathyporeiea pelagica	no	0	0	4	0	0	1	0	0	4	0	0	0
	no/m²	-	-	256	-	-	64	-	-	256	-	-	-
Arenicola marina	casts/m²	0	0	0	0	0	0	2	3	1	1	3	2
Mytilus edulis	no/m²	0	0	0	0	0	0	0	0	0	0	62	1

(also present, *Cardium edule*, *Crangon vulgaris*, *Talitrus saltator*, *Scoloplos armiger*).

APPENDIX 12 (continued)

RESULTS FROM ESTUARINE INVERTEBRATE SURVEY

TRANSECT 12

		DISTANCE BELOW MEAN HIGH WATER SPRING (MHWS)																	
		0	50m	75m	100m	125m	150m	175m	200m	225m	250m	275m	300m	325m	350m	375m	400m	425m	450m
Nereis diversicolor	no	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	no/m²	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	64
Corophium volutator	no	0	0	2	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0
	no/m²	-	-	128	-	128	-	-	-	-	-	-	-	-	64	-	-	-	-
Nepthys hombergii	no	0	0	0	2	0	0	0	0	1	1	1	0	2	4	1	0	2	0
	no/m²	-	-	-	128	-	-	-	-	64	64	64	-	128	256	64	-	128	-
Euridice pulchra	no	0	0	0	0	0	1	2	0	0	0	1	1	0	0	0	0	0	0
	no/m²	-	-	-	-	-	64	128	-	-	-	64	64	-	-	-	-	-	-
Gammarus sp.	no	0	1	2	0	0	0	1	0	2	2	5	2	0	0	8	15	4	0
	no/m²	-	64	128	-	-	-	64	-	128	128	318	128	-	-	510	960	256	-
Arenicola marina	casts/m²	0	0	0	0	0	0	0	7	18	9	0	0	1	1	0	0	0	0

(also present, Bathyporeia pelagic, Talitrus saltator, Haustorius aurenarius)

APPENDIX 12 (continued)

RESULTS FROM ESTUARINE INVERTEBRATE SURVEY

TRANSECT 13

		DISTANCE BELOW MEAN HIGH WATER SPRING (MHWS)									
		0	50m	100m	150m	200m	250m	300m	350m	400m	450m
Corophium volutator	no	0	0	0	0	0	0	0	0	0	0
	no/m^2	-	-	-	-	-	-	-	-	-	-
Gammarus sp.	no	0	6	0	2	2	14	14	6	10	10
	no/m^2	-	382	-	128	128	891	891	382	637	637

(also present, Scoloplos armiger, Eurydice pulchra, Haustaurius aurenarius, Talitris saltator)

The total breeding failure in the Ravenglass Black-headed Gull colony in 1984 emphasised the importance of fox predation as a determinant of breeding success and it had been intended to quantify its effects in subsequent years. However, because no Black-headed Gulls have attempted to breed at Ravenglass since 1984 studies on Fox predation on breeding birds at Ravenglass have had to be confined to effects on Oystercatcher and Ringed Plover (Chapter 8). These studies indicate that predation was the major factor influencing the breeding success of shorebirds on the Ravenglass reserve in the period 1985-1987.

Foxes have long been recognised as important predators on breeding ground-nesting birds both at Ravenglass (Kruuk 1964, Patterson 1965, Tinbergen et.al. 1967) and other sites (e.g. Axell 1956, Bergmann 1966, Kadlec 1971, Larson 1960, Norman 1971, Patton and Southern 1977, Southern et.al. 1985). Larson (1960) suggested that in coastal areas of low-arctic Greenland Arctic Foxes (Alopex lagopus) feed almost entirely on birds during the breeding season and that this accounts for the gaps in the breeding distribution of Dunlin (Calidris alpina), Turnstone (Arenaria interpres) and Ringed Plover in these areas. Norman (1971) found that fox predation on Short-tailed Shearwaters (Puffinus tenuirostris) in Australia reduced breeding success only on islands where no other vertebrate prey existed, possibly because they have difficulty attacking hole-nesting birds. (This may also explain the apparent lack of fox predation on Shelduck nesting at Ravenglass). Southern and his co-workers (Southern et.al. 1982, 1985) studied predation by foxes on various gull species on South Manitou Island in Lake Michigan. They found that neither Ring-billed nor Herring Gulls are likely to produce progeny when subjected to regular fox predation and that the persistence of colonies depended upon a nucleus of experienced, site-tenacious breeders returning to the site year after year. It is clear, therefore, that fox predation can have severe effects on colonies of breeding seabirds.

The diet of foxes on the Ravenglass reserve was investigated in an attempt to establish the preferred prey and quantify the amount of fox predation on the gulleries during the breeding season. It had been hoped to investigate the amount of predation on the gulleries in subsequent years, however, with the failure of the gulls to re-establish the colony after 1984, work was concentrated on identifying the food of foxes. Faeces were collected systematically to give an estimate of the amount of fox activity on the Ravenglass Reserve and to measure how this changed when the gullery left.

A few fox faeces pellets were collected at the Ravenglass gullery site during the 1984 breeding season but the main study of fox-diet was not begun until Spring 1985. Pellets were collected along a regular path through the dunes (figure 1) every 4/6 weeks. All faeces found were stored in plastic bags, labelled with date and location and removed to the laboratory for analysis by the method of Lockie (1959), which had also been used by Kruuk (1964) in his study of fox diets at Ravenglass. Faecal pellets were weighed and measured before being dried in an oven at 60'C to constant weight. Samples were then dissected and their constituent parts removed and identified (Day 1966, Appleyard 1960). The proportion of each component was estimated as a percentage of the whole. Faecal pellets were grouped into two-monthly periods to allow a sufficient total weight to be obtained. The mean of each component for each time period was calculated, giving a figure of "estimated relative bulk" for each component for that period. Using this figure and knowing the total dry weight of faeces for each time period it was possible to calculate the relative weights of each component in each group of samples.

RESULTS

The percentage composition of the fox scats and the total weight collected in each time period are shown in table 1. Beetle remains were found in all periods but were most important during the 1984 gull breeding season, after the outbreak of myxomatosis in rabbits in Autumn 1983. Eggshell was found in two periods only, during the breeding season in 1984 when 14% of the weight of the scats was compound of eggshell and in July/August 1985 when 1% was found. It is likely that the eggshell found in the faeces in 1984 was from the Ravenglass gullery; however, identification was impossible as the eggshell pattern was removed during passage through the foxes digestive system. Bird remains were found in all periods. Using the method of Day (1966) it was possible to identify some feathers as far as Order (table 2). Often the passage of feathers through the fox's gut resulted in the matting of barbules (which are used for identification) Anseriformes and Charadriiformes were the most important bird items throughout most of the period; however, during November/December '1985, when little bird prey was taken, Passeriformes were the major order represented in scats.

FIGURE 1 ROUTE TAKEN TO COLLECT FOX FAECES AT RAVENGLASS

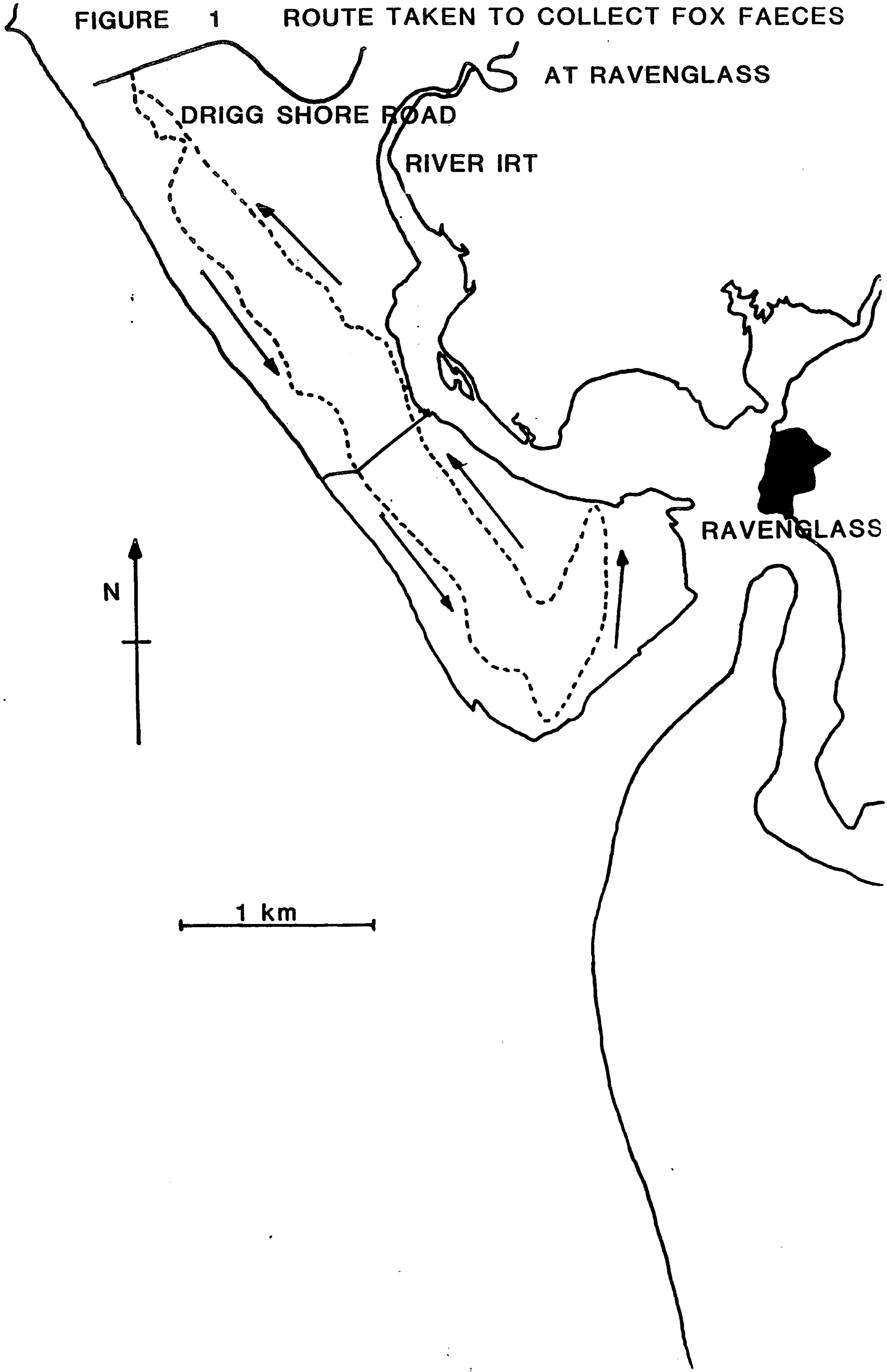

TABLE 1

% OCCURRENCE BY WEIGHT OF ITEMS IN FOX FAECES COLLECTED AT RAVENGLASS BETWEEN 1984 AND 1987

		% Occurrence					
Time Period	Total weight (g)	Beetle	Eggshell	Bird	Mammal	Vegetation	Others
1. May/June 1984	23.41	36	14	22	24	3	1
2. May/June 1985	65.20	6	0	33	57	3	1
3. July/Aug.1985	23.77	13	0	52	29	5	0
4. Sep./Oct.1985	234.99	23	0	26	41	5	6
5. Nov./Dec.1985	144.55	12	0	31	46	10	1
6. Jan./Feb.1986	225.97	6	0	45	43	6	0
7. Mar./Apr.1986	215.32	3	0	46	44	6	0
8. May/June 1986	154.82	5	0	29	65	1	0
9. July/Aug.1986	244.13	12	1	24	62	1	0
10. Sep./Oct.1986	48.80	3	0	28	65	3	0
11. Nov./Dec.1986	50.68	2	0	2	91	4	1
12. Jan./Feb.1987	67.70	2	0	18	76	5	0

Mammal remains were found more commonly than birds in all periods except July/August 1985 and January - April 1986 and were the most common remains in the majority of the time periods. Where possible mammal hairs were identified (Day 1966, Appleyard 1960) and the results are shown in table 3. Rabbit hair was present in all periods but fluctuated between a maximum of 50% in May/June 1985 and January/February 1986 and a minimum of 12% in March/April 1986. Mouse (no distinction was made between Mus and Apodemus although both are present on the reserve (G Egarr pers. comm.)) hair was found in all periods from September 1985 onwards with a maximum of 52% in November/December 1986 when mammal hair accounted for 91% of the total remains found. Sheep remains were present in some periods. It seems likely that these arose from carrion.

DISCUSSION

The occurrence of the major groups of food items in the fox faeces (table 1) show considerable concordance between all time periods (Kendall Rank Coefficient of Concordance W=0.795, p<0.01), Mammal remains were found in the greatest proportions in all except four periods; July/August 1985 and January/April 1986 when birds remains predominated and May/June 1984 when beetle remains were found most commonly. Within the mammal remains, there was also concordance between time periods concerning which remains were found in faeces most regularly (Kendall Rank Coefficient of Concordance W=0.538, p<0.01). Rabbit was found in the greatest proportion in most cases, suggesting that, even when rabbit populations were low due to myxomatosis (following a severe outbreak in late 1983) they were still the preferred mammalian prey.

With bird remains there was also concordance between time periods concerning which orders were most represented (Kendall Rank Coefficient or Concordance W=0.339, p<0.01). Discounting unidentified feathers, the orders most commonly found in large amounts were Charadriiformes and Anseriformes. This is as expected because gulls, waders and ducks are the commonest groups found around the Ravenglass estuary so would be taken most frequently.

Unfortunately, only one group of fox faecal samples were taken in 1984 when foxes preyed heavily on the Black-headed Gull colony. This sample, however, shows that bird remains and eggshell taken together were found more frequently than rabbit remains, as expected from the heavy fox predation recorded from the gullery. The proportion of beetle remains was also very high.

TABLE 2

COMPOSITION OF BIRD REMAINS FOUND IN FOX FAECES AT RAVENGLASS 1984-1987

		% of total					
Time period	Total bird	Unidentified	Charadriiformes	Anseriformes	Passeriformes	Columbiformes	Galliformes
1. May/June 1984	22	0	13	9	0	0	0
2. May/June 1985	33	6	18	6	3	0	0
3. July/Aug.1985	52	0	35	17	0	0	0
4. Sep./Oct.1985	26	13	7	0	6	0	0
5. Nov./Dec.1985	31	10	0	7	11	0	5
6. Jan./Feb.1986	45	12	6	20	7	0	0
7. Mar./Apr.1986	46	19	17	3	3	5	0
8. May/June 1986	29	2	10	11	1	1	3
9. July/Aug.1986	24	8	7	2	4	2	0
10. Sep./Oct.1986	28	20	7	0	0	0	2
11. Nov./Dec.1986	2	0	2	0	0	0	0
12. Jan./Feb.1987	18	1	10	5	0	0	2

TABLE 3

COMPOSITION OF MAMMAL REMAINS FOUND IN FOX FAECES FROM RAVENGLASS 1984-1987

Time period	Total mammal	Unidentified	Mouse*	Vole	Sheep	Rabbit
1. May/June 1984	24	0	0	0	0	24
2. May/June 1985	57	0	0	0	7	50
3. July/Aug.1985	29	0	0	0	0	29
4. Sep./Oct.1985	41	1	7	0	2	30
5. Nov./Dec.1985	46	6	16	0	0	25
6. Jan./Feb.1985	43	11	4	0	4	24
7. Mar./Apr.1986	44	7	13	0	12	12
8. May/June 1986	65	10	12	3	26	17
9. July/Aug.1986	62	6	18	0	20	17
10. Sep./Oct.1986	65	12	24	0	0	29
11. Nov./Dec.1986	91	0	52	0	6	34
12. Jan./Feb.1987	76	3	11	0	12	50

* No distinction was made between Mus and Apodemus.

Kruuk (1964) found that fox faeces collected at Ravenglass in 1962 and 1963 did not contain insect remains in any appreciable amount, in contrast to the results for 1984 when insects were found in all faecal samples examined. In Australia, Green and Osborne (1981) studied the diet of foxes and found that during the summer the most commonly available foodstuffs were invertebrates of the orders Lepidoptera and Orthoptera and that foxed preyed on these preferentially. It is possible that towards the end of the gull breeding season in 1984 when few eggs or chicks were available and rabbit numbers were low foxes turned to the most abundant available food source, beetles.

No Black-headed Gulls have nested on the reserve since 1984 so it has been impossible to compare the importance of nesting birds and their eggs in the diet of foxes in different years. Both Oystercatcher and Ringed Plover nests on the reserve were preyed upon in both years when fox diet data were collected; however, eggshell appeared only once after 1984. This suggests that fox faeces collected on the reserve may no longer be representative of the diet of foxes having dens within the reserve boundary and that foxes may be feeding further afield since the demise of the localised, seasonal abundance of food provided by the gullery. The presence of Blackberry (Rubus fruticosus) seeds in faeces collected on the reserve in Autumn 1985 and 1986 also indicates that foxes moved onto the reserve from outside as there are no brambles on the reserve.

Boronovska and Kolosov (in Southern and Watson 1941) found that birds' eggs were an important food source for foxes. However, they found egg-shell fragments in only 5 out of 600 feacal pellets they examined. A similar situation was found by Sargeant (1972) who considered that although Mallard (Anas platyrhynchos), Pintail (Anas acuta) and Blue-winged Teal (Anas discors) were badly affected by fox predation none of them contributed significantly to the fox diet. It is possible that a similar situation exists at Ravenglass with fox predation on Oystercatcher and Ringed Plover being significant, however, few egg-shell remains were found in fox faeces. Although the dry weight of faeces collected on the route around the reserve fluctuated through 1985 and early 1986, there was a noticeable decrease in late 1986. This, together with the noticeable reduction in fox activity on the estuary beaches noted in early 1987 suggested that the whole reserve was being used less by foxes.