THE BREEDING BIOLOGY AND CONSERVATION OF AUDOUIN´S GULL LARUS AUDOUINII ON THE CHAFARINAS ISLANDS.

A thesis submitted to the Faculty of Science, University of
Glasgow, for the degree of Doctor of Philosophy

by

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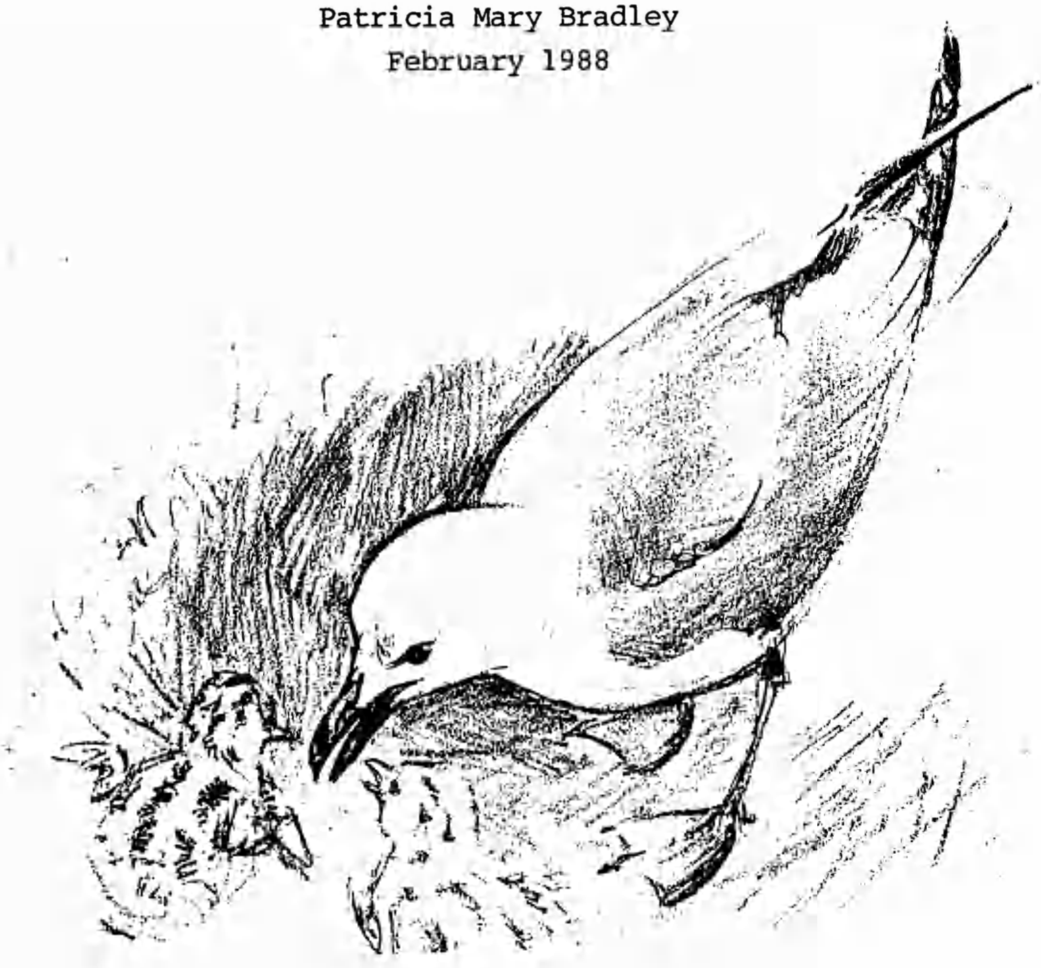

Line drawing courtesy of Juan Varela

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CONTENTS

CHAPTER 4: SITE OCCUPATION AND THE ONSET OF BREEDING

CHAPTER 5: THE EGG

CHAPTER 6: INCUBATION AND HATCHING

CHAPTER 7: CHICK GROWTH AND SURVIVAL

CHAPTER 8: VARIATION IN BREEDING SUCCESS IN RELATION TO ENVIRONMENTAL FACTORS.

CHAPTER 9: THE IMPACT OF HERRING GULL INTERFERENCE UPON AUDOUIN´S GULL REPRODUCTIVE SUCCESS

CHAPTER 10: MANAGING AUDOUIN´S GULLS ON THE CHAFARINAS ISLANDS

APPENDICES

SUMMARY

The breeding population of Audouin´s gull Larus audouinii, a Red Data Book species, is endemic to the Mediterranean. Its population was estimated at 4000 pairs in 1985, but its restricted distribution and suggestions of low fecundity and vulnerability to disturbance and competition prompted this study. The gull´s most numerically important breeding colony is on Rey Island, in the Chafarinas archipelago off the Mediterranean coast of Morocco, where in 1983 this three year study began. Its aims were to discover the factors limiting the size of the colony and to formulate a management plan.

In comparison with many other Palearctic gull species, the breeding biology of Audouin´s gull is little known. Data were collected during the three study seasons at two study sites which were established within the only two habitat types commonly occupied (**NORTH SITE** an elevated exposed site, little ground cover, high Audouin´s gull nesting densities; **SOUTH SITE** a sheltered gentle slope, ample ground cover, low Audouin´s gull nesting densities).

Data presented here have shown that although there is considerable variation between years and sites, Audouin´s gulls have the capacity to sustain and indeed even increase their population size at this colony. The largest mean clutch size was observed at the North site in 1983 (mean=2.75, s.e.=0.06, n=85) and the smallest at the South site in 1984 (mean=2.38, s.e.=0.09, n=98). A measure of survival to a stage close to fledging was made, that of the number of chicks surviving to twenty days per nest. The highest mean site value was at the South site in 1983 (mean=1.26, s.e.=0.10, n=74) and the lowest was at the South site in 1985 when not one chick survived from 52 nests.

In order explain this variation in success, the relationships between breeding success and the following factors: environmental factors; Audouin´s gull behavioural factors; and interactions with other species, were examined.

Analysis of variance in hatching success in relation to laying period, study site and year, showed that hatching success varied in relation to timing of breeding at both sites in each season. Those breeding earlier were generally those to have the greater success. Hatching success was consistently higher at the North site as compared with the South. 1983 was overall the year when hatching success was greatest and 1985 the least successful.

Environmental factors which included: laying date; height of vegetation surrounding the nest; distance to the edge of the sub-colony; nesting density; and visibility from the nest, were shown, in analyses of variance, to influence the success of pairs in raising at least one chick to twenty days.

Behavioural patterns which influenced breeding success were also recorded. Audouin´s gulls are not aggressive, their only defence in the face of attack upon their clutch or brood was to mob the attacker. This proved to be successful only when Audouin´s gulls were nesting at high densities. However, it was also found that at high nesting densities the incidence of intra-specific attacks upon chicks was high.

Audouin´s gull chicks are generally able to leave their nests when they are only one day old. Many did not return to their nests but remained concealed within the cover of bushes. Chick mobility appeared to be influenced by environmental factors. At sites where nest cover was available, chicks were less likely to leave their natal territories and if they did had a shorter distance to travel whilst exposed to intra- and inter-specific aggression.

Whilst great variation in survival of chicks was recorded between sites and years, Audouin´s gull chick growth took place at a steady and similar rate each season for chicks of various brood sizes, with weight and wing length increasing in a regular sigmoid manner. Together these observations do not suggest that food was in short supply.

The most important influence upon Audouin´s gull reproductive success on the Chafarinas Islands during this study was the growth of the yellow-legged Mediterranean herring gull colony on Rey. Whilst the number of pairs of Audouin´s gulls remained approximately the same over the three seasons (2100±100 pairs), there has been a 79% increase in the number of herring gull pairs. There is no evidence to suggest that the predominantly fish-eating Audouin´s gull is in competition with the omnivorous herring gull for food, however the herring gull is certainly larger, more aggressive, and earlier breeding than Audouin´s gull. The herring gulls are not only occupying what were previously Audouin´s gull nest sites on Rey but have been shown to be considerable predators of Audouin´s gull eggs, chicks and adults. Over the course of this study the level of herring gull interference with Audouin´s gull breeding attempts intensified.

A management plan was therefore developed which incorporates:

a) the reservation of nesting space for Audouin´s gulls;
b) improvement of the nesting environment for Audouin´s gull;
c) and the control of disturbance and predation of breeding Audouin´s gulls by herring gulls.

In 1987, the Instituto para la Conservacion de la Naturaleza, acting upon the findings and recommendations of this study, conducted a cull on Rey of 950 adult herring gulls. The breeding population of Audouin´s gull has subsequently increased from 1930 nests in 1986 to 2845 nests in 1987.

CHAPTER ONE: INTRODUCTION

Animals with specialised habitat requirements and or small population sizes are particularly vulnerable to detrimental human influence. In order to adequately conserve such species we need a detailed understanding of their ecology and behaviour. Audouin´s gull, Larus audouinii, Payraudeau 1826, is one of only two gull species to have a population size so small that they merit inclusion in the International Union for the Conservation of Nature and Natural Resources´ (IUCN) Red Data Book (King 1981) which lists the world´s bird species which have been identified as either rare or endangered. In 1976 the world population size of Audouin´s gull was estimated to be as small as 600 to 800 breeding pairs (Witt 1976). Such was the concern for this species that WWF(World Wide Fund for Nature)/IUCN initiated Project number 1413, ´The Conservation of Audouin´s gull´. As a result of the more detailed surveys which ensued and the founding of new colonies, the breeding population of Audouin´s gull is now estimated to be approximately 5000 pairs. Of these 45% currently breed on the tiny Chafarinas Islands (see Section 3.1) and a further 25% of the estimated world population breed at a site on the Ebro Delta, on the nearby Iberian coast. That the only endemic breeding seabird within the Mediterranean should be concentrated within so few breeding sites has, in itself, maintained the concern of conservationists and ecologists. By breeding at only a small number of sites the species is made more vulnerable to changes in that area.

The present study of Audouin´s gull began in 1983 when it became clear that a continuous study of the breeding biology and factors influencing breeding success throughout the breeding season was the only way to gain an insight into the factors which constrain the breeding success of Audouin´s gulls and how these may be alleviated.

In comparison with other Paleartic gull species, for example the herring gull and the ring-billed gull, the biology of Audouin´s gull is little known, and what little is known arouses the interest even more (Cramp and Simmons 1983).

Outside the breeding season adult Audouin´s gulls generally leave the Mediterranean Sea and migrate down the Atlantic coast of Morocco, with sightings occurring as far south as Senegal (Beaubrun 1984, Morel and Roux 1966). Like all seabirds, Audouin´s gull´s small clutch size, low breeding success, higher juvenile than adult mortality and deferred maturity, as compared with passerine species, make populations particularly sensitive to changes in adult mortality rates. These typical seabird characteristics reduce the population´s capacity to compensate for loss of breeding adults. It may therefore appear desirable to begin a study of the factors limiting Audouin´s gull population growth with a survey of adult mortality rates, both within and outside the breeding season. However, both the assessment of survival and the identification of actual and potential threats are not currently possible due to the low densities of ornithologists living along the very long coastline which would need to be studied and should remain necessary tasks for national survey teams. For the same reason the level of juvenile mortality is also unknown. In order to ascertain adult and juvenile mortality large scale adult and pulli ringing programmes are necessary.

Whilst the Atlantic coast may be considered as having abundant fish stocks and the adult Audouin´s gulls do not appear to have any need to remain at any site which is unsuitable during the breeding season, it is known that they breed at sites in the Mediterranean which are frequently disturbed, or threatened with development, or for which they may have to compete with other gull species. At breeding sites it is also known that Audouin´s gulls have suffered from egg collection by humans (Bradley and Monaghan 1986). Therefore, this study focuses upon Audouin´s gull during its reproductive phase as it is then that questions of conservation value can be addressed for the greatest returns.

A study of the breeding biology, especially when undertaken at what is, in numerical terms, the most important colony (that on the Chafarinas Island) allows pressing questions relating to reproductive output to be answered. The world population size of Audouin´s gull, in contrast with the majority of other gull species, does not appear to be increasing. Is the reproductive ability of Audouin´s gull less than other gull species, as has been suggested by Simon and Geroudet(1970)? Papacotsia et al. (1980) suggested that the main constraints to Audouin´s gull population growth in Corsica were human disturbance, caused by tourists visiting colony sites, and predation by rats. Witt (1977b) hypothesized that the low numbers were due to Audouin´s gull being limited by its specialised ecological niche, that it is constrained by, and dependent upon, a unique source of food and that, because it is near the top of the Mediterranean food chain, it may be affected by a scarcity of food.

Audouin´s gull is held to be mainly a fish feeder with a distinctive mode of fish capture (see Section 2.5). Concern is being expressed over the size of the Mediterranean fish stocks and the effect of pollution upon the fish and the other wildlife dependent upon the Mediterranean ecosystem (Attenborough 1987). If Audouin´s gulls do rely upon fish as a major component of their diet, and that of their chicks, then the breeding success or failure of the Audouin´s gull may give an indication of the quantity and the quality of their fish prey. The present study was designed to explore which factors affect Audouin´s gull breeding success and whether practical schemes can be designed which might at least safeguard the current population size and perhaps lead to increased productivity or longevity.

A second reason for studying Audouin´s gulls at a breeding site is that these breeding sites are under threat from development within the Mediterranean and it has been suggested that fish stocks in the area are in general threatened by over-fishing (Witt 1977). A management plan and conservation measures are needed for these sites now.

Habitat loss and deterioration is one of the primary causes of extinction today (Frankel and Soule 1981). Thus a thorough knowledge of the habitat requirements is essential for the protection of many endangered species. Habitat destruction and human disturbance have been identified as major threats to a number of tern species. The little tern has suffered severe population declines (Cramp 1985, Kotliar and Burger 1986, Nisbet 1973, Norman and Saunders 1969). Audouin´s gull´s breeding distribution is restricted to the Mediterranean, to small islands and undisturbed coastal sites, see Section 2.2. As the touristic development of the Mediterranean continues, such sites are becoming increasingly rare and current breeding sites are threatened by such developments. For example, only 3 km from the Chafarinas Islands a tourist resort is currently under construction.

It is also important that we gain an understanding of the extent to and manner in which environmental factors influence Audouin´s gull´s reproductive success. If Audouin´s gull is to continue to colonize such a limited number of breeding sites, these sites must be protected and managed in such a way as to try to safeguard the breeding success of pairs nesting there. Therefore, in order to develop habitat and management procedures to protect the Audouin´s gull population, nest site quality and breeding success were studied using multivariate analysis in order to determine if there were environmental differences between successful and unsuccessful sites.

Why, when another sympatric gull species, the yellow-legged Mediterranean herring gull, is rapidly increasing in number is the population size of Audouin´s gull remaining comparatively low? The Chafarinas Islands provide an ideal study site at which to observe the interactions between the rare Audouin´s gull, the increasingly abundant yellow legged herring gull and humans. Throughout the Mediterranean the yellow-legged herring gull population has been increasing (Guyot and Thibault 1981 and see Section 3.4). One possible explanation for this relatively recent expansion is that herring gulls have adapted to feed on human garbage and fisheries waste. Humans have in other instances altered marine ecosystems, inadvertently alternating the competitive balance between species. Breeding terns have apparently been forced to abandon breeding sites by gulls, and arctic skuas have been replaced by great skuas which have benefited from discards from trawlers and increased sand eel stocks (Thomas 1972, Becker 1984, Furness and Monaghan 1987).

On the Chafarinas Islands the number of breeding pairs of herring gulls has increased from 850 in 1976 to 4500 pairs in 1985, an increase of 429% in less than ten years, see Section 9.3. The second largest Audouin´s gull colony (1200 pairs) at the Ebro Delta in Spain has not, as yet, seen the same rate of expansion of the local herring gull colony which numbered only 500 pairs in 1986. However there is the potential for such expansion. A demonstration that the expansion of the herring gull population on the Chafarinas Islands interferes with the Audouin´s gull reproductive success, may suggest that preventive measures should be undertaken at the Ebro Delta at an early stage to avoid such an expansion.

The objectives of this study were:

a) to undertake a detailed study of Audouin´s gull breeding biology.

b) to measure Audouin´s gull reproductive success during the three breeding seasons.

c) to study the influence of environmental factors upon Audouin´s gull breeding success.

d) to estimate the impact of the expanding herring gull population upon Audouin´s gull breeding success.

e) to make recommendations for the design of a management plan for the Audouin´s gull colony on the Chafarinas Islands.

The following chapter briefly summarizes the information, which has been collected during other studies, relating to Audouin´s gull distribution throughout the year and the species´ general biology. It also discusses the aspects of Audouin´s gull biology which still require further investigation.

CHAPTER TWO: AN INTRODUCTION TO THE BIOLOGY AND DISTRIBUTION OF AUDOUIN´S GULL.

2.1 INTRODUCTION

Concern for this gull species was aroused by the declarations of Audouin´s gull as being at risk of extinction (Kumerloeve 1962, Brosset 1966, Hudson 1975). In order to improve our understanding of the conservation measures needed throughout its range, and to discover why numbers are so low, a number of studies of this bird´s distribution and biology have since been undertaken. The main study of the status of Audouin´s gull was initiated, in 1977, by the IUCN/WWF (Project 1413). The main objectives of this study were to survey the Mediterranean area for breeding colonies and to promote active conservation measures. Many biologists, including de Juana, Witt, Varela, Watson and Schenk, have participated. Work has progressed some way towards an understanding of this gull´s ecology and the factors that may be limiting its distribution and numbers. Prior to this project H.-H. Witt´s Ph.D. thesis (1976), based on work in Turkish, Sardinian and Spanish colonies, detailed some of the basic biology of this gull. In addition, de Juana, Varela and others have studied breeding Audouin´s gulls on the Chafarinas Islands in Spanish Morocco.

With the growth of the Chafarinas colony and the discovery of the healthy breeding colonies on the Spanish mainland and off the Algerian and Italian coasts (see below), fears for the species´s extinction in the immediate future have been allayed. However, in comparison with our knowledge of the biology of some other gull species, such as the herring gull and the ring-billed gull, the facts we possess are as yet few, often sketchy, and some of the conclusions rather tentatively drawn. The findings of research to date, which are referred to but not discussed in later chapters, are summarized in this review. The information is presented under the following headings: distribution of breeding sites; distribution of Audouin´s gulls outwith the breeding season; feeding behaviour; diet; toxic chemicals and information yet required concerning the general biology of this species.

2.2 DISTRIBUTION OF BREEDING SITES

On present evidence Audouin´s gull breeds only on islands in, and coasts around, the Mediterranean sea. Census information currently available suggests that greater numbers are found in the western Mediterranean than have been counted in the east of the Sea. Table 2.1 lists the known sites of breeding colonies and the existing details of their size. Their distribution is shown in Figure 2.1. Apart from the known breeding sites, Audouin´s gulls are thought to breed, or have bred in the past, on various islands in the Cyclades including Andros (juveniles repeatedly observed), Syros (not rare), and in small numbers on Tinos, Paros and Dilos (A. Dimitropoulos in litt. to N.J. Collar 1982). Moreover the islands of the Galite archipelago, Tunisia (La Galite, Galiton, and La Fauchelle) are reported to "represent important breeding areas for the rare Eleonora´s falcon and Audouin´s gull" (Miles 1978). (This archipelago may be that mentioned in King 1978-79 as "Jeziret Jalita off the north-eastern coast of Tunisia"). The search for colonies has certainly not yet exhausted all possibilities. Most Italian islands have been investigated and no breeding pairs are known from the Isole Ponziane (F. Palombelli, per E. Meschini and M. Lambertini in litt. to N.J. Collar 1982), Isole Napoletane, Isole Lipari or Isole Egadi, or Isole Pelagie or Pantelleria (B. Massa and C. Iapichino, per E. Meschini and M. Lambertini in litt. to N.J. Collar 1982).

In 1981 a new colony was discovered on mainland Spain on the Ebro Delta. The number of Audouin´s gulls breeding at this site increased yearly until 1985 when the size of the colony, at least temporarily, stabilised at 1200 pairs. De Juana has suggested that the birds which founded this colony may well have originated from the Chafarinas Islands (in litt. to N.J.Collar 1983).

Of all the colonies known, that on the Chafarinas is by far the largest representing approximately 45% of the known world breeding population of Audouin´s gull.

TABLE 2.1: DETAILS OF KNOWN BREEDING SITES OF AUDOUIN´S GULL.

These figures have been collected by ornithologists visiting the sites in the years indicated in the third column. How accurate these individual records are cannot be estimated. All possible sites have not been surveyed. Sp.= Spanish;Fr.= French;
It.= Italian; Gr.= Greek.

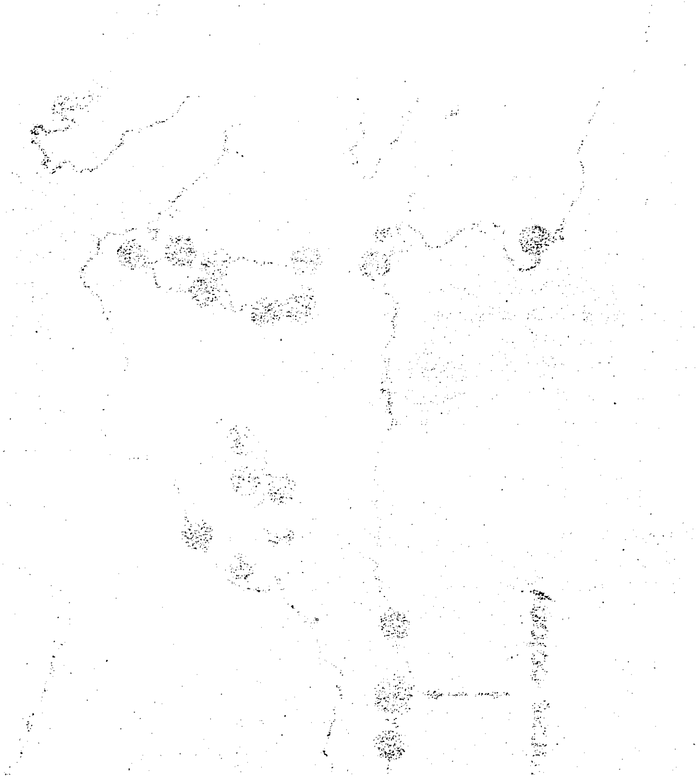
Sector	Site (co-ords)	Year	Number of pairs	Reference
Balearic	Chafarinas (Sp.)	1966	500	Brosset & Olier (1966)
	35 10N 3 35W	1970	000	Groh (1970)
		1973	200	" "
		1976	1000	Juana & Varela (1980)
		1978	1250	Mayol (1978)
		1979	1350	Juana & Varela (1981a)
		1980	1870	" "
		1981	2220	" "
		1982	1710	Juana et al. (1982)
		1983	2020	this study
		1984	2194	" "
		1985	2198	" "
	Calpe (Sp.)	1976	20	King (1978-79)
	39 50N 0 40E	1979	0	H.-H. Witt in litt. to N.J. Collar 1982
	Columbretes (Sp.)	1974	45	Pechuan (1975)
	39 50N 0 40E	1975	100	Mayol (1978)
		1977	50	" "
		1978	50	" "
		1982	130	Juana et al. (1982)
		1983	300	A.Mira in litt.to E.de Juana 1983

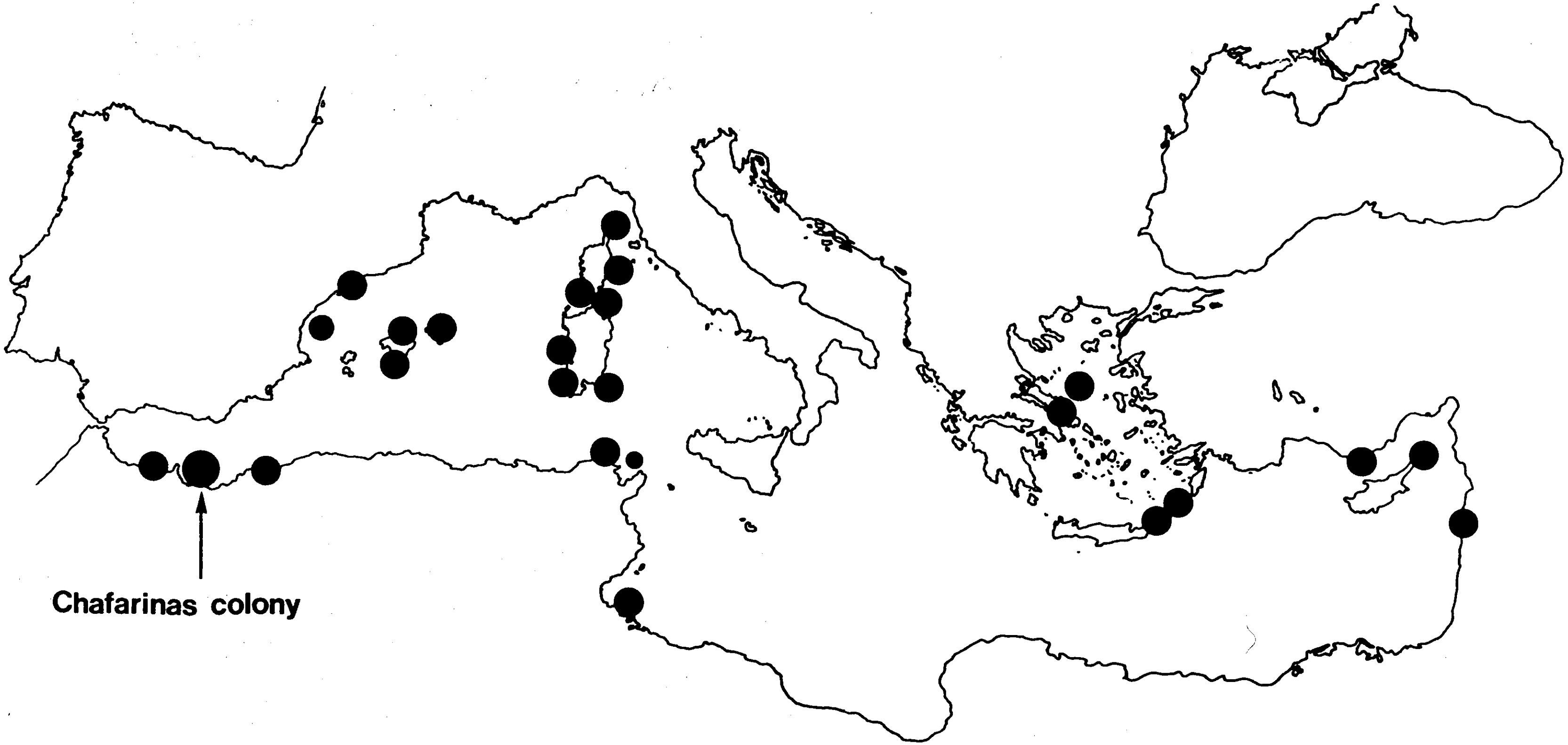
Ebro Delta (Sp.)	1981	36	Ferrer and Martinez-Vilalta (1986)
	1982	200	
	1983	550	" "
	1984	1200	" "
	1985	1200	" "
Balearics (Sp.)	1981	300	Juana & Varela (1981)
39 30N 3E	1983	500	Juana in litt.to N.J.Collar (1983)
Pitiusas	1978	200	Mayol (1978)
Cabrera	1978	63	" "
Conejera	1978	60	" "
Mallorca	1978	34	" "
Menorca	1978	19	" "
Balearics	1982	300	Juana *et al.* (1982)
	1983	500	comm. to Juana from Mayol 1983
Alhoceima, Morocco	1982	12	pers. comm. P.-C.Beaubrun
Algeria	1978	500	Jacob & Courbet (1980)
Saint-Piastre	1978	45-50	" "
Colombi Is.	1978	1-2	" "
Cap Falcon	1978	56	" "
Plane Is.	1978	50	" "
(Islands off Cap Blanc)			
east	1978	101	" "
West	1978	96	" "
Islet of Madakth	1978	80-85	" "
Islet between Cap Figalo & Beni Saf	1978	60	" "
Sardinia Corsica (Fr.)	1963	70	Brichetti & Cambi (1979)
42N 9E	1971	27	Papacotsia *et al.* (1980)
	1974	40	Brichetti & Cambi (1979)

	1975	3	Papacotsia *et al.* (1980)
	1977	5	Brichetti & Cambi (1979)
	1978	11	Thibault & Guyot (1981)
	1979	29	Papacotsia *et al.* (1980)
	1980	63	Guyot & Thibault (1981)
	1981	66	" "
	1982	90	I. Guyot in litt. to N.J. Collar (1982)
	1984	30	Guyot & Thibault in litt. to Varela (1984)
Capraia (It.) 43 5N 9 45E	1977	60	E.Meschini & M. Lambertini in litt to N.Collar (1982)
	1978	110	" "
	1979	30	" "
	1980	0	" "
	1981	36	" "
	1982	20	" "
Name withheld (It.)	1982	50	" "
Montecristo (It.) 42 20N 10 20E	1982	10	" "
Elba (It.) 42 45N 10 10E	1982	10	" "
Sardinia (It.) 40N 9E	1976	50-150	Schenk (1976)
	1979	200-225	Schenk (1979)
	1980	250-300	Schenk (1980)
	1984	458	Schenk & Torre (1986)

	Cerbicales (Fr.) 41 35N 9 25E	1955	3	Etchecopar & Hue (1955)
		1962	12	Meschini *et al.* (1979)
		1963	70	Bournville (1964)
		1970	2	Guyot & Thibault (1981)
Ionian	Zembra, Tunisia	1981	15	J.M.Thiollay in litt. to N.J.Collar (1982)
		1984	20	Gaultier in litt. to J. Varela (1984)
	Tunisian Islands 37 10N 10 45E	1973	25	J.M.Thiollay in litt. to N.J.Collar (1982)
		1974	28	" "
		1984	30	Gaultier in litt. to J.Varela (1984)
Aegean	Crete Islands (Gr.)	1982	5	G.E.Watson pers.comm. to N.J.Collar (1982)
	Northern Sporades	1973	20-30	" "
	Dodecanese	1973	52	" "
Levant	Klidhes Island off Cyprus	1960	20-25	Watson (1973)
		1961	9	"
		1973	40	Neophytou (undated)
	Nakl Island	1940	12-15	Tohme & Neuschwander (1974)
	off Lebanon	1973	18 birds	"
	Turkish coast	1973	25	Witt (1976)
		1974	28	"
		1975	30	Witt (1982) WWF. Project Proposal

Figure 2.1 Distribution of Audouin´s gull colonies.




Chafarinas colony

The relative instability of Audouin´s gull colonies makes the status of the species difficult to evaluate. Do changes in numbers at a site reflect past breeding success or failure, or simply immigration from or emigration to unknown sites? It may be easier to answer this when a greater proportion of colony sizes are monitored or when ringing programmes are more advanced. De Juana and Varela have proposed that the degree of protection inadvertently given to breeding Audouin´s gulls on the Chafarinas by the Spanish army has allowed them to become a stock from which other colonies could be founded or replenished. They suggest that this is what may have happened in the case of the recently discovered Algerian colony, only 170 km from the Chafarinas (Jacob & Courbet 1980) and at the Spanish mainland site (de Juana in litt. to N.J.Collar 1983). No evidence has yet been found to support this hypothesis, i.e. no individuals ringed on the Chafarinas have been found breeding at other sites despite annual ringing of chicks on the Chafarinas Islands, although no information concerning the amount of effort spent looking for ringed birds is available for other sites.

2.3 DISTRIBUTION OF AUDOUIN´S GULLS OUTSIDE THE BREEDING SEASON

Still less is known about the distribution of Audouin´s gull outside of the breeding season, when some birds move west to the Atlantic coast. Post-nuptial migration begins through the Straits of Gibraltar towards the end of July (Beaubrun 1982). Most of these birds which winter on the Atlantic Coast of Africa are found between Cape Cantin and Agadir, Morocco, but some have been found as far south as Senegal (Smith 1972, Reille 1975).

Substantial numbers remain within the Mediterranean throughout the winter. However they are evidently not evenly distributed. They have not been observed during this period in Valencian and Catalonian waters (Carrera and Callissa 1983). Jacob (1979) in the winter of 1977 counted 824 along Algerian coasts. In January 1984, a count was made of all the seabirds around the Iberian coastline. Of the 132 Audouin´s gulls observed 13% were on the Andalucian coastline and the other 87% were counted on that of Murcia (Bermejo et al. 1984). Of these birds which remain within the Mediterranean throughout the winter only about 2% are immatures. Both Beaubrun (1982) and Smith (1972) are of the opinion that the juveniles tend to leave the Mediterranean first and that the adults, although well represented in the wintering populations outside the Mediterranean, tend to remain. The attraction of the waters outside the Mediterranean may lie in their comparative richness of clupeids (Witt 1977, Beaubrun 1982). More data are needed to test this hypothesis.

2.4 FEEDING BEHAVIOUR

Fish are reported to be the main food source of this gull throughout the Mediterranean. Wallace (1969) was the first to describe a specialized fishing technique which it employs. Vision is used to detect fish, perhaps by the ripples the fish make while swimming just beneath the surface. The fish are then snapped up as the gull skims slowly over the water surface. This method, apparently unique amongst gulls, depends on the availability of small fish in the uppermost layer of the sea and on suitable weather conditions so that fish can be detected and low flight permitted (Witt 1981). Other fish predators, such as shags, dolphins and tuna, are important to the feeding Audouin's gulls as they increase fish availability by chasing them upwards from below (Witt 1982). Fewer observations have been made of other Audouin's gull feeding methods. Wallace (1969) emphasised that the technique described above was not employed under adverse weather conditions (stormy conditions). Instead Audouin's gulls made short low flights over the surf attempting to catch prey without being hit by waves and without being forced to land on the water. Apparently capture rates declined when the birds fished in this way (Witt 1977). This may, however, be due to the altered distribution of the fish rather than decreased efficiency on the part of the gulls. Wallace (1969) and Witt (1977) both mentioned a further prey capture method; gulls sat on cliffs or soared above them watching for fish made obvious by the turbulence. The gulls took these following a short glide and dive. Witt (1977) also recorded observations of beachcombing Audouin's gulls looking for edible remains. Audouin's gull is such an easily disturbed bird that observations of feeding groups are hampered by the birds´ tendency to avoid boats and people.

Much of the published literature on Audouin´s gull suggests that a considerable proportion of feeding takes place at night (de Juana & Varela 1980b, Witt et al. 1981, Witt 1982 and pers. ob.). They have been reported to take fish normally found in deep water (e.g. blue whiting Micromesistius sp. and Rockling Phycis sp.) (Witt 1982). Unless discarded from the local fishing fleets, these fish presumably come to the surface at night to feed on plankton (Witt 1982). Dawn and dusk have been recorded as the times of maximum arrivals and departures, respectively, of Audouin´s gulls from the colonies (de Juana & Varela 1980b, Beaubrun 1982, Witt 1982). The sea may be used as a nocturnal roost by non-breeders of the colonies, as is the case for some other gull species (Vermeer 1963) or they could be flying off to drink. It is not known how Audouin´s gull would detect fish at night. Witt (1982) suggests that, like the nocturnal forked-tailed gull, the dark iris and the comparatively large outer eye of Audouin´s gull facilitates nocturnal foraging.

Opinions vary as to whether this gull takes advantage of man´s industry and refuse for foraging. Witt (1982) noted that sardine fishing boats, whilst using acetylene lamps to lure fish to the surface at night, were often accompanied by gulls. During this study many of these gulls were identified as Audouin´s gulls. Audouin´s gulls have also been known to feed at sites of detonation fishing (Brichetti and Cambi 1979). De Juana and Varela (1980b) and I found that Audouin´s gulls in the vicinity of the Chafarinas Islands rarely accompanied fishing boats during the day. This probably depends upon the nutritional quality of a site, the time of year and how accustomed birds of a particular colony are to man´s presence.

2.5 DIET

Whilst the Mediterranean herring gull takes fish, insects, molluscs, plants and garbage in approximately the same proportions throughout the Mediterranean, the same is not true for Audouin´s gull. Witt (1980) found fish in 90% of all faeces and pellets collected, during April-June 1979, in the Chafarinas colony; 70% contained fish in the Turkish colonies. In Sardinia in August 1974, all of the 50 samples examined contained fish, 11 contained insects and 5 crustaceans (Witt et al. 1981). On Cabrera, in the Balearics, Araujo et al. (1977) found similar results, whilst on Ibiza only fish were recorded (Mester 1971). Table 2.2 lists the food items of Audouin´s gull recorded over approximately the same time period for the two main study colonies, at opposite ends of the Mediterranean (taken from Witt et al. 1981). In Turkey, in 1974, Audouin´s gull utilized a broad spectrum of foods, principally plants, Molluscs, Arthropods, (Crustacea and Insecta), birds and mice. Especially noticeable is the extent to which crop cereals feature. This, in conjunction with the large numbers of insect species and other land-bound food items in their diet, adds weight to the observations made by Witt et al. (1981) that Audouin´s gull in Turkey often forages inland. The entire diet of the gull in the Chafarinas could be found at sea or at the breeding site. In the west of the Mediterranean the birds were rarely seen feeding in-shore (de Juana & Varela 1980b, Witt 1980, Beaubrun 1982). They only resorted to inland feeding and other foodstuffs during conditions unsuitable for fishing (Witt et al. 1981). Following heavy April storms on the Chafarinas islands, pellets were found to contain the bones of many small migratory birds. These included most frequently the pied flycatcher and also commonly woodchat shrike, swallows, house martins and swifts (de Juana et al. 1979). Apparently, during storms fish remain well below the surface and turbulence is too great to allow the gulls to fly sufficiently close to the surface of the water to allow them to detect and capture fish. Under these conditions small migratory birds are easier prey (Witt 1977b, Witt et al. 1981). At all sites, during the period of hatching and chick-rearing, fish formed a predominant part of the diet (Witt et al. 1981). This may be due to the absence of storms during the latter part of the breeding season and the completion of the passage of the migratory birds.

TABLE 2.2: FOOD ITEMS OF BREEDING ADULT AUDOUIN´S GULLS IN THE MEDITERRANEAN (AS FOUND IN FAECES AND PELLETS).

Food item	Turkey (1 April-22 June 1974)	Chafarinas (5 April-25 July 1979)
Plant matter	Peanut *Arachis* spp., Olive *Olea sativa* grain *Graminea*	Grass stalk *Graminea*
molluscs	snail *Diotocardia* & *Monotocardia*,Bivalves, squid *Sepia officinalis*.	Snail,squid *Sepia officinalis*, *S. elegans*,*Allotheutis* spp., Bivalves.
Crustacea	Crab *Portunus* spp., shrimp *Natantia*.	Crab *Portunus corrugatus*, *Poybius henslowi*,*Lepas anatifera*.
Insects	Dragonfly *Libellula*, mole cricket *Gryllotalpa* spp.,locust(Acrididae), praying mantis *Mantis religiosa*,ant (Formicinae) *Camponotus* spp.,beetle (Carabidae) *Coprophaginae*, *Tenebrio* spp.,(Curculionidae).	Locust *Calliptamus* spp., Beetle (Coleoptera).
Fish	*Sardinella* spp.,*B. belone*, *Hippocampus guttulatus*, *Atherina hepsetus*,*Mugil saliens*,*Serranus cabrilla*, *Diplodus sargus*,*Oblada melanura*,*B. boops*,*Maena chryselis*,*M. smaris*,*M. maena*, *C. chromis*,*Labrus* spp., *Scomber scombrus*, *Stepanolepis ocheticus*.	*Sardina pilchardus*, *Engraulis encrasicolus*, *Sardinella aurita*,*B. belone*, *B. boops*,*Diplodus* spp., *Peristedion cataphractum* *Bothus podus*,*Capros aper*, *Serranidae*,*C. coelorhynchus*, *Nezumia aequalis*,*Micromesistius poutassou*,*Phycis* spp., *Pagellus* spp..
Birds	*Lanius collurio*, *(Alaudidae)*	*Apus* spp.,*Emberiza calandra*, *Sturnus* spp.,*Phylloscopus trochilus* & spp.,*Sylvia* spp., *Luscinia megarhynchos*.
Other	Skink *Chalcides ocellatus*, mouse *Microtus guentheri*, bread,meat,garbage.	

Taken from Witt *et al.*(1981)

Clupeids are the most important fish prey, in particular sardines and anchovies. Witt (1981) examined the F.A.O. (Food and Agriculture Organisation) figures for fish landed in the Mediterranean annually. The amount of fish landed in the Balearic sector, where approximately 85% of the known world population of Audouin´s gulls breed, is 13 times higher than that in the similarly sized Levant sector where only 3% of the Audouin´s gull population nests, though Witt did not state whether the Levant sector is similarly fished. In any case the extent to which these fish landings truly reflect fish abundance remains in some doubt, and the lack of breeding Audouin´s gulls in the sector may in be in part due to the lack of available nesting sites in this region. However Witt (1979) suggested that the passage of nutrient-rich water through the Straits of Gibraltar may explain the uneven distribution of fish and perhaps therefore, the uneven distribution of nesting colonies. Following discussions with personnel from the oceanographic division of the Spanish Armada, it would appear that the Chafarinas Islands are particularly suitably situated as a nesting site for a fish-eating species as the Atlantic currents eddy in the bay behind the peninsula on which the town of Melilla is to be found. The sardine species *Sardina pilchardus* and anchovy populations have an eastern distribution limit at Crete. *Sardinella aurita*, another species of sardine, is the only small clupeid with a comparatively abundant east Mediterranean occurrence. Since the construction of the Aswan Dam the influx of non-saline Nile water into the Mediterranean has been stemmed, the nutritive level of the east Mediterranean waters has decreased and the numbers of *Sardinella aurita* have subsequently declined (Witt 1980a, Attenborough 1987).

Current information thus suggests that Audouin´s gull is not the exclusively open sea forager it was once thought to be (Makatsch 1968, Lack 1971, Mester 1971) but rather a comparatively specialised fish feeder that will take advantage of other food sources when necessary.

2.6 TOXIC CHEMICALS

Bijleveld _et al._ (1979) tested 7 addled Audouin´s gull eggs from western Mediterranean colonies for persistent toxic chemicals. The levels of organochlorines found were higher than those found in herring gull eggs, especially in samples from northern Mediterranean sites. H.H. Witt was also alarmed by the quantities of heavy metal and toxic chemicals found in seven Audouin´s gull eggs collected on the Chafarinas Islands in 1979 (H.H.Witt in litt. to P.C.Beaubrun 1980). This, they suggested, reflects the higher position of Audouin´s gull in the food chain. Although a strong correlation has been found between the amounts of pollutants in the eggs and the reproductive success or decline of the brown pelican in South Carolina (Blus _et al._ 1974), there is no evidence that this is the case for Audouin´s gull (Guyot & Thibault 1981, Witt 1981, de Juana _et al._ 1982). Moreover Bourne & Bogan (1980) suggested that the organochlorine levels found by Bijleveld _et al._ (1979) were not particularly high for a member of the genus _Larus_, which seem to be relatively resistant to toxins of this sort. No opportunity, however, should be missed to monitor the levels of toxic chemicals in Audouin´s gulls´ eggs.

2.7 ASPECTS OF THE GENERAL BIOLOGY OF AUDOUIN´S GULL STILL REQUIRING INVESTIGATION.

The world status and distribution of Audouin´s gull has not yet been established with any certainty. Further survey work to complete the coverage of possible breeding sites in the Mediterranean, and to update our information from known sites, is highly desirable. This needs to involve more accurate census methods than head counts at a single point in time during the breeding season, as has often been the case in the past for other seabird species (Wanless and Harris 1985). There must also be a distinction drawn between non-breeding and breeding individuals. As this work reveals new sites the impression might be given that the total number of birds is increasing, but this may not be the case. Changes in world population size are due, in any species, to changes either in mortality rate and/or breeding success.

Until now only local changes during the breeding period have been monitored. Fluctuations at, or the disappearance of, a colony may be due to sporadic desertions. This is a subject needing attention. An understanding of the factors causing infidelity and those which influence recruitment should be sought so that management of existing colony sites might take place.

Much has been postulated about the feeding of Audouin's gull. However, there is as yet no firm scientific evidence that sardines and anchovies are the gulls' optimal food, apart from their similar distributions which would explain why they form such a large part of the diet. Nor is there any evidence that less fish in the diet (for example the birds in the Turkish colonies) decreases breeding success. Why then should Audouin's gull be more dependent upon fish than the herring gulls breeding in the same area, and why should it retain a specialized fishing technique which appears to confine breeding birds to the Mediterranean? Perhaps the diet of chicks or their parents' dietary requirements during the breeding season differ from that of the non-breeding adult. There has been no information concerning the food taken during the wintering period. On the clupeid-rich Atlantic coast what do these gulls eat? Does it differ from the food eaten by Audouin's gulls which spend the winter in the Mediterranean?

Audouin's gull is apparently unique amongst gulls in its fishing technique. The efficiency of this skill is sensitive to changes in weather conditions and fish distribution. Interesting comparisons can be made between Audouin's gull and the Mediterranean herring gull. The herring gull has a different diet, breeds earlier, lays larger eggs and yet, according to the literature, has a shorter incubation period. Do these differences explain the success of herring gull populations and the restricted distribution of Audouin's gull? Information must be acquired and these questions must be answered if the Mediterranean's only endemic breeding seabird is to be understood and effectively protected.

CHAPTER THREE: DESCRIPTION OF THE STUDY AREAS AND GENERAL METHODS

3.1 RESTRICTING THE IMPACT OF THE STUDY

Scientific investigations concerning "Endangered Species" require especially considerate design and execution. Experimental procedures which may reduce breeding success must be avoided where possible. Audouin´s gull is easily disturbed by human presence, all the adults leaving colonies to sit on the sea when they are approached and not returning until the disturbance has long since passed (in contrast the herring gulls nesting on the Chafarinas remain incubating, except for those in the immediate vicinity of the disturbance). To minimize the damage caused by the investigation, the time spent working in the open, within view of the gulls was restricted to a maximum of one hour per day per study site. In each year control sites were established at which disturbance by humans was minimal. These sites were visited only to mark the area, census the nests and finally to ring the chicks. This time limit on exposure in the colony reduced the feasibility of a more comparative study of the breeding biology of Audouin´s gull and the herring gull due to the Island of Rey being so small that the collection of data pertaining to the breeding biology of the herring gull would have increased the duration of disturbance of the Audouin´s gulls.

3.2 THE STUDY AREA

The Chafarinas Islands lie 3.5 km. off the north-east coast of Morocco, near the mouth of the Moulouya River (Lat. 35^{o} 10´N, Long. 2^{o} 23´W, see Figure 3.1). Three small islands belong to the group; Isabel II, Rey Fernando (referred to as Rey from this point onwards) and Congreso, with maximal areas being 21 ha., 17 ha. and 51 ha. respectively (see Figure 3.2). The three are of volcanic origin and as such are characteristically steep and surrounded by cliffs.

Congreso is the largest and the highest island of the group, reaching 137m. It is totally surrounded by cliffs with a rocky

Figure 3.1 Location of the Chafarinas Islands.

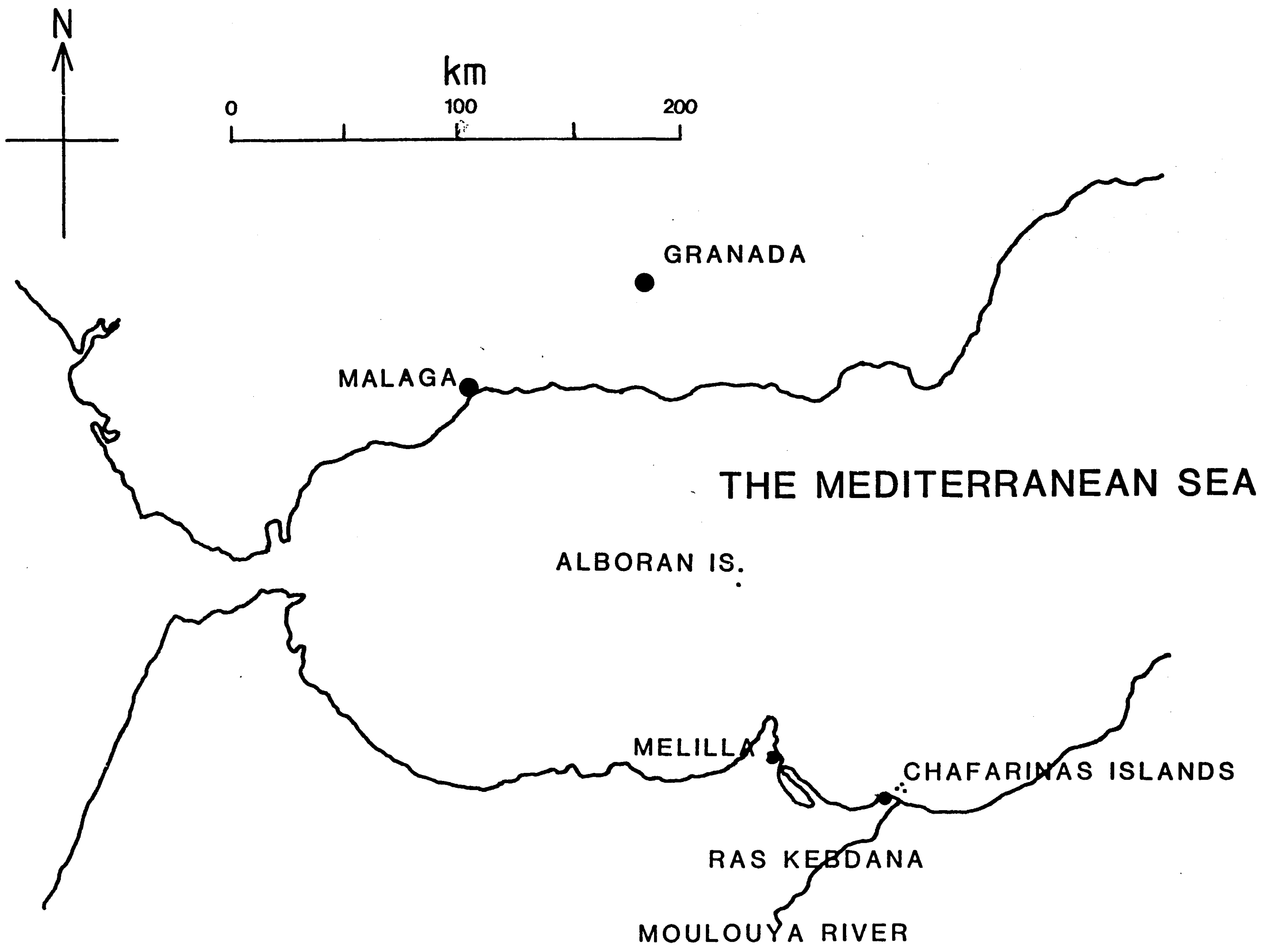
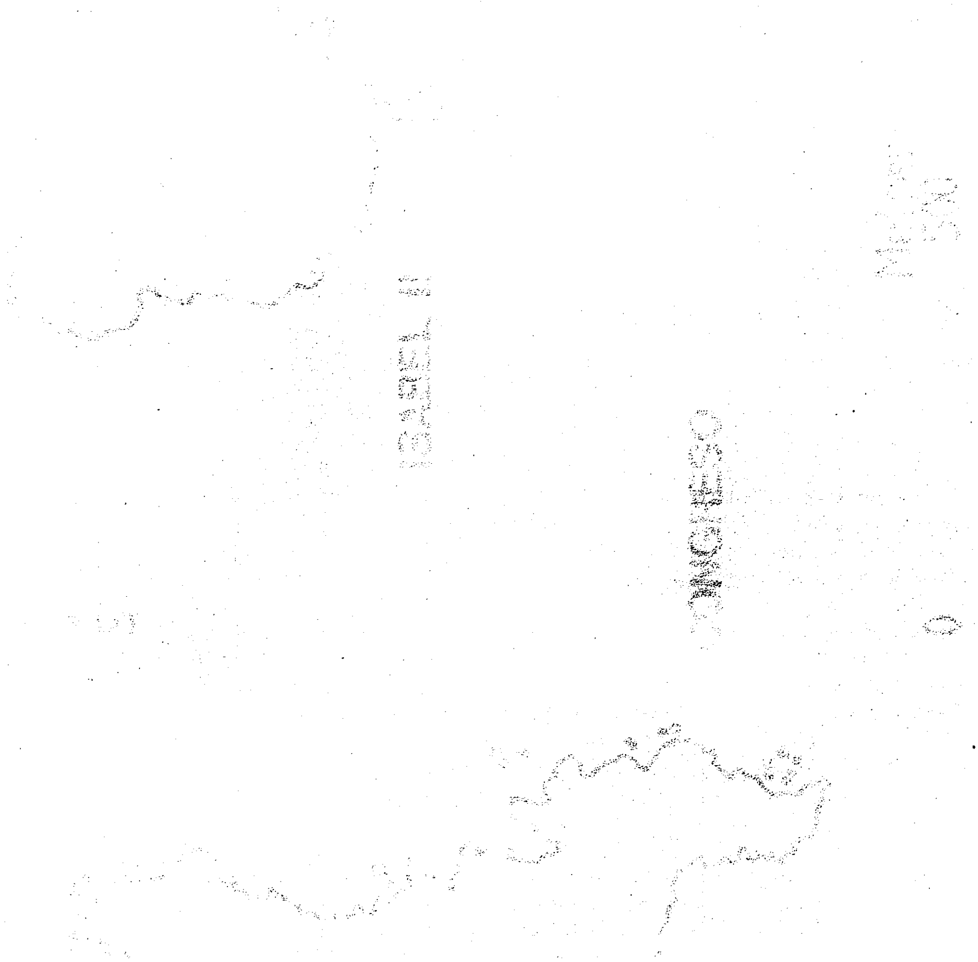
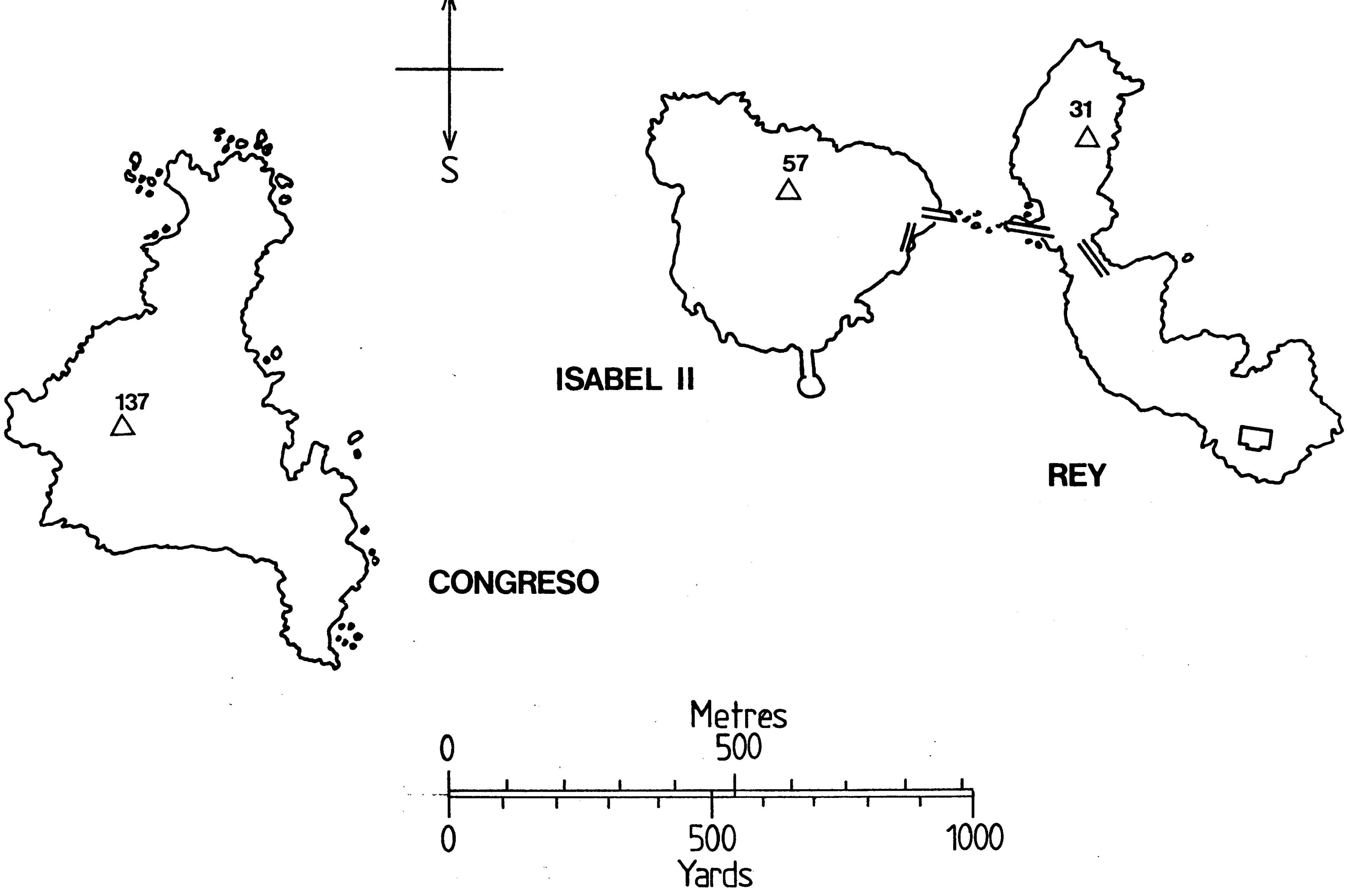

N
km
0
100
200
GRANADA
MALAGA
THE MEDITERRANEAN SEA
ALBORAN IS.
MELILLA
CHAFARINAS ISLANDS
RAS KEBDANA
MOULOUYA RIVER

Figure 3.2   The Chafarinas Islands.





S
137
CONGRESO
ISABEL II
57
31
REY
Metres
0
500
0
500
1000
Yards

beach only on the south-west face. Access to the upper part of the island is facilitated by steps which start at the southern tip of the island. These steps lead from a tiny harbour up through the island to the more gradually inclined upper slopes.

Isabel II is a fortified garrison island. Much of its surface is covered with dwellings, a heliport, a harbour and paths. The bare ground is grazed by two mules and a small herd of sheep. Since 1978, Isabel II has been the only inhabited island of the group. In previous years barracks were additionally occupied on the other two islands. In 1887 Isabel II was the site of a small town with 700 inhabitants (Calderon 1894) but during the period of this study it was purely a military base. In 1983 and 1984 approximately 200 soldiers and 10 officers of the Spanish Infantry, Regulares No.2, were billeted on Isabel II. This force was reduced in 1985 to some 50 soldiers and 5 officers in preparation for their replacement by another Spanish military force.

Lying only 170m. to the east of Isabel II is Rey, (see Figure 3.2) a long centrally waisted island. Rey has been the focus of this study as it was the only island of the group on which Audouin´s gulls bred in 1983, 1984 and 1985. An elevated ridge runs down the east side of the island forming cliffs on that edge. The slope in the south of the island runs to sea-level at the south and west. Rey was previously connected to Isabel by a 250m. long dike. This was destroyed in 1914 by a Levante storm. Ruins of a cemetery lie in the south of the island.

3.3 CLIMATE AND VEGETATION

The islands are composed of igneous rock which has been dramatically eroded by wind and sea. Annual temperatures average between 16-20^{o}C and the annual rainfall is less than 200 ml. per m^2 (Asensi and Salvo 1980). The soil cover is very thin and no freshwater is to be found on the islands. The vegetation is dominated by a few species which are typical of Northern Africa. The most common plants on Rey are xerophytic maritime scrub bushes of Lycium intricatum and Atriplex halimus with a sparse ground cover of iceplant Mesembryanthemum cristallinum, Salsola verticillata and Chenopodium opulifolum.

3.4 THE AUDOUIN´S GULL POPULATION

Since 1956 the French biologist A. Brosset, who worked in Morocco, had noticed frequent aggregations of Audouin´s Gulls at the mouth of the Moulouya River and recognised the possibility that a breeding colony might be situated on the Chafarinas Islands. It was not however until 1966 that he acquired permission to visit the islands and found the colony which consisted of 500 pairs. Until then Audouin´s Gull had been considered to breed only in small groups and this discovery revealed a colony which represented a doubling of the previously estimated world population (Brosset 1966).

The colony on the Chafarinas has grown in size since then. In 1985, 2198 pairs nested on the Island of Rey. During the late seventies the number of Audouin´s Gulls breeding on the Chafarinas Islands increased dramatically (see Figure 9.1). This increase apparently ended in 1983. The changes in the position of the colony on the islands is discussed in Section 9.3. During the course of this study all the successful Audouin´s Gull nests were restricted to Rey where their distribution was neither even throughout the island nor concentrated in one sector. Nests were built in scattered groups. These groups of nests, ranging in size between 22 and 1413 nests, are referred to in this study as sub-colonies (see Figures 9.2, 9.3, 9.4). This term is chosen to suggest a degree of independence, in that each sub-colony was out of view of the others and that the birds did not walk from one to another. They were not, however, totally independent as they reacted to alarm flights made by other sub-colonies, had views of the other sub-colonies from the the air and could see members of the other sub-colonies flying off to fish. The possibility remains, therefore, that the sub-colonies received information through visual and audible cues regarding danger and food sources from outwith the sub-colony. The distribution and the size of the sub-colonies during the three years of this study are shown in Figures 9.3, 9.4, and 9.5.

3.5 THE HERRING GULL POPULATION

The herring gull referred to in this study is the yellow-legged herring gull (or yellow-legged gull as it is sometimes referred to by Spanish and Italian biologists) commonly found in the Mediterranean. This gull has been referred to by two scientific names Larus argentatus michahellis and Larus cachinnans michahellis (de Juana et al. 1982, Monbailliu and Torre 1986, Anon 1987). As the latter was not adopted by Cramp (1985) the former name has been used throughout this study.

The herring gull colony on the Chafarinas Islands represents one of the largest colonies of this species in the Mediterranean. The only other colonies of comparable size in the western Mediterranean are that of Riou Island off Marseilles, France, where 3,400-3,600 pairs bred in 1981 (Guyot in de Juana et al. 1982) and that on the Medas Islands, in the province of Gerona, Spain, where up to 7,500 have been recorded (Carrera in de Juana et al. 1982). In Algeria only 2,500 pairs have been reported (Jacob and Courbet 1980), in Corsica past records indicate breeding populations of 2,100-2,400 pairs (Guyot and Miege 1980) and in Mediterranean France 22,200 (+ 1,000) pairs (Guyot, Launay and Vidal 1985). The breeding population within the ´Alboran Sea´ of the Mediterranean is estimated to be at least 5,500 pairs with perhaps 85% of those being located on the Moroccan side of the region (de Juana and Patterson 1986). For the Spanish Mediterranean there have been recent estimates of 15,000 pairs for the area which includes the Balearic Islands (de Juana 1984). In Catalonia around 8,140 pairs have bred in one season (Nebot and Vilagrasa in de Juana et al. 1982).

As has been witnessed throughout Britain (Parsons 1971, Harris 1970 and Chabryzk and Coulson 1976) and North America (Kadlec and Drury 1968) the herring gull has adapted very well to its sympatrism with man, increasing in population size and range (Monaghan 1983). Similar trends have been observed in the Mediterranean area (Guyot and Thibault 1981).

On the Chafarinas Islands the herring gulls have been shown to benefit from the garrison island through the consumption of the food left-over from the kitchens, which is given to the pigs, and the rubbish which is dumped daily into the sea. Evidence of the herring gulls taking domestic rubbish from the Moroccan village 3.5km. away has also been found (Witt et al. 1981). The fishing boats which not only frequent the duty free Chafarinas harbour but also the developing fishing village at Ras Kebdana, Morocco, may provide the herring gulls with offal, discards and opportunities to raid the filled nets as they are being raised. Olive stones carried by the herring gulls from the Moroccan mainland also litter the colony islands. The increase in the herring gull numbers on the Chafarinas Islands is shown in Figure 9.1. Unfortunately records have not been made of the herring gull colony size earlier than 1976. For a description of the herring gull distribution on the Chafarinas Islands during the study period, 1983-1985, see Section 9.3.

3.6 OTHER FAUNA

The Chafarinas Islands also boast the second largest colony of Cory´s shearwater in the Mediterranean (the largest being Zembra in Tunisia). Although there is some uncertainty about the actual population size, it is considered it be in the region of 3,000 pairs (de Juana and Varela 1983). The shearwater burrows are to be found on the high cliffs and amongst the fallen boulders on the western face of the island of Congreso. It has also been suggested that shearwaters may breed in smaller numbers on Isabel II and Rey but no burrows have been located.

Each year since the start of these studies on the Chafarinas islands in 1976 at least one osprey nest has been observed on the cliffs of Congreso. During the last three years full clutches have been laid but only in 1983 did the three chicks reach fledging age. In 1984 and 1985 only one chick survived to this stage.

During each field season groups of shags were frequently seen on the southern rocks of Congreso. This species has become very rare in the Mediterranean, with the exceptions of Corsica and the Balearic islands where several hundreds of pairs breed (Thibault and Guyot 1981). It is possible that shags breed on the Chafarinas islands but, as their breeding season falls months earlier than that of the Audouin´s gull, no ornithologist has been present to observe them. The island of Congreso is the breeding site of a pair of peregrine falcons. Eleanora´s falcons have also been observed flying across the islands. Various reptiles inhabit the island group: geckoes; wall lizards; skinks; and other, yet to be identified, large snakes.

Both Isabel II and Congreso have large populations of rats. Those on Isabel II are supported, unintentionally, by the human population. On Congreso the size of the rat population fluctuates with the avian breeding season (J.M.Cabo pers.comm). Before the birds start to breed rat numbers are very low apparently due to food shortages. Once gull egg-laying begins, however, food becomes available and numbers begin to increase. Currently Rey is rat-free. Congreso has also a large rabbit population, originally of domestic stock, which were released on Congreso for hunting purposes.

The mammal which also attracts the attention of conservationists to the islands is a monk seal. This resident seal, which measures approximately 3 m. in length, earns the hatred of the locals by occasionally consuming all but the heads of entire catches of fish from fishing nets, which they might also damage. In the Autumn, it is said, a female is seen in attendance but offspring have never been observed. Most probably the female gives birth at another site, perhaps in Algeria, where reproductive colonies are known to exist. The Mediterranean Monk seal was in 1984 placed on the IUCN ´Top Ten List´ as one of the ten endangered mammal species that should be given top priority for conservation action (Fitter 1984).

3.7 THE STUDY SITES

Rey, as mentioned previously, narrows centrally (see Figure 3.2.). This conveniently divides the island into two areas sufficiently separate for one to be disturbed without the incubating birds in the other area being affected. The island has only two major habitat types within the Audouin´s gull breeding area 1) open and sparsely vegetated, the vegetation including the very thorny Lycium intricatum and 2) sheltered with considerable plant cover. A study site was established in both of these types, ´**NORTH**´ representing the former type and ´**SOUTH**´ the latter (see Figure 3.3). In each year a further site was demarcated as a control site (see Figure 3.3, 3.4 and 3.5). In 1983 and 1984 the control site was in the northern part of the Rey and in 1985 in the southern part. This site was not visited daily and was left relatively undisturbed apart from 3 - 4 checks to allow estimations of productivity to be made.

CHARACTERISTICS OF STUDY SITES IN 1983

NORTH

a) elevated site on a plateau with cliffs to right and left.

b) sparse vegetation (Atriplex halimus, Lycium intricatum).

c) no herring gulls nesting within 30 m.

d) average distance from an Audouin´s gull nest to its nearest Audouin´s gull neighbour 117 cm, s.d. 45.8, n = 83.

SOUTH

a) on a gentle south-westerly slope.

b) abundant vegetation including many bushes (Atriplex halimus) with some low creeping plants including (Mesembryanthemum cristallinum).

c) no herring gulls nesting within 15 m.

d) average distance from an Audouin´s gull nest to its nearest Audouin´s gull neighbour 185cm., s.d. 92.9, n = 71.

Photographs of the two study sites are shown in Plates 3.1 and 3.2. The physical characteristics of the study sites remained the same from year to year. Details of density changes are outlined below as appropriate.

Within the sub-colonies in these areas 10 m^2 quadrats were staked out and all the nests within two such quadrats at the northern site and three at the southern site were marked with numbered wooden sticks so that a minimum of fifty nests were included in the study area.

During the season the following measurements and observations were made at each nest at the two sites. At the end of the season the following information collected was entered in the University of Glasgow´s Mainframe computer (ICL 2976) for analysis.

a) clutch size and laying dates.
b) brood size and hatching dates.
c) size of the eggs (length and maximum breadth).
d) distance from the nest to its nearest neighbour.
e) number of nests within a radius of 3 m. of focal nest.
f) nest material.
g) nest quality (graded 1-4, see below)
h) nest dimensions.
i) height and species of neighbouring vegetation.
j) visibility (the number of 45° units through which an incubating bird could see without obstruction, see below).
k) distance to the edge of the colony
l) distance to the nearest herring gull nest.

There was considerable variation in the amount of material

Figure 3.3 Location of the study and control sites in 1983. Stipled area shows the distribution of Audouin´s gull breeding areas.

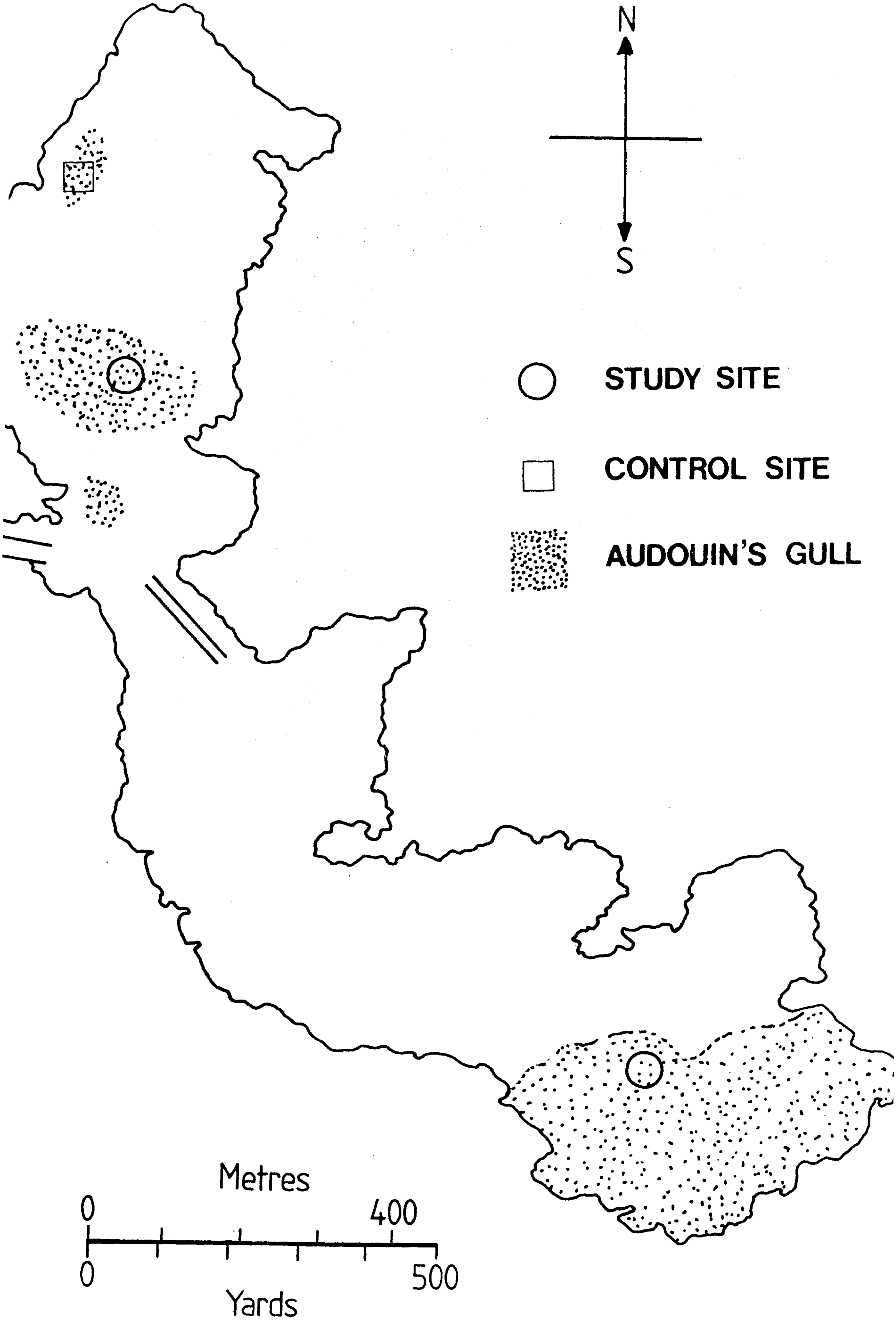

N
S
STUDY SITE
CONTROL SITE
AUDOUIN'S GULL
Metres
0
400
0
500
Yards

Figure 3.4 Location of the study and control sites in 1984. Stipled area shows the distribution of Audouin´s gull breeding areas.

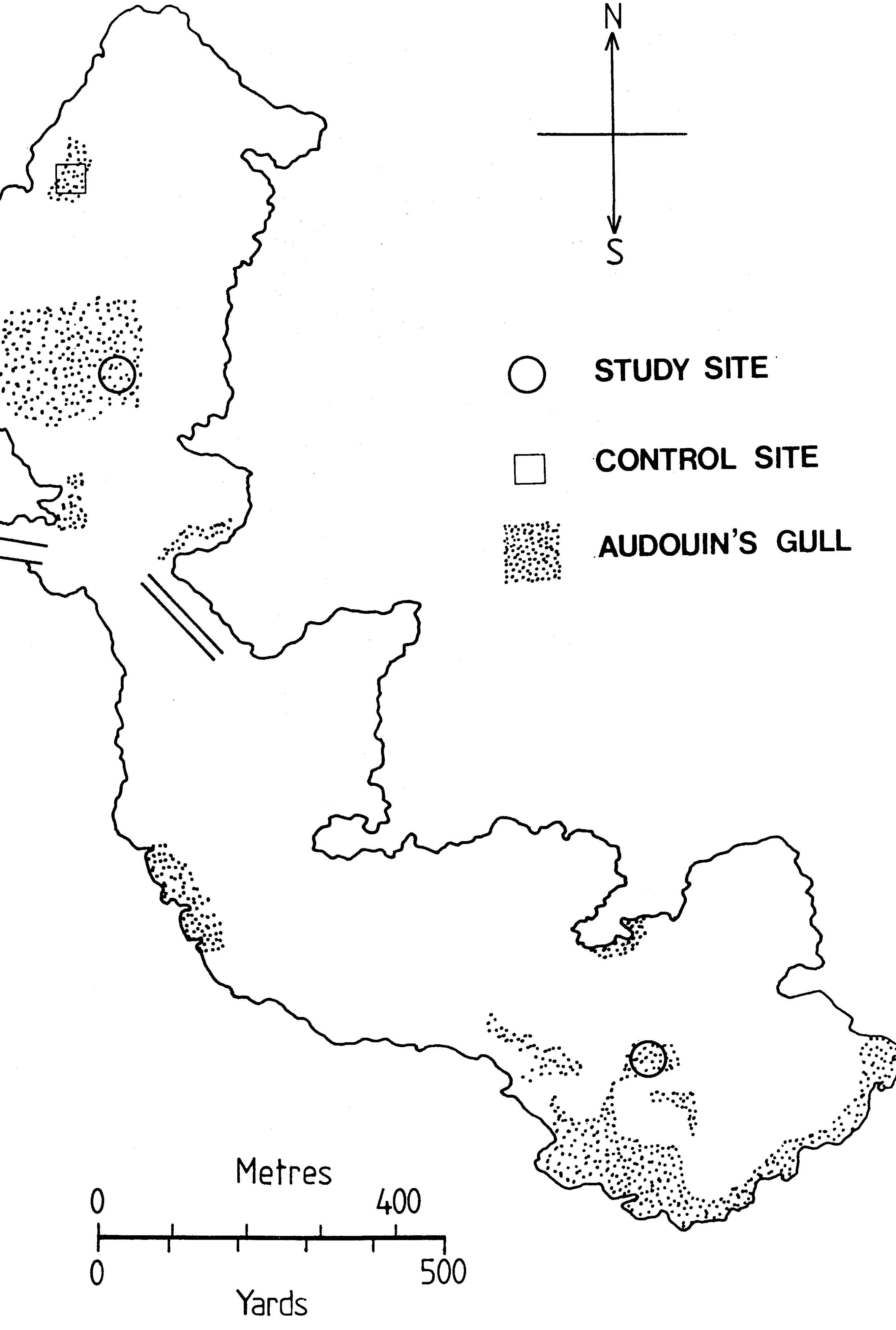

N
S
STUDY SITE
CONTROL SITE
AUDOUIN'S GULL
Metres
0
400
0
500
Yards

Figure 3.5 Location of the study and control sites in 1985. Stipled area shows the distribution of Audouin´s gull breeding areas.

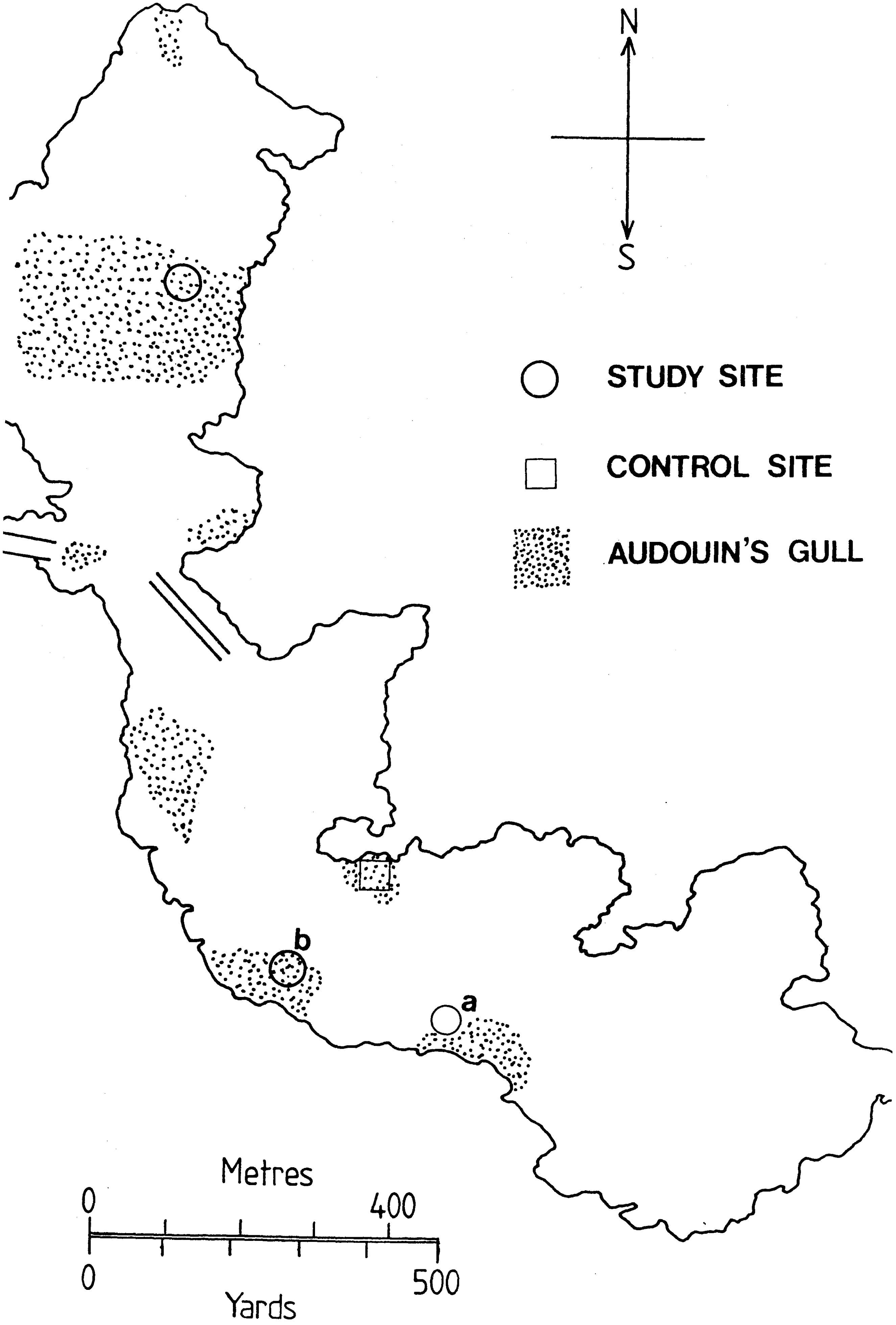

N
S
STUDY SITE
CONTROL SITE
AUDOUIN'S GULL
a
b
Metres
0
400
0
500
Yards

Plate 3.1 Northern site and predominant vegetation species <u>Lycium</u> <u>intricatum</u>.

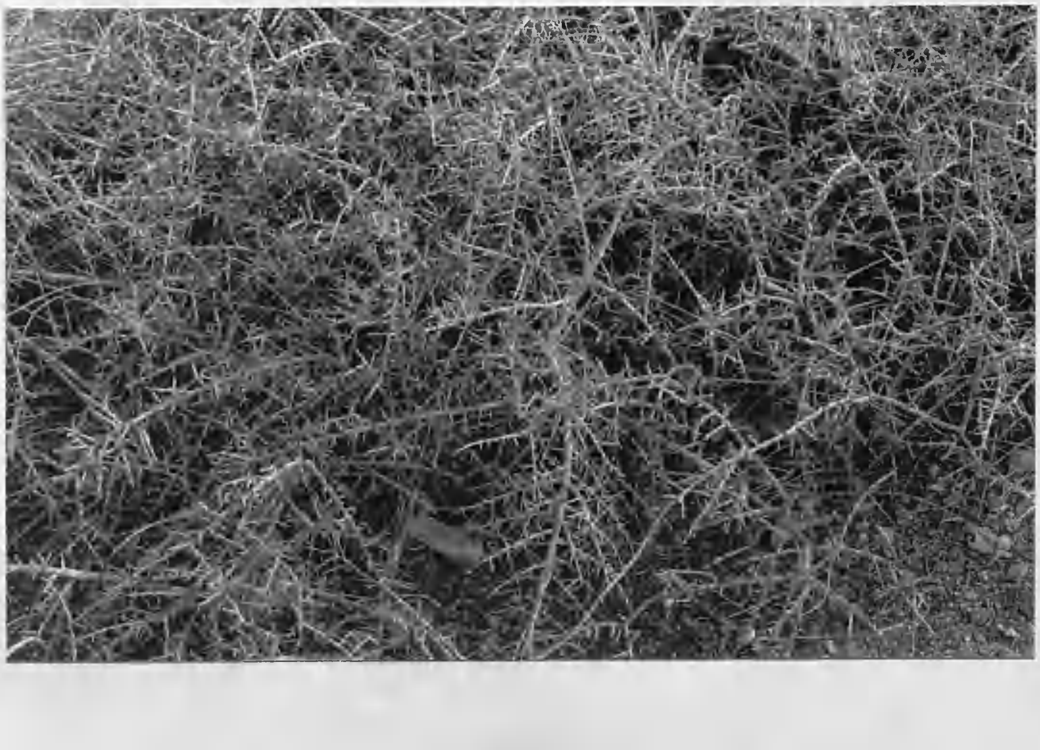


Plate 3.2 Southern study site, showing the hide and the derelict barracks. The predominant vegetation species at this site is <u>Atriplex halimus</u>.

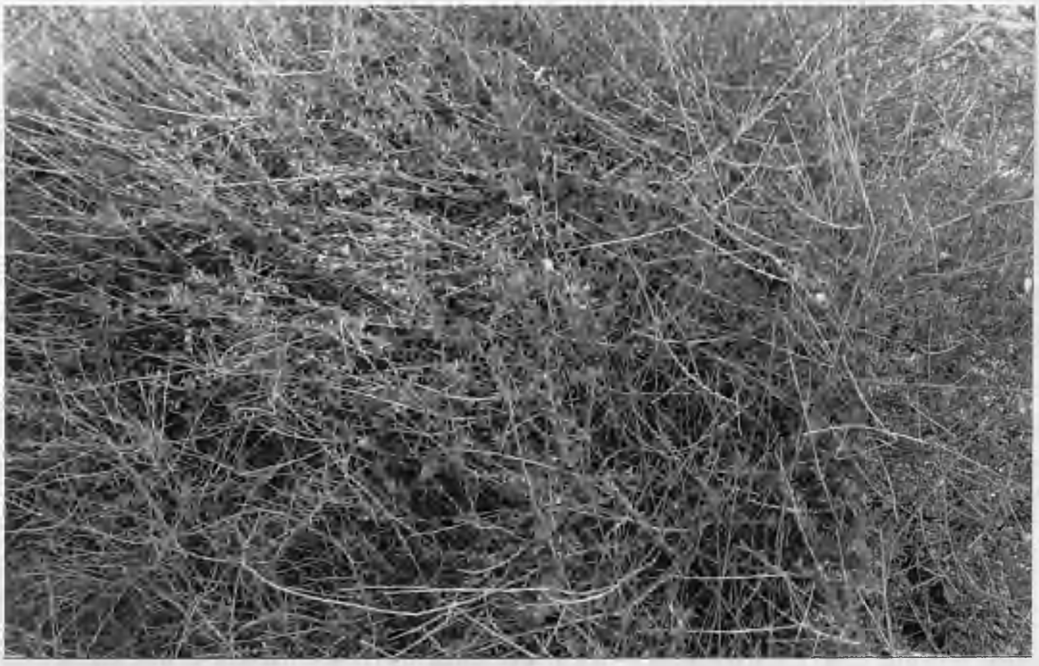
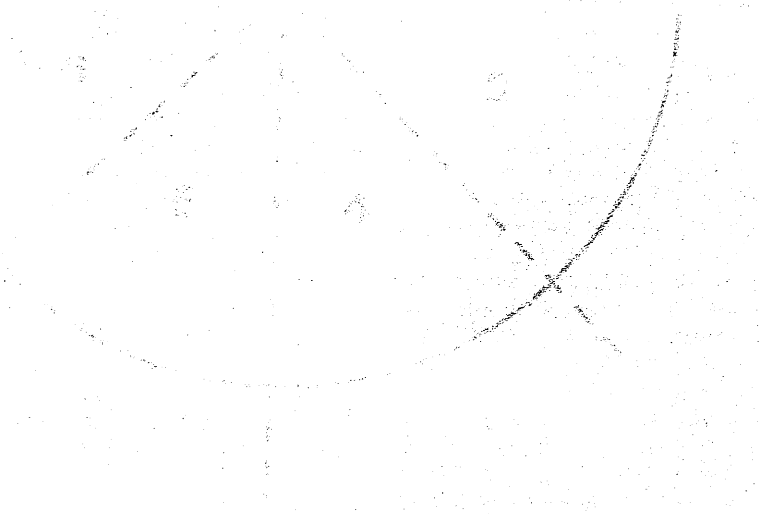
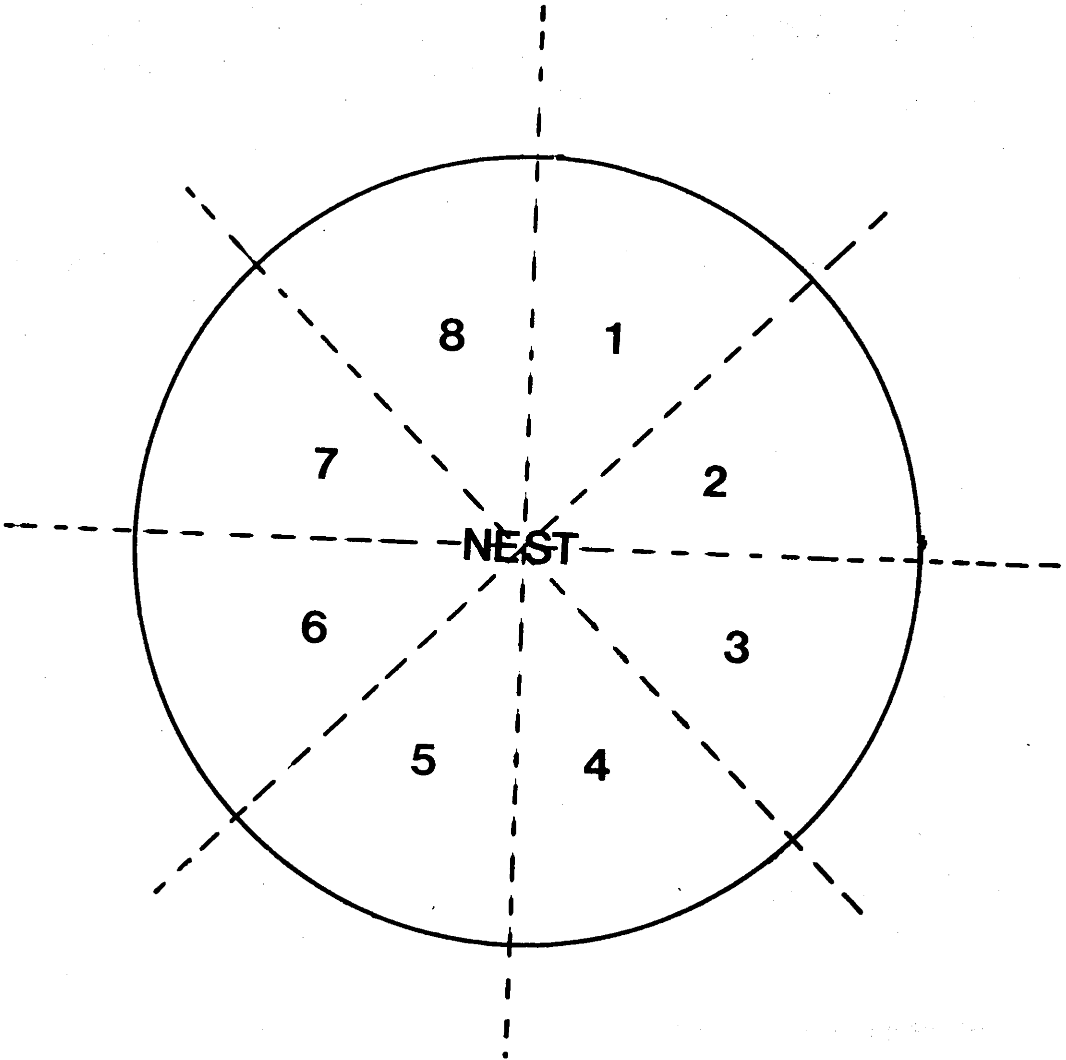


Figure 3.6 Method of scoring visibility from the nest (see text for details).




8
1
7
2
NEST
6
3
5
4

shown with the faint circle in Figure 3.5, but predation by herring gulls was so heavy that no eggs survived the incubation period. Another study site was then chosen at a more central sub-colony which then became the focus of the study of breeding success at a vegetated site. No herring gulls bred within 20 m. of this sub-colony and the Audouin´s Gull nests were well separated (mean distance to nearest neighbour = 119 cm, s.d. 65.7, n = 46).

3.8 MARKING EGGS AND NESTS

All nests, once identified as in use, were marked with numbered sticks before the first eggs appeared. Eggs were numbered in the order of appearance with indelible ink. Throughout this thesis the convention c/3 is used to denote a clutch of three, c/2 a clutch of two and c/1 a single egg clutch. As each egg was found and marked its length and breadth was measured to the nearest 0.1 mm. using vernier calipers. Eggs were not weighed as all the periods working in the open were restricted to one hour (see 3.1). This time was more than occupied marking and measuring the eggs.

3.9 VISITS TO THE COLONY

Visits to the study site were made daily during egg laying, incubation and when the chicks were very young. Once the chicks became mobile, the frequency of visits was reduced to every other day. Disturbance in the colony, caused by the observer being in the open, was restricted to one hour per day per site. This time limit was necessary as adult Audouin´s gulls, being much more cautious than herring gulls, abandoned the area completely whilst humans were within the area. Eggs and chicks were therefore exposed to fluctuations in predation and temperature. Visits were also confined to the early morning and late evening to reduce the likelihood of heat stress. The timing of the visits to the sites were alternated between morning and evening to permit observations of diurnal changes in behaviour to be made during hide watches (see below). All chick deaths were noted and the cause of death determined and recorded when possible.

3.10 OBSERVATIONS FROM THE HIDE

On an edge of each study site an observational blind or hide was erected. Three hours were spent each day within the hide at each site. In 1983, 498 hours were spent in observation at the north and south study sites, in 1984 444 hours and in 1985 294 hours. This three hour observation period followed morning site checks and preceded evening checks. The aims of these observation periods were to gather information concerning behaviour which may influence breeding success (e.g. courtship feeding, territorial aggression, parental behaviour, attempts to reduce heat stress etc.) and interactions between the herring gulls and the Audouin´s gulls. Focal nests were observed for periods of three hours whilst events occurring were recorded on check sheets.

The following records were kept during the observation periods and, at the end of the season, were entered on the Glasgow University Mainframe computer. Each observation record included the following information:

a date of watch
b start time
c site
d focal nest number
e duration of observation (minutes)
f weather condition
g number of days since onset of laying
h contents of nest (number of chicks/eggs)
i number of minutes for which the male/female/ or unidentified adult was present, alone or accompanied
j time spent thermoregulating by adult/s or offspring
k time spent by herring gull within sub-colony
l Duration and direction of any aggression
m number of begging movements made by chicks
n number of feeds
o identity of feeder
p number of head tosses

q number of courtship feeds
r number of cloacal contacts
s number of changeovers of incubators on nest

Observations were made using 8x30 binoculars and a 15-60x zoom telescope. Records were kept using a tape recorder, record sheets and a 35mm Olympus OM-1n camera with a 80-200mm zoom lens.

3.11 POPULATION COUNTS

The most satisfactory method of censusing the breeding population (and probably the only one with an acceptable measure of accuracy) was to count all the occupied nest sites in the sub-colonies. This was undertaken for Audouin´s gulls in early May, just before the onset of hatching when the majority of nests had eggs. With extra assistance, each of the sub-colonies was visited and a point near each nest spray-marked with a small quantity of car enamel paint to prevent double counts and over-sights. Each year the census was made over the period of a number of days with visits to the northern side of the island being interspersed with visits to the southern side so as to reduce the level of disturbance. The census was made in this way in 1983 and 1984. In 1985 spray paint was not available for all of the census. Instead temporary stakes were used to divide the large northern sub-colony into narrow 10 m. strips running east-west across the island. One person walked the strip calling numbers of nests and their clutch size and another person wrote. This method was less satisfactory than the former but due to the relatively small size of the colony was considered acceptable (see Wanless and Harris 1985).

Marking individual nests of herring gulls on the island of Congreso was not feasible due to the large number of nests involved. The only practical means of censusing the Congreso population was to count nests within representative quadrats within the various grades of vegetation and to multiply up to obtain a figure for the entire colony. Nests on the cliffs were included in the census by counting, from the sea, the numbers of incubating adults. In 1983 and 1985 censuses of the herring gulls nesting on Congreso were made in this way. In each year of the study herring gull nests on Rey were individually counted using spray cans to mark each nest site.

3.12 CATCHING AND RINGING ADULT AUDOUIN´S GULLS

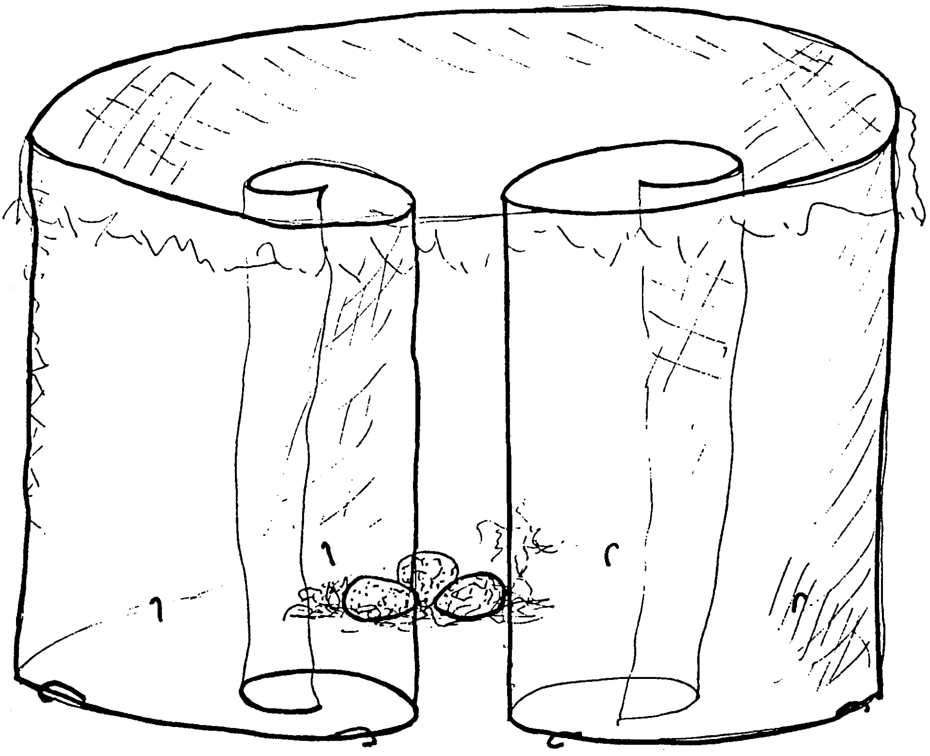
In 1983 two incubating adult Audouin´s gulls were caught using walk-in wire mesh traps (see Figure 3.7a). These traps caused the gulls, both those being caught and their neighbours, much distress and those that were caught deserted on release. The walk-in traps were also very cumbersome to transport. Another design was tested in 1984 (see Figure 3.7b). With this ten incubating adults were caught none of which subsequently deserted. The traps were employed when clutches were complete. Audouin´s gulls soon returned to their nests following the disturbance associated with the positioning of the trap and were found to continue to incubate even after the trap had fallen. As the adults were calm within the trap the likelihood of the adult, in its panic, damaging the eggs was reduced.

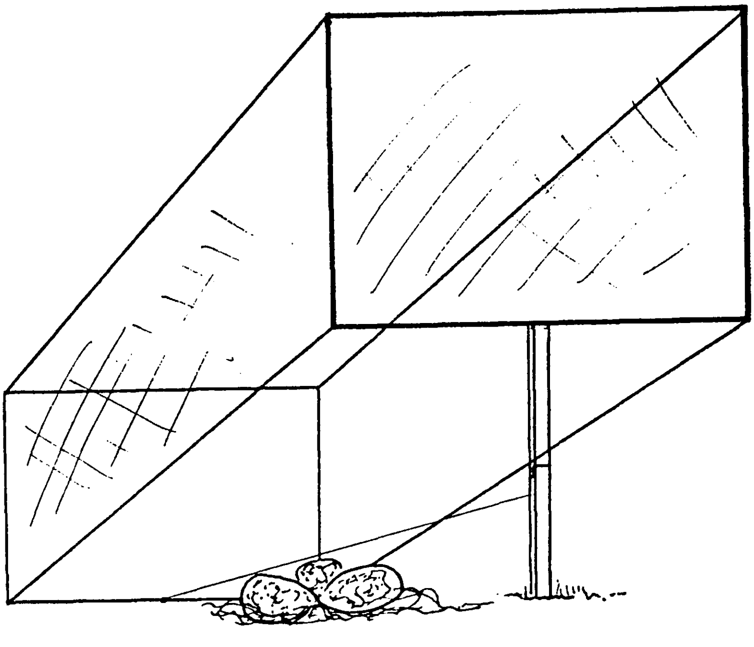
Each adult was given a metal ring (these were supplied by ICONA, Instituto para la Conservacion de la Naturaleza), bearing an address and a unique number, on one leg and a two-ring (Darvic, ICI plastics) colour-combination by which the individual could be recognised from a distance. These colour combinations were necessary to identify individual adults away from the nest, i.e. once the chicks had become mobile, to observe the movement of individual birds about the islands, and to assess nest site fidelity. Only weights, bill depths and wing lengths were usually measured as these were considered the most useful and to have made more measurements would have meant delaying the release of the bird.

In 1985 no adults were caught. Instead sponges were soaked in a picric acid suspension and placed on the part of the rim of the nest with which the breast of the bird incubating normally made contact. This proved very effective as a means of distinguishing between the adults at a nest. Audouin´s gull is not markedly sexually dimorphic (Witt et al. 1982). With certain

Figure 3.7a ´Walk In Trap´ made from chicken wire for the capture of incubating adult Audouin´s gulls.

Figure 3.7b ´Drop Trap´ a self activated trap for the capture of incubating adult Audouin´s gulls.





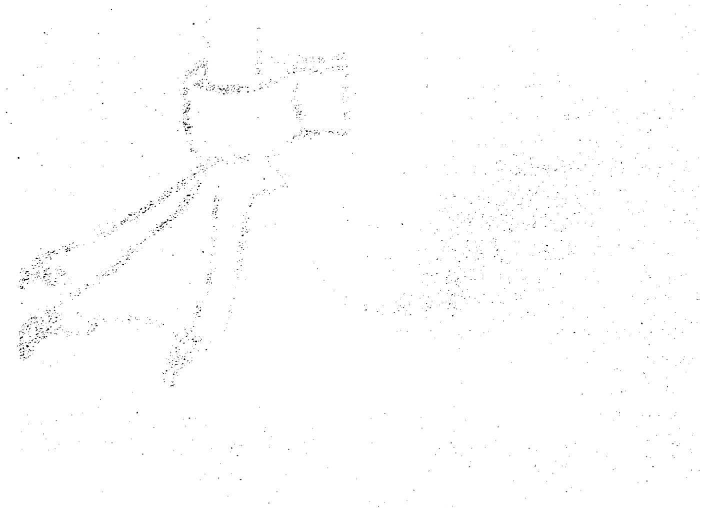
pairs its was possible to distinguish the male from the female by virtue of the fact that males are slightly larger and have a ´heavier´ forehead. Generally this was only possible to tell when the pair were together which was often not the case during entire hide watches.

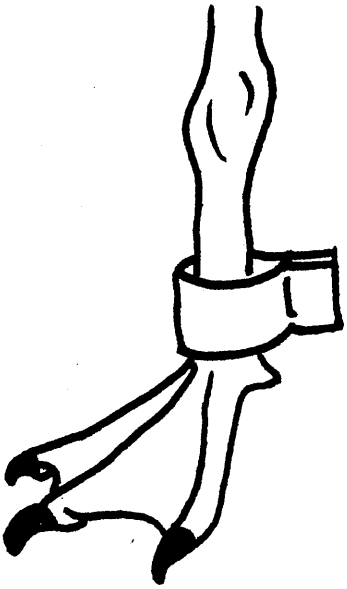
3.13 RINGING OF CHICKS

The nest sites were visited daily as eggs were hatching. All chicks with dry plumage in the study nests were individually marked. Soft Dymo plastic tape was loosely stapled around the young chick´s leg (see Figure 3.8). Three colours of tape were used to aid the identification of the chicks during the observation periods. The chick from the first egg to hatch was ringed with yellow, the second chick blue and the third red. Each Dymo tape ring had a unique number embossed upon it. The number, which coded an individual chick, and the colour were noted against the nest number. These soft rings were used so that if chicks became entangled in the vegetation, as they frequently did, and the leg was caught, the staple would open so that the ring did not impede the chick´s escape. Additionally, if the chick was not retrapped the staple would open before the ring restricted the growth of the leg. A further advantage associated with the use of Dymo ring is that predatory herring gulls consume the chicks complete with the ring. The rings may later be recovered in food pellets, on the ground within the colony, with the embossed number fully legible.

Once chicks appeared to have sufficient strength to enable them to free themselves from the bushes, at approximately two weeks of age, the dymo rings were replaced with rings intended to last the lifetime of the bird. A metal and a Darvic plastic ring of the colour selected for marking all the Audouin´s Gull chicks from the Chafarinas Islands hatched in that year were placed on specified legs. For the three years of this study the arrangements of the rings were as shown below.

Figure 3.8 Soft plastic rings, made from Dymo tape, were stapled around a leg of Audouin´s gulls hatchlings.





YEAR	LEFT LEG	RIGHT LEG
1983	METAL	RED
1984	YELLOW	METAL
1985	METAL	GREEN

On a sample of the chicks within the study sites the metal and the year colour-ring were placed on the same leg and a two ring Darvic colour combination was placed on the other. Generally, once the chicks were more than four days old the nests became redundant as the chicks sheltered instead in the vegetation. The individually colour ringed chicks allowed observations of parental care to continue as the broods generally remained united away from the nest. This marking of individuals also enabled the age at which Audouin´s gulls fledge to be estimated, as these birds could be identified whilst in flight.

Audouin´s gull chicks have been ringed on the Chafarinas Islands with aluminium metal and colour rings since 1976 (between 1976 and 1985 3044 pulli were ringed). Unfortunately the rings, both the metal and plastic, have failed to retain their information i.e. the embossed individual number and colour respectively. This is probably partly due to the high salinity of the Mediterranean Sea. Since 1982 Darvic plastic rings have been used and in 1985 Swiss-made metal alloy rings were introduced, designed to have a higher level of resistance to salt water erosion.

3.14 MEASUREMENT OF CHICKS

Daily, during the first weeks of chick growth, one hour was spent catching chicks for weighing and wing length measurement. Chicks were placed in a weighing sack and weighed using a Pesola spring balance. The wing length (maximum chord length) was measured using an ended ruler. These measurements were, whenever possible, made by the same person.

3.15 STATISTICAL METHODS

All statistical tests and methods were as used in Sokal and Rolfe (1981) and Siegel (1956). The computer packages used are described in Nie _et al._ (1975). All other methods used pertaining to separate chapters are described in these chapters.

CHAPTER FOUR: SITE OCCUPATION AND THE ONSET OF BREEDING

4.1 INTRODUCTION

In comparison with other groups of birds, seabirds are generally long lived, lay small clutches and delay breeding until at least the second year of life. Although this is true of seabirds as a group, within the group there is considerable variation in the lifestyles and breeding biologies that have evolved depending on the birds´ environment, both physical and social (Furness and Monaghan 1987). As yet it is not known how Audouin´s gull fits into the currently accepted patterns.

The act of producing offspring is generally seen as the most important aspect of an animal´s life, natural selection favouring those individuals which produce during their lifetime the largest number of offspring surviving to breed. In this chapter the timing and rate of reproduction of Audouin´s gulls on the Chafarinas Islands during three consecutive breeding seasons (1983-1985 inclusive) are discussed.

4.2 METHODS

During each breeding season distribution maps for the Audouin´s gull subcolonies were drawn and a close watch was kept for the onset of laying throughout the Audouin´s gull colony (see Section 3.8). In each season a study site was established in each of two areas as outlined in section 3.7. A relatively undisturbed control site was also selected each season. At the study sites a minimum of fifty nests were marked each season. Records were then kept of the onset and pattern of laying at these nests and also of the clutch size and environmental characteristics associated with the nest. For a detailed description of the marking of nests, positions of the study and control sites and the records kept, see chapter three.

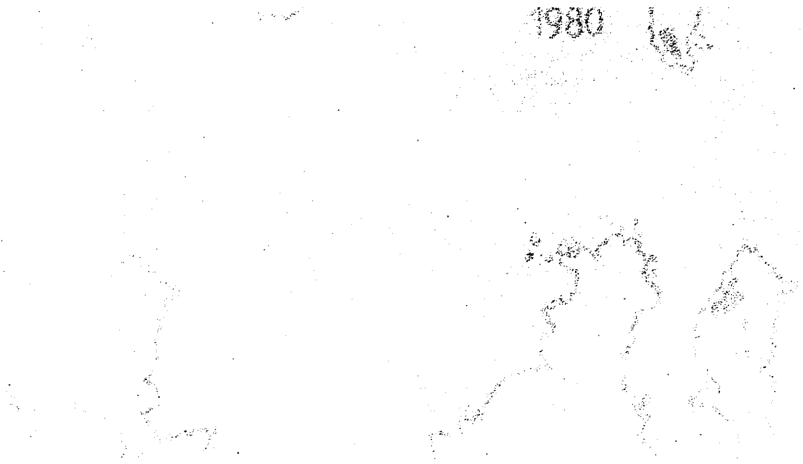
4.3 SITE TENACITY

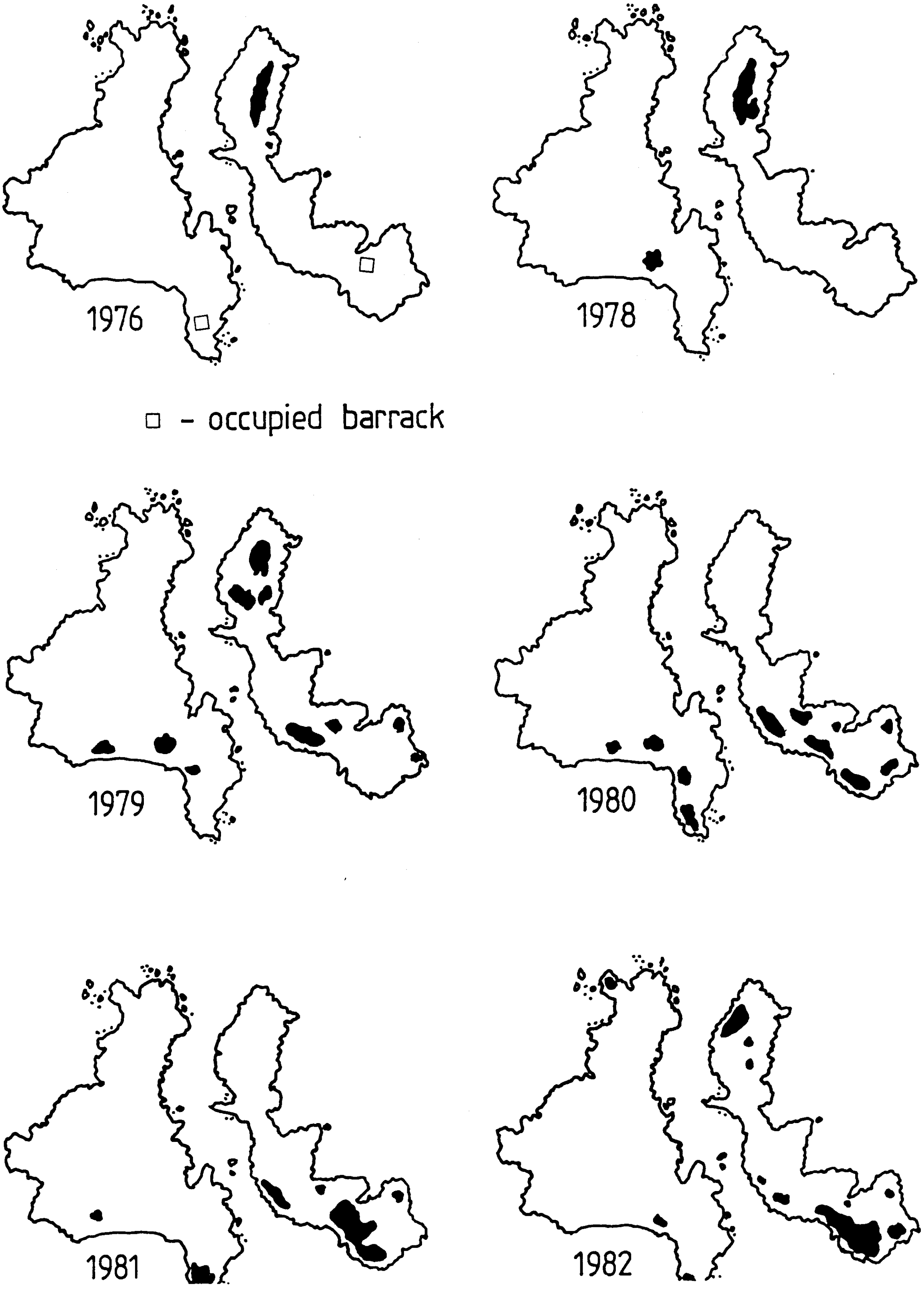
Site tenacity is the tendency of birds to return to their previous nesting site. A total of 12 adult Audouin´s gulls were ringed during this study (see Section 3.12). Two adults which were ringed from nests close to the hide in site 1 1984, were seen using the same nest sites in 1985. Of the remainder, for only two birds was their original nest site in an area used by Audouin´s gulls in the following year; neither of these birds nested at their previous site.

Considering the details of known breeding sites of Audouin´s gull given in Table 2.1, the following breeding sites appear to have been abandoned by Audouin´s gull; Calpe (Spain); Al Hoceima (Morocco); sites in Algeria and on Alboran Island (Brehm 1879). At other sites the colonies have shifted between islands in the same group (Papacotsia et al. 1980). The continuous occupation of the Chafarinas Islands would therefore appear the exception rather than the rule.

This impression of site stability and fidelity is lost when the distribution of Audouin´s gull within the Chafarinas Island group is examined between years. In Figure 4.1 the distribution of Audouin´s gull subcolonies on the Chafarinas is shown, as censused by E.de Juana and J.Varela, for six years between 1976-1982 and in the figures 9.2, 9.3 and 9.4, the distributions during this study are indicated. The alterations in the sitings of the breeding areas have not only been between islands but also between areas on the same island. Considering the normal lifespan of gulls in general, it must be assumed that a large proportion of these birds have already bred in previous seasons. Some of these translocations can be explained by the birds´ avoidance of man and competition with herring gulls for nest sites. In 1976 (see Figure 4.1) the small barracks on the islands of Congreso and Rey were still occupied. The Audouin´s gulls bred only in the extreme north of Rey. By 1978 these small barracks were abandoned and a subcolony of Audouin´s gull had developed on the gravelly cliffs of Congreso, an area which in each year has been occupied by relatively low densities of herring gulls. In 1980 no Audouin´s gulls bred on north Rey.

Figure 4.1 Distribution of Audouin´s gull breeding sites on the islands of Congreso and Rey in the years 1976, 1978, 1979 - 1982. The position of occupied military barracks are shown by open squares.




1976
1978
□ - occupied barrack
1979
1980
1981
1982

According to de Juana and Varela (1980) this was due to prolific growth of vegetation in this zone. The colonization of the southern part of south Rey which began in 1979 therefore became more extensive in the area around the disused barracks. The area around the barracks was also colonized on Congreso.

Over these years the number of breeding herring gulls on the Chafarinas Islands has increased (see Table 9.2). The herring gull begins to breed earlier in the season than Audouin´s gull (Pechuan 1975, Papacotsia et al. 1980, Jacob and Courbet 1980, see Section 9.4). According to Brosset and Olier (1966) herring gulls, on the Chafarinas, bred only on Congreso. It is not known in which year this species first nested on Rey but it appears that the first areas to be colonized were the higher parts of the island where the vegetation is sparse and visibility good. Jacob and Courbet (1980) noticed a similar preference shown by herring gulls nesting in Algeria. As the number of herring gulls has increased their nesting distribution has gradually spread down the slope of Rey (see Figures 9.2, 9.3 and 9.4). As the herring gulls establish their territories several weeks before the Audouin´s gulls the space available to the Audouin´s gulls is restricted to the lower areas of the islands. This is discussed in more detail in chapter nine. This competition for nest sites was also observed by Papacotsia et al. (1980) at the Corsican mixed colonies of herring gulls and Audouin´s gulls.

Another factor which may cause Audouin´s gull sites to be abandoned is failed breeding (Papacotsia et al. 1980). In 1984 birds breeding in both the south site and the control site in the north (see Figure 9.3) failed to produce any fledglings. Neither site was recolonised in 1985. In 1985 a small sub-colony was established, for the first time, on the rocky central beach of Rey (see Figure 9.4). This was within the sea splash-zone during storms and was very close to nesting herring gulls. It would appear that this is an example of Audouin´s gulls, perhaps through competitive pressure, nesting at a poor quality site as breeding failed at this site with few chicks and no fledglings being produced from the 48 nests occupied.

4.4 PHILOPATRY AND AGE OF FIRST TIME BREEDERS

Few, if any, Audouin´s gulls remain at the breeding colonies during the winter (Beaubrun 1984, Jacob and Courbet 1980, J.M.Cabo-Hernandez, pers. comm.). According to Beaubrun´s census and work along the Moroccan coastline, the pre-nuptial migration begins at the end of January or beginning of February, with the majority of adult Audouin´s gulls having completed their return to the Mediterranean by the first weeks of March (Beaubrun 1982). Since 1976 some 2800 Audouin´s gull chicks have been ringed on the Chafarinas. No Chafarinas ringed birds have been observed at other breeding colonies.

In 1985, birds ringed as chicks in 1982 bred on Rey. Audouin´s gulls may therefore start to breed at three years. An individually colour-ringed adult, a 1983 chick, was seen in its natal sub-colony in 1985 although not breeding.

4.5 NEST SITE SELECTION

Two of the serious problems confronting breeding Audouin´s gulls on the Chafarinas Islands are predation, by the herring gulls and humans, and heat stress. Proximity to cover might reduce the threat of both. Audouin´s gulls do make use of any available shelter, tending to nest around the perimeter of the bushy vegetation or close to large rocks. The vegetation/rocks are used in many ways by the adults and chicks. The adults avoided mates and chicks which were begging persistently for food, by standing out of reach of their pecks and used the extra height as a "look-out" post during disturbances and as display sites during territorial conflicts. During the heat of the day the difference in the thermoregulatory behaviour of the incubating birds without shade as compared with those with shade was marked (see section 6.5). Those incubating without shade spent much more time panting, showing gular fluttering and with all, including the head, feathers erected. These birds also spent more time standing over the eggs than did those in the shade. As described in the methods section, the vegetation height and type was identified and recorded for each nest included in the study. This allowed the examination of breeding success in relation to nest site type to be made (see section 8.4).

4.6 NEST CONSTRUCTION

For the majority of pairs nest construction began less than a week prior to the laying of the first egg and continued throughout incubation. Frequently the changeover of incubators was initiated by the incoming bird collecting and carrying nest building material to the nest. This form of nest relief has been observed for other gull species (black-headed gull, Beer 1963; Franklin´s gull, Burger 1974). The quality of the nests varied from scrapes in the bare earth to elaborately padded bowls; each nest was categorized on a discrete scale ranging from 1-4 (see Section 3.7). In general nests were poorly assembled with such small amounts of material that their insulation properties were probably low, thus affording little protection against possible heat gain or loss during the incubation period. White and Kinney (1974) suggested that insulation is a manipulative factor through which breeding ranges may be extended. Nests were constructed from all and any materials within the colony. This included old corpses, dry sea-grass, feathers and various grasses. Only one nest during the course of the three year study was constructed on top of a bush; normally Audouin´s gulls nest on the ground. The Audouin´s gulls nests are significantly smaller than those of the herring gull (see Table 5.3), with an average inner diameter of 16.7 cm, s.d. = 4.6, n = 85 and average outer diameter of 25.9 cm, s.d. = 7.8, n = 85. This distinction between the two species´ nests may be of use should a management programme for the herring gull population be adopted.

4.7 NESTING DISPERSION

The nesting distribution within the sub-colonies is largely determined by the presence or absence of vegetation. Where bushes grow within the site the birds distribute themselves around the perimeter of the bushes often nesting very close together, with inter-nest distances as small as 0.25 m. if the nests are separated by branches. Nesting densities were estimated as described in section 3.6. In accordance with Bongiorno´s findings for laughing gulls (1970) and Burger´s for Franklin´s gull (1974), Audouin´s gulls appear to space first with respect to the vegetation and then further space with regard to neighbours. This creates a situation where densities expressed per m^2 are low, but when described as the number of nests within a radius of 3 metres (m.), the clustering of nests around bushes generates a high value. Even bearing this in mind, the number of nests within a radius of 3 m. of focal nests for vegetated sites (southern sites) in 1983, 1984 and 1985 were, in two of the three seasons, significantly lower than the same values for sites with less vegetation (northern sites), see Table 4.1.

Table 4.1: COMPARISON OF NUMBERS OF NESTS WITHIN A RADIUS OF 3 METRES OF STUDY NESTS AT STUDY SITES DURING THE THREE SEASONS 1983-1985 USING THE STUDENTS´ t TEST.

YEAR	SITE	n	AVERAGE NUMBER OF NESTS WITHIN 3 m.	S.D.	d.f	t	P
1983	north	83	7.75	2.3	152	16.94	< 0.001
1983	south	71	2.32	1.6			
1984	north	73	5.94	2.9	155	1.15	> 0.25
1984	south	84	5.15	2.8			
1985	north	70	9.26	3.5	115	6.38	< 0.001
1985	south	47	5.45	2.9			

In these sparsely vegetated sites, which were in each year on the high northern plateau of Rey, nests were more regularly spaced and densities were higher.

4.8 ONSET AND DURATION OF LAYING

The breeding season of a species can be defined as the period of the year during which, in a particular area, birds of a given species mate, build their nests, lay their eggs and rear their young. More precisely the timing of breeding of a species is usually based on the average date on which each female laid the first egg of her clutch. Such a definition applies only to the first clutch and excludes replacement clutches. Lack (1968) developed the theory that the timing of laying of some species of birds, especially those of temperate regions, is influenced by the seasonal availability of food for the female. It has been suggested that it is to increase the availability of food that Audouin´s gulls migrate into the Mediterranean to breed, so that when the need for food is greatest, i.e. when chicks are growing, the adults can benefit from the more reliably settled waters of the Mediterranean to fish as often as possible (Witt 1977).

In 1983, 1984 and 1985 the first egg in the colony was found on 15.4.83, 12.4.84 and 15.4.85 respectively. The pattern of the initiation of egg-laying within the nests for the study sites in each year is shown in Figure 4.2. To simplify calculations, all breeding data are considered with reference to the number of days since the first egg was laid within the Audouin´s gull colony on the Chafarinas Islands each year as this relative measure was considered more important than the absolute date. Hence 15.4.83, 12.4.84 and 15.4.85 are each considered as the dates on which Audouin´s gull laying began on the islands and are referred to as day 1 for each of the three years. As the sub-colonies are so small it is thought that these dates are true representations of the dates on which laying began, as the difficulties which face those judging the onset of breeding seasons at larger colonies are avoided (Wanless and Harris 1985).

In the table below the median laying date for the first egg of clutches at each study site during the three years is shown (see Table 4.2).

Figure 4.2 The onset of laying at nests in the study sites during the three breeding seasons (1983 - 1985) expressed as the number of nests at which laying commenced (y-axis) on days after the appearance of the first Audouin´s gull egg in the colony (number of days after the first egg was laid in the colony is shown on the x-axis). The arrows on the x-axis show the division of the laying period into early, mid and late laying, each containing approximately one third of the nests, see chapter 8.

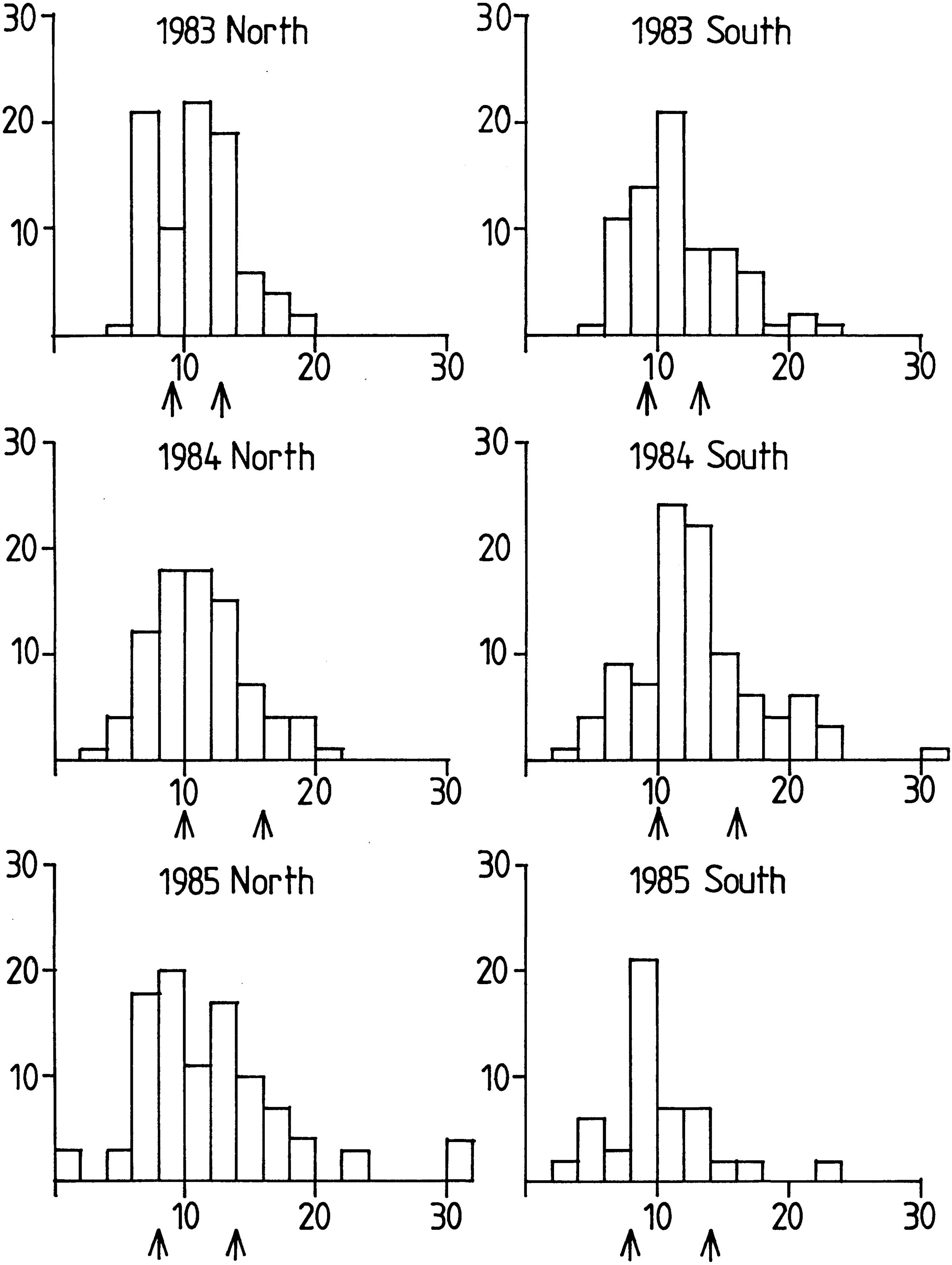

1983 North
1983 South
1984 North
1984 South
1985 North
1985 South
30
20
10
10
20
30

TABLE 4.2: THE MEDIAN LAYING DATE FOR SITES DURING THE THREE YEARS OF THE STUDY.

	MEDIAN LAYING DATE		
SITE	1983	1984	1985
NORTH	26TH APRIL	23TH APRIL	26TH APRIL
SOUTH	26TH APRIL	25TH APRIL	26TH APRIL

Synchrony is a measure of temporal clustering, referring to the tendency for two or more events to happen close together in time. The standard deviation of the laying date about the mean gives an impression of the degree of spread of dates, or an inverse measure of the degree of synchrony at each site, provided the data are normally distributed (Burger 1979). Table 4.3 shows the mean number of days since the onset of laying in the colony for nests in the study sites, in each year, and the standard deviation of the values from these means. In 1983, there was no significant difference between sites in relation to the degree of synchrony ($F = 1.35_{84,83}$, $P > 0.05$). In 1984, there was a difference between the sites with less synchrony at the southern site ($F = 1.54_{97,85}$, $P < 0.05$). This can probably be attributed to the effect of egg predation by herring gulls at the southern site (see section 5.9) since the first and replacement clutches could not always be distinguished. Similarly in 1985 there was a difference between the sites, with the higher synchrony in this case being at the southern site ($F = 2.94_{105,51}$, $P < 0.05$). At both sites in this year herring gull predation occurred. It is not known why synchrony appeared to be particularly low at the northern site but this may have been a combination of interference and a high probability of the loss of the first egg laid.

TABLE 4.3: THE MEAN LAYING DATE, EXPRESSED AS THE NUMBER OF DAYS AFTER THE LAYING OF THE FIRST EGG IN THE COLONY, AND STANDARD DEVIATIONS FOR THE SITES DURING THE THREE YEARS OF THE STUDY.

MEAN LAYING DATE (S.D)

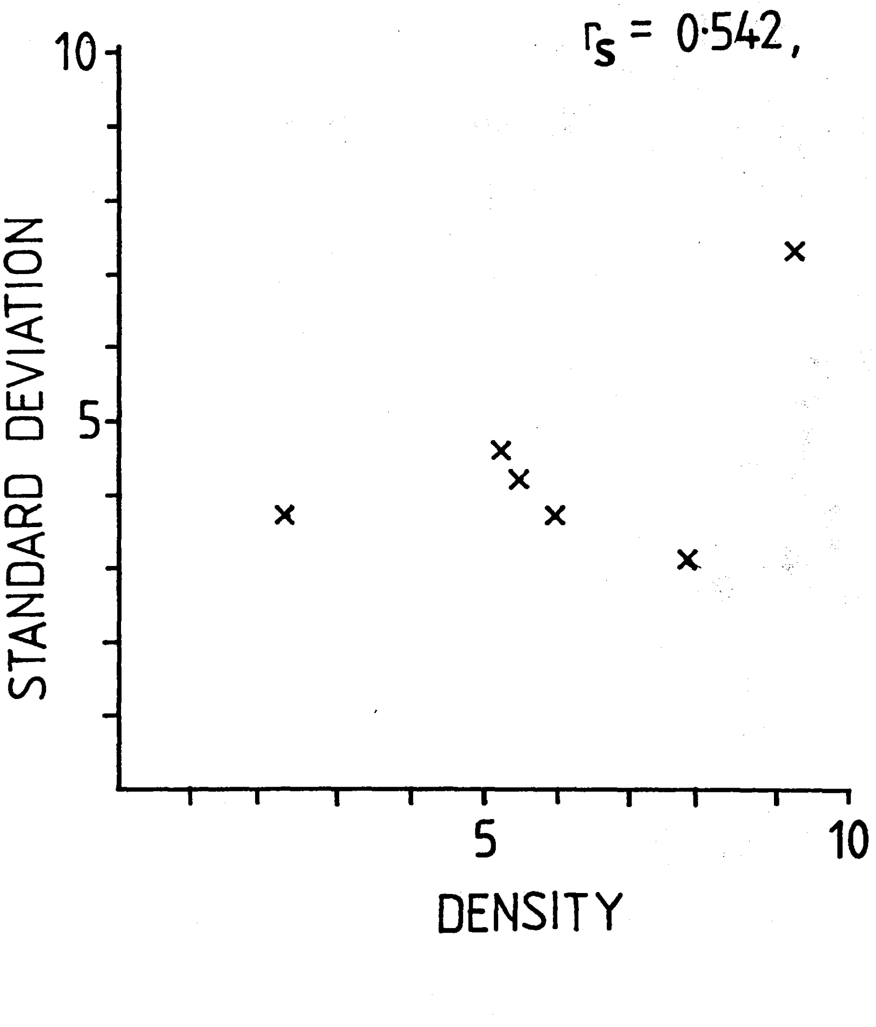
SITE	1983			1984			1985		
	n	mean	s.d	n	mean	s.d	n	mean	s.d
NORTH	85	11.45	(3.1)	85	11.49	3.7	100	12.77	7.2
SOUTH	74	12.22	(3.6)	97	13.48	4.6	52	10.42	4.2

For Audouin´s gull in this study there does not appear to be any relationship between the standard deviation of the laying date and either the size of the sub-colony, the number of nests in the study site or the density, at any of the study sites during the three year study (see Figure 4.3).

An alternative approach was to look, as did Parsons (1971) with herring gull colonies on the Isle of May, for clustering patterns within the sub-colonies, for neighbouring nests sharing similar laying dates. In each year the laying period was divided as shown in Figure 4.2 into early, middle and late. Figure 4.4 depicts the situation at site 1 in 1984 with the early, middle and late nests distinguished from one another. The extent to which nests were clustered in relation to timing of laying was examined by testing whether the probability that the nearest nest contained a clutch laid in the same period differed from what would be expected if the distribution was random. Such a goodness of fit test was carried out for early, middle and late nests. Only for the latter was any significant difference found, and in this case the probability of a similar neighbour was less than expected from a distribution (i.e. they appeared to be more widely spaced $X^2 = 3.99$, d.f. = 1, $P < 0.05$). Thus in contrast to Parsons´s research (1971) a clustering pattern does not emerge.

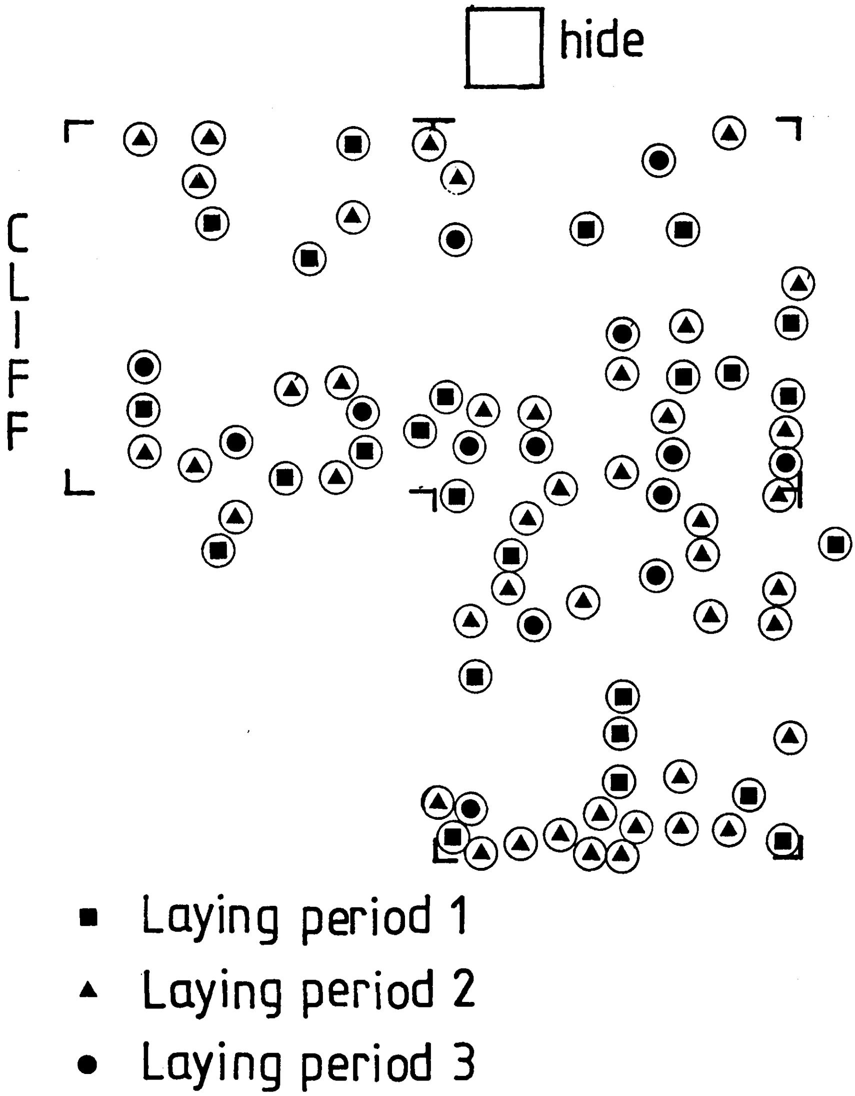
Figure 4.3 Relationship between the spread of laying dates (standard deviation about the mean) at the two study sites during the three seasons and Audouin´s gull nesting density.

Figure 4.4 Pattern of onset of laying at the northern site in 1984. Laying period 1 denotes early nests and laying period 3 nests at which laying was initiated late in the season. The position of the 10 m. quadrats is also shown.



$r_s = 0{\cdot}542$,
10
5
STANDARD DEVIATION
5
10
DENSITY

NORTH REY 1984



4.9 CLUTCH SIZE

The most common clutch size for gulls is three although a few species lay two-egg clutches (kittiwake, Cullen 1957; black-billed gull, Beer 1965 and swallow-tailed gull, Harris 1970). H.H. Witt´s investigation and this study are the only two that have involved attendance at the Audouin´s gull breeding site throughout the gulls´ reproductive season. Most of the other quotations of clutch size have been as a result of a brief visit to the colonies. It is therefore possible in other less comprehensive studies that: clutches may not have been completed; eggs may have been taken for human consumption; or that nests may have suffered predation. As far as possible the date on which the estimate was made is given in Table 4.4 in which the mean clutch sizes found at sites throughout the Mediterranean are shown.

TABLE 4.4: AUDOUIN´S GULL CLUTCH SIZES, where there is more than one sample for the same colony these are denoted by letters, e.g. a, b, c. Where available standard deviations are given.

SITE	COUNTRY	DATE	MEAN CLUTCH SIZE	SAMPLE SIZE	SOURCE
Chafarinas	Spain	1980	2.27		Juana and Varela 1980
"	"	14-20.5.1976	2.62	107	" " 1979
"	"	8-12.5.1979	2.30	86	" " 1979
Balearics	Spain				
Conejera		16.5.1978	a)2.26	15	Mayol 1978
			b)2.32	34	" "
Pitiusas		6.5.1978	2.65	26	" "
Mallorca		11.5.1978	a)2.33	27	" "
			b)2.75	4	" "
Menorca		17.5.1978	1.95	14	" "

SITE	COUNTRY	DATE	MEAN CLUTCH SIZE	SAMPLE SIZE	SOURCE
Sardinia	Italy	1972	2.2 + 0.05	15	Witt 1977
Sardinia	"	1978	a)1.70	50	Schenk 1978
			b)2.28	101	" "
			c)2.02	41	" "
Isola Soffi	"	1979	1.71	48	Schenk 1979
Isola Piana	"	1979	1.53	45	" "
Esporades	Greece	1966	2.8	20	Makatsch 1968
Northern Sporades		1968	2.7	22	" "
	Turkey	1973	2.5 + 0.02	14	Witt 1976
		1974	2.3 + 0.3	28	Witt 1976
Corsica	France	1971	2		Papacotsia *et al.* 1980
	Algeria	1978	2.6	89	Jacob and Corbet 1984

The clutch size can vary between 1-4, 3 egg-clutches being the most common. Clutches of 5 and 6 eggs have been found but it has been obvious that two females have been involved in these cases as two sets of slightly differently coloured eggs could be distinguished. Clutches of four are relatively common as shown below (see Table 4.5).

TABLE 4.5: THE FREQUENCY OF FOUR EGG CLUTCHES ON THE CHAFARINAS ISLANDS.

YEAR	%OF THE TOTAL NUMBER OF NESTS REPRESENTING 4-EGG CLUTCHES	SOURCE
1976	1.16	de Juana & Varela (1979)
1979	1.86	" "
1983	0.99	this study
1984	1.65	"
1985	0.64	"

The median and mean clutch size for each study site and the standard deviation from the mean are given in Table 4.6.

Table 4.6: MEDIAN AND MEAN CLUTCH SIZES FOR ALL THE STUDY SITES ON THE CHAFARINAS ISLANDS 1983-1985.

			CLUTCH SIZE		
YEAR	SITE	n	MEDIAN	MEAN (S.D.)	significance of differences in clutch size between sites. (Mann-Whitney test)
1983	north	85	3	2.75 (0.59)	U = 6843, P = 0.8820
1983	south	74	3	2.72 (0.62)	
1984	north	86	3	2.74 (0.64)	** U = 8890, P = 0.0095
1984	south	98	3	2.38 (0.88)	
1985	north	102	3	2.62 (0.72)	U = 7861, P = 0.8695
1985	south	52	3	2.59 (0.82)	

At all sites, with the exception of the southern site in 1984, the average clutch size was equal to, or in excess of, 2.6. This value suggests that the Chafarinas Islands colony is no less successful than other Audouin´s gull colonies in other years (see Table 4.4).

No significant inter-year differences were found in mean clutch sizes for the sites on the northern plateau of Rey (comparing north site in 1983 and 1984 using the Mann-Whitney U Test; U = 7315, P = 0.9889, N.S. and between north site 1984 and 1985; U = 8545, P = 0.2608, N.S.). The decrease in clutch size at south site between 1983 and 1984 was significant (U = 7172, P = 0.0171). The reason for this decline is discussed in section 8.3 as it was due to herring gull predation.

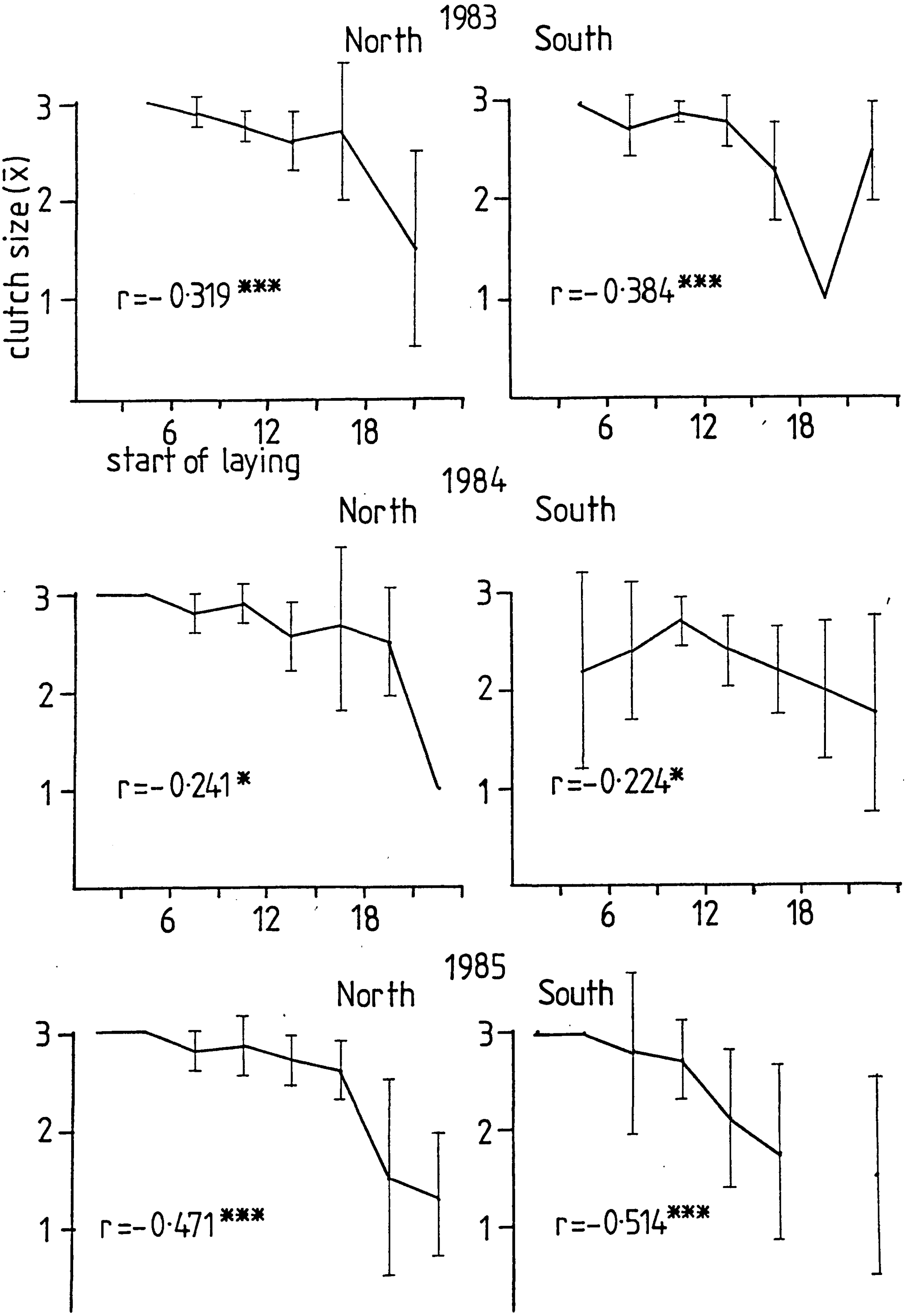
4.10 SEASONAL VARIATION IN CLUTCH SIZE

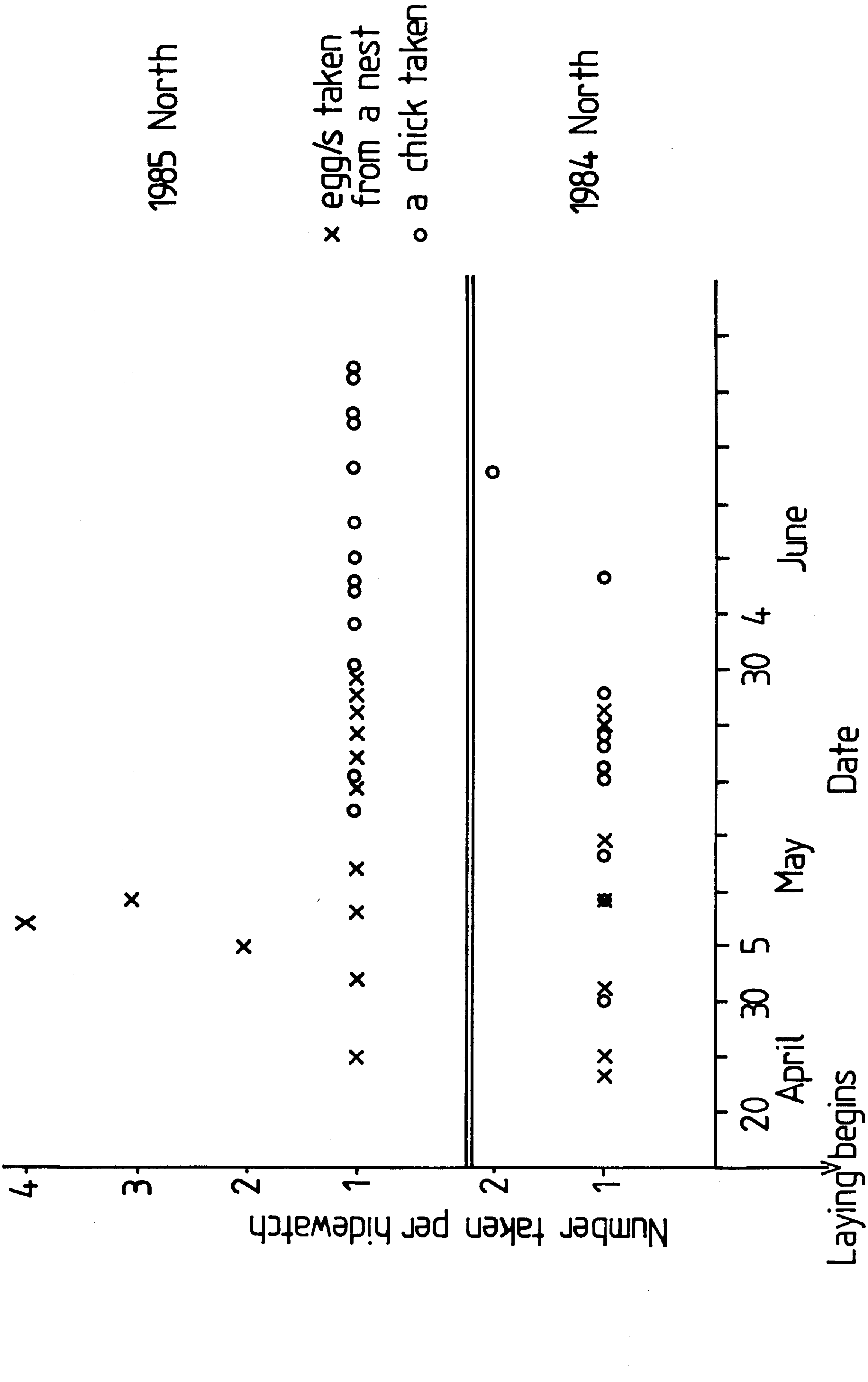
In many birds, clutch size changes through the breeding season with late breeding individuals commonly laying smaller clutches than those breeding early. In Figure 4.5 the mean clutch size, with two standard errors, is plotted for three day intervals, for each site studied during the three years. In each case the clutch size was found to decline with the advance of the season. On each plot the Rank Correlation Coefficient for the original data, not the means, is plotted, and the level of significance of the trend is indicated. Unfortunately the ages of the study animals are not known so that the influence of age (and therefore presumably experience) cannot be corrected for. A further factor which may have caused an apparent reduction in the clutch size is predation by herring gulls. Unmarked eggs may have been removed in the 14-34 hours between visits to the study areas, this would reduce the clutch size and may increase the number of relaying nests (birds which are relaying generally produce smaller clutches). Herring gulls appear capable of learning a behavioural trait having watched others, therefore the level of predation might be expected to increase as the season advances. In Figure 4.6 this possibility is examined. The number of eggs observed to be taken by herring gulls during hidewatches remained constant throughout the incubation period, despite changes in the number of available

Figure 4.5 Relationship between clutch size and the timing of breeding at each site during the three study seasons. Time of laying is expressed in terms of the number of days since laying began in the Audouin´s gull colony (+ 2 s.e.). A correlation coefficient is quoted for each plot and the significance of the relationship shown by the number of *.

* = P<0.05
** = P<0.01
*** = P<0.001

Figure 4.6 The number of incidences of predation of eggs and chicks per watch at the northern sites in 1984 and 1985.


1983
North
South
3
2
1
clutch size (x̄)
r=-0·319***
r=-0·384***
6
12
18
start of laying
1984
North
South
r=-0·241*
r=-0·224*
1985
North
South
r=-0·471***
r=-0·514***


1985 North
× egg/s taken from a nest
o a chick taken
1984 North
Number taken per hidewatch
4
3
2
1
2
1
Laying begins
20
April
30
5
May
Date
30
4
June

clutches as laying and hatching progress. The herring gulls thus do not appear to be acting in a density dependent manner.

4.11 DISCUSSION

Tinbergen (1953) drew attention to the importance and implications of strong attachment to a breeding place, suggesting that this might lead to populations which do not interbreed although mixing freely outwith the breeding season. Many seabird colonies are long-established. T.Severin in "Jason and the Argonauts" BBC 1985 would like us to believe that the herring gull and cormorant colonies found today near Georgia, USSR are still on the "Bird Islands" referred to by Jason in the original Greek Legends. Site tenacity appears to be advantageous for many species of colonial seabirds. The sites provide a focus for pair re-formation, using perhaps an old nest bowl with the further advantage that familiarity with the environment will allow fullest utilization of the available resources. The herring gull and the kittiwake have been shown to exhibit strong site tenacity (Parsons 1971, Coulson and Wooller 1966). Parsons (1971) in a study on the Isle of May, Scotland, found that of 99 colour-ringed adults known to return to the May in consecutive years, only 5 nested away from the immediate vicinity of their previous territories.

Audouin´s gull is atypical amongst the Laridae. In this chapter it has been shown that colonies are unstable with fluctuations in size, appearances and disappearances of colonies (Brichetti and Cambi 1979, Papacotsia et al. 1980). In the literature, the other examples of Laridae similarly exhibiting a lack of site tenacity are often frequently associated with unstable habitats. Rapid changes in colony locations have been reported for the least tern especially in river sand bar populations (Ganier 1930), royal tern, (Kale 1965), sandwich tern (Gareth Thomas pers.comm) and the ring-billed gull (Southern 1977). M^{c} Nicholl (1975) suggests that the degree of site tenacity developed in a population may reflect the stability of the nesting habitat and that in situations where habitats are unstable, group adherence may be especially important, allowing the colonization of another site. That Audouin´s gull has been observed to exhibit marked group adherence has been reported by various authors (Beaubrun 1984, and J.M.Cabo-Hernandez pers.com). They are generally observed in tight groups on the periphery of other mixed species flocks both within and outwith the breeding season. Gochfeld (1980) discussed the importance of social attraction in seabird breeding biology highlighting its usefulness in: a) indicating appropriate breeding sites to birds breeding for the first time; and b) allowing birds that had failed at a nesting site to recognize more suitable sites by the presence of apparently successful breeders.

The evidence gathered to date suggests that Audouin´s gulls appear to return to their natal colony to breed, although de Juana and Varela (1981) suggested that the Algerian colony was probably stocked by birds from the Chafarinas Islands. It may be that Audouin´s gulls do return to their natal colony to breed but if conditions are unsuitable, if there is, for example, much human disturbance, or the site is overgrown with vegetation or that breeding attempts have failed in the previous season at that site then they might chose to breed away from that site. This theory might have been tested in 1986. As no young were produced by birds nesting at both of the study sites in the south of Rey in 1985 (see Section 3.6) neither site should have been recolonised in 1986. Obviously if this is the case then failure of breeding in one year could be seen as restricting the available breeding space for the Audouin´s gulls in at least the following year.

Breeding biology studies of other bird species have shown that the quality of the nest site can influence reproductive success (shag, Potts et al. 1980; least terns, Koliar and Burger 1986; western gulls, Winnett-Murray 1979; laughing gulls, Montevecchi 1978; herring gulls, Parsons 1982, Parsons and Chao 1983, Pierotti 1982). In the development of a management plan for the Audouin´s gull colony on the Chafarinas Island, the study of the influence of environmental features of the nest site upon breeding success was given a high priority. Considerable variation in the nesting density, nest quality and the proximity to vegetation was recorded between the study nests and the two sites. The results of this study are presented and discussed in chapter eight.

The influence of vegetation types upon the dispersal of nests and the reproductive success of gulls was indicated by Hosey and Goodridge (1980) who suggested that the presence of the vegetation might allow more gulls to occupy the same space by reducing territorial aggression, which would also make more energy available for reproduction, and may reduce predation.

In 1938 Frazer Darling hypothesized, from observations of breeding herring gulls, that birds in larger colonies would experience greater social stimulation which, mediated by the endocrine pathways, may lead to reproductive synchrony. This could be advantageous as the effect of predation would be diluted should the span of hatching be reduced. For Audouin´s gull in this study there does not appear to be any relationship between the standard deviation of the laying date and either the size of the subcolony, the number of nests in the study site and the nesting density at any of the study sites during the three years of study. It must also be stated that although almost all students of synchrony study the timing of clutch initiation as this is the most convenient measure because each datum point is clear - either an egg is present or not, important synchronising factors may act before laying and after hatching. It may have proven rewarding to compare the synchrony at nest initiation with that at clutch initiation. The apparent lack of relationship between synchrony and density may also be an artifact of the mode of assessment of nest density used in this study. Distances to nearest neighbours and nesting densities were both measured when all nests had been established. As Gochfeld (1980) suggests, it is very possible that many of the later settling birds included in the density measurements may not have been present at all at the peak of courtship and laying.

Wiedmann (1956) similarly found no such correlation between synchrony in laying dates and nesting density in the black-headed gull. Burger (1979) suggests that the standard deviation from the mean laying date decreases with colony size up to a limit of approximately 200 pairs after which the colony effectively fragments into separate synchronous subcolonies. As it was not possible, in this study, to collect data for all the nests within the sub-colonies, due to the time limitations, it is difficult to assess the situation within the Chafarinas sub-colonies.

Gochfeld (1980) found, contrary to the "Frazer Darling Effect", that the span of laying was usually greater in larger colonies partly for purely statistical reasons (a greater range would be expected considering the normal probability curve) and also due to the late birds being attracted to the largest aggregations. Coulson and White (1956) showed that small kittiwake colonies lay later because of the larger proportions of young birds in new, small colonies. They found, however, a strong correlation between density and the timing of breeding although in the same investigation (1960) the spread of breeding was greater in the denser colonies. Morris and Haymes (1977), whilst studying the breeding biology of two Lake Erie colonies of herring gulls, recorded clutch initiation to be more synchronized where densities were highest.

The situation is probably more complicated for Audouin´s gull breeding on the Chafarinas as the sub-colonies frequently alter their positions from one breeding season to the next, making it unlikely that birds hold similar positions with regard to position and neighbours within the colony from one breeding season to the next. It has been suggested that stimulation received from other birds in the previous season(s) is cumulative (Coulson and White 1959), therefore a change in nesting site and, presumably, neighbours would result in a decrease in synchrony.

The time at which birds breed has evolved through natural selection, like other features of their biology, in order to maximize the number of young produced. Lack (1954) suggested that birds lay their eggs at the time of year when food is most abundant thereby allowing them to produce a maximum number of chicks. Since Lack´s, suggestion Parsons (1975) has demonstrated that the timing of breeding in the herring gull is almost independent of the extent of food availability and, equally important, that the termination of laying is not directly influenced by food shortage since it coincides with the time when there is an abundance of food for both the adults and the young. He found, as did Duncan (1978), that the timing of breeding was very similar over their study periods. This was also found to be the case in this investigation, even in the face of very varied meteorological conditions between years, during the first weeks of April (see Appendices 1, 2 and 3).

According to scientists on a Spanish Armada oceanographic vessel taking recordings off the Chafarinas in May 1985, the waters of the Chafarinas Islands are especially well stocked with fish due to the Atlantic currents which are concentrated in the vicinity. In contrast the eastern Mediterranean waters are impoverished due to lack of nutrients and high salinity (Witt 1984). It is possible that the clutch sizes of Audouin´s gulls breeding at these extremes should reflect the relative wealth and poverty of the sites. The clutch sizes recorded at other sites during other seasons in the Mediterranean are of small sample sizes, however, they show no indications that this is the case. Instead, it may be that birds in the eastern Mediterranean make use of alternative food supplies, as has been suggested by Witt *et al.* 1987. The availability of food in the pre-laying stage has been shown by Winkler and Walters (1983) to influence the clutch size and egg size for two populations of California gulls.

As the breeding season progresses the size of the Audouin´s gull clutches laid decreases. This seasonal effect on clutch size has been demonstrated for many species, including the great tit (Perrins 1970), the kittiwake (Coulson 1963) and the herring gull (Parsons 1971). Lack (1968) regarded the decline in the clutch size as an adaptation to the poorer chance of raising young later in the season, which is usually due to reduced availability of food. The probability of post-fledging mortality was shown by Parsons *et al.* (1976) to increase progressively as the season advanced in one out of three year classes studied, with broods of three fledged chicks surviving less well than broods of two. A proportion of the decline in clutch size with season has been attributed, by Coulson and White (1961) to the fact that experienced birds which lay more eggs tend to lay earlier than young inexperienced birds.

Consequently, a large number of factors have been seen to influence, to varying degrees, the onset, duration and even the location of egg laying in Audouin´s gull on the Chafarinas Islands. These factors include disturbance, vegetation, characteristics and past experience at a particular colony site. Undoubtably other factors are involved either independently or related to those already studied and discussed.

CHAPTER FIVE: THE EGG

5.1 INTRODUCTION

Birds typically lay their eggs about one day apart (Murton and Westwood 1977) and most species initiate incubation only after the clutch has been completed which tends to synchronize the time of hatching of the brood (Lack 1968). In some species, however, incubation begins before the clutch is complete. This causes the eggs to hatch asynchronously with the result that later hatching offspring often have a competitive disadvantage relative to older siblings. This disadvantage, under some conditions, may lead to the reduced survival of later hatched offspring and reduced reproductive output.

One of the more generally accepted explanations of why asynchronicity in the breeding of some species may have evolved is that asynchronous hatching increases parental reproductive output by reducing the chances of total reproductive failure when food is scarce and the parents cannot provide adequately for the entire brood (Lack 1968, O´Connor 1984). This implies that in periods when there is a short supply of food more food is provided to early-hatching offspring, and late hatching offspring survive only when food is in plentiful supply (Graves 1984).

In gulls not only is hatching asynchronous but the third, or last egg laid in a three egg clutch is typically significantly smaller in length and width, weighs less and hatches last (Coulson 1963, Harris 1964, Paludan 1951, Parsons 1970, 1972, 1975a, Pierotti 1982, Runde and Barrett 1981).

Egg size alone has also been shown to affect the length of the incubation period of an egg, the hatching success and the chick hatching weight (Parsons 1970, Ricklefs et al. 1978) which all contribute to the survival of the chick. It has, however, also been shown that both egg size and clutch size in Larids may increase when food is abundant (Winkler and Walters 1983). Thus making egg dimensions and hatching sequences valuable sources of information.

5.2 METHODS

In the course of this study the biometrics and fates of many clutches at both study sites in three seasons were studied in an attempt to determine the factors which influence the survival of the egg and the hatched chick until fledgling, see Table 5.1.

TABLE 5.1: THE NUMBER OF CLUTCHES STUDIED IN THE YEARS 1983-1985.

YEAR	SITE	NUMBER OF CLUTCHES STUDIED
1983	north	85
1983	south	74
1984	north	86
1984	south	98
1985	north	102
1985	south	52
TOTAL		497

Each nest was individually marked, as were the eggs within the nests (see Section 3.8). Eggs were numbered in the order of their appearance in the nest. The length and maximum breadth of each egg was measured using vernier calipers. The date of laying was also recorded and the sequence of laying was determined.

When chicks hatched the date and the hatching weight were recorded. Chicks were initially banded with soft plastic tape stapled round their right leg (see Section 3.13). This soft tape was coloured to indicate the position of that chick in the hatching sequence (yellow - first, blue - second and red - third). The tape was also embossed with a unique number which identified the individual chick on its recapture. One hour per day per study site was spent catching and measuring these marked chicks, as described in Section 3.14. All chick deaths were noted and the cause of death was determined whenever possible. The terrain of the study sites was generally flat and open so dead chicks whose remains were within the site were easily found.

In agreement with other avian breeding biology studies, a shape index has been calculated as shown in equation 1 (Coulson 1963).

equation 1 EGG SHAPE INDEX = (BREADTH/LENGTH) X 100

In other studies the volumes of eggs were calculated from a relationship derived from the equation for the volume of an elipsoid (Coulson 1963, Coulson <u>et al.</u> 1982, Paludan 1951). The volume of an egg is less than that of an elipsoid so a correction factor must be introduced (see equation 2).

equation 2 $\text{VOLUME} = 0.5236 \cdot \text{BREADTH}^2 \cdot \text{LENGTH} \cdot k$

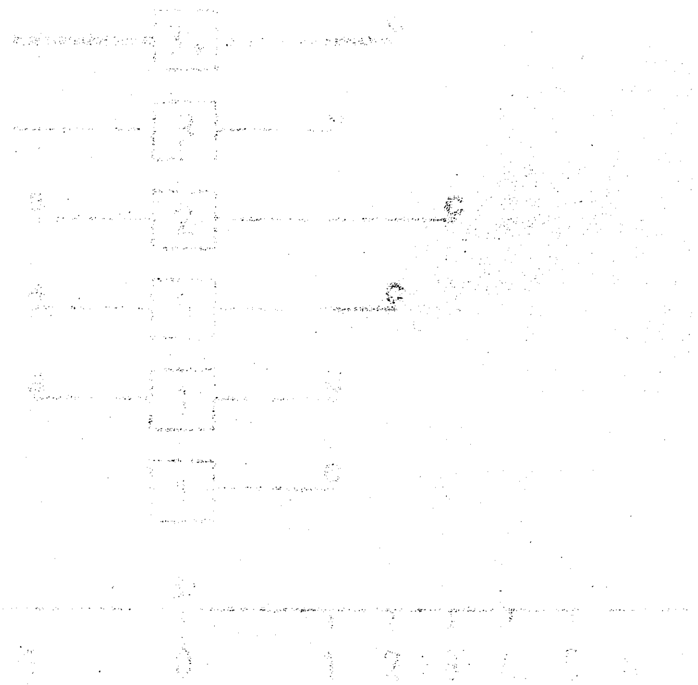
where breadths and lengths measured are maximal
and k is a constant correction factor

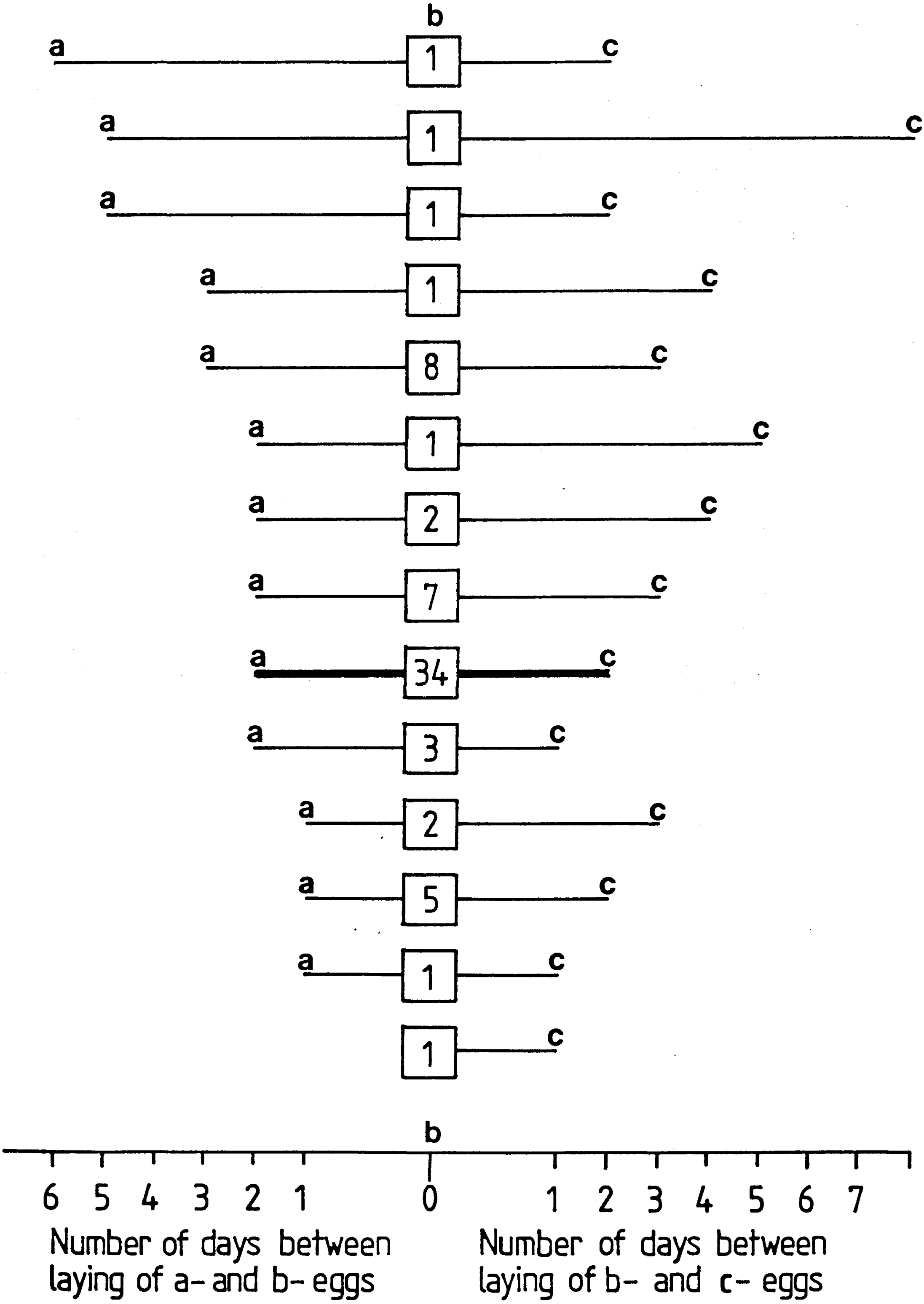
The value of the correction factor is usually determined by measuring the length and breadth of a sample of eggs and then finding their internal volumes. Audouin´s gulls eggs were not taken from the colony and it was not possible to gain access to collections of Audouin´s gull eggs in Britain. Calculations of the egg length x (egg breadth)^2 (LB^2), which provides a "volume index", still allow comparisons to made as there is a linear relationship between the volume index and the real volume (Grossfeld 1938).

5.3 THE PATTERN OF LAYING

Laying patterns have been recorded for Larus species by various authors, for the herring gull and the lesser black-backed gull (Paludan 1951) and by Barth (1955) for the common gull. In this study visits were made only once a day to the nesting sites so there is a margin of error of ±0·5 days. Figure 5.1 gives the frequency of the different laying patterns for the north site in 1984. It shows the number of days which elapsed between the laying of the a- and the b- eggs and between the laying of the b-

Figure 5.1 The laying sequence of 3-egg clutches at the northern site in 1984. The frequency with which each pattern was recorded at the site is shown in the central square which denotes the laying of the b-egg.




b
a
c
1
1
1
1
8
1
2
7
34
3
2
5
1
1
b
6 5 4 3 2 1
0
1 2 3 4 5 6 7
Number of days between laying of a- and b- eggs
Number of days between laying of b- and c- eggs

and the c-egg of each clutch. In the figure the laying of the b-egg is shown at the centre of the figure. The most common frequency is drawn in a heavy line. At each site five days was the most common period at each nest for the completion of the clutch. It is likely for physiological reasons that the single recorded case of the a- and b- egg being laid on the same day is an example of egg-dumping. The time delays between the laying of the eggs in three egg clutches were not significantly different, see Table 5.2.

TABLE 5.2: THE TIME INTERVALS BETWEEN THE LAYING OF THE EGGS IN THREE EGG CLUTCHES. (Significance is tested with a t-Test).

YEAR	SITE	AVERAGE DELAY a-b eggs (s.d)	AVERAGE DELAY b-c eggs (s.d)	t	P
1983	north	1.79 (1.11) days	2.17 (0.8) days	-2.358	0.0197
1983	south	1.90 (1.19) days	2.22 (0.78) days	-1.811	0.0726
1984	north	2.26 (1.15) days	2.28 (0.95) days	-0.082	0.9345
1984	south	2.24 (1.30) days	2.43 (1.01) days	0.027	0.9787
1985	north	2.46 (1.67) days	2.50 (1.36) days	-0.142	0.8876
1985	south	2.05 (1.40) days	1.87 (1.09) days	0.642	0.5226

5.4 COMPARISON OF AUDOUIN´S GULL EGG DIMENSIONS WITH THOSE OF HERRING GULLS.

The Audouin´s gull nests on the Chafarinas Islands can be distinguished with ease from those of the herring gulls on the following grounds that: they are on average at a stage of development two weeks behind those of the herring gulls; usually in tightly packed clusters; smaller nests and they are generally constructed less well, see Table 5.3. In Table 5.3 Audouin´s gull and herring gull egg dimensions are compared. Data collected by de Juana and Varela are shown for Audouin´s gull as these measurements were made in the same season as those of the herring gulls. Coulson et al. (1982) have shown that, for the herring gull, there can be a change in egg dimensions between years.

Table 5.3: A COMPARISON BETWEEN THE EGG DIMENSIONS OF AUDOUIN´S GULL AND HERRING GULL. (data taken from de Juana and Varela 1979)

	AUDOUIN´S GULL	HERRING GULL
inner nest diameter (cm.)	X = 17.4 ± 1.0, n=18	X = 21.99 ± 1.23, n=35
egg length (mm.)	X = 63.3 ± 2.3, n=45	X = 69.96 ± 3.05, n=99
egg breadth (mm.)	X = 44.1 ± 1.2, n=45	X = 48.87 ± 1.30, n=99
shape	X = 28.0 ± 1.4, n=45	X = 34.23 ± 1.90, n=99
weight (g.)	X = 65.0 ± 3.6, n=45	X = 85.0 ± 7.0, n=99

5.5 VARIATION IN EGG SIZE WITHIN THE CLUTCH

The mean dimensions for the eggs of 3-, 2-, and 1-egg clutches in 1984 at the northern study site are given in Table 5.4, the dimensions at other sites are given in Appendix 12. The a-egg is generally the largest, and the c-egg the smallest in Audouin´s gull clutches. Whilst the a-egg and the b-egg are not significantly different in 3-egg clutches, the c-egg is significantly smaller than both in each year and at each site, see Table 5.5 and Figure 5.2.

TABLE 5.4: THE AVERAGE DIMENSIONS FOR THE EGGS OF 3-, 2-, AND 1-EGG CLUTCHES FOR NORTH SITE in 1984 (mean values, standard errors and standard deviations are quoted for each egg category).

	a-EGG			b-EGG			c-EGG		
	X	s.e	s.d	X	s.e	s.d	X	s.e	s.d
3 EGG CLUTCHES (N = 63)									
length (mm.)	65.3	3.5	28.2	65.0	3.2	25.3	64.2	3.0	23.9
breadth (mm.)	44.8	1.1	8.7	44.9	1.25	9.9	43.8	1.3	10.2
volume index	131.3	1.0	8.1	131.8	0.9	7.5	123.3	1.1	8.4
shape index	68.7	0.4	3.0	69.2	0.4	3.1	68.3	0.3	2.5

2 EGG CLUTCHES (N = 10)

length (mm.)	64·9	7.6	23.9	63·0	6.2	19.2
breadth (mm.)	44·1	2.6	8.2	44·2	3.2	10.2
volume index	126.8	2.4	7.5	123.6	2.8	8.7
shape index	68.1	0.8	2.5	70.3	0.5	1.6

1 EGG CLUTCHES (N = 6)

length (mm.)	64·8	5.8	14.1
breadth (mm.)	43·7	2.3	5.7
volume index	124.0	0.7	1.8
shape index	67.5	0.9	2.2

TABLE 5.5: COMPARISON OF THE SIZES OF EGGS AT DIFFERENT POSITIONS IN THE LAYING SEQUENCE WITHIN THE CLUTCH USING A t-TEST AND ANOVA ON THE VOLUME INDICES.

YEAR	SITE	COMPARING SIZES OF EGGS	t	P	F (ANOVA)	P
1983	north	a with b	1.457	0.147		
		a with c	7.191	0.000	77.08 2,201	<0.01
		b with c	5.730	0.000		
	south	a with b	1.572	0.118		
		a with c	5.368	0.000	06.29 2,177	<0.01
		b with c	3.994	0.001		
1984	north	a with b	0.009	0.993		
		a with c	5.281	0.000	22.4 2,186	<0.01
		b with c	5.405	0.000		
	south	a with b	1.505	0.134		
		a with c	4.144	0.000	29.3 2,156	<0.01
		b with c	3.510	0.007		
1985	north	a with b	1.578	0.116		
		a with c	3.603	0.000		
		b with c	3.603	0.000		

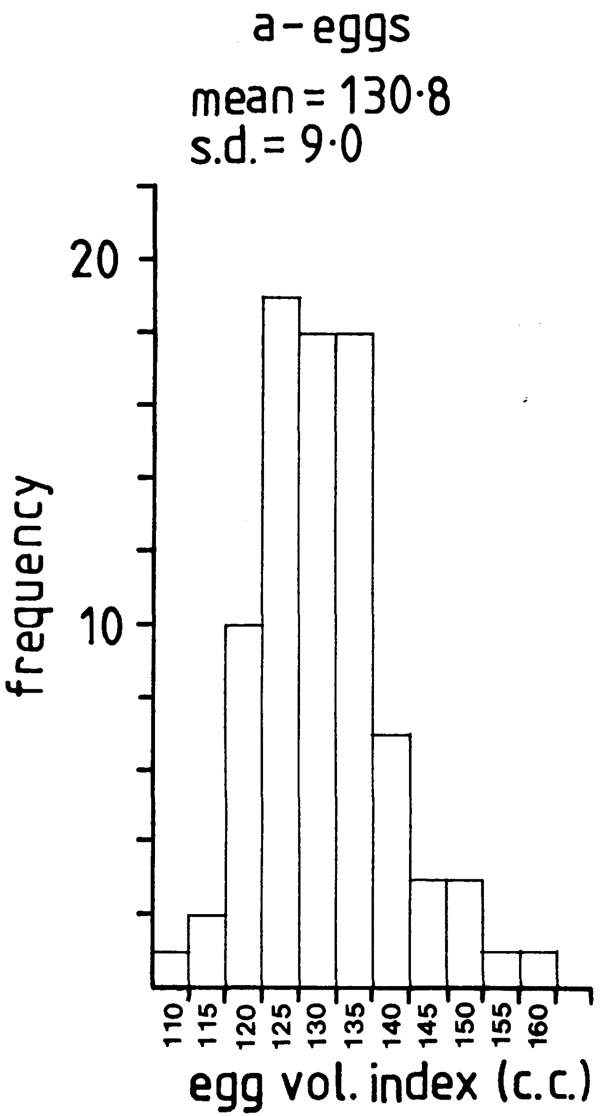
south	a with b	1.088	0.297
	a with c	4.972	0.000
	b with c	3.684	0.000

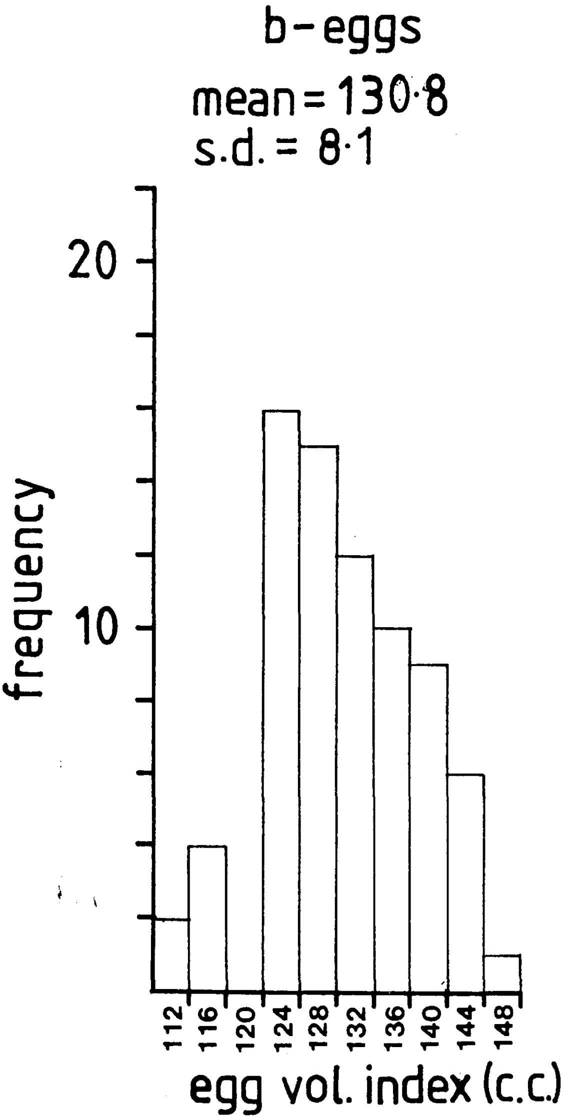
Considering the percentage decrease in the volume index between eggs in the 3-egg clutches, the b-egg is an average 2% smaller than the a-egg and the c-egg 7% smaller than the a-egg. This disparity between the volumes of the a- and c-eggs has been found for other gulls, see Table 5.6.

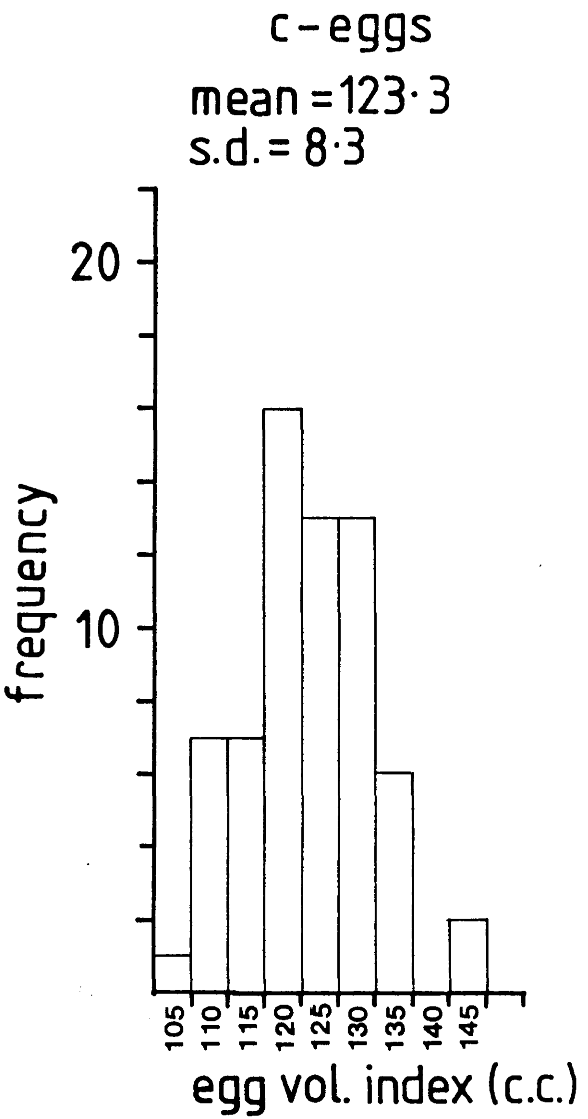
TABLE 5.6: THE % DIFFERENCE BETWEEN a- AND c- EGG VOLUMES FOR VARIOUS MEMBERS OF THE LARIDAE. (adapted from Parsons 1971)

SPECIES	N	% DIFFERENCE BETWEEN a- AND c- EGG VOLUMES	SOURCE
herring gull	57	9.7	Paludan (1951)
herring gull	310	8.1	Barth (1967)
herring gull	455	11.0	Parsons (1971)
lesser black-backed	62	9.4	Paludan (1951)
lesser black-backed	59	5.7	Harris (1964)
great black-backed	218	5.8	Barth (1967)
laughing gull	25	7.0	Preston and Preston (1953)
kittiwake	33	7.3	Coulson (1963)
common tern	22	5.8	Gemperle and Preston (1955)
Audouin´s gull	68	7.0	this study.

Figure 5.2 The distribution of egg volume indices (LB^2) amongst a-, b- and c-eggs in 3-egg clutches at the northern site in 1984. Plots show mean egg volume indices and the standard deviation from the mean for a-, b- and c- eggs.


a-eggs
mean = 130·8
s.d. = 9·0
20
10
frequency
110
115
120
125
130
135
140
145
150
155
160
egg vol. index (c.c.)


b-eggs
mean = 130·8
s.d. = 8·1
20
10
frequency
112
116
120
124
128
132
136
140
144
148
egg vol. index (c.c.)


c-eggs
mean = 123·3
s.d. = 8·3
20
10
frequency
105
110
115
120
125
130
135
140
145
egg vol. index (c.c.)

5.6 SEASONAL VARIATION IN EGG SIZE

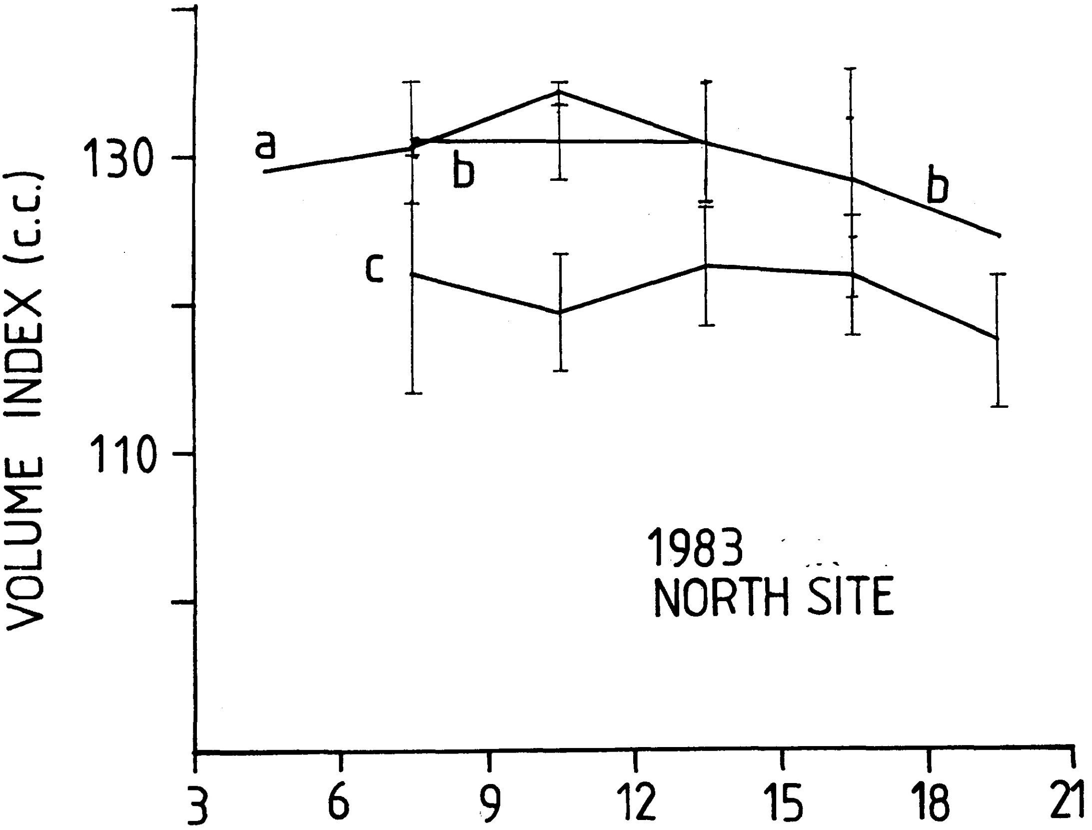
In Figure 5.3 the seasonal variation in the volume index (LB^2) is plotted for both the Audouin's gull sites studied in 1983. There is no apparent trend in egg size with regard to the season. The relationship was tested using a Rank Correlation Test on the original data for both sites in 1983 and 1984. The results are shown in Table 5.7.

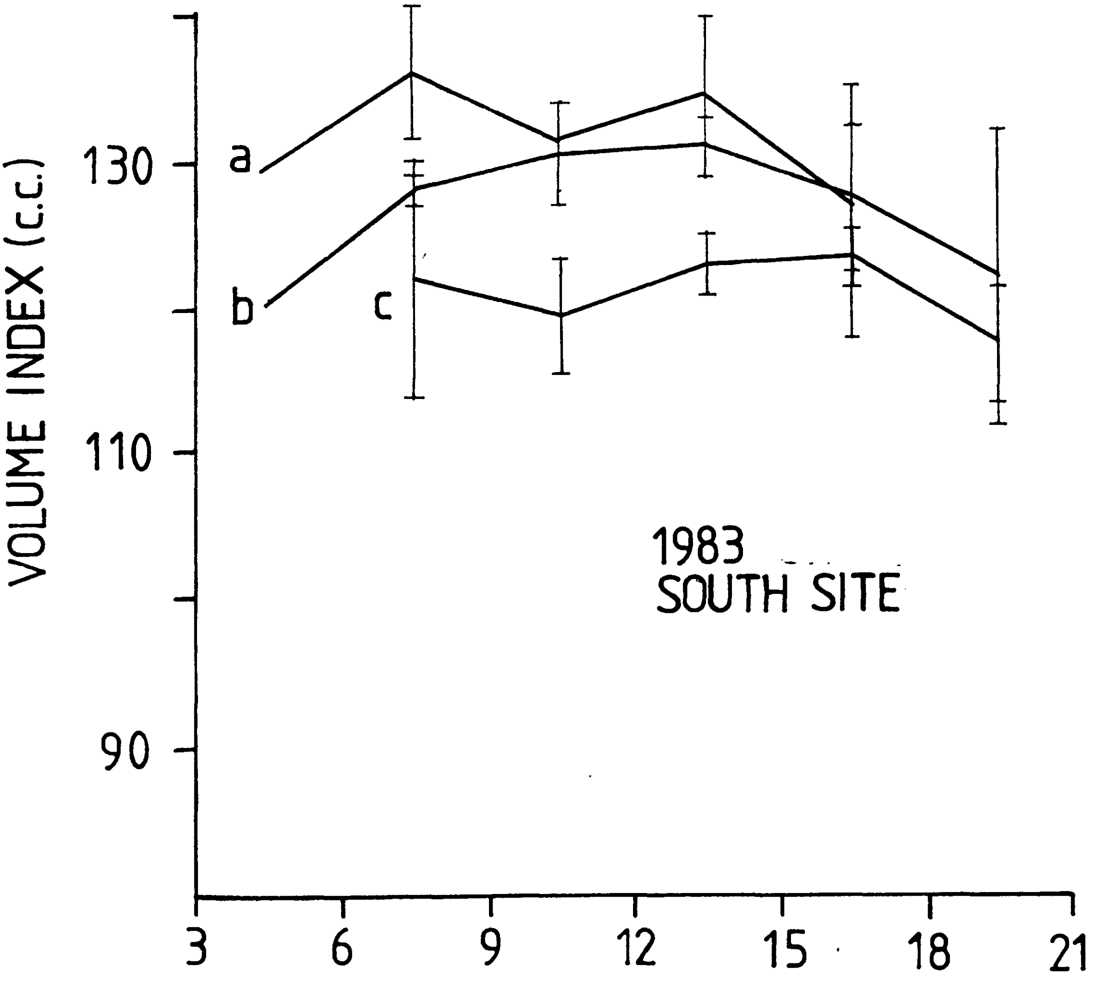
TABLE 5.7: THE CORRELATION BETWEEN THE VOLUME INDEX AND THE DATE ON WHICH THE EGG WAS LAID FOR ALL EGGS OF THE LAYING SEQUENCE.

YEAR	SITE	EGG	CORRELATION VALUE (r_s)	N	SIGNIFICANCE
1983	north	a	-0.038	86	N.S.
		b	-0.215	78	N.S.
		c	0.101	68	N.S.
1983	south	a	-0.336	74	SIG **
		b	-0.208	69	N.S.
		c	-0.061	60	N.S.
1984	north	a	-0.014	83	N.S.
		b	0.074	75	N.S.
		c	0.188	65	N.S.
1984	south	a	-0.168	93	N.S.
		b	-0.163	71	N.S.
		c	-0.163	53	N.S.

In only one instance was the correlation significant and this was for an a- egg and that may be expected by chance alone. Parsons (1977) showed that for the 455 herring gull clutches he studied that volume decreased least in the a- egg and most in the c- egg producing an increasingly marked disparity between the sizes of the a- and c- egg as the season advanced. This correlation was not found for Audouin's gull in this study. Egg shape was also examined and no seasonal effect was found.

Figure 5.3 Seasonal variation in the size of eggs from 3-egg clutches. Size is expressed as the egg volume index (egg length x egg breadth ^{2}) ± 2 standard errors plotted against the number of days since laying began in 1983 in the Audouin's gull colony.


VOLUME INDEX (c.c.)
130
110
a
b
b
c
1983
NORTH SITE
3
6
9
12
15
18
21


VOLUME INDEX (c.c.)
130
110
90
a
b
c
1983
SOUTH SITE
3
6
9
12
15
18
21

5.7 THE RELATIONSHIP BETWEEN EGG SIZE AND THE LENGTH OF THE INCUBATION PERIOD

In general large eggs have been shown to require longer incubation periods (Lack 1968). Parsons (1971) showed that within the Laridae there is a tendency for the average length of the incubation period to increase as the size of the eggs increases. The data collected during this study do not suggest that Audouin´s gull is an exception to this pattern, see Table 5.8.

TABLE 5.8: EGG VOLUMES AND INCUBATION PERIODS FOR VARIOUS LARUS SPECIES. Assuming k = 0.476 for the calculation of the volumes (adapted from Parsons 1971).

GULL SPECIES	N	MEAN EGG VOLUME (cc.)	INCUBATION PERIOD (DAYS)	SOURCE
black headed gull	624	32	22.6	Ytreberg (1956)
common gull	100	48	25.9	Barth (1955)
Audouin´s gull	229	61	26.8	this study
herring gull	30	70	27.0	Parsons (1971)
great black-backed	35	94	29.0	Harris (1964)

No significant correlation was found between the length of the Audouin´s gull incubation and the sizes of the a-, b-, and c-eggs in either 1983 or 1984, see Table 5.9, except for the one significant value for the a-egg at site 2 in 1983. In order to take into account differences in the incubation behaviour of the birds during the immediate post-laying period for each egg, the effect of variation in size was considered for a, b, and c-eggs separately. In 2 out of the 12 cases a negative correlation, although not significant, was found.

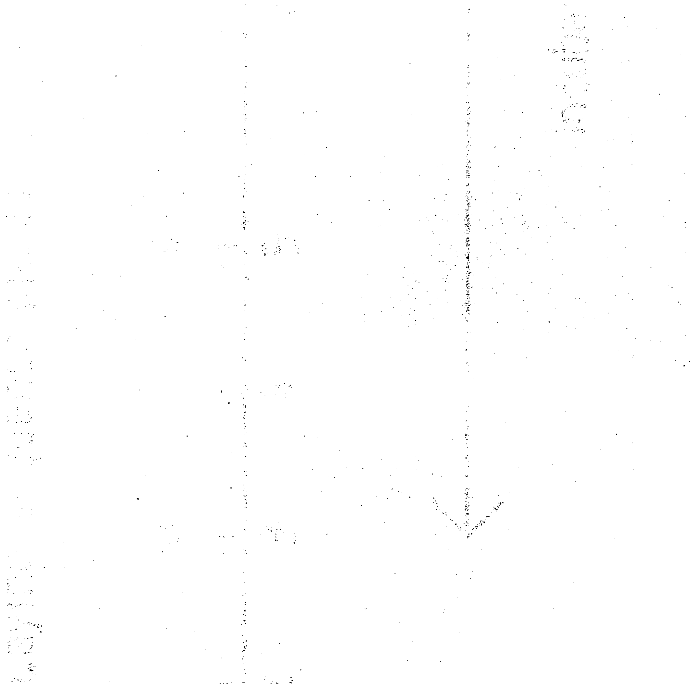
On the other hand, Parsons (1972) extended this study of the relationship between egg size and incubation period from the species level to the individual and found that, for the herring gull, large eggs took significantly longer to hatch than smaller eggs, with an average difference of 16 hours for a 10 cc. increase in volume.

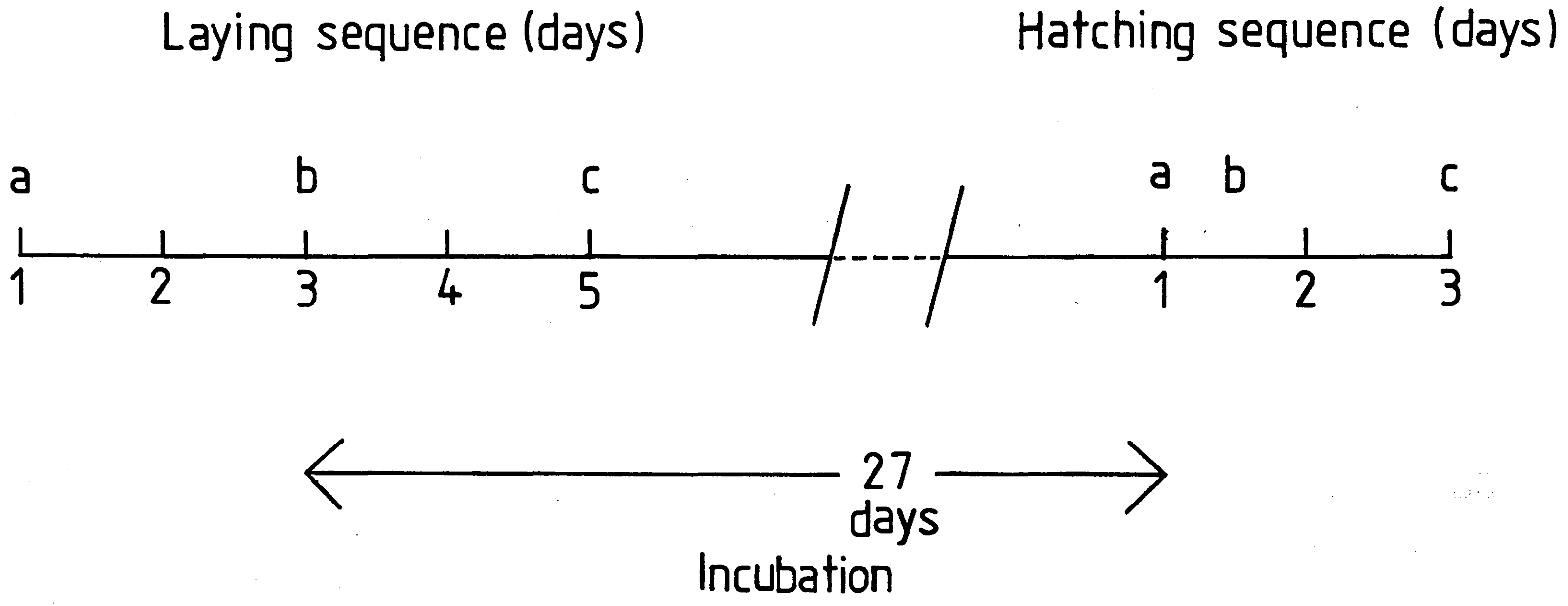
TABLE 5.9: THE RELATIONSHIP BETWEEN EGG SIZE AND THE DURATION OF THE INCUBATION PERIOD. (The incubation period for an egg, in this case, is the time between the laying of the egg and its hatching).

YEAR	SITE	CORRELATION COEFFICIENT (r_s)	EGG	PROBABILITY
1983	north	0.087	a	$P>0.05$
		0.134	b	$P>0.05$
		0.041	c	$P>0.05$
1983	south	0.338	a	$P<0.01$
		0.023	b	$P>0.05$
		0.013	c	$P>0.05$
1984	north	0.174	a	$P>0.05$
		0.098	b	$P>0.05$
		0.059	c	$P>0.05$
1984	south	-0.103	a	$P>0.05$
		-0.107	b	$P>0.05$
		0.086	c	$P>0.05$

Although no significant correlation was found between egg size and the length of the incubation period, in this study, broods of three Audouin´s gull chicks were found to hatch in less time than was taken for the clutch of 3 eggs to be laid (see Figure 5.4). As was shown in section 5.3, for Audouin´s gull, laying takes place over a period of five days, there being no significant difference in the time gap between the laying of the a- egg and the b- egg and the b- and the c-egg. Hatching is more rapid with only a time period of a half-day elapsing, on average, between the hatching of the a- and the b-chicks and one and a

Figure 5.4 Diagrammatic representation of the onset of laying, the incubation period and the hatching sequence of a 3-egg Audouin´s gull clutch.




Laying sequence (days)
Hatching sequence (days)
a
b
c
1
2
3
4
5
a
b
c
1
2
3
27
days
Incubation

half days between the hatching of the b- and the c- chicks (see Table 5.10).

TABLE 5.10: THE TIME INTERVALS BETWEEN THE HATCHING OF THE CHICKS IN THREE CHICK BROODS.

YEAR	SITE	HATCHING INTERVAL IN DAYS	MEAN	s.d.	
1983	N	a-b	0.68	0.8	
					t = -3.59, P = 0.0007
		b-c	1.55	1.4	
			n= 68		
1983	S	a-b	0.5	0.8	
					t = -3.54, P = 0.0009
		b-c	1.5	1.4	
			n=60		
1984	N	a-b	0.2	2.9	
					t = -2.36, P = 0.02
		b-c	1.8	3.4	
			n= 63		
1984	S	a-b	0.5	0.8	
					t = -4.13, P = 0.0002
		b-c	1.3	0.7	
			n= 53		
1985	N	a-b	0.6	0.7	
					t = -5.2, P = 0.000
		b-c	1.4	0.7	
			n = 68		
1985	S	a-b	0.6	0.7	
					t = 0.05, P = N.S
		b-c	1.5	0.9	
			n= 38		

Incubation would therefore appear to begin with the laying of the b- egg, see Figure 5.4. Observations made during the hide watches confirm that this is the case. The a- egg therefore develops little during its almost two day headstart on the b-egg. The developmental time separation between the b- and the c-eggs appear also to be reduced during incubation. This may be for reasons other than the differences in size. In April severe storms can bring rain and low temperatures but throughout May temperatures gradually rise, see Appendices (2 - 4). These increases in temperature during the incubation period may affect the length of the incubation period. MacRoberts and MacRoberts (1972) have suggested that changes in attentiveness may also shorten the incubation period.

5.8 CORRELATIONS BETWEEN EGG SIZE AND HATCHING SUCCESS

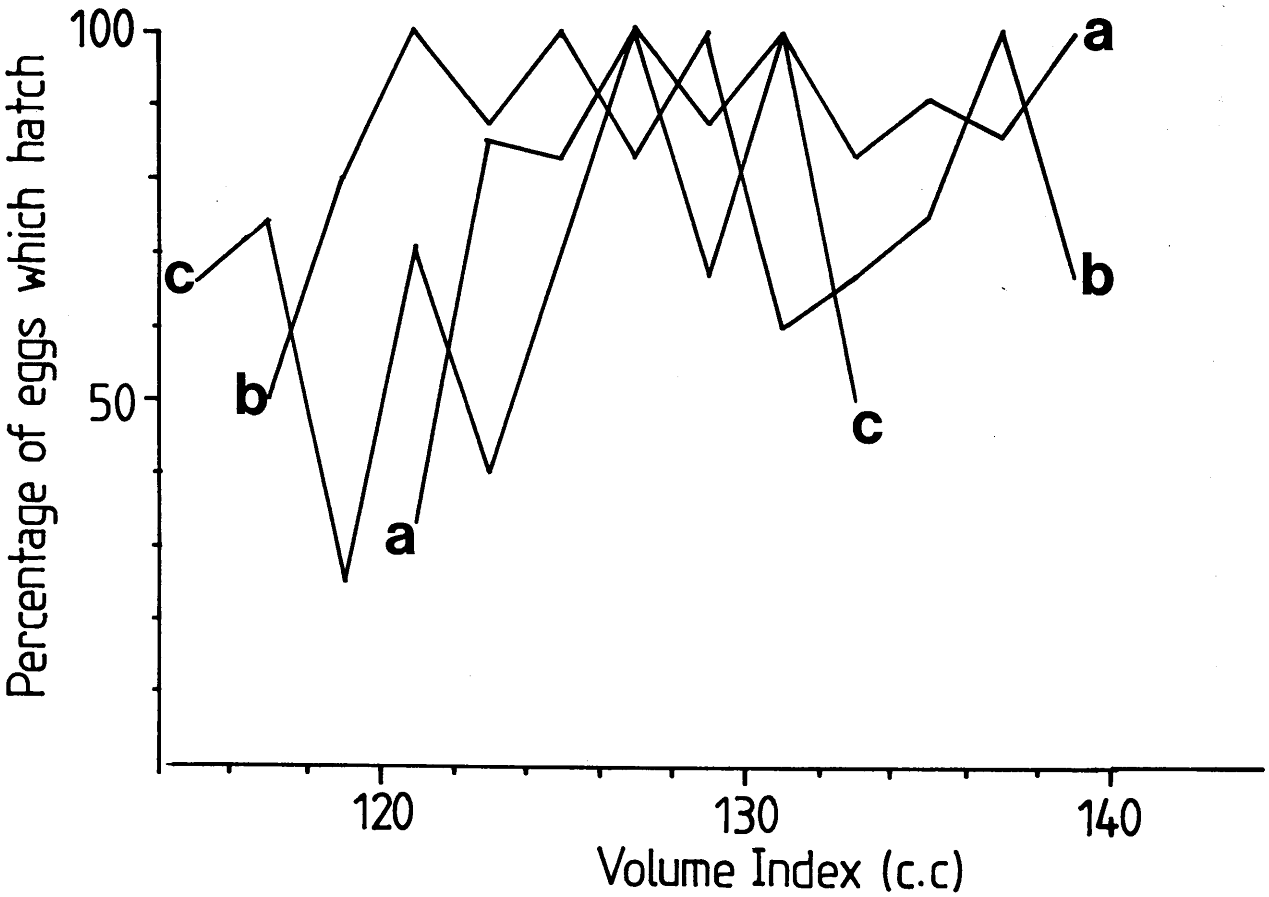
The hatching success of eggs from different size categories were compared for 1983 and no significant correlation was found (Table 5.11). There does appear to be a decline in the hatching success for small eggs and perhaps also for very large eggs (see Figure 5.5).

TABLE 5.11 COMPARISON OF THE HATCHING SUCCESS OF EGGS (from 3-egg clutches) FROM DIFFERENT SIZE CATEGORIES. Hatching success is shown as the number of eggs hatching/number of eggs laid expressed as a percentage.

	POSITION OF EGG IN HATCHING SEQUENCE					
	a		b		c	
VOLUME INDEX (LB^2)	n	%	n	%	n	%
112-115					13	69
116-119			7	71	11	54
120-123	10	70	10	90	15	60
124-127	14	93	18	89	9	78
128-131	16	94	11	82	6	67
132-135	17	88	14	71		
136-139	11	91	10	80		

Is the hatching success within the various size categories significantly different? Considering the original data and

Figure 5.5 Variation in hatching success at the northern site in 1983; the percentage of eggs laid which hatch, with egg size. Egg size is expressed as the volume index (length x breadth^2).


100
50
Percentage of eggs which hatch
120
130
140
Volume Index (c.c)
a
b
c
a
b
c

testing for significance with the X^2 Test.

a egg $X^2 = 0.27$, d.f. = 4, not significant
b egg $X^2 = 0.26$, d.f. = 5, not significant
c egg $X^2 = 0.31$, d.f. = 4, not significant

Parsons (1971) found no appreciable differences in the hatching success of herring gull a-, b-, and c- eggs. To examine this in Audouin´s gull, clutches where at least one egg failed and at least one hatched were considered. Clutches where all eggs failed to hatch were excluded, as were those where all hatched. Since hatching success was comparatively poor in 1984 and 1985, data from these years were examined, see Table 5.12. At each site in 1984 and 1985, the hatching success of the c- Audouin´s gull eggs was significantly lower than that of the eggs earlier in the laying sequence, Table 5.12. The exception was at south site in 1985 where, and when, herring gull interference with the reproduction of Audouin´s gulls was great (see section 3.7).

TABLE 5.12: THE PATTERN OF HATCHING FAILURE FOR NESTS WITH THREE EGG CLUTCHES, FROM WHICH AT LEAST 1 AND LESS THAN 3 EGGS FAILED TO HATCH. (Failed to hatch includes those predated)

YEAR	SITE	N	NUMBER AND CATEGORY OF FAILED EGGS (%)			
			a	b	c	
1984	N	35	9 (26%)	6 (17%)	20 (57%)	$X^2 = 9.31$, P = 0.01.
1984	S	34	9 (26%)	3 (9%)	22 (65%)	$X^2 = 16.65$, P = 0.001
1985	N	27	5 (18%)	6 (22%)	16 (59%)	$X^2 = 8.22$, P = 0.05.
1985	S	15	3 (20%)	4 (27%)	8 (53%)	$X^2 = 2.8$,

This lower hatching success for the c-egg appeared to be partly due to differential predation of the c-egg (see section 9.5) but mainly due to a breakdown in incubation. Once the first chicks had hatched the adults appeared to spend more time standing over the chicks and eggs offering food to the first hatched chicks leaving the remaining egg/s open to temperature gain or loss. This will be discussed in greater detail in the next chapter.

5.9 CORRELATION BETWEEN EGG SIZE AND CHICK HATCHING WEIGHT

Audouin´s gull egg volume and chick weight on hatching were found to be positively correlated (see Table 5.13a). The relationship between Audouin´s gull egg volume and chick wing length was less clear (see Table 5.13b).

TABLE 5.13a THE CORRELATION BETWEEN CHICK HATCHING WEIGHT AND EGG VOLUME AT THE STUDY SITES DURING THE THREE BREEDING SEASONS.

YEAR	SITE	n	CORRELATION COEFFICIENT (r)	P
1985	North	46	0.636	P<0.001
1984	South	47	0.565	P<0.001
1984	North	24	0.480	P<0.01
1983	South	89	0.18	0.1>P>0.05
1983	North	27	0.2	P>0.05

TABLE 5.13b THE CORRELATION BETWEEN CHICK WING LENGTH AT HATCHING AND EGG VOLUME AT THE SITES DURING THE THREE BREEDING SEASONS.

YEAR	SITE	n	CORRELATION COEFFICIENT (r)	P
1985	North	10	0.506	P>0.05
1984	South	49	-0.045	P>0.05
1984	North	44	0.397	0.1>P>0.05
1983	South	144	0.074	P>0.05
1983	North	88	0.135	P>0.05

In three out of the five cases examined, the trend was significantly positive and in another very nearly significant. The wing length of newly hatched chicks, in contrast, was only significantly correlated with egg volume for one example. It would appear that chick weight, rather than chick size, is more influenced by the size of the egg from which it developed.

The volume indices for nests at the northern sites in 1984 and 1985 were grouped into intervals of 10 cc. and the fates of the chicks were categorized into four exclusive categories:

0 - an egg laid which did not hatch
1 - hatched but lived less than 5 days
2 - hatched and lived more than 5 but less than 20 days
3 - lived more than 20 days

The correlation between the survival of the chicks and the volume index of the egg was tested for all the eggs in the laying sequence using a rank correlation test, see Table 5.14.

TABLE 5.14: THE RELATIONSHIP BETWEEN EGG VOLUME INDEX AND CHICK SURVIVAL

YEAR SITE	N	POSITION OF EGG IN THE LAYING SEQ.	RANK CORRELATION COEFFICIENT	SIGNIFICANCE
1984 north	83	a	0.073	N.S.
	75	b	-0.010	N.S.
	65	c	-0.180	N.S.
1985 north	95	a	0.086	N.S.
	83	b	0.176	N.S.
	68	c	0.074	N.S.

No significant correlation was detected. The benefit of hatching from a large egg would therefore not appear to extend throughout the chick pre-fledging stage.

5.10 REPEAT LAYING

Instead of experimental removal of eggs from the nests to examine the relaying abilities of Audouin´s gull, advantage was taken of natural disappearances due to eggs either rolling out of the nests or being predated. In the years preceding this study, thousands of Audouin´s gulls eggs were apparently collected on the Chafarinas Islands by the local Moroccan fishermen for human consumption (Beaubrun in litt to H.-H.Witt 1982). Juana and Varela, who were studying Audouin´s gull on the Chafarinas during this time, have suggested that relaying of lost clutches occurred frequently as towards the end of the breeding season chicks of widely differing ages could be seen on the islands. In 1979 the same authors reported relaying occurring at five nests on Rey and at nests in a subcolony on Congreso. They estimated that 80% of the pairs which lost eggs could relay but that the clutch size was reduced to an average 1.76 and that the success of these relaid clutches was almost zero towards the end of the season (1980). In the years 1983-1985 only herring gull eggs were taken for human consumption as tightening of the control of unauthorized landings on the Chafarinas confined the collectors to less frequently monitored island of Congreso where no Audouin´s gulls bred.

On three out of four occasions, in the study sites, during the field seasons, when an egg rolled out of a nest a replacement egg was laid. In the fourth instance the egg was lost within a week of when it should have hatched.

Eggs predated by herring gulls were not replaced so frequently, see table 5.15. This apparent lack of relaying is probably due to the delay between the laying of the egg and the loss of the egg.

TABLE 5.15: FREQUENCY OF RELAYING AFTER PREDATION AT SITES IN 1984 AND 1985.

		NUMBERS OF NESTS (%) WHICH WERE			
YEAR	SITE	LEFT INTACT	ABANDONED	PREDATED BUT NO RELAYING	PREDATED AND RELAID
1984	north	67 (84%)	2 (2.5%)	8 (10%)	3 (4%)
1984	south	45 (49%)	3 (3%)	40 (43%)	4 (4%)
1985	north	14 (25%)	17 (31%)	23 (42%)	0
1985	south	60 (61%)	0	36 (37%)	2 (2%)

5.11 DISCUSSION

In other avian studies egg dimensions have been shown to provide much information with regard to the age and experience of the parents, the laying sequence and the likelihood of the chick, developing therein to survive. A correlation was found between the age of the parents and the egg-shape and egg volume of the yellow-eyed penguin, (Richdale 1955), for the kittiwake (Coulson 1963), for the arctic tern, (Coulson and Horobin 1976) and for the herring gull (Duncan 1978). Unfortunately, as the ages of the breeding Audouin´s gulls were not known, the effect of adult age and experience on the size of eggs laid, and the subsequent survival of the chicks, remains unknown.

That the size of eggs laid generally decreases as the season advances has been shown for the kittiwake (Coulson 1963), the shag (Coulson _et al._ 1969), the gannet (Nelson 1966) and the herring gull (Parsons 1971). Young seabirds are known to breed later and lay smaller clutches than older birds (Mills 1973, Ryder 1980). Coulson and White (1961), controlled for the female age and showed that, for female kittiwakes of the same age, those laying later in the breeding season lay smaller eggs.

The apparent absence of a seasonal decline in Audouin´s gull egg size, as shown in Section 5.6, may suggest that there is not the same relationship between the experience of the female and the size of the eggs laid as has been shown to exist for the kittiwake (Coulson 1963) and the herring gull (Duncan 1978). As a result of the ringing programmes carried out on the Chafarinas since 1976, within a few years there should be a sizeable proportion of age-marked birds breeding in the colonies. It would be interesting to continue this investigation in order to gain an insight into the influence of female experience on reproductive success. It may also be that food remains available well into the season so there is no shortage of nutrient for the latter breeding birds thus removing a constraint on egg size which has been found to play a role in determining the size of eggs produced by other gull species (Winkler and Walters 1983).

Like Audouin´s gull, the a-egg of the herring gull 3-egg clutches is significantly larger than the c-egg, although the herring gull a-egg has also been found to be significantly larger than the b-egg with regard to length, breadth and volume (Paludan 1951, Barth 1951, Parsons 1971). Most species, however, show little variation in the egg size within the clutch, most of the intra-population variation occurring instead between clutches (Kendeigh _et_ _al._ 1956). In the cases where there is a within clutch pattern it is not always the same as that of the herring gull. Coulson _et_ _al._ (1969) showed the a-egg of shag clutches as being the smallest and the b-egg the largest. In the house wren when the final egg is laid it is usually the largest (Kendeigh _et al._ 1956).

Parsons (1971) analysed the components of herring gull eggs and concluded that the c-egg is not a scaled down version of the a-egg, rather that the stimulus provided by the presence of the a-egg in the nest initiates the onset of incubation and this results in a significant reduction of the amount of albumen laid down in the last egg laid in the clutch. He found that whilst, for the herring gull, there was an 11% size difference between the a- and the c- eggs, the c- yolk was on average only 2.2% lighter than the a- yolk. It is possible that the small size of the c-egg is adaptive, as in the face of predation, the reduction of the incubation period, which is normal with smaller eggs (Parsons 1972), will tend to reduce the asynchronicity of the hatching thus diluting the effects of predation. An alternative theory is that suggested by Graves et al. (1984) that the third egg is laid as a form of insurance. Small eggs may contain inadequate reserves for development whereas very large eggs will have greater heat exchange requirements than small eggs. Parsons (1971) found a significant positive correlation between herring gull hatching success and egg size and a decline in success for eggs outside the normal range of egg volumes. In this study no obvious relationship between Audouin´s gull hatching success and egg size was found although there was a suggestion that there was a decline in hatching success at the extremes of the egg size range, see Figure 5.5.

That there is a relationship between egg size and chick size for domestic fowl has been known for more than 60 years (Halbersleben and Mussehl 1922). In 1970, Parsons showed that large herring gull eggs produced large chicks which grew faster and which possibly survived better than did chicks from smaller eggs. Other studies have also indicated a correlation between the chick size and the egg size, for example, in the laughing gull and the Japanese quail (Ricklefs et al. 1978), the great tit (Jones 1973), and the common and roseate terns (Nisbet 1978). Parsons (1970) suggested that the important difference between large and small eggs was the larger lipid reserves which could tide the chicks over the initial post-hatching days when the mortality risk is highest. O´Connor (1975) expressed reluctance to consider this relationship on its own at either specific or individual levels as he interpreted the differences in egg sizes and weights at hatching as being strategies particular to that breeding environment, and as intelligible only when seen as part of the whole scheme. This appears true, for although Audouin´s gull chicks from large eggs are heavier, although not significantly larger than chicks from smaller eggs, there appears to be no correlation between their egg size and the survival of the chicks.

For the herring gull it has been suggested (Parsons 1971) that contact of the brood patches with the first egg produces a reduction in the fourth follicle. This suggests that the likelihood of the formation of replacement eggs will decline as a function of the time spent incubating the original clutch. Weidmann (1956) had already identified that it was the brooding of the adults which results in the cessation of egg-laying, not the size of the clutch laid but observed that if all three eggs of a black-headed gull were removed no replacement eggs were laid immediately but a full second clutch appeared after 8-13 days. The time already spent incubating a clutch also appears important in the determination of whether replacement eggs are laid by an female Audouin´s gull.

It is likely that the Moroccan fishermen in their search for fresh eggs would remove recently laid eggs, by focusing their attention on less than complete clutches. The herring gull, in contrast, is not, apparently, a selective predator, taking eggs at all stages of development. When eggs were stolen by herring gulls before the b-eggs were laid, the nests were more frequently abandoned than replacement eggs were laid (for example, at the southern site in 1985, 14 nests were deserted after the a-egg had been taken at only 2 nests did relaying occur, $X^2 = 9$, d.f. = 1, $P = <0.01$). It is possible that, in 1984 at the southern site, the adults having lost an egg/s to the predators, switched to renest at another site as in 1984 a sub-colony was established in the south much later than the other sub-colonies. In 1985 all sub-colonies were established at approximately the same time so that birds, whose nests were predated, which abandoned their first nest did not appear to re-nest at another site.

Through Audouin´s gull adults´ mobbing response in the presence of herring gulls and lack of response to other birds (for example cattle egrets which are tolerated standing amongst the nesting Audouin´s gulls) it would appear that Audouin´s gulls recognize herring gulls as an effective predator. It may be a behavioural adaptation of Audouin´s gulls that once predated by herring gulls they give up rather than risk committing further resources to a replacement clutch when it is possible that it too will be taken if herring gulls are active in the area. Humans are much less consistent in their predation patterns that they inflict so it is thought unlikely that any response strategy has, or could be, developed.

CHAPTER SIX: THE INCUBATION AND HATCHING PERIOD

6.1 INTRODUCTION

Breeding populations of nearly three dozen species of the genus Larus occur from the arctic through the tropics into the subantarctic. Most species of the genus are temperate or boreal in distribution. A few, however, nest in extremely hot regions. Heermann´s gull is a conspicuous example, often nesting in barren desert sites characterized by extreme aridity and intense solar radiation. Bennett and Dawson (1979) showed that decreases in ambient temperature to slightly lower than normal adult body temperature can suppress the physiological processes of the Heermann´s gull embryos and can lead to irreversible damage. Additionally, an increase of 5-7^{O}C above normal incubation temperatures can prove lethal to developing Heermann´s gull embryos. The embryos of gulls breeding in tropical and subtropical areas may therefore be susceptible to thermal injury. The risk of such damage may be reduced by the incubation and shading behaviour of the adult gulls.

Incubation can be effectively defined as the process by which the heat necessary for embryonic development is transferred to and from an egg after it has been laid (Beer 1964). Heat is transferred via the brood patches. White and Kinney (1974) demonstrated that these areas of vascularised feather-free tissue have sensory receptors which influence the attentiveness of the incubating adult. Overheating or underheating is prevented by the bird sitting more or less tightly on the eggs, the extent depending on the feedback from the eggs. Mourning doves nesting in the Sonoran Desert maintain their eggs´ temperatures well below (40^{O}), the normal environmental temperature being 45^{O}. Previous gull studies have suggested that gulls are better equipped to heat cooled eggs than to cool warmed eggs (Baerends and Drent 1970). Whilst unattended, White and Kinney (1974) found that eggs in general tend to equilibrate with the environmental temperature at a rate dependent on the heat retaining capacity of the eggs and nest.

In addition to the thermal control, the presence of the adults at the nest during incubation generally reduces the losses due to predation, as the gulls often defend their nests. However, the levels of attentiveness at the nest which may be required to maintain optimum temperatures do have costs for the adults. In most gull species the parents share the incubation duties. The behaviour of the pair must be co-ordinated so that the nest is not left unattended at vulnerable times and that one member of the pair is not left incubating whilst stressed by temperature extremes or hunger. Attendance at the colony may also increase the predation risk to the adult gulls themselves through increased conspicuousness, although the proximity of many vigilant individuals generally forms an effective early warning system (Hoogland and Sherman, 1976, Caraco et al., 1980) and nesting birds are able to defend themselves and their eggs better by effective communal mobbing (Kruuk 1964, Furness and Monaghan 1987).

In this chapter the factors which affect the course and outcome of the incubation period in Audouin´s gull on the Chafarinas Islands are discussed.

6.2 METHODS

This study followed the breeding success of gulls nesting at two sites in each of three seasons. Observations were made during each season of the breeding behaviour of the adults and their offspring from a hide (see section 3.10).

The regime of watches was designed to suit both the gulls (so that disturbance was minimal and at the coolest times of day, early morning and late evening, see Section 6.5) and the habits of the garrison island inhabitants (from late evening until early morning the gates to the island harbour were locked and guarded). Following the hour spent checking the nest contents of the study site in the early morning (6-7 am.), three hours were spent in one hide and then in the evening three hours were spent in the other hide before the checking of that site (7-8 pm.). The site that was checked and observed in the morning on one day was visited in the evening on the following day and so on.

Attempts were made to distinguish between the male and female of the pair at each of the focal nests. Male Audouin´s gulls are slightly larger and appeared to have a slightly heavier bill than female (Witt et al. 1982). It was difficult however to identify incubating birds in the absence of the other member of the pair for comparison, unless one of the two were colour-ringed or bore distinguishing marks. At the start of the project it was thought that members of the pair could be distinguished by the construction of a key which made use of the considerable individual variation in bill patterns. Some adults were observed to have single black bands on their otherwise red bills with yellow tips. Other adults had double or Y-shaped bands (Witt 1970). By the middle of the second season the explanation for the lack of success of this exercise was identified. It was realized that the shape of the banding alters during the season, developing from a single band to a double band during the late stages of incubation/early hatching. It was therefore difficult to sex members of a pair in isolation. This study therefore relied upon easy identification of those adults that were 1) colour-ringed, 2) those that had been stained with dye from a loaded sponge placed in the nest bowl and 3) those birds which bore distinguishing features (see section 3.12 for details).

In this chapter, detailed behavioural observations for 1983 will be examined, as this was the year in which interference by herring gulls (which will be discussed in chapter 9) was least. Any conclusions concerning more general incubation and hatching behaviour are discussed with additional reference to the data collected in 1984 and 1985.

6.3. INCUBATION BEHAVIOUR

Generally Audouin´s gulls began to incubate following the laying of the first egg of the clutch. However, the adults did not sit very tightly on the single egg, leaving the egg exposed for long periods whilst they continued to dispute territory boundaries and add material to the nest. Following the appearance of the second egg the birds settled down and incubation bouts became more extended.

The average proportion of the time spent at the nest by at least one member of the pair during the incubation period was initially high (> 90%), but increased still further during the first week following the initiation of egg laying to a level of virtually continuous attendance, in the absence of severe disturbance, see Figure 6.1. Mean attendance was seen to drop slightly, although not significantly, in the week before hatching.

At the height of incubation, the eggs are continuously incubated, with only short interruptions for resettling, nest building, changeovers of incubators and disturbances. Resettling, or as Tinbergen (1953) describes it ´egg-shifting´, occurred throughout the incubation period. It involved the incubating adult suddenly rising and often moving the eggs with its bill. Resettling often followed nest relief but also occurred periodically during long spells of quiet incubation.

Both male and female Audouin´s gulls incubate, see Figure 6.2. Nests were not left unattended, but it was not always possible to identify the sex of the incubating bird. In 1983, at nests at the southern site, when sex could be determined, females attended the nests significantly more than the known males, especially in the week immediately pre-hatching, see Table 6.1. At the northern site, in the same year, no such difference was found, nor at any of the other sites during any other season.

TABLE 6.1: MEAN PROPORTION OF TIME (± 1 S.E.) PER 3-HOUR HIDEWATCH THAT MALE OR FEMALE WAS IN ATTENDANCE AND SEX COULD BE DETERMINED. Season - 1983. The mean proportions of time spent by the members of the pair were compared using the Mann-Whitney U Test.

SOUTHERN SITE	n	mean	s.e	U	Corrected 2-tailed P
MALE	433	0.34	0.02	87144.5	0.0420
FEMALE	433	0.40	0.02		
NORTHERN SITE					
MALE	240	0.19	0.02	28406.0	0.9775
FEMALE	240	0.19	0.02		

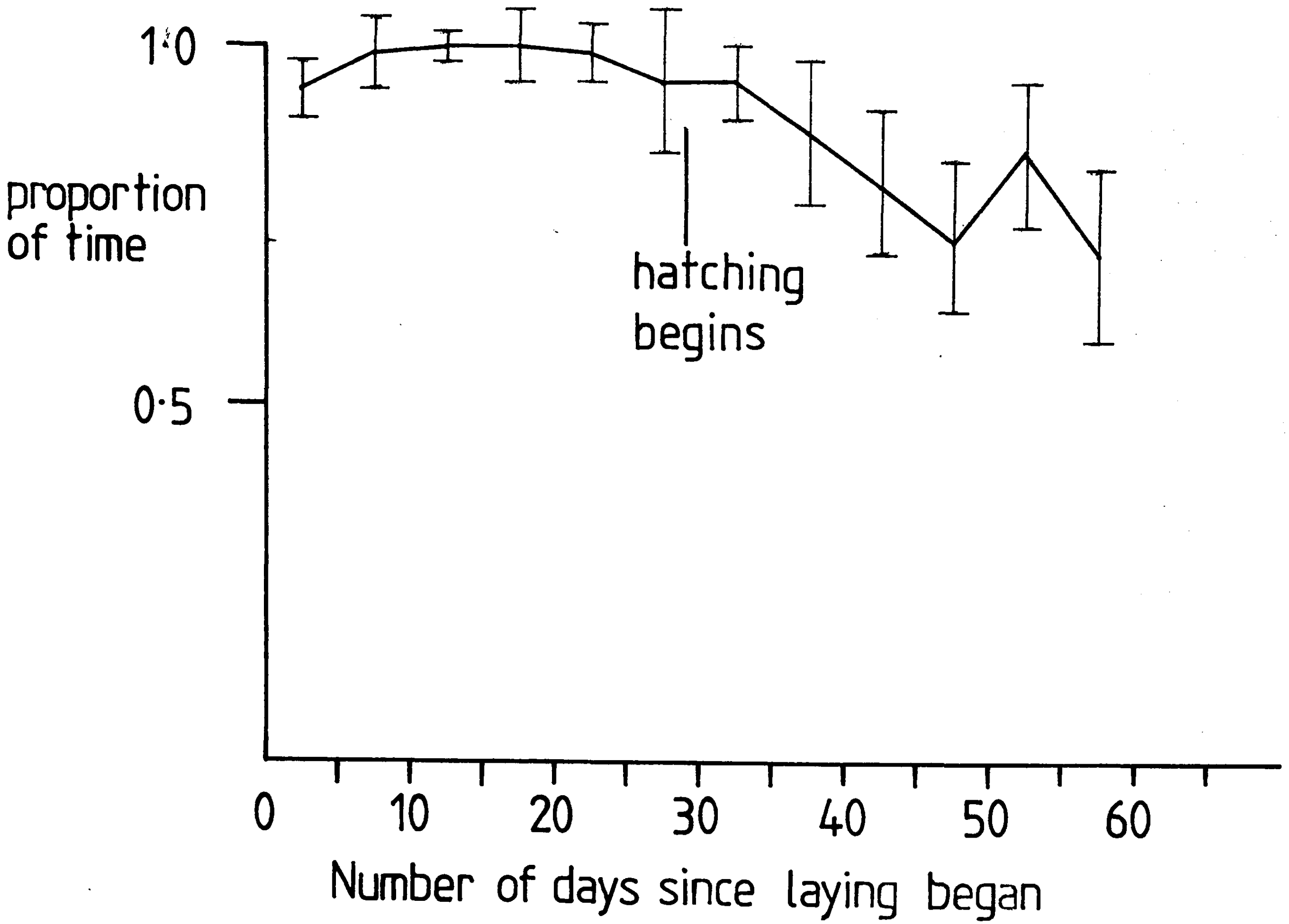
6.4 DURATION OF THE INCUBATION BOUTS

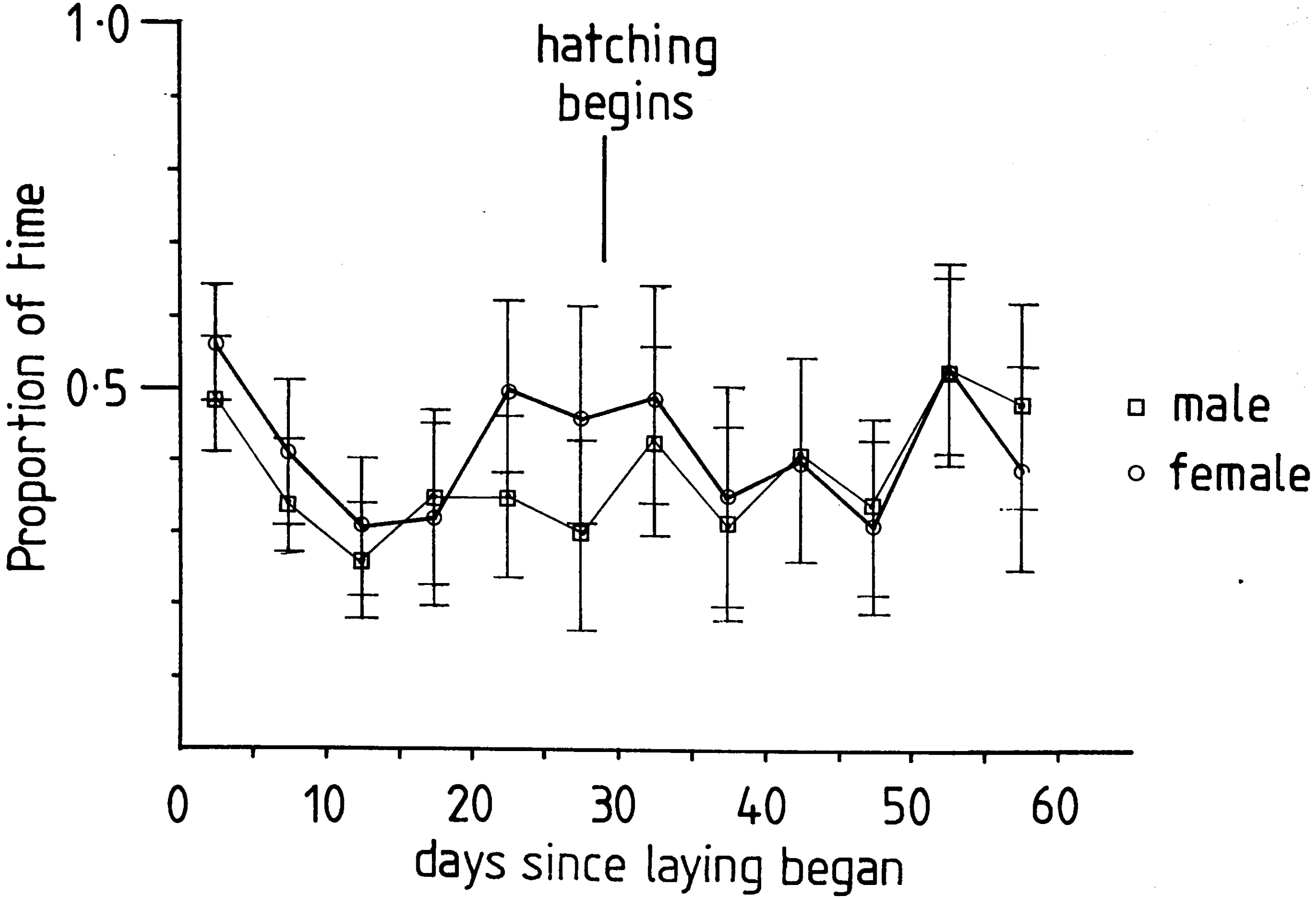
Drent (1967) postulated that the length of the parental incubation shift is determined by the foraging pattern of the off-duty bird and could therefore be used to estimate the foraging range of the birds. The length of the Audouin´s gull incubation spells was not so dependent on the feeding behaviour as this species does not spend all of its off-duty time, during the day, foraging. Rafts of gulls frequently bathed on the sea close to the islands. Birds relieved from incubation often flew immediately in the direction of these bathing birds. The rate of changeovers of adults at the nest was calculated for the 1983 sites combined, see Figure 6.3. The number of changeovers per hour were initially very high but decreased in frequency during the first week following the start of egg laying. This reduction continued until the final week of incubation when the rate increased gradually, again suggestive of a change in the motivational state of the adults. At the height of incubation the average incubation bout was probably considerably longer than that suggested by the data as no bouts longer than three hours were recorded due to the restrictions of the daily regime (see

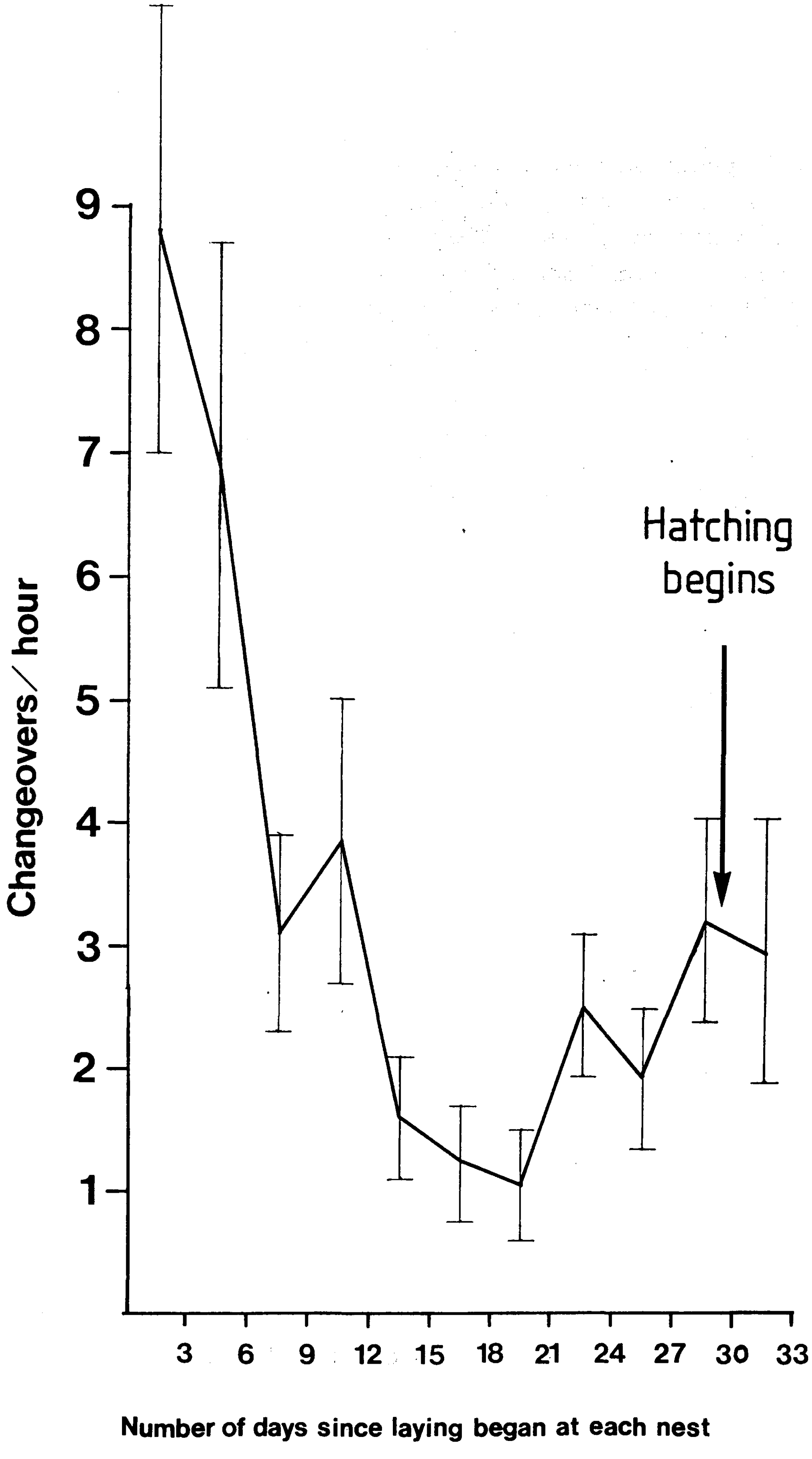
Figure 6.1 The mean proportion of the time (±2 s.e.) per hide watch, at the southern site in 1983, during which the nest territory was attended by one or more adult Audouin´s gulls. Total number of 3 hour watches at a nest = 655. The same pattern was observed at the northern study site.

Figure 6.2 The mean proportion of time (± 2 s.e.) per hide watch when the female/male Audouin´s gulls were known to be in attendance in territories at the southern site in 1983. Total number of 3 hour watches at a nest = 655.

Figure 6.3 The mean rate of changeovers (± 1 s.e.) of incubating birds at nests in 1983 (data collected at both sites combined) during the incubation period. Total number of watches at a nest considered = 903.


1·0
proportion
of time
0·5
hatching
begins
0
10
20
30
40
50
60
Number of days since laying began


1·0
0·5
Proportion of time
hatching
begins
0
10
20
30
40
50
60
days since laying began
□ male
○ female


Changeovers/ hour
9
8
7
6
5
4
3
2
1
Hatching begins
3
6
9
12
15
18
21
24
27
30
33
Number of days since laying began at each nest

section 6.2).

Unfortunately no data could be collected regarding nocturnal activity patterns due to military restrictions. Much gull traffic was seen leaving and entering the sub-colonies at dusk and dawn respectively and adult calls were heard from the breeding colony at all hours. It is not known if night desertion occurs during the season at any time or whether incubation shifts are longer whilst the off-duty bird feeds. Audouin´s gull is reputed to be a nocturnal fishing bird (see section 2.4) and indeed young chicks trapped early in the morning regurgitate with much greater frequency than those caught in the evening (see section 7.5). Audouin´s gulls were observed, by the lights of naval and fishing vessels, fishing at night in large numbers. The nocturnal behaviour of Audouin´s gull is one area requiring investigation. During the heat of the middle of the day the adults are largely inactive with many non-incubating birds loafing in the colony.

6.5 PATTERNS IN THERMOREGULATORY BEHAVIOUR DURING THE BREEDING SEASON.

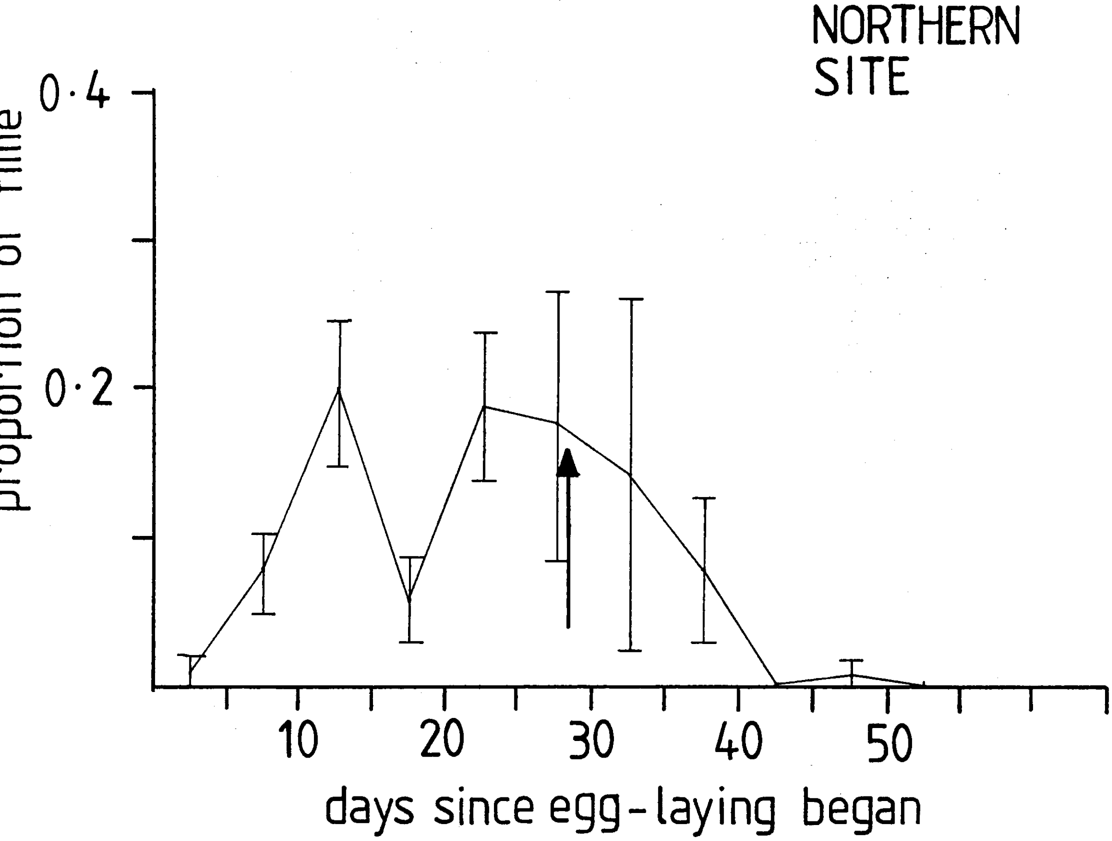
Birds can regulate their temperature by changing their position with regard to their environment either by making use of shade or by facing into the prevailing wind (Lustick et al. 1978). They may also alter the rate at which they exchange heat with the environment, either by exposing flesh to the breeze, by evaporation or by trapping air within their feathers as a form of insulation. When incubating Audouin´s gulls were exposed to sharp cold winds they sat tightly with their heads tucked in, thus reducing the surface area available for heat loss and fluffed out plumage to trap air. In contrast, birds incubating when temperatures were high adopted a range of activities and postures. Under mild heat stress birds, whilst incubating, were seen to raise their scapulars. As temperatures rose birds began to gape and extend their necks. At still higher temperatures birds exhibited gular fluttering and raised the feathers on their nape and crown, often with wings drooped and tail raised. Exposed to very high temperatures incubating Audouin´s gulls were also seen to stand in the nest with wings held away from the body.

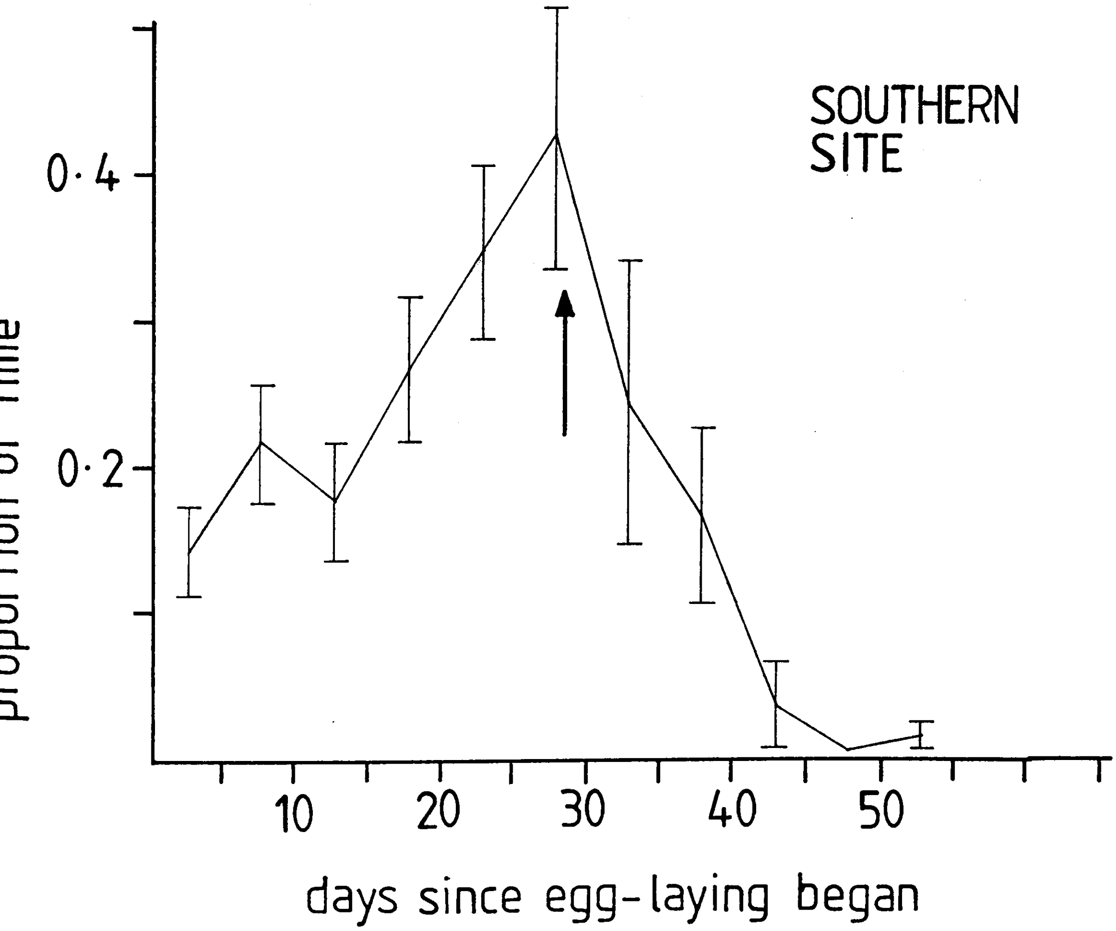
Thermoregulatory behaviour occurs in response to the immediate weather conditions and their effect upon the temperature of the adult and the egg/s. As these vary greatly during the incubation period, and from one season to the next (see appendices 2,3 and 4), no clear pattern emerges. However, as the embryo develops it itself becomes a source of warmth. Baerends and Drent (1970) report that after the fourteenth day of incubation, the temperature of herring gull eggs rose above nest temperature. Therefore, assuming that Audouin´s gull physiology does not differ markedly from the herring gull, on the Chafarinas, where temperatures are generally high (see Appendices 2-4), one might expect that, as the embryos develop and as the increasing temperatures of the summer advance, incubating birds will have to work harder to keep egg temperatures at the optimum for embryo development. Figure 6.4 indicates the proportion of time during hidewatches, at both sites in 1983, for which incubating birds showed patterns of behaviour associated with temperature control. As mentioned in section 6.2, watches were always made during the cooler parts of the day, the first three hours after sunrise and the three hours preceding sunset, so this figure represents the lowest level of thermoregulatory behaviour required during these days. It does however illustrate an overall increasing trend in the proportion of time spent thermoregulating during the incubation period from when the chicks were first laid until after the chicks hatched. Although there is a general increase in the proportion of time spent thermoregulating after egg laying, a difference was found in the proportion of time spent thermoregulating at the two sites in 1983 during the incubation period. At the southern site thermoregulation was much more frequent and increased steadily in frequency during the latter half of the incubation period, see Figure 6.4. This was probably due to the location of the southern site on a sheltered gentle slope as compared with the elevated breezy situation of the northern site.

Once chicks were a few days old, the proportion of time during watches when the adults were seen to thermoregulate

Figure 6.4 The mean proportion of time (± 1 s.e.) per hide watch at study sites in 1983 that either adult on the nest territory spent thermoregulating (panting, gaping, raising scapular feathers etc). Sample size of 3 hr. watches at a nest; north = 284, south = 303. x-axis is the number of days since laying began at a particular nest.

1983


NORTHERN SITE
0·4
0·2
10
20
30
40
50
days since egg-laying began


SOUTHERN SITE
0·4
0·2
10
20
30
40
50
days since egg-laying began

decreased markedly, see Figure 6.4. This was in part due to the fact that the adults no longer had to regulate the temperatures of the eggs or chicks (apart from when they were newly hatched) but was to a greater extent due to the relaxation of their commitment to remain in the vicinity of the nest. Hot birds could position themselves as they wished to reduce the heat stress (Lustick et al. 1978).

6.6 DISTURBANCES DURING INCUBATION AND THEIR EFFECT.

When temperatures were high Audouin´s gulls appeared to regulate their temperature and that of their clutch by increasing their rate of heat loss. Throughout the incubation periods Audouin´s gulls were noticeably flighty. Man´s approach generally resulted in desertion of the area, the birds taking up to half an hour to return (the exceptional period was that closely preceding and following hatching when adults effected shallow dives over intruding humans and during very high winds). When herring gulls approached the nesting area the reaction of the adult Audouin´s gulls in the loosely aggregated nesting areas was abandonment of the nests. Nests were only defended by mobbing birds in densely colonized areas where it was possible for large numbers of Audouin´s gulls to react together. This fleeing response meant long absences from the nest and eggs or chicks. If the adults left the nest on a hot day the eggs became warmer. This readiness with which Audouin´s gulls can be disturbed from their nests presented serious problems not only for the eggs and chicks but also for the observer wishing to minimize their impact upon the birds´ breeding success. (For this reason visits to the colony were kept as short as possible and restricted to the coolest parts of the day - see section 6.2).

6.7 AGGRESSION AND NEST DEFENCE

In comparison with many other Larus species, Audouin´s gulls are not aggressive birds. Territorial disputes, even during nest building, generally took the form of threatening postures - aggressive uprights - and only very infrequently developed into physical contact being made and even that took the form of very deliberate and protracted holding of one individual´s wing or tail feathers by another, see Plate 6.1. This was in marked contrast to the frequent and violent confrontations between yellow legged herring gulls nesting within view.

Aggressive behaviour was so rarely observed during hide watches that the median values for the frequency distribution of aggression rates (aggression rate = the number of aggressive acts by either member of pair per minute during hide watches) in 1983 for each sex class were 0, both pre and post hatching.

The mean values for the rates of aggression shown by pairs during hidewatches at both sites in 1983 are shown in Table 6.2. In three of the four cases the standard deviation is greater than the mean, suggesting over-dispersion of the data. This is the result of the clumping of values around zero.

TABLE 6.2: THE OVERALL MEAN RATE OF AGGRESSION SHOWN BY AUDOUIN´S GULL PAIRS (i.e. both sexes considered) ATTENDING NEST TERRITORIES AT STUDY SITES IN 1983. The rate is expressed as the number of aggressive acts per minute that either adult was present. Status 1 refers to the incubation period. Status 2 refers to the chick rearing period.

SITE	STATUS	SAMPLE SIZE	MEAN AGGRESSION RATE	STANDARD DEVIATION
NORTH	1	239	0.0325	0.1411
NORTH	2	46	0.0407	0.1218
SOUTH	1	433	0.6570	0.2769
SOUTH	2	223	0.1334	0.1876

To examine the influence of seasonal trends upon the aggression rates of breeding pairs correlation coefficients were calculated for the pre- and post-hatching periods at both sites in 1983 (see Table 6.3). In only one case was a significant effect observed. At the northern site in 1983 the rate of aggression shown by

Plate 6.1 Aggressive behaviour in Audouin´s gull - a typically slow interaction with much looking away from the aggressor and aggressive upright threats.

nesting adults during observation periods decreased as the incubation period progressed. Distances to nearest nesting Audouin´s gull pairs were significantly less at the northern site in 1983 as compared with distances between southern site nests (df=98, t=-5.667, significant at P <0.0001). It is therefore possible that the initially high rates of aggression at this site were associated with territory establishment within the densely packed study site (see Section 8.6).

TABLE 6.3: CORRELATION COEFFICIENTS BETWEEN THE TOTAL RATE OF AGGRESSION SHOWN BY AUDOUIN´S GULL PAIRS (i.e. both sexes combined) AT STUDY SITES IN 1983 AND THE NUMBER OF DAYS SINCE LAYING BEGAN AT THEIR NESTS. Status 1 refers to the incubation period. Status 2 refers to the chick rearing period.

SITE	STATUS	N CASES	CORRELATION COEFFICIENT	SIGNIFICANCE
NORTH	1	239	-0.18848	0.00172
NORTH	2	46	0.17223	0.12620
SOUTH	1	433	-0.06974	0.07371
SOUTH	2	223	-0.05546	0.20493

In order to compare the levels of aggression between the sexes, the sites and pre- and post-hatching, the aggression rates of the different classes were compared using the Mann-Whitney U Test, see Tables 6.4a, 6.4b and 6.4c.

TABLE 6.4A: A COMPARISON, USING MANN-WHITNEY U TEST, OF THE OVERALL MEAN RATES OF AGGRESSION OF MALE AND FEMALE AUDOUIN'S GULLS, PRE- AND POST-HATCHING AT THE NORTHERN SITE 1983. Site 1 = North. Status 1 = Incubation Period, Status 2 = Chick Rearing Period.

SEX	SITE	STATUS	VS SEX	SITE	STATUS	N1	N2	U	SIGNIF.
MALE	1	1	MALE	1	2	233	49	5365	0.51
FEMALE	1	1	FEMALE	1	2	237	50	5688	0.66
MALE	1	1	FEMALE	1	1	233	237	27018	0.69
MALE	1	2	FEMALE	1	2	49	50	1175	0.73

At the northern site whilst comparing overall mean rates of aggression during hidewatches, there were no significant differences between the aggression rates of the sexes nor between the overall mean aggression rates for the pre- and post-hatching periods, see Table 6.4a.

TABLE 6.4B: A COMPARISON, USING MANN-WHITNEY U TEST, OF THE OVERALL MEAN RATES OF AGGRESSION OF MALE AND FEMALE AUDOUIN'S GULLS, PRE- AND POST-HATCHING AT THE SOUTHERN SITE 1983. Site 2 = South. Status 1 = Incubation Period, Status 2 = Chick Rearing Period.

SEX	SITE	STATUS	VS SEX	SITE	STATUS	N1	N2	U	SIGNIF.
MALE	2	1	MALE	2	2	401	188	27116	0.000
FEMALE	2	1	FEMALE	2	2	427	196	36594	0.012
MALE	2	1	FEMALE	2	1	401	427	84294	0.700
MALE	2	2	FEMALE	2	2	188	196	15292	0.004

At the southern site, a strongly significant difference was found between the overall mean rates of aggression before and after hatching for both sexes, see Table 6.4b. Aggression rates being significantly lower post-hatching than pre-hatching. This is probably due to the movement of the the chicks from the open nests to the relative safety of the bushes soon after hatching (see Section 7.3). This movement of chicks reduced the need for adults to defend their offspring from attacks from predators or neighbours.

TABLE 6.4C: A COMPARISON, USING MANN-WHITNEY U TEST, OF THE OVERALL MEAN RATES OF AGGRESSION OF MALE AND FEMALE AUDOUIN´S GULLS, PRE- AND POST-HATCHING AT BOTH SITES IN 1983. Site 1 = North, Site 2 = South. Status 1 = Incubation Period, Status 2 = Chick Rearing Period.

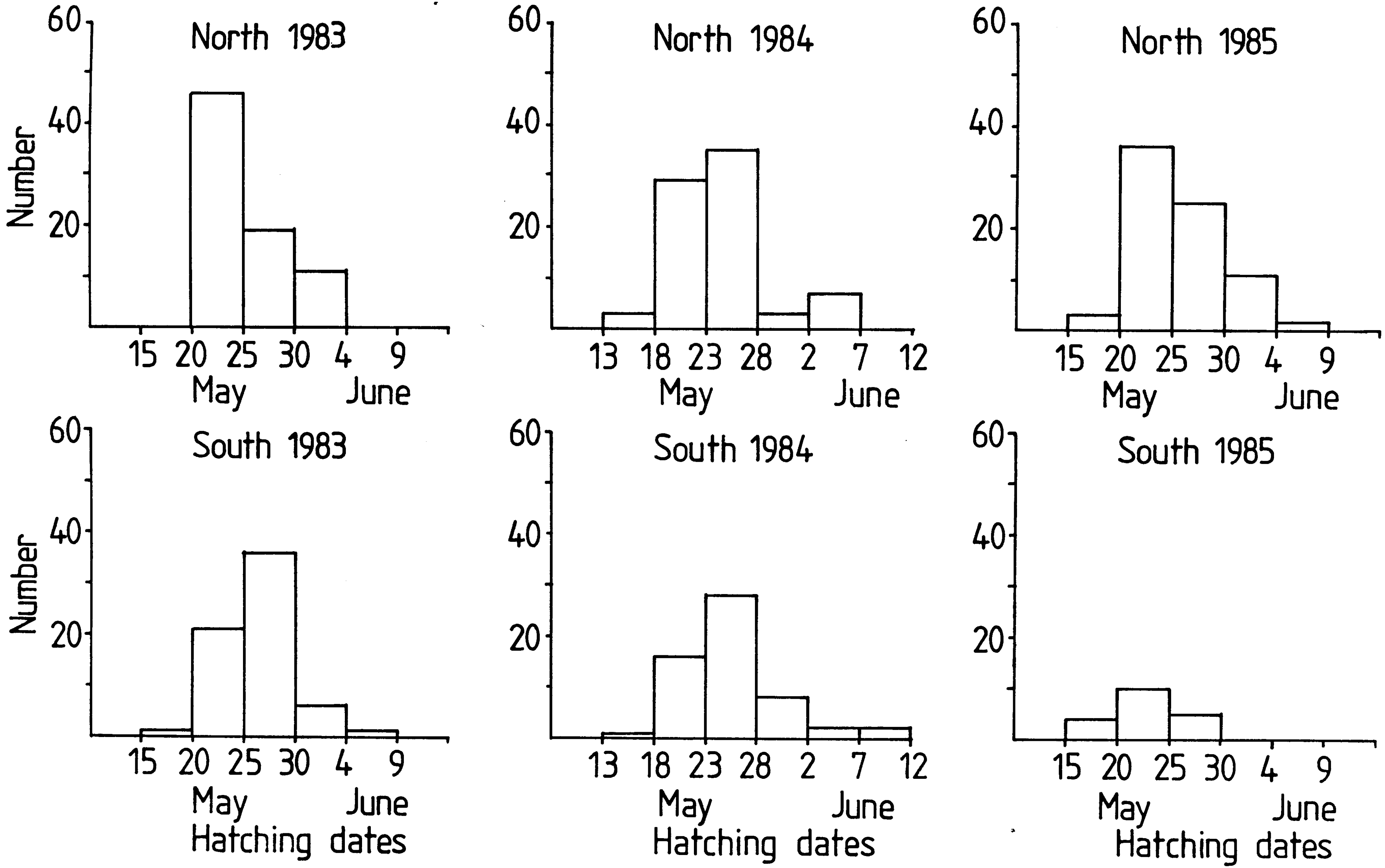
SEX	SITE	STATUS	VS	SEX	SITE	STATUS	N1	N2	U	SIGNIF.
MALE	1	1		MALE	2	1	233	401	46673	0.98
MALE	1	2		MALE	2	2	49	188	3604	0.020
FEMALE	1	1		FEMALE	2	1	237	427	50244	0.88
FEMALE	1	2		FEMALE	2	2	50	196	4443	0.308

During the incubation period no significant difference was found between the mean rates of aggression of either males or females at the two study sites, see Table 6.4c. Post-hatching rates of aggression of females were not significantly different whilst males at the southern site were shown to be significantly more aggressive than males at the northern site, see Table 6.4c.

6.8 THE ONSET AND DURATION OF HATCHING

During each of the three years of the study, hatching began during the second week of May. The first Audouin´s gull chicks hatched on the islands during the three study seasons, 1983 - 1985, on May 13th, May 11th and May 12th respectively. The pattern of hatching within the study sites is shown in Figure 6.5. Hatching occurred fairly synchronously at all sites. Hatching within a clutch was asynchronous, with the chick from the a- egg (the a- chick) hatching before the b- chick which hatched before the c- chick, see Figure 5.4.

Figure 6.5 The frequency distribution of the onset of hatching at nests in the study sites during 1983, 1984 and 1985.


North 1983
North 1984
North 1985
South 1983
South 1984
South 1985
Number
60
40
20
15
20
25
30
4
9
13
18
23
28
2
7
12
May
June
Hatching dates

Hatching occurred after an average of 29 days of incubation for the a-egg (26-33 days, n = 70), 27.5 days for the b-egg (26-31 days, n = 59) and 27·0days for the c-egg (25-30 days, n = 39, see Figure 5.4). Other reports of the length of Audouin's gull incubation periods are shown in Table 6.5.

TABLE 6.5: PREVIOUS RECORDS OF INCUBATION PERIODS FOR AUDOUIN'S GULL EGGS.

POSITION OF EGG IN THE CLUTCH	INCUBATION PERIOD (DAYS)	SAMPLE SIZE	SOURCE
a	29.8	11	Witt (1977b)
b	27.8	8	"
c	28.5	6	"
a	28.8	7	Juana and Varela (1979)
b	27.5	4	"

The outcome of this lack of synchronicity in the hatching within a clutch, in conjunction with the differences in the volumes of the eggs (see section 5.2) and the laying dates of the eggs, is that, for successful three egg clutches, it produces two chicks of similar size differing in hatching time by 0.5 day and one younger and smaller chick which is 2 and 1.5 days, respectively, younger than the other a and b chicks.

Hatching success per clutch was examined in relation to laying period, site and year using a three-way analysis of variance, Table 6.6. The data have been split into early, mid and late laying nests to examine the influence of laying date upon the hatching success (the details of the ranges of laying periods can be found in section 4.6).

TABLE 6.6: MEAN HATCHING SUCCESS PER AUDOUIN´S GULL CLUTCH IN RELATION TO LAYING PERIOD AND SITE FOR THE THREE YEARS OF THE STUDY (± 1 S.E). BASED ON 488 CLUTCHES. Hatching success is expressed as the mean number of chicks to hatch per egg laid.

		MEAN HATCHING SUCCESS (1 S.E.)		
YEAR	SITE	Laying Period		
		1	2	3
1983	NORTH	0.78 (0.05)	0.74 (0.05)	0.62 (0.13)
	SOUTH	0.77 (0.08)	0.78 (0.04)	0.64 (0.11)
1984	NORTH	0.73 (0.06)	0.66 (0.06)	0.65 (0.09)
	SOUTH	0.46 (0.09)	0.51 (0.05)	0.23 (0.09)
1985	NORTH	0.75 (0.06)	0.71 (0.05)	0.47 (0.08)
	SOUTH	0.61 (0.11)	0.22 (0.06)	0.00 (0.00)

Hatching success varied significantly in relation to each of the three variables (laying period $F=9.93_{2,\ 485}$, $P<0.0001$; site $F=33.74_{2,\ 485}$, $P<0.001$; year $F=16.94_{2,\ 485}$, $P<0.001$). Hatching success was highest early in the season (i.e. period 1) and lowest during period 3, see Table 6.6. Hatching success per brood was also higher at the northern site than at the southern site and highest in 1983 and lowest in 1985, see Table 6.6. The only significant interaction occurred between site and year ($F=12.88$, d.f. = 2, $P<0.0001$). However whilst the degree of difference between the sites varied between years (being greatest in 1985, see Table 6.6), the direction of the difference was the same in all three years with the northern site having a consistently higher success than the southern, see Table 6.6.

All clutch sizes were not found to produce, on average, the same number of chicks per egg, see Table 6.7.

TABLE 6.7: HATCHING SUCCESS RELATED TO CLUTCH SIZE AT SITES IN 1984. THE NUMBER OF CHICKS EXPECTED IS BASED ON AN ASSUMPTION OF AVERAGE PRODUCTIVITY (0.69 chicks/egg). n = the number of clutches.

SITE	CLUTCH SIZE	n	NO.OF CHICKS EXPECTED	OBSERVED NO. OF CHICKS	NO.OF CHICKS HATCHED PER EGG
NORTH	1	7	4.8	3	0.4
	2	10	13.8	16	0.8
	3	67	138.7	142	0.7
	4	2	5.5	2	0.2
SOUTH	1	23	11.9	2	0.1
	2	18	18.6	17	0.5
	3	53	82.3	94	0.6
	4	3	6.2	6	0.5

for the northern site in 1984 $X^2 = 3.36$, d.f.= 3, $P<0.5$, n.s.
for the southern site in 1984 $X^2 = 10.03$, d.f.= 3, $P<0.02$, sig.

In each case hatching successes for clutches of 1 and 4 eggs were lower than would have been expected if all clutch sizes were equally productive. Appendix 8 includes the data for other years and sites. In five out of six comparisons of the hatching successes of three egg clutches with those of two egg clutches, the three egg clutches realized the higher hatching success. When this was tested statistically by X^2 with Yate´s Correction for Continuity (Seigel 1956) the difference in hatching success between three egg and two egg clutches was never significant.

Within three egg clutches the third egg was generally the least likely to hatch, see Table 6.8. At both sites there was a significant difference in the proportions of eggs hatching, between the eggs in the different positions within the clutches, although no significant difference was found between sites. In the Northern site in 1985 there was a significant difference between the a, b, and c eggs in the proportion hatching, the c-eggs hatching less frequently than did the other eggs (X^2 for North 1985 = 10.74, d.f. = 2, $0.01 < P < 0.001$). However, at the heavily predated southern site in 1985 no significant difference was found.

TABLE 6.8: COMPARISON OF HATCHING SUCCESS OF a-, b- and c- EGGS IN 3-EGG CLUTCHES IN 1984.

EGG	NORTH		SOUTH	
POSITION	total number of eggs (%)		total number of eggs (%)	
	hatching	not hatching	hatching	not hatching
a	50 (72%)	19 (28%)	35 (64%)	20 (36%)
b	54 (78%)	15 (22%)	41 (75%)	14 (25%)
c	40 (58%)	29 (42%)	23 (42%)	32 (58%)

X^2 for North = 7.11, d.f. = 2, $0.05 < P < 0.01$
X^2 for South = 12.72, d.f. = 2, $0.01 < P < 0.001$

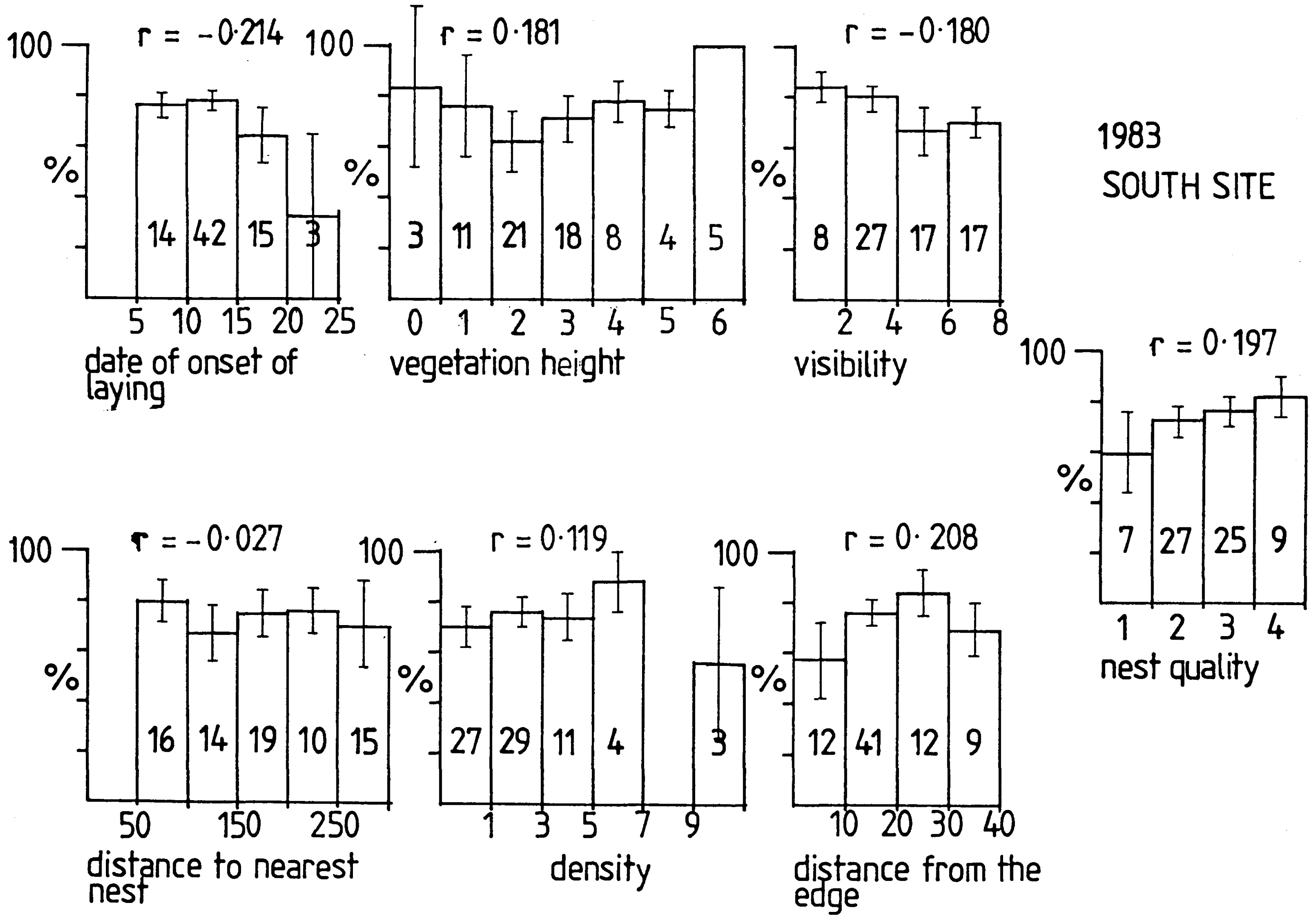
6.9 HATCHING SUCCESS IN RELATION TO ENVIRONMENTAL FACTORS

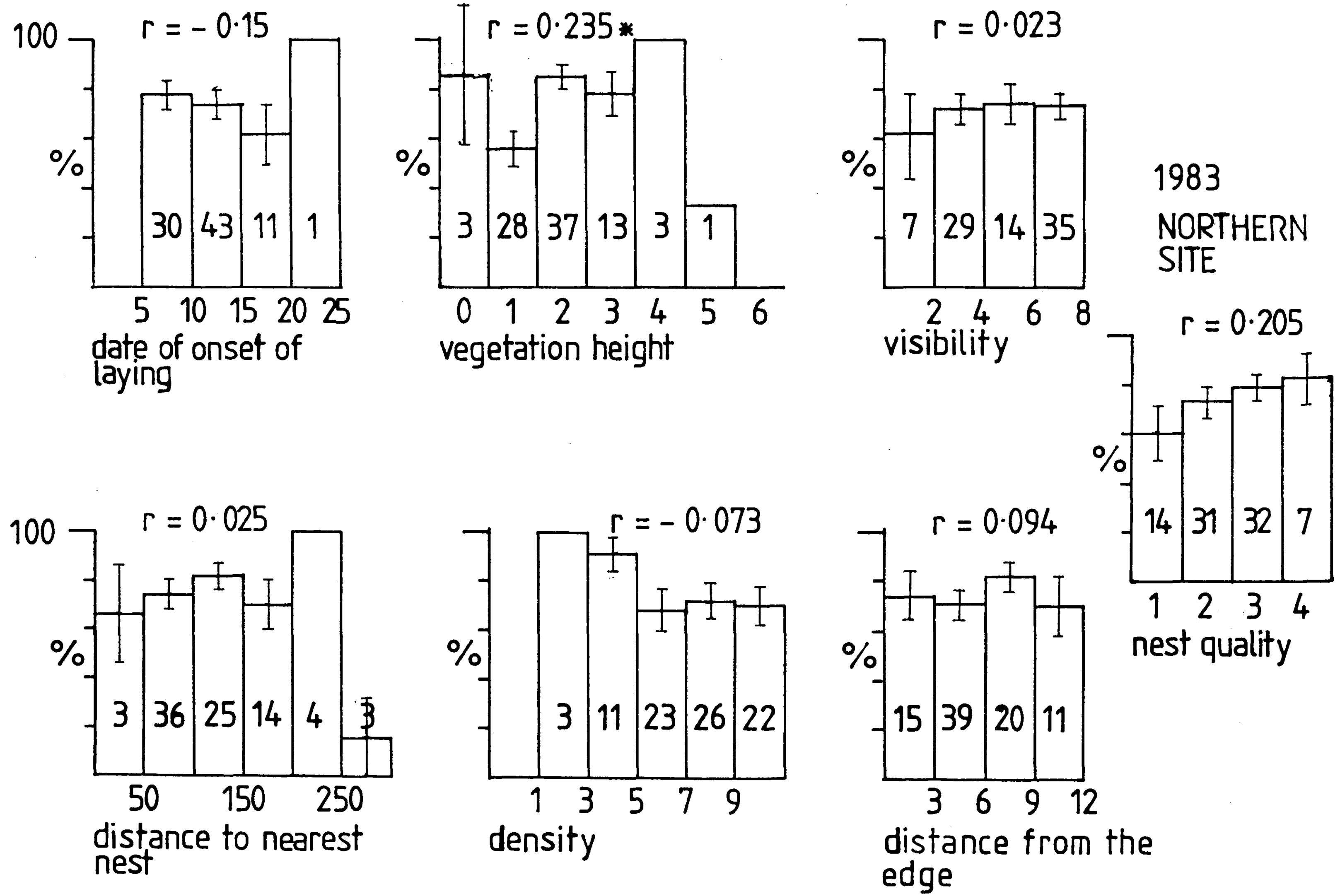
Figures 6.6 and 6.7 indicate the variation in the percentage of eggs per clutch to hatch from nests in the study sites in 1983 in relation to various environmental factors. Section 3.6 describes how variation in each of these factors was measured. 1983 has already been described as the year in which predation by herring gulls made the least impact upon hatching success in the Audouin´s gull colony. Appendices 5, 6 and 7 show the influence of the same factors on hatching success in 1984 at both sites and in 1985 at the northern site. From these figures some trends are identifiable.

Although the overall correlations (which were calculated using the original data) are generally insignificant, hatching success tends to decline as the season progresses when the data are divided into early, middle and late, see Section 6.8. The height of vegetation surrounding the nest had a significant effect on hatching success at the northern site in 1983. As discussed in Section 6.5, the poorer success of sites with low vegetation was probably due less to over-exposure to heat through

Figure 6.6 The variation in hatching success in relation to environmental factors at the southern site in 1983 (number of nests = 74). Hatching success is expressed as the percentage of eggs laid in a nest which hatch. For a description of the mode of measurement of the environmental variables see section 3.6.

Figure 6.7 The variation in hatching success in relation to environmental factors at the northern site in 1983 (number of nests = 85). Hatching success is expressed as the percentage of eggs laid in a nest which hatch. For a description of the mode of measurement of the environmental variables see section 3.6.


1983
SOUTH SITE
100
%
r = −0·214
14
42
15
3
5
10
15
20
25
date of onset of laying
r = 0·181
3
11
21
18
8
4
5
0
1
2
3
4
5
6
vegetation height
r = −0·180
8
27
17
17
2
4
6
8
visibility
r = 0·197
7
27
25
9
1
2
3
4
nest quality
r = −0·027
16
14
19
10
15
50
150
250
distance to nearest nest
r = 0·119
27
29
11
4
3
1
3
5
7
9
density
r = 0· 208
12
41
12
9
10
20
30
40
distance from the edge


1983
NORTHERN SITE
100
%
r = - 0·15
30
43
11
1
5
10
15
20
25
date of onset of laying
r = 0·235*
3
28
37
13
3
1
0
1
2
3
4
5
6
vegetation height
r = 0·023
7
29
14
35
2
4
6
8
visibility
r = 0·205
14
31
32
7
1
2
3
4
nest quality
r = 0·025
3
36
25
14
4
3
50
150
250
distance to nearest nest
r = - 0·073
3
11
23
26
22
1
3
5
7
9
density
r = 0·094
15
39
20
11
3
6
9
12
distance from the edge

lack of shade but more to exposure to neighbours and increased aggression, see Section 6.7. At the other site and in other years such a trend not apparent. In retrospect the height of vegetation cover is probably a less relevant measure than the amount of shade or barrier to vision that the vegetation provided.

In 1983 the degree of visibility, from the incubating adult´s viewpoint, appeared to have little bearing upon the hatching success of the clutch. In 1984 and 1985 however hatching success did seem to be effected by both a very open nest with visibility through more than 360° and by enclosed conditions with visibility through less than 90° from the nest. The first may increase thermoregulatory problems and may leave the nests obvious to predators; the second may mean that the nest is in dense bushes which will separate nests producing low nesting densities which are less effective at allowing adults mob predators.

The effect of nesting density is also shown in the figures. In 1983, when antipredator responses were not quite as crucial as in 1984 and in 1985, hatching success tended to be greatest at the lower densities and lowest at high densities, but the difference was not found to be significant. In 1984 at the southern site and in 1985 at the northern site, where predation pressures were high, hatching success tended to be greatest at the higher densities, although not significantly. In 1984 at the northern site, no trends was discernible.

Neither the distances to the nearest neighbouring nest nor to the edge of the colony were found to have great bearing upon the hatching success.

The quality or the extent of the development of the nest structure was also scored on an arbitrary scale from 1 - 4 (1 representing a bare scrape, as shown in plate 6.2; 4 representing one of the few deeply lined well defined bowl shaped nests). Fewer eggs appeared to hatch in the poorly constructed nests but in no year at any of the sites was an apparent correlation between nest quality and hatching success found to be

Plate 6.2 An Audouin´s gull nest at the northern site consisting only of a bare scrape. Chicks remained within this particular nest for less than two days after hatching,

significant.

The influence of environmental factors on whether a nest failed totally or produced young is considered in detail in Chapter 8.

6.10 DISCUSSION

The duration of the incubation period for Audouin´s gull clutches approximates to that calculated during other studies. Witt (1977) also found the hatching interval between the a- and the b-egg to be shorter (0.8 days) then the interval between the b- and the c-egg. Brosset (1967) placed fresh Audouin´s gull eggs in an incubator and recorded that the eggs required 30-31 days of development before hatching. Makatsch (1968) measured an incubation period of 21-25 days, with incubation not beginning until the second, and sometimes not until the third egg, was laid.

During the incubation period both adults appeared equally involved in caring for the eggs. One adult was almost always present on the nest although attendance was reduced slightly immediately preceding hatching. Baerends (1959) observed the same pattern for the herring gulls and Burger (1974) the same for Franklin´s gull. The reduction in attentiveness immediately prior to hatching may be explained by Baerends and Drent´s (1970) demonstration that, for herring gulls, the heat produced by the embryo is positively correlated with the weight of the developing embryo. On the Chafarinas Islands the problem for the incubating adults, which were observed only during the day, was more commonly keeping the temperatures below those of the air. Increased heat production by the embryo would therefore necessitate further effort on the part of the adults to maintain temperatures at the level suitable for normal development. Another possibility is a change in the motivational state of the adults, perhaps due to the feedback from the almost fully developed embryos, in preparation for brooding behaviour.

During each season there were cold, wet periods followed by very high temperatures (see Appendices 2,3 and 4). Through incubation the adults attempted to maintain the temperature of the eggs within the range of temperatures suitable for development. During cold spells the adults sat very tightly, reluctant to move even at the start of a disturbance. Baerends (1959) found that under similar conditions herring gulls would barely rise to retrieve an egg from the rim of the nest. In 1970 Baerends and Drent recorded sitting spells for herring gulls as being significantly longer in wet weather than in dry. During warm weather there was great variation in the extent to which birds sat tightly, even leaving the nest unattended whilst they briefly left the colony area.

Under extremely hot and calm conditions birds were observed to stand in their nests thus breaking contact with the eggs. This standing in the nest is likely to occur only when the heat load upon the incubating adult is extreme, as the removal of the brood patch from contact with the eggs effectively stops the flow of information about the temperature of the egg to the adult. It has been stressed by many authors that the exposed and heavily vascularised feet of birds are very effective heat dissipators (Kilgore and Schmidt-Nielsen 1975, Baudinette et al. 1976). Standing in the nest would therefore allow the incubating birds to lose heat rapidly. Hand et al. (1981) found that incubating western gull adults at a colony in the Gulf of California, after minutes standing over eggs, stopped panting for several minutes. At such high temperatures at which birds stand in the nest it would therefore appear that birds override the stimuli mediated by the sensory receptors in the brood patch and higher priority is given to the adult´s well being. As was shown by Bartholomew and Dawson (1979) this form of behaviour when heat stressed is not found throughout the Larus genus.

Nests with high insulation properties reduce the rate at which heat is gained or lost. Audouin´s gulls´ nests are, in general, loosely built assemblages of small amounts of plant material and feathers which are unlikely to offer much resistance to temperature change (see section 4.4). It is therefore very much up to the adults to select a site with some cover to provide shade and shelter from strong winds and for them to co-ordinate incubation behaviour between the pair.

It was observed that birds incubating eggs in nests which were shaded by vegetation appeared less affected by high temperatures than those totally exposed to direct sunlight. Although there was a tight coupling of thermoregulatory behaviour and environmental thermal conditions, it was observed that these differences in the grade of the response to overheating depending on the position of the nest with regard to their immediate environment. Experiments were designed, in 1984, to test the effect of having shade by furnishing test nests with artificial cover (see plate 6.3). Adults whose nests acquired artificial cover at the onset of incubation continued to incubate and hatched clutches successfully. Unfortunately a comparison of the hatching success of these nests with control nests was invalidated by another factor, that of predation, becoming the greater determinant of hatching success (see section 9.5).

Interruptions of the incubation period lead to changes in the temperature of the egg. The probability that the effect is injurious increases with the duration of the disturbance, the extent of the change in temperature and the age of the embryo. Baerends (1959) states that temperature changes affect the egg more after the allantois has taken over the respiratory function from the yolk sac than before. Without body contact between the adult and the eggs, when the ambient temperature is high, the eggs heat up. If there is a risk of the temperature of the eggs rising above the level at which the embryos can be damaged it would seem that the adults, if they are not going to expose themselves to high risks, would be most productive if they stayed with the eggs as long as possible and, if disturbed, should return as soon as the danger has passed. Bartholomew and Dawson (1979) observed that Heerman´s gulls, incubating under heat stressed conditions sat very tightly in their nests neither standing over the eggs nor leaving them when disturbed. White-winged doves nesting in the peripheral branches of trees and cacti, in places that receive intense solar radiation, never break contact with their eggs, apart from changeovers of the incubators, once incubation has begun (Russell 1969). Other

Plate 6.3 Nests provided with artificial cover in order to examine the effect of shelter from sun upon breeding success.

studies have suggested that, where birds are breeding in difficult conditions, under stress due to high temperatures, the birds are reluctant to prolong absences from the nests even during disturbances (sooty tern, Howell and Bartholomew 1962; western gull, Hand et al. 1981).

Audouin´s gull embryos may be adapted to such temperature fluctuations as would result from these absences of the incubating adults and may not be at risk. The tolerance of the embryos of exposure to high temperatures for such periods might be tested if Audouin´s gulls were common enough to allow such experiments. Another possible explanation is that Audouin´s gulls´ strategy is to preserve the adults of reproducing age, a more valuable resource than an egg in terms of individual productivity. Although Audouin´s gulls´ response of leaving the nest unattended when disturbed may appear maladapted for a species which breeds under such conditions, Audouin´s gull is not unique. De Naurois (1959) records the desert-breeding grey-headed gull responding to disturbance in the same manner.

Although there is no evidence of embryos dying as a direct and sole consequence of exposure to heat, there is evidence of eggs and chicks dying due to cold exposure at night. In 1980, a fishing vessel moored off one of the sub colonies on Rey and spent a night there. No records exist regarding the duration of the adults´ subsequent absence from their nests, but directly as a result of this disturbance it is said that this site totally failed. Both young chicks and embryos at all stages of development died (de Juana and Varela 1980).

All clutch sizes were not equally successful at hatching. The literature and the observations made from the hides suggest that information about temperature is not the only feedback which the adults receive from the eggs (Tinbergen 1953). The adults inspect the eggs frequently during periods of resettling and make contact with the eggs via the brood patches during incubation. The apparent reduced hatching success associated with smaller and larger than average clutch sizes may be due, as some authors have suggested for other bird species, to the reduced or imperfect stimulus given to the incubating adult by having too many or too few eggs to match the number of brood patches which the bird develops (Baerends and Drent 1970). It may however be due to other factors, such as is suggested by the observations made on other species which have shown that it is the younger birds which lay the smaller clutches and that it is their inexperience that depresses the hatching success (Coulson and White 1959). Clutches of one egg were unlikely to be very successful as observations have shown that if the first egg was predated the adults rarely relayed (see section 5.8) but abandoned the nest altogether, perhaps moving to make another attempt at another site. In 1984 at the southern site many nests were abandoned after early predation by herring gulls. It was not clear if these birds renested at a late-forming sub-colony near the middle of Rey as none of these birds were individually marked. However, the delay in laying dates recorded for this site would support this theory.

Each of the eggs in a clutch of three did not have an equal chance of hatching. Parsons (1970) found that the lower success of the third herring gull egg to hatch could not be explained by size difference alone (as was shown in section 5.2 the herring gull c-egg, like Audouin´s gull c-eggs, is smaller than the other two eggs in the clutch). It has been suggested that c-eggs suffer from their position in the hatching sequence. Graves et al. (1984) theorised that the third egg is laid as a type of insurance; once the first two have begun to develop/hatch the attention given to the third egg is reduced. Unfortunately, time did not permit the systematic analysis of the stage at which the third Audouin´s gull egg died when it remained in the nest. Within the small sample of unhatched eggs which were tested (5) all but one had a well developed embryo. It is possible that they might have died of heat stress (Winnett-Murray 1979). This was likely as temperatures during the hatching period fluctuated widely (see appendices 2, 3, and 4). In 1984 and 1985 at three out of the four sites studied, the third egg was less successful at hatching than the other two eggs in three egg clutches. However at the southern site in 1985 there was no difference in the hatching success of the eggs in the clutches. This was due to the high percentage of eggs predated at this site by herring gulls (see section 9.5).

The three-way analysis of variance in hatching success in relation to laying period, site and year showed that hatching success varied in relation to the timing of breeding at both sites in 1983, 1984 and 1985. Variation in hatching success with season has been found in previous seabird studies (Gochfeld 1980, Harris 1980, Lloyd 1975); those breeding early in the season were generally those to have the greater hatching success, for a number of reasons. It may be due to the quality of the parents which lay late, since studies on other species have demonstrated that it is the young inexperienced birds which tend to lay late (Coulson 1966, Mills 1973). For Audouin´s gulls conditions may deteriorate for late breeding birds since they will have to cope with the extreme heat of the Moroccan summer. The relationship between hatching success and laying period may also be explained by social factors, by the change in stimuli given to the incubating adult if surrounded by brooding adults and growing chicks.

The analysis of variance also showed that the breeding site and year also had a significant effect on the hatching success of Audouin´s gulls during the seasons 1983-1985. Hatching success was consistently higher at the northern site as compared the southern site. 1983 was, overall, the year when hatching success was greatest and 1985 the least successful. Hatching success is dependent upon the successful completion of so many stages preceding it that it is not unexpected that the impact, of an environmental factor, taken in isolation is difficult to assess.

CHAPTER SEVEN: CHICK GROWTH AND SURVIVAL

7.1 INTRODUCTION

Audouin´s gull chicks emerge from the egg at least as dependent upon adult attention as in the pre-hatching period. They are semi-precocial, as defined by Nice (1962), being able to walk soon after hatching but remaining within the vicinity of the nest where they are fed by their parents. The chicks do not rely upon their parents solely for nutrition, but also, until various stages, for temperature regulation and defence. Indeed the survival of the chick and consequently the reproductive success of the nesting pair will largely be determined by the ability of the parents to switch quickly from the pattern of behaviour associated with incubation, to the repertoire necessary for the successful rearing of chicks.

The efforts of the breeding pair and the chick are not the only factors which determine the survival of the chick. The chick may have siblings with whom it may be in competition. There are also the risks of predation, inclement weather and interactions with the physical environment all of which have a part to play in the determination of the chick´s survival.

This chapter presents the data collected during three season´s periods of chick growth and discusses the factors affecting the breeding success and the suitability of the Chafarinas Islands, under current conditions, to accommodate the world´s most important colony of this rare species.

7.2 METHODS

7.2.1. Observation of behaviour

As described in section 3.10, the main body of the observations were made from within hides situated at the edge of each study site. Watches generally lasted for three hours at each site, each day, and took place in the early morning or in the late evening. For details of the data collected during hidewatches see Section 3.10. The data were analysed using non-parametric statistical programmes as described in Nie et. al (1975).

Identification of adults was facilitated by certain adults and many chicks wearing individual markers. Such markings were essential as a few days after hatching chicks left their nests and moved into the cover of the bushes making it impossible to identify families solely by their position within the colony. For details of adult and chick markings see Sections 3.12 and 3.13 respectively.

7.2.2 Measurement of chick growth

As described in section 3.14, each day during the chicks´ first two weeks, and later in the season every other day, one hour was spent at each site catching and measuring chicks. The same chicks were not caught each day for two reasons; firstly so as to increase the sample size; and secondly to attempt to minimize the stress experienced by the chicks. Chicks were always returned to the spot form which they had been lifted for measurement to minimize their disorientation. During the early weeks approximately twenty chicks could be caught and measured within the hour but this number fell to just over ten as the chicks became mobile and more awkward to handle. The chick´s weight was measured by suspending it from a pesola spring balance, of an appropriate size, whilst placed in a cotton bag of known weight. Cotton bags were found to be the most suitable receptacles in which to place the birds as plastic cones, although easier to keep clean, were hot, panicked the chicks and made contact with both the chick´s eyes. The chick´s wing length or wing chord was measured from the carpal joint to the end of the flesh of the longest developing primary wing using a wing-rule (this is an adapted ruler which has the wood before the zero removed and a piece of metal attached perpendicularly at that end, against which the wrist bone can be braced allowing a true reading to be made). The same person made all the wing length measurements whenever this was possible to avoid possible differences in technique leading to errors. Only the chick weights (± 1g) and wing lengths (± 1mm) were measured due to the time limit.

These data were entered as individual records on the University Mainframe computer (ICL 2976) accompanied by the following information:

a chick number (each chick in the study area was allocated one)
b position within the brood (1st, 2nd or 3rd hatched)
c site
d nest number
e laying and hatching dates of egg
f age at re-capture (± 0.5 day)
g whether the chick regurgitated before or after
h egg size
i weather conditions

7.2.3 Estimation of chick survival

All opportunities were taken to record the death or survival of chicks. Notes were made during hide-watches when identifiable adults or chicks were seen with offspring or siblings. The majority of checks were made during chick measuring sessions when, by searching different parts of the site, pockets of hiding chicks were encountered. Care was taken to examine any corpses for rings and to visit herring gull resting places, so that food pellets could be examined for remains and rings. A few family groups, once fully mobile, did move considerable distances from their nesting site. However, these were relocated during the general ringing programme which took place just before fledging began.

7.3 ADULT AND CHICK POST-HATCHING BEHAVIOUR

The first indications of changes in the adult behaviour, away from that typical of incubation, came on the day before hatching commenced in the nest. The incubating adult, sometimes accompanied by the off-duty bird, stood over the eggs for periods lasting up to five minutes. Looking at them, calling gently and rearranging the nest. After the first chick hatched, and the egg-shells had been removed, the adults continued to brood the nest at least until all the chicks had hatched and their plumage had dried out.

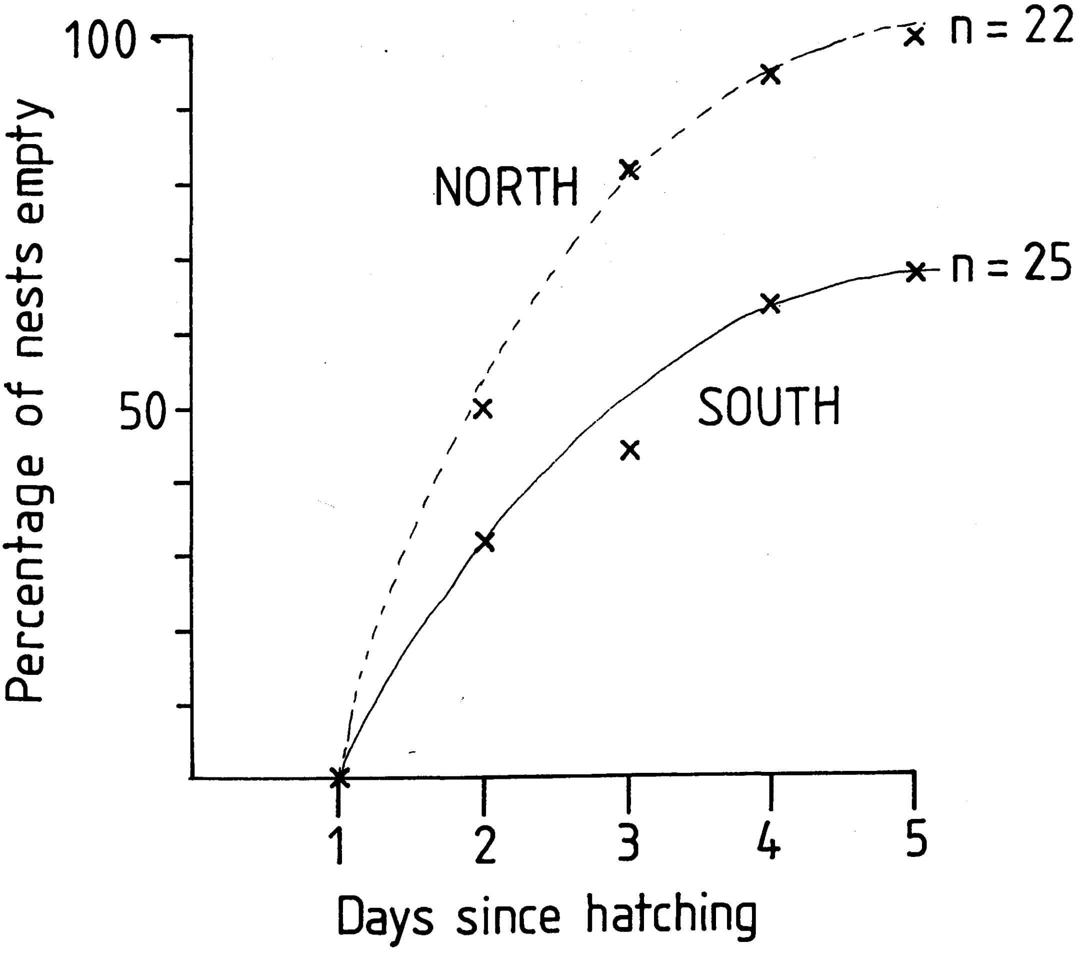
Like other gull chicks (Burger 1974), Audouin´s gull chicks are able to walk on the same day as they hatched. Some chicks within a day of hatching left their nests permanently, to hide in the nearby bushes. The amount of time spent at the nest after hatching appeared to depend on the nest´s proximity to cover, the amount of disturbance and the weather. There were differences between the two sites in the length of time spent by the chicks at the nest after hatching. During the daily site checks notes were made as to which chicks remained in their nests and whether or not they were accompanied by siblings. Figure 7.1 shows the pattern of nest abandonment at both sites in 1984 for the first five days post-hatching. There was a significant difference between the two sites in the proportion of nests abandoned over this five day period. Chicks at nests in the north site left their nests significantly earlier than those in the south (X^2 12.68, d.f. = 4, $0.01 < P < 0.05$). The same trend was observed for both other seasons. Chicks and adults at exposed nest sites left their nests and moved to bushes earlier than those at vegetated sites. This trend was also observed at control sites which were only very infrequently subjected to human disturbance.

The trip to cover often involved crossing other nest territories, leaving the chick open to attacks by defending adults. The run may also have exposed the chick to predators or have lead to it being lost or entangled in vegetation. These fates are discussed in later sections.

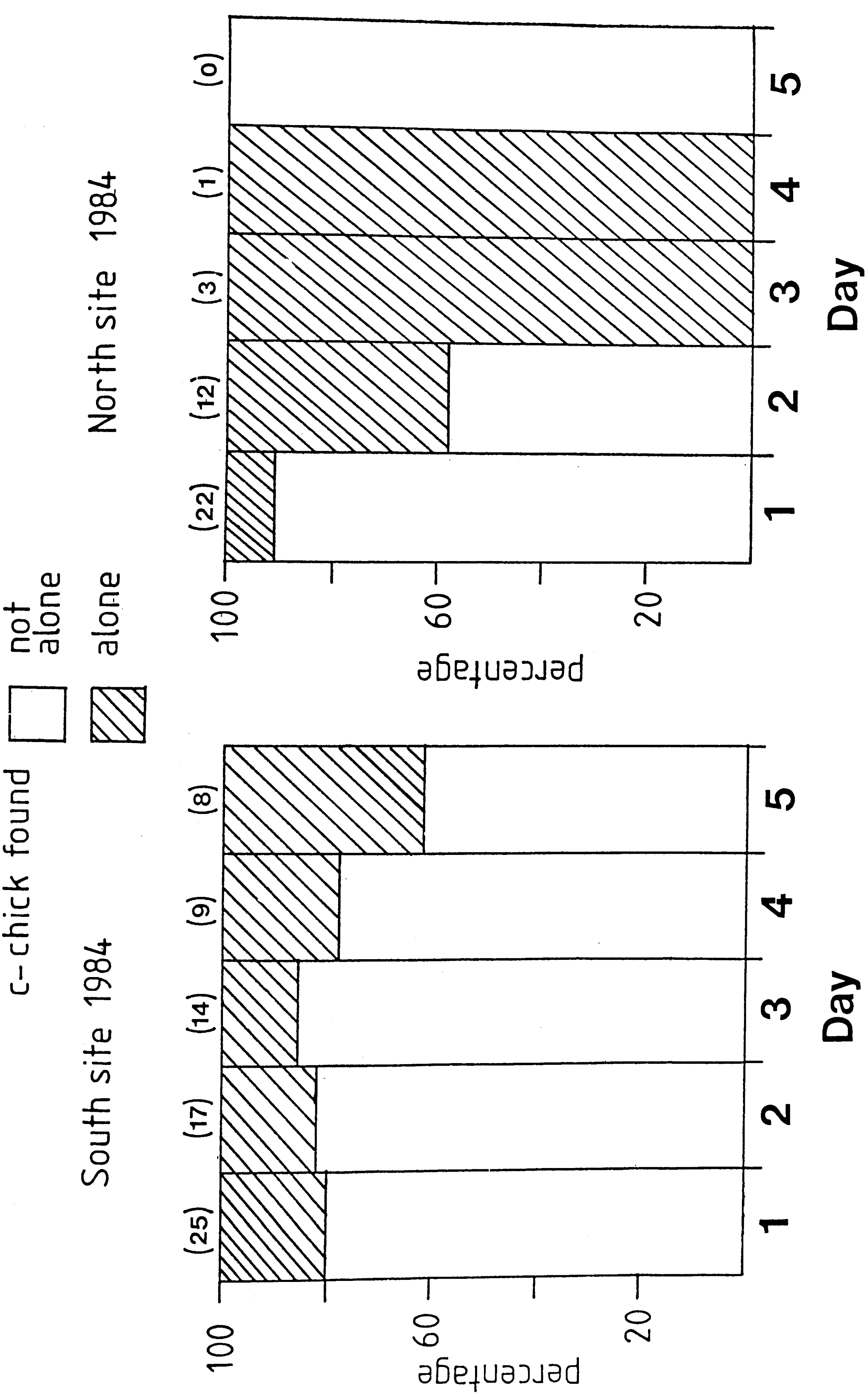
Eggs within a clutch do not hatch synchronously (see section 6.10). The b-egg generally hatches within 0.5 days of the a-egg. The c-egg hatches on average 1.5 days after the b-egg. Consequently, due the difference in ages between chicks within a brood, when the a- and perhaps the b-chicks were able to leave the nest the c-chick was still younger and smaller and could be left behind. Figure 7.2 suggests that this occurred more frequently in the north more than in the south. The figure shows, for a sample of nests with broods of three, the pattern of departure of chicks from the nests. For each day following

Figure 7.1 The pattern of nest abandonment at both study sites in 1984. n = sample size.

Figure 7.2 The percentage of nests which contained accompanied and unaccompanied c-chicks in relation to the number of days since hatching completed in the nest. Sample sites are shown within brackets. The Figure shows data collected at both study sites in 1984



100
50
Percentage of nests empty
NORTH
SOUTH
n = 22
n = 25
1
2
3
4
5
Days since hatching


c-chick found
not alone
alone
South site 1984
North site 1984
percentage
100
60
20
Day
1
2
3
4
5
(25)
(17)
(14)
(9)
(8)
(22)
(12)
(3)
(1)
(0)

hatching, the Figure shows the percentage of occupied nests which contained accompanied or solitary c-chicks. The a- and the b-chicks were never, in this study, recorded as being the last to leave the nest. At the 1984 southern site chicks stayed in the nest for longer than in the 1984 northern site and as a result the c-chick was less frequently left alone.

Those birds that did leave the nest apparently did so to gain shelter. The bushes provided cover from aerial predators and from intense solar radiation, from the time when nests were abandoned until the chicks had grown too large to hide in the bushes. Chicks spent all their time, apart from feeding and preening bouts, within the bushes. The adults therefore divided their time within the colony either loafing on the bushes within which the chicks were hidden or on the ground near the bush interacting with the chicks. The bushes, to a large extent, relieved the adults of the need to shade and defend the chicks so adult attendance fell off once the chicks had left the nest and had moved to the bushes (see Figure 6.1).

7.4 IDENTIFICATION AND ADOPTION.

One of the main problems associated with early mobility is loss of the nest as a focus of adult-chick communication. With the chicks leaving the nest at as early an age as 1 day old the adults need to have some means of relocating the chicks and gaining their attention. This appeared to be achieved by the adults landing on the bushes within which the chicks were hidden, and calling to the chicks within. The calls given were long-calls followed by mew-calls. Fortunately family groups generally reassembled within a single group of bushes and remained faithful to the bush, provided its cover was sufficient. Chicks remained within particular bushes even when they were being captured for measurement within that bush every other day. Once chicks were too large to remain within the bushes they reacted to alarms by becoming increasingly mobile, running in large flocks over the site.

Although infrequent, adoptions did occur within the study areas. Hidewatches allowed observations to be made as to whether an adult was regurgitating to an a-, b-, or c-chick or whatever combination of the former as chicks wore coloured Dymo plastic rings (a- yellow, b- blue, c- red). Only on two occasions were adoptions seen to occur when a pair continued to feed an extra chick. In one of the two cases, at the 1984 northern site, a 3-brood pair adopted another b-chick when it was two days old and their chicks were of a similar age. The other adoption occurred at the north site in 1985 when a 2-brood pair adopted a c-chick when it was very young. These adoptions took place in areas of high nesting densities, when the chicks were young and when the adults had chicks of a similar age to the chick that was adopted. Only these two instances of chick adoptions were recorded. It is thought that should there have been more cases of adoption they would have been noticed, if not during hidewatches, then during the site checks when sibling chicks, or chicks being fed by the same adults, were trapped together.

7.5 FEEDING

During the first three days chicks did not appear to beg in order to solicit food. Instead the attendant adult would give mew calls and begin to form a food bolus which it would then regurgitate. The food was held for the young chicks by the adult in its bill. If the chicks did not eat any or all of the food the adult would swallow the food. Infrequently the other mate would feed from the brooding adults bill making the same approach as was seen during the courtship period. After the first few days the chicks would beg for food from either member of the pair approaching them calling and pecking at the adults´ bills until either food was regurgitated or the adult moved out of reach. Generally, if food was to be regurgitated at all, few begging movements by the chicks were necessary in order for food to be produced. However, on some occasions chicks begged for extended periods making more than 30 pecks at the adults bill before the adults moved out of chick peck-range.

The type of food regurgitated to the chicks depended on the weather. Although there are few references in the literature to the lack of activity in Audouin´s gull colonies during high winds, it was clearly observed that during very high winds on the islands Audouin´s gulls spent very little time flying as they appeared to have little control of their flight under such conditions. Audouin´s gulls which attempted to fly were buffeted by the wind and forced to land in much less graceful fashion than normal. This reduced ability to fly was reflected by the absence or reduced quantities of marine food in the diet supplied to the chicks. Under prolonged poor weather conditions, as was the case for example between 20.5.83 - 23.5.83, chicks were entirely fed with grasshoppers and other insects. Under windy conditions the remains of small birds were also found in food pellets both during and outside the chick growth period.

When winds were not high and the sea was not rough Audouin´s gulls fed their chicks on marine animals, predominantly fish species and squid. During this study chick regurgitates were collected during the measuring period and studied for content and size. For example in 1984 eighty-one chick regurgitates were collected at the sites. The mean weight of these regurgitates was 14.4 g. (s.d. 10.9). The range of regurgitate contents is shown in Table 7.1.

Table 7.1: THE RANGE OF FOOD TYPES FOUND IN CHICK REGURGITATES COLLECTED ON REY ISLAND, 1983.

FISH	sardine	Sardinella pilchardus
	anchovy	Engraulis encrasicolus
	oblada (bream)	Oblada melanura
	red mullet	Mullus sp.
	bogue	Boops boops
	eel	Anguilla anguilla
	seahorse	Hippocampus guttulatus
CEPHALOPODS	squid	Sepia sp.
	octopus	Octopus vulgaris
INSECTS	grasshoppers	Acrididae sp.
	locust	Acrididae sp.
	beetle	Coleoptera sp.

The regurgitates were examined only to give an impression of the type of food which was fed to the chicks as a detailed study of the diet of Audouin´s gulls on the Chafarinas Islands has already been undertaken (Witt et al. 1981). All regurgitates contained fish and other marine animals, or they contained insects caught on land. Regurgitates containing the former were much more common than the later. No indications were found that chicks were being fed any plant matter or anything that suggested that adult Audouin´s gulls were feeding the chicks on the waste disposed of by the inhabitants of island into the sea or the fish detritus from the local fleets of fishing vessels or the Moroccan fishing village of Ras Kebdana. One adult Audouin´s gull was found freshly dead on the island of Rey in 1983 and was sent to the University of Glasgow for analysis and preservation. This gull´s stomach contained not only the otoliths of 3 fish but also the caudal vertebra and pygostyle of a relatively large bird, probably a chicken *Gallus domesticus*, which had been cooked (B. Zonfrillo, *pers. comm.*). This suggests that some of the adults may take waste from inhabited areas despite Audouin´s gulls never being seen taking waste either from the islands or villages. The closest Audouin´s gulls appeared to come to scavenging food was seen and photographed in 1984. During the day fishermen waiting for darkness, so as to be able to begin work again, would pass hours fishing with a hook and line from small rowing boats. They would circle a line with a hook above their heads and let the baited hook fall with a splash some distance from the boat. Audouin´s gulls were occasionally seen swooping in to catch the object making the splash as it fell beneath the surface. This may explain the recovery of two adult Audouin´s gull corpses found in the same year, 1984, dead on top of bushes. Fishing line, which was attached to their bodies, had become entangled with the jagged bushes. In general, however, Audouin´s gulls were found to feed their chicks on a primarily fish diet with insects being caught on land when conditions did not appear to allow them to fish.

Chicks were fed throughout the day. No observations were made of activities within the colony during the night (see Section 6.4). Chicks were found to regurgitate more frequently if handled in the early morning than in the evening. This may be associated with observations of mass movements of Audouin´s gulls between the breeding sites and the sea; many birds were seen to leave the island each evening. Large numbers of birds were also seen to approach the island of Rey in the early hours of morning. Those chicks caught in the morning may have been regurgitating food recently brought by the adults after nocturnal fishing. Unfortunately no observations could be made at dawn within the colony during this possible period of intense feeding.

During the rest of the day chicks were fed at a rate of around one feed per hour except for a short period following the hatching of the chicks when the feeds were at a higher frequency, see Figure 7.3. Figure 7.3 shows the frequency (± 2 s.e.) with which chicks were fed in relation to age. As the chicks grew older the frequency of feeds remained approximately the same. It is therefore likely that as the chicks grow older the parents deliver more food per feed.

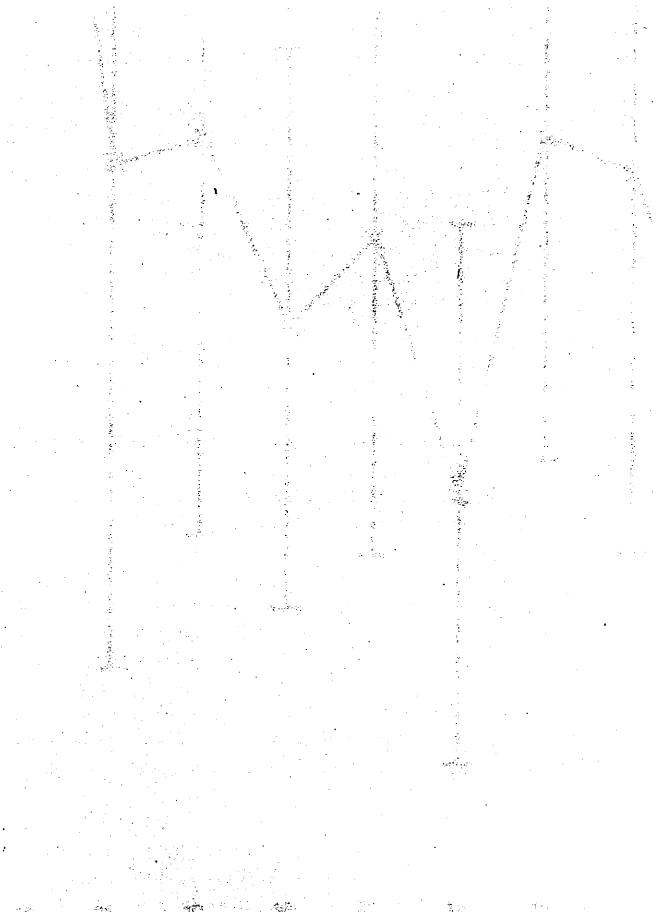
The next section addresses the question of whether there were differences in the weight gain and structural growth of chicks from different brood sizes and sites.

7.6 CHICK GROWTH

As described in sections 3.14 and 7.2.2, the weight and wing length of chicks of known age and identity were measured throughout the growing period. It was not known how much time had elapsed between the chicks last feed and their weighing; although this factor is likely to have some effect on the weights recorded, it was not practicable to make the observations necessary to correct for it. Weights were, however, generally taken either in the early morning or late evening.

When either the weight or wing length of chicks was plotted against their age the resulting curve tended to be s-shaped (see Figures 7.4 and 7.5). The growth of wings and increase in weight appeared, both for the group and the individuals, to occur relatively smoothly as opposed to a sporadically.

Figure 7.3 Mean feeding rates (± 2 s.e.) per chick by adults at the southern study site in 1984 in relation to chick age. Sample sizes are given above the x-axis.



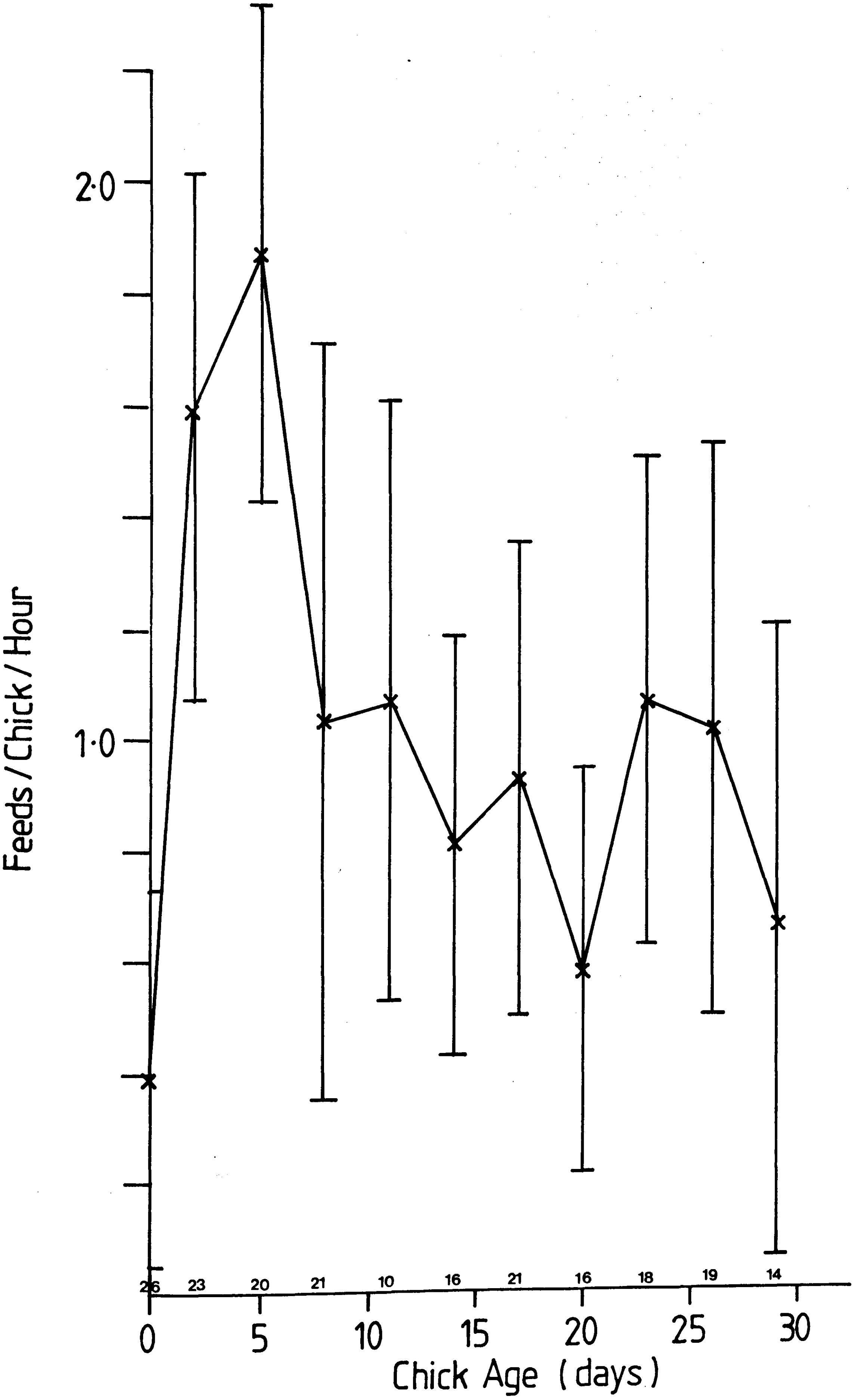
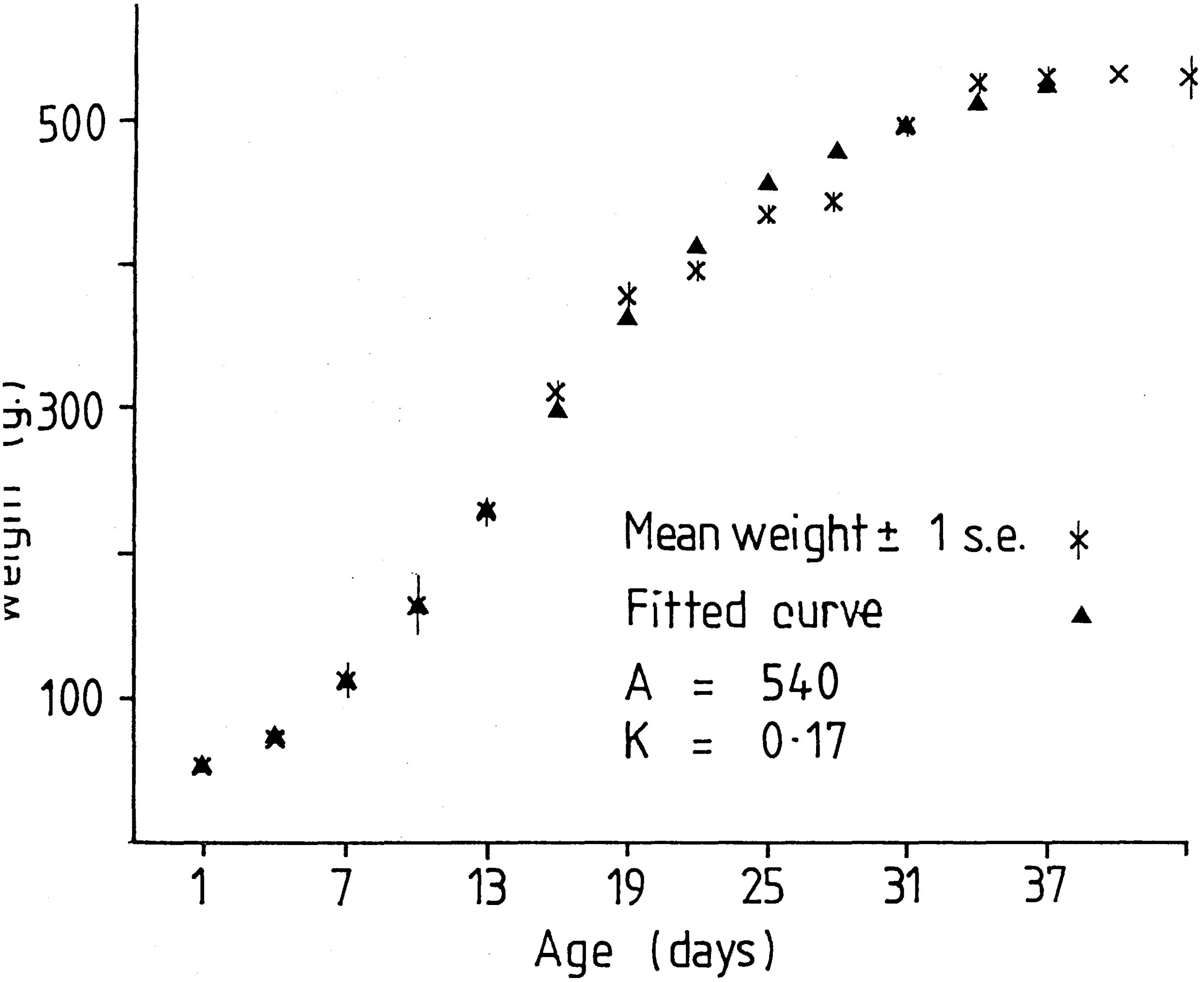
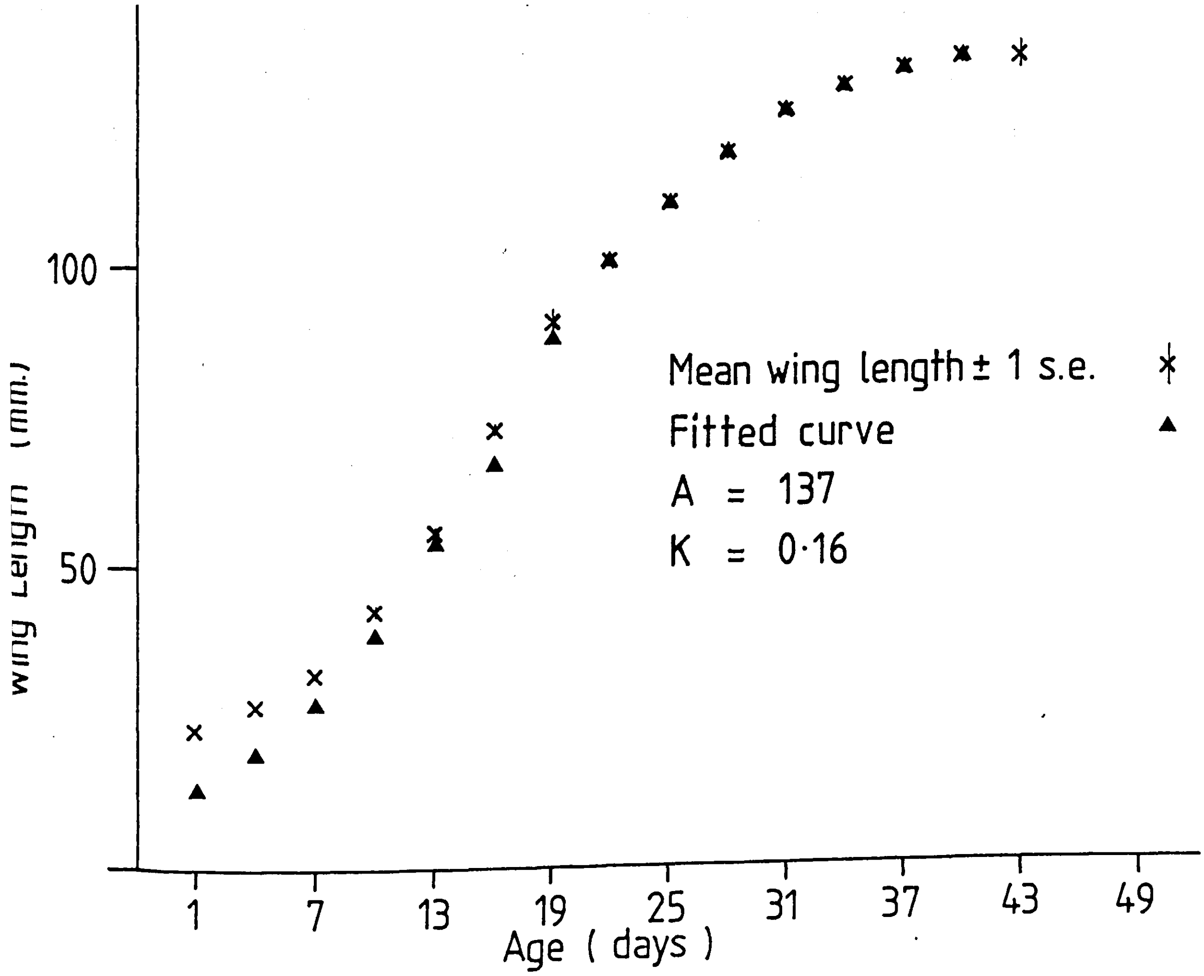

Feeds / Chick / Hour
2·0
1·0
26
23
20
21
10
16
21
16
18
19
14
0
5
10
15
20
25
30
Chick Age (days)

Figure 7.4 Weight increase curve for chicks at the northern site in 1983. The plot shows the mean weight (± 1 s.e.) for chicks of known age and the logistic fitted curve (see text).

Figure 7.5 Wing length growth curve for chicks at the northern study site in 1983. The plot shows the mean wing length (± 1 s.e.) for chicks of known age and the logistic fitted curve (see text).


500
300
100
1
7
13
19
25
31
37
Age (days)
Mean weight ± 1 s.e.
Fitted curve
A = 540
K = 0·17


100
50
1
7
13
19
25
31
37
43
49
Age (days)
Mean wing length ± 1 s.e.
Fitted curve
A = 137
K = 0·16

The data were found to be best described by the logistic equation, as opposed to the Gompertz or von Bertalanffy equations, where the absolute growth rate $dw/dt = Kw\ (1-w/A)$

when w = weight of chick
A = asymptote of growth curve
K = growth constant
t = time

For the method used to test the suitability of the logistic equation see Ricklefs (1967).

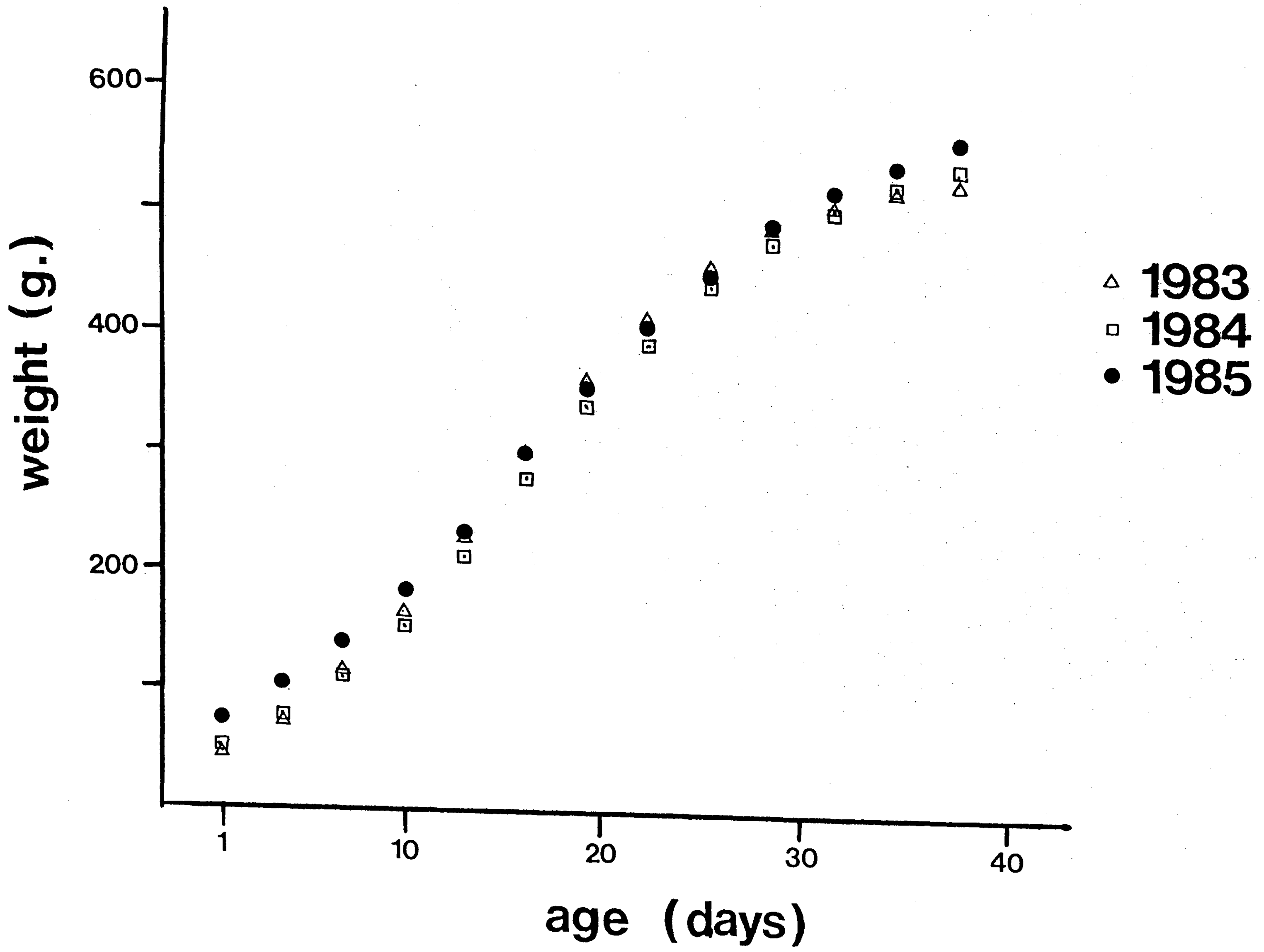
Using the conversion methods described by Ricklefs (1967) the curve can be converted into a straight line which allows the calculation of a K and A value and a means by which a single logistic curve can be drawn which represents the data for a class of chicks. Figure 7.6 shows the logistic curves for all chicks of northern sites for the three seasons of the study. A similar figure for southern sites cannot be drawn as there were too few chicks surviving at the southern site in 1985 for chicks to be further disturbed by catching for measuring purposes. Figure 7.7 shows the logistic curves for the chicks at the southern sites in 1983 and 1984. There was no difference between the two, and very little variation was recorded in chick weight. The weights of chicks of the same age were also compared between sites in the different years; no statistically significant difference was found between the cohorts' weights when the students t-test was applied, see Table 7.2.

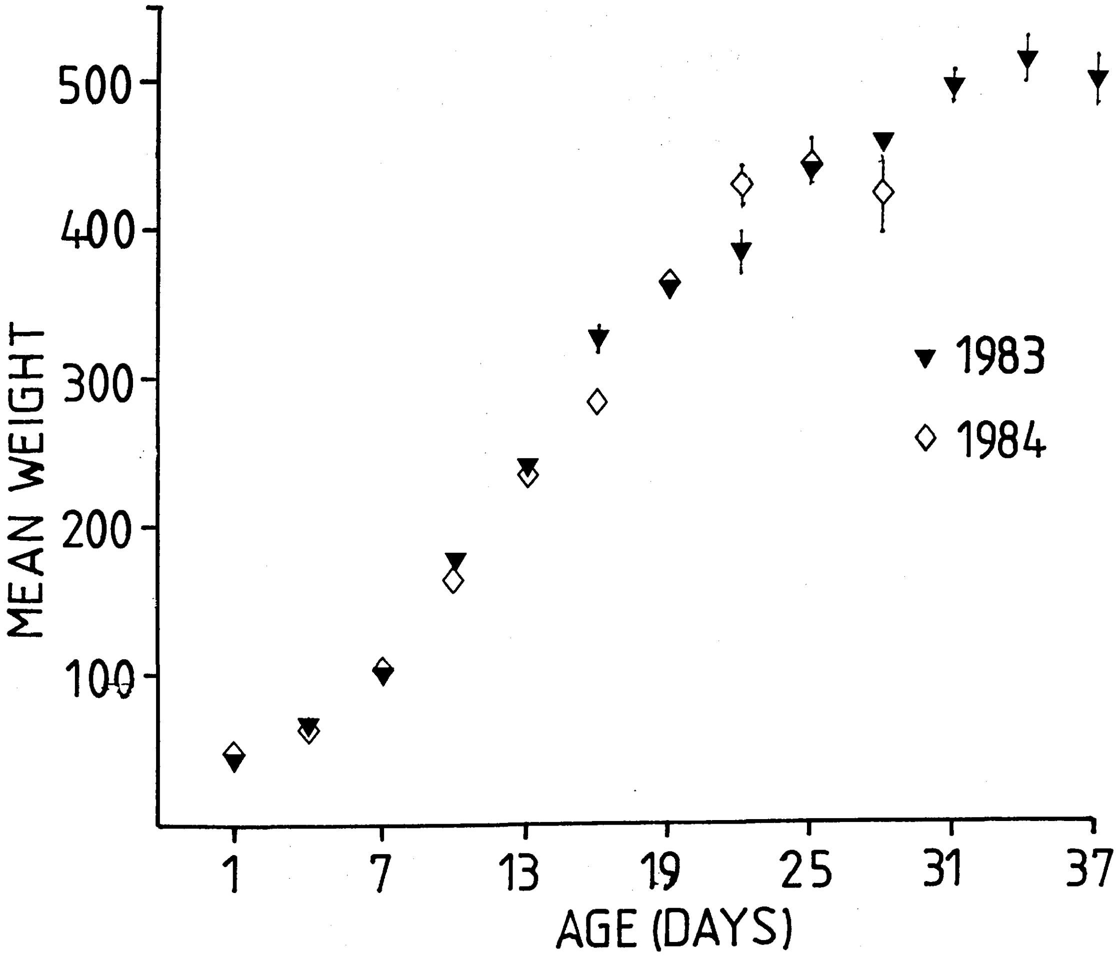
TABLE 7.2: A COMPARISON OF THE MEAN WEIGHTS OF 20 DAY OLD CHICKS AT NORTHERN SITES DURING THE THREE YEAR STUDY.

YEAR	MEAN WEIGHT (g)	S.D.	t	d.f.	sig.
1983	401.06	41.5			
			1.061	83	ns
1984	389.87	59.8			
			0.924	72	ns
1985	400.39	39.2			

Figure 7.6 Logistic growth curves fitted to weight increase data for all chicks at northern study sites during the three seasons 1983-1985.

Figure 7.7 Comparison of mean weight increase (± 1 s.e.) with age of chicks at southern study sites in the seasons of 1983 and 1984.


weight (g.)
600
400
200
1
10
20
30
40
age (days)
△ 1983
□ 1984
● 1985


500
400
300
200
100
MEAN WEIGHT
1
7
13
19
25
31
37
AGE (DAYS)
▼ 1983
◇ 1984

In 1983 there were no significant differences between the growth patterns of chicks from broods of three and two chicks, see Table 7.3 and Figure 7.8. Insufficient numbers of one chick broods prevented them from being included in the comparisons.

TABLE 7.3: THE GROWTH PATTERNS OF CHICKS AT BOTH SITES IN 1983. Where K = a growth constant and A indicates the value of the asymptote of the growth curve, see equation above.

	WEIGHT		WING LENGTH	
	NORTH	SOUTH	NORTH	SOUTH
K of all chicks	0.17	0.18	0.16	0.16
A of all chicks	540	520	137	135
K of broods of 3	0.16	0.18	0.16	0.15
A of broods of 3	545	520	135	136
K of broods of 2	0.16	0.16	0.16	0.16
A of broods of 2	540	540	135	135

This lengthy analysis was not repeated for other years as there were no indications from the general analyses that there were any changes in growth rates or any reason for the situation to have altered from that of 1983 with regard to brood size.

Due to the nature of the most common causes of chick mortality at the study sites (see section 7.8) differences in the patterns of growth for chicks which eventually died were not expected when compared with the population as a whole. However the data for 1984 was tested, see Figures 7.9 and 7.10. The figures consider the growth of the wings which gives an indication of the size and developmental state of chicks and is less sensitive to short term changes than chick weight. Figures 7.9 and 7.10 show that there was little difference between the size, at any point in time, of the chicks which were eventually successful or unsuccessful. There were no indications that chicks which died were smaller than the other chicks of the same

Figure 7.8 Comparison of mean wing length (± 1 s.e.) increase with age of chicks at the northern study site in 1983. Mean wing length growth of chicks from broods of 3 is shown against the growth curve for chicks from 2-chick broods.

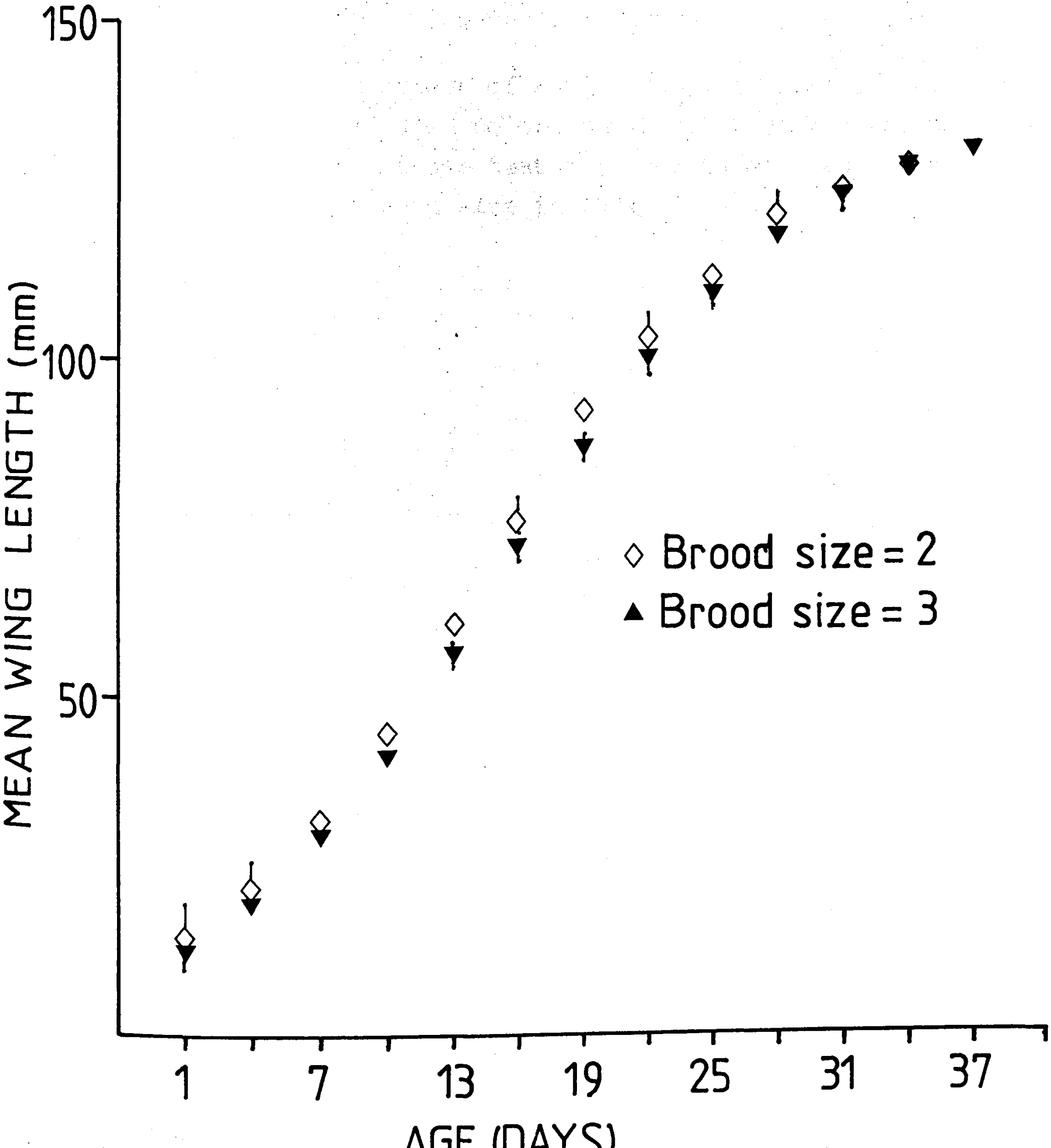
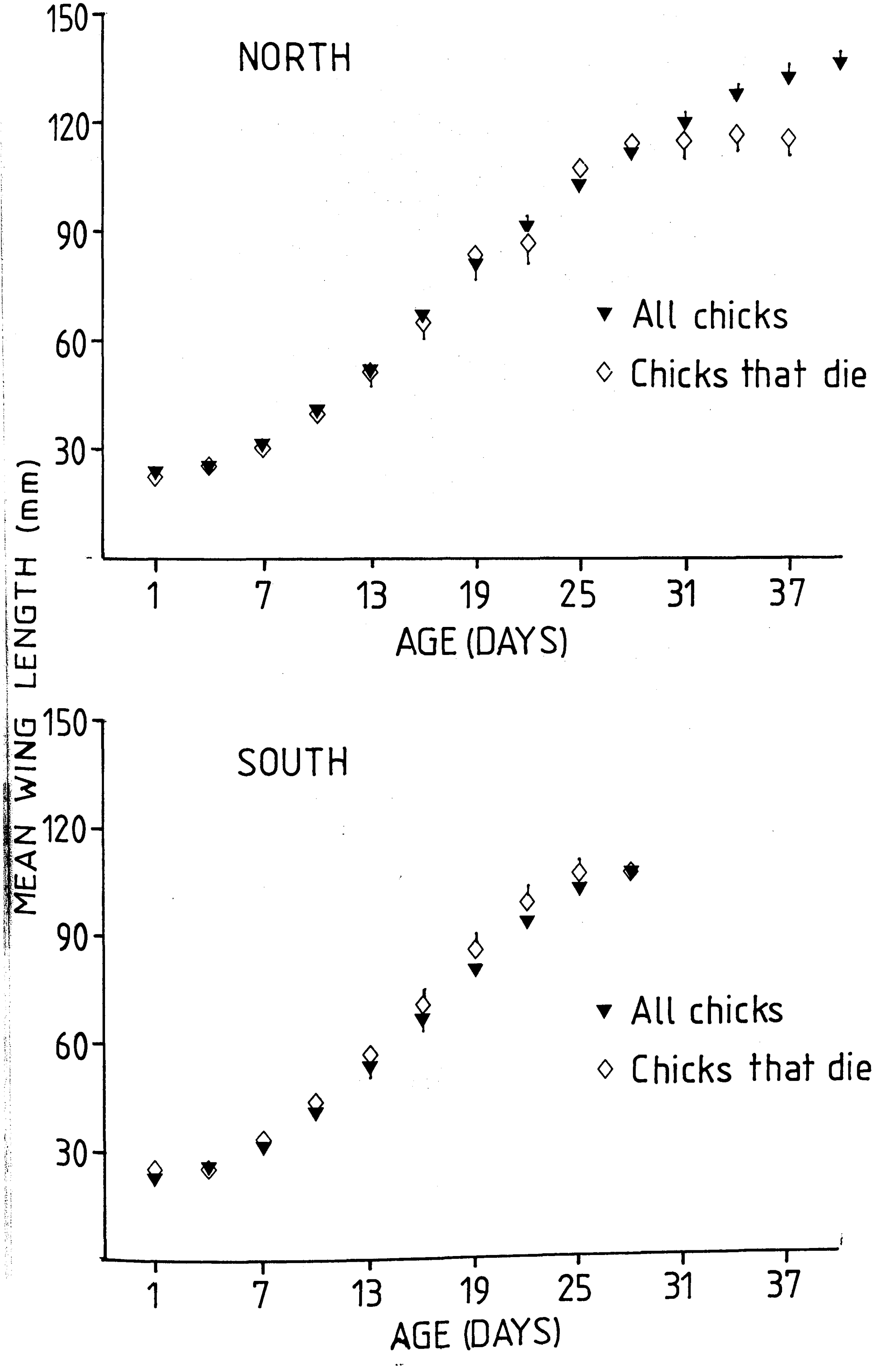

150
100
50
MEAN WING LENGTH (mm)
1
7
13
19
25
31
37
AGE (DAYS)
◇ Brood size = 2
▲ Brood size = 3

Figure 7.9 Comparison of mean wing lengths (± 1 s.e.) of chicks that died before reaching 20 days after hatching with those that survived to at least 20 days at the northern site in 1984.

Figure 7.10 Comparison of mean wing lengths (± 1 s.e.) of chicks that died before 20 days after hatching with those that survived to at least 20 days at the southern site in 1984. Age which is indicated on the horizontal axis is the number of days since hatching.


MEAN WING LENGTH (mm)
NORTH
150
120
90
60
30
1
7
13
19
25
31
37
AGE (DAYS)
▼ All chicks
◇ Chicks that die
SOUTH
150
120
90
60
30
1
7
13
19
25
31
37
AGE (DAYS)
▼ All chicks
◇ Chicks that die

age. Figures 7.11 and 7.12 compare the mean weights of chicks which eventually died in 1984 at both sites with the population of the site as a whole. Chick weight may be considered as an indicator of chick condition. The figures suggest that, at least for the first three weeks after hatching, there is little difference in condition between the two classes. This is another indication the food supply to the chicks was not the factor limiting survival.

7.7 CHICK SURVIVAL

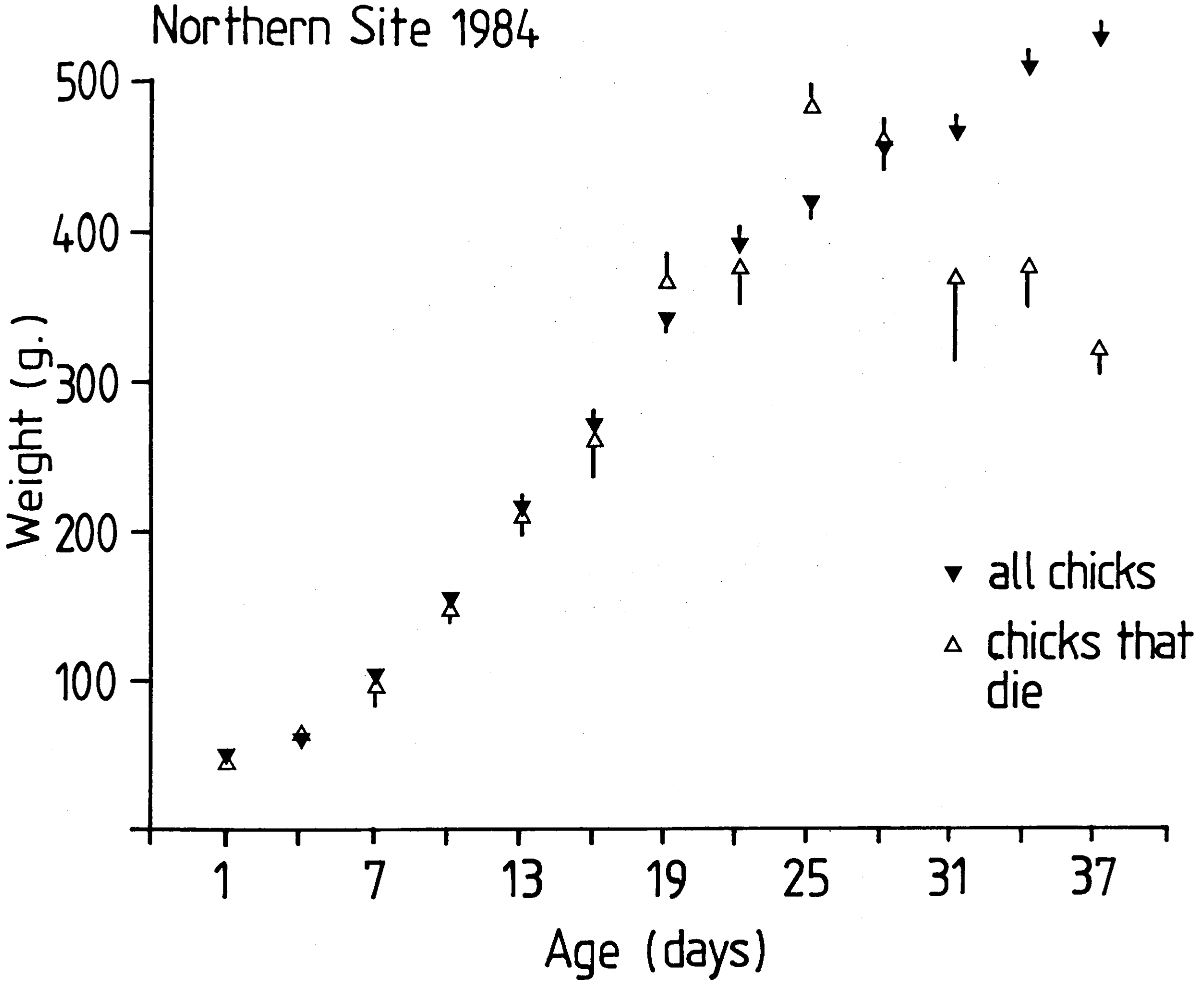
Audouin´s gull chicks died at all ages on Rey Island. In 1983, at the end of the breeding season, all the Audouin´s gull corpses were collected, categorized by size and counted. Figure 7.13 shows the percentages of the total number of corpses which were found in each size class. The numbers in the young classes are probably underestimated as corpses of this age are more difficult to locate than those of older chicks. The results show that even large chicks are dying.

7.7.1 General chick survival

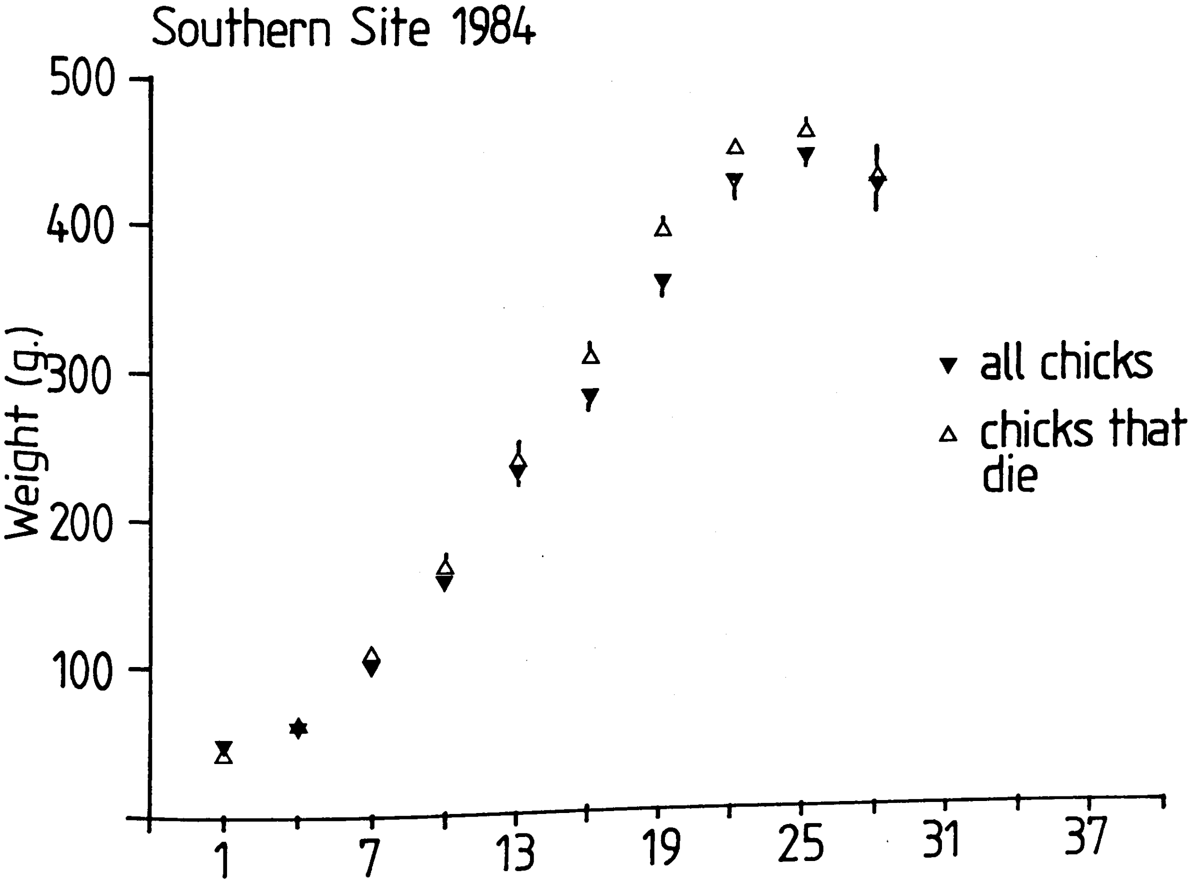
Survivorship curves plotted for chicks from the study areas whose ages and identities were known also show that chicks in 1983 died off at an almost constant rate during the pre-fledging period, see Figures 7.14 and 7.15. In 1984 and 1985 mortality appeared to occur at a higher rate during the first five days post-hatching. These figures also show that there were large differences between years and sites in the rate at which chicks died and the percentage of chicks which eventually survived the period. The numbers of chicks which were studied at each site in each year are shown in Table 7.4. The Kolmogorov Smirnov 2-sample test (Siegel 1956) was used to compare the survival patterns from hatching of chicks at different sites and in different years, see Table 7.4.

Figure 7.11 Comparison of mean weights (± 1 s.e.) of chicks that died before reaching 20 days after hatching with those that survived to at least 20 days at the northern site in 1984.

Figure 7.12 Comparison of weights (± 1 s.e.) of chicks that died before 20 days after hatching with those that survived to at least 20 days at the southern site in 1984. Age which is indicated on the horizontal axis is the number of days since hatching.



Northern Site 1984



Southern Site 1984

Figure 7.13 Age class distribution of corpses found at the end of the 1983 breeding season on Rey Island. H = hatchlings.

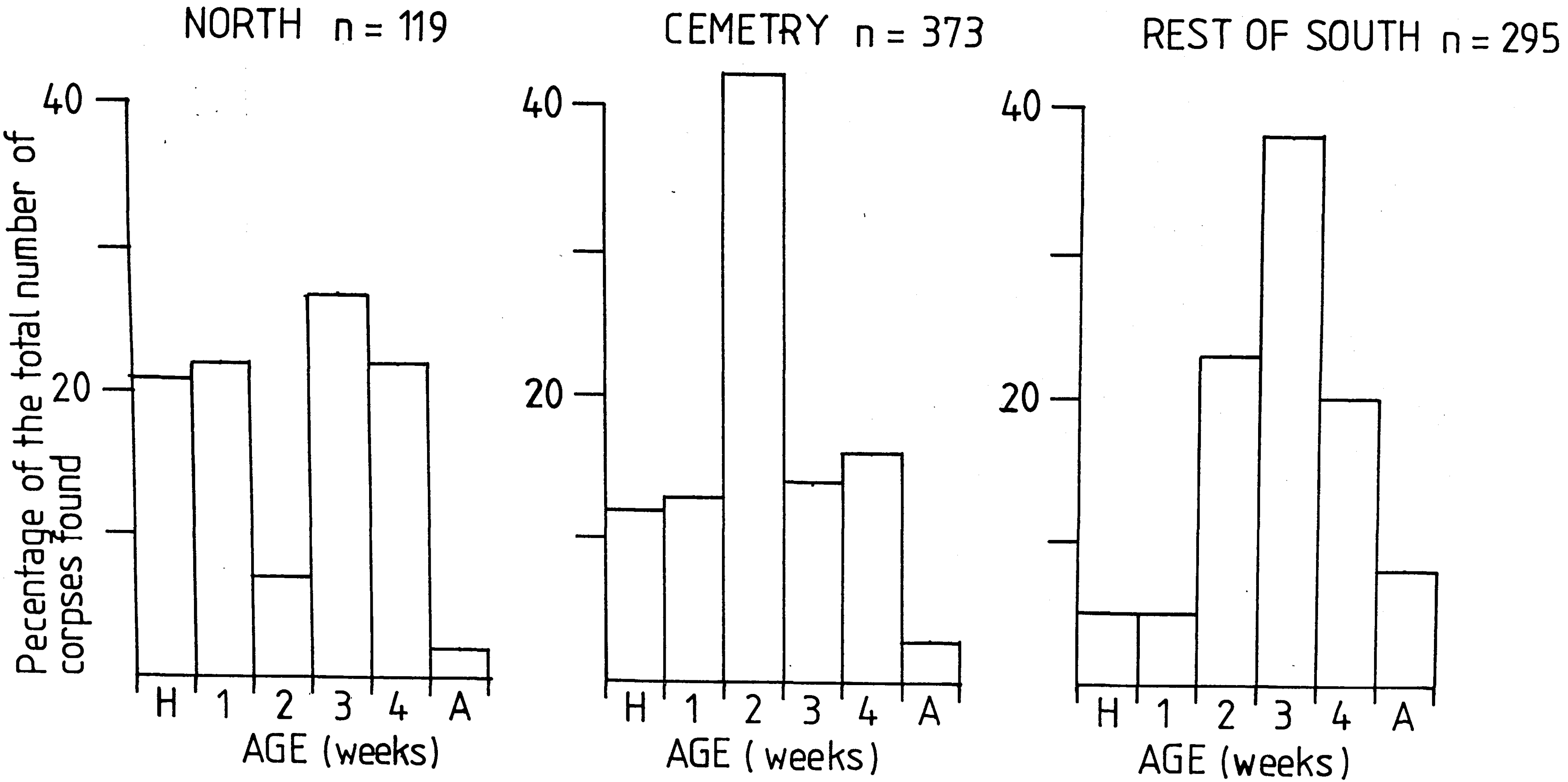
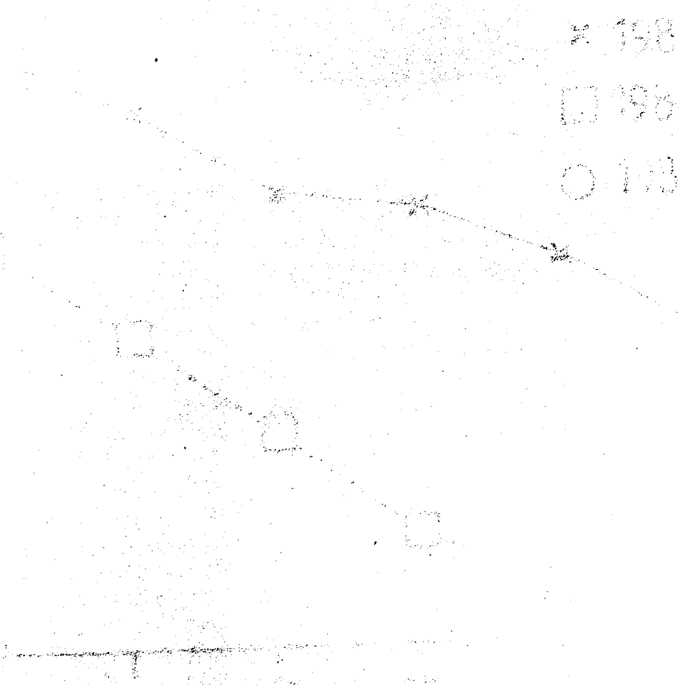
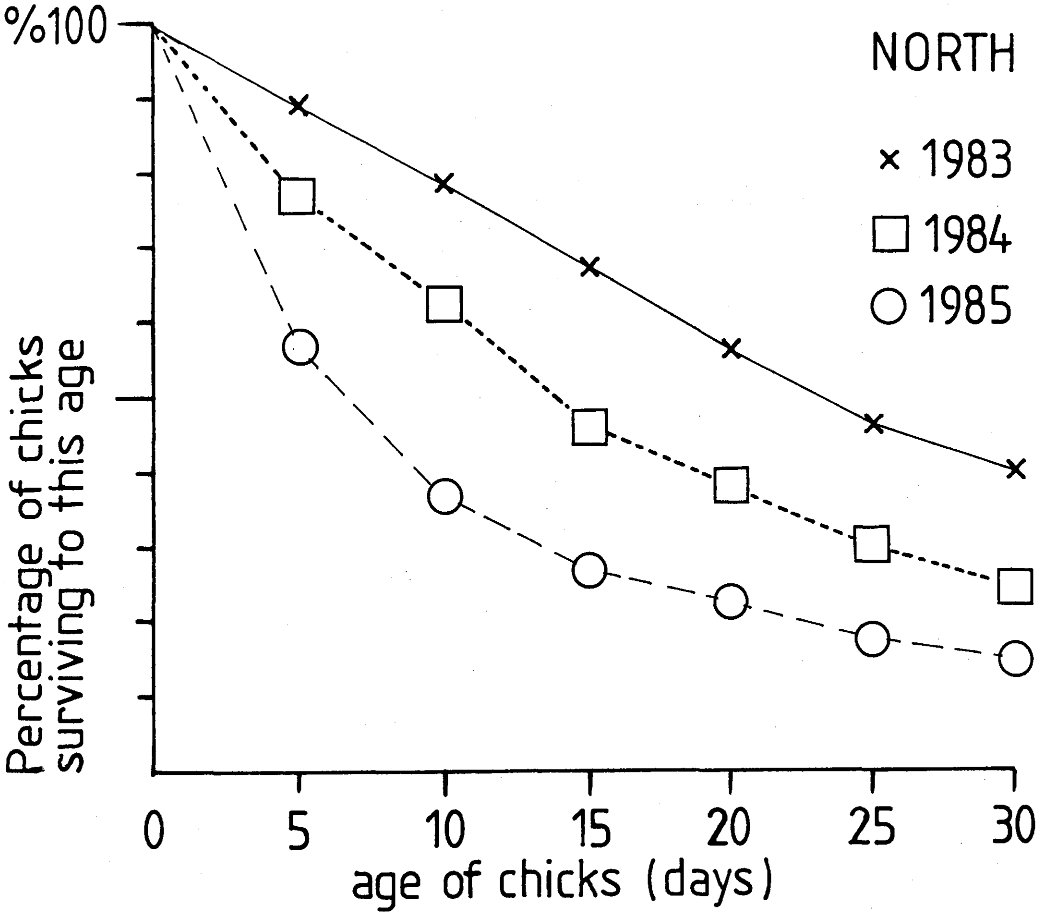

NORTH n = 119
CEMETRY n = 373
REST OF SOUTH n = 295
40
20
Pecentage of the total number of corpses found
H
1
2
3
4
A
AGE (weeks)

Figure 7.14 Survivorship curves for chicks at the northern study site in each of the three study seasons 1983-1985.

Figure 7.15 Survivorship curves for chicks at the southern study site in each of the three study seasons 1983-1985.




%100
NORTH
× 1983
□ 1984
○ 1985
Percentage of chicks surviving to this age
0
5
10
15
20
25
30
age of chicks (days)

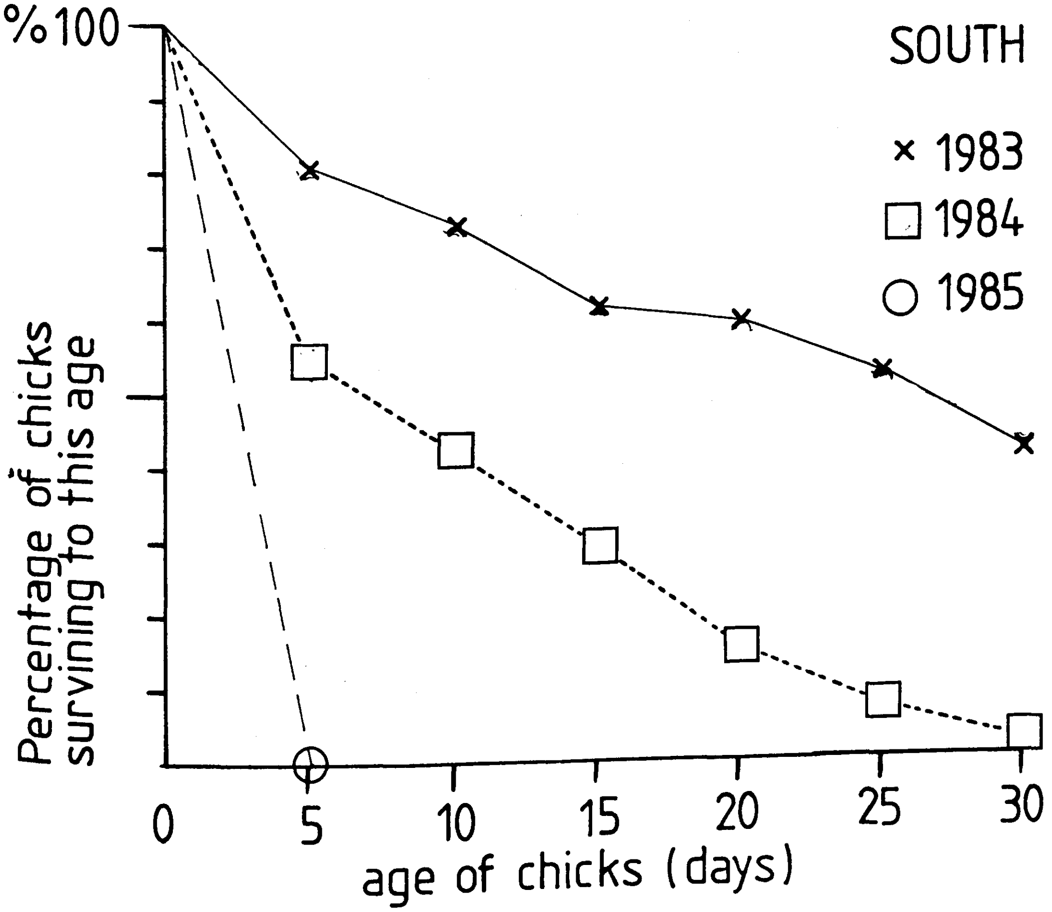

%100
SOUTH
× 1983
□ 1984
○ 1985
Percentage of chicks surviving to this age
0
5
10
15
20
25
30
age of chicks (days)

TABLE 7.4: NUMBER OF CHICKS TO SURVIVE TO EACH AGE AND A COMPARISON OF THE SURVIVAL OF CHICKS AT EACH SITE BETWEEN YEARS.

Year	Site	No. chicks hatched	No. of chicks surviving to age (days) 5	10	15	20	20+
1983	North	121	105	93	80	68	55
	South	144	117	105	89	87	77
1984	North	155	119	96	71	59	46
	South	110	61	46	32	17	8
1985	North	171	98	63	46	39	30
	South	35	0	0	0	0	0

Results of Kolmogorov-Smirnov 2 sample test

Categories compared	Value which D must exceed to be signif.	D	P
1983 North and South	0.166	0.081	n.s.
1984 North and South	0.168	0.227	$P<0.01$
North in 1983 and 1984	0.19	0.203	$P<0.05$
North in 1984 and 1985	0.14	0.25	$P<0.01$
South in 1983 and 1984	0.17	0.46	$P<0.01$

At both sites percentages surviving to each age decreased significantly in successive seasons. The reasons for this decline are discussed in Chapter 9. The end result of this decline is shown in Table 7.5, which shows the mean number of chicks per nest to survive to twenty days at each site.

TABLE 7.5: THE MEAN NUMBER OF CHICKS PER NEST TO SURVIVE TO AT LEAST TWENTY DAYS OF AGE.

YEAR	SITE	MEAN NUMBER OF CHICKS PER NEST SURVIVING > 20 DAYS	s.d	MEDIAN VALUE	n
1983	N	0.85	0.95	1.0	85
1983	S	1.26	0.99	1.0	70
1984	N	0.70	0.74	1.0	86
1984	S	0.19	0.47	0.0	98
1985	N	0.56	0.81	1.0	71
1985	S	0.00	0.00	0.0	20

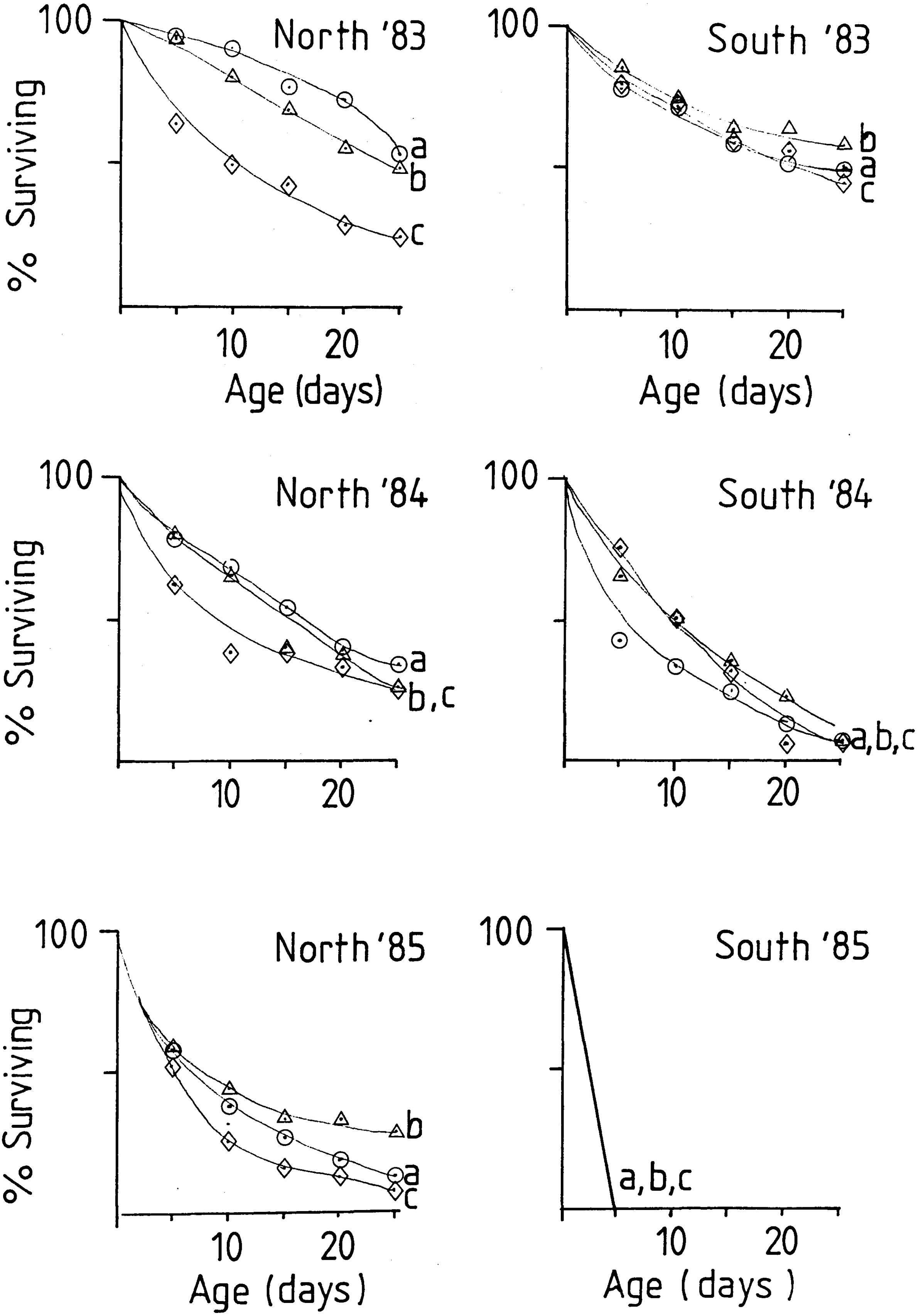
As a large number of the nests failed to produce any chicks surviving to at least twenty days of age the standard deviation is in four out of six cases larger than the mean indicating that the data are not normally distributed. The southern site in 1983 was the most productive site studied during the three seasons. However, in consideration of the low productivity at the southern site in 1984 and 1985, overall the northern sites were more productive.

7.7.2 Third chick disadvantage

In section 7.3 the behaviour of the chicks with particular reference to movement away from the nest was discussed. It was suggested that the timing of the departure of the third chick with respect to that of earlier chicks may add to the primary disadvantages associated with being the third egg/chick in the laying/hatching sequence. The third egg is generally smaller than the the a and b-eggs and so the third chick hatches smaller (see section 5.2). Hatching almost two days after the earlier chicks it is also younger and smaller than its siblings and perhaps as such less able to compete with them for food and shelter. It was therefore expected that the c-chick would suffer higher mortality rates than either a- or b- chicks. Figure 7.16 shows the survival of chicks at each of the sites on each year subdivided into the a-,b- and c-chick groups. The plots suggest that differences are not so apparent at the southern sites as

Figure 7.16 Survivorship curves for a-, b-, and c-chicks at each of the study sites in each of the three study seasons 1983-1985.

a = ○
b = △
c = ◇


North '83
South '83
North '84
South '84
North '85
South '85
100
% Surviving
10
20
Age (days)
a
b
c
b,c
a,b,c

they are at northern sites. The significance of these differences were tested using the chi-squared test on the numbers of each chick class (a-, b-, or -c) surviving to 30 days and the number known to die, see Table 7.6.

TABLE 7.6: COMPARISONS OF THE SURVIVAL OF A-, B- AND C- CHICKS TO THIRTY DAYS AT EACH OF THE SITES DURING THE STUDY (USING CHI-SQUARED TEST).

		Chi-squared value	d.f.	P
1983	north	7.04	2	<0.05
1983	south	0.29	2	>0.05
1984	north	1.34	2	>0.05
1984	south	1.38	2	>0.05
1985	north	6.23	2	<0.05
1985	south	all failed to survive more than five days		

C- chicks were therefore more disadvantaged at northern sites than at southern sites where intra sibling differences were not so pronounced. It should also be noted that whereas the gradients of the survival slopes from ten days onwards are similar for all chick categories, at the northern sites the gradients of the slopes representing the survival rate during the first five days are much greater for the last chick in the brood, see Figure 7.16. This may support earlier speculation that the third chick may suffer especially during the period around the abandonment of the nest by the family group for the shelter of the bushes. This may also explain why at the southern sites, where family groups have been demonstrated to remain for longer periods in the nest, this pattern is not so apparent.

Intra-brood aggression was not observed. Nor were any other indications of competition between siblings recorded. It was not possible to quantify the amount of food taken by each member of the brood during feeding bouts as chicks frequently took bill-fulls from items held in the adult´s bill rather than entire food items. Therefore it was not possible to calculate whether position within the brood determined, to any degree, the amount of food taken by a chick.

7.8 CAUSES OF CHICK MORTALITY

The causes of chick deaths were many. As was indicated in Figure 7.13, Audouin´s gull chicks died throughout the growing period with high mortality rates during the first few days after hatching. In the seasons of 1984 and 1985 particular care was taken to record the date and likely cause of any chick deaths within the study areas. Whereas some categories are likely to be well recorded, for example chicks becoming trapped and dying within _Lycium intricatum_ bushes (see Plate 7.1) the category of chicks predated by herring gulls is likely to be under estimated. These records depended upon either direct observation of the event, the collection of its remains wherever they were deposited by the herring gull, or in a few cases by observing the disappearance of a chick from the middle of the site whose siblings remain being fed by their parents. However, in order to provide an impression of the known range of causes of chick deaths and their relative importance, Table 7.7 presents the records collected at sites during these two years.

TABLE 7.7: RECORDED CAUSES OF CHICK DEATHS, AND THEIR FREQUENCIES (%), AT STUDY SITES IN 1984 AND 1985.

CAUSE	1984		1985	
	north	south	north	south
Killed by herring gull	18 (32)	4 (21)	2 (4)	29 (65)
Killed by Audouin´s gull	19 (33)	1 (5)	14 (28)	-
Trapped in vegetation	4 (7)	-	5 (10)	-
died hatching	4 (7)	2 (11)	9 (18)	5 (11)
cause unknown	12 (21)	12 (63)	20 (40)	11 (24)

That chicks were killed at all by Audouin´s gulls may come as a surprise in view of the information given in Section 6.9. Audouin´s gulls are not aggressive birds, but they will defend their territory against intruding birds. Wandering chicks were

Plate 7.1 *Lycium intracatum* bushes - within which chicks were occasionally found dead, impaled upon the thorns. This bush was common within the northern study site.

frequently pecked and chased by adults other than their parents when they strayed away from their normal position. Chick´s parents did not defend their chicks when they were being attacked on another territory but stood calling (long calls) from their own territory. Chicks died after receiving repeated blows delivered to their heads by adults´ bills. They were never subsequently eaten.

Whereas large percentages of chick deaths in northern sites were due to attacks by conspecifics, low percentages were killed in this way at the southern sites. It is suggested here that this may be due to two differences between northern and southern nest sites. Northern sites were less vegetated than southern sites. Chicks seeking shade under bushes had to travel further in the north than in the south perhaps having to cross other territories. In the north this lack of vegetation also provided less cover in which attacked chicks could seek refuge. The second difference lies in the nesting densities at the sites. The mean number of nests within 3 m. of each focal nest for each site is shown in Table 7.8.

TABLE 7.8: MEAN NUMBER OF NESTS WITHIN 3 m. OF FOCAL NESTS AT EACH SITE.

	1983		1984		1985	
	NORTH	SOUTH	NORTH	SOUTH	NORTH	SOUTH
Mean number of nests within 3 metres (s.d.)	7.75 (2.33)	2.32 (1.59)	5.94 (2.92)	5.15 (2.80)	9.26 (3.50)	5.45 (2.90)
Sample size	83	71	73	84	70	47
Student´s t-test value for each year comparing sites.(d.f.)	16.94 (152)		1.149 (155)		6.37 (115)	
P	<0.000		<0.25		<0.000	

The mean distances to the nearest nest from each focal nest is given in Table 7.9.

TABLE 7.9: MEAN DISTANCE (cm.) FROM FOCAL NESTS TO THEIR NEAREST NEIGHBOURING NEST.

	1983		1984		1985	
	NORTH	SOUTH	NORTH	SOUTH	NORTH	SOUTH
Mean distance nearest nest in cm.(s.d.)	117.0 (45.8)	185.7 (92.9)	124.2 (55.3)	156.3 (91.1)	78.0 (37.3)	119.4 (65.7)
Sample size	83	71	84	84	87	46
Student´s t-test value for each year comparing sites.(d.f.)	-5.667 (152)		-2.801 (166)		-4.009 (131)	
P	<0.000		<0.006		<0.000	

Nests at the northern sites were more tightly packed than at the southern sites. A clumped distribution may increase the likelihood of a chick from one nest straying onto another territory and consequently being attacked. This may explain the increase in the percentage of chicks killed by Audouin´s gulls in 1985 as compared with 1984. The density was higher in 1985 than in 1984 (Student´s t-test on number of nests within 3m of focal nest, $t = -6.75$, d.f. = 132, $P < 0.000$. Student´s t-test on distance to nearest nest $t = 6.354$, d.f. = 147, $P < 0.000$). The reasons why Audouin´s gull nesting densities were so high in 1985 at the northern site are discussed in Chapter 9.

7.9 FLEDGING

Unfortunately, little information could be collected regarding the age at which Audouin´s gull chicks fledge. When chicks were fully grown (see Figure 7.6 for weight of chicks at growth curve asymptote and Appendix 9 for adult measurements) they were very mobile and attempts to capture birds increased the likelihood that chicks would either stray into herring gull areas, fall off cliffs or fly prematurely without control over their destination. Consequently visits to the colony were abandoned. Chicks were seen flying from early July onwards and sightings were made of individually colour-ringed fledglings. These sightings suggest that Audouin´s gull chicks spend 41-45 days within the colony before fledging. Witt (1977) also recorded c.a. forty days as being the time at which chick weight peaked and fledging took place.

7.10 DISCUSSION

In contrast with other Larid chicks, (glaucous-winged gull, California gull, ring-billed gull (Vermeer 1970); herring gull (Harris 1964, Kadlec _et al._ 1969, Parsons 1970, Haycock and Threlfall 1975, Morris and Haymes 1977); Kittiwake (Barrett and Runde 1980); and the common tern (Langham 1972, Morris _et al._ 1976)), more than half the Audouin´s gull chicks which died on the Chafarinas Islands during this study did not die when they were less than ten days old. Chick mortality, during this study and those of de Juana _et al._ (1979), Mayol (1978) and Witt (1979) also on the Chafarinas, continued throughout the chick growth period. In each case the most numerically serious causes of death were due to the inability of Audouin´s gull adults to protect their young from intra- and inter- specific attacks and to the inability of chicks to remain under cover.

Audouin´s gull chicks hatch with three primary requirements food, defence and protection from temperature extremes. These are generally satisfied during the first few days after hatching by the adults taking turns to brood and feed the chicks whilst the chicks remain within the nest. However, when the colony was disturbed or attacked, the adults abandoned the nests and the chicks, taking to the air. Like most alarmed Larid chicks of less than two days of age (Tinbergen 1953), Audouin´s gull chicks tried to find cover in the immediate vicinity of the nest in which they could crouch until danger had passed. Older chicks hid in the bushes. This is where this study suggests that chick survival problems begin.

When the alarm passed either chicks returned to the nest or the adults relocated the chicks. Larid chicks do not hatch from the egg immediately recognizing their parents´ mew call, just as adults do not appear able to distinguish between their own chicks and those of other pairs immediately after hatching. Rather, as the chicks´ mobility necessitates it, the two-way process develops (Evans 1970, Beer 1970, O´Connor 1984). During this period of learning therefore, in addition to the normal risks of predation and attack, very young chicks may become lost and adults may either adopt foreign chicks or spend time searching for a chick while the rest of the brood is exposed to danger.

Once the Audouin´s gull chicks gained mobility they abandoned the nest and its territory for positions with vegetation or rock cover. The timing of this move varied but was generally within one week of hatching. Makatsch (1969) recorded Audouin´s gull chicks as leaving the nests on the second day after hatching. Abandonment of the breeding territory so soon after hatching is not typical of Larus sp. (Herring gull, Tinbergen 1953; Franklin´s gull, Burger 1974; great black-backed gull, Butler and Janes-Butler 1983). Dawson et al. (1976) showed that where ring-billed gulls were breeding in hot environments chicks moved to shade at a young age relying on their parents only for nutrition after the first week. This study has suggested that Audouin´s gull chicks move most quickly to cover when their nests do not provide any cover, hence the difference in rates of movement between chicks at northern and southern sites.

Once the brood moved to the bushes, adult attendance fell off with adults, eventually, only making contact with chicks when food was available. This is in contrast with the behaviour of other Larid species, where attendance remains high throughout the period of chick growth (herring gull, Tinbergen 1953; great black-backed gull, Butler and Janes-Butler 1983; and Franklin´s gull, Burger 1974).

Chicks left the bushes to beg, feed, stretch and exercise their developing flight muscles. Once outside they could be attacked either by conspecific adults or herring gulls. Audouin's gulls are not aggressive but they do protect their brood and defend the area about them. A small chick may not appear to pose much of a threat to an Audouin's gull adult or its brood but it may be attacked in order to prevent the chick competing with the brood for food and to avoid its adoption. Amongst Larids infanticide without cannibalism is generally caused by chicks straying onto other territories (Hunt and Hunt 1976) rather than by adults initiating unprovoked attacks. Such attacks are also most commonly associated with Larids breeding at high densities (Parson 1971b, Hunt and Loon 1975, Ewald et al. 1980, Holley 1984). High nesting densities can also result in increased numbers of adoptions (Vermeer 1963). During such attacks on chicks as they moved within the colony and were attacked, the chick's parent/s did not come to the chick's assistance in the other adult's territory but stood long-calling loudly. Attacking an adult on its territory may have involved risking the reproductive output of the adult in future years which may be worth more than the single chick being attacked. So chicks from nests without cover left their nests for shelter elsewhere, risking exposure to attacks from Audouin's gulls and herring gulls. Winnett-Murray (1979) suggested that western gull chicks, developing in a very similar environment to that of Audouin's gulls on the Chafarinas Islands; western gulls whose nests were without sufficient cover travelled larger distances than chicks with well covered nests thus rendering themselves more susceptible to attacks by other gulls.

According to Witt's trans-Mediterranean study of Audouin's gull (1976, 1981) the food taken by Audouin's gull reflects the relative abundance of particular food in that region. Fish is the main food of Audouin's gull throughout the Mediterranean but more so in the central and western Mediterranean than in the east where adults were found to eat a wide range of food items which included plant material, garbage and small birds and mammals (for full discussion see section 2.5). During this study Audouin's gull adults fed their chicks almost exclusively on a marine diet of fish, mainly small clupeids and squid. However, during storms, chicks were fed on insects, grasshoppers and beetles, the adults appearing unable to control their flight sufficiently in high winds to allow them to fish. Under such conditions Audouin´s gulls were seen in places which they did not normally frequent, like the almost enclosed harbour of the large port of Melilla. This lack of fishing over high seas may mean as suggested that Audouin´s gulls are not aerodynamically adapted to fly under such conditions. This seems unlikely since the species possesses a typically Larid form. It could also mean that Audouin´s gull´s fishing technique was less successful under such conditions, making it unprofitable to attempt to fish under such conditions. Taylor (1983) found that wave height affected the fishing performance of common and sandwich terns, causing them to change their technique as they could not detect fish beneath the surface under windy conditions. It is however difficult to compare the effect of weather conditions upon the foraging behaviour of different species without first of all comparing their prey, their methods of foraging and their physical attributes (Elkins 1983). However, the rough seas may similarly affect Audouin´s gull´s foraging success reducing below a cost-effective level. As this abandonment of foraging at sea under poor conditions has not been reported elsewhere in the literature it may be that the seas around the Chafarinas Islands were so well stocked with prey, and that Audouin´s gull´s fishing technique is normally so effective that they can afford to not fish for a few days without drastic consequences, making up for lost time after the seas have calmed. Another possible explanation might be that insects etc are a reasonable alternative to fish.

This study showed that for Audouin´s gull chicks, the rate of feeding did not increase as chicks grew older. The size of feeds were not measured but as chick growth was steady and of the sigmoid pattern typical of bird growth (O´Connor 1984), it is likely that the amount of food provided at each feed increased. Unfortunately, the identity and therefore the age of the chicks whose regurgitates were collected were not recorded. Such results may have allowed the testing of this hypothesis assuming that the entire food bolus was regurgitated at any one time. For most bird species the feeding rate gradually increases throughout the nestling period (O´Connor 1975). A possible explanation for the absence of such an increase in the rate at which Audouin´s gull chicks were fed is that when adults approached the chicks they left the shelter of the bushes thus exposing themselves to danger. By approaching only when necessary, when a large amount of food was available and some time had passed since the last feed, adults could reduce the risk of losing part of their brood. Hunt and M^{c}Loon (1975) found that glaucous-winged gulls were more exposed to attacks by other gulls following begging and feeding than prior to begging. They also found that chicks became more active and wandered still further when begging had been unsuccessful. The return of the parent to the territory often stimulated its chicks to emerge from cover and beg, thus exposing the chicks to danger which could be reduced by minimizing the frequency of visits by the adults.

Audouin´s gull chick growth took place at a steady and similar rate in each year with weight being gained in a regular manner. Chicks from broods of three grew and gained weight at similar rates to those of broods of two. Together these observations do not suggest that food was in short supply during any of the three seasons studied. The waters around the Chafarinas Islands would appear to be as good for fishing Audouin´s gulls as they so obviously are for the Spanish fishing vessels which sail from even the northern ports of Spain to benefit from the high fish densities in this particular area.

This plentiful supply of food may also explain why a peck order was absent from among the broods. In most bird species, where the brood hatches asynchronously, the chicks behave aggressively for their own advantage towards the younger chicks, resulting in the oldest chick securing the ´lion´s share´. No aggression was observed between siblings and all members of the three chick broods were able to feed peaceably together. Cullen (1957) suggested that peck orders, amongst Kittiwake chicks, are only obvious in times of food shortage. It would be interesting to test for their existence in Audouin´s gull broods in the eastern Mediterranean sites.

As has already been mentioned, Audouin´s gull´s pattern of chick mortality is not typical of gull species, for which normally the majority of chicks which die before fledging do so within the first ten days and whose deaths are largely due to an inability of the adults to switch from incubation of the eggs to caring for the chicks quickly enough. This chapter has shown that whilst there were few differences in the rates and patterns of chick growth and weight gain between years and within sites, there was considerable variation in the survival of the chicks. Chapters Eight and Nine present and discuss data regarding alterations to the nesting environment on the Chafarinas which were responsible for the marked reductions in the rates of survival of the chicks, the difference in breeding success between the study sites and the general deterioration in the reproductive success of Audouin´s gull on the Chafarinas Islands.

CHAPTER EIGHT: VARIATION IN BREEDING SUCCESS IN RELATION TO ENVIRONMENTAL FACTORS.

8.1 INTRODUCTION

In comparison with other Palearctic gulls, the breeding biology of Audouin´s gull is little known. Most information concerns its limited population size, restricted breeding distribution and its narrow range of preferred food types. Thus data concerning its reproductive success are valuable and intriguing. The second justification for such a study as this is that, if we are to establish whether Audouin´s gull is an endangered species, as opposed to a species which has existed in small numbers and probably always will, we must examine its capacity to reproduce successfully under the current conditions so as to maintain its current population size. This three season study can provide a baseline against which future breeding success or failure can be compared. In addition, it is hoped that the results may suggest measures which may be taken to safeguard Audouin´s gulls within this area of the Mediterranean.

8.2 METHODS

As described in Chapter 3, the nest contents within the study sites were recorded daily in the pre-hatching period. Hatching success and chick survival were recorded as shown in section 6.2. Fledging occurs approximately 40-45 days after hatching. As it was not possible to individually identify all fledglings and because of the potentially disturbing effects of chasing large young, it was not possible to record actual fledging success. Thus, most analyses discussed in this chapter consider the number of chicks which were known to survive to at least 20 days after hatching. This study has already shown that chicks did suffer some mortality after the age of 20 days so this must not be considered to represent the actual number of chicks successfully fledging. However, as the mortality rate of chicks was relatively constant after the first five days after hatching, the average number of chicks surviving to at least twenty days is related to the fledging success, see Figure 8.1.

Discriminant analysis (SPSS, Nie et al. 1975) was applied to the data collected in order to examine the relationship between environmental factors and breeding failure. This is a multivariate technique which can be used in order to examine the extent to which populations overlap one another or diverge with respect to the variables measured. In this case the populations compared were successful and unsuccessful nests i.e. a) those from which at least one chick hatched and those which failed to produce any chicks; and b) those from which at least one chick survived to twenty days and those from which none were recorded as surviving even to 20 days of age. The discriminating variables used in the analysis were:

a) the day on which laying began
b) the height of vegetation at the nest
c) visibility at the nest
d) quality of the nest
e) distance to the nearest neighbouring nest
f) the number of nests within a radius of 3 metres
g) the distance to the edge of the subcolony

(For a discussion of what these variables are and how they were measured, see Section 3.6). The programme used to run the analysis was the SPSS subprogramme Discriminant using a stepwise method by which the programme selected the best set of discriminating variables and entered these in order of importance into the analysis. Rao´s V was used in order to specify the groups entered in the analysis. Discriminant analysis forms one or more linear combinations of the discriminating variables into what are generally called Discriminant Functions. The functions are generated so that they maximize the separation of the populations. Once formed their ability to separate the populations can be tested. The results of the analyses are presented in the forms of the Canonical Correlation, Wilk´s Lambda and the Standardised Discriminant Function Coefficients. The canonical correlation is a measure of the function´s ability to discriminate between the populations. Wilk´s Lambda is an inverse measure of the discriminating power which has not been removed by the discriminant function. Lambda can be transformed into a chi-squared statistic for an easy test of statistical significance. This value is also quoted in the results. Standardised Discriminant Function Coefficients for the variables selected which were selected by the stepwise subprogramme, are also given. Each coefficient, when the sign is ignored, represents the relative contribution of its associated variable to the discriminant function.

8.3 SUMMARY OF BREEDING SUCCESS

As was discussed in section 4.4, the clutch size of the nests at the study sites varied between seasons and sites. Table 8.1 summarises the information on clutch size and initial brood size for the nests studied.

TABLE 8.1: SUMMARY OF PRODUCTIVITY AT THE SITES DURING THE STUDY.

YEAR	SITE	NUMBER OF NESTS	MEAN CLUTCH SIZE (s.e.)	MEAN BROOD SIZE (s.e.)
1983	NORTH	85	2.75 (0.06)	2.15 (0.11)
1983	SOUTH	74	2.73 (0.06)	2.11 (0.12)
1984	NORTH	86	2.74 (0.06)	1.89 (0.11)
1984	SOUTH	98	2.38 (0.09)	1.24 (0.11)
1985	NORTH	102	2.62 (0.07)	1.81 (0.12)
1985	SOUTH	52	2.59 (0.11)	0.79 (0.15)

For a statistical examination of the significance of the differences between mean clutch sizes at study sites see Section 4.9. Mann-Whitney U tests showed the differences in the mean brood sizes at the study sites between sites and years. Whilst the brood sizes at the sites did not differ significantly in 1983 ($U = 6901$, $P < 0.7286$) they were found to be significantly different in 1984 ($U = 9181$, $P < 0.0002$) and in 1985 ($U = 9078$, $P < 0.0000$).

There were much larger changes in the success at the southern sites than at the northern. 1983 was the best year for egg and subsequent chick production.

Table 8.2 summarises the reproductive success at each site up to the age of twenty days. Only the data for nests whose chicks were ringed on hatching are considered here. Again, this shows the dramatic decline in breeding success, both hatching success and chick survival, at the southern sites over the three years.

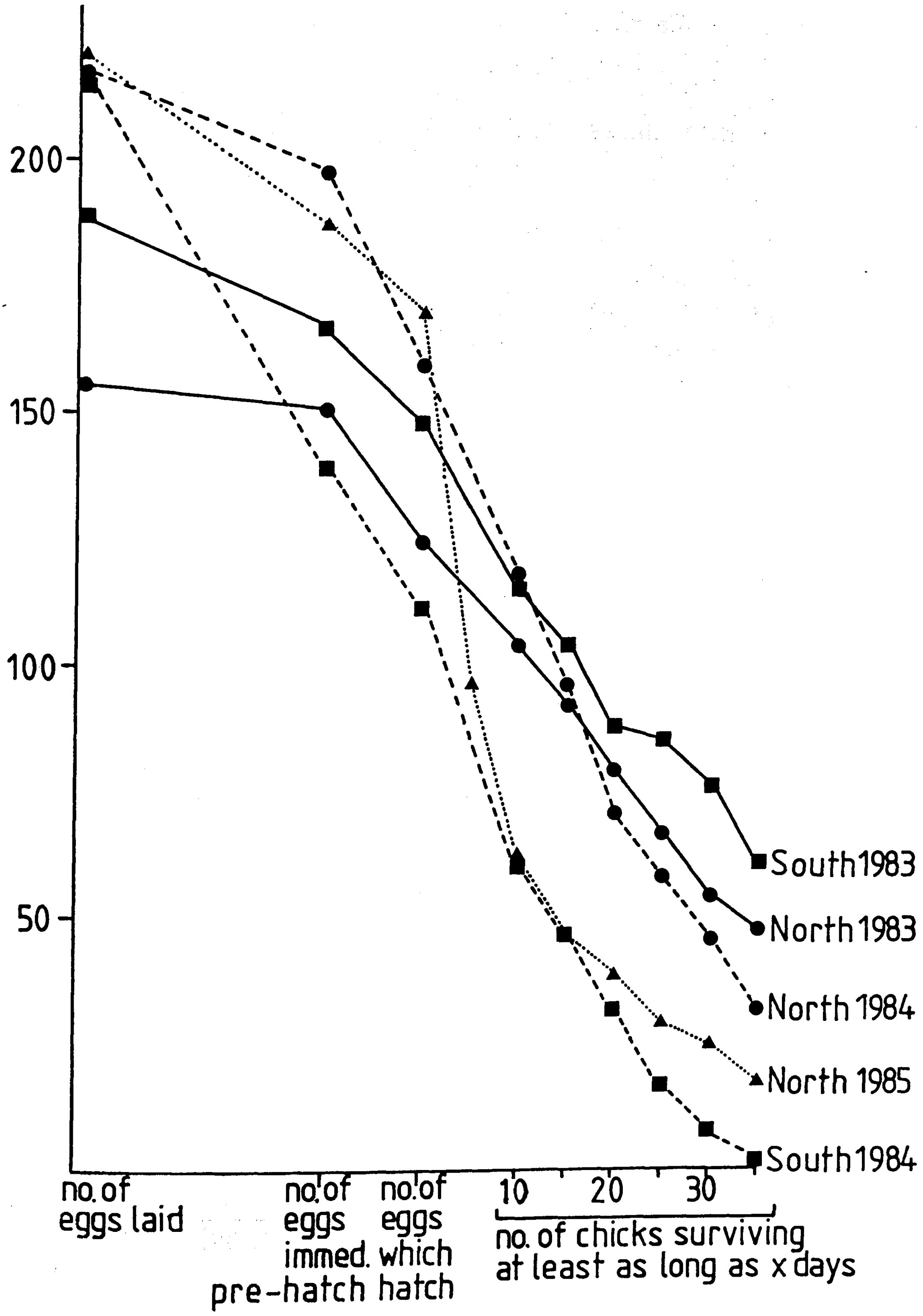
TABLE 8.2: SUMMARY OF SUCCESS OF NESTS WHOSE CHICKS WERE RINGED ON HATCHING AT STUDY SITES DURING THE THREE SEASONS.

	YEAR AND SITE					
	1983		1984		1985	
	North	South	North	South	North	South
Total no. eggs laid	155	189	217	215	267	134
Total no. eggs hatched	125	149	160	112	185	43
No. hatched/No. laid	0.81	0.79	0.74	0.52	0.69	0.32
Total no. chicks surviving to 20 d.(%)	72(58)	87(58)	71(44)	32(29)	40(22)	0(0)

Whilst there was no significant difference between the proportions of young recorded surviving to 20 days at the sites in 1983 (X^2 = 0.015, d.f. = 1, P>0.05), there were significant differences between the proportions surviving to 20 days at the northern site in 1984 as compared with 1983 (X^2= 4.9, d.f. = 1, P<0.05) and at the southern site in 1984 compared with 1983 (X^2 = 23.4, d.f. = 1, P<0.001). There was a further decline recorded at both sites in 1985 when the proportions of chicks surviving were compared with 1984 (northern sites 1984 vs 1985 X^2 = 20.4, d.f. = 1, P,0.001).

The data for all the sites in 1983 and 1984, and for the north site 1985 are represented graphically in Figure 8.1. In this figure the gradients should be compared rather than the starting and finishing points. This figure shows that the number

Figure 8.1 Graphical representation of egg and chick productivity and survival at all study sites (with the exception of South 1985) during the three breeding seasons 1983-1985. The number of eggs/chicks surviving to each stage are shown on the vertical axis. The horizontal axis represents the various stages during the breeding season.


200
150
100
50
South1983
North1983
North1984
North 1985
South1984
no. of eggs laid
no. of eggs immed. pre-hatch
no. of eggs which hatch
10
20
30
no. of chicks surviving at least as long as x days

of chicks which fledged from the southern site in 1984 were very low, the site virtually failing to produce any fledglings. In 1985 the southern site failed completely, with not a single chick surviving for as long as ten days and is not shown in Figure 8.1.

8.4 DISCRIMINANT ANALYSIS OF ENVIRONMENTAL FACTORS AFFECTING REPRODUCTIVE SUCCESS.

Such drastic differences between the success of pairs breeding at the different sites in different seasons invites an attempt to explain the success of some nests and the failure of others in terms of differences in nesting conditions and parent quality. As described in the methods, Section 8.2, a discriminant analysis programme was applied to data concerning hatching success and failure and secondly, success at rearing at least one chick to 20 days as compared with unsuccessful nests.

8.4.1. Factors affecting hatching success

In Chapter Six, the factors affecting hatching success were discussed and correlation coefficients were calculated for the effect of individual factors upon hatching success (see Section 6.10 for a description of the factors and their effects). Few significant correlations were found but trends were discussed. Multivariate discriminant analysis produced values for Wilk´s Lambda whose Chi-squared distributions showed significant separations between those nests which failed to produce any chicks and the nests from which at least one chick hatched, in four out of the six site/year combinations, see Table 8.3.

Table 8.4 lists the variables which the stepwise analysis selected as being those within which the two considered populations differed most. As stated in the methods section, Section 8.2, the magnitude of the standardised canonical coefficients represents the importance of that variable in discriminating between the two groups of nests, the larger the coefficient the more important the variable is.

TABLE 8.3: RESULTS OF DISCRIMINANT ANALYSIS FOR EACH SITE BETWEEN NESTS WHOSE EGGS HATCHED SUCCESSFULLY AND UNSUCCESSFUL NESTS.

Site	Canonical Correlation	Wilk's Lambda	X^2 Value	d.f.	P	% cases correctly classified
83 North	0.350	0.877	10.14	3	0.017	71%
83 South	0.366	0.866	8.63	4	0.071	70%
84 North	0.357	0.873	8.99	4	0.061	67%
84 South	0.460	0.769	16.56	3	0.001	75%
85 North	0.480	0.769	14.18	2	0.001	75%
85 South	0.677	0.541	22.73	4	0.000	83%

TABLE 8.4: VALUES OF STANDARDISED DISCRIMINANT FUNCTION COEFFICIENTS RELATING NEST CHARACTERISTICS TO HATCHING SUCCESS

	1983		1984		1985	
	North	South	North	South	North	South
Laying date						-0.588
vegetation height	0.419	0.523	0.940			
distance to colony edge	0.429	0.722	0.748	0.741		
visibility at nest			0.779		-0.450	0.684
nesting density		0.688		0.571		0.449
distance to nearest nest						0.300
nest quality	0.780	0.388	0.544	0.618	0.971	

A clear pattern of influential factors does not emerge, neither for all sites considered together nor for northern or southern sites taken separately. However, the results presented in Table 8.4 do suggest that nest quality and distance from the edge of the colony are important factors affecting hatching failure. At both sites in 1983 and at the northern 1984 site the height of vegetation surrounding the nest also differed between those nests whose eggs hatched and those at which hatching failed. At the southern site in 1985, the most important factors were visibility and the timing of breeding at the nest. As this analysis considers success and failure per nest it does not take into account the effect of laying date upon clutch size, see Section 4.10. This should make the difference between early nests and late nests even more marked as the reduction in clutch size with season alone may reduce the probability of a nest producing at least one live chick.

8.4.2. Factors affecting nesting success

In this instance nesting success is defined as ability of the adults at a nest to rear at least one chick to at least twenty days of age. In all but one of the five site/year combinations (South 1985 was not included in the analysis as no chicks survived to 20 days) the discriminant analysis produced a significant separation, on the basis of a discriminant function generated from the variables, between successful and unsuccessful nests, see Table 8.5. The fifth analysis was for the northern site in 1985 when the best discriminant function correctly classified only 59% of the cases and was not significant.

TABLE 8.5: RESULTS FOR EACH SITE OF DISCRIMINANT ANALYSIS BETWEEN NESTS WHOSE ADULTS SUCCEEDED IN REARING AT LEAST ONE CHICK TO TWENTY DAYS AND THOSE WHICH DID NOT.

Site	Canonical Corre- lation	Wilk´s Lambda	X^2 Value	d.f.	P	% cases correctly classified
83 North	0.506	0.744	23.1	2	0.000	78%
83 South	0.398	0.842	10.5	2	0.005	61%
84 North	0.551	0.697	23.8	4	0.000	76%
84 South	0.483	0.766	18.2	5	0.003	75%
85 North	0.288	0.917	4.7	2	0.096	59%

Successful and unsuccessful nests were best separated at the northern sites in 1983 and 1984, when the canonical correlations of the functions were greater than 0.5.

TABLE 8.6: VALUES OF STANDARDISED DISCRIMINANT FUNCTION COEFFICIENTS FOR SIGNIFICANT VARIABLES FOR THE MULTIVARIATE DISCRIMINANT ANALYSIS ON NESTS WHICH PRODUCE, OR FAIL TO PRODUCE, CHICKS WHICH SURVIVE UNTIL AT LEAST TWENTY DAYS AFTER HATCHING.

	1983		1984		1985
	NORTH	SOUTH	NORTH	SOUTH	NORTH
Laying date	0.891		0.644		
height of vegetation	0.444		0.757		
distance to edge		0.847	0.322	-0.466	
visibility at nest		-0.442		0.522	0.578
density of nests			0.398	0.510	0.830
dist.to nearest nest					
nest quality					

In both of these analyses the variables selected as most useful in bringing about a separation included, the timing of breeding and the height of vegetation at the nest, see Table 8.6. In 1984 the nesting density and the distance of the nest from the edge of the colony were also included in the formulation of the function. At both the southern sites in 1983 and 1984, the distance of nest from the edge of the subcolony and the visibility at the nest were used in the stepwise computation, with the nesting density also being used at the southern site in 1984. The relative importance of these variables is shown by the magnitude of the standardised canonical coefficient, see Table 8.6.

The value of the discriminant analysis programme is shown by comparing these results with the correlation coefficients calculated for the effect of individual factors upon the mean number of chicks surviving to twenty days per nest, see Table 8.7.

TABLE 8.7: CORRELATIONS BETWEEN NESTING SUCCESS (NUMBER OF CHICKS SURVIVING TO AT LEAST 20 DAYS PER EGG) AND ENVIRONMENTAL FACTORS AT SITES IN 1983 AND 1984.

	1983				1984			
	NORTH		SOUTH		NORTH		SOUTH	
	r	n	r	n	r	n	r	n
timing of breeding	**-0.42	85	-0.04	70	*-0.24	85	-0.12	97
height of vegetation	* 0.28	85	0.05	66	* 0.30	84	0.15	82
visibility from the nest	-0.11	85	-0.17	65	*-0.26	85	*-0.24	83
nest quality	*0.25	83	-0.00	65	0.16	85	0.09	77
distance to nearest nest	0.01	83	0.05	67	-0.04	84	-0.17	84
density of nests	-0.06	83	0.06	67	*-0.22	73	-0.15	84
distance to edge of subcolony	0.07	83	* 0.24	68	0.13	80	** 0.39	84

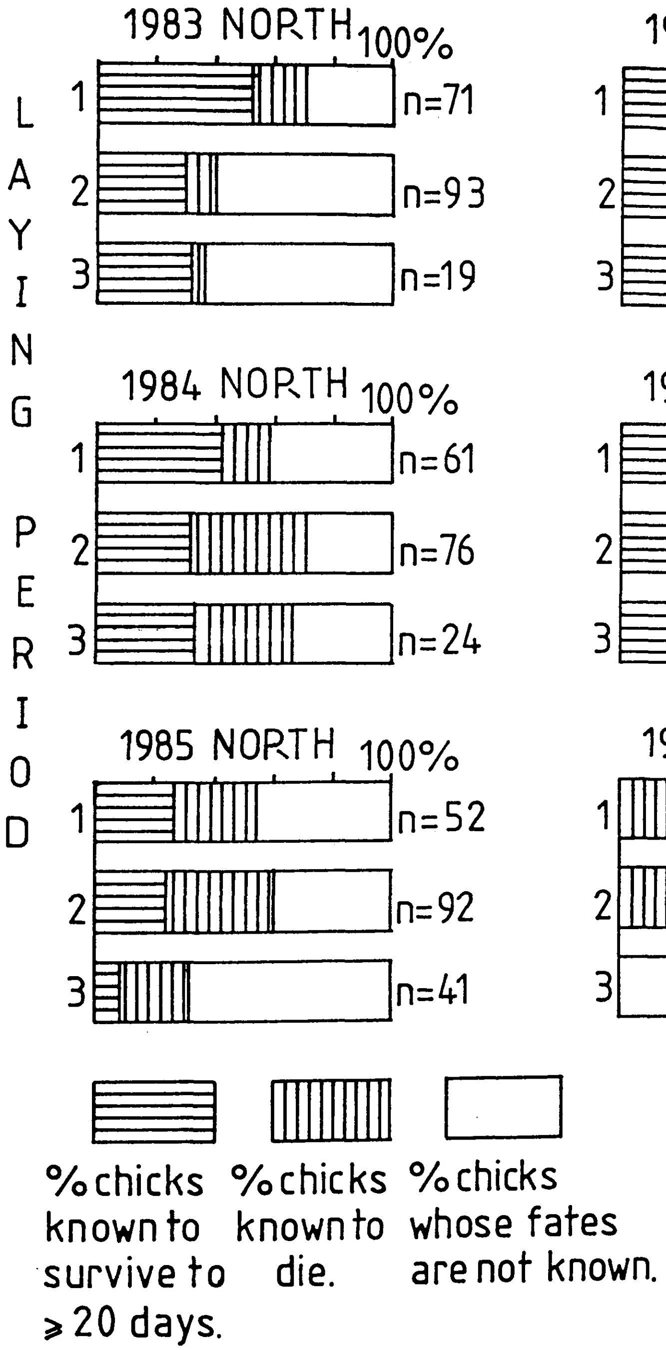
* = $P < 0.05$, ** = $P < 0.001$

8.5 TIMING OF BREEDING

The results presented in Tables 8.6 and 8.7 suggest that the earlier laying began at nests in northern sites, the greater were the chances that the nests would produce at least one chick which would survive to twenty days. Figure 8.2 shows the fates of chicks from the three laying periods at each of the sites during the three breeding seasons. Again it appears that the timing of breeding is of greater importance at the northern sites, as far as the percentage of chicks surviving to at least 20 days, are concerned. However, whereas the timing of breeding appears to have little affect upon the percentage of chicks known to die at the northern sites, at the southern sites the percentage of chicks known to die appears to increase as the season progresses.

Figure 8.2 The fates of chicks hatching early, mid and late breeding season at all study sites during the three seasons 1983-1985.

Laying period 1 = early
Laying period 2 = mid
Laying period 3 = late


1983 NORTH
100%
1
n=71
2
n=93
3
n=19
1983 SOUTH
100%
1
n=30
2
n=99
3
n=24
1984 NORTH
100%
1
n=61
2
n=76
3
n=24
1984 SOUTH
100%
1
n=60
2
n=75
3
n=24
1985 NORTH
100%
1
n=52
2
n=92
3
n=41
1985 SOUTH
100%
1
n=20
2
n=23
3
n=0
LAYING PERIOD
% chicks known to survive to ≥ 20 days.
% chicks known to die.
% chicks whose fates are not known.

8.6 THE EFFECT OF NESTING DENSITY UPON HATCHING SUCCESS AND CHICK SURVIVAL.

In Chapter Seven the considerable variation in nest densities between sites and seasons was discussed (see Section 7.8 and Table 7.9) and it was suggested that whereas defence at low nesting densities was ineffective against aerial predators, at high densities mobile chicks were at risk of straying onto neighbouring territories and suffering attacks. Densities of nesting Audouin´s gulls were significantly higher in 1983 and 1985 at the northern sites as compared with the southern sites (see Table 7.8). There were also significant differences between the nesting densities at sites from one season to the next. In 1984 nesting densities were significantly lower at the northern site as compared with 1983 ($t = 4.99$, d.f. = 154, $P<0.000$). Did these changes in nesting density have any impact upon either hatching success or chick survival?

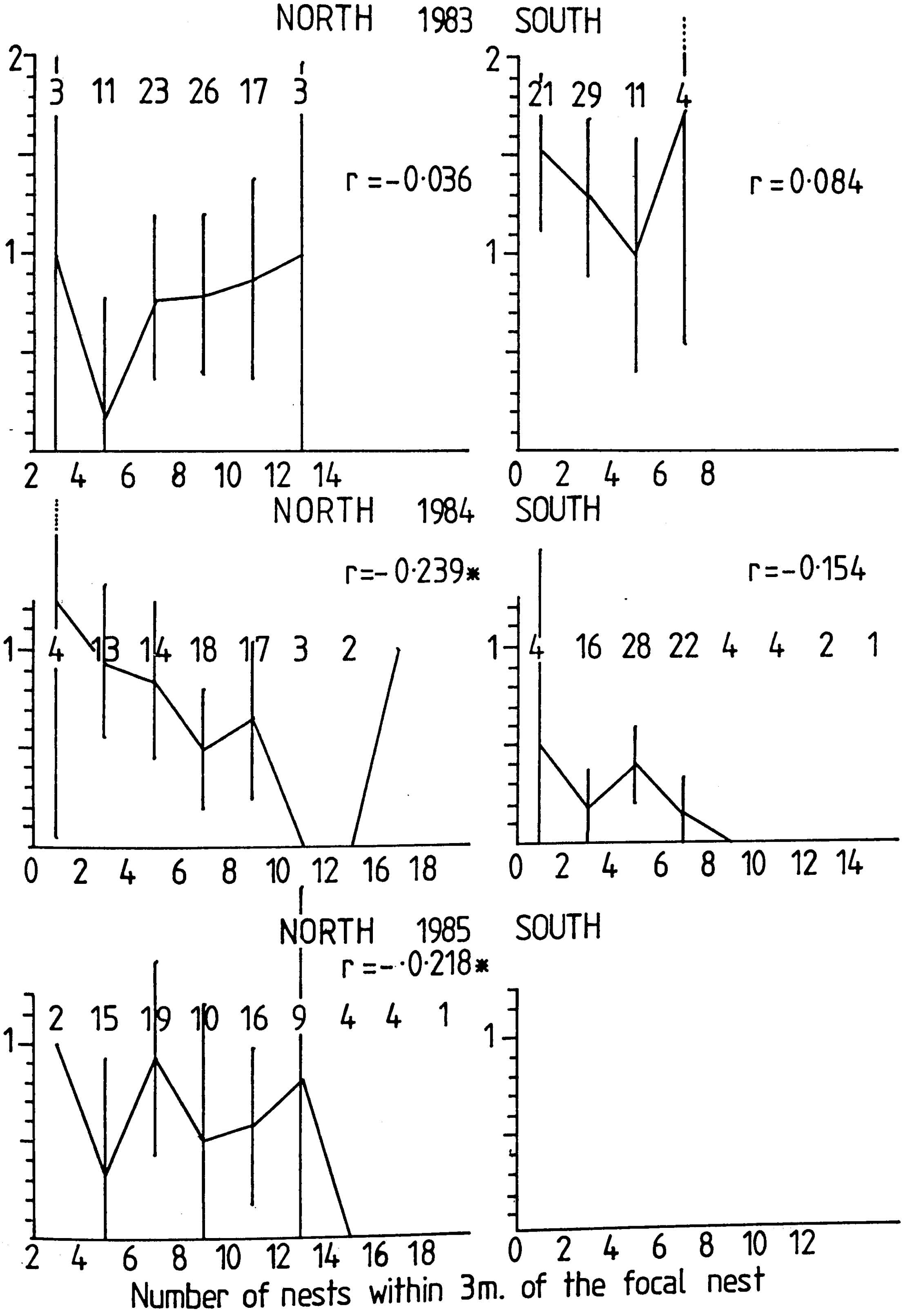
The discriminant analyses on hatching success at the study sites suggest that density was more important at the southern sites than at the northern sites, as the density variable was eliminated from the formulation of the discriminant function for the three northern sites, see Table 8.4.

The discriminant analyses selected density as being of some importance in separating successful and unsuccessful nests, those producing and those not producing at least one chick which survives to 20 days, at both sites in 1984 (see Table 8.6). Density was also retained for the north site in 1985 but as the discriminant function was unsuccessful at discriminating between the two populations, this can be ignored. Figure 8.3 shows that at both the sites in 1984, as density increased success decreased. At the other sites the relationship between nest density and nesting success was less clear but suggestive of a non-linear relationship.

Figure 8.3 The relationship between nesting density (number of nests within 3 m. of the focal nest) and the mean number (± 2 s.e.) of chicks known to survive to 20 days per nest for each study site during the three seasons 1983-1985.

Horizontal axis = number of nests within 3 m. of each focal nest. Vertical axis = mean number of chicks per nest to survive to 20 days.

* denotes a correlation coefficient significant at $P<0.05$.


NORTH 1983 SOUTH
2
3 11 23 26 17 3
r =-0·036
1
2 4 6 8 10 12 14
2
21 29 11 4
r = 0·084
1
0 2 4 6 8
NORTH 1984 SOUTH
r=- 0·239*
1
4 13 14 18 17 3 2
0 2 4 6 8 10 12 16 18
r=-0·154
1
4 16 28 22 4 4 2 1
0 2 4 6 8 10 12 14
NORTH 1985 SOUTH
r =-·0·218*
2 15 19 10 16 9 4 4 1
1
2 4 6 8 10 12 14 16 18
1
0 2 4 6 8 10 12
Number of nests within 3m. of the focal nest

8.7 DISCUSSION

In Chapter Seven, Table 7.6, it was shown that the mean number of chicks alive at 20 days after hatching per nest was 1.26 (s.d. = 0.99) in the southern site in 1983. This study has also shown that chick mortality continued right up to fledging. So it can be said that fewer than a mean of 1.26 chicks fledged in 1983 from the southern study sites. At the other study sites fledging success was probably lower than this. There are no other records of fledging success for Audouin´s gull with which this can be compared.

In this chapter data concerning the mean clutch size at each site was given in Table 8.1. The lowest recorded mean clutch size was that at the south site in 1984 (2.38 ± 0.9) and the highest was at the north site in 1983 (2.75 ± 0.6). Clutch sizes measured during other studies of Audouin´s gulls are shown in Table 4.2. The clutch sizes given for this study are among the highest quoted. This may, in part, be due to the fact that many of the other figures are given following a single visit to a colony at which either laying may have not yet been completed or where predation levels may have been high. In Table 4.5 clutch sizes for other gull species are given. Audouin´s gull clutch sizes are not consistently lower than these.

Records of Audouin´s gull hatching success at other colonies and for other seasons on the Chafarinas Islands are also rare in the literature. Witt (1977) followed the incubation of 65 eggs laid at an Aegean site in 1974. Of these 33 hatched (51%) successfully. Mayol (1978) also studied hatching success of Audouin´s gulls on the Chafarinas Islands. From 1062 eggs, 420 failed to hatch (hatching success = 60%). At five colonies in the Balearic Islands Mayol (1978) found that out of 382 nests 30 eggs failed to hatch (hatching success = 97%). As Mayol´s visits to all the colonies were of very short duration it is certain that these values are over-estimates of the hatching success as it is unlikely that all other eggs survived the incubation period and hatched successfully. In this study the mean numbers of chicks hatching per egg laid at each site are shown in Table 8.1 as the mean brood size at each site. Table 8.2 shows the ratio of chicks hatching per egg laid at each site. The greatest hatching success was recorded at the northern site in 1983 (81%) and the lowest at the southern site in 1985 (32%). Hatching success showed considerable variation at the sites between seasons, however. If 1983 can be considered to represent hatching success when predation pressures are low, then the number of chicks hatching from eggs does not appear lower than the values for hatching success listed in the literature for other Larid species, see Table 8.9. There does not appear to be any evidence to suggest that hatching success is limiting the reproductive performance and thereby population size of Audouin´s gulls.

TABLE 8.9: HATCHING SUCCESS OF SOME GULL AND TERN SPECIES.

Species	Location of study	Percentage of eggs laid which hatch	Source of data
Lesser Black-Backed	Wales	66.2	Harris (1964a)
Lesser Black Backed	Skokholm	65	Davis + Dunn (1976)
Lesser Black-Backed	Walney Is	72	Brown (1967)
Lesser Black-Backed	Scotland	92.5-95.1	Darling (1938)
Lesser Black-Backed	Denmark	61	Paludan (1951)
Greater Black-Backed	Maine	95	Butler + Janes Butler (1982)
Greater Black-Backed	Wales	76	Harris (1964b)
Arctic Terns	Farne Is.	53	Coulson + Horobin (1976)
Herring	Wales	64	Harris (1964)
Herring	Scotland	84.5-95.7	Darling (1938)
Herring	Denmark	55	Paludan (1951)
Herring	Scotland	70	Parsons (1971)
Kittiwake	England	68	Coulson + White (1958)

In 1983, at both sites, approximately 58% of the chicks which hatched developed to at least 20 days of age. This figure can be compared with data collected from the general literature concerning fledging success of other gull species, see Table 8.10.

TABLE 8.10: FLEDGING SUCCESS OF SOME GULL SPECIES.

Species (study location)	Percentage of chicks which fledge	Source
Lesser Black Back (Wales)	>50	Harris (1964)
Lesser Black Back (Skokholm)	43	Davis +Dunn (1976)
Lesser Black Back (Scotland)	48-62	Darling (1938)
Herring (Wales)	30	Harris (1964)
Herring (Scotland)	12-49	Darling (1938)
Herring	50	Kadlec + Drury (1969)
Herring (Wales)	31	Davis (1975)
Great Black Backed (Maine)	59	Butler + Trivelpiece (1981)

Again, Audouin´s gull does not stand out as the least successful amongst the gull species considered here. It would therefore appear that this study does not provide any evidence to support Simon and Geroudet´s hypothesis (1970) that Audouin´s gull´s reproductive ability was less than that of other gull species.

During this study much emphasis has been placed upon measuring reproductive success and attempting to evaluate the effect of various environmental factors upon this success. This has been considered important because, between the expansion of the touristic developments on the coast of the Mediterranean and the increase in the size of the nesting population of herring gulls, suitable breeding sites for Audouin´s gulls are becoming scarce and likely to become even more uncommon unless direct conservation action is taken. It is therefore all the more important that where Audouin´s gulls are breeding the conditions are as close to ideal as possible so as to maximize reproductive output.

Where gulls nest has been shown to be influenced, in addition to the physical attractiveness of a site, by the following parameters: the level of disturbance; previous breeding failures and nesting densities of conspecifics already at the site (Furness and Monaghan 1986). Where a gull breeds for a first time may also depend upon where it hatched itself. After that the bird may return to the same nest site with the same mate. Its age, experience and previous success as a breeder may influence a large range of selection parameters, such as those considered here, i.e. the pair´s timing of breeding; selected position within the colony (centre vs edge) and chosen nesting density. This is particularly relevant to large stable colonies which tend to become structured with the older birds forming a nucleus to which the younger pairs are attracted (Coulson 1968). Audouin´s gull colonies, at least on the Chafarinas Islands, are not likely to follow this pattern as the distribution of the sub colonies alters each season (see Section 4.1). It is suggested here that, in contrast to stable gull colonies, the quality and position of the nest territory of a pair are less likely to implicitly reflect the pair´s age and experience, and may instead directly affect the pairs´ subsequent breeding success. It is possible that experienced gulls may be able to select favourable habitats even within unstable colonies but whether this is the case will only become apparent when a larger proportion of the adult population is age identifiable (i.e. when more carry year coded colour rings).

Until the actual process of site selection, which has not been included in this study has been elucidated the ability of the adult Audouin´s gulls to choose suitable nest sites will remain unknown. Audouin´s gulls have, during these three study seasons, chosen to breed, in addition to the two study habitats (described in Section 3.6) on the Chafarinas on cliffs and rocky outcrops. Gulls breeding at both of these sites proved even less successful than the northern and southern sites discussed in this study and numerically represented but a small proportion of the breeding population on Rey in 1984 and 1985, the two years in which they were colonized.

The factors which were found to have an impact upon hatching and chick rearing success differed from one site to the other and also from one season to the next depending upon the conditions and threats to the Audouin´s gulls´ reproductive output. Many studies of avian breeding biologies have emphasised the importance of the timing of breeding. In gulls a decline in the nesting success with date of laying has been observed in the lesser black-backed gull (Brown 1967), herring gull (Paynter 1949, Kadlec and Drury 1968, Spaans and Spaans 1975, Pierotti 1982), the glaucous-winged gull and California gull (Vermeer 1963, 1970). For some species, however, eggs hatching at the peak of hatching within the colony were the most successful (black-headed gull, Patterson 1965). Following a study of glaucous-winged gull breeding biology, Hunt and Hunt (1976) suggested that during years of high food availability the effect of timing of breeding should be less noticeable and proposed a model for predicting the effect of timing of breeding on reproductive success: that when survival depends on the avoidance of neighbours it is best to hatch early but when survival depends on the avoidance of predators it is best to hatch in the middle of the season at the peak of hatching within the colony. This assumes that the predators kill only enough prey to satisfy their appetite and that this number of prey is exceeded at the peak of the season. There was no evidence that Audouin´s gulls breeding on the Chafarinas Islands were short of food during the three seasons studies but there was evidence that during some seasons there was an advantage to be gained by avoiding predators.

The effect of nesting density upon reproductive success also depends upon the nature of the threats to such success which might make nesting at high densities more, or less, successful. In some gull studies, chick and egg survival was not influenced by nest density (glaucous-winged gull, Vermeer 1963; black-headed gull, Patterson 1965; ring billed gull, Dexheimer and Southern 1974; and the western gull, Hunt and Hunt 1975). Others have found chick or egg survival to be negatively correlated with nesting density (kelp gull, Fordham 1970; and great black backed gull, Butler and Trivelpiece 1981). Parsons (1976) showed that maximum herring gull reproductive success was found at intermediate nesting densities and that as Hunt and Hunt (1976) hypothesized for glaucous-winged gull chick survival, there are trade-offs between interference with neighbours at high densities and lack of effective defence against predators at low densities. This would also appear to be the case for Audouin´s gull on the Chafarinas. The findings of this study, and those of Mayol (1978a) suggest that Audouin´s gulls breeding at both low and high nesting densities suffer reduced breeding success. Those at low densities cannot defend themselves against attacks by herring gulls and those at high densities risk having their chicks killed by neighbours. Monbailliu and Torre (1986) also found that Audouin´s gulls breeding at high densities on the island of Asinara, Sardinia, frequently attacked neighbouring chicks when they strayed.

Few studies have discussed the influence of nest quality upon reproductive success. In this study nest quality, how well constructed a nest appeared to the human eye, was one of the environmental factors which was found to influence hatching failure at all sites, apart from the southern site in 1985 which was heavily predated during the incubation period. As described in Section 6.3, nests varied from mere scrapes in the bare earth to deeply upholstered bowls of vegetable material, feathers and dried bird limbs. In Section 6.3, nest building was described as continuing during the incubation period and was frequently associated with changeovers of incubating adults on the nest. The quality of the nest may reflect the quality of the adults. Young or inexperienced adults, not accustomed to nest building, may not construct such good nests or be prepared to persuade the other adult off the nest by approaching with further nest material. That poor nests are the products of young pairs could be tested in future years by comparing nests of adults of known ages. If young pairs did build inferior nests this might also explain the reduced success of eggs laid within the nest by them, as young birds generally lay smaller eggs later in the season and have lower hatching success than experienced birds (Ryder 1980). Another possible explanation for the lower hatching success at poorly constructed nests may be that they provide little insulation from the ambient temperatures. Eggs in low quality nests may be more sensitive to changes in temperature than eggs in well padded nests. The ground within the colony was also very rocky with sharp stones exposed within the scrapes. High quality nests cushioned the eggs and protected them from breaking against the stones. Mere scrapes offered no such protection.

Bushes close to nests served a number of useful functions. They provided, during the incubation period, shade for the adults and cover from predators. Because bushes also acted as a boundary between neighbours, nests could be placed very close to one another, without intra-specific aggression, if a bush separated them. In this way the nesting density could be high enough to allow effective mobbing of predators to take place but, because chicks would be less likely to stray into neighbouring territories in search of shelter, the risk of chick mortality, as caused by intra-specific aggression could be reduced. At the southern sites bushes were plentiful and nests were distributed around their edges (see Appendix 10). In the north of Rey bushes were low, thin and scarce, hence their importance as indicated in the discriminant analysis of nesting success.

Other studies have shown vegetation cover as important in influencing nesting success and in nest site selection. Bongiorno (1970) found that marsh nesting laughing gulls select their nest site with primary regard for the position of marsh grasses and debris and secondarily adjust their spacing with regard to the proximity of neighbours. Hill (1984) found that the number of mallard nests destroyed by predators increased as the height of vegetation surrounding the nests decreased. Hosey and Goodridge (1980) found that amongst lesser black backed gulls those nesting amongst vegetation spent less energy on territorial aggression and were exposed to lower predation rates than nests in the open. Herring gulls were found to hatch more eggs in nests with cover and chick survival was greater under shelter than in open habitats (Parsons and Chao 1983).

Audouin´s gulls on the Chafarinas Islands nest only on the periphery of bushes, never amongst them and only once, during the three seasons, was a nest built on top of a bush. In 1980 the vegetation in the north of Rey was very high and dense (de Juana 1980). In this year no Audouin´s gulls nested in the north of Rey. During the three seasons studied no evidence was found of any ground predators on Rey. Should these ever be introduced vegetative cover would also provide them with shelter and protect them from attacking adults and would therefore probably reduce the advantages for Audouin´s gulls gained by breeding close to bushes. The type of vegetation is also important. The northern study site was partially colonized by the heavily thorned Lycium intricatum amongst which a number of chicks were wounded or killed, see Section 7.8).

The most obvious disadvantage associated with nesting close to the edge of an Audouin´s gull sub-colony was the relative ease of access which herring gulls had to eggs and chicks. Herring gulls were seen to loaf upon raised areas from which attacks would be launched. Unfortunate nests close to these vantage points were the first to lose their contents. At the edge of the sub-colonies densities were also lower than in the main body of the sub-colony, making it more difficult for adults to defend their offspring.

Differences between the breeding success of pairs at the centre as compared with those at the edge need not necessarily be explained by differences in exposure to predation. Coulson (1968) found that pairs at the centre of a kittiwake colony had the following: larger mean clutch sizes; higher hatching success; more young fledged per pair; and fewer changes of mate. This was largely due to the age structure within the colony and, as has already been discussed, seems less likely to have such an effect within the unstable Audouin´s gull subcolonies on the Chafarinas. Tenaza (1973) makes the point that the smaller the colonies are, the larger the proportion of nests which are peripheral will be and thus lower the average number of young that can be produced per nest. On Rey each cluster of Audouin´s gull nests is in close proximity to nesting herring gulls. The smaller subcolonies would present a smaller perimeter to the herring gulls if they were aggregated.

This part of the study has presented the data concerning the reproduction of Audouin´s gull on the island of Rey of the Chafarinas archipelago. To summarize, during the three breeding seasons studied there was a dramatic decline in the reproductive success recorded, see Table 8.11.

TABLE 8.11: NUMBER OF CHICKS PER NEST SURVIVING TO 20 DAYS AFTER HATCHING FOR STUDY SITES DURING THE THREE SEASONS, 1983-1985.

YEAR	SITE	NUMBER OF YOUNG SURVIVING TO 20 DAYS			
		n	MEDIAN	MEAN	s.e
1983	NORTH	85	1	0.86	0.10
1983	SOUTH	74	1	1.26	0.10
1984	NORTH	86	1	0.70	0.08
1984	SOUTH	98	1	0.19	0.05
1985	NORTH	105	1	0.56	0.08
1985	SOUTH	52	0	0.00	0.00

The figure given for the success at the southern site in 1983 would suggest that Audouin´s gull, assuming that the duration of their breeding life is similar to other Larid species and that post-fledging mortality is not excessive, should at very least be able to maintain the current population size on the Chafarinas. Using the data from the adult censuses and chick production and assuming the following; adults begin to breed in their fourth year; that adult mortality is approximately 10% per annum with first year mortality approximately 30% - a potential growth of 10% per annum can be calculated. The very successful herring gull has been shown to rear, on average, one fledgling per pair each season (Brown 1967, Kadlec and Drury 1968).

Nest quality and the distance of the nests from the edge of the colony were found, by stepwise multivariate analysis, to be important in producing a separation between nests from which at least one egg hatched successfully and those which were unsuccessful in producing any. Similar analyses on the success of nests at producing at least one chick which survived to at least 20 days suggested that successful nests in the north tended to have more cover close to the nest and that breeding began earlier in the season than unsuccessful nests. Successful nests in the south were more likely to be away from the edge of the subcolony, away from herring gulls and in a more exposed position than unsuccessful nests.

Many previous studies have shown that disturbances caused by humans within the colony can have deleterious effects upon the reproductive success of the study animals (herring gulls, Hunt 1972, Schoen and Harris 1984; ring-billed gulls, Fetterolf 1983b; western gull, Robert and Ralph 1975, Hand 1980; and comorants, Krury and Gochfeld 1975). For most of these studies the explanation of the reduced success was an amplification of intra- or inter-specific predation upon eggs and chicks. Predators often take advantage of temporary absences of the protecting adults from their vulnerable offspring. Human disturbance can affect success in other ways. Hunt (1972) suggested that disturbances caused by picnickers resulted in adult herring gulls leaving their nests and eggs exposed to solar radiation which killed the embryos. Burger (1974) found that Franklin´s gulls would change their nesting distribution from one year to the next so as to avoid nesting near a hide. Chick distribution and survival can also be affected by human disturbance. Burger (1974) found that chicks of the marsh-nesting Franklin´s gull, at undisturbed sites, remained for longer in the relative safety of the nest platform than those in disturbed areas. Fetterolf (1983a, 1983b, 1984) during a study of ring-billed gulls found that whilst infanticide was uncommon at undisturbed colonies, both infanticide and adoptions were common at disturbed colonies and chick mortality was correspondingly higher.

Audouin´s gulls were very sensitive to human disturbance and the herring gulls did often take advantage of the adults´ absences to raid the colony. It is therefore likely that the human disturbance associated with this study, even after the precautions described in Section 3.9 were taken, did deleteriously affect breeding success. However, observations made from the hide and of the control sites did suggest that the disturbance involved with this study did not alter the overall picture of the scale of the success or failure of the areas and reflected the causes and scale of egg and chick mortality which occurred at similar sites throughout the colony. For example, the very high predation at the southern sites in 1984 and 1985 were also observed at the undisturbed control sites in 1984 and 1985. The positions of the control sites are shown in Figures 3.3, 3.5 and 3.6. The observations made from the hides also showed that chicks hid and adults left the colony whenever a disturbance occurred, whatever its nature. It is possible that the activities of the observer heightened the sensitivity of the birds to the disturbances. Additionally, the island of Rey is not free from human disturbance in the absence of a study such as this. The island on which all the military personnel are billeted is featureless and crowded, therefore off-duty officers and civilian employees of the army would visit the island of Rey for recreational purposes. It is therefore suggested that human disturbance does amplify those problems that already exist but in this case the disturbance associated with the study is justifiable on the grounds that the island will, unless given protection, continue to receive a certain amount of disturbance and that it is important to gather the data necessary in order to understand the challenges facing the gulls´ reproductive success so that constructive management measures may be undertaken to secure its position.

CHAPTER NINE: THE IMPACT OF THE HERRING GULL UPON THE REPRODUCTIVE SUCCESS OF AUDOUIN´S GULL.

9.1 INTRODUCTION

Yellow-legged herring gulls and Audouin´s gulls have both bred on the Chafarinas Islands since the existence of the Audouin´s gull colony was first reported (Brosset 1966). Birds of the genus Larus commonly breed in mixed species assemblages. For example, herring gulls in northern Europe frequently nest with lesser black-backed gulls (Brown 1967, Mac Roberts and Mac Roberts 1972) and black headed gulls (Greenhalgh 1972). In North America ring-billed gulls nest with California gulls (Vermeer 1970) and herring gulls (Southern 1977), and laughing gulls with herring gulls (Burger 1979b). In 1934 Gause wrote that as a result of competition, two similar species scarcely ever occupy similar niches, but displace each other in such a manner that each takes possession of certain kinds of food and modes of life in which it has an advantage over its competitor (Gause 1934 page 19). Previous studies have shown that, at least with regards to food types, Audouin´s gulls do not completely overlap with herring gulls (see Section 2.5). The extent to which the two species compete for nest sites on the Chafarinas Islands and the effect of herring gull predation on Audouin´s gull breeding success have yet to be assessed. This chapter will attempt to present new data concerning interactions between the two species and discuss their implications for the future of the gulls on the Chafarinas Islands.

9.2 METHODS

9.2.1 Observation of interactions between the two species

During hide watches all herring gull intrusions into the Audouin´s gull colony were noted. The frequency and duration of such visits were recorded, along with information concerning the damage, if any, which may have followed and the reactions of the Audouin´s gulls. In 1985 herring gulls were breeding within view of both the northern and the first southern hide (the first southern study site was abandoned due to predation of all eggs by herring gulls, see Section 3.7). To facilitate the identification of these nearby nesting herring gulls, picric acid soaked sponges were placed on the herring gull nest rims so that birds returning to incubate the eggs would also settle on the sponges and acquire distinctive yellow marks. These adult herring gulls were marked in order to find out whether the herring gulls nesting closest to the Audouin´s gulls were the most frequent predators, see Section 9.8.

9.2.2 Collection of evidence of predation

The predation of eggs was assumed when eggs disappeared from nests within the study site. There were no other predators to which these losses could be attributed and the numbers of observed instances in which Audouin´s gulls broke their eggs were very few. The study areas were within view of the main military island where guards were permanently posted so it is unlikely, especially in view of the continuous loss of a relatively small numbers of eggs, that humans were robbing nests as has frequently been the case in the past, see Section 10.5.

All corpses of chicks within the study areas were checked for indications of predation, i.e. usually that their intestines and pectoral muscles had been at least partially consumed. No Audouin´s gulls were ever observed to eat chicks of either species whereas they were frequently observed to be eaten by herring gull adults. Rings were also collected from within the herring gull breeding sites on both Congreso and Rey islands, both from corpses which had been carried there for consumption, and from food pellets.

9.3 DEVELOPMENT OF THE BREEDING DISTRIBUTION OF THE TWO GULL SPECIES.

The first records of gull numbers on the Chafarinas Islands were those of Brosset and Olier (1966) who wrote that in 1960 hundreds of herring gulls bred on Congreso and that 500 pairs of Audouin´s gulls nested on the Island of Rey. Since then the numbers of both species have increased, see Tables 9.1 and 9.2. Both species have, at some time, bred on both the islands of Congreso and Rey.

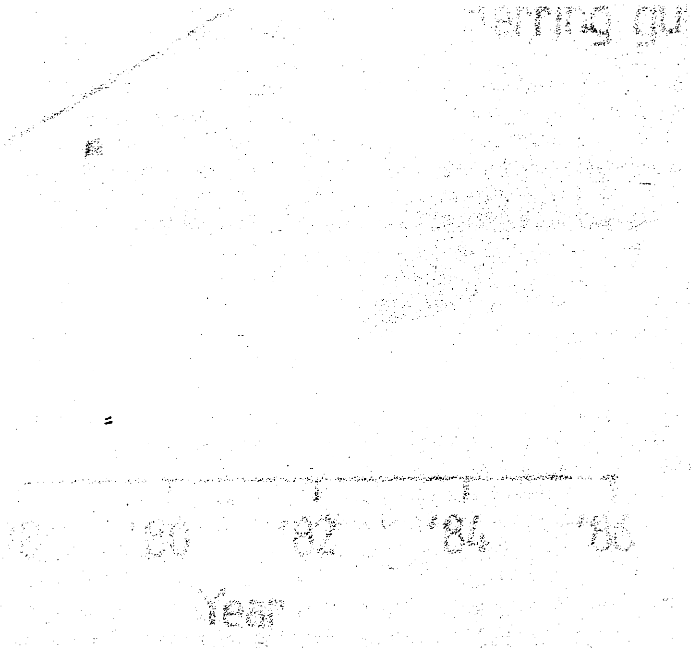
TABLE 9.1: DISTRIBUTION AND NUMBER OF AUDOUIN´S GULL PAIRS ON THE CHAFARINAS ISLANDS FROM 1966 ONWARDS.

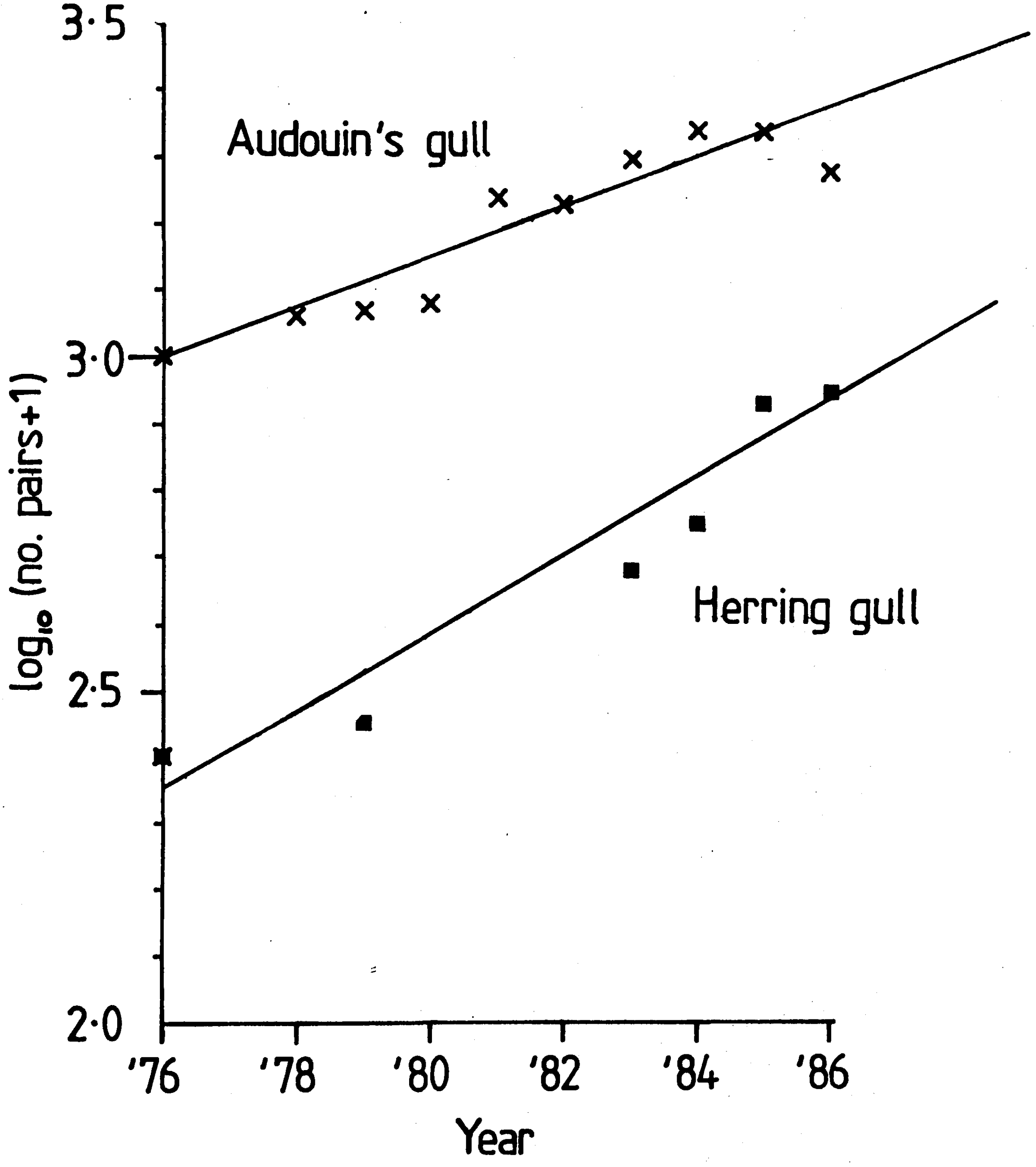
YEAR	TOTAL NUMBER	I.REY	I.CONGRESO	SOURCE
1960	500	500	0	Brosset and Olier 1966
1976	1000	1000	0	de Juana *et al.* 1980
1978	1190	1150	40	Mayol 1978
1979	1300-1375	1150-1225	150	de Juana *et al.* 1982
1980	1870	1195	675	de Juana *et al.* 1982
1981	2220	1724	496	de Juana *et al.* 1982
1982	1954	1710	244	de Juana *et al.* 1982
1983	2012	2002	10	this study
1984	2194	2194	0	this study
1985	2198	2198	0	this study
1986	1930	1930	0	Varela pers. comm.

Audouin´s gulls, to our knowledge, only bred on Congreso between, and including, the years of 1978 to 1983. Since 1976 the numbers of Audouin´s gulls nesting on the island of Rey have been increasing rapidly and steadily (see Figure 9.1). The regression line ($y = 0.026x + 1.11$, $r = 0.95$, $df = 9$, $P < 0.05$) drawn through the data points in Figure 9.1 indicates that since 1976 there has been a more or less steady increase of 6.2% per annum in the Audouin´s gull population nesting there.

Accurate counts of herring gull nests have been made on Rey each year. These have shown an increase from some 250 pairs counted in 1976 to 850 pairs in 1985. The regression line ($y = 0.058x - 2.05$, $r = 0.96$, $df = 4$, $P > 0.05$) drawn through these data points in Figure 9.1 indicates that since 1976 there has been a more or less steady increase averaging 14.3% per annum in the herring gull population nesting on Rey.

Figure 9.1 The growth of the Audouin´s gull and herring gull population on the island of Rey from 1960 until 1986. The population size is expressed on the vertical axis as $\log_{10}(n + 1)$.





3·5
3·0
2·5
2·0
log₁₀ (no. pairs+1)
Audouin's gull
Herring gull
'76
'78
'80
'82
'84
'86
Year

TABLE 9.2: DISTRIBUTION AND NUMBER OF PAIRS OF HERRING GULLS BREEDING ON THE CHAFARINAS FROM 1966 ONWARDS.

YEAR	CONGRESO	REY	SOURCE
1960	HUNDREDS	0	Brosset and Olier 1966
1976	600	250	Varela and De Juana 1986
1979	1500	280	Varela and De Juana 1986
1983	3514	450-500	this study
1984	no census	569±70	this study
1985	3650	850	this study
1986	no census	900	Varela pers. comm.

As the herring gull colony of Congreso was very much larger than that on Rey and personnel were in short supply, a thorough census was carried out in 1983 alone. In 1983 adult gulls on the cliffs were counted from the sea and from the neighbouring island by three independent counters. Many counts within random quadrats were also made within the differently vegetated areas. This gave, for 1983, a figure of 3514 pairs of herring gulls nesting on the island of Congreso. In following years comparisons could only be made between the average numbers of nests found within quadrats with those densities recorded in 1983. From 1983 to 1985 the mean density of herring gull nests on Congreso rose from $4.5/100m^2$ to $5.6/100m^2$, suggesting an increase to 3650 pairs (Varela and de Juana 1986).

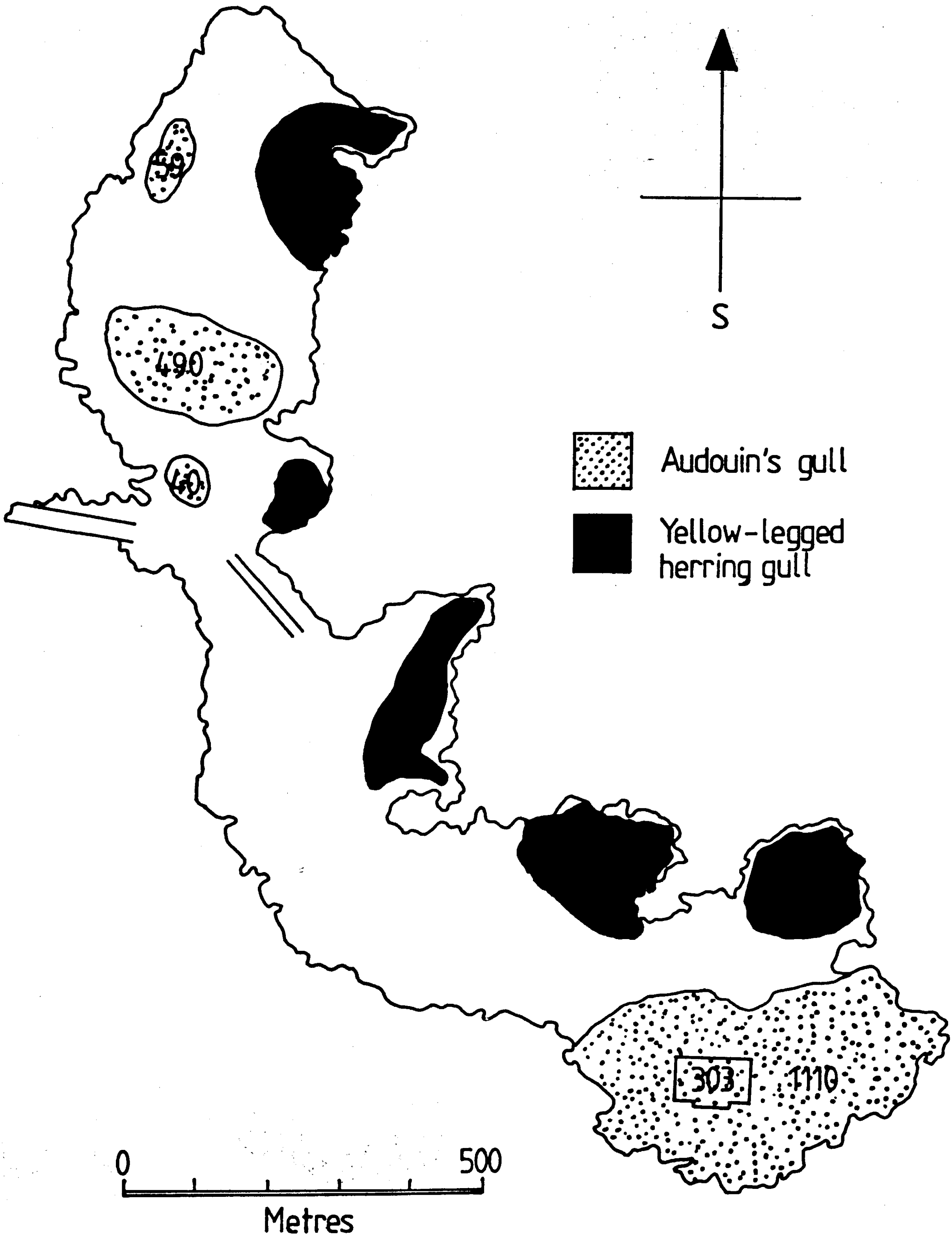
The censuses also allowed the distribution of the species to be mapped each year. Figures 9.2, 9.3 and 9.4 show the distribution of the two species on Rey during the three study seasons. Along the length of Rey, the island slopes from right to left with a precipitous drop from the cliffs on the eastern side. Since 1976 the herring gull colony has been gradually extending down the slope.

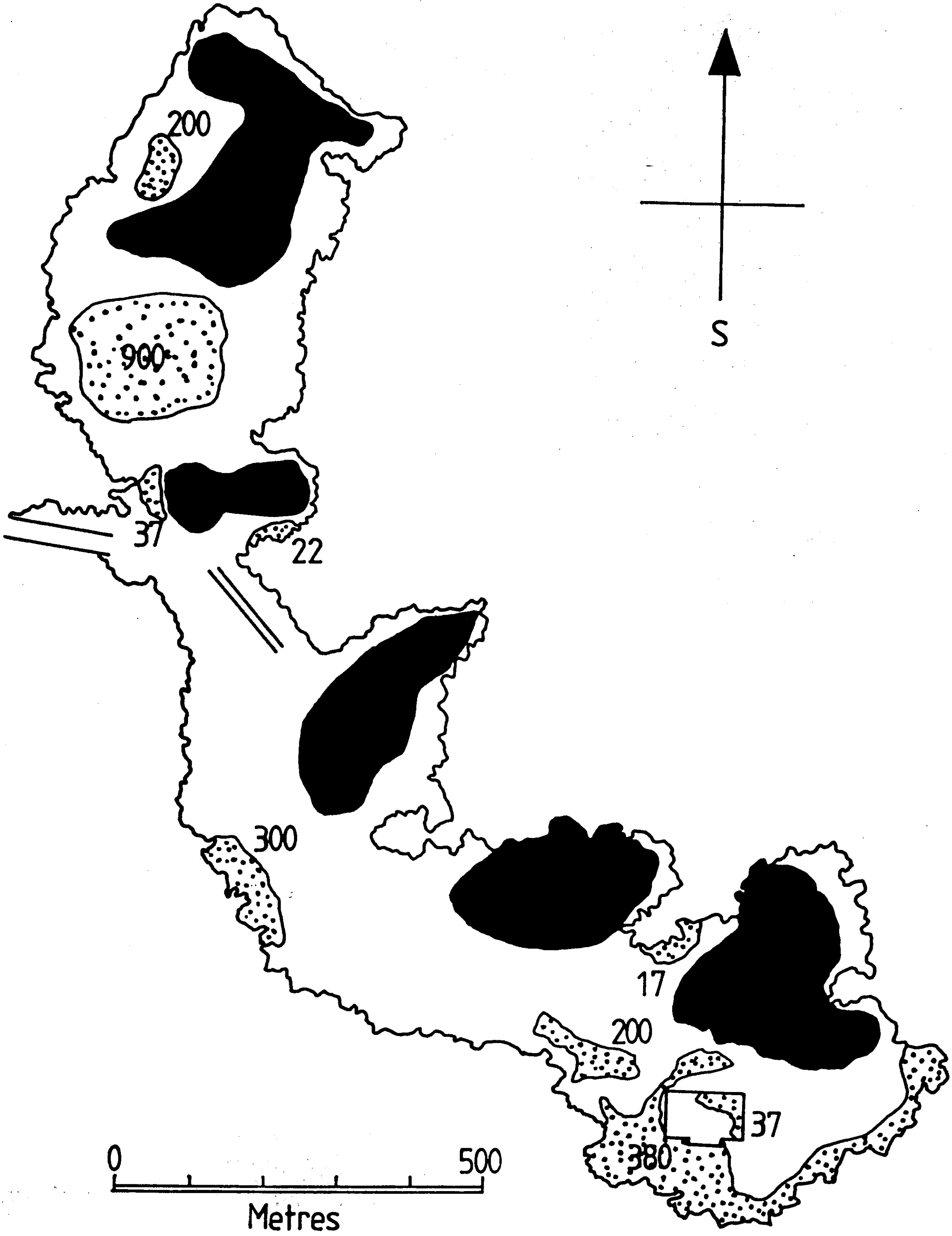
The Audouin´s gull colony appears to be fragmenting into more units each breeding season; in 1983 there were 4 subcolonies, in 1984 8 and in 1985 there were 9 (see Figures 9.2, 9.3 and 9.4). A pattern in Audouin´s gull site selection is less

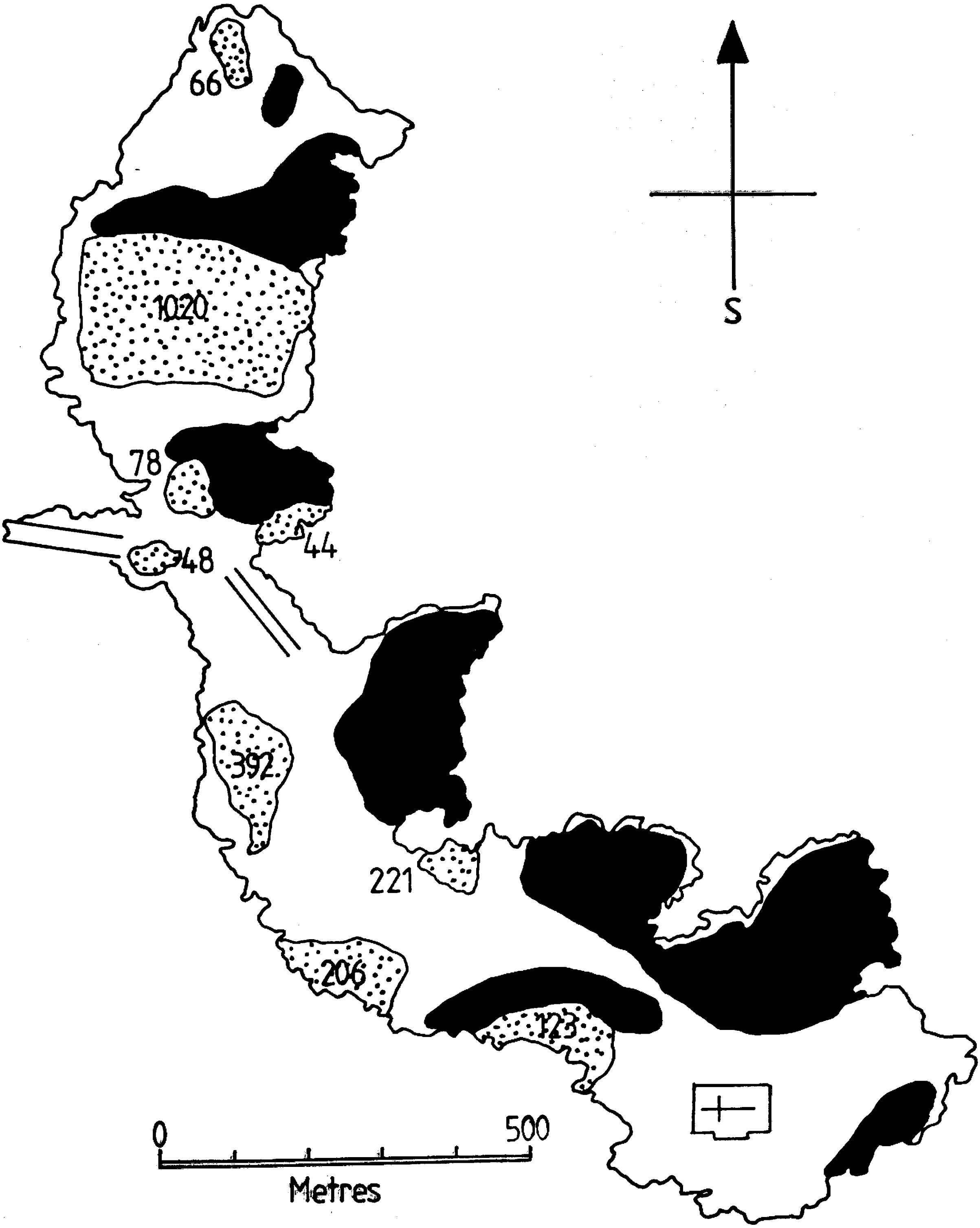
Figure 9.2 The distribution of Audouin´s gulls and herring gull nesting areas on the island of Rey in 1983. At each site the number of Audouin´s gull nests is given.

Figure 9.3 The distribution of Audouin´s gulls and herring gull nesting areas on the island of Rey in 1984. At each site the number of Audouin´s gull nests is given.

Figure 9.4 The distribution of Audouin´s gulls and herring gull nesting areas on the island of Rey in 1985. At each site the number of Audouin´s gull nests is given.


S
59
490
40
303
1110
Audouin's gull
Yellow-legged herring gull
0
500
Metres


S
200
900
37
22
300
17
200
37
380
0
500
Metres


66
1020
78
44
48
392
221
206
123
S
0
500
Metres

easy to detect than for herring gulls. Where a nesting site had failed in the previous season this site was not colonized in the following year. (After the southern site and the control site in 1984 both failed to produce any fledglings, neither site was reoccupied in 1985). In 1980, according to de Juana _et al_ (1980), the north of the island of Rey had become so densely vegetated that no Audouin´s gulls nested there. Audouin´s gulls appear to nest so as to avoid disturbance from either humans or herring gulls and where vegetation is neither very dense nor high.

One of the most significant changes in the breeding distribution of Audouin´s gulls over the years, has been the cessation of nesting on Congreso. For at least five years Audouin´s gulls nested on the steep gravelly slopes above the rocky beach to the south west of the island. In 1983 a maximum of ten nests were found there, and it was dubious that any of those few nests produced young as the adults abandoned the site long before the incubation period was completed. The area in which they were breeding was amongst large numbers of herring gulls. It is possible that as breeding failed on Congreso the unsuccessful adults may have relocated future breeding attempts on Rey where a large colony was already established, rather than amongst the herring gulls on Congreso. These suppositions are supported by observations made in 1984, that at the start of the breeding season many Audouin´s gulls were seen on Congreso but later in the season not a single bird remained.

9.4 TIMING OF BREEDING OF THE TWO SPECIES

One of the reasons for the apparent inability of Audouin´s gulls to compete for breeding sites against herring gulls is that the latter commence breeding earlier than Audouin´s gulls. On the Chafarinas Islands, whilst the majority of herring gulls have already begun to incubate their completed clutches, Audouin´s gulls are building their nests, a timing difference of almost a month. This difference in the timing of breeding of the two species has been observed throughout the Mediterranean (Cabrera, Araujo _et al._ 1977; Colombretes, Pechuan 1975; Turkey and

Sardinia, Witt 1976; and Algeria, Jacob and Courbet 1980). Audouin´s gulls have been observed to migrate post-nuptially to outside the Mediterranean not returning until immediately before the breeding season begins (see Section 2.3). Birds returning to the Mediterranean to breed have been seen at the bay of Malaga from February onwards (de Juana and Paterson 1986). Herring gulls, in contrast, appear to remain close to the Chafarinas throughout the year (Varela and de Juana 1986, J.M.Cabo pers. comm.).

The observations from the hide provided no evidence that Audouin´s gulls made any attempt to displace herring gulls from any site even when herring gulls selected to nest in the middle of what had, in the previous year, been the middle of an Audouin´s gull subcolony (e.g. the north site in 1985).

9.5 PREDATION OF AUDOUIN´S GULL EGGS BY HERRING GULLS.

During the 1984 and 1985 field seasons attempts were made to quantify the effect of the herring gull predation upon the reproductive success of the Audouin´s gulls within the study areas. Table 9.3 shows the number, and percentage of the total number, of nests whose contents were reduced in number, at least temporarily, during the incubation period. This includes all losses for whatever reasons.

TABLE 9.3: NUMBERS OF NESTS WHICH LOST EGGS DURING 1984 AND 1985 AT THE STUDY SITES.

YEAR AND SITE	NUMBER OF NESTS WHICH LOST AT LEAST ONE EGG (%)	TOTAL NUMBER OF NESTS
1984 SOUTH	44 (49%)	89
1984 NORTH	12 (15%)	79
1985 SOUTH	40 (74%)	54
1985 NORTH	39 (39%)	99

Because many of these losses occurred outside the observation period, and most frequently no remains of the eggs were left to give clues as to the cause of the damage not all losses could be attributed to herring gull predation. However, the observations made during the hide watches did not suggest that Audouin´s gulls were taking eggs or that there were other predators whereas herring gulls were frequently observed taking eggs from the colony. The only other possible causes of egg loss were eggs being damaged on stony ground. Eggs did, very infrequently, roll out of poorly constructed nests when the adults took flight during a disturbance. As this was only observed on two occasions during the three study periods this appeared to account for only a very small proportion of the losses recorded.

Table 9.4 shows the number of days which had passed since laying began at the nest, when an egg or eggs were lost from the nest.

TABLE 9.4: TIMING OF EGG LOSSES FROM NESTS AT BOTH STUDY SITES DURING 1984 AND 1985 ON THE CHAFARINAS ISLANDS. The percentage of the total number of nests at the site are shown in brackets.

NUMBER OF DAYS AFTER	NUMBER OF NESTS LOSING AN EGG/S AFTER LAYING BEGAN AT SITES (%)			
LAYING	NORTH 1984	SOUTH 1984	NORTH 1985	SOUTH 1985
1- 6	7 (8.1)	30 (30.6)	4 (3.9)	5 (9.6)
7-13	2 (2.3)	4 (4.1)	11 (10.8)	4 (7.7)
14-20	2 (2.3)	6 (6.1)	7 (6.9)	10 (19.2)
21-28	1 (1.2)	4 (4.1)	7 (6.9)	21 (40.4)

Egg loss could occur at any point during the incubation period but its probability at any particular point in time varied from site to site and between years. In 1984 at the southern site many nests lost eggs during the first week after laying, while at the southern site in 1985 losses increased during the incubation period. The pattern of egg losses probably varied with the availability of other easily available prey items, the number of predators and the readiness of the Audouin´s gulls to defend their nests. Like many gull species, Audouin´s gulls were observed to defend their nests more vigourously against human and herring gull interference as hatching approached. The northern nesting sites were defended more vigourously and effectively by more tightly nesting Audouin´s gulls which managed to prevent herring gulls from landing in the colony. This may therefore have avoided more egg losses later in the season more effectively than the less densely packed birds at the southern site, which were unable to drive herring gulls out of the colony. As has already been shown (see Figure 4.6, section 4.10) there was no one time during which predation was particularly intense.

The physical characteristics of the nests which appeared to have lost eggs as a result of herring gull predation were compared with those whose contents remained intact throughout the period. In 1984, at the northern site, no significant separation could be made between the nests on the basis of any of the environmental factors considered (timing of breeding, height of vegetation about the nest, visibility, nest quality, distance to the nearest neighbouring nest, nesting density and distance to the edge of the subcolony). At the southern site in 1984 nests which survived the period intact tended to be more associated with cover than those nests which lost eggs, see Table 9.5.

At the northern site in 1985, predated nests appeared to be more open (having higher visibility values), less well constructed and closer to the edge of the subcolony than nests which were not predated, see Table 9.6.

TABLE 9.5: A COMPARISON OF THE CHARACTERISTICS OF AUDOUIN´S GULL NESTS, AT THE SOUTH SITE IN 1984, WHICH HAVE HAD EGGS PREDATED WITH THOSE WHICH HAVE NOT, USING MANN-WHITNEY TEST (W = the sum of ranks as calculated by Minitab).

NEST CHARACTERISTICS	MEDIAN VALUE FOR NESTS (number of nests)		W	P
	NOT PREDATED	PREDATED		
laying date	(56) 13.0	(41) 13.0	2719	0.86
vegetation height	(48) 3.0	(34) 2.0	2231	*0.02
visibility	(50) 4.0	(33) 5.0	1930	0.11
nest quality	(49) 3.0	(28) 2.0	1993	0.38
distance to near.nest	(50) 117.5	(34) 145.0	1940	0.09
density	(50) 5.0	(34) 5.0	2264	0.21
edge	(50) 5.0	(34) 4.5	2326	0.07

TABLE 9.6: A COMPARISON OF THE CHARACTERISTICS OF AUDOUIN´S GULL NESTS, AT THE NORTH SITE IN 1985, WHICH HAVE HAD EGGS PREDATED WITH THOSE WHICH HAVE NOT, USING MANN-WHITNEY TEST (W = the sum of ranks as calculated by Minitab).

	MEDIAN VALUE FOR NESTS (number of nests)			
NEST CHARACTERISTICS	NOT PREDATED	PREDATED	W	P
laying date	(78) 11.0	(22) 13.0	3727	0.08
vegetation height	(73) 1.0	(19) 0.0	3552	0.13
visibility	(74) 6.0	(21) 7.0	3299	*0.02
nest quality	(72) 2.0	(19) 1.0	3605	*0.00
distance to near.nest	(69) 70.0	(18) 60.0	3064	0.77
density	(50) 9.5	(20) 8.5	1809	0.66
edge	(69) 10.0	(21) 6.0	3423	*0.01

9.6 PREDATION OF AUDOUIN´S GULL CHICKS

Predation on Audouin´s gull chicks occurred throughout the pre-fledging period at all sites at which chicks were still present (see Figure 4.6, section 4.10). Not only were small chicks liable to predation, but larger chicks also, see Table 9.7.

TABLE 9.7: AGE AT WHICH AUDOUIN´S GULL CHICKS WERE OBSERVED TO BE PREDATED BY HERRING GULLS. Results obtained either by direct observation or by the collection of partly consumed corpses

AGE OF	NUMBER FOUND AT EACH SITE			
CHICK (days)	NORTH 1984	SOUTH 1984	NORTH 1985	SOUTH 1985
1- 6	4	6	4	6
7-13	2	4	1	4
14-20	1	5	3	NONE SURVIVING
21-27	2	7	3	-
28-34	2	2	3	-
35-	1	2	2	-

Table 9.7 refers only to direct observations of predations of identified adults and recovered half-eaten corpses. The number of chicks found at each site that were in the 0-2 weeks, 2-4 weeks and 4+ weeks were compared using the X^2 Test (1984 North $X^2 = 1.5$, 1984 South $X^2 = 4.0$, 1985 North $X^2 = 0.1$). In no case was the value of X^2 significant (i.e. >5.991 with 2 d.f.). Figure 4.6 shows that observations made during hidewatches also indicate that Audouin´s gull chicks were taken at a steady rate during the pre-fledging period by herring gulls.

At the northern site chicks were attacked from the air by herring gull predators and were generally carried away from the immediate area of the subcolony for consumption. At the southern site, herring gulls acted more frequently as ground predators, extracting chicks from their hiding places amongst the bushes and usually partially consuming them within the subcolony.

9.7 PREDATION OF ADULT AUDOUIN´S GULLS.

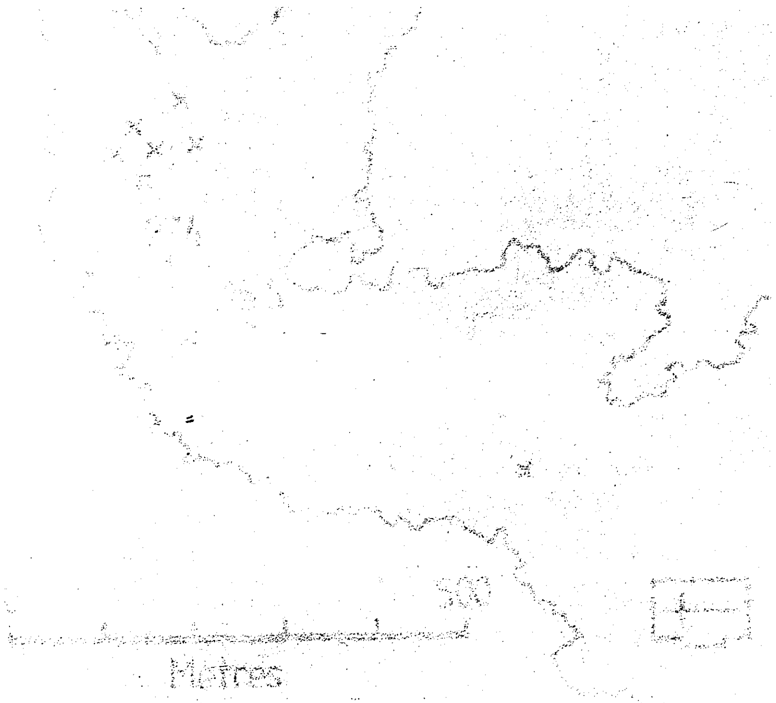
During previous studies on the Chafarinas Islands corpses of Audouin´s gulls which had been killed had been recovered (de Juana et al. 1982 and Witt 1979). In each case the deaths were attributed to attacks by peregrine falcons, which are known to breed on the islands. No such corpses or killings were seen during the 1983 and 1984 field seasons. However, on April 25th 1985, during an observation period, a herring gull attacking an Audouin´s gull nest caught an Audouin´s gull which was diving in an attempt to save its eggs, by the wing. It brought the latter to the ground, killed it and consumed the pectoral muscles and internal organs. This explained the fate of other Audouin´s gull corpses found in similar condition during the 1985 season. In all fifteen adults were killed and partially eaten, presumably by herring gulls. Figure 9.5 shows where the corpses were found on the island of Rey. Dates are given beside the position indicators when birds were found freshly killed. The scattered distribution of corpses suggests that more than one herring gull may have been responsible for the mortalities.

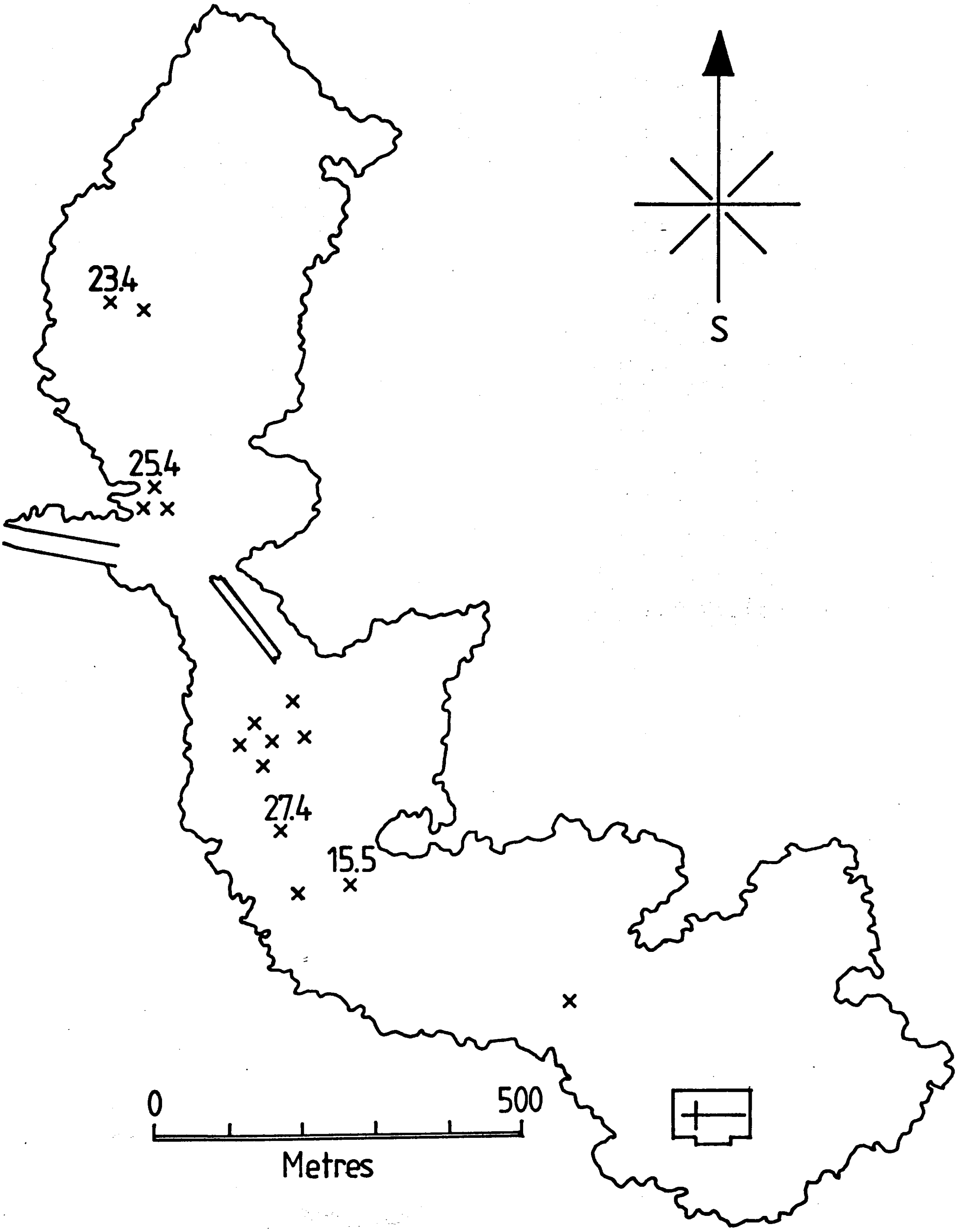
9.8 IDENTITY OF PREDATORS

In order to design a management policy for the Chafarinas Islands, the predators must be identified, since management techniques developed to control breeding herring gulls will achieve little if the majority of the predators are immature gulls, non breeding gulls or already failed breeders. Unfortunately, with few herring gulls individually recognizable, such information is difficult to collect.

At both the northern site and the southern sites, in 1985, all the herring gull nests within view of the hides had at least one member of the breeding pair partially stained yellow with dilute picric acid, see Section 9.2. None of these adults were ever seen taking either Audouin´s gull eggs or chicks. Audouin´s gulls tolerated the movements of these birds even though they were in very close proximity and, in turn, were ignored by the herring gulls. Herring gulls which flew overhead or which took

Figure 9.5 The distribution of adult Audouin´s gull corpses found partly consumed during 1985. When a fresh corpse was found the date of the find was recorded and is shown beside its position marker on the map.




S
23.4
25.4
27.4
15.5
0
500
Metres

up positions within the Audouin´s gull colony were generally mobbed by one or more Audouin´s gulls, the number of mobbing birds depending upon the nesting densities.

Predators were always observed to arrive from, or depart to, the elevated ridge of Rey where the main herring gull colony was situated. Whilst many Audouin´s gull rings and chick corpses were found in the herring gull breeding areas or within and around loafing sites on Rey, no evidence of predation within the Rey Audouin´s gull colony was found on the islands of Congreso or Isabel II. Both Isabel II and Congreso are only short distances from Rey and are islands on which large numbers of herring gulls were seen and bred, respectively. Congreso is a relatively large island and less time was spent searching for rings and corpses than was on Rey, making it less likely that rings would be found. Isabel II, in contrast, is inhabited with many people sufficiently interested in the study that if rings were found they would have been passed on to me. No rings or corpses were found on Isabel II although many herring gulls visit the island to feed in the farm, the harbour and to loaf. It would therefore appear that the Herring gull predators are associated with the island of Rey.

At the northern sites during the three seasons no individual herring gulls were identified as specialised predators of Audouin´s gulls. At the southern site, however, because herring gulls could spend time on ground within the colony (due to a lack of mobbing by Audouin´s gulls) some herring gulls were very regular predators. These gulls loafed for a time a short distance for the sub-colony and then using the same direction of entry each time landed within the sub-colony. They then spent up to one quarter of a hour walking and standing amongst the Audouin´s gulls. In 1984 a specialist, which could be individually recognised, was observed at the beginning of the season. This particular herring gull adult visited the southern study site so frequently during the day that it was seen during each hide watch although not every visit it made was successful. This bird remained a predator throughout the season taking first eggs and then chicks. It is not known if this bird was a successful breeder or not but after each visit it returned to the herring gull colony directly north east of the Audouin´s gull colony, where high densities of herring gulls bred. This bird was recognizable through its fidelity to particular loafing areas and points of entry and exit from the Audouin´s gull colony.

In addition to the identified specialists there were other herring gulls whose visits were intermittent and of much shorter duration. The pattern of their predatory attempts throughout the season is unknown, as is their reproductive status. All predators were in full adult plumage.

9.9 DISCUSSION

Direct competition for nest sites with herring gulls and predation by herring gulls appear influential in the nest site selection and reproductive success of Audouin´s gull on the Chafarinas Islands. In direct encounters with herring gulls Audouin´s gulls were unable to successfully defend their nest sites. Audouin´s gulls are physically much smaller than herring gulls, see Plate 9.2 for a photographic comparison. Herring gulls are also of a heavier build than Audouin´s gulls with a heavier bill making attacks all the more effective. It has been suggested by other authors that airborne Audouin´s gulls can, with superior aerial skills, out-manoeuvre attacking herring gulls whilst in the air (Witt 1976). Audouin´s gulls were never observed winning an aggressive interaction with a herring gull. Neither were Audouin´s gulls ever observed raiding nests of either species of anything more than nest material, even when nests were left unattended. This lack of aggression and predatory behaviour amongst Audouin´s gulls rules out any possibility of an Audouin´s gull pair evicting an already territory holding herring gull pair.

That the situation might arise when it would be desirable for Audouin´s gulls to be able to alter herring gull distribution, has been shown in the distribution maps for reproducing gulls on Rey during the three seasons, see Figures 9.2, 9.3 and 9.4. Whereas herring gulls have fully colonised the island of Congreso and are rapidly increasing in number on the

Plate 9.1 A comparison of the shape and size of an Audouin´s gull corpse with that of a Mediterranean yellow-legged herring gull.

island of Rey, Audouin´s gulls have abandoned breeding attempts on Congreso and now nest only on Rey. Until 1983 the Audouin´s gull breeding population size was increasing on Rey but since then, this expansion has ceased.

As discussed in Varela and de Juana (1986), herring gulls on Rey tend to breed later than the population on Congreso and in 1985 two adult herring gulls were recovered nesting on Rey which had been ringed as pulli on Congreso six years earlier. Both of these points allow the possibility that Rey is acting as an overspill of reproducing herring gulls from Congreso to be given serious consideration. Other studies have demonstrated that young seabirds breed later than experienced birds (Ryder 1980). It is therefore possible that the first time breeding herring gulls not being able to establish a nesting territory in their natal area on Congreso, due to the high nesting densities of conspecifics, colonise Rey instead. Currently herring gulls on Rey appear to breed slightly later on those breeding on the island of Congreso. This may be due to differences in the age structure of the two colonies. If this is so, this difference will eventually disappear. Herring gulls breeding on Rey are very faithful to their previous nest site, with many using the same nest bowls year after year. This was shown by the persistence of paint marks from the previous year´s censuses. It was possible to identify certain herring gulls by virtue of their particular aggressiveness. These birds occupied the same nest site in each season. It would therefore appear that the herring gull sub-colony on Rey is gradually extending down the slope of Rey in an aged gradient. The oldest pairs at the top, the newly arrived pairs near the base.

Audouin´s gull´s inability to successfully defend nest sites is not only a function of size but also temporal factors. Whereas herring gulls which reproduce on the Chafarinas appear to spend most of the year in the vicinity of the islands (Varela and de Juana 1986), Audouin´s gulls migrate post-nuptially and do not return to the breeding site until the following season (de Juana and Paterson 1986). By the time the Audouin´s gulls arrive herring gull nest site selection is generally completed. It has been suggested that this difference in timing of breeding seasons is due to Audouin´s gulls´ dependence on fish which become more abundant in the early Summer (Witt 1976). The omnivorous herring gulls are not so restrained by the seasonality of food supplies. Audouin´s gulls would appear to be arriving each season to find the space available for nesting reduced. As Tinbergen (1953) and others have shown, a territory owner, even of the same species, has a greater probability of winning an encounter than does an intruder. Thus, even discounting their size advantage, herring gulls would probably win their encounters with the newly arrived Audouin´s gulls. Not being able to alter the distribution of the herring gulls, Audouin´s gulls must breed in whatever space is available. During the three study seasons and from previous studies, it has become apparent that although Audouin´s gulls will breed in a wide range of sites, from high rocky cliffs in the north of Rey to the steep gravelly slopes of Congreso, and from the rocky beach of Rey to the high barren plateau in the north of Rey, there are certain conditions which Audouin´s gulls will avoid. These are: sites covered by dense vegetation (de Juana et al. 1980); sites near inhabited army barracks (de Juana et al 1980); near where hides have been positioned in previous years; and at sites where breeding attempts have failed in the previous season. These conditions, combined with the area already held by reproducing herring gulls, narrow the options for a prospective Audouin´s gull pair and can result in them breeding in apparently unsuitable sites. This appears to have occurred in 1985 at the site on the central beach and close to the herring gull colony in the very far north, see Figure 9.4. Audouin´s gulls and herring gulls do not appear to actively compete for nest sites; herring gulls have unrivaled first choice which they can successfully defend.

Competition for food between the two species appears minor. Whilst breeding on the Chafarinas Islands the two species appear to rely upon different types of food. Herring gulls fed daily on the domestic waste discarded from the cliffs of Isabel II. This waste disposal site was directly opposite the northern study site close by and clearly visible from the hide in the north of Rey. While many herring gulls were observed to feed at this site there was no traffic between the Audouin´s gull subcolony and the rubbish site. Observations were also made of the gulls feeding on the small farm on Isabel II. Again, whilst hundreds of herring gulls would be seen feeding from the pig sties, not a single Audouin´s gull utilised this food source. That none of the inhabitants of Isabel II, who had not the opportunity to visit Rey, knew what an Audouin´s gull looked like is an indication of the little use which the latter species made of the man-made resources on Isabel II. Similarly, many herring gulls fed at the busy fishing harbour of Ras Kebdana, on the Moroccan coast. Audouin´s gulls were never seen to feed in the harbour and were only seen there when winds were high and the harbour offered calm waters and shelter. Indeed the Moroccan people, until recent studies began, thought that Audouin´s gulls were the female gulls and herring gulls the males (thus reflecting the very different roles of males and females in rural human Moroccan society!). Audouin´s gulls also only rarely followed fishing boats during the day whereas large flocks of Audouin´s gulls were observed fishing by the light of small fishing vessels associated with sardine fishing boats and anchored naval vessels. It is known that many fish species are attracted to the surface by lights at night. No herring gulls were observed fishing in this way. The herring gull colony was also littered with olive stones and other evidence that herring gulls were feeding inland along the Moroccan coast. Audouin´s gulls and herring gulls, on the Chafarinas Islands, do not appear to be competiting for food items.

Predation plays a critical role in the relationship between herring gulls and Audouin´s gulls. Although herring gulls have access to domestic waste from the islands´ human inhabitants, to waste from the farm, to discards and offal from the large Spanish fishing fleet which frequents the islands´ waters and all that a Moroccan fishing village and agricultural land has to offer, they still take and eat Audouin´s gull eggs, chicks and adults. Why?

Some herring gulls are specialist cannibals (Parsons 1971) as well as predators of other species (Patterson 1965, Tinbergen _et al._ 1967, Montevecchi 1977). The impression gained during observations periods was that predation of eggs and chicks occurred when herring gulls were returning from, or going to, some other destination. Only the few obvious specialist predators spent long periods within the Audouin´s gull colony. All other predators appeared to stop off on their way to, or from, somewhere else. The Audouin´s gull colony appeared to provide herring gulls with a risk- and effort- free "snack". This may also explain the constant rate of predation of eggs and chicks and why the eggs which were predated tended at some sites to be those that were the more recently laid. It is unlikely that herring gulls can distinguish instantaneously a newly laid egg from an older egg but it has been shown that Audouin´s gull adults are less attentive right at the beginning of the incubation period than they are later, see Figure 6.1. Opportunistic herring gulls are therefore more likely to find a fresh egg unguarded than an older egg and more likely to take that rather than suffer a mobbing. On the other hand in 1985 older eggs were more heavily predated.

Previous records of Audouin´s gull predation by herring gulls have suggested much lower predation levels than those recorded here. It is however rare that any herring gull leaves any shell or other evidence of an attack, as they were generally seen to consume the whole egg. It is however possible, although never observed, that if shell is left then the Audouin´s gull adult might carry it away from the nest, as they do for hatched eggs, so that further attention is not drawn to what remains of the clutch or brood by the conspicuous inside of the eggshell. De Juana and Varela (1981), for example, estimated that herring gulls predated only 1% of the eggs laid, during a census made of the Audouin´s gull colony in 1980. This estimate was, however, based on the number of eggs found broken rather than, as in this study, the disappearance of eggs from nests of known content which probably represents an overestimate (for percentages of study nests predated see Table 9.3). No data concerning predation of chicks during other studies is available apart from observations made by de Juana and Varela (1979) that herring gulls only eat ill chicks and corpses and Mayol (1978) reports of finding very large numbers of dead chicks of various ages on the Chafarinas Islands. Nor is there information relating to predation of chicks at other sites within the Mediterranean although predation is cited as a major factor contributing to reduced reproductive output (Mayol 1978, Witt 1979, Papacotsia <u>et</u>

al. 1980). At least on the Chafarinas Islands Audouin´s gull, as yet, have only herring gulls to contend with as active predators. Predators at other sites have included: rats (Corsica, Papacotsia et al. 1980, Thibault and Guyot 1981; Italian islands, Brichetti and Cambi 1979; Sardinia, Schenk 1979); carrion crows (Italian islands, Brichetti and Cambi 1979; Sardinia, Sardinia, Schenk 1979; Turkey and Sardinia, Witt 1976) and grey herons and white-tailed eagles (Witt 1977).

One way in which the influence of the timing of breeding upon Audouin´s gull reproductive success may be mediated is a ´predator swamping´ effect. The theory is, that if predation remains at a constant level predators will have a proportionally greater effect on the asynchronous rather than the synchronous pairs. This has been well documented for many bird species (black-headed gulls, Patterson 1965; common terns, Nisbet 1975; sooty terns, Feare 1976; guillemot, Birkhead 1977; herring gulls, Parsons 1971b). In all these studies, birds breeding at the same time as the majority of the other pairs were more successful than those breeding asynchronously. On the Chafarinas the level of predation appeared to remain fairly constant throughout the seasons at the sites in 1984 and 1985 and at all sites, with the exception of the northern site in 1983, it was found that those pairs which did not breed first or last amongst the colony members tended to rear a higher percentage of chicks to twenty days after hatching, see Appendix 11.

Whereas the predation of eggs and chicks appeared to continue throughout the incubation and pre-fledging periods respectively, the predation of adult Audouin´s gulls during the 1985 season occurred within a restricted period, that immediately preceding hatching. Adult corpses were generally found within Audouin´s gull subcolonies and the only attacks by herring gulls upon adult Audouin´s gulls which were observed involved Audouin´s gulls which had been trying to defend their nest against herring gull attacks. Soon after hatching the chicks become mobile and can shelter within the bushes so reducing the need for the adults to defend them. De Juana et al. (1982) reported that each year they found half eaten corpses of Audouin´s gulls but attributed them to attacks by peregrine falcons. Witt, in 1979, found twenty dead Audouin´s gulls on the Chafarinas. Although Witt on that occasion discussed the possibility that they might have been eaten and killed by herring gulls, he finally blamed peregrine falcons for the mortalities. In 1986 Varela (pers. comm) found sixteen partially eaten corpses on Rey and agreed that herring gull attacks had probably been responsible.

It would therefore appear that as yet Audouin´s gulls have not adopted a breeding strategy which allows them to escape the interference of herring gulls with their reproductive success. Audouin´s gulls do not appear to compete with herring gulls for food and there is no evidence of them suffering food shortages. This study, however, has shown that Audouin´s gulls must contend, on the island of Rey with an ever-expanding herring gull breeding population which occupies its nest sites earlier than Audouin´s gulls and cannot be displaced by the smaller and less aggressive species. Herring gulls are also very considerable predators of Audouin´s gull eggs and chicks and caused the complete failure of certain sites during this three breeding season study.

CHAPTER 10: MANAGING AUDOUIN´S GULLS ON THE CHAFARINAS ISLANDS.

10.1 INTRODUCTION

On the Chafarinas Islands it would now appear that human interference is required to allow Audouin´s gulls the opportunity to breed successfully. To me this appears justifiable as it is mans´ alteration of the Mediterranean habitat that has allowed the opportunistic herring gull to increase dramatically in number (see Section 3.4) on the Chafarinas island group. The data presented as a result of this study have shown that whilst herring gulls are a) increasing in number on the Chafarinas Islands, b) having first pick of the breeding sites on the islands and c) are preying upon Audouin´s gull eggs, chicks and adults, Audouin´s gull reproductive success is suffering.

Management of the gull populations on the Chafarinas Islands must have two objectives a) the release of sufficient suitable space for the Audouin´s gulls to breed upon and b) the control of predation by the other species.

During the 1985 breeding season, trials were carried out to test the potential effectiveness of some of the management techniques commonly applied in gull control. General discussions of common control methods are given in Thomas (1972) and Kress (1982). Those described by Thomas (1972) are summarized in Table 10.1.

TABLE 10.1: POSSIBLE METHODS FOR CONTROLLING GULL NUMBERS.

1. Eliminating adults	a) rocket or canon netting
	b) trapping
	c) catching at night
	d) poisoning
	e) narcotizing
	f) shooting

2. Scaring
    a) distress calls
    b) noise machines
    c) scarecrows

3. Modification of gull´s habitat

4. Removal of eggs
    a) traditional egg collection
    b) organised egg collection
    c) nest and egg removal
    d) biological control
    e) substitute eggs

5. Sterilisation of eggs
    a) pricking
    b) hypodermic injection with formalin
    c) shaking
    d) spraying/dipping with an oil emulsion solution
    e) embryonicide

The main problems which Audouin´s gulls reproducing on the Chafarinas Islands have to face are the acquisition of a suitable nest site and the defence of its contents against predation by either humans or herring gulls. This study has shown that these appear to be the weak points in Audouin´s gull´s adaptation to its current environment. Audouin´s gulls have the potential to reproduce successfully, see Section 8.3, and do not appear to have problems providing food for the growing chicks, see Section 7.6. If a management strategy is to be successful it must find ways of reinforcing these points which have been weakened by our development of the Mediterranean and its repercussions on that ecosystem.

In order to prevent the decline of the Audouin´s gull breeding population in this area, a management plan must act on three fronts:

a) The reservation of nesting space for Audouin´s gulls.
b) The improvement of this space to suit Audouin´s gulls.

c) The control of disturbance and predation by herring gulls and humans.

This study has included small scale field trials designed to test the suitability of the wide range of techniques currently used in avian management and control to achieve these objectives.

10.2 THE RESERVATION OF NESTING SPACE FOR AUDOUIN´S GULL.

As described in Section 9.4, herring gulls breed earlier than Audouin´s gulls and no instances have been recorded of Audouin´s gulls managing to displace herring gulls from territories. Herring gull numbers are increasing on the island of Rey, where all the Audouin´s gulls currently breed (see Section 9.3). If Audouin´s gulls are to be allowed space to breed then measures must be taken to ensure that, at the very least, the area which is occupied by herring gulls, on Rey, does not increase beyond current levels.

Table 10.1 summarizes the gull control methods currently recognised. The first three groups of methods would have an immediate impact upon the pressure for nesting space, whereas control via eggs and young does not show immediate results, since herring gulls do not breed until, on average, five years of age (Chabrzyk and Coulson 1976). Therefore control via eggs and young would need to be kept up for at least four and probably seven to nine years for the number of annually recruiting gulls to decrease. Control of population growth through the removal or damage of eggs assumes that immigration from other sites is neglible. Therefore, in the short term, a more immediate technique is desirable, especially since control via the eggs often leaves adults on their territories, often using their time, freed from the duties of incubation, to rob other nests (Davies et al. 1976).

Like many other flocking birds, herring gulls emit a distress call when in pain or caught by a predator. Playbacks of recordings of such calls have been used successfully to alter the distribution of gulls roosting on reservoirs (Shedden 1983).

However, scaring is generally less effective when attempted at breeding sites where the incentives for the birds to remain in a particular place are high. When distress calls have been played to nesting gulls they have been known to elicit defence displays rather than fleeing responses (Monaghan 1984). It may be that if calls were played earlier in the breeding season, when gulls are still selecting sites and have not already made the investment of procuring a territory, building a nest or laying a clutch, it would be possible to make the site appear unsafe and unattractive which may lead to the gulls deserting the site. An additional problem on the Chafarinas Islands is that, due to the proximity of the breeding species, it would be difficult to scare one species without alarming the other as well. Scaring attempts on Rey would have to be restricted to the period preceding the arrival of the Audouin´s gulls.

It also seems unlikely that modification of the breeding habitat on Rey could make the area unsuitable for herring gulls whilst suitable for Audouin´s gulls as their current habitat requirements are similar. Although at present the herring gull breeding sites are generally found on the higher areas of Rey and Congreso, places where the Audouin´s gulls have never been observed to breed, this may be due to lack of opportunity. Herring gulls have always had first choice of the sites during the seasons when records have been kept.

It would appear that the most effective way of immediately ensuring the availability of particular areas to Audouin´s gulls would be the elimination of the the adult herring gulls already nesting in that area. Table 10.1 showed six methods which could be used to achieve this. The major consideration which must be borne in mind whilst selecting from amongst these techniques is the need to avoid disturbing or harming Audouin´s gulls and other non target birds. Rocket or cannon netting, shooting and trapping all involve large amounts of disturbance. In Chapter 9, it was stated that whilst a large proportion of predation was due to irregular visits by unfamiliar gulls, some specialist predators spent large periods of time within the south study sites in 1984 and 1985, taking large numbers of eggs and chicks. It would have been easy to arrange for a Spanish military officer, from the island garrison, to assist with the removal of these birds using a gun with a silencer but as this was not an activity which could be encouraged and as it was expected that the effect on the herring gulls might greatly disturb the Audouin´s gulls, even to the point of desertion, this idea was shelved. Shooting and trapping are possible useful measures, but only if the number of birds or pairs to be removed are small. Catching at night is also a possibility when small numbers are concerned, but it was found in 1983 that night visits to the colony caused much alarm and it was thought that it might result in desertion of the colony by the night flying Audouin´s gulls. Poisoning is an unattractive method, for although Audouin´s gulls did not enter the herring gull colony, presumably the areas which would be first to be reclaimed from the herring gulls would be those closest to the Audouin´s gull breeding nuclei and the risk of Audouin´s gulls having access to the poisoned baits would be unacceptable, even if low.

Narcotizing breeding pest birds is a measure which many control programmes have adopted. Culling, using drug-containing baits to facilitate selective killing, has a long history in the management of gull populations in both France and Britain. In the Camargue herring gulls have been culled since 1960, as they were found to prey heavily upon the eggs and young of shelduck, terns, mallards and flamingos (Kearsey 1982) and in Brittany, herring gulls were eradicated from sites near tern colonies (Camberlain and Flote 1979). Within Britain the examples are numerous. Culls have been carried out regularly since 1972 by the Nature Conservancy Council (NCC) on their reserve the Isle of May, Scotland, as a means of reducing habitat destruction by the gulls and to increase species diversity (Duncan 1978). The herring gull population size has been reduced from the 1972 level of 17000 to 3000 in 1980. For the same reasons culls of herring gulls were carried out in 1982 on the islands of Skomer and Skokholm (Sutcliffe 1982). In 1975 and 1976 potentially dangerous levels of bacterial contamination from gulls in the water catchments at Abbeystead, Lancashire, lead to a Ministry of Agriculture and Fisheries (MAFF) supervised cull (Jones 1982). Gull culls have also taken place since 1939 in the Netherlands (Bruyns 1958), Germany (Drost 1958), Sweden (Borg 1955), New

Zealand (Caithness 1968) and the United States of America (Kress 1983).

Culling may, however, have undesirable side effects due to the relationship between recruitment and gull nesting density. At a herring gull colony on the Isle of May, Scotland, it has been shown that after some ten years of annual culling, the herring gulls in this colony now breed at an earlier age, are themselves slightly bigger and lay larger eggs which may enhance adult and juvenile survival (Coulson et al. 1982). These changes have presumably come about through a reduction in intra-specific competition for food and breeding sites. However, merely reducing the overall density, through culling, may even increase the attractiveness to new recruits of an area within a colony by reducing the nesting density. To avoid such a situation it will be necessary to clear the area of nesting birds so that the culling does not just enable more young birds to establish territories than would possible in a more densely nested area (Chabrzyk and Coulson 1976). As new recruits tend to be attracted to high nesting density areas the cull must reduce densities to an unattractive level in order to be successful.

In the majority of cases culling has been found to be an effective short term method of controlling the distribution of breeding birds and may offer a partial solution of the problem for the Audouin´s gulls on the Chafarinas Islands.

A small scale cull was carried out in 1985 on Rey. Baits were prepared using slices of bread divided into nine parts each measuring 5 cm X 5 cm. Each bait was then spread with margarine to which 250 mg of a-chloralose and 35 mg of seconal were added. Seconal is a powerful sedative. A-chloralose acts as an immobilising agent. In colder parts of the world the effects of the a-chloralose may kill a bird as the drug has the effect of lowering the bird´s metabolic rate, leading to the bird´s death through hypothermia. This is unlikely to happen on the Chafarinas due to the higher ambient temperatures (see Appendix 2,3 and 4). As a bird given a-chloralose may drown if it flies off before the drug has taken full effect and lands in the sea, the drug seconal is added. This relaxes the bird so that it does not panic and leave the area before the drug has taken affect and does not therefore disturb the other birds adjacent nesting by behaving strangely.

The baits were placed on the rims of six nests which were within view of hides. Ideally baits should be placed only in nests whose clutches are already complete, as at these nests the adults would be more likely to return as soon as possible in order to incubate. They would thus be more likely to consume the baits within a short period of time, succumbing to the drugs long in advance of the return of the operators of the cull. The trial plots were left undisturbed for two hours, at the end of which the bodies were recovered, removed from the immediate vicinity and a sharp blow was dealt to the head of each bird. The birds died whilst still sedated. All nests were checked for unconsumed baits which were removed and destroyed.

The test culls could only be carried out in the presence of Dr Eduardo de Juana, Autonoma University, Madrid, and his visit to the island terminated before the herring gull clutches on the Chafarinas Islands were completed. Ideally, only nests at which laying has terminated and incubation begun should be baited as it is then that birds will be most likely to return to the nest and consume the bait within a short time, thus allowing the drugs plenty of time time to take effect before the area is disturbed again. In this experiment, five of the nests baited had only one egg on the day on which the cull took place (April 8, 1984). When the nests were returned to, two hours after the placement of the baits, only two bodies were recovered, although all six baits had disappeared and the entire area was searched. It is therefore likely that an adult from each of these nests was affected by the drug away from the nest. This, probably, would not have happened if the cull had been arranged when breeding was further advanced.

It would have been useful in this trial to establish the effect of the loss of a mate upon the remaining member of the pair. During hide watches on the following days the nests were observed without adults and were presumed abandoned. Unfortunately as the remaining single adults at these six nests bore no distinguishing marks it could not be ascertained whether these birds remained within the colony or abandoned the colony altogether, nor whether these birds disrupted the breeding of either other herring gull pairs or Audouin´s gulls.

A separate test was made later in the season; drug-less baits were also placed on the rims of Audouin´s gull nests to test whether or not this species, which generally consumes fish, would eat bread and margarine if it was left within the immediate area of the nest. The majority of these harmless baits were consumed thus demonstrating that if ever a cull was planned for the Chafarinas Islands, care would need to be taken to keep baits away from Audouin´s gull nesting areas and to check Audouin´s gull breeding areas for drugged birds which may have consumed baits regurgitated by herring gulls, so that they may be revived. Fortunately as herring gulls breed earlier in the season than do Audouin´s gulls, the chances of Audouin´s gulls being exposed to baits may be reduced.

Categories 4 and 5 in Table 10.1 represent longer term remedies for controlling the expansion of the gull populations. The main problems associated with their implementation are the disturbance caused and the amount of time required to execute them. All apart from 4(d) could possibly be used on the Chafarinas Islands as it is unlikely that any biological control could be found that would be specific to herring gulls and not affect Audouin´s gulls at all. All the techniques included in categories 4 and 5 involve the disruption of the reproduction of the target pairs, whilst allowing the adults to survive. Measures 4 a-c (see Table 10.1) would disrupt the reproductive attempts of the adults from the incubation period onwards, leaving the adults without eggs to incubate. This may give rise to further problems for the Audouin´s gulls as the herring gulls would have fewer commitments to occupy their time and may allow them time to spend predating within the Audouin´s gull colony. Replacing eggs with substitute eggs and all those techniques in category 5, in theory, keep the gull occupied with nest-related tasks during the incubation period but make them totally unproductive.

In 1984, a study was made of the effect, upon the behaviour of herring gulls on the Chafarinas Island, Rey, of having eggs which could not hatch. Four herring gull nests near the southern and northern Audouin´s gull sites had all their eggs injected with formaldehyde, which kills the embryos. All the nests were incubated as normal and for approximately one week longer than the normal incubation period. The nests were then abandoned. These nests were close to Audouin´s gull nests but the herring gulls attending these nests were never observed predating upon Audouin´s gull nests. This is a way in which the number of herring gulls recruiting to the island of Rey could eventually be reduced (assuming that not many young birds are being recruited from the very close-by island of Congreso) but in the meantime reducing the reproductive output of herring gulls will do little to alleviate the immediate problem for Audouin´s gulls of where they will find nesting space in future seasons.

10.3 THE IMPROVEMENT OF NESTING HABITAT SO AS TO MAXIMIZE AUDOUIN´S GULL REPRODUCTIVE SUCCESS

This study has drawn attention to the importance of nest cover to breeding Audouin´s gulls, especially with regard to the period immediately after hatching when chicks appear to seek out cover in which to hide during disturbances (see Section 7.3). Bushes close to nests also provided shade for incubating adults and their eggs. Audouin´s gulls built their nests near bushes wherever possible (i.e. wherever there were bushes within an Audouin´s gull sub-colony gulls nested beside them). Where vegetation was dense, however, Audouin´s gulls nested at reduced densities as this species was rarely seen nesting either on top of or within bushes (compare nesting densities in 1983 at the northern site with those at the less vegetated southern site, see Table 7.9). It may be that Audouin´s gulls, like common terns (Houde 1983), when nesting in vegetated areas avoided nesting in the vicinity of other conspecifics, while pairs breeding in open sandy habitats placed nests randomly relative to other pairs in response to predation pressure. In the vegetated area there is perhaps advantage to be gained from being separated from others and consequently less conspicuous amongst the bushes, whereas on open ground,as there is little chance of camouflage, there is some advantage to be gained in being numerous. Lower densities resulted in fewer adults being threatened by a localized herring gull attack and therefore fewer adults mounted a mobbing attack. The effectiveness of these mobbings was correspondingly reduced. There were, however, also disadvantages associated with nesting at high densities. At high densities, as discussed in Section 7.8, the probability that chicks would stray onto neighbouring territories was much larger. This study would appear to conclude, as did Parsons (1976) study of herring gulls reproducing on the Isle of May, Scotland, that there were disadvantages associated with breeding at both high and low densities and that the optimum nesting density, with regard to productivity during the season, was to be found at intermediate densities.

Having come to this conclusion, it should be possible to manage the Audouin´s gull colony so that densities do not become too low nor too high by:

a) providing shelters so that birds are attracted together but not so close that the level of territorial aggression arises;
b) by breaking into smaller units the large dense bushes so that they provide a much greater circumference about which the Audouin´s gull can breed;
c) by providing a larger area of herring gull-free nesting area for Audouin´s gull.

Thus the trend of nesting each year at still higher densities in the north of Rey may be reversed, perhaps leading to reduced mortality caused by con-specific aggression.

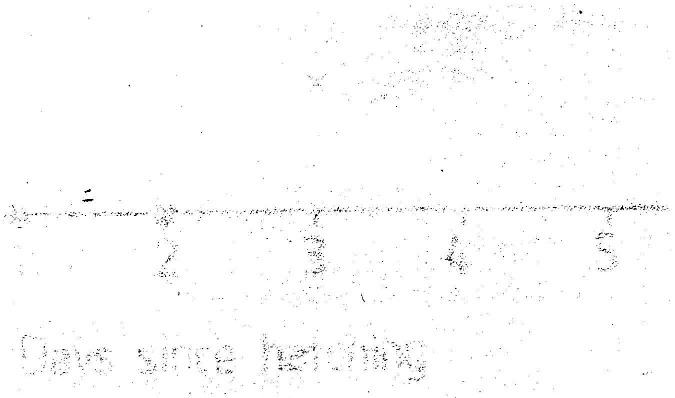
Jenks-Jay (1982) provided artificial shelters for least terns at colonies on Nantucket Island, Massachusetts, and found that not only did the shelters provide the growing chicks with shade but they also prevented the predation of the chicks by birds of prey. In 1984 artificial shelters were placed over nests. The island substrate is a thin covering of dusty sand over hard igneous rocks which make the provision of shelters more problematic than simply transplanting bushes which, alive or dead, would probably be uprooted during the first storm. Instead, over six nests with completed clutches at the northern site, wooden crates were placed in order to test whether Audouin´s gulls would continue to incubate within such shelters, and whether, after hatching, chicks would remain within the shelters rather than move to nearby bushes during disturbances. The wooden crates had one side removed and were weighed down with large boulders, see Plate 10.1. Shelters were only provided at the northern site because at the southern site natural vegetation and therefore shelter was abundant. All six pairs accepted the presence of the artificial shelters and continued to incubate within them. As it was not possible to see the adults incubating within the shelters observations could not be made as to how the presence of the shelter affected the behaviour of the adults during the incubation period. Six three eggs clutches were selected as those over which the shelters were placed and off these eighteen eggs only three did not hatch. This gives a hatching success value of 83%. In Section 7.3 the movement of chicks away from their nests was described. Figures 7.1 and 7.2 showed that 50% of all the northern study site nests in 1984 were empty by the second day after hatching was complete and by the fourth day almost all nests were empty. The sample size of six is small but suggests that where nests have been supplied with artificial cover chicks do remain together and on the nest territory for longer as is shown in Figure 10.1. None of the fifteen chicks died whilst they were making use of the shelters.

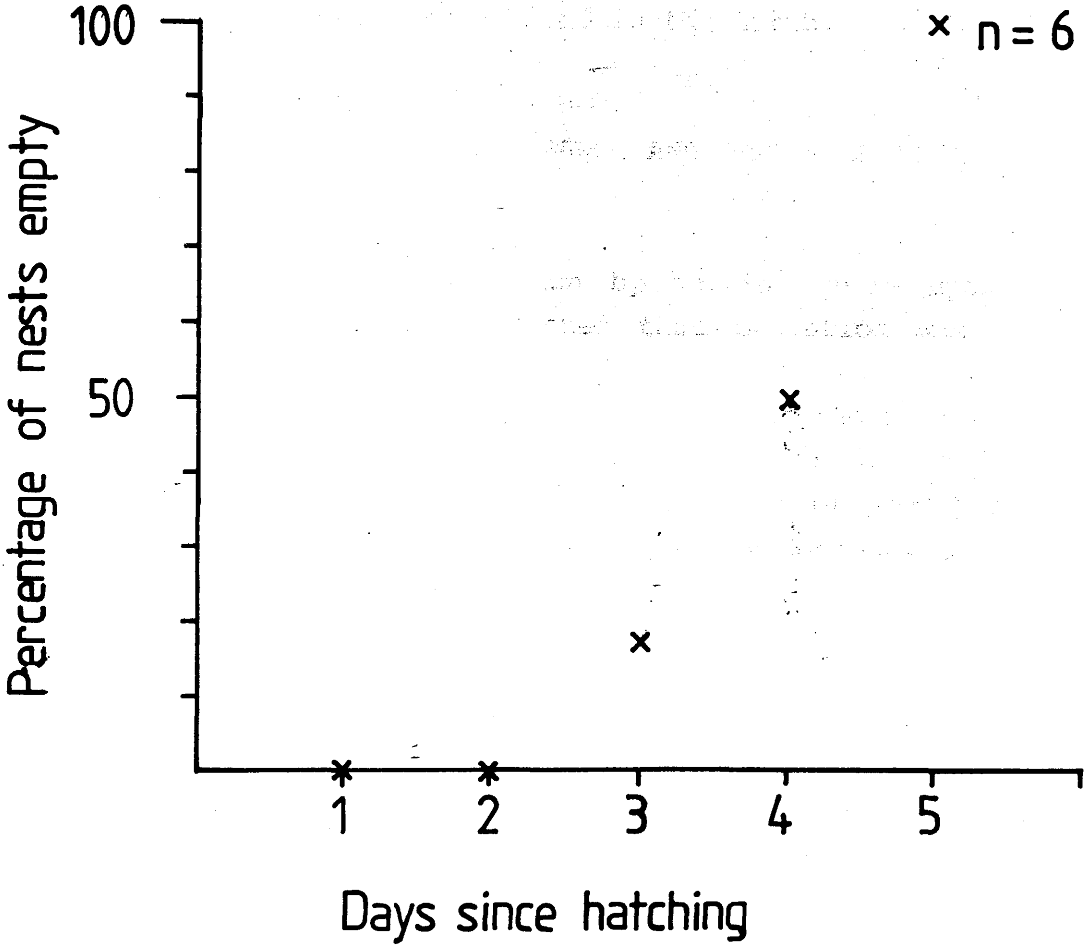
In 1984 shelters were provided over already established nests in which full clutches had already been laid. In future seasons it might be interesting to test the extent to which artificial shelters would be used if they were made available before the Audouin´s gulls returned from their wintering grounds. If they did, then further behavioural observations would allow the identification of an optimal nesting density at which Audouin´s gulls could successfully mob predators and yet at which intraspecific aggression and the frequency of attacks by adults Audouin´s gulls on straying chicks were low.

As the numbers of herring gulls breeding on the island of

Plate 10.1 Audouin´s gull chicks within a nest which was provided with artificial shelter, at the northern study site in 1984.

Figure 10.1 Pattern of abandonment by Audouin´s gull chicks of nests provided with artificial shelter at the northern study site in 1984. The vertical axis shows the percentage of the six nests that were found abandoned during site checks. The horizontal axis shows the number of days since the completion of hatching and the nest check.




100
50
Percentage of nests empty
1
2
3
4
5
Days since hatching
× n = 6

Rey have increased, so also have the nesting densities of Audouin´s gulls, particularly in the north of the island. It appears likely that due to the increase in the area occupied by the reproducing herring gulls and the increase in the size of the area which Audouin´s gulls appear to find unattractive due to the failure of previous breeding attempts, Audouin´s gulls are being crowded into smaller areas. These increased nesting densities encourage behavioural reactions deleterious to the breeding success of the Audouin´s gulls. The removal of nesting pairs of herring gulls, in the manner suggested in Section 10.4, would free more space, allowing Audouin´s gulls the option to reduce the density at which they breed in the north.

10.4 THE CONTROL OF DISTURBANCE AND PREDATION BY HERRING GULLS AND HUMANS.

Previous studies of predation by herring gulls upon Audouin´s gull eggs and chicks suggested that predation was limited to approximately 1% of eggs and only to dead and dying chicks (de Juana and Varela 1979, 1981). Since these studies the numbers of herring gulls nesting in close proximity to the Audouin´s gulls has increased (see Figure 9.1). The levels of predation recorded during this study suggest that predation is much heavier and a serious restriction on the reproductive success of Audouin´s gulls (see Sections 9.5 and 9.6). If it were possible, the ideal type of control measure to counteract this effect would be to make Audouin´s gull eggs and chicks unattractive to herring gulls. On the Chafarinas Islands, food for both gull species appears to be abundant and if, as was suggested in Chapter 9, many of the herring gull predators were not dependent upon the Audouin´s gull colony as a vital food source, it should be less difficult to alter the food preferences so that fewer Audouin´s gull eggs/chicks would be taken.

Previous studies have shown that the use of taste aversion agents can successfully alter the food preferences of animals (Nicolaus _et_ _al._ 1982, 1983). Many animal species rapidly develop an aversion to a food if it makes them sick. This reaction is known as the ´Garcia Effect´ (Dickinson 1979).

Herring gull eggs were placed within Audouin´s gull subcolonies which had been experiencing herring gull predation. These eggs were readily consumed. Herring gull eggs were then injected with a taste aversion agent, Union Carbide 27867 (2,3,5 and 3,4,5 trimethylphenyl methyl carbamate). The UC 27867 was suspended in egg yolk and injected into the eggs which were then scrambled in their shells with a rapidly rotating bent steel wire, so that the agent became uniformly distributed. In all, over a period of two weeks, ten treated eggs were tested within the Audouin´s gull subcolonies. Despite seven being broken open, none were consumed. Ideally the trials should have been made using Audouin´s gull eggs as even the human eye can readily distinguish between the larger, broader herring gull eggs and the smaller Audouin´s gull eggs (see Section 5.4). However, until a more successful presentation method is found the use of Audouin´s gull eggs would have been an unjustifiable waste and so the success of the taste aversion agent remains remains untested.

A possible alternative to training herring gulls to associate eggs with distaste is to provide something that is very much more attractive. Krury and Gochfeld (1975) found that fish regurgitated by comorants within a colony appeared to protect nests as the predatory herring gulls preferred the fish to cormorant eggs. This strategy is however more likely to attract even more herring gulls to the Audouin´s gull colony and is potentially very dangerous.

The breeding environment of Audouin´s gull could also be improved by reducing the level of disturbance caused by humans during the months of April through to August. During these months visits to the island of Rey should be even more strictly controlled with permission from the commanding officer necessary for each disembarcation and the erection of multilingual noticeboards at all disembarcations, of which there are few (the harbour and three coves). These posters could warn Spanish and Moroccan fishermen that if they land without permission they will be breaking the law and will be prosecuted.

During the recent period of intense interest in Audouin´s gulls on Rey, there have been no large scale robberies of gull eggs for human consumption in either Moroccan villages nor Melilla, as there have been in the past. Traditionally the bird colonies in the area suffered heavily from fishermen taking eggs (Bradley and Monaghan 1986). As Audouin´s gulls do not defend their nests against humans and because they nest in dense aggregations made obvious by the large quantities of guano they suffer more than other species. Also their eggs have a local reputation for being the perfect ingredient for pastry and cake-making! Only seven years ago over 1000 eggs were taken from the Audouin´s gull colony (H.H. Witt in litt. to P.C. Beaubrun 1980). Care must be taken that such activities are not resumed or that if gull egg consumption does occur, that it is properly controlled and directed. The islands´ inhabitants rely upon food being brought once fortnightly by sea to the islands. Food is generally tinned and fresh food is highly prized. In 1985 soldiers were given permission to visit the island of Congreso, where no Audouin´s gulls were breeding, once a day, to collect eggs from herring gull nests which contained a single egg. These eggs were then eaten and enjoyed by all on the island of Isabel II and enthusiasm was expressed that this should be allowed to occur each breeding season. Although the herring gulls are likely to relay these first eggs, gulls´ egg laid late in the season are generally less successful than eggs laid earlier in the season, in synchrony with the rest of the colony (Parsons 1975b). Such egg collecting may therefore be considered as a long term control measure of the herring gull colony. It must however be supervised so that there is no possibility that Audouin´s gull eggs would be taken. The re-distribution of these failed Herring gull breeders must be carefully monitored so as to avoid increased interference with the Audouin´s gull colony on Rey.

Such utilization of Herring gull eggs may also help reverse the more negative attitude towards gulls which is held at the moment by the inhabitants of the islands. Gulls are seen as aggressive pests because the soldiers only make contact with the herring gulls which frequent the farms and rubbish dumps on the island. These controlled egg collecting activities could be accompanied by information programmes stressing the existence of the two quite distinct gull species on the islands and the rarity of Audouin´s gulls.

Current trends in the population sizes of the species of gull breeding on the Chafarinas Islands and estimates of breeding success indicate that a continued increase in the number of herring gulls is to be expected over the next few years. The number of Audouin´s gulls have remained relatively stable and as the 1984 and 1985 seasons were unproductive, as compared with 1983, it must be expected that the numbers of adults returning to their natal site in future years to breed for the first time will be lower then previously. The seriousness of this situation must be recognised now because if Audouin´s gulls are left unassisted to face 1) reduced area of potential breeding site, through competition with herring gulls and 2) increased predation of eggs, chicks and as was seen in 1985, adults, their future on the Chafarinas Islands is very much in the balance. Clearly this would be unacceptable especially as this colony represents such a significant proportion of the world population. Moreover, as herring gull pressure at other Audouin´s gull colony sites is also increasing with the same consequences (Papacotsia et al. 1980, Jacob and Courbet 1980, Guyot and Thibault 1981) it would now appear that if in the past Audouin´s gull was unnecessarily classified as ´endangered´ rather than ´rare´ the former classification is now appropriate.

If control is to be undertaken, its aim must be to curb the expansion of the herring gull colony on Rey. Herring gulls breed approximately four weeks earlier than do Audouin´s gulls. This difference in timing could be used to alter the distribution of the herring gulls whilst avoiding the disturbance of the Audouin´s gulls.

There are a number of ways in which this could be achieved. Having established which areas are the most suitable as Audouin´s gull breeding sites (those which have been previously successful, which have bushes but bushes which are neither too large, dense or of the species Lycium intricatum within which chicks could become entangled). One method would be the daily removal of all herring gull nests and eggs from these sites. All the nests, in these areas, would have to be removed as it is possible that removing just a few would increase the sites´ attractiveness with regard to recruiting new pairs (Chabryz and Coulson 1976). If densities are reduced well below the level at which they are attractive to site selecting birds, the area will remain herring gull-free and available to Audouin´s gulls. As a result of this removal of eggs/nests the herring gulls may give up trying to nest at that site and either re-nest in another part of the islands or they may not attempt to breed at all. A problem would arise if the herring gulls persisted in the area without nests. With no need to incubate these birds would have more time to interfere with the breeding attempts of the Audouin´s gulls.

A herring gull cull could be another way to vacate nest sites for Audouin´s gulls whilst also reducing herring gull interference with their reproductive attempts. However, a cull does require very careful consideration as:

a) a cull involves a lot of disturbance of the area.
b) the herring gull lives are also important.
c) Audouin´s gulls will also take baits if they are placed near Audouin´s gull nests or if they are regurgitated there by herring gulls.
d) there are political considerations which must be borne in mind. ICONA (Instituto para la Conservacion de la Naturaleza), a part of the Spanish Ministry of Agriculture, has banned the use of poisons for the killing of birds, in an attempt to control illegal persecution in Spain. The compounds used for culling are included in this ban.

Obviously the design of a suitable management plan is a complicated matter and it is clear that for the conservation of the Audouin´s gull colony on the Chafarinas Islands, effort on a long term scale will be required. None of the measures discussed in this chapter will, through one application, safeguard the colony for all time. What will be necessary will be regular reassessments of the status of both species and modifications of the plan.

In 1982, Spain designated the Chafarinas Islands by a Royal Decree, as a ´Refugio de Caza´ (National Game Reserve). ICONA has declared its intention to:

a) Control all visits and supervise scientific research on the islands.
b) Prohibit hunting.
c) Construct hides, fences, gates etc.
d) Limit fishing activities.

However, this status has in fact provided comparatively little protection for the fauna of the Chafarinas Islands as there is no one to enforce the regulations or even to inform the inhabitants of the Decree´s existence and conditions.

In March 1986, The Alghero Declaration, made at the First Mediterranean Seabird Symposium, named the Chafarinas Islands as one of the most important areas for breeding birds in the Mediterranean and one of the areas most in need of conservation (MEDMARAVIS, 1986). The current status of the islands does not appear to demand sufficient urgency in the activity of Spain´s official conservation organisation, ICONA. If the Chafarinas Islands were recognised by Spain as a Reserve Integral and given the appropriate level of protection and management the future of the Audouin´s gull colony and an entire cross-section of Mediterranean wildlife might be safeguarded.

CHAPTER 11: DISCUSSION

The objective of this study was to address the question of whether Audouin´s gulls do face serious problems whilst breeding, at what is currently their largest breeding site, the island of Rey in the Chafarinas Island group. In the past it has been said that Audouin´s gulls have low fecundity and that they are very specialised birds having restricted breeding distribution and diet. This discussion looks closely at the first of these claims and examines it, in the light of increasing pressure through the expansion of the herring gull population, in order to develop an appropriate management plan.

The data presented here have shown that, although there is considerable variation between years, Audouin´s gulls have the breeding capacity to sustain and indeed increase their population level at this site. For example, at the southern site in 1983 a mean of 1.26 (s.d. = 0.99) chicks survived to twenty days after hatching per nest. The only estimate of fledging success was that of de Juana and Varela 1981 who suggested that 1.3 chicks fledged per nest in 1979 and 1.25 in 1981. These figures have been shown to compare favourably with the reproductive success of other Larid species. At the same time this study has shown that Audouin´s gull´s reproductive success on the Chafarinas can, in certain seasons, be lower than that recorded at the southern site in 1983, and may completely fail, as was seen at both the southern sites in 1985. The following discussion examines the factors found to influence Audouin´s gull breeding success, and how this could be maximized.

Since the colony was discovered, the population has dramatically increased from 500 pairs in 1960 until 1982 when 2220 pairs bred. Since then, until 1987, the breeding population size remained more or less stable at just over 2000 pairs. Between 1978 and 1983 Audouin´s gull bred on the island of Congreso as well as on Rey. In 1976 the breeding colony was found only in the northern most part of Rey (De Juana et al. 1980) probably because at that time the barracks on Rey and Congreso were occupied. The barracks on Rey and Congreso are on the southern extremes of the islands facing Isabel II. From 1978 onwards, both barracks were abandoned. In subsequent years both Audouin´s gulls and herring gulls expanded their distribution to include the areas once disturbed by activity at the barracks. It appears likely that Audouin´s gulls ceased to breed on Congreso due, at least in part, to competition for space with the larger, more aggressive, earlier breeding herring gulls. On Rey the precise location of the nuclei of breeding Audouin´s gulls varied between years apparently dependent on the height and density of the vegetation (De Juana _et al._ 1980) and, as has been suggested here, the success or failure of the site in previous seasons. Since 1979 there has, each year, been a dramatic increase in the number of herring gulls breeding on Rey. The situation on the Chafarinas is now entering a new phase - the island of Congreso is densely populated by herring gulls; Isabel II is occupied by Spanish military, with many buildings and a farm occupying all but the steep cliffs; Rey is now the breeding site of upwards of 850 pairs of herring gulls, with much of the remaining area appearing unsuitable to Audouin´s gulls since the failure of previous season´s breeding attempts. What steps can therefore be taken to protect the breeding population of Audouin´s gull on the Chafarinas Islands?

Like most Larid species, Audouin´s gull is a highly colonial species showing great synchrony in its timing of breeding. Darling (1938) suggested that in colonial species, individuals received increased social stimulation which produced greater breeding synchrony, resulting in an earlier and shorter egg laying period. Subsequently several authors have presented evidence for increased synchrony with increased colony size (reviewed by Coulson and White 1956, Gochfeld 1980a, and Perrins and Birkhead 1983). Other authors have failed to find any correlation between colony size and synchrony (see specifically Weidmann 1956, Vermeer 1963 and review by Gochfeld 1980a). A correlation between colony size and degree of synchrony has yet to be shown for Audouin´s gull.

Colonial breeding has advantages and disadvantages for Audouin´s gulls. Breeding in dense groups can form an attractive focus for conspecifics and attract attention from predators. It is partly for this latter reason that Audouin´s gulls have suffered at the hands of human egg collectors in the past. Audouin´s gull nests are very tightly clustered and are therefore more obvious and easier to raid than the more widely dispersed herring gull nests. Audouin´s gull eggs are also more attractive to bakers than herring gull eggs, having deeply coloured yolks. Also Audouin´s gulls do not defend their nests as vigourously against humans as do herring gulls.

As the laying of eggs requires considerable resources, birds time the laying of their eggs so that food is generally abundant (Perrins 1970). In other words, the breeding may be synchronised to coincide with a peak in food availability. Witt (1976) suggested that the breeding season of Audouin´s gull may be timed to coincide with the abatement of the high winds and seas common in Spring and the arrival of huge shoals of clupeids in that area of the Mediterranean. Lack (1968) showed that clutch size and the relative size of the eggs laid by waterfowl were inversely related to the advance of the breeding season and suggested that, as the female has limited reserves, she may lay a few large eggs or many small eggs. Both egg size and clutch size in the herring gull population studied by Parsons (1975), on the Isle of May in Scotland, were largest at the beginning of the season suggesting that, even then, there was ample food for egg production. Additionally, as the timing of egg laying in this herring gull population was so similar from one season to the next, Parsons (1975b) suggests that the timing of breeding was independent of proximate food constraints. Similarly on the Chafarinas the date of the onset of Audouin´s gull laying varied little from one season to the next. Clutch size was also largest at the beginning of the season and decreased as the season advanced. Egg size did not differ significantly between seasons. This suggests that either Audouin´s gulls´ timing of breeding each year was such that, even for the early breeding birds, the onset coincided with the improvement of the food supply, or that the timing of breeding was independent of food. There were no indications of food being a limiting factor at any point during the breeding period. Adult birds spent long periods loafing within the colony often with both adults present on a territory. This may be irrelevant if the adults do, as suggested in the literature, feed mainly at night (Witt _et_ _al._ 1981). Chick growth curves were however almost identical from one season to the next suggesting either that chicks suffered the same lack of food from one season to the next or that in each season there was no shortage of food. As the growth curves for chicks during very successful seasons, for example the northern site in 1983, had curves similar to those found in poor seasons. I would suggest that there is no evidence to indicate that Audouin´s gulls breeding on the Chafarinas Islands, even asynchronous breeders, experience food shortages.

If food is available even earlier in the season we might hope that if competition between herring and Audouin´s gulls for the limited nest sites becomes even more marked, then selective forces would bring about a gradual advance of the Audouin´s gull breeding season. This is however unlikely as the weather conditions in spring in the Chafarinas area are generally poor with rough seas preventing the capture of fish by Audouin´s gulls. Whereas herring gulls are much more aggressive it is thus unlikely that a pair of Audouin´s gulls could prevent herring gulls from supplanting them from their a territory. Also, whereas Audouin´s gulls generally migrate postnuptially, Herring gulls are present on the Chafarinas Islands all year round (J.M.Cabo pers. comm). Audouin´s gulls´ inability to secure other nest sites is likely to be a combination of temporal, behavioural and size factors.

The most obvious advantage of colonial breeding for Audouin´s gulls is that of increasing the effectiveness of predator mobbing. Defence of offspring by mobbing by adults or through ´swamping´ the predatory capacity of the predator through excessive availability of prey, should be most effective when nests are clumped (Kruuk 1964, Patterson 1965, Parsons 1971). However protection derived from cryptic colouration should be more effective if nests are widely spaced (Patterson 1965, Tinbergen et al. 1967, Lack 1968, Ward and Zahavi 1973). Patterson (1965) first suggested that the interactions of the two types of defence should result in an optimal spacing of nests. The determination of the optimal spacing becomes yet more complex when intraspecific aggression is considered.

The selection and defence of nesting territories by Audouin´s gulls is an area of particular interest in the design of a management plan for the Chafarinas Islands. Audouin´s gulls´ access to suitable nesting sites must be protected but until the information relating to optimal nest site conditions is available this will not be possible. Audouin´s gulls are social birds normally nesting in tight dense groups. Such close spacing is apparently common to small gull species which are inoffensive to neighbours and which defend against predators by mobbing (Burger 1974). Audouin´s gulls were never observed in cannibalistic activities, leaving eggs and dead chicks untouched even when they were undefended and within easy reach. There is probably an interaction between habitat suitability and social factors which determines whether a site will be occupied or not (Kotliar and Burger 1986). The following factors may be involved: Audouin´s gulls´ fidelity to a site; previous breeding record of the site; the social attractiveness of the site; amount of cover available; etc. The results of this study indicate that suitable Audouin´s gull nesting areas are characterized by: low vegetation preferably distributed as small discrete areas; the presence of materials for nest construction; and freedom from disturbance from both humans and herring gulls. Therefore management effort should be directed towards providing these conditions.

Audouin´s gulls are, as already stated, not cannibalistic. They do, however, defend their territories. One of the principal causes of mortality in chicks of gulls of the genus Larus is attacks or cannibalism by conspecific or generic adults (Paynter 1949, Tinbergen 1960, Parsons 1971, Hunt 1972, Hunt and Hunt 1976, Pierotti 1979,1980, 1982a, b, Fetterolf 1983). Adult gulls have rarely been observed to attack or kill their own offspring, therefore it is generally assumed that gulls develop the ability to recognize their young (Tinbergen 1960, Evans 1970). The onset of parental recognition of young appears to correlate with the age at which the brood is likely to move about on, or depart from, the natal territory (Evans 1970, Beer 1970). For example, the marsh nesting Franklin´s gull adult will accept alien chicks less than about 14 days old until their own chicks are older than about 14 days (Burger 1974). Similarly, cliff breeding birds, whose chicks´ movements are also restricted until the chicks are quite large, do not distinguish between their own and chicks from other nests until chicks are large (Cullen 1957). Evans (1970) studied black billed gulls nesting on riverine sand bars. For these black billed gulls recognition of young develops at the same time as the chicks become mobile, by 2 to 3 days post hatching. Audouin´s gull chicks can leave their nests when they are only one day old, many not returning to their nest at all but remaining concealed within bushes. Very few adoptions were observed and the few that did occur were of very young chicks (about 2 days old) by adults with very young chicks of their own. It would therefore appear that chick mobility and chick recognition both occur at a very early stage for Audouin´s gulls. This can be very dangerous for chicks since, in species in which recognition occurs early, the cost to the chick, if recognised in a strange territory, is high - usually death by pecking.

This study has shown that chick mobility may be influenced by environmental factors. In the southern sites where cover was available near nests, chicks were less likely to leave their natal territories and if they did, they had a shorter distance to travel before reaching cover and were therefore less exposed to attack. At the southern sites, partly because of the availability of cover and partly due to the larger size of the Audouin´s gull territories (and correspondingly lower densities of adults), no chicks were found with the wounds typically dealt by conspecific adults. Audouin´s gull chicks were found to suffer from intra specific aggression in the high density colonies in the northern sites. However chick mortality was even higher at the lower nesting densities in the south of Rey through predation by herring gulls. The high densities of Audouin´s gulls found at the northern sites may be encouraged by the shortage of available nesting space and may be indirectly caused by the increased presence of herring gulls.

It is also possible that disturbance leads to increased movement of chicks, as was suggested by Fetterolf (1983a, 1983b and 1984). Observations made from hides and of undisturbed control sites with telescopes, however, provide some evidence that mobility does develop at a very early age in Audouin´s gulls and that chicks do move from the nests even in the absence of disturbance. This movement to cover may be an adaptation to reduce the exposure of young vulnerable chicks to temperature extremes.

Various aspects of colonial breeding, particularly nest density and synchronization of laying have an antipredator function. Other studies have shown that predator success upon colonially breeding gulls decreases as the number of defenders increases (Kruuk 1964, Gotmark and Andersson 1984). This was also found to be the case within the Audouin´s gull colony on the Chafarinas. Those birds nesting in the dense nuclei in the north managed to defend their territories so that no herring gulls, were able to land within the colony. Predatory herring gulls in the north were only able to snatch chicks and eggs whilst airborne. In the south of the island herring gulls walked, almost undisturbed by the few diving defending adults, as they searched in the undergrowth for prey.

For many colonial species such predation has been shown to account for a major proportion of all egg and chick losses, for example: black headed gulls (Kruuk 1964, Patterson 1965, Tinbergen et al. 1967); and the herring gull as studied by Parsons (1971). This study has highlighted the impact of the herring gull predation upon Audouin´s gull eggs, chicks and adults. Predation has been shown to have caused the total failure of breeding Audouin´s gulls at study sites and drastically reduced the output at other sites. The values quoted may represent an overestimation, as in this study it was presumed that the majority of eggs disappearing from nests during incubation were predated by herring gulls. This produced estimates that 39% and 74% of nests at the 1985 northern and southern sites, respectively, had at least one egg ´predated´.

Parsons (1971b) suggests that for herring gulls on the Isle of May so significant are the losses of early and late clutches due to egg and chick predation by conspecifics that, even if food is not limiting, predation alone will tend to maintain the present pattern of laying. This tendency for smaller percentages of egg and chick losses for birds breeding during the peak breeding time for the colony arises from a swamping effect, of a temporal nature as opposed to the spatial type described earlier. That a smaller proportion of nest contents are lost to predators during the peak breeding period has been found in other members of the Larid family: black-headed gulls (Patterson 1965); common terns (Nisbet 1975); sooty terns (Feare 1976); and sandwich terns (Veen 1977). During the three seasons that Audouin´s gulls were studied on the Chafarinas Islands the timing of breeding was shown to influence breeding success only at the northern sites in 1983 and 1984, with no indications that early breeders were disadvantaged. Whereas the timing of breeding appeared to have little effect upon the percentage of chicks known to die from early, mid and late initiated nests at the northern sites, at the southern sites the percentages of chicks known to die increased as the season progressed. Observations of these predatory acts were plotted against time. At no particular point during the breeding season was there an obvious increase in the number of eggs or chicks killed and consumed by herring gulls.

It is of interest to consider why herring gulls take the trouble to prey upon Audouin´s gulls at all. Breeding on the Chafarinas Islands herring gulls consume the islands´ domestic waste, the offal and discards from the many fishing boats that moor in the island bay or which visit the fishing town of Ras Kebdana 3 km. away, or the abundant plant and insect material available in the Moroccan fields. With such a variety and wealth of food, why do herring gulls consume Audouin´s gull eggs, chicks and adults? High levels of predation by herring gulls need not be evidence of a food shortage for them. As Ashmole (1963) points out, a gull will be more efficient if it can collect food quickly during a search around the colony for the chicks of other gulls rather than undertake a flight to another food source. This is supported by observations made of predating herring gulls. None of these were seen to arrive from the island of Congreso. Although there were some specialist Audouin´s gull predators who spent many hours at a time within the colony and at very regular intervals, the other predating birds were seen to stop off at the Audouin´s gull nucleus on their way to or from herring gull nesting areas. It would appear that Audouin´s gull for these birds provided a form of diet supplement. Herring gulls also appeared to have little difficulty in trapping, killing and consuming even chicks of fledging size. This could well explain why Audouin´s gull chicks of all ages were taken at approximately equal rates, without an expected peak relating either to colonial synchrony or high chick vulnerability at any specific time or age.

To conclude, the outlook for Audouin´s gull on the Chafarinas Islands has become very serious. Whilst Audouin´s gull numbers on Rey, the only island of the group on which they now breed, have apparently stablised, herring gull numbers on the same island have increased dramatically with some evidence suggesting that Rey is acting as an overspill for the already densely populated island of Congreso. Herring gulls ringed as pulli on Congreso have been recaptured breeding on Rey. The timing of breeding of the herring gull population on Rey is currently generally later than that of the birds on Congreso, a possible explanation for which is that the population on Rey is younger (Ryder 1980). Herring gulls generally remain in the vicinity of the islands throughout the year and commence breeding approximately 3 weeks earlier than do Audouin´s gulls. Audouin´s gull is smaller and much less aggressive than the herring gull; as with Burger´s (1979b) study where laughing gulls, arriving later at breeding sites on a salt marsh island in New Jersey than herring gulls, fail to oust the latter, Audouin´s gulls are compelled to breed in the remaining available areas. Those birds breeding in areas of overlap with herring gulls have a reduced breeding success in comparison with conspecifics breeding farther away. In the past there was room for both species, specially as herring gulls tended to breed on higher, more exposed sites than did Audouin´s gulls. Due to the recent expansion of the herring gull population on Rey herring gulls now breed in what were traditionally Audouin´s gull breeding sites and Audouin´s gulls are to be found occupying obviously suboptimal sites - for instance on the beach within the splash-zone (1985) - where the risk of failure is high. Audouin´s gull also appears to shun breeding at sites where breeding attempts in previous seasons failed. Together therefore, between the decrease in the availability of breeding sites and the reduction of the attractiveness of certain locations, perhaps through herring gull activity in previous seasons, Audouin´s gulls are deprived of breeding space and their breeding success appears to be decreasing annually, largely through the predation of Audouin´s gulls´ eggs and chicks by herring gulls. As breeding adults die through natural mortality and the number of new recruits to the colony declines, through reduced breeding success as described above, and assuming little immigration, the size of this important colony is certain to become reduced. Should this be the case it is likely to be experienced from the 1988 season onwards. This must be avoided.

Audouin´s gull, as the Mediterranean´s only endemic breeding seabird, represents a remaining vestige of the once rich Mediterranean fauna. Its extinction would signify for the countries bordering the Mediterranean, and the many nations that have a vested interest in this area of world renowned recreational importance, the failure of many national and international initiatives directed at protecting the Mediterranean ecosystem.

Audouin´s gull must be given the chance to establish territories in suitable sites and the opportunity to rear chicks successfully, so as to maintain or even increase population numbers. This study has suggested practical steps which should be taken to achieve these end results.

In 1987, ICONA, acting on the recommendations of this study, conducted a cull on Rey of 950 adult herring gulls. The breeding population of Audouin´s gull subsequently increased from 1930 nests in 1986 to 2845 nests in 1987 (Anon. 1987). This suggests that recruitment of adults capable of breeding occurred either from a pool of non-breeders, or young breeders, or of breeders from another site, as breeding space was made available. The situation may improve further as the Instituto para la Conservacion de la Naturaleza (ICONA), which is in charge of managing the islands, plans to repeat the culling campaign in future seasons.

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APPENDIX 1: LIST OF COMMON ENGLISH AND SCIENTIFIC NAMES OF SPECIES MENTIONED IN THE TEXT.

COMMON NAME	SCIENTIFIC NAME
PLANTS	
sea-grass	*Posedonia sp.*
FISH	
sardine	*Sardina pilchardus*
anchovy	*Engraulis encrasicolous*
REPTILES	
wall lizard	*Podarcis hispanica*
ringed lizard	*Trogonophis wiegmanni*
geckoes	*Tarentola mauritanica* *Saurodactylus mauritanicus*
skinks	*Chalcides ocellatus*
BIRDS	
Sphensicidae	
yellow-eyed penguin	*Megadyptes antipodes*
Procellariidae	
Cory´s shearwater	*Calonectris diomedea*
Pelcanidae	
brown pelican	*Pelicanus occidentalis*
Phalacrocoracidae	
shag	*Phalacrocorax aristotelis*
Ardeidae	
cattle egret	*Bubulcus ibis*

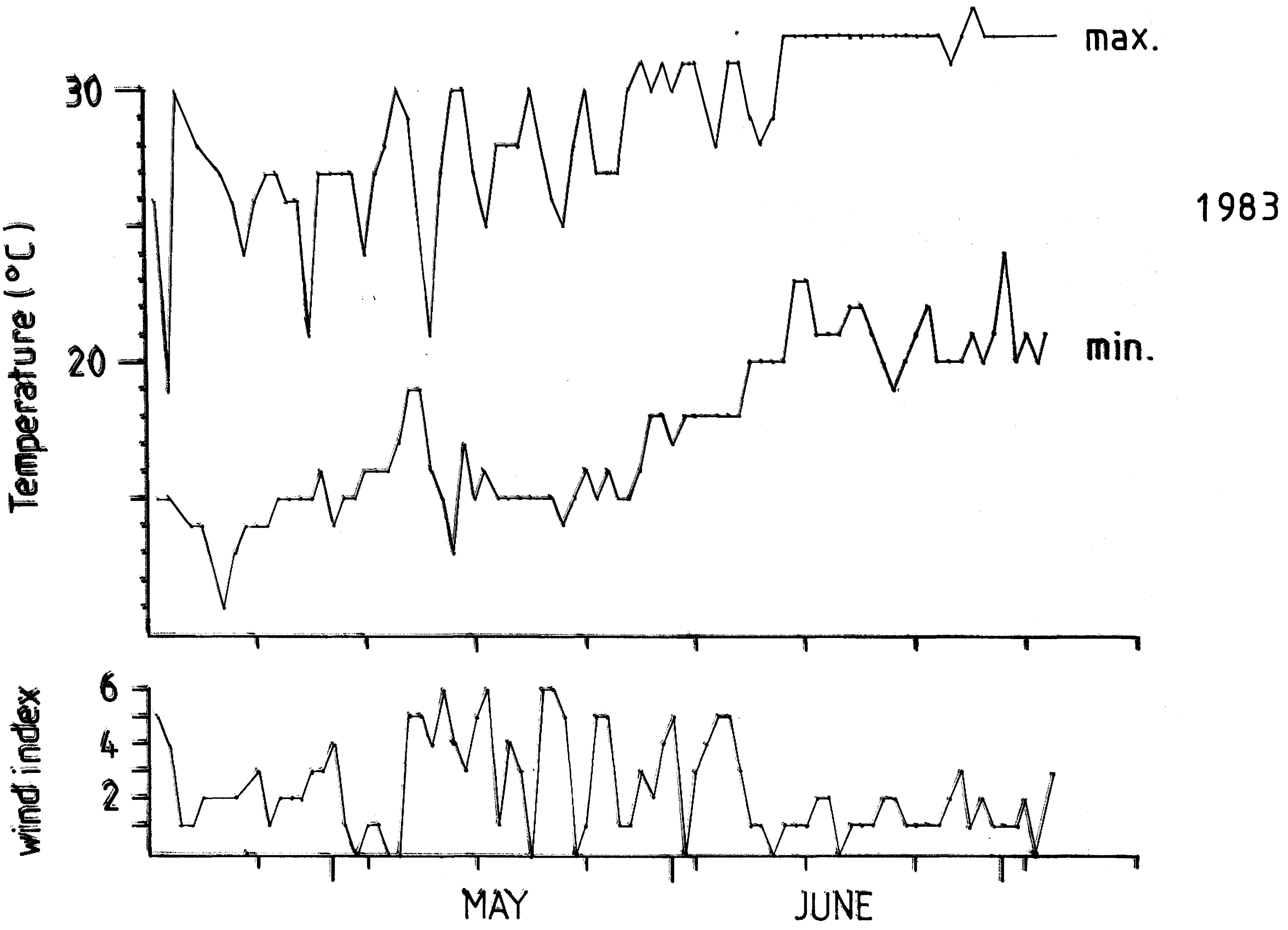
Pandionidae	
osprey	Pandion haliaetus
Falconidae	
peregrine	Falco peregrinus
Eleonora´s falcon	Falco eleonorae
Phasianidae	
Japanese Quail	Coturnix japonica
Laridae	
Audouin´s gull	Larus audouinii
ring-billed gull	Larus delawarensis
herring gull	Larus argentatus michahelles
	Larus argentatus argentatus
	Larus cachinnans michahelles
fork-tailed gull	Creagrus furcatus
California gull	Larus californicus
laughing gull	Larus atricilla
western gull	Larus occidentalis
grey-headed gull	Larus cirrocephalus
Heerman´s gull	Larus heermanni
glaucous-winged gull	Larus glaucescens
kittiwake	Rissa tridactlyla
great black-backed	Larus marinus
Franklin´s gull	Larus pipixcan
black-headed gull	Larus ridibundus
arctic tern	Sterna paradisaea
little tern	Sterna albifrons
royal tern	Thalasseus maximus
sandwich tern	Sterna sandvicensis
common tern	Sterna hirundo
roseate tern	Sterna dougallii
sooty tern	Sterna fuscata
Alcidae	
common guillemot	Uria aalge

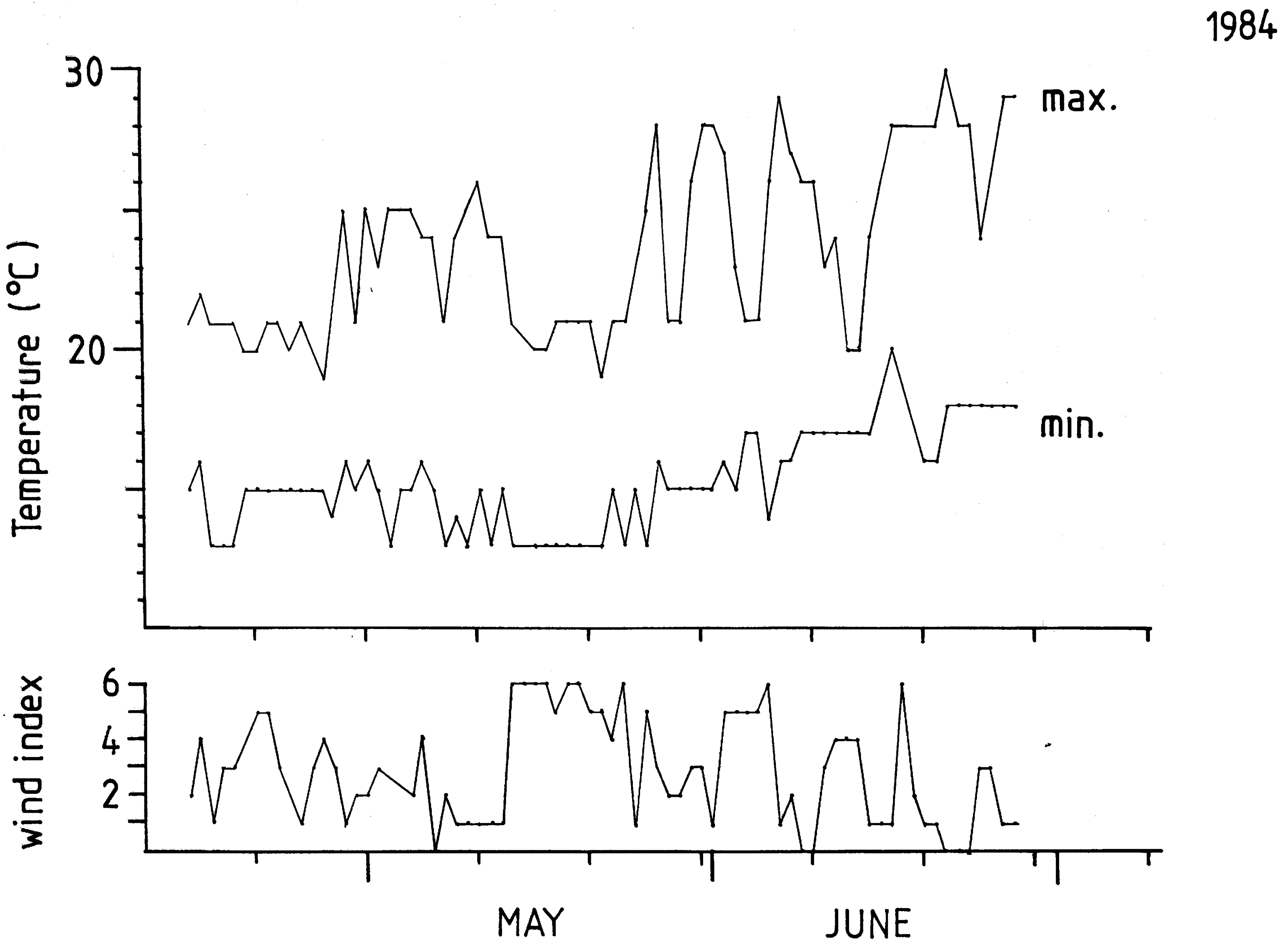
Columbidae	
feral rock dove	*Paloma livia*
mourning dove	*Zenaida macroura*
white-winged dove	*Zenaida asiatic*
Apodidae	
common swift	*Apus apus*
Hirundinidae	
swallow	*Hirundo rustica*
house martin	*Delichon urbica*
Laniidae	
woodchat shrike	*Lanius senator*
Troglodytidae	
wren	*Troglodytes troglodytes*
Muscicapidae	
pied flycatcher	*Ficedula hypoleuca*
Paridae	
great tit	*Parus major*
MAMMALS	
rats	*Rattus rattus*
monk seal	*Monachus monachus*

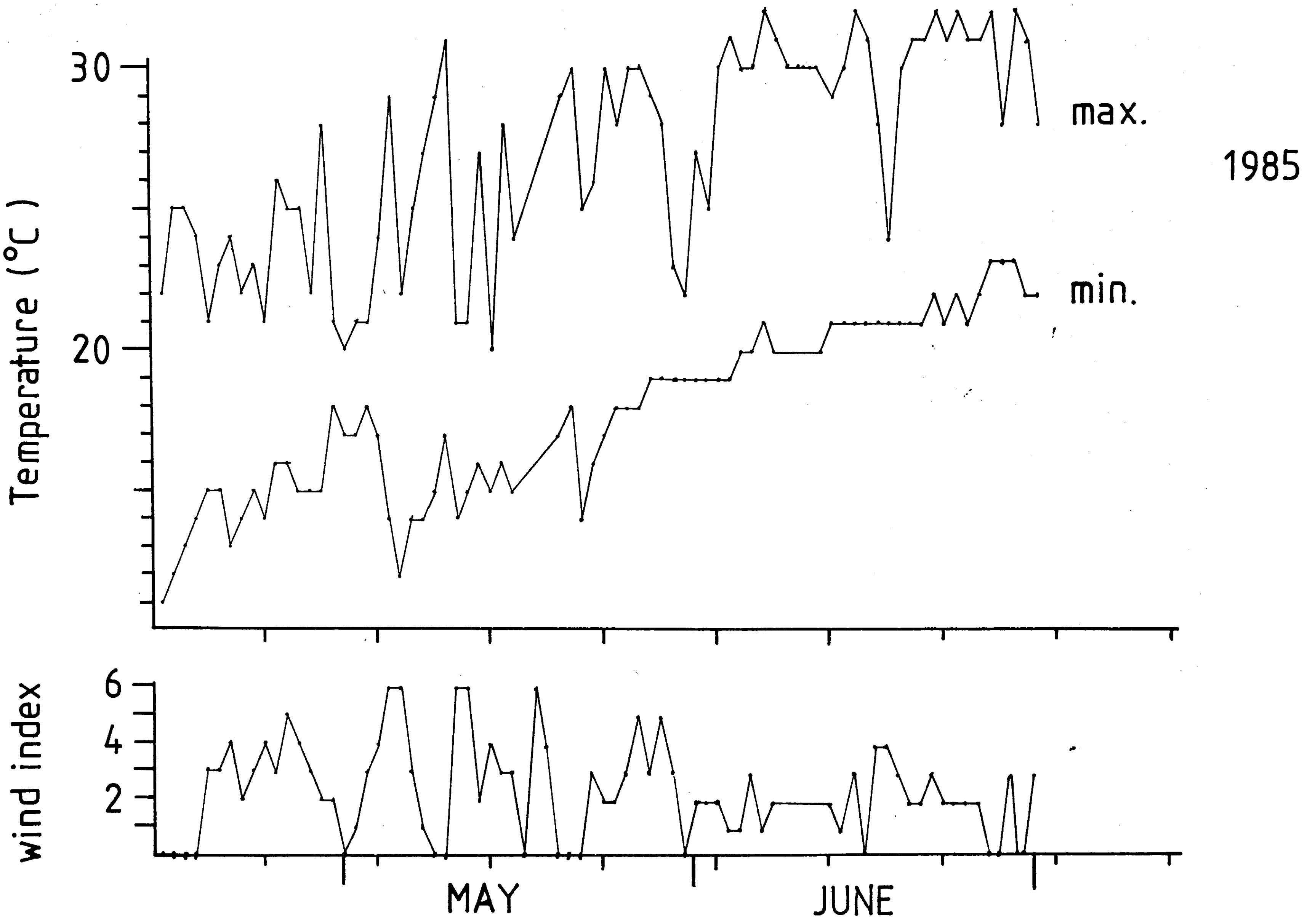
APPENDIX 2: Maximum, minimum shade temperatures and wind conditions in 1983 measured on Isabel 11.

APPENDIX 3: Maximum, minimum shade temperatures and wind conditions in 1984 measured on Isabel 11.

APPENDIX 4: Maximum, minimum shade temperatures and wind conditions in 1985 measured on Isabel 11.


max.
1983
min.
30
20
Temperature (°C)
6
4
2
wind index
MAY
JUNE

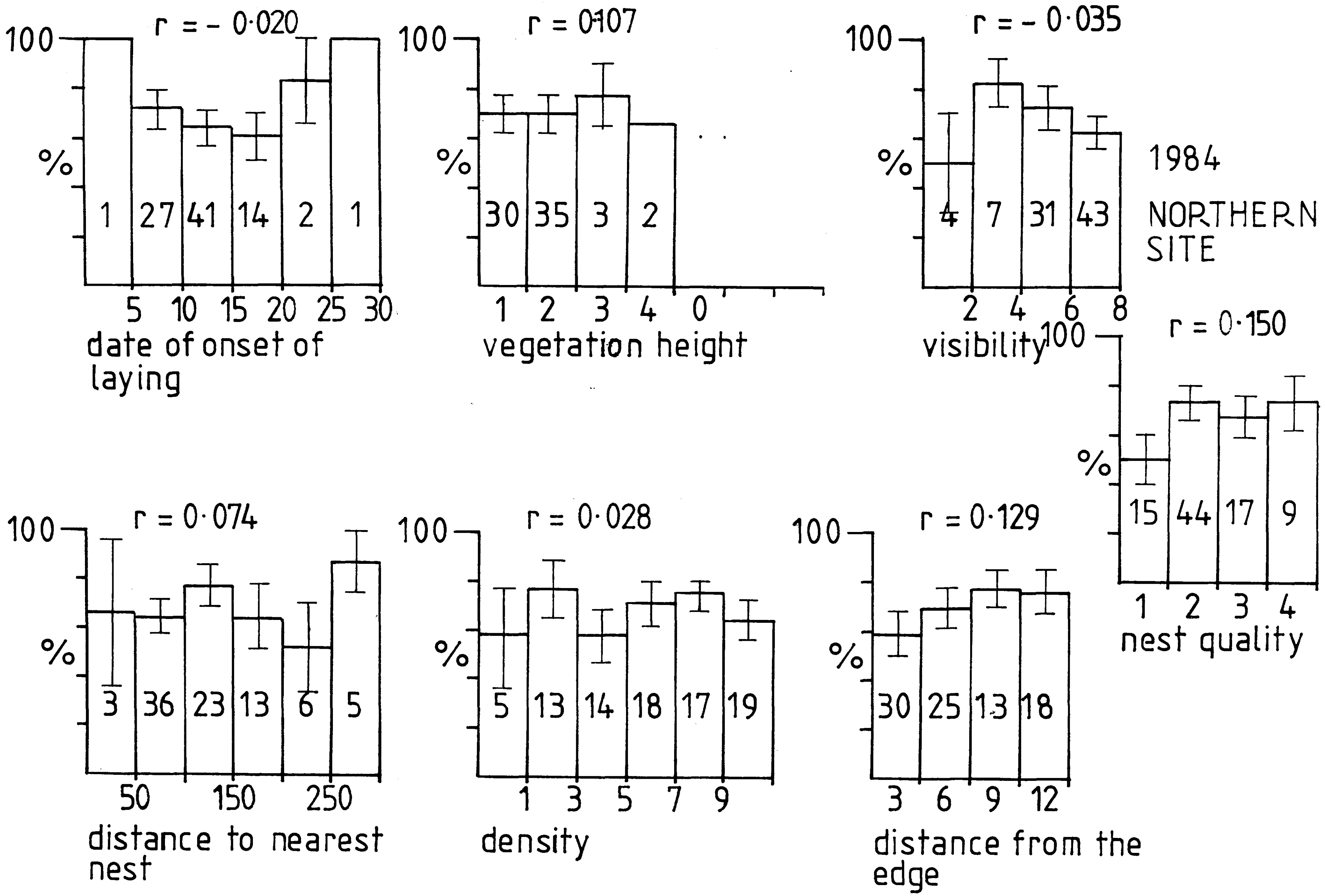

1984
30
20
Temperature (°C)
max.
min.
6
4
2
wind index
MAY
JUNE

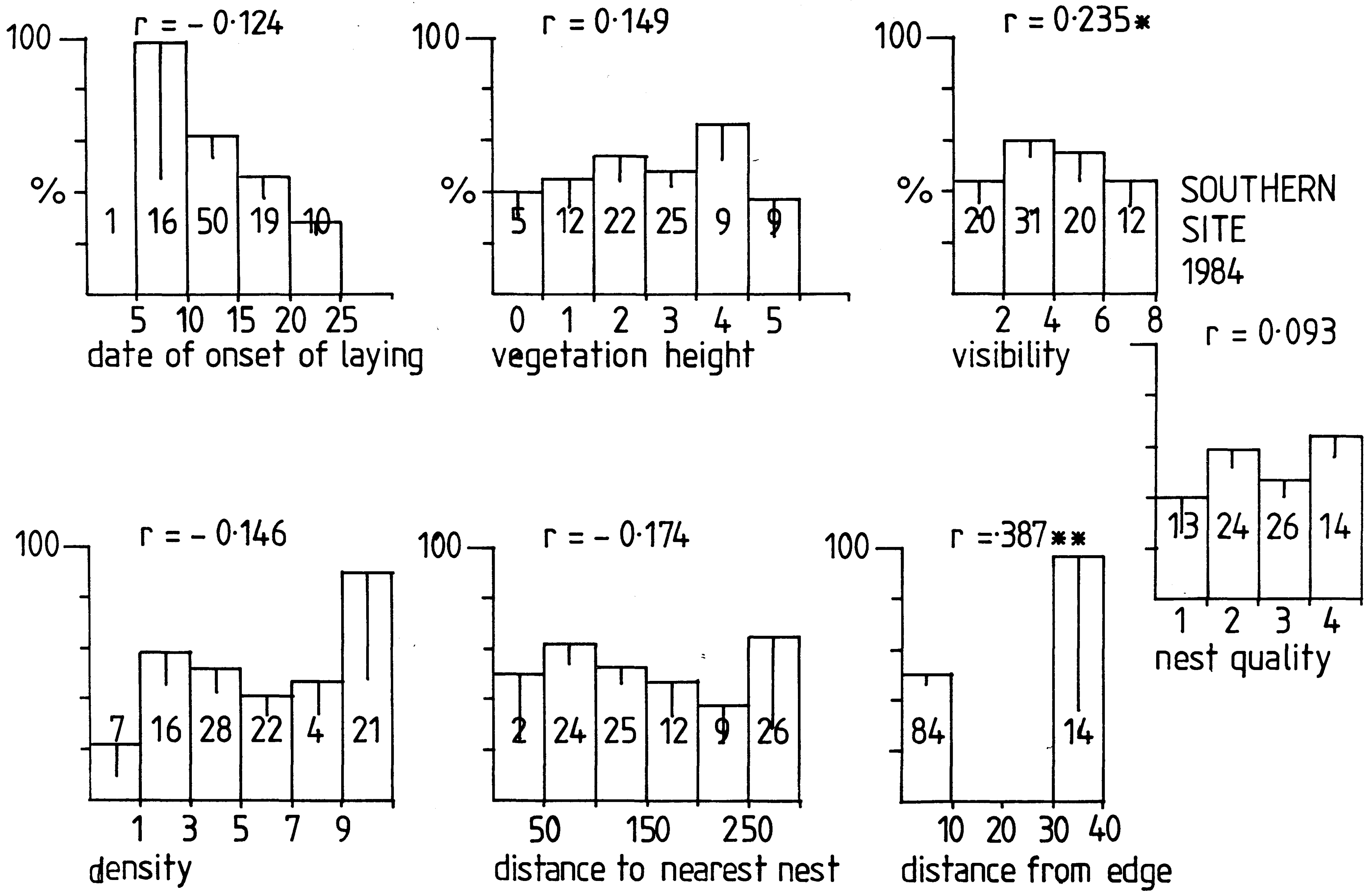

1985
max.
min.
Temperature (°C)
30
20
wind index
6
4
2
MAY
JUNE

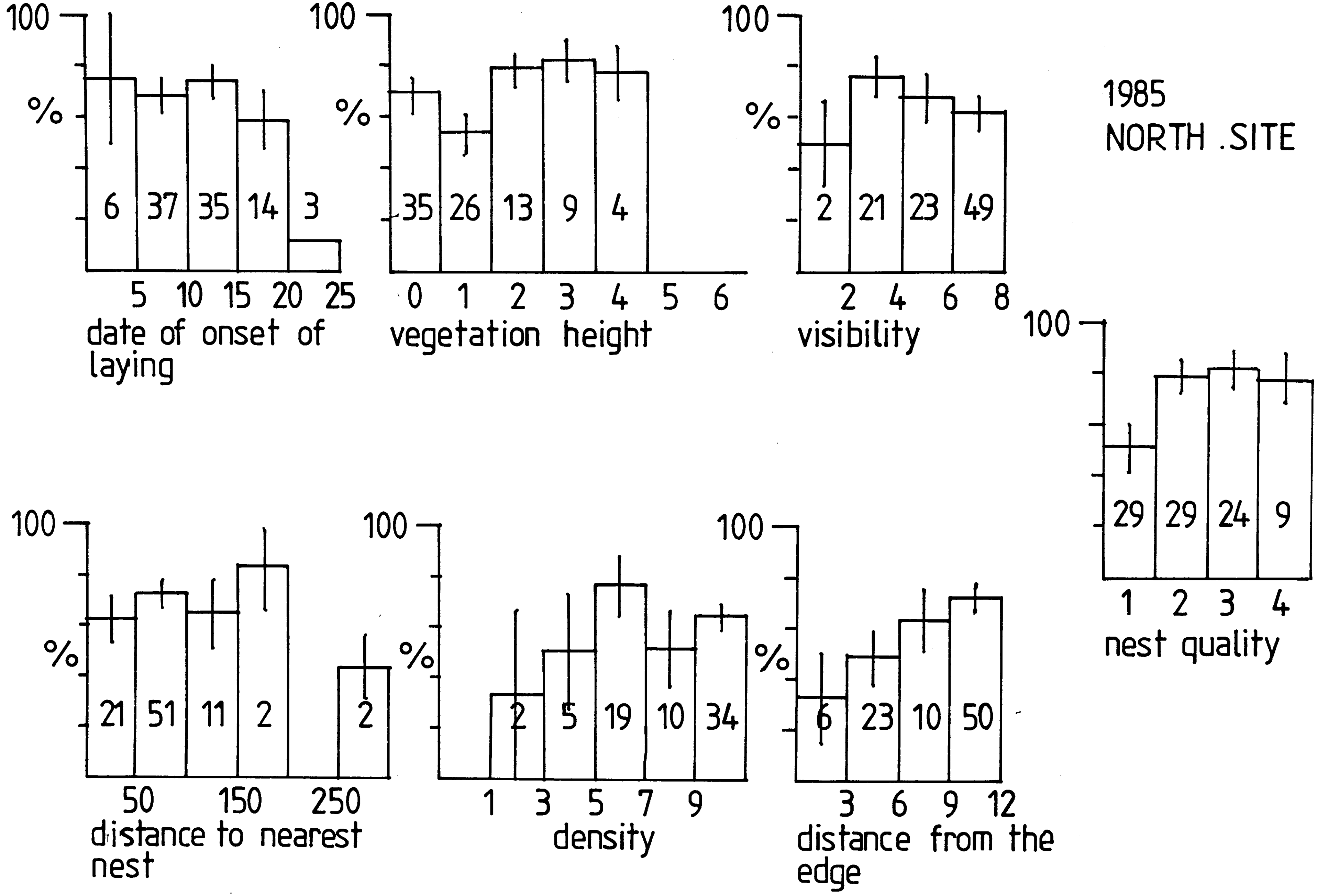
APPENDIX 5: Variation in hatching success in relation to environmental factors at the northern site in 1984.

APPENDIX 6: Variation in hatching success in relation to environmental factors at the southern site in 1984.

APPENDIX 7: Variation in hatching success in relation to environmental factors at the northern site in 1985.


1984
NORTHERN SITE
r = - 0·020
100
%
1 27 41 14 2 1
5 10 15 20 25 30
date of onset of laying
r = 0·107
100
%
30 35 3 2
1 2 3 4 0
vegetation height
r = - 0·035
100
%
4 7 31 43
2 4 6 8
visibility
r = 0·150
100
%
15 44 17 9
1 2 3 4
nest quality
r = 0·074
100
%
3 36 23 13 6 5
50 150 250
distance to nearest nest
r = 0·028
100
%
5 13 14 18 17 19
1 3 5 7 9
density
r = 0·129
100
%
30 25 13 18
3 6 9 12
distance from the edge


r = − 0·124
100
%
1
16
50
19
10
5 10 15 20 25
date of onset of laying
r = 0·149
100
%
5
12
22
25
9
9
0 1 2 3 4 5
vegetation height
r = 0·235*
100
%
20
31
20
12
2 4 6 8
visibility
SOUTHERN
SITE
1984
r = 0·093
13
24
26
14
1 2 3 4
nest quality
r = − 0·146
100
7
16
28
22
4
21
1 3 5 7 9
density
r = − 0·174
100
2
24
25
12
9
26
50 150 250
distance to nearest nest
r =·387**
100
84
14
10 20 30 40
distance from edge


1985
NORTH .SITE
100
%
6
37
35
14
3
5
10
15
20
25
date of onset of laying
100
%
35
26
13
9
4
0
1
2
3
4
5
6
vegetation height
100
%
2
21
23
49
2
4
6
8
visibility
100
29
29
24
9
1
2
3
4
nest quality
100
%
21
51
11
2
2
50
150
250
distance to nearest nest
100
%
2
5
19
10
34
1
3
5
7
9
density
100
%
6
23
10
50
3
6
9
12
distance from the edge

APPENDIX 8: HATCHING SUCCESS IN RELATION TO CLUTCH SIZE AT STUDY SITES IN 1983 AND 1985. n is the number of clutches in each size category.

1983

	NORTH		SOUTH	
CLUTCH SIZE	n	EGGS HATCHED	n	EGGS HATCHED
1	6	0	6	1
2	11	13	9	11
3	68	166	57	144
4	1	2	1	3

1985

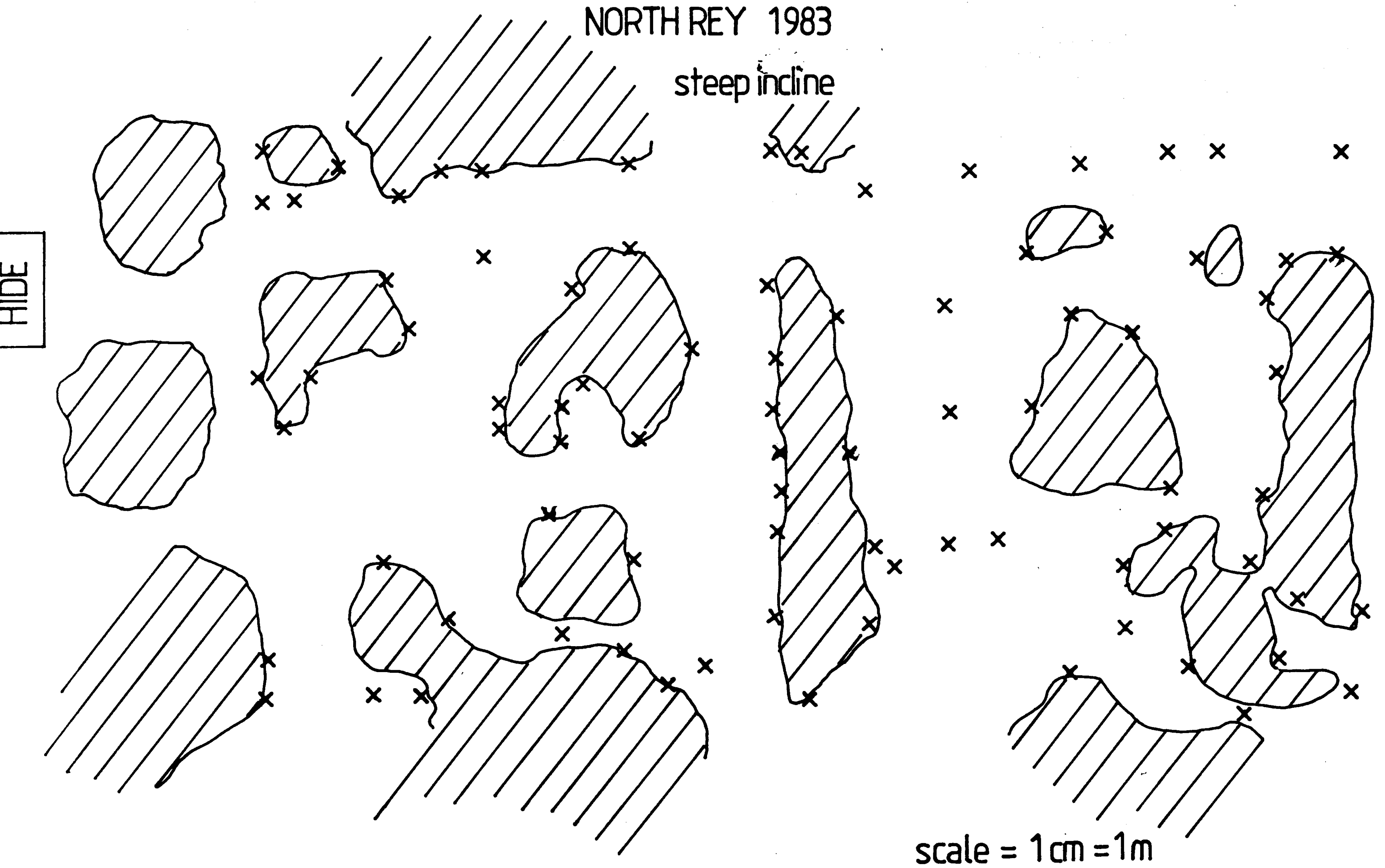
	NORTH		SOUTH	
CLUTCH SIZE	n	EGGS HATCHED	n	EGGS HATCHED
1	11	1	9	0
2	19	18	4	0
3	69	162	36	38
4	3	5	2	3

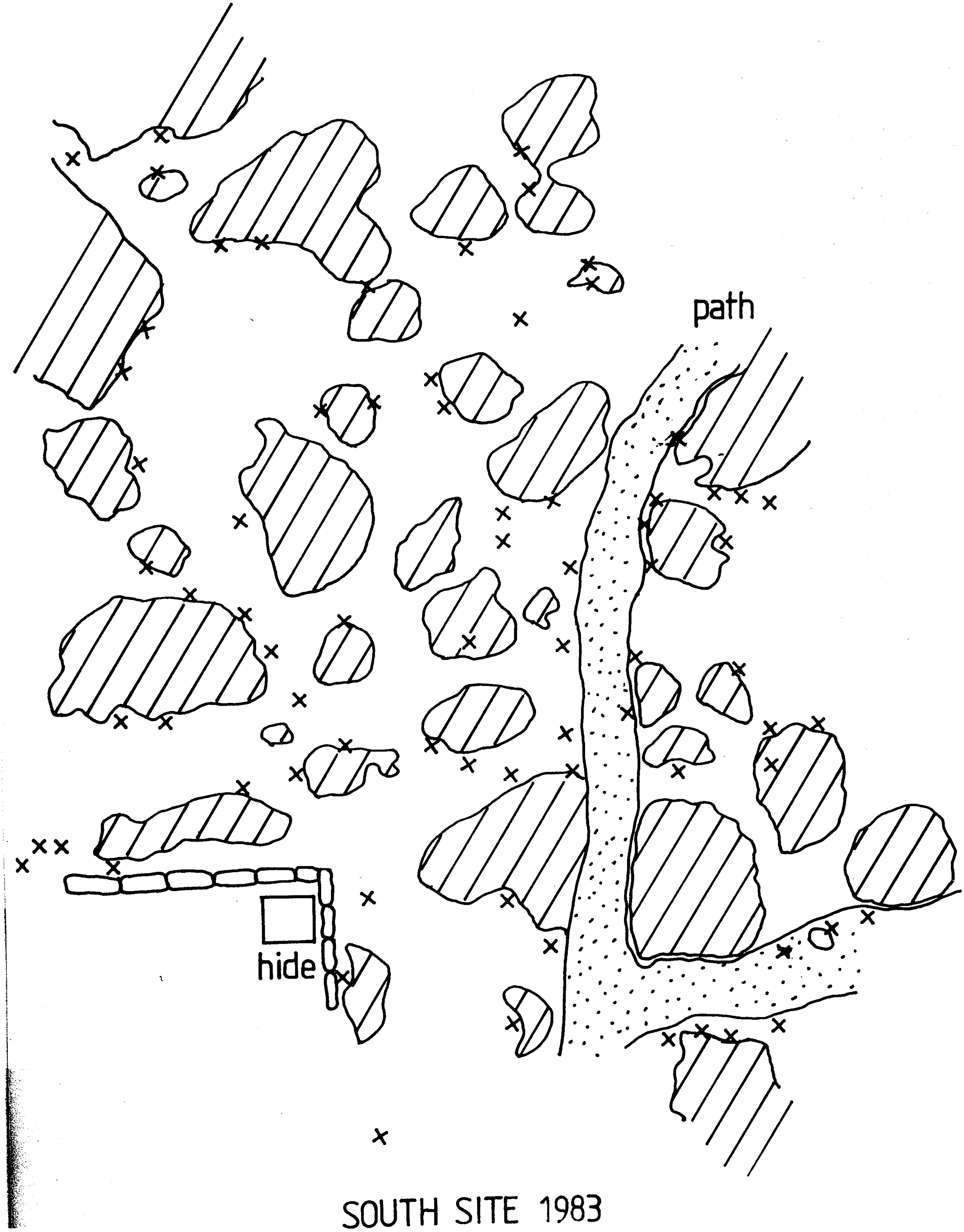
APPENDIX 9: AUDOUIN´S GULL RINGED AS ADULTS DURING THE STUDY

WEIGHT (g.)	BILL DEPTH (mm.)
620	14.6
675	
660	16.6
535	15.3
715	16.9
660	16.2
515	14.7
550	14.6
685	17.2
705	16.2
632	15.8

APPENDIX 10a: Distribution of nests in relation to vegetation at the northern site in 1983. Bushes are represented by shaded areas.

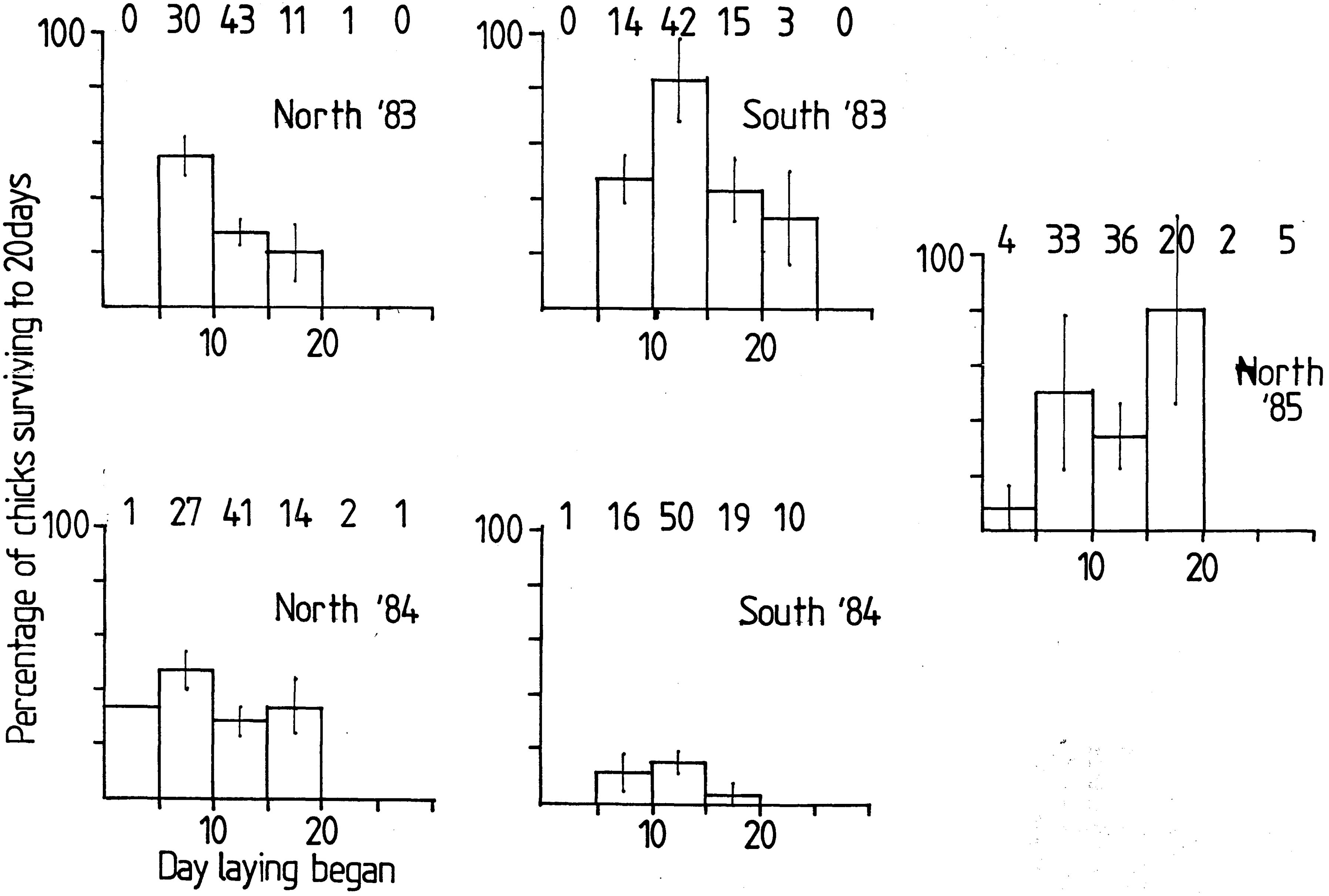
APPENDIX 10b: Distribution of nests in relation to vegetation at the southern site in 1983. Bushes are represented by shaded areas.


NORTH REY 1983
steep incline
HIDE
scale = 1cm = 1m



SOUTH SITE 1983
scale = 1 cm = 2 m

APPENDIX 11: Variation in the percentage of chicks surviving to 20 days in relation to laying date at each of the study sites 1983-1985.


Percentage of chicks surviving to 20days
100
0 30 43 11 1 0
North '83
10
20
0 14 42 15 3 0
South '83
4 33 36 20 2 5
North '85
1 27 41 14 2 1
North '84
1 16 50 19 10
South '84
Day laying began

APPENDIX 12: MEAN EGG DIMENSIONS FOR THE DIFFERENT STUDY SITES IN THE DIFFERENT YEARS (standard deviations are given within brackets).

1983

	NORTH					SOUTH				
	n	LENGTH (mm)		BREADTH (mm)		n	LENGTH (mm)		BREADTH (mm)	
a	83	65·7	(22.6)	44·6	(11.3)	74	65·2	(24.2)	44·7	(10.8)
b	78	64·9	(20.3)	44·6	(10.5)	69	64·5	(20.5)	44·6	(11.6)
c	68	63·6	(33.0)	43·7	(10.5)	60	64·3	(25.0)	43·6	(11.0)

1984

	NORTH					SOUTH				
	n	LENGTH (mm)		BREADTH (mm)		n	LENGTH (mm)		BREADTH (mm)	
a	83	65·3	(27.0)	44·7	(10.7)	93	65·0	(27.8)	44·4	(21.6)
b	75	64·8	(25.6)	44·8	(10.1)	71	64·2	(25.9)	44·2	(11.8)
c	65	64·2	(23.6)	43·7	(10.1)	53	63·9	(27.2)	43·1	(17.2)

1985

	NORTH					SOUTH				
	n	LENGTH (mm)		BREADTH (mm)		n	LENGTH (mm)		BREADTH (mm)	
a	95	64·3	(25.6)	44·4	(11.2)	51	64·9	(23.8)	44·5	(09.6)
b	83	63·4	(23.8)	44·4	(11.3)	43	64·1	(23.2)	44·4	(10.9)
c	68	63·2	(26.3)	43·5	(11.4)	38	63·7	(20.3)	43·5	(09.3)