THE ECOLOGY OF SEABIRDS ON AILSA CRAIG, FIRTH OF CLYDE

Ph D. Thesis

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DECLARATION

I hereby declare that all the work within this Thesis is entirely of my own composition unless specifically stated. No part of this work has been offered or submitted for any other examination or degree.

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Signed

Bernard Zonfrillo.

30 September 1997

SUMMARY

The focus of this thesis is the ecology of seabirds on Ailsa Craig, a remote, high, rocky island situated in the Firth of Clyde in south-west Scotland. The island is principally an internationally important Gannet colony but has locally significant numbers of other breeding seabirds.

The status of seabirds on Ailsa Craig and in the Firth of Clyde in general, was examined. Possible reasons for the observed species fluctuations are examined.

Selected aspects of the breeding ecology of seven seabird species on Ailsa Craig were studied. These are Fulmar, Gannet, Great Black-backed Gull, Herring Gull, Kittiwake, Guillemot and Razorbill. Diets of adult and young of most species are analysed and the growth rate of young is also examined in most cases from hatching to fledging. Growth rate is presented, in most instances, as both the absolute growth rate and the instantaneous growth rate, the latter being used for comparative purposes since it accounts for variation such as individual size, which may be a factor of sex or clinal variation. Dietary data and chick growth rates largely reflect food availability in the marine environment, and this is discussed with respect to the diet and foraging behaviour of the species involved.

Remote seabird islands are usually free of any naturally occurring mammalian predators but when alien mammals are transported to islands through anthropogenic agents the consequences for breeding seabirds can be disastrous. Burrow nesting species in particular can be seriously affected by fast-reproducing predators such as rats. Ailsa Craig was colonised by brown rats through shipwrecks around 1889. Following that time certain seabird species, all burrow nesters, gradually and completely died out. This was generally attributed to the effects of rat predation. The final section of this thesis describes a method whereby rats were eliminated from Ailsa Craig and details the techniques and monitoring methods involved. Following the commencement of rat eradication in 1991, preliminary results indicated increased biodiversity and increases in productivity of some bird species. Other important fauna and flora of the island also increased in the absence of rats. After monitoring for six years, the eradication of rats on Ailsa Craig appears to have been completely successful.

Ailsa Craig from the South. Photo. S. Murray, August 1995

Sonnet on Ailsa Rock

Hearken, thou craggy ocean-pyramid !
Give answer from thy voice the sea-fowls screams !
When were thy shoulders mantled in huge streams ?
When from the sun was thy broad forehead hid ?
How long is't since the Mighty Power bid
Thee heave to airy sleep from fathom dreams ?
Sleep, in the lap of thunder or sunbeams,
Or when grey clouds are thy cold coverlid ?
Thou answer'st not, for thou art dead asleep !
Thy life is but two dead eternities -
The last in air, the former in the deep
First with the whales, last in the eagle-skies -
Drown'd wast thou 'til an earthquake made thee steep,
Another cannot wake thy giant size.

John Keats, Ayrshire, June 1818

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The Ecology of Seabirds on Ailsa Craig, Firth of Clyde

Introduction

Seabirds

The British Isles lie towards the north-western end of the Eurasian landmass, facing the incoming north-Atlantic drift of the Gulf Stream. Rugged islands and coasts combined with an abundance of marine life have given rise to populations of certain seabirds which are unsurpassed elsewhere in the world today. Only around 3 percent of bird species as a whole are adapted to exploit the potentially large food resources presented by the marine environment. Seabirds are generally either aerial feeders, which snatch or pick their food from on or near the surface, or divers, which obtain their prey underwater, often at considerable depth. In general surface feeders are physically better adapted for long-range foraging and migration than are diving birds. Their foraging is largely over two dimensions of the marine environment while divers may forage over three.

Around 70 percent of the world's breeding Northern Gannets and Manx Shearwaters are contained within the British Isles as are half the world's British Storm-petrels and Great Skuas (Lloyd *et al.*, 1991). Today, British populations of several seabird species and their breeding areas are the subject of international directives aimed at protecting them in perpetuity (European Community Directive on Conservation of Wild Birds, 1979; European Community Habitats and Species Directive, 1992). The west coast of Scotland, and the Clyde area in particular, have a number of sites and species designated as important at international, national and local levels. Caring for these areas and the birds they contain involves studies both on land and at sea, in order that influences determining changes in populations can be understood and, if necessary, acted upon. It is generally accepted that a numerically healthy and diverse avifauna is an indication of a healthy environment. Mankind can also benefit or suffer from changes in the ecosystem in both the broad sense and at a local level. Seabirds can be studied to provide an indication of the health of the marine ecosystem since they are sensitive, in several aspects, to changes (Furness, 1987).

The productivity of the sea will, in part at least, determine the size of the bird populations that the marine ecosystem can support. Factors influencing the productivity of the marine ecosystem will in turn result in fluctuations in seabird populations. Although superficially uniform, the marine environment can be as biologically diverse as any equal area of land. The sea can be described in terms of discrete habitats such as substrate, salinity, temperature, depth and turbulence, to name but a few parameters. Seabirds may feed from one or more trophic layers. The organisms of the phytoplankton and zooplankton "bloom" on a seasonal basis, largely governed by light levels at different periods of the year (Hardy, 1956). These form the basis of a food-chain for higher, more evolved organisms such as fish, cetaceans and birds. The phototropic vertical migrations of many planktonic organisms can provide an abundance of food for many seabirds over the northern winter months. With two thirds of the day in winter darkness, those seabirds that do not migrate must feed nocturnally at sea in the north Atlantic. However, when breeding occurs, seabirds are constrained by the need to attend young and provision their brood and can only forage within finite parameters. Lack (1966) suggested that density-dependent competition for food was the single most important factor regulating seabird numbers outside of the breeding season. Seabird colonies may even be spaced at discrete intervals, lessening the effects of intensive competition (Furness and Birkhead, 1984). Colony spacing may also simply be the consequence of man-induced marine changes. Large tracts of ocean are untouched by seabirds and distance from land, as well as depth, forms an effective barrier to all but a very few specially adapted species. When prolonged bad weather or lack of appropriate feeding affects seabirds they occasionally perish in large numbers - resulting in what is commonly termed "wrecks". Mass starvation or "wrecking" of marine species is usually visible evidence of an environmental catastrophe at sea but it is doubtful that seabirds alone can reduce their prey to the point where they precipitate such phenomena.

Intrinsic aspects of islands may contribute to the diversity of species they can support. Islands with habitat suitable for surface nesting species, cliff nesters, burrowers, cave and rock nesters will provide more diverse habitat than, say, a low flat sandy island where perhaps only a few species can nest. The area of an island may increase diversity with increasing habitats found thereon but seabirds will tend to occupy specific niches given that the islands are predator-free. In Scotland in general, almost all seabird species that nest on isolated islands can also be found nesting on the mainland (Lloyd *et al.*, 1991). Perhaps only small petrels and shearwaters do not breed to any extent on the mainland. Guillemots may nest on vertical cliffs and be relatively safe from mammalian predators but are susceptible in such situations to avian predators such as gulls and raptors. Burrow nesters suffer little from avian predators when incubating but are highly susceptible to mammalian predators. As well as on cliffs, Guillemots may also nest in sea-caves and in boulder-beaches on some isolated rocks (e.g. at Glunnimore on the Sanda Islands in the Clyde) and can thus adapt the habitat utilised to a certain extent, provided these habitats are free of significant predators.

Threats to seabirds

Marine changes can be induced by man via several sources. Some of these changes will be beneficial to seabirds while others will be detrimental. Changes in the chemical composition of the sea due to anthropogenic pollutants, both organic and inorganic can be detected in the diets, eggs or tissue of seabirds and alterations to age cohorts of fish stocks can affect seabirds directly and indirectly (Coulson *et al.* 1972 ; Furness, 1987). Generally speaking, birds that can adapt to feeding on more than one or two marine species will be at an advantage over those locked into a specialised diet. Species with surface foraging methods and relatively short foraging ranges appear to suffer breeding failures from fluctuating food supplies more than underwater feeders (Monaghan *et al.*, 1996). On land, those seabirds with a breeding niche or breeding behaviour which protects their young from factors such as weather and predators will have an advantage over those where eggs and young are exposed or rely only on crypsis. Where suitable islands with adequate seabird habitats exist, but no seabirds, then mammalian predators, including man, have probably been active in the past. There appears to be a strong demarcation between islands with seabirds and no mammalian predators and those with mammals and no seabirds.(Moors *et al.*, 1989). Mammalian predators are usually absent on islands or coasts where seabirds breed, unless introduced accidentally or deliberately by man. When this occurs the effects can be devastating to the seabirds both in the long and the short term. In the past man alone has been the major predator of seabirds, when colonising remote islands where seabirds breed in abundance, such as St Kilda (Harris and Murray, 1978) or simply when exploiting locally abundant seabirds, such as in the Faroe Islands today (pers. obs.) or on Ailsa Craig earlier in this and in the last century (Gibson, 1951). Killing seabirds for food affects the local populations directly particularly if adult breeding birds are removed. Taking immature birds has less of an effect on future populations since juvenile mortality is generally relatively high. To a certain extent seabirds have been "farmed" by man for food.

Indirectly, seabird populations can be altered by man through fishing (Montevecchi, 1993). While some fishing operations probably aid winter survival of certain seabirds other operations, such as trawling, can be detrimental particularly in the long-term, causing major disruptions to the food chain. These changes in the marine ecosystem are reflected in the population ecology and behaviour of breeding seabirds (Furness, 1987; Monaghan *et al.*, 1996).

Modern man, even within the past 150 years, persisted in harvesting seabirds ashore at colonies and evolved unselective and highly destructive methods of fishing at sea that were also largely unregulated. Added to this was the more recent human ability to destroy both avian and marine life by pollution and the transportation of alien mammals such as rats on ships to seabird colonies. Rats are among the most destructive of the alien mammals regularly reaching remote islands (Atkinson, 1985). Their presence on remote islands is almost always due to man. I can find no instance where rats have naturally died out once having adapted to an island existence.

By precipitating chemical changes to the ozone layer through chloro-fluoro-carbons in the atmosphere, man may also have induced changes in weather patterns which also affect seabird productivity. Warm or cold weather may proliferate or inhibit phytoplankton growth with its knock-on effects for seabirds (Hardy, 1956; Daly and Smith, 1993.). Studies of climatic effects on seabird breeding success may form a major part of future seabird investigations.

Comparatively little is also at present known of the effects of nuclear radiation, via outfalls of coastal nuclear power stations such as that at Hunterston on the Clyde, on both marine life and seabirds. It is known for example that *Acanthacaria*, planktonic Radiolarians (Order; Rhizopoda), have skeletons composed of strontium sulphate, a gypsum-like substance, while most other groups are silica (Hardy, 1956). The ability to extract radioactive strontium from sea water and fix it in an insoluble form as part of their skeleton will in future probably prove to be of environmental importance, particularly since Radiolarians are eaten by fish which in turn are eaten by seabirds and man.

Seabird studies

In general many seabird studies include long-term monitoring and aspects of breeding success, diet and recruitment of a single species at certain locations. For example British and North Atlantic studies include those on the Fulmar (Fisher, 1952 ; Dunnet, 1979), the Gannet (Nelson, 1982), Kittiwake (Coulson, 1985), the Puffin (Harris, 1984), Great Skua (Furness, 1988) Guillemot and Razorbill (Nettleship and Birkhead, 1985). While some seabird locations have received intensive long-term study, e.g. Skomer Island (Birkhead and Perrins), Foula, Shetland (Furness), and Isle of May, Fife (Harris), the emphasis has still generally been on a single species, or relatively few, at any given period of time. A notable exception to this generalisation was the work of Pearson (1968) done on the Farne Islands with a group of nine seabird species. Occasionally two areas harbouring the same species have been compared (Furness and Todd, 1984). Elsewhere, Harrison *et al.* (1983), looked at the dietary preferences of all seabirds in Hawaii and earlier, in a similar paper, Ashmole and Ashmole (1967) studied seabird ecology in the tropics, concentrating on niche exploitation. Belopol'skii (1957) perhaps pioneered ecological studies of several seabird species simultaneously, covering all those found in the Barents Sea. Broader based continuing studies and comparative studies between species can lead to a much better understanding of seabird life-histories and their role in the marine ecosystem.

Focus of this study

The focus of this study is the ecology of seabirds at a single location, Ailsa Craig in the Firth of Clyde. The work is descriptive and is based on my own close association with the island over several years. A two-pronged approach is taken, covering aspects of both community structure and single species ecology. This thesis describes aspects of population change and details selected aspects of seabird breeding ecology and diet. Also appended is a detailed flora of the island.

Firstly, changes in seabird populations are examined to give a broad picture of current status in the defined study area and possible reasons for these changes are examined.

Secondly. the breeding success and feeding regimes of a range of seabird species on Ailsa Craig are examined. These are Fulmar, Gannet, Great Black-backed Gull, Herring Gull, Kittiwake, Razorbill and Guillemot. This has implications for conservation of marine and terrestrial habitats and reveals ways in which those habitats are exploited by both seabirds and man.

A key aspect of the ecology of seabirds and the structure of the community has been the presence of rats which prey upon adults, eggs and young and prevent certain species from breeding at all. The final section of this thesis deals with determining a method of monitoring and eradicating rats from seabird islands, such that seabird numbers and diversity are enhanced on the island without eliminating non-target species and other wildlife.

[N.B. Scientific names for all birds, mammals, fish and plants mentioned in the chapters are given in Appendix I and Appendix II]

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Chapter 1.

Seabird Populations of Ailsa Craig and The Firth of Clyde

1. 1. Introduction

The Clyde Sea Area and its islands provide an ecosystem of great diversity and complexity for both land and marine life (Fig.1.1.). From all but southerly winds, Clyde sea waters are to a certain extent protected by surrounding hills and the marine circulations involve water from the North Channel and River Clyde, creating a clockwise motion around the Island of Arran, largest of the Clyde islands. Much of the landscape and scenery evolved from volcanic action over 60 million years ago and then was modified and sculptured by the glacial Ice-age action from around 20,000 years Before Present (Harrison *et al.* 1987). The action of glaciers had formed not only cliffs and islands suitable for seabirds to nest upon, but modified the sub-sea habitat by forming deep gouges that were then colonised by marine life more usually found off the continental shelf. The north-to-south glacial gouging in the upper Firth of Clyde deposited debris on the open southern Firth that formed a barrier of sand and mud and which, when above the waves, formed a land bridge between Ayrshire and Kintyre (MacGregor and MacGregor 1968; Harrison *et al.*, 1987). When erosion and rising sea level submerged the debris, left behind were some terrestrial vertebrates such as Pygmy Shrew, Common Lizard and Slow Worm that had crossed the land-bridge to remain on Ailsa Craig, at the half way mark between Ayrshire and Kintyre. These effects also provided conditions conducive to the proliferation of marine life. Seabirds therefore found a pristine habitat and ideal conditions for feeding and reproduction soon after the ice began to retreat.

Twenty-one seabird species breed or have been known to breed on the Firth of Clyde, from a grand total of around twenty-five species which regularly nest on the British Isles (see Table 1.1.). Roseate Tern has not bred for many years and is omitted from the 20 species listed. Few terns of the remaining four species, Common, Arctic, Sandwich and Little presently breed on the Clyde.

Species such as Cory's Shearwater, Sooty Shearwater, Balearic Shearwater, Leach's Storm-petrel. Iceland Gull, Glaucous Gull, Great Skua, Arctic Skua and Little Auk occur in the Clyde as scarce or seasonal visitors, but do not breed.

Since the advent of man, and particularly modern man in the past 150 years, threats to the wildlife on land and in the sea have been both real and apparent. On land, mediaeval man visited islands to hunt birds and collect their eggs, and no doubt had an effect in suppressing or exterminating local populations of certain species. At sea methods were simpler, less specific and perhaps less prone to causing wide environmental change. Modern man, on the other hand, has been the agent of change, sometimes drastic and rapid, in both narrow habitat and broad ecosystem by direct and indirect actions.

1. 2. Ailsa Craig

Ailsa Craig is located in the Firth of Clyde, Strathclyde, south-west Scotland, (Lat. 55° 15' N, Long. 05° 07' W.), (Fig.1.2.). It rises abruptly from a plateau of sub-marine mud and sand to almost 380 m above sea level and is composed of a unique, very hard micro-granite, radio-metrically dated at around 61 million years Before Present (Harrison *et al.*, 1987). In geological terms the island is an "igneous intrusion" and is almost 6 kilometres in circumference. In all but a few hollows the soil is light and exceptionally well drained. The columnar granite cliffs are hexagonal in structure and interlaced with dykes and seams of dolerite. The weathered columnar ledges form ideal breeding sites for seabirds while the sea-washed dolerite has been eroded to form sea caves, some of which are now at the head of raised beaches. For a relatively small island, Ailsa Craig has a diverse flora (Zonfrillo, 1994; see Appendix ii) and an interesting fauna. Among several previously introduced mammals only Rabbits and Brown Rats persisted.

Over the past 200 years, Ailsa had a community of around 30 human inhabitants, part crofting, part fishing but mainly involved in quarrying and dressing the granite firstly for kerbstones and laterally for curling stones, used in a popular winter sport. Human involvement on the island largely ceased in the late 1950's. A stone and granite "castle" that exists on the island as a ruin was reputedly built around 1300 A.D. by the monks of Crossraguel Abbey, a former ecclesiastical centre in south Ayrshire (Lawson, 1896). Judging by the deep bone-meal layer in the basement of the Castle, and its large chimney-places, it was used mainly as a summer smoke-house by the visitors who exploited the breeding seabirds and their eggs and young (pers. obs). Very little written documentation from the area exists until the 16th century, when for military reasons the island was given by the monks to the Earls of Cassillis for protection. The island remains to this day in the ownership of the present Earl, the Marquess of Ailsa. Strategically placed at the entrance to the Clyde, the island also had a military role in the recent past, being occupied during the first and second World Wars of this century.

Despite harbouring major populations of some seabird species, studies of these and other seabirds from the Clyde area have been few and far between, and in the past, often anecdotal and unsystematic (Lawson, 1896). This chapter presents population data on a range of seabird species breeding on Ailsa Craig, and from other sites in the Firth of Clyde, south-west Scotland.

1. 3. Methods

Standardised methods for estimating seabirds numbers at colonies (see Lloyd *et al.* 1991) removes future doubt concerning potentially confusing methodological differences when comparing seabird fluctuations over time. Many old seabird population accounts were nothing better than rough estimates, in error by perhaps even an order of magnitude (Paton and Pike, 1929). Figures such as these cannot be used to monitor population changes, much more systematic counting methods being required. While modern counting methods are generally aimed at one or two visits to a colony in the breeding season, continuous residency at the colony during the season as in this study will result in greater accuracy.

For Ailsa Craig studies, and at other Clyde seabird colonies, the methods and units used for each species were as follows, and as outlined in detail in Lloyd *et al.* (1991).

Fulmar - occupied sites with eggs or young.

Gannet - apparently occupied nests (photographic survey).

Kittiwake - occupied nests.

Razorbill - nesting pairs and regularly occupied sites.

Guillemot - all birds apparently incubating.

Herring Gull - nests with eggs.

Great Black-backed Gull - nests with eggs.

For all other species with less than 50 pairs breeding (e.g. Shag and Black Guillemot) the actual nests were counted. Lesser Black-backed Gull was the only seabird species with a population of over 50 pairs on Ailsa Craig which was not examined in detail in this study.

Counts were carried out during the months of April to July, over the years 1986 to 1987, when the author was essentially resident on the island. Additional counts on the island were made during the period of study 1989 to 1993.

Great Black-backed Gulls on Ailsa were counted in 1993. Gannets were counted in 1995 by Wanless and Murray (pers.com.) and elsewhere, Guillemots and Razorbills on the Sanda Islands were counted in 1993 by I. Livingstone (pers.com). All other sites and species apart from those on the Sanda Islands were personally counted by the author.

The main Clyde colonies and cliffs are as shown in Fig. 1. 1., and most breeding seabirds are concentrated in these areas.

Rates of change in population size were calculated using the formula -

% change per annum = (an. log b - 1) x 100.

- where b is the slope of the regression line for Log.e numbers against year.

The count data are pooled to give indication of overall Clyde population levels. The Ailsa populations, based on Table 1.1., are stated on the figures as a percentage of the overall Clyde population.

1. 4. Results

Counts given in Table 1.1. were done in 1986 and 1987, as a contribution to the Seabird Colony Register (Lloyd *et al.*, 1991), with additions as above.

Table 1. 1. Recent counts (1986 to 1995) of seabirds breeding on Ailsa Craig and in the Clyde Area (units as noted previously). Numbers of non-breeding birds are not included in the totals here presented. British Populations from Lloyd *et al.*, (1991).

SPECIES	*AILSA CRAIG*	*REST OF CLYDE AREA*	*CLYDE GRAND TOTAL*	*Clyde Total as % of British Population*
Fulmar *Fulmarus glacialis*	157	1047	1204	0.2
Manx Shearwater *Puffinus puffinus*	0	37	37	0.01
Storm Petrel *Hydrobates pelagicus*	0	50	50	0.03
Gannet *Morus bassanus*	34,000	0	34,000	18.1
Cormorant *Phalacrocorax carbo*	0	119	119	0.01
Shag *Phalacrocorax aristotelis*	30	1021	1051	2.2
Terns (4 species) *Sterna* -sp.*	0	32	32	<0.01
Lesser Black-backed Gull *Larus fuscus*	500	5504	6004	6.7
Herring Gull *Larus argentatus*	3000	7986	10,986	5.3

Great Black-backed Gull *Larus marinus*	85	151	236	1.0
Common Gull *Larus canus*	0	245	245	0.3
Kittiwake *Rissa tridactyla*	3000	70	3070	0.5
Black-headed Gull *Larus ridibundus***	0	25	25	<0.01
Razorbill *Alca torda*	1000	1083	2083	1.7
Guillemot *Uria aalge*	5000	1508	6508	0.8
Puffin *Fratercula arctica*	0	50	50	0.01
Black Guillemot *Cepphus grylle*	2	122	124	0.6

* = Grouped for convenience. ** = All major colonies are inland.
[For each species where the counts have been reasonably derived over the years the average percentage annual rate of change has been calculated (see Figures 1.3 to 1.10)].

1. 4. 1. *Population changes*

Some seabird populations have fluctuated widely over the years within the Clyde Area. Figs. 1.3 to 1.10, show the main species and their rate of increase or decrease over the past three decades.

The Fulmar in the Clyde (Fig 1.3.) has increased from zero to over a thousand breeding pairs since 1938 when the species first bred (Fisher, 1952 and 1966), and the number of colonies it occupies (Fig. 1.4.), has also increased. Chapter 2 documents the details of the breeding performance of this spectacularly successful species in the area. Between 1980 and 1990 the annual rate of increase was 14 percent. Only 13 percent of Clyde Fulmars breed on Ailsa Craig.
Gannet breeding numbers on Ailsa Craig (Fig. 1.5.), have increased gradually at a rate of 3 - 4 percent per annum since the 1970's (Nelson, 1978), with the present internationally important Ailsa population estimated at almost 34,000 breeding pairs in 1995 (Wanless, pers. comm.). Ailsa holds all of the Clyde Gannets and 18.1 percent of Gannets breeding in Great Britain and Ireland. Despite difficulties experienced by other species, Gannets are adaptable in their feeding and raise young successfully most years.

Shags (Fig. 1.6), showed an average 2 percent per annum decline between the mid fifties and the late sixties followed by a 3 percent increase up to 1980, thereafter an average 11 percent increase until the present. This species has its strongest colony on the Sanda islands where it nests under boulders and on small cliffs. Ailsa Craig holds only 3 percent of the Clyde total, with most of these birds on high vertical cliffs. A few birds now breed under rocks.

The Herring Gull, like the Fulmar, has gone through a period of increase in part of the twentieth century since formerly being scarce as a breeding species (Gray, 1871). Between 1969 and 1979 the Clyde area population increased by around 6 percent per annum and in 1987 stood at almost 11,000 breeding pairs, the increase having been maintained into the following decade, (Fig. 1.7.). Currently Little Cumbrae Island holds the largest colony (pers.obs, 1992 visit), but numbers have been culled at some islands e.g. Horse Island, R.S.P.B. Reserve, which influences overall fluctuations to some extent. Ailsa holds 38 percent of the breeding Clyde Herring Gulls. There is no evidence of the decline noted elsewhere in the U.K. in recent years (Lloyd *et al.*, 1991).

Fig. 1.8 shows the population changes for Great Black-backed Gulls within the Clyde area. Ailsa Craig holds 36 percent of the Clyde breeding total. Its breeding numbers fluctuate, perhaps through persecution, at and away from the colonies, as well as through natural causes. The recent decline of 4 percent per annum in the past decade follows a gradual increase over a 30 year period. On Ailsa the trend is upwards (see Chapter 5), 85 pairs having bred on Ailsa Craig in 1993.

The current trend for the Kittiwake (Fig. 1.9.) breeding population is to show an increase, but past counts (up to 1970) seem excessive (i.e. more than double the number of sites currently occupied) and may not have been accurate. Similarly the 1981 count may have been an under-estimate due to early failed breeding attempts. Overall numbers may only be stable. Most breeding sites on Ailsa Craig are on high vertical cliffs and are largely free from mammalian predation. Ailsa Craig holds 98 percent of the Kittiwakes breeding in the Clyde area.

Terns (all species) have also declined in the Clyde, going from several colonies, and many hundreds of breeding pairs, since 1965 to just over 30 pairs at present. No tern species has ever been recorded breeding on Ailsa Craig. Indeed it is rare to see any species of tern at sea from Ailsa Craig.

Razorbill numbers (Fig. 1.10.) also increased on Sanda Island while remaining fairly stable on Ailsa Craig, but present numbers are still below those recorded in the past, having gone from some mainland cliff sites on the Clyde side of Kintyre (pers. obs). Ailsa Craig holds 48 percent of the Clyde Razorbills at present.

Guillemots on the Clyde and on Ailsa Craig (Fig. 1.10.) had shown a slight long-term decline since the 1950's but stabilised by the early 1980's (Monaghan and Zonfrillo, 1986). Ailsa now holds 77 percent of the Clyde breeding total, the remainder being on the Sanda islands. Paradoxically, Guillemot numbers during the late 1980's and early 1990's have increased on the Sanda group, only 15 km away and visible from Ailsa Craig. Less than a hundred birds bred on the Sanda islands for much of the 1960's and 1970's (most on Glunimore, a small, cave-worn isolated rock-stack of around 30 metres height, Maguire. 1981 ; Lloyd *et al.* 1991). Here numbers increased rapidly in a 4 year period to over 1500 breeding pairs in 1991. Thus a slight decline at Ailsa Craig was countered by a massive increase on the Sanda Islands giving an overall increase of 4 percent per annum since 1980.

Puffins, on the other hand, have declined catastrophically on their former major stronghold of Ailsa Craig, going from many tens or perhaps even hundreds of thousands of breeding pairs in the late 19th century to a few hundreds in the 1930's with zero at present (Lawson, 1896; Gibson, 1951; Harris, 1984). The reasons for this particular decline is probably a totally land-based phenomenon through the accidental introduction of predatory Brown Rats (Chapter 8). Lack of accurate counts precludes producing a useful picture of the pattern of decline. Only a single Clyde outpost remains today on the Sanda Islands totalling no more than fifty pairs (Maguire, 1981). Sanda has no rats.

In the Clyde the smaller, mainly uninhabited islands such as Ailsa Craig, Sanda and Little Cumbrae have between them all 17 seabirds species known to regularly breed in the Clyde area, whereas the larger inhabited islands such as Arran, Bute and Great Cumbrae have only 8 species between them. Fig 1.11 shows the relationship between island size and number of species breeding. There is a negative correlation between seabird breeding species and island area for seven Clyde Islands (Spearman's Rank Correlation ; $r_S = -0.964$, $P < 0.01$).

1. 5. Discussion

The Clyde sea area therefore is important in both bird species diversity and overall numbers, and for some island areas their international status has been acknowledged under European Community directives and as Sites of Special Scientific Interest under United Kingdom legislation.

Reasons for population changes

Seabird populations fluctuate for several reasons. Because seabirds are long-lived, their declines tend to be slow when related to environmental factors such as over-exploitation of the sea by man. Oiling incidents are more immediate and high-profile, although insidious oil leaking into the marine environment might not be as rapid, but equally as effective. Factors which affect adult mortality rather than young production, will have the most rapid and marked effects.

Bird species which show a high degree of philopatry and breed in large numbers can mask declines in productivity simply by their sheer numbers and longevity, unless scientifically monitored.

The Clyde Fulmars have experienced very poor breeding success and predation on land by mammals for at least the past two decades (see Chapter 2) and the population increase (Fig. 1.4), is largely explained by immigration. Since many birds are still in the process of colonisation, it is probable that the annual rate of increase of 14 percent since 1980 until 1990 was due to recruitment from more northern colonies. Ailsa Craig holds only 13 percent of Clyde Fulmars but numbers there may now increase in the absence of rats, a major predator of the young. The largest colony is on Sanda where rats are absent.

The Puffin decline on Ailsa Craig, following the accidental introduction of Brown Rats, took over thirty years of low-recruitment before a decline became obvious to those who made their living from seabird "farming" (Campbell, 1892; Lawson, 1896 and Chapter 8). Terns on the other hand can simply desert their colonies en-masse when birds in colonies fail to breed successfully through disturbance by alien mammals such as American Mink or through poor food supply (Monaghan and Zonfrillo 1986; Craik, 1995). Such desertion may only be temporary because birds may return in future years if breeding conditions improve or predators are removed. For many islands, particularly rocky ones, the status and effects of mammalian predators is unknown, particularly since rats and mink are largely nocturnal or secretive in their behaviour. Many Scottish islands however do harbour rats or equally harmful American Mink (Craik, 1995).

The rise or fall in some seabird numbers may indicate changing marine conditions. The fluctuations in numbers of Shags (Fig. 1.6) is not easily explained but may be due to a decline, through time, of human persecution, a stabilisation or slight increase due to less persecution followed by a substantial increase due to protection, environmental clean-up and an abundance of small fish on the upper reaches of the Clyde where this species shows the greatest increases. Ailsa Craig was historically never a large colony, and Shag chicks and eggs may have suffered from the depredations of rats. Only small numbers breed at present although nearby Sanda Island has a large thriving colony and other colonies now exist on Little Cumbrae, Pladda and Lady Isle (Fig. 1.1). This species feeds mainly on sandeels and small Clupeid fish and probably indicates an abundance of such species within foraging range of the breeding sites. The new colonies now appearing on the upper small islands of the Clyde, combined with recent modernised treatment of sewage effluent resulting in an abundance of small estuarine fish, may be attracting Shags to a new area of rich feeding. On Ailsa Craig any impending colonists may have been put off by rats in the past but since their removal (1991 - this study), Shags now nest in small numbers under boulders, as they do on Sanda and Little Cumbrae island.

It can be argued that many seabird species owe their increase to improved feeding conditions and to protection from persecution and exploitation by law when on land. Herring Gulls and Lesser Black-backed Gulls increased during the first half of this century for these and perhaps similar sorts of reasons. However, for many areas of Scotland, Herring Gulls have shown a drop in breeding numbers during the 1970's and 1980's (Lloyd *et al.*, 1991). The Clyde area appears unaffected with major colonies on Ailsa, Little Cumbrae and Inchmarnock and an upward trend in breeding numbers overall.

Great Black-backed Gull numbers (Fig.1.5.) have shown a gradual rise since the fifties followed by a decline from the eighties until present. This species was (Gibson, 1951) and is still persecuted by man. The Ailsa population is increasing (Chapter 5.) - as at other seabird colonies in the area - but an overall decline is evident from smaller scattered breeding areas where it has either died out or been eliminated (Lloyd *et al.*, 1991).

In recent years Guillemots and Razorbills were probably not under the same threats from the oiling incidents which were commonplace on the Clyde until the late sixties (pers.obs.). Over the past fifty years oil pollution incidents in the Clyde, although locally damaging, have proved to have little long-term effect on overall numbers of seabirds. However, incidents of oiling have been mainly in winter (in e.g. 1969, 1973 and 1981).

Alien mammals, rats in particular, were both deliberately and accidentally transported by shipping to islands where they caused added problems by direct depredation of breeding birds and by altering habitat directly and indirectly usually to the detriment of the indigenous animal and plant species (Chapter 8). While some seabird colonies had existed for many thousands of years, rats, introduced through the agency of man, led to their extirpation in only three or four decades.

Terns declined as an important component of Clyde seabird stock many years ago and their continuing failure to breed may be sea-based rather than land-based. Their historic decline can be linked with man-induced changes in the stocks of young Herring, an over-fished species with major spawning grounds in the southern Clyde sea area (Monaghan and Zonfrillo, 1986). Improved water conditions and fish stocks on the upper Clyde may lead to a re-colonisation of former tern colonies in future years. Seldom seen from Ailsa Craig, the immediate deep waters surrounding the island are probably unsuitable for feeding terns in general, there are no tidal sand or mud substrates. Black Guillemots have colonised the island (breeding in 1991), in the absence of rats, and Puffins have been seen ashore prospecting. Seabird population monitoring will in future reveal trends for numbers on Ailsa. the Clyde and elsewhere.

The Clyde Herring fishery was at the turn of the century a major source of food and local income. Nearly all the small Clyde fishing ports were bustling as purse and seine-net fishing from mechanised fishing vessels overtook the more traditional line fishing from sailboats. Trawling for benthic fish species and crustaceans became popular by the 1950's and from then on the Herring population experienced problems. The life-cycle of the Herring and the problems of over-fishing were recognised many years ago and discussed at the time by Hardy (1959). Over 5 million tonnes of Herring were being landed annually in the UK during the mid 1950's. The Herring spawning grounds on the Clyde were at the Ballantrae Banks off the south Ayrshire coast. Here the Herring hatch and as elsewhere, live for six months as a planktonic organism feeding on the upper trophic layers, mainly on copepods, and migrating northwards in vast shoals to the shallower Clyde estuarine waters. When approaching maturity, Herring become benthic feeding mainly on copepods, amphipods and euphausiid crustaceans (Hardy, 1959), and inhabiting the deeper Clyde waters of Loch Fyne and around Arran. Over-fishing through different methods removed not only adult fish (Hardy, 1959) but fishing over the spawning grounds probably further removed vast numbers of breeding females. Trawlers then dragged their gear through the egg-mats, perhaps in pursuit of Cod which will feed on Herring eggs, releasing them into the tidal currents to drift away in small clumps. Those which did hatch then migrated north into waters increasingly polluted by industrial effluent from Glasgow and other major Clyde ports and conurbations and from sewage dumping at sea. Herring have proved sensitive to marine contamination. Herring, in laboratory experiments died after only 6 minutes exposure to hydrogen sulphide in regulated concentration, while other more tolerant species lasted over 3 hours at similar dilution (Vernberg - *in* Kinne, 1972). Herring also avoid areas of very dense phytoplankton (Wilber - *in* Kinne, 1972), conditions at sea frequently occasioned by operations such as sludge dumping. It is no surprise that Herring stocks collapsed in many areas (Hardy, 1959) and today, when stocks allow, a brief "season" of a few weeks is permitted for Herring fishing in the Clyde using nets. Today (1997) around 25 commercial fishing vessels regularly fish Clyde waters and that number declines with each passing year (pers.obs).

Threats to seabird populations on the Clyde, and in general, also come from shooting and other forms of direct persecution by humans, e.g. egg collecting, long-line fishing, lobster traps, and oil pollution (Gibson, 1951; pers. obs). Indirectly, humans also destroy seabirds through botulism and habitat destruction. Seabirds on Ailsa Craig have suffered from all of these at one time or another in the past and at present, and during wartime the island was also used for naval target practice even during the breeding season (Gibson, 1951).

Island size (surface area) in the Clyde, has an inverse relationship to numbers of breeding seabirds. In contrast to land birds, Monaghan (1994) showed there was no significant relationship between seabird species breeding on eleven selected islands of varying size on the west coast of Scotland. Frequently however a small satellite of an island can hold many more seabirds than its larger neighbour. Perhaps the relationship depends more on the amount of human disturbance or local human population size and influence of land-based predators rather than physical size. Disturbance, predators, proximity to dependable food supplies and suitable breeding habitat presumably influence breeding seabirds more when selecting nest sites rather than simply the physical size of an island. Only a few gull species may obtain their food wholly from the land and freshwater which may be found on a large island.

The future

Some seabirds are presently doing well in raising young, other are experiencing problems. Both categories require systematic monitoring on a regular basis. Many seabird studies focus on the effects of changes in the marine ecosystem but do not examine the causes.

As data are built up over long periods it may be possible to relate causes to effects observed in the fluctuating fortunes of seabirds as both individuals and colonies.

Climatic factors apart, only the agency of man can rectify the activities of the past, both on land and at sea. The period of environmental recovery required by an island may even equal that of the deterioration, although the effort put into conservation can sometimes produce immediate results in the short term. While land-based problems may be tackled more immediately than those at sea, it is the sea-based changes that urgently require a much more enlightened approach than at present and sweeping, if not draconian, legal measures to save what little remains. Large areas of the sea must be designated as "marine reserves" and properly policed with all fishing forbidden at all times of year. In this way at least some populations of formerly common fish species might survive and seabirds as well as the fishing industry may in the longer term benefit. Otherwise climatic factors and the results of long-term anthropogenic pollution on the marine ecosystem might prove to be irreversible.

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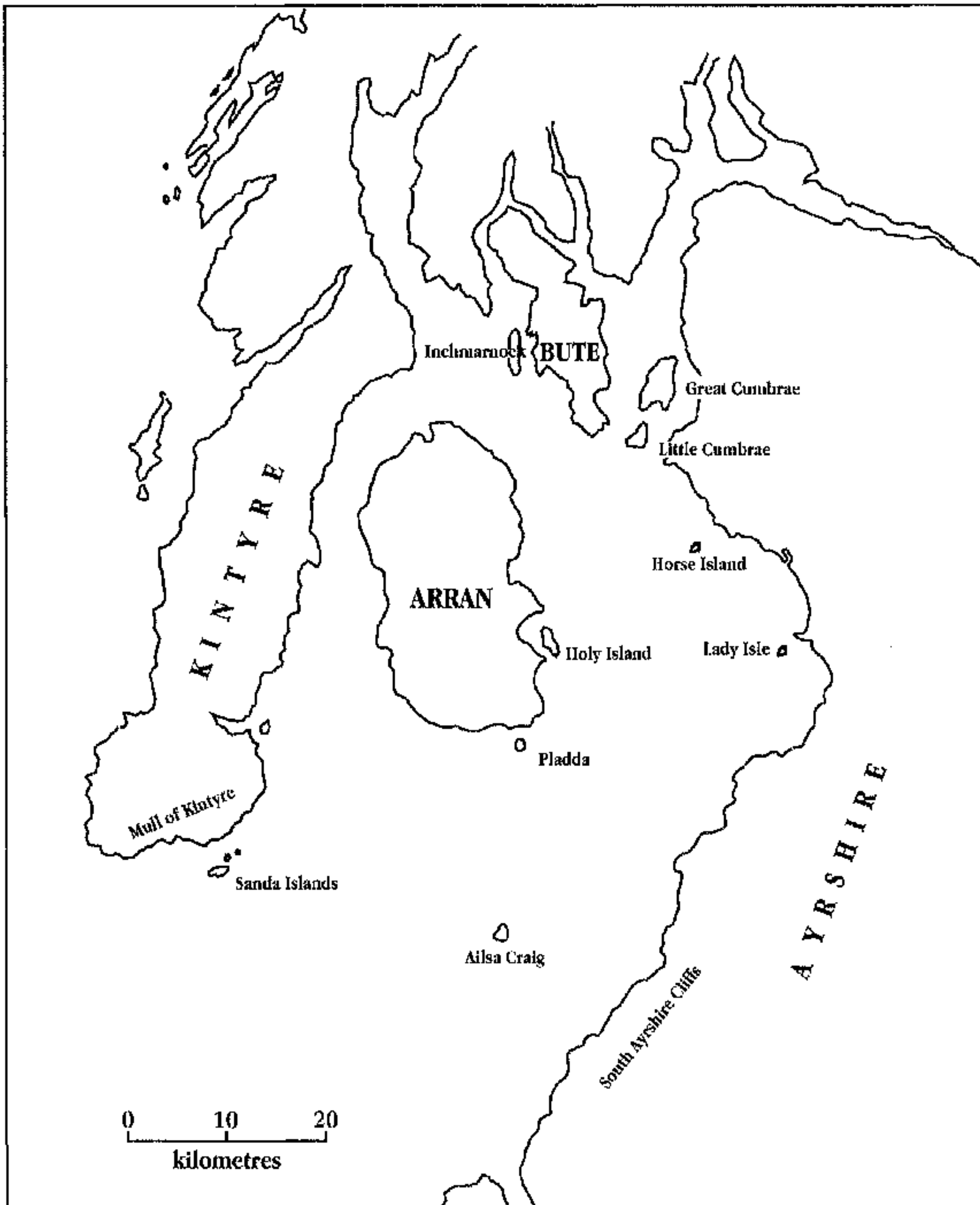

Fig 1.1 Firth of Clyde, showing Ailsa Craig and other major seabird colonies (in lower case lettering).

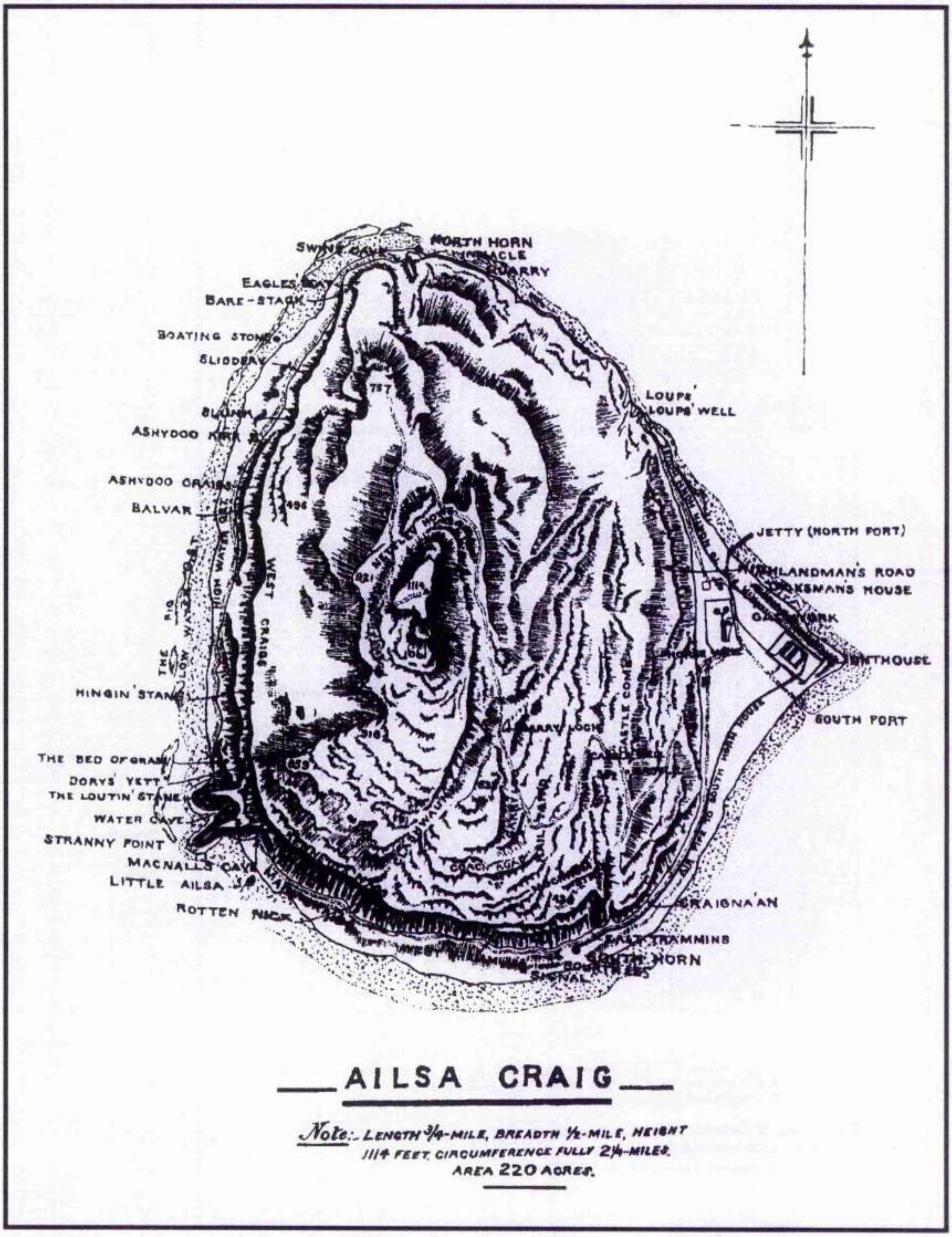

Fig. 1.2 Map of Ailsa Craig from Lawson (1896).

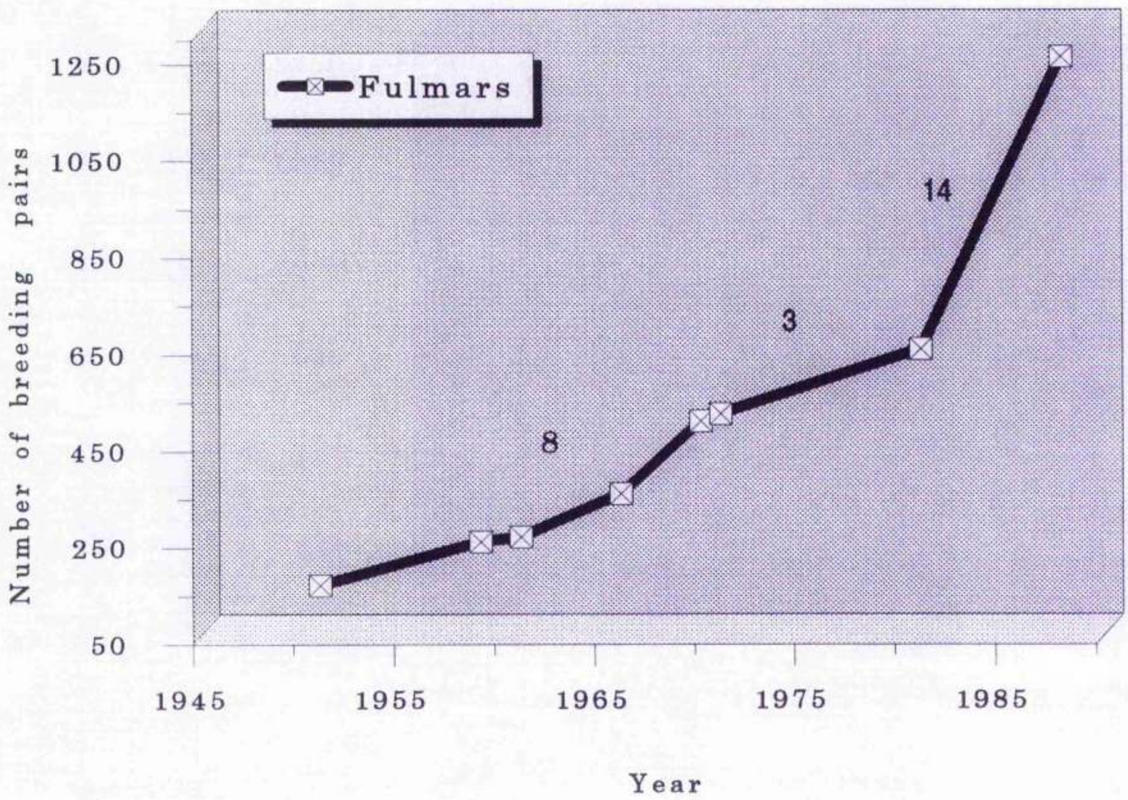

Fig. 1. 3. Changes in the number of breeding pairs of Fulmars in the Clyde area. Ailsa Craig holds 13% of the Clyde total. The numbers on the lines between data points represent average percentage annual changes in population.

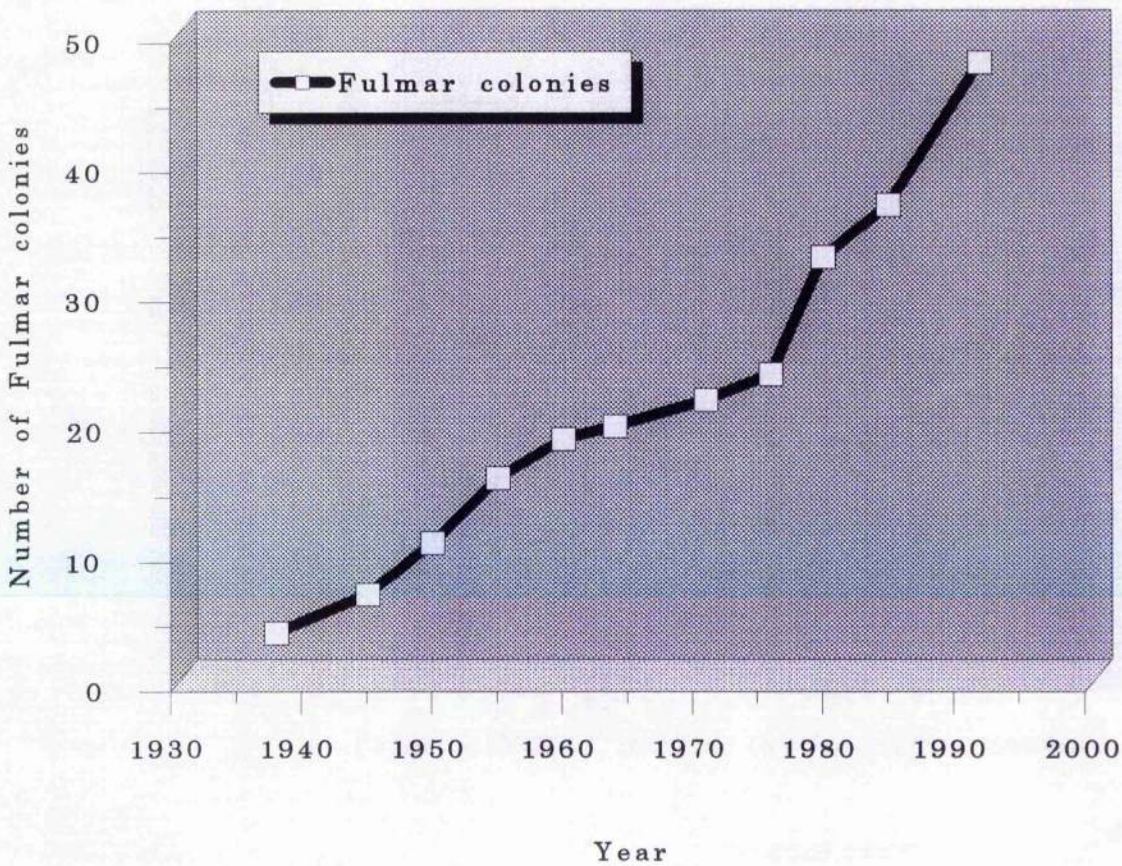

Fig. 1. 4. Changes in the number of Fulmar colonies in the Clyde area.

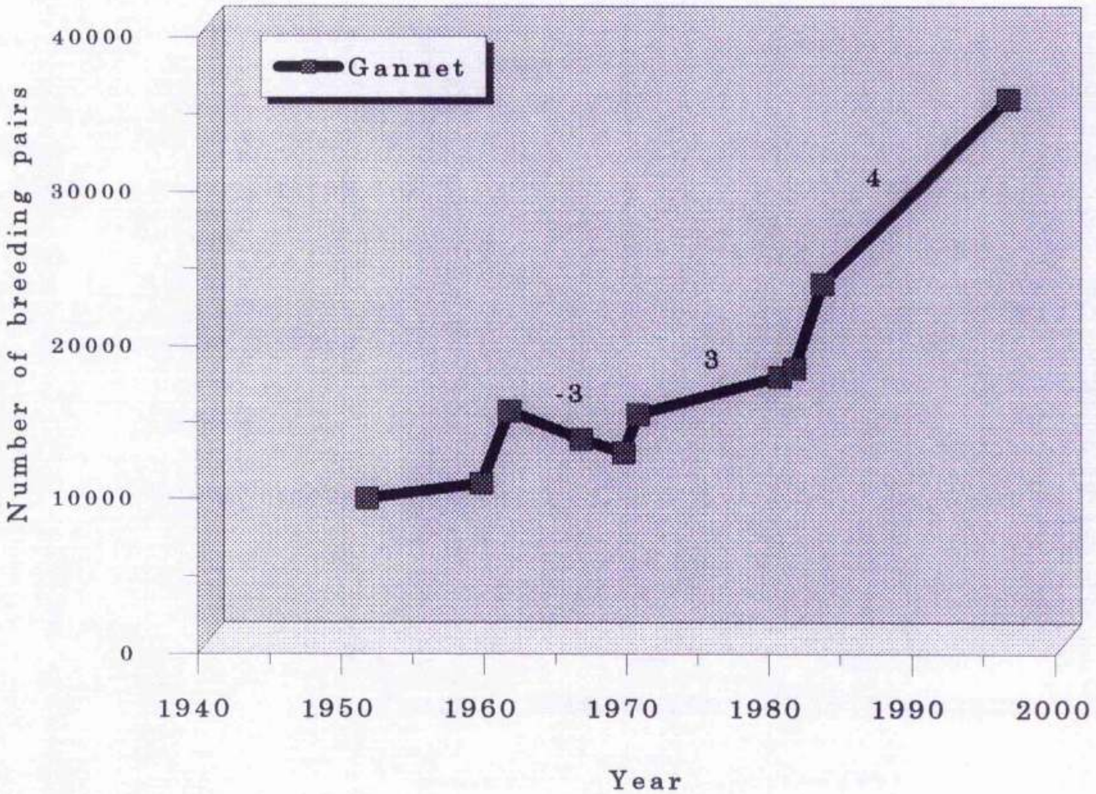

Fig. 1. 5. Population changes in breeding Gannets in the Clyde. Ailsa Craig holds 100% of Clyde total. The numbers on the lines between data points represent average percentage annual changes in population.

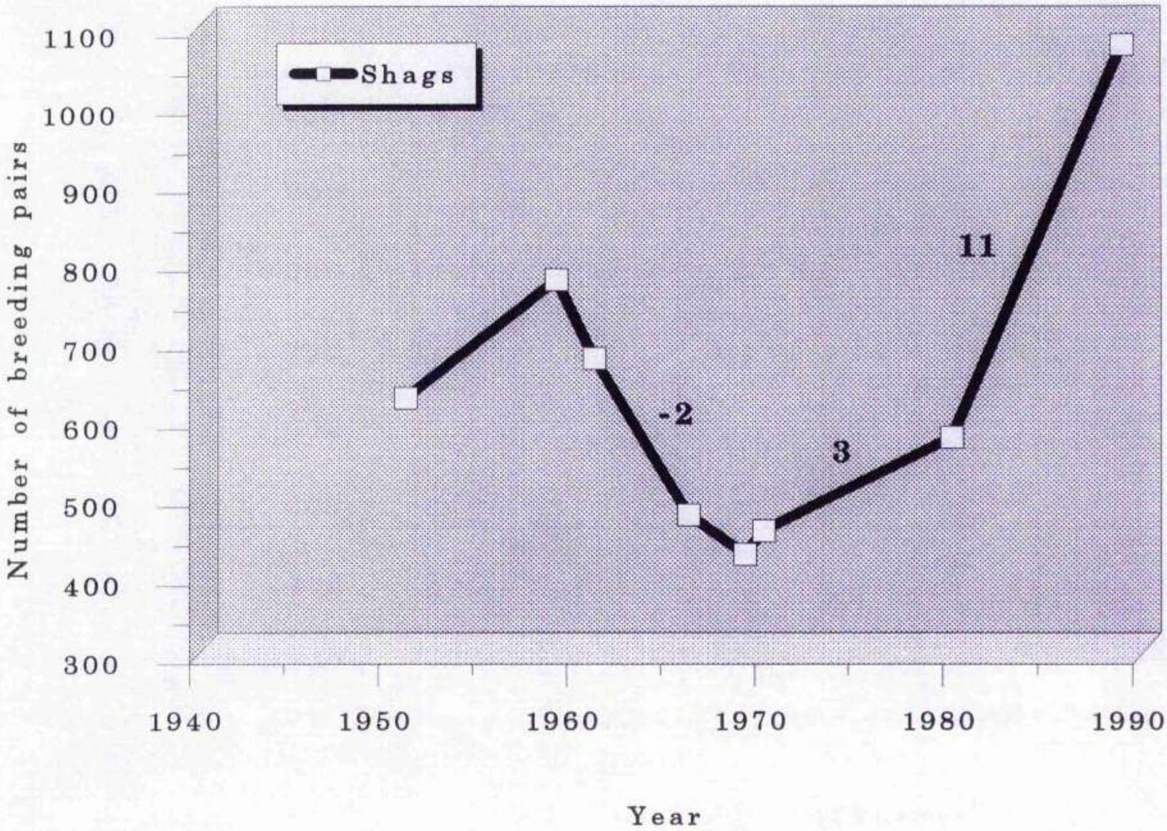

Fig. 1. 6. Changes in populations of breeding Shags in the Clyde area. Ailsa Craig holds 3% of the Clyde total. The numbers on the lines between data points represent average precentage annual change in population.

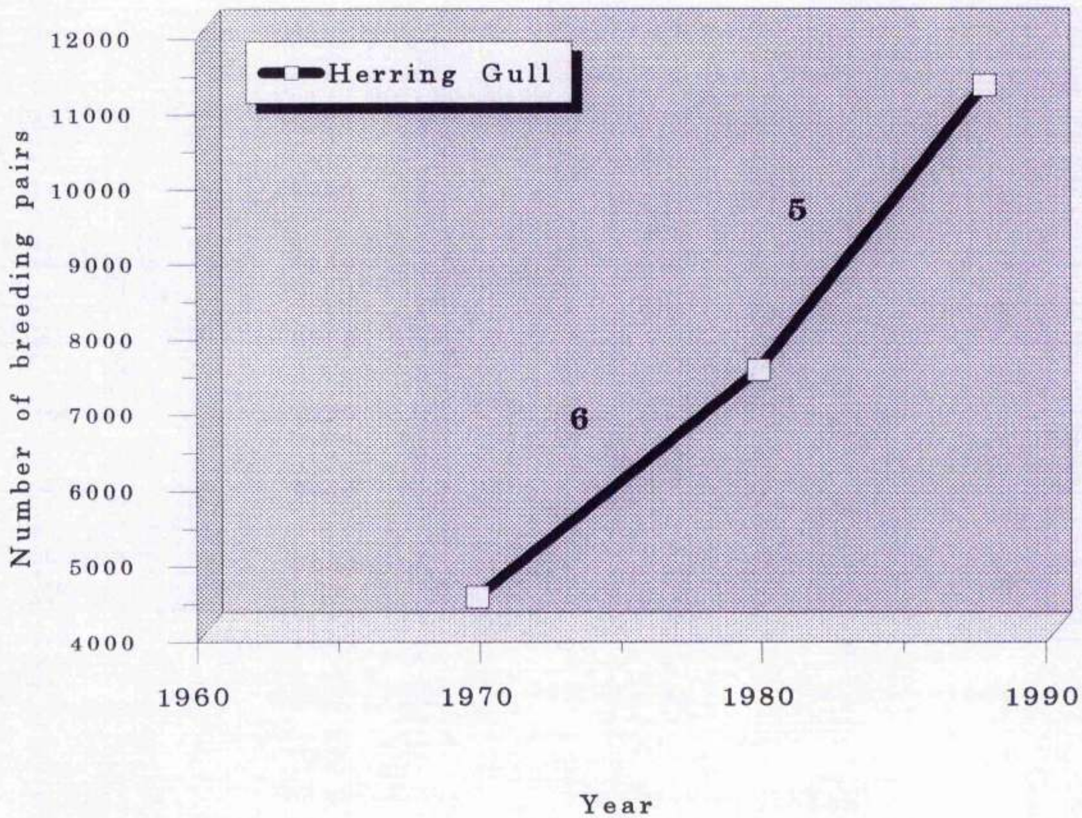

Fig. 1. 7. Population changes in breeding Herring Gulls in the Clyde area. Ailsa Craig holds 38% of the Clyde total. The numbers on the lines between data points represent average percentage annual change in population.

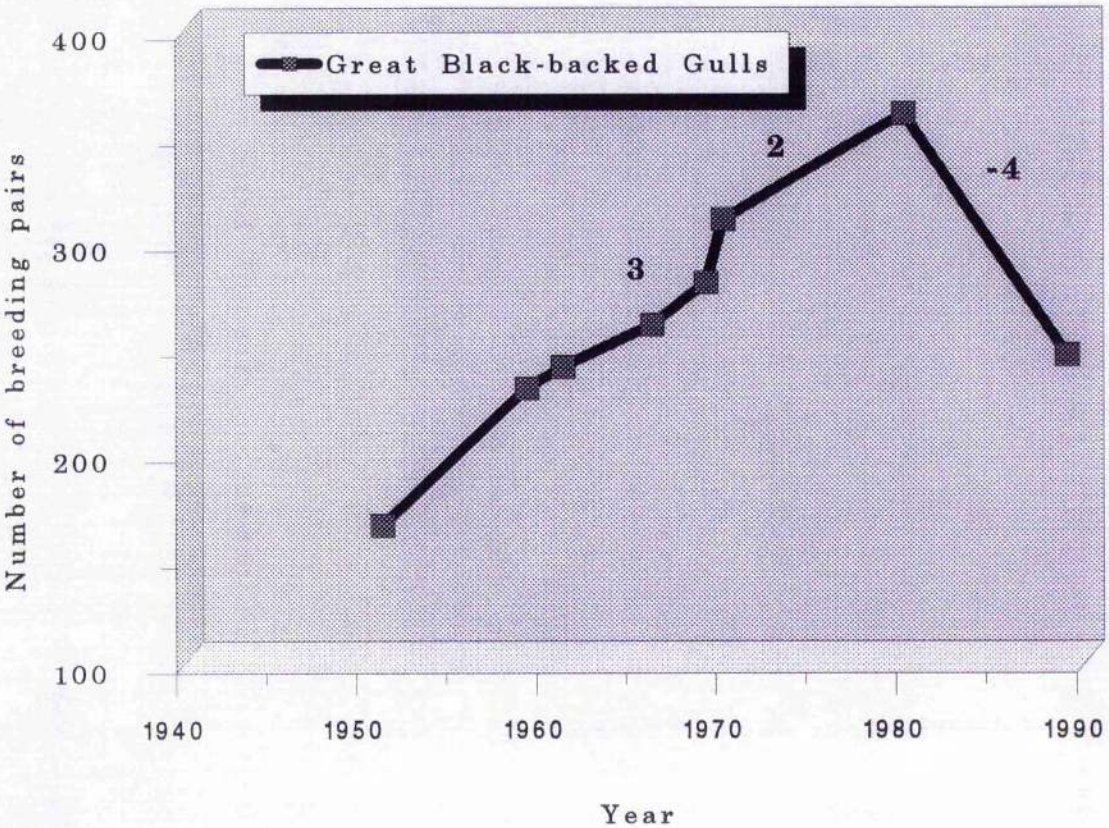

Fig. 1. 8. Changes in populations of breeding Great Black-backed Gulls in the Clyde area. Ailsa Craig holds 36% of the Clyde total. The numbers on the lines between data points represent average percentage annual change in population.

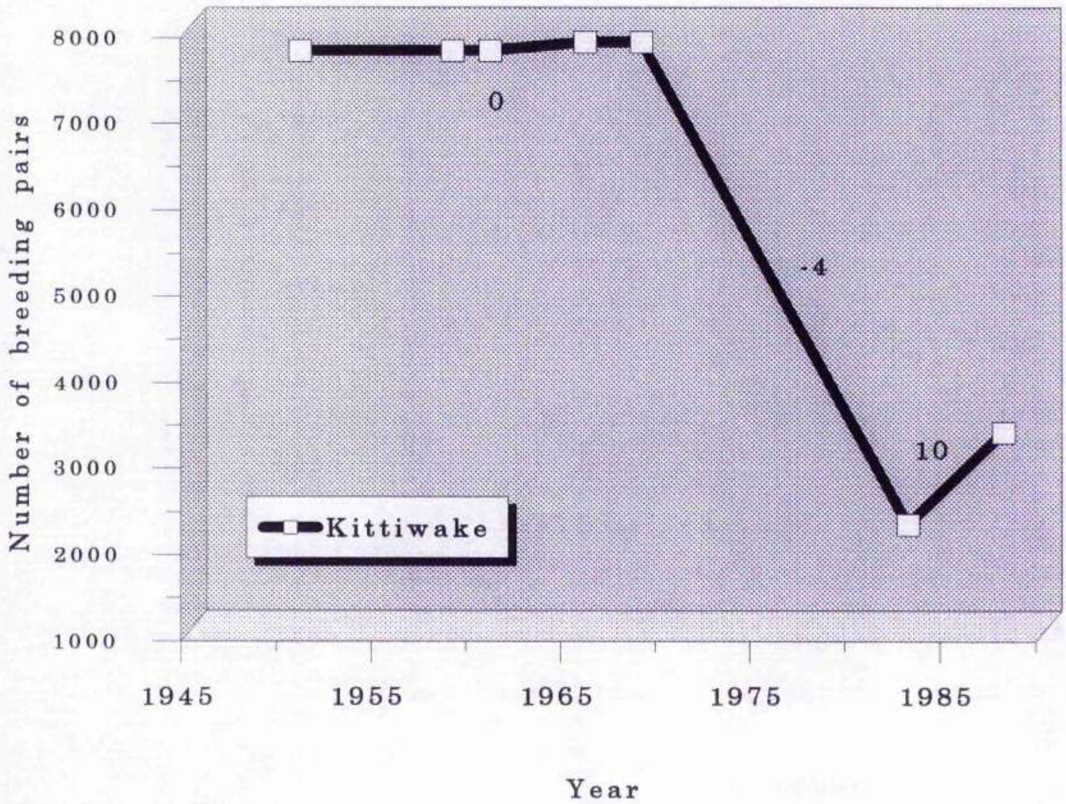

Fig. 1. 9. Population changes in breeding Kittiwakes in the Clyde area. Ailsa Craig holds 98% of the Clyde total. The numbers on the lines between data points represent average percentage annual change in population.

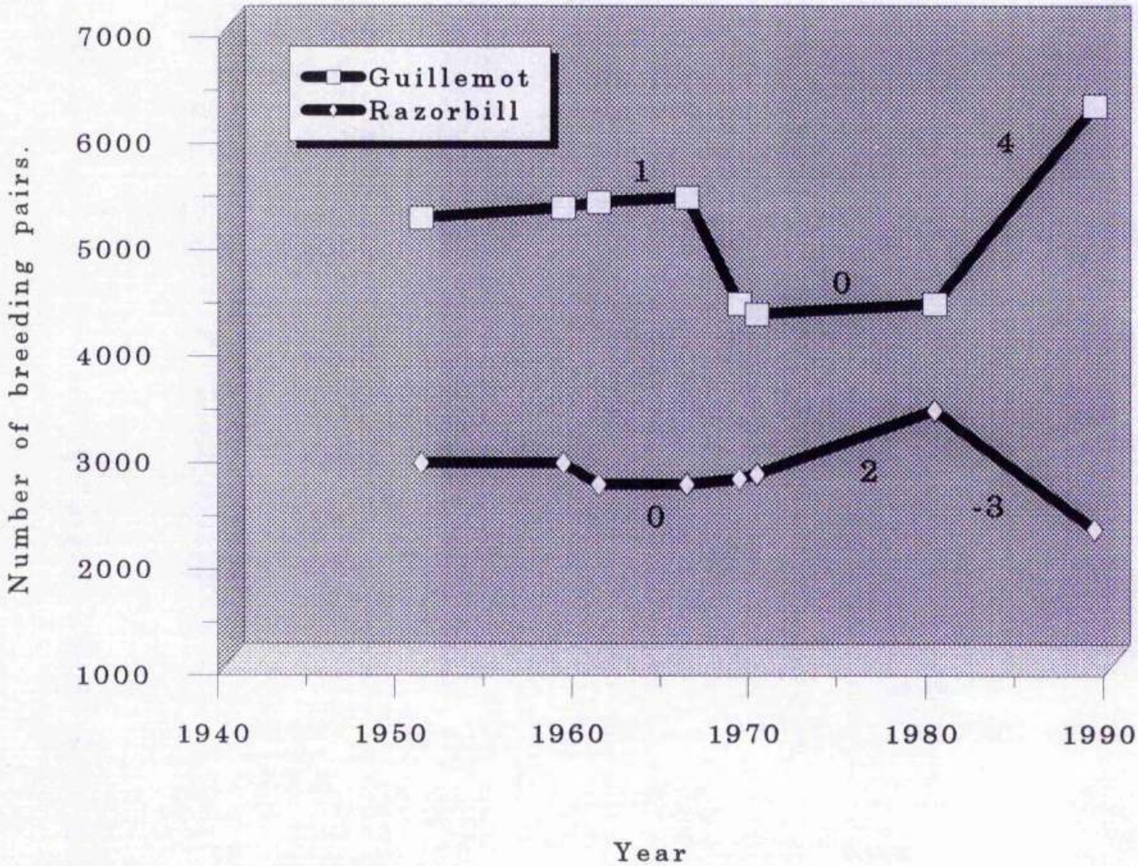

Fig. 1. 10. Population changes in breeding Guillemots and Razorbills in the Clyde Area. Ailsa Craig holds 48% of Razorbills and 77% of Clyde Guillemots. The number on the line between data points represents average percentage annual change in population.

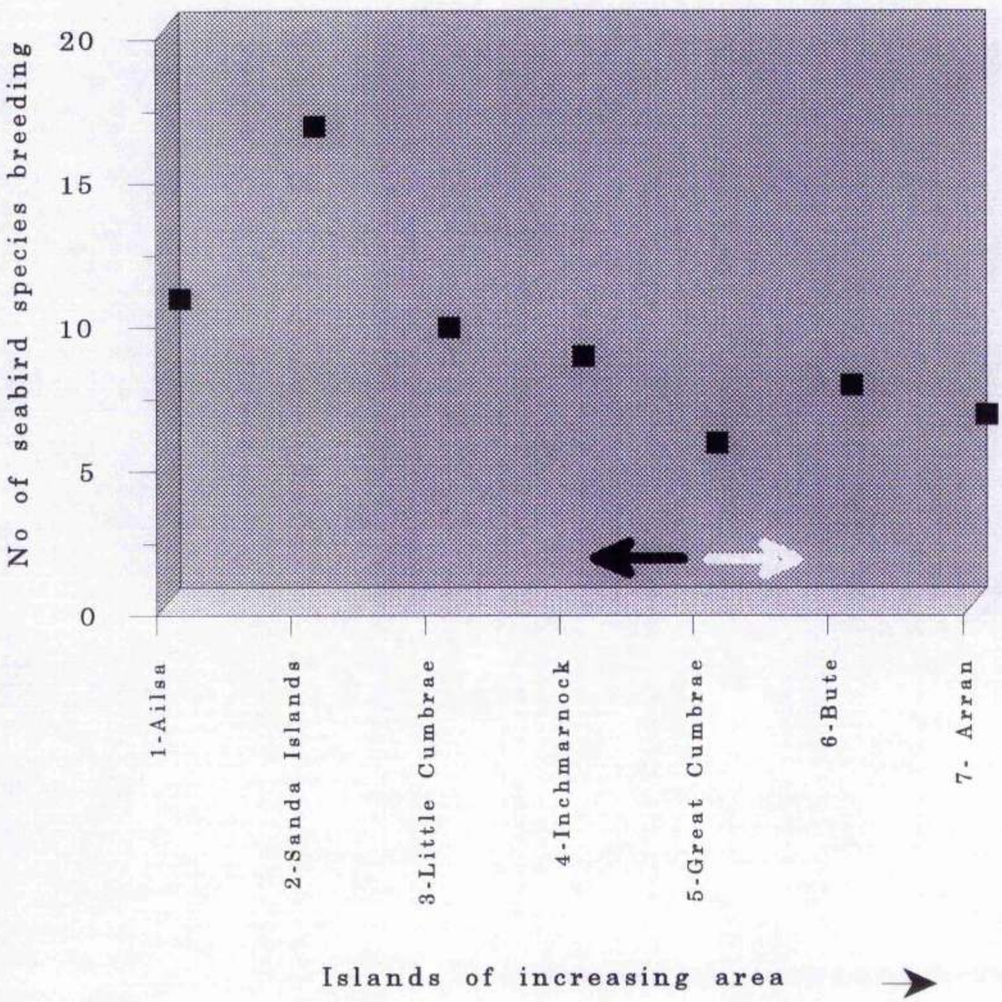

Fig. 1. 11. Clyde islands and their breeding seabird species in relation to surface area. The black arrow indicates mainly uninhabited islands, the white arrow indicates islands with large human populations.

Chapter 2.

The Fulmar *Fulmarus glacialis* in the Firth of Clyde : breeding success, diet and growth of chicks on Ailsa Craig, and the effects of predatory Brown Rats *Rattus norvegicus.*

2. 1. Introduction

2. 1. 1. *Fulmars in the North Atlantic*

Fisher, in his review of the status of the Fulmar population of Britain and Ireland in 1959, (1966), described the increase in the Fulmars of the north Atlantic as one of the most remarkable population explosions known in the class of Birds. ***" Fortunately this increase in the Fulmar occurred at a time of increasing human literacy and socio-scientific progress and thus for almost 200 years has received comment to a greater or lesser degree in the published literature".*** Although the Fulmar was documented in Scotland from the islands of St Kilda, from at least the 9th century A.D., it was probably present many centuries before then. Remains of Fulmars have been found at the Viking settlement at Jarlshof, Shetland (circa 90 A.D.), but these may have been remains of birds caught at sea as food, and/or transported from colonies further north. Similarly, bones from the Viking middens at Vardo, in north Norway found by Christiani, in 1929, (Fisher, 1952) may or may not have been those of birds born locally. Fulmar stomach oil has certain preservative properties (Warham *et al.*, 1976), which might have made the Fulmar an ideal food for transportation when undertaking long sea journeys with uncertain destinations.

In northern Europe the Fulmar probably arrived from the north Pacific via the Canadian North-west Passage during periods of inter-glacial and post-glacial melts (Fisher, 1952). The Fulmar doubtless originated in the Pacific, probably as an all-dark burrow-nesting species: such birds are still found in the Aleutians (Clarke, 1914; Fisher, 1952; Salomonsen, 1965). Successful inter-glacial forays would have introduced the dispersing Canadian Fulmars to the plankton and nekton-rich waters of the north Atlantic, and St Kilda provided the ideal breeding habitat on the eastern side of the Atlantic. There the population appeared to remain stable and any possible expansion on those islands was probably curtailed by the human exploitation of Fulmars for food, evident since at least the Iron-age (Fisher, 1952).

Drastic changes in the food-webs of the northern north Atlantic occurred with the introduction of modern mechanised fishing. Some of these changes appear to have been beneficial to the opportunistic Fulmar. Apart from "natural" foods such as crustaceans and cephalopods, the Fulmar had foods presented to it through human agency as by-catch from trawling activities through gutting of fish at sea and discards from pelagic fisheries. Prior to this was also the whaling activity which for two centuries saw cetaceans, both in form of meat and gut contents, as a probable item in Fulmar diet (Fisher, 1952). The Fulmar was on a "win-win" situation during this era and further increased its numbers and distribution.

Genetic isolation on St Kilda resulted in an apparently sedentary population of small-billed Fulmars (Salomonsen, 1965; Wynne-Edwards, 1952). With the second successful colonisation of northern waters and the resultant expansion of populations of large-billed birds, the isolated St Kilda gene pool was evidently swamped. Van Franeker and Wattel, (1983) could not distinguish between the bill lengths of the present day St Kilda Fulmars and those of other northern colonies. However Fulmars ringed on St Kilda still show a westward dispersal after fledging, to feed at the Grand Banks off Newfoundland (Fisher, 1952 ; Furness and Todd, 1984).

2. 1. 2. *The Fulmar colonisation of Scotland*

The first Fulmars found breeding away from St Kilda were those on Foula, Shetland in 1878, following documented expansion of colonies firstly in Iceland and then the Faroes (Fisher, 1952).

While some areas of mainland Scotland were perhaps prospected around the time of first breeding on Foula, the general trend was a gradual southward colonisation of most suitable coastal and a few inland habitats in the British Isles. By the 1930's much of Scotland had been prospected by Fulmars and many counties had acquired breeding records.

Paradoxically, around the same time, the many cliffs and vast fishing fleets of Norway attracted few Fulmars to breed in that country. This could possibly be explained, at least in part, by the westerly wind systems prevailing along the apparently otherwise suitable

Norwegian coasts. Fulmars, like other petrels, have evolved in zones of strong prevailing wind systems. There are presently only 24 Fulmar colonies in all of Norway, totalling less than 6,000 breeding pairs (Gjershaug. *et al.*, 1994), compared with 570,000 in the British Isles (Lloyd *et al.*, 1991).

2. 1. 3. *Colonisation of the Clyde Area by Fulmars*

The first documented Fulmars to breed around the Clyde sea area were noted on Sanda Island, Kintyre, in 1938 (Robertson, 1943). Ailsa Craig, 25 km distant, was next to be colonised and one pair bred in 1939, although birds had first prospected the island in 1931 (Gibson, 1951). In 1940 a young bird was observed on the cliffs at the Mull of Kintyre (Robertson, 1943).

In 1986 and 1987 I counted over 40 Fulmar colonies on islands and headlands around the Firth of Clyde and Kintyre coasts. Colonies are here defined as being entities (e.g. on islands, headlands, outcrops etc) each more than 1 kilometer apart with no breeding birds in between. Virtually all areas of suitable and probably also unsuitable mainland and island coastline were walked in 1986 and 1987, with most sites visited more than once. All birds regularly occupying a suitable nest site or proven to breed by evidence of egg or young were counted. This survey revealed not only an increase in colonies but also an increase in the numbers of birds occupying previously established colonies (Chapter 1. Fig 1.6) since the surveys by Fisher, (1952, 1966). Birds occupying sites always greatly outnumber birds eventually breeding. The distribution of Clyde area Fulmars is shown on the map, Fig. 2. 1. Further colony data were collected in 1990 from Arran (Table 2.1.).

2. 1. 4. *Colony location and number of apparently occupied breeding sites*

All colonies on Fig 2.1 were surveyed by me, using the agreed standard counting methods in 1986 or 1987, as a contribution to the national Seabird Colony Register. The data from this British and Irish project were subsequently published (Lloyd *et al.*, 1991). Details of the Fulmar colonies of the Clyde sea area are presented to show the number of colonies and estimates of breeding pairs. Most colonies are small. Data from 1986 or 1987 have been upgraded with further colony records from Arran, until summer 1990 (Table 2.1.).
Only a very few kilometres of marginal habitat have not been visited by me within the entire area and at present there are no true inland colonies, i.e. 10 kilometres from the sea,

although one (on Bute) is not immediately beside the sea, being at least 2 kilometres from the coast. Table 2.1 shows colonies and numbers breeding.

Colony numbers referred to in Table 2.1 below are located on the map in Fig 2.1.

Table 2. 1. The colonies and number of Fulmars breeding in 1986 and 1987 - with Arran updated in 1990. Counts made during May, June and July of apparently occupied sites. At all colonies breeding was confirmed by presence of eggs or young.

Colony Number	Location	Breeding Pairs
	Ailsa Craig	
1	Ailsa Craig, Ayrshire	150
	Mainland Ayrshire	
2	The Old Quarry, Ayrshire	5
3	Currarie Port, Ayrshire	65
4	Bennane Head, Ayrshire	22
5	Pinbain Hill , Ayrshire	6
6	Kennedy's Pass, Ayrshire	3
7	Culzean Castle, Ayrshire	30
8	Eggknock, Ayrshire	3
9	Fisherton, Ayrshire	16
10	Heads of Ayr, Ayrshire	1
11	Portencross, Ayrshire	27
	The Cumbraes	
12	Gull Point, Little Cumbrae	9
13	Craignabbin, Little Cumbrae	28
14	Keppel, Great Cumbrae	14
15	Doughend Hole, Great Cumbrae	14
	Isles of Bute and Inchmarnock	
16	Kerrytonlia Point, Bute	4
17	Largizean Farm, Bute	7
18	Dunstrone, Bute	3
19	Straad Point, Bute	11
20	Clate Point, Bute	3
21	Inchmarnock, Bute	24
	Isle of Arran and Holy Island	
22	Catacol, Arran	9
23	Imachar Point, Arran	8
24	Machrie, Arran	8
25	King's Cave, Arran	3
26	Drumadoon, Arran	21
27	Brown Head, Arran	9
28	Corriecravie, Arran	2
29	Bennane Head, Arran	34
30	Dippen Head, Arran	50
31	Claughlands Point, Arran	26
32	Holy Island, Arran	6

	Kintyre peninsula, The Sanda Islands and Gigha.	
33	The Sanda Islands, Kintyre	300
34	The Castles, Kintyre	23
35	Brunnerican Bay, Kintyre	11
36	Dunaverty, Kintyre	6
37	Keil Point, Kintyre	19
38	Mull of Kintyre, Kintyre	40
39	Largybaan, Kintyre	73
40	Craigaig, Kintyre	30
41	Galdrings, Kintyre	18
42	Port Crom, Kintrye	25
43	Stac-a-Chagair, Kintyre	17
44	Muasdale, Kintyre	16
45	Cara Island, Gigha, Kintyre	65
46	Gighalum, Gigha, Kintyre	8

No occupied colony appears to have ever been deserted once the colonisation process has commenced (c.f. Fisher, 1966.). Partly responsible for this may be the scent of Fulmar oil left at former nest sites. Catching birds at colonies on the Ayrshire coast, for ringing purposes, showed a high turnover of individuals at some locations. While some colonies might entirely change their breeding individuals in 3 years, (as happened at Kennedy's Pass, Ayrshire), the sites themselves appear attractive to other Fulmars. Up to 5 different Fulmars were caught successively on a single occupied April site at Bennane Head, Ayrshire.

The Firth of Clyde harbours deep glacial gouges (see map Fig.2.3.) which, in its upper areas surrounding the islands of Bute and Arran, provides ideal conditions for euphausiid shrimps. These form a major component of the marine biomass (Mauchline, 1959). Certain euphausiid crustaceans require a minimum water column of 120 metres in which to reproduce (Mauchline, 1959) and, along with squid, appear to form a staple diet of Fulmars, throughout much of its sub-arctic range, (Cramp and Simmons, 1977), and particularly in winter when surface swarming is common (Mauchline, 1959; Conway, 1973). Recently formed Fulmar colonies in the Clyde (map Fig. 2.1) have been settled within 15 kilometres of this confined seasonally abundant and dependable winter food source. Table 2.2 shows the gradual colonisation of Clyde Fulmar colonies where breeding dates are known accurately.

Table 2. 2. The known chronology of occupancy of some Clyde Fulmar colonies.

Year of Proven Breeding	Colony / Place	Year when first Prospected
1938	Sanda, South Kintyre	1931
1939	Ailsa Craig, Ayrshire	1931
1940	Mull of Kintyre, Kintyre	1929
1941	Bennane Head, Ayrshire	1887* see below.
1943	Keil Point, Kintyre	1940
1946	Currarie Port, Ayrshire	1940
1948	Kennedy's Pass, Ayrshire	1945
1948	Drumadoon, Arran	1944
1950	Galdrings, Kintyre	1921
1952	Dunaverty, Kintyre	circa 1950
1953	The Castles, Kintyre	1945
1953	Heads of Ayr, Ayrshire	1944
1954	Fisherton, Ayrshire	1945
1956	Corriecravie Arran	circa 1946
1956	Machrie, Arran	circa 1945
1958	Port Crom, Kintyre	1953
1977	Culzean Castle, Ayrshire	1971

As noted above, the first Clyde Fulmars were discovered ashore only 9 years after the time of first proven breeding on Foula, Shetland in 1878. There were four records from the Bennane Head site before the turn of the century, suggesting that this site was indeed being prospected (Paton and Pike, 1929). Bennane Head, in south Ayrshire, is presently a breeding colony with a low success rate. Charles Berry, a local naturalist and collector of birds in the late 1800's, documented the first Fulmars which had been found ashore. " A female in good condition" was found on 1 July 1897 and another in February 1906 (Berry, 1908). Fulmars attend their colonies over the winter months and the February record could easily have been another prospecting bird. These early records do not sit easily with the expansion and colonisation notes plotted by Fisher (1952), but are perhaps significant.

Breeding was finally established at Bennane Head in 1941 (Robertson, 1943). Although the islands and cliffs of the Firth of Clyde were colonised in the 1930's, the upper parts approaching the Clyde estuary were not entirely neglected and a dead Fulmar was recorded ashore near Largs, Ayrshire in 1932 (McWilliam, 1936), near to where the present colony at Portencross exists.

Thus at a time when Fulmars were first recorded breeding in Scotland, other than on St Kilda, the birds had prospected sites on the Clyde and by the early 1930's had found the deep waters at the upper Firth. While Sanda and south Kintyre, along with Ayrshire, were rapidly colonised, the larger Clyde Islands such as Arran, Bute and the Cumbraes were colonised much more slowly. The Island of Bute had breeding Fulmars only recently (1980's) although prospecting had been recorded over a long period, since the early 1960's.

Fulmars reach sexual maturity from around their 6th year of life, but typically breed at 10 years onwards (Ollason and Dunnet, 1978), thus the rapid colonisation of nearby headlands and islands within a 6 year period was the result of immigration and not through local recruitment. Birds which failed to breed successfully usually vacate the immediate area of their failed attempt and chose areas much further afield for future attempts (Ollason and Dunnet, 1978; Ollason and Dunnet, 1980). In the absence of ringing data, first-time breeding Fulmars can be identified by their tendency to lay smaller or more elongate eggs than experienced females (Ollason and Dunnet 1978). This trait in seabird egg shape was first noted in Kittiwakes, (Coulson, 1963).

2. 2. Fulmars on Ailsa Craig

2. 2. 1. *Breeding failure*

The exact date and site of first breeding of the Fulmar on Ailsa Craig was recorded. In May of 1939 a pair bred at Stranny Point on the south side of the island, but the egg was collected (Mr J. Girvan *pers. comm*). While the Fulmar was undergoing a rapid range extension in Scotland and the Clyde (see Table 2.2.) , its numbers on Ailsa Craig remained fairly low and in 1993, totalled less than 200 occupied breeding sites. The breeding success at 19 other Clyde colonies was variable during 14 years of annual monitoring - e.g., good at Sanda Island, but virtually nil on most of the Ayrshire coast, Kintyre coast and Isle of Arran (pers.obs.).

Paradoxically, despite relatively poor breeding success, new Clyde colonies continued to be established (Fig 2.2 and Table 2.2 above) and the numbers at these colonies slowly increased (Chapter 1 Fig 1.3.). Between 1951 and 1969 Fulmars increased in breeding numbers annually by 8% at Clyde colonies (Monaghan and Zonfrillo, 1986). Between 1976 and 1988 this annual increase had risen to 14%.

Since the mid 1970's an effort was made to ring Fulmar chicks at most of the known breeding sites on the Clyde / Kintyre coasts. However when colonies were visited for the purposes of chick ringing, many were found to have failed completely, year after year. This failure was at the chick stage, since a few chicks were known to hatch at most colonies but did not reach an age where the tarsus was developed enough to take a bird ring, at *circa* 15 days old. It was evident from ringing and re-trapping adults that incubation and chick-rearing to only 10 -15 days was enough to "imprint" most of the Fulmar pairs to their site, and cause them to return year after year to breed unsuccessfully.

The anomaly of an increasing adult population and a virtual total failure to breed successfully at most sites, is likely to be explained by immigration. The vast population of Fulmars in Britain (around 70%) exist in the Northern Isles, the north-east coast of Scotland and the Outer Hebrides (Lloyd *et al.*, 1991). In these situations monitoring shows they appear to breed successfully (Thompson *et al*, 1996), although they have only been regularly studied in biological detail at one colony, Eynhallow in Orkney (Dunnet and Ollason, 1979).

2. 3. Investigation into the breeding failure of Fulmars on Ailsa Craig

To gain insight into the breeding success of the Fulmar on Ailsa Craig, studies at two accessible locations, Rotten Nick and the North Foghorn, (see map, Chapter 1, Fig. 1.2) were commenced in 1989. Rotten Nick is an area of broad, well-vegetated, granite ledges at the south side of the island about 80 m a.s.l, and has been inhabited by Fulmars for at least 30 years. Around 15 to 20 eggs were laid annually at this site.
On the north side of the island Fulmars began colonising the area below the "Pinnacle" near to the North Foghorn (disused) in 1984. No eggs were laid at this site until 1988, by which time 6 sites were being permanently occupied. These were thus two sites containing 1., a fairly dense concentration of established birds and 2., a new site in the throes of establishing itself. The south side of the island is also usually drier and sunnier than the north, reflected in a different vegetation covering (Zonfrillo, 1994; see Appendix ii).

In 1989 this study commenced with the aim of finding why Fulmars consistently failed to raise young on Ailsa Craig, while remaining faithful to the nest sites. Ground-nesting gulls - Herring and Great Black-backed were also monitored for breeding success since their numbers of fledglings appeared depressed in relation to the numbers of pairs breeding (see Chapters 4 and 5).

Data were also gathered on diet to study distribution of prey species and to ascertain if food supply was a contributory factor in the failure of Fulmars to raise chicks to the fledging stage.

2. 3. 1. *Methods*

In 1989 detailed monitoring studies of the Fulmars at the two study plots on Ailsa Craig commenced and continued until 1993.

Fulmars on Ailsa Craig lay their eggs from mid May to mid June. If lost, eggs are not replaced. Fulmar eggs are large, white and conspicuous, and generally laid in exposed situations, such that predation by gulls is likely if the nest is unprotected for any period of time. To gain information on breeding success, sites were visited once in early June to mark the eggs with an indelible marker. Eggs were marked at the most pointed end, which usually survives being smashed open by predators and the numerals are not worn off through rotation during incubation. Some elongate Fulmar eggs were almost pointed at both ends, probably being laid by inexperienced birds (Coulson, 1963; Ollason and Dunnet, 1978).

After descent from the site in June 1989, a period of time was spent observing how quickly the birds returned to incubate the egg. Most did this very quickly, within five minutes, but others did not and on a few occasions the egg was taken by Herring Gulls which bred below the site. Fulmar egg loss to gulls was, in this instance, therefore the result of human intrusion. To minimise this effect in future seasons the eggs were marked at dusk or twilight when gulls are less active. Only two eggs were lost to gulls in two years utilising this method. Approaching hatching date, nests were again observed at dusk to minimise any loss of eggs or small chicks.

From hatching, Fulmar chicks were weighed, using a Pesola spring balance and wing and bill length taken, with a wing rule and dial callipers respectively every two or three days in 1989 and 1990, and every 10 days in 1993, depending on weather conditions. All birds were processed on the same day.

In the course of handling the chicks, regurgitations were collected and later analysed (see feeding ecology - below).

To minimise the amount of food lost through regurgitation, the Fulmar chicks were weighed using a neck collar, which prevented any loss of food or oil. Larger young were also lifted from the nest using a wire crook, which again prevented food and oil loss through regurgitation. Chicks were returned to the nest and released using a slip-noose which allowed (the ringer) rapid egress and no regurgitation by the chick. Growth patterns were therefore largely unaffected by human interference after 1989.

Gut contents of 8 dead adult Clyde Fulmars in spring were analysed for comparison, and biometrics recorded. In addition, 6 Fulmars found dead in the Clyde area (including Ailsa Craig) had gut tracts removed for analyses. All gut contents were preserved in alcohol and later examined under a X8 binocular microscope to determine prey species.

2. 4. Results

2. 4. 1. *Breeding Success*

Of 30 occupied Fulmar sites in both study areas on Ailsa Craig in 1989, eggs were laid at 16 sites. Eggs hatched at 6 of these nest sites in 1989, with a further 3 eggs infertile. The remaining 7 eggs were lost, with 3 definitely to gulls and the other 4 probably to rats (see Chapter 8).

From these studies in 1989 it became apparent from monitoring, that eggs were laid and chicks did hatch. However few chicks fledged anywhere on the island and daily checks on nests of both Fulmars and Gulls (Chapter 4) found chicks missing from sites on a regular basis.

While cliff nesting Kittiwake chicks at the same period that fell to the rocks below, were apparently starving, the Fulmar chicks showed expected normal rapid growth (compared retrospectively with data from the same sites) until death or disappearance (see Figs. 2.4. and 2.6). Of the 6 which hatched, all young were eaten by rats from between 10 and 25 days after hatching (Fig. 2.5.).

In 1990 a pilot scheme for eradicating rats was inaugurated and the Rotten Nick ledges were treated with Warfarin, in 2 baitboxes and selectively introduced down known rat burrows. Margarine-coated wooden spatulas - chewsticks - were used to monitor the rat activity (See Chapter 8). Nine eggs were laid in 1990 at Rotten Nick and from the 6 eggs which hatched, all 6 young fledged successfully.

In 1991 rats were eradicated (Chapter 8) and in that year and in 1992 Fulmars again raised young successfully (Table 2.3.). In 1993, 8 young fledged from Rotten Nick and 4 young from North Foghorn.

Table 2. 3. Summary of Fulmar breeding sites North Horn (N.H.) and Rotten Nick (R.N.) monitored during 1988 to 1993.

Year	No. eggs laid		Total No.	Total No.	Total No.	Total
	N.H.	R.N.	hatched	fledged	infertile	No. lost
1988	16	2	8	0	3	7
1989	14	2	6	0	3	7
1990	17	2	7	6	5	5
1991	12	2	7	7	4	3
1992	9	4	10	10	2	1
1993	11	6	12	12	4	1

NB. Rat eradication commenced at Rotten Nick in 1990 as a pilot site and was extended to the whole island in March 1991.

2. 4. 2 . *Growth of young*

There are few published data on the growth of young Fulmars. Only Mougin (1967) obtained full data from Scottish breeding birds, which he compared with Antarctic Fulmars *Fulmarus glacialoides*. Hamer et al (1997) provided partial growth data from two Scottish colonies - St Kilda and Foula, over two seasons.

On Ailsa Craig, Fulmar chicks were well provisioned and grew better than those studied by Mougin (1967) and Hamer (1997). Ailsa chicks reached 1000 gms at 30 days in two different years, whereas with Mougin they reached 750 gms and with Hamer 800 gms over the same 30 day period. There was no evidence of food shortage, and the growth of chicks prior to rat eradication was very similar to that following it. Adult weight is achieved after only 20 days and fledging time is at around 45 - 50 days after hatching. (see growth curves, Figs. 2.6, 2.7, and 2.8 for 1989,1990 and 1993 respectively). The mean Log weight for the 11 which fledged in 1993 is plotted on Fig. 2. 9.

Fig. 2.6. shows the growth of six chicks in 1989 which were gradually eliminated by rats. The growth pattern indicates that development was normal and similar to that of 1990 when chicks survived. Chicks were killed by rats after 15 days old, by which time they had reached half adult weight and were not constantly attended by at least one parent

Growth continues until a peak of almost double the adult weight is achieved at around 35 days after which appetite appears to be inhibited or parental feeding ceases and utilisation of body fat continues without further food. In 1990 and until 1993 the full cycle of chick rearing was achieved, with one chick in 1993 remaining on the nest site much longer than the others (Figs 2.7 and 2.8). By this period the breeding numbers were beginning to slowly increase (see Chapter 8, Fig 8.2.) .

The instantaneous growth rate for the 11 chicks measured in 1993 (Fig. 2.9) is plotted in Fig. 2.10.

The instantaneous growth rate (R) was calculated using the formula ;

$$R = \frac{\log e\, W_2 - \log e\, W_1}{t_2 - t_1}$$

where w = weight and t = interval in days.

This is considered the most accurate measure of growth parameters and best method for intra-specific comparison, being essentially the percentage growth rate per day.

The ***R*** value is initially high before dropping off at around 12 days and gradually declining until fledging. This proportional rate pattern illustrates effects of both diet and behaviour with the high energy food fed to small chicks (mainly lipid-rich stomach-oil) for 10 - 15 days before both parents forage independently, leaving the chick to remain unprotected for several hours at the nest site.

2. 4. 3 . *Diet*

Diets were studied using regurgitations from chicks at the breeding sites. Adults were deliberately not caught to avoid feeding irregularities while chicks were growing. Chick diets were collected during 1989 - 1993. The technique used to catch chicks prevented regurgitation in many instances so the data are limited and have been pooled according to the age of the chick. Some stomachs from dead chicks were also examined. The diet of live adult birds on Ailsa Craig was not examined. Dead adult Fulmars from Ailsa Craig and Kintyre were examined and the gut contents removed for analyses and identification.

Items are listed chronologically in Tables 2.4 and 2.5 since no systematic method was employed to collect the regurgitations or corpses; Fulmars are among the least likely seabirds found dead on Clyde beaches at any time of year and are seldom found with oiled plumage (pers.obs). Fulmars, either by sight or scent, appear to avoid oil slicks although some young birds may become contaminated through their inexperience.

Table 2 . 4. Diet of different individual living Fulmar chicks on Ailsa Craig.

Age of each chick in days	Food	Year	Probable origin of food
5	*Hyperia galba*[1]	1989	Natural planktonic
9	*Gonatus steenstrupii*[2]	1991	Epipelagic
9	Gadoid fish[3]	1991	Vessel discards
9	Sandeels[4]	1991	Natural planktonic
12	*Gonatus steenstrupii*[2]	1992	Epipelagic
12	Gadoid fish[3]	1991	Vessel discards
12	*Nephrops norvegicus*[5]	1993	Trawler discards
13	*Nephrops norvegicus*[5]	1991	Trawler discards
13	Sandeels[4]	1991	Natural planktonic
14	Sandeels[4]	1992	Natural planktonic
15	Gadoid fish[3]	1989	Vessel discards
15	Gadoid fish[3]	1989	Vessel discards
15	*Nephrops norvegicus*[5]	1990	Trawler discards
15	Gadoid fish[3]	1992	Vessel discards
18	*Eupagurus sp.*[6]	1990	Trawler discards
19	Paper napkin	1992	Vessel debris
20	*Hyperia galba*[1]	1993	Natural planktonic
21	Gadoid fish[3]	1993	Vessel discards
22	*Nephrops norvegicus*[5]	1992	Trawler discards
25	*Hyperia galba*[1]	1993	Natural planktonic
25	*Hyperia galba*[1]	1993	Natural planktonic
28	Gadoid fish[3]	1990	Vessel discards
28	Gadoid fish[3]	1992	Vessel discards
31	*Nephrops norvegicus*[5]	1990	Trawler discards

Notes on food items.

[1] ***Hyperia galba*** **is a normally benthic Amphipod crustacean which, in summer, swims to the upper trophic layers and is parasitic within the float chambers of jellyfish. It is from this source that Fulmars probably obtain the species.**

[2] ***Gonatus steenstrupii*** **is the southern counterpart of the boreal squid *G. fabricii*, upon which Fulmars feed in more northern seas. *Gonatus* is seldom caught in nets but drifts on the upper planktonic layers at night. It is bioluminescent and occurs off the continental shelf.**

[3] **Gadoid fish are probably Norway Pout** *Trisopterus esmarkii*, **the species most commonly taken by local fishing vessels.**

[4] **Sandeels are *Ammodytes* species, the smaller sandeels. The Greater Sandeel *Hyperoplus lanceolatus* has not been found in Clyde Fulmar diets. The sandeels are probably taken naturally by day since there is no sandeel fishery in Clyde waters.**

[5] ***Nephrops norvegicus*** **is commonly fished by trawlers around Ailsa Craig.**

[6] ***Eupagurus*** sp. **is a Hermit Crab and probably brought to the surface by trawlers.**

Table 2.5 lists the items found in the stomachs of 6 dead Fulmars from the Clyde sea area.

Table 2. 5. Cephalopods, crustacea and debris in gut content of 6 Fulmars from Ailsa Craig (4),Culzean(1) and Kintyre (1) found dead.

Date	Status	*Cephalopoda*	*Crustacea*	*Non-food*
21/3	Adult	*Gonatus 6* *Histeoteuthis reversa 10* Unidentified *1*	-	-
22/5	Breeding	-	*Meganyct. norv* 30	-
22/5	Breeding	-	*Meganyct. norv.* 8	-
15/7	Breeding	*Gonatus 2* Ommastrephid sp. 1	-	Grit 2 ; Nylon 2 Paper 1
17/8	Fledgling	*Eledone cirrhosa* *Rossia macrosoma*	*Nephrops norv* . 1	Grit 2 ; Nylon 1 Plant fibre 1; Pine needle 1
12/8	Chick	*Gonatus 1* *Loligo 1*	-	Grit. 2; Polyethylene resin beads 14. Grape seed 1 ; Flying ant wing 1; Moulded plastic 5

Three other items recorded were ; **Fish** - Whiting 2 and **Polychaetes** - *Aphrodite* 1.

Outwith the breeding period, 8 full grown Fulmars were found fresh dead during a winter 1990 attendance period further north in the Clyde (Table 2.6.). These birds appeared to have eaten a toxic substance which apparently caused instant death (the white putty-like material still present in the mouth of most birds). This die-off coincided with a period when dumped plastic explosives were trawled to the surface by fishing vessels in the Clyde from an area reserved for ammunition dumping in the deep waters east of Arran.
The biometrics are typical of Fulmars breeding in the Clyde area (pers.obs) and all were within a few kilometres of established breeding colonies.

Table. 2. 6. Analyses of 8 dead adult Fulmars beached on the upper Firth of Clyde (near Ardrossan, Ayrshire) from 27 January - 2 April 1990. Such mortality was unprecedented in the Clyde area.

Bird No. → Food ↓	1	2	3	4	5	6	7	8
Total of fish items	15	7	11	1	10	-	14	4
Whiting	5	-	-	1	1	-	-	-
Trisopterus sp.	2	2	3	-	2	-	-	-
Mesopelagic sp.	-	-	2	-	-	-	-	-
Total squid beaks	1	4	-	1	-	5	2	-
Gonatus sp.	1	2	-	1	-	3	1	-
Rossia sp.	-	-	-	-	-	1	-	-
Polychaetes	-	-	-	-	-	-	-	1
Aphrodite	-	-	-	-	-	-	-	1

Non-food								
Polyethylene resin	-	-	3	-	3	10	1	2
Polystyrene	-	-	2	-	-	2	-	-
Moulded plastic	-	4	-	4	5	-	-	2
Rope fibres	-	2	-	-	-	-	-	-
Sheet polythene	-	1	-	-	-	-	1	-
Grit	-	2	2	-	2	2	1	4
"White Paste"*	1	1	1	1	1	1	1	1

*** The "white paste" corresponded to the description of a plastic explosive dumped into the Clyde (by I.C.I.) and trawled up by fishermen around the time, within a 6 km radius of the beach. Coastguard warnings were issued locally in February 1990 as to the toxicity of this substance.**

All were in good body-fat and were of typical body weight for females at this time of year (pers.obs). There were no signs of starvation or disease in any of the birds dissected.

Table 2. 7. Biometrics of beached Fulmars found fresh-dead in the Clyde from 27 January to 2 April 1990.

Specimen No.	Date.	Weight gms.	Wing length mm.	Bill length mm.	Bill depth mm.	Sex.*
1	27 Jan	742.2	329	39.0	19.6	female
2	03 Feb	693.7	334	39.5	18.9	female
3	03 Feb	713.3	319	37.0	19.1	female
4	28 Feb	684.4	323	37.8	18.0	female
5	28 Feb	732.8	323	39.5	18.5	female
6	28 Feb	674.8	350	39.3	21.0	female
7	28 Feb	903.3	328	38.9	20.1	female
8	02 Apr	820.0	342	40.0	20.5	female

|* All birds sexed internally. Only bird No. 6 showed slight signs of oiling on the plumage.|

Bill length was measured from top of nasal tube to tip and bill depth was at the base of the bill over both mandibles including nasal tube with the bill closed.
All the above birds (Table 2.7) were weighed and measured before dissection. The skins of all the specimens are retained in the bird collection at Kelvingrove Museum, Glasgow.

2. 5. Discussion

Populations

For most of the present century, Fulmars have been present in the Firth of Clyde, but only since the 1930's has it become a regular breeding species.
Although a continuous process of increase in numbers of Fulmars in the British Isles persists, the rate of increase fluctuates (Lloyd *et al.*, 1991). Colony growth and overall numbers in the Clyde continue to expand. Limiting factors on growth of colonies and breeding success are perhaps a combination of land-based predators, climate and habitat

availability. The latter is probably heavily affected by human disturbance, since Fulmars will nest on most coastal and some inland cliffs, even on sandy beaches in northern latitudes and also on buildings, when undisturbed.

The current annual rate of increase for Clyde colonies is 14 % compared with an overall British rate of 4% per annum (Lloyd *et al.*, 1991). This suggest a population boosted by immigration, since the known reproductive rate and age of first breeding are unlikely to permit such an increase without birds coming in from outside.

Predators.

For most species of petrels, the adult weight is achieved and surpassed by the growing chick within a matter of a few weeks, or sometimes less (Warham, 1990). A diet of lipid-rich food leads to sub-cutaneous deposits of fat and this protein source may be important to island rats, which for much of the year may exist on a frugal, low protein diet. The period in the breeding cycle when chicks were vanishing from the sites on Ailsa Craig, and elsewhere on the Clyde, coincided with a behavioural switch in Fulmar chick rearing. Fulmars remain with their chicks for the first 10 - 15 days of life, after which time the chick is probably homeothermic. Eventually both parents forage at sea, leaving the chick which by now is grown enough to fend for itself. This it does very effectively by squirting stomach oil at approaching enemies (usually avian). However it appears that predators such as rats can overcome this defence mechanism, perhaps by force of numbers, and kill the unguarded chick.

Fisher, in *The Fulmar* (1952), did not consider the Brown Rat to be amongst the Fulmar's enemies, although he mentions that a captive adult Fulmar was killed by a rat in Norwich.

The synchronous and annual mortality of Fulmar chicks at most other colonies on the Firth of Clyde may also be largely due to rat predation. At the few colonies where rats certainly are not present, birds survive well and fledge young annually. Rats and rat droppings were encountered at 15 of the Clyde colonies where a search was made (in Ayrshire, Great Cumbrae, Bute and Kintyre). On Arran, rat droppings were noted at two colonies, at two others American Mink were also seen under the low cliffs. Imber (1975), argued that rats only kill live prey which they equal in approximate weight. Brown rats can achieve a peak weight of around 500 gms (Corbet and Southern, 1977). Rats killed on Ailsa Craig weighed a maximum of 320 gms, with a mean weight of 260 gms (st.dev. 38.3. s.e. 12.1; range 200 - 320 gms, n = 10 - See Chapter 8). Fulmar chicks of around 1 kilogram (i.e. double the weight of the heaviest recorded rat) were killed and eaten by rats on the study ledges. Unlike the chicks of Gannets, Fulmar chicks remain immobile until shortly before fledging, and seldom stray from the nest site.

Predators, such as rats and mink perhaps play a much greater role in controlling breeding Fulmar and other seabird populations than hitherto imagined. Rat eradication on Ailsa Craig (Chapter 8) has demonstrated that when alien mammalian predators are eliminated, Fulmars raise their young successfully.

The southern range extension of the Fulmar will bring it into contact with predators not normally found in its sub-boreal breeding grounds.

Food availability does not appear to be a constraint for the Fulmar. All chicks which hatch stand an excellent chance of reaching the fledging stage. Predation on Fulmar eggs by gulls on Ailsa Craig is slight and that on Fulmar chicks virtually non-existent, according to dietary studies (Chapters 4 and 5).

Growth and Diet.

The Fulmar chick is fed by both parents through the cycle but after 35 or so days, even when it appears food is available, the chick shows little interest in obtaining it from the parent. Comparison of growth rate of Fulmar chicks during 1990 (n=6) and in 1993 (n=11) showed very similar patterns and all chicks which hatched fledged in both years. Their growth curves showed faster mean growth than those of Mougin's (1967) Orkney sample and those measured by Hamer *et al.* (1997) from St Kilda and Foula (750 gms and 800 gms respectively at 30 days, c.f. 1000 gms at 30 days on Ailsa). In both instances more frequent handling than those on Ailsa may have affected growth rate. Towards fledging, the period between chick visits by adults increases and at the right time and conditions the chick fledges, usually in late August or early September. The adult birds will pay a few visits to the empty site before leaving temporarily for at least some weeks. By late September some adults (or rather fully-grown birds) appear back at the sites, but again only briefly. Attendance patterns appears set by October and this spasmodic appearance at the nest sites lasts until April when copulation commences and is followed by a pre-laying exodus (Dunnet *et al.,* 1963). Attendance patterns ashore between September and April may be governed by prey activity at sea, particularly at night. Numbers peak again in April, when occupied sites can total three times that of actual breeding sites. The winter component may be young or immigrant birds which temporarily boost local populations (ringing recovery data; pers.obs).

Eggs sometimes hatch slowly, with one Ailsa bird taking 5 days from chipping the egg to emerging. The rapid growth of Fulmar chicks may in itself be an anti-predator strategy.

Although not very mobile, Fulmar chicks have rapidly evolved the defensive/offensive mechanism of stomach-oil ejection, mainly if not entirely, to repel avian predators. Many bird species have fallen foul of Fulmar oil, particularly raptors (Broad, 1974). Oils are derived from prey and the prey species usually are lipid-rich (Watts and Warham, 1976). Winter-swarming euphausiids are not available to Fulmars until late summer at the earliest but other crustaceans, particularly the lipid-rich amphipod *Hyperia galba* are sought from the float chambers of jellyfish in summer. Camphuysen and Van Franeker (1996) found *Hyperia* in 42% of samples from St Kilda in summer.

Other items fed to chicks are gleaned from discards of fishing vessels. These include small cephalopods, gadoid fish and Norway Lobsters (*Nephrops*) along with other debris. sandeels, *Ammodytes* and the cephalopod *Gonatus* are presumed taken naturally, that is without the agency of man. *Gonatus* in particular are squid which form a major part of Fulmar diet over much of its range, indeed it may have evolved to hunt this genus in its sub-polar range where the squid is abundant (Hills and Fiscus, 1988 ; Piatkowski and Wieland, 1993). *Gonatus* does not occur in the Clyde Sea Area (Allen, 1962), but is a vertically migrating deep water species, with the nearest locations off the continental shelf, 100 + kilometres away. Fulmars frequently undertake such long foraging trips, given suitable winds (Dunnet and Ollason, 1982).

Much of the Fulmar's diet and food fed to chicks may be obtained by nocturnal foraging at sea. The later colonisation of the upper deep water areas of the Firth of Clyde may arise from contact with the abundant swarms of *Meganyctiphanes norvegicus* an important major biomass for both fish and birds (Mauchline, 1959). The distribution of *Meganyctiphanes* in the Clyde follows that of the waters over 90 m deep, which water column it requires for reproduction (see map, Fig. 2.2). The Fulmar is conspicuously absent around vessels fishing diurnally on the Clyde (pers.obs), and particularly in winter, when it spends most daylight hours on land, albeit intermittently. At night Fulmars can be seen near Ailsa Craig in the lights of trawlers sorting the catch offshore. All euphausiids and many squid species are bioluminescent and migrate vertically at night to the surface, where the large light gathering eyes of the Fulmar will easily locate them. The little squid *Histeoteuthis* is particularly bioluminescent, having much of its body and tentacles studded with photophores, similarly the euphausiid *Meganyctiphanes* has photophores at the 10 leg joints, producing a bright light in an otherwise dark sea. Other cephalopods such as the small squid *Rossia macrosoma* and the Lesser Octopus *Eledone cirrhosa*, are essentially benthic and arrive on the surface through trawling activities, mainly for *Nephrops* and gadoid fish. *Loligo* is the only squid fished commercially in U.K. waters, but not in the Clyde. It is rare in the diet of Clyde Fulmars. Squid beaks are of a hard chitonous substance which will persist in the gut longer than most other parts of the animal when ingested (Furness *et al.*, 1984). Cephalopods are a major items of marine food for Fulmars, as they are for many petrel species, and not simply an accumulated artefact. They are regularly found in regurgitations and gizzards of both young and adults alike (pers.obs. - 9 Atlantic Procellariiform species examined). Furness and Todd (1984) found only 1 cephalopod species (not identified) in their samples from both St Kilda, Outer Hebrides and Foula, Shetland. Foula birds ate mainly sandeels while St Kilda birds ate pelagic zooplankton and benthic invertebrates. Ailsa Craig birds ate all of these foods as well as cephalopods, combining natural feeding with scavenging from fishing vessels. Elsewhere, Hill and Fiscus (1988) found only cephalopods (representing nine Families) from 28 beached dead Pacific Fulmars.

The amount of non-food in the diet is perhaps indicative of the scavenging habits of the Fulmar. Much of the debris ingested is anthropogenic and may be derived from local boats and ferries. The polyethelene resin beads are the product of chemical industry "cracker" plants servicing the plastics industry. The resin beads float and may resemble certain fish eggs. Their presence in the marine environment is a cause for concern (Van Franeker, 1985; Zonfrillo, 1985) and their distribution is world-wide (Zonfrillo, 1986; Bayer and Olson, 1988).

The significance of all the 8 dead (presumed poisoned) birds (Table 2.4.) being female raises some questions. For example - do females re-colonise the breeding areas before males ?. Or, do females feed closer to colonies than males or in different sea areas to males, as do some Albatrosses ? Hamer *et al.* (1997) speculated along similar lines in discussing parental duties regarding foraging strategies and ranges in northern Fulmars.

Breeding success.

Despite their failure to annually raise chicks to fledging, when rats were eradicated the Fulmars managed this task with no obvious problems or past experience. Experience in rearing young appears important for Fulmars and probably most other seabird species (Coulson and Horobin, 1976; Ollason and Dunnet, 1978 ; Coulson and Thomas, 1985). There seemed little annual variation in the abilities of the individual Fulmars to raise young. Factors other than parental qualities have obviously precipitated breeding failure, although experienced or perhaps simply older parents are no doubt important in establishing successful chick rearing (Ollason and Dunnet, 1980; Ollason and Dunnet, 1986).

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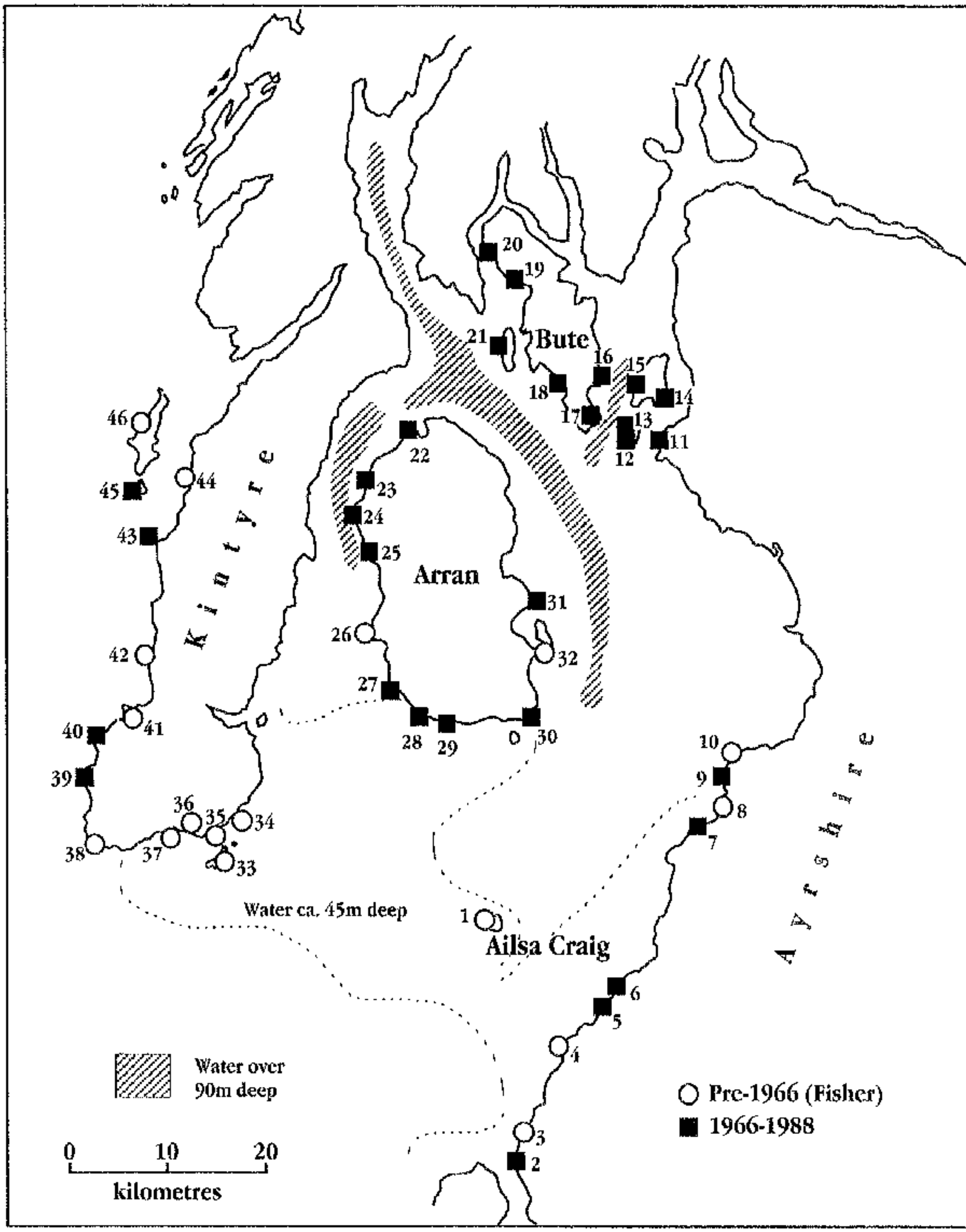

Fig. 2.1 Clyde Fulmar colonies. Numbers refer to colonies listed in Table 2.1. All colonies listed remain occupied.

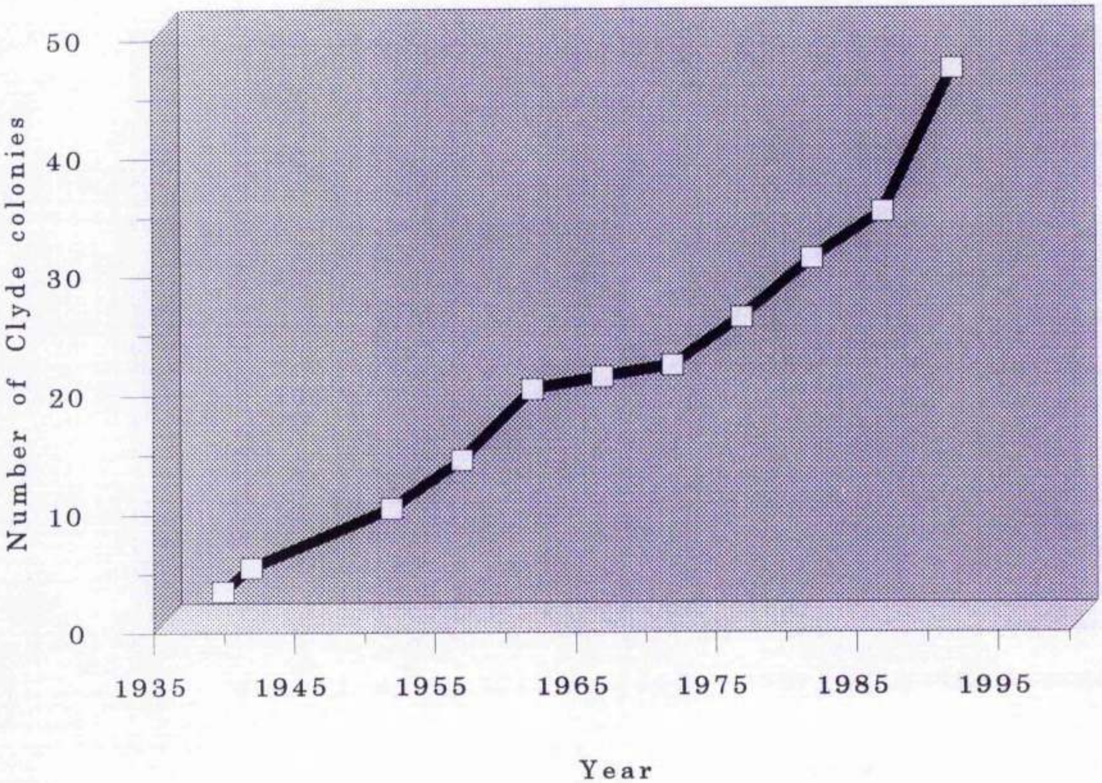

Fig. 2. 2. Increase in number of Fulmar colonies established in the Clyde Area. Only a few seemingly suitable coastal cliff areas remain to be colonised.

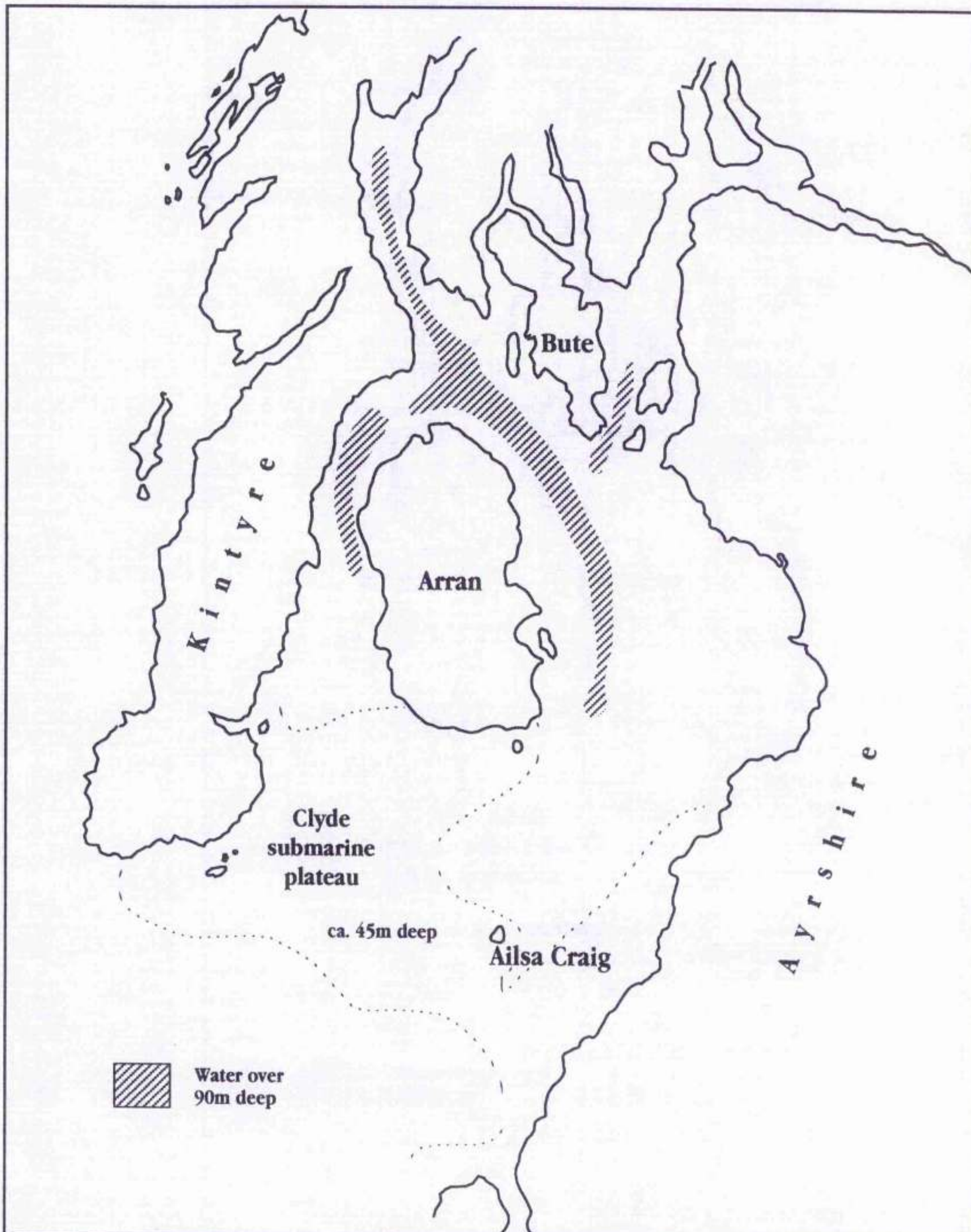

Fig. 2.3 Distribution of deep and shallow waters around the Clyde Islands

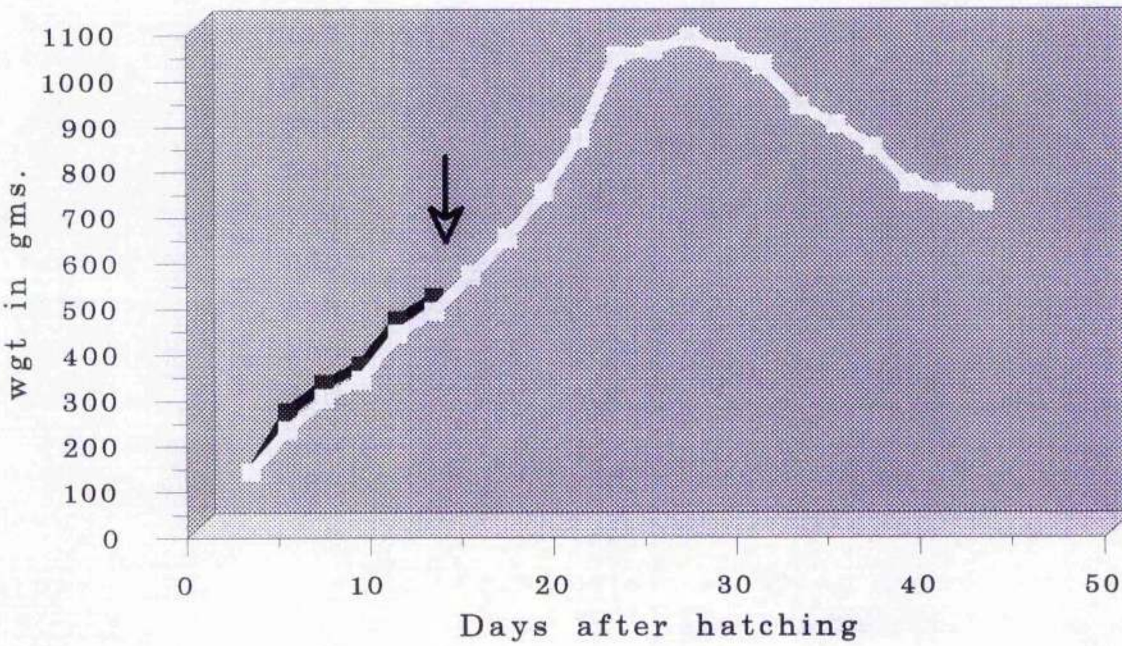

Fig. 2. 4. Growth in weight of Fulmar chick at nest site No. 5 in 1989 (black) and 1990 (white). The arrow marks the death of the chick in 1989.

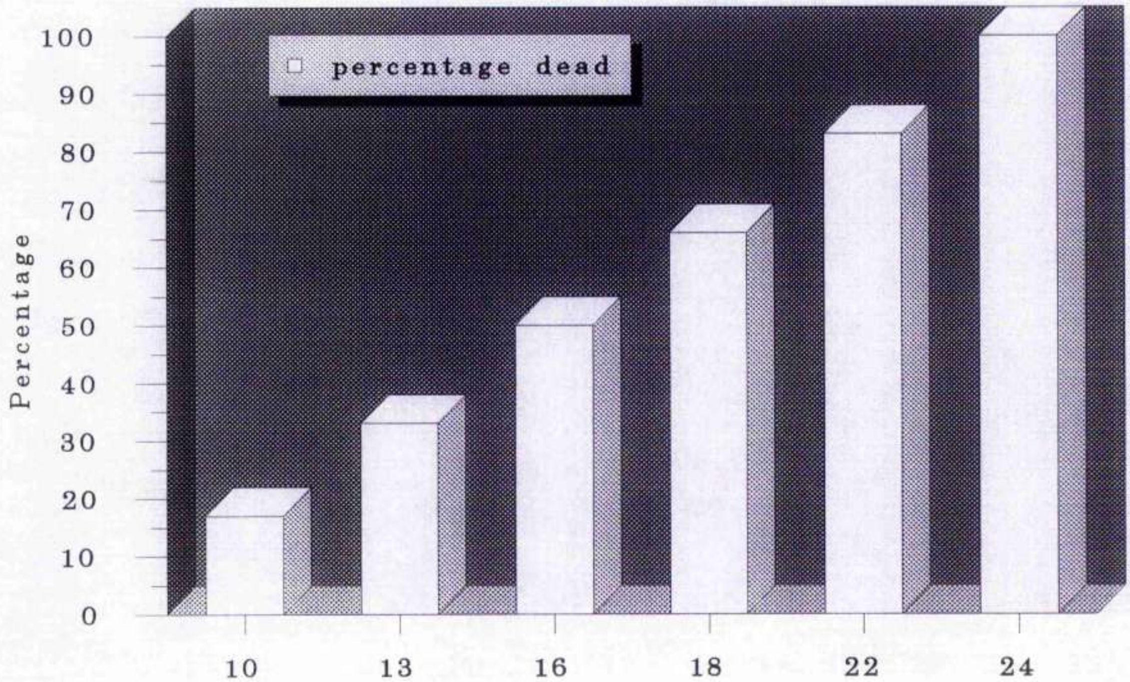

Fig. 2. 5. Mortality frequency of 6 young Fulmars in days after hatching on Ailsa Craig in 1989.

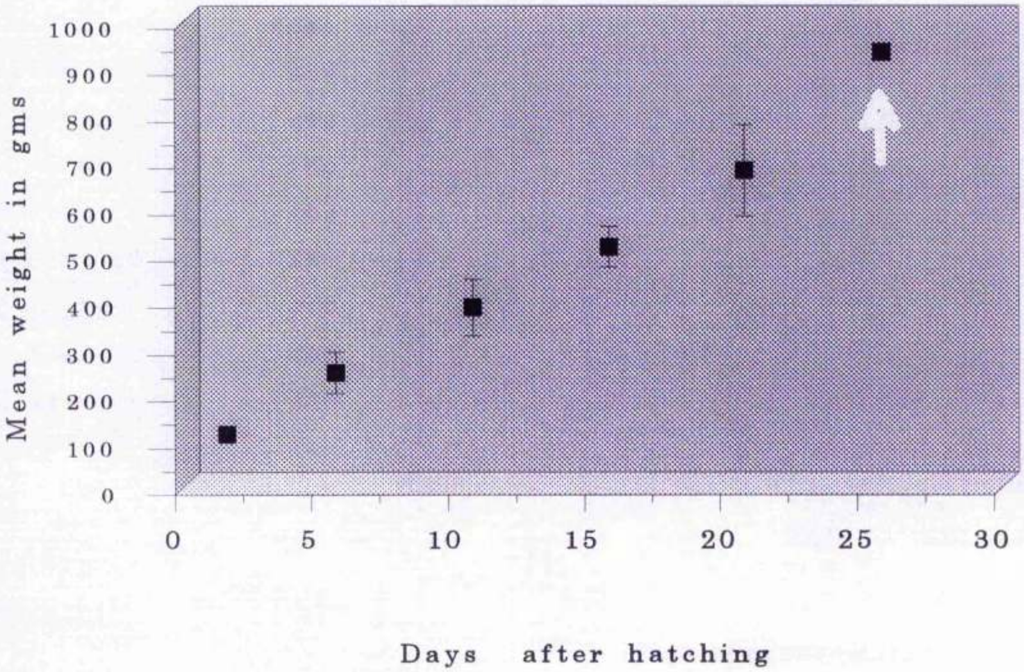

Fig. 2. 6. Mean weight (+- s.e.) of 6 Fulmar chicks on Ailsa Craig in 1989 (arrow marks death of last chick).

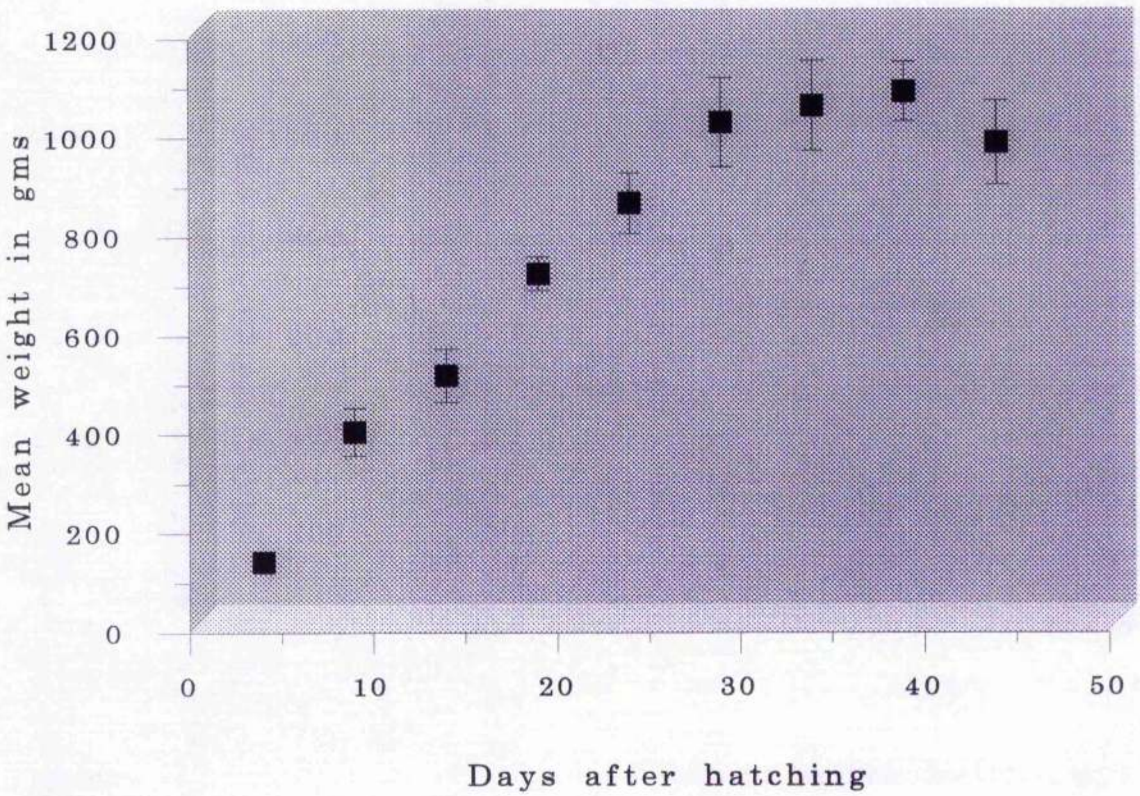

Fig. 2. 7. Mean weight (+- s.e.) of 6 Fulmar chicks on Ailsa Craig in 1990 from hatching to fledging.

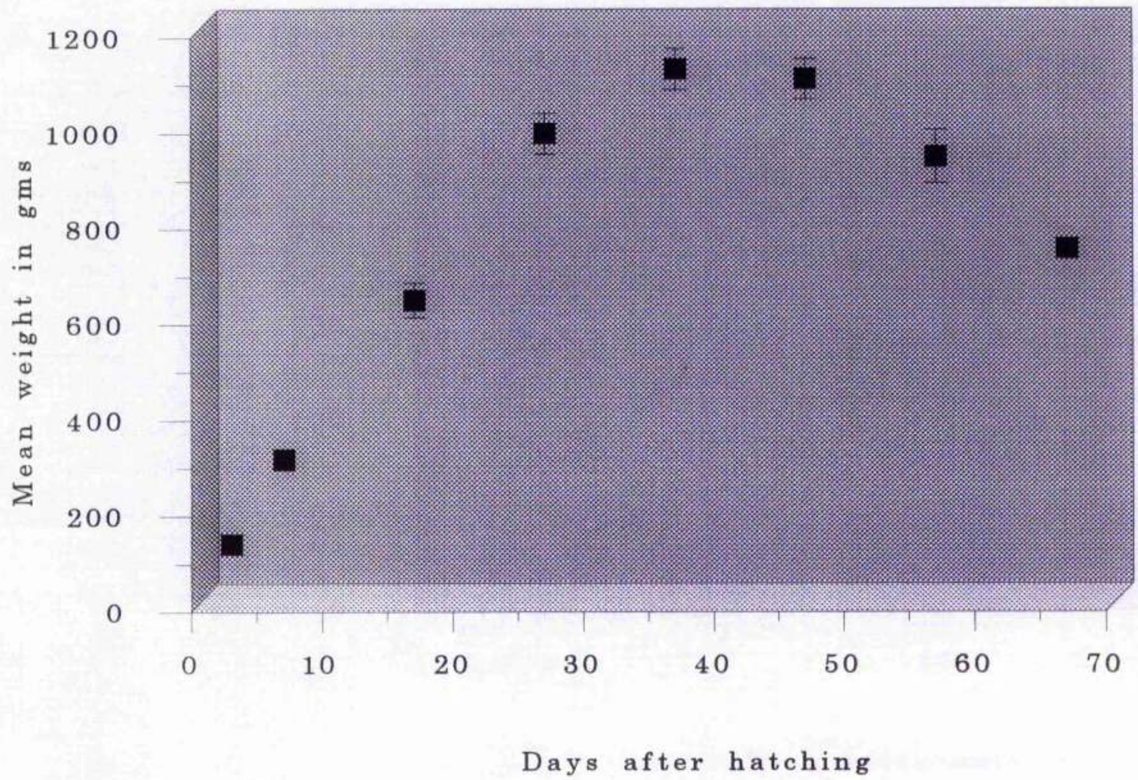

Fig. 2. 8. Mean weight (+-s.e.) of 11 Fulmar chicks on Ailsa Craig in 1993 from hatching to fledging

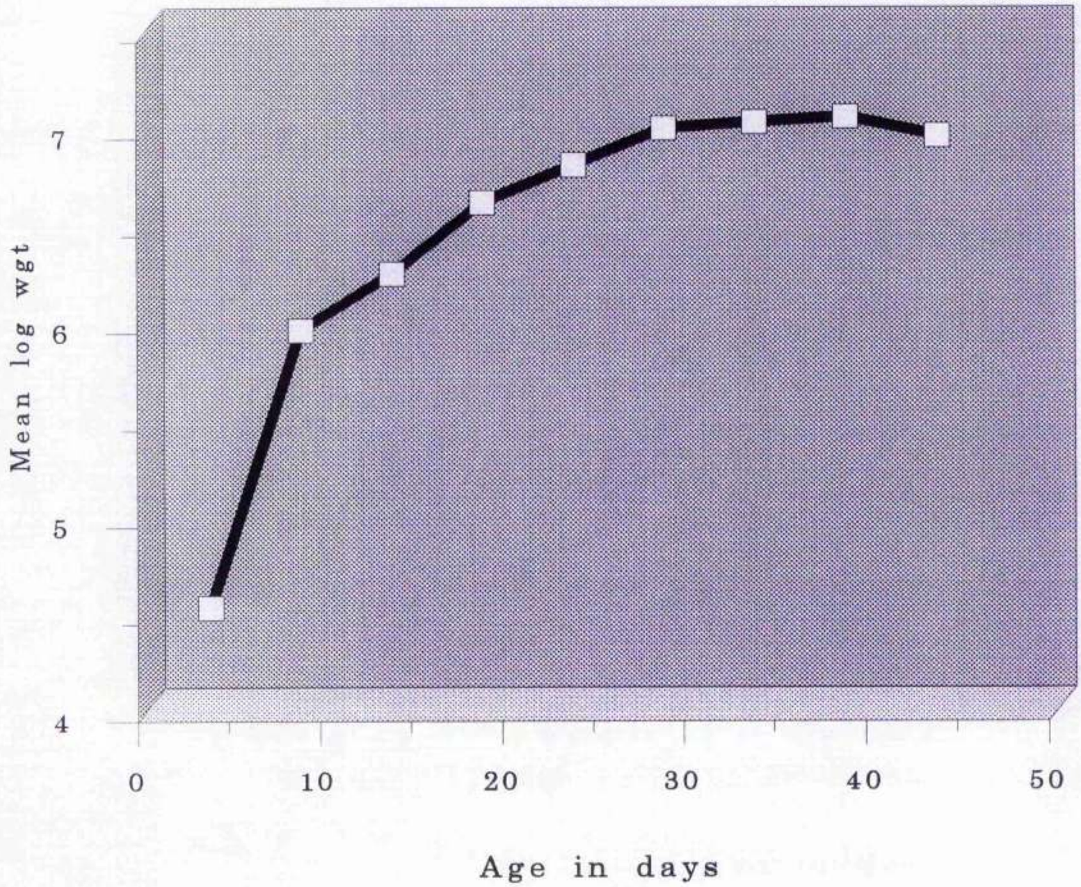

Fig. 2. 9. Mean Log weight of 11 Fulmar chicks on Ailsa Craig in 1993 measured from hatching to fledging.

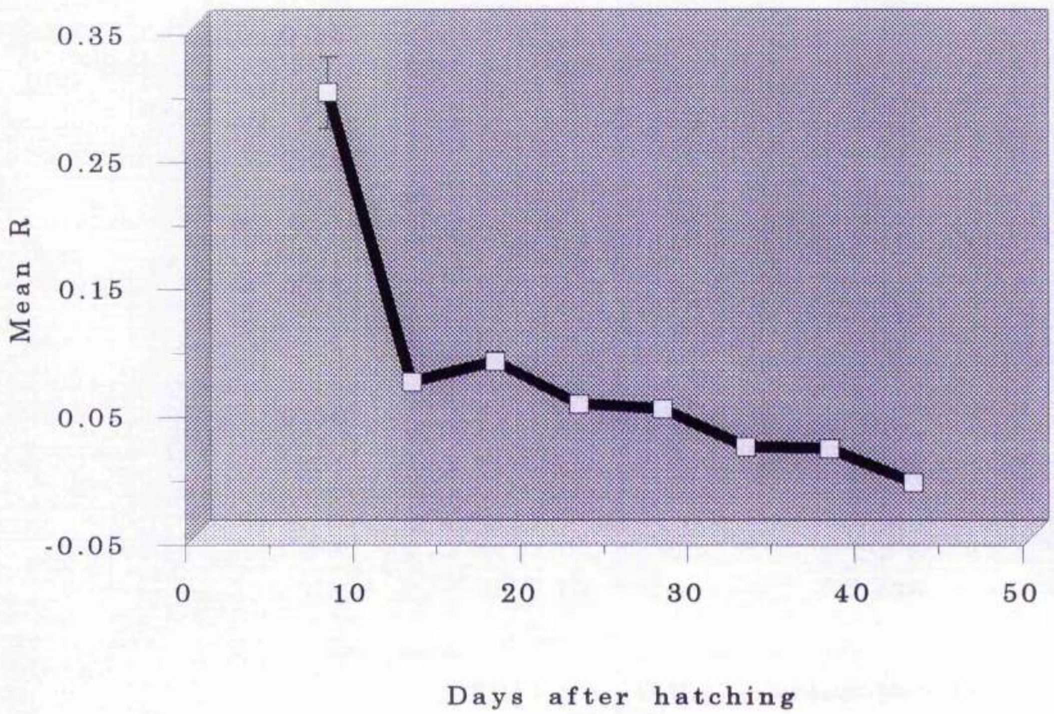

Fig. 2.10. Mean instantaneous growth rate in weight of 11 Fulmar chicks (+-s.e.) measured on Ailsa Craig in 1993 from hatching to fledging.

Chapter. 3

Diet, growth, breeding success and migration of Gannets *Morus bassanus* on Ailsa Craig

3. 1. Introduction

The Gannet, by its sheer numbers, is a very important component of the Clyde marine ecosystem and on Ailsa Craig the Gannetry is of international importance (see Chapter 1). In 1995 it held an estimated 34,000 breeding pairs (aerial survey by Murray and Wanless, pers.comm.). In addition there are several thousand non-breeding and sub-adult birds always around the colony in summer. The Gannet is the largest indigenous north Atlantic seabird, and feeds largely on a range of commercial-sized fish species. It lays a single egg and has a very protracted breeding season with the first eggs laid in late March and the last young fledging into November. From hatching to fledging is normally around 91 days (Nelson, 1978), and one adult always attends the chick. Adults leave the colony soon after the chick fledges and the first birds do not return until the following calendar year, usually around the second week of January.

Although the breeding cycle and behaviour patterns are well documented (Nelson, 1978a, 1978b), the complete growth pattern of the young has been little studied. This is largely due to the fact that after about 5 weeks the high mobility of young Gannets makes it difficult to track individuals without causing an unacceptable level of colony disturbance. Measuring birds beyond 60 days is generally considered too hazardous for data collection (Wanless, 1984). Such data as are available are therefore largely restricted to the early chick stage, with studies over a longer period involving captive birds; the maximum period for which data are available in the wild is 77 days, still almost 2 weeks from fledging, (Poulin, 1968; Wanless, 1984).

Inter-colony comparisons are correspondingly limited, and may be confounded by differences in data collection methods and in the status of the birds being measured. Okill and Wanless, (1986) compared physical measurements of young Gannets from two colonies 800 km apart. However at one colony (Noss, Shetland) measurements were taken from live chicks caught at sea around the colony; at the other, (Ailsa Craig, Firth of

Clyde) data from dead birds found on land, below the colony, were used with no live birds caught at sea.

In this study, in addition to studying the growth of chicks until they became too mobile, a small sample of chicks at sites on Ailsa Craig was measured regularly in 1993 from hatching to within a few days (at circa 86 days old) of fledging (usually at circa 91 days old); this was made possible by the nature of the sites chosen. Measurements of these study birds were compared with those newly fledged, caught at sea, and with living young birds found below the cliffs on Ailsa Craig in 1991 and 1993. At the same time, dietary information was collected from chick regurgitations and from stomachs of some adult birds found dead in the non-breeding period. Data on breeding success were obtained from a monitored, undisturbed cliff study site.

In total around 10,000 Gannets, the vast majority chicks, have been ringed on Ailsa Craig mainly by the author and other members of the Clyde Ringing Group. Dispersal of young Gannets was plotted from ringing recoveries and controlled birds, all of which had been ringed as nestlings on Ailsa Craig.

3. 2. Methods

A sample of 27 known-age (hatch date recorded) chicks was measured (weight and wing) at a sub-colony of some 120 pairs on the upper cliff edge for almost 7 weeks in 1991, beyond which age mobility of young and colony disturbance precluded data collection.
In 1993 a complete set of measurements from hatching to fledging was obtained by reducing the sample to 4 chicks and choosing specific cliff sites which were safe for the young Gannets at all ages. Near to fledging, the 10 day intervals between measures were reduced to 5 days to help clarify the growth patterns immediately before fledging. These 4 young were caught with a noose and weighed initially to the nearest 5 gms with a 1 kg balance, then a 10 kg spring balance was used with weight taken to the nearest 50 gms. As the chicks developed they were weighed using a neck collar made from car seat-belt material with a series of holes through which the balance hook was slotted, accommodating the neck diameter and holding the bird firmly during the few seconds of weighing. The birds could therefore be weighed quickly and with minimal disturbance and without causing or allowing regurgitation.

At the colony site in 1991 regurgitation by chicks could not be prevented since this was occasioned often by simple visual contact. Weights, therefore, of the large sample were biased because food was being disgorged during handling. Wing lengths were measured with a 600 mm steel wing rule at maximum length, flat and straight, to the nearest millimetre.

On the cliff site in 1993, the four birds chosen could all be approached and noosed from immediately below the nest. After release back onto the nest pedestal, using a long slip-line noose on a 4m bamboo pole, the birds did not regurgitate and quickly settled down, without any movement. Since approach was from below, exit from the site could also be rapid and visual disturbance was therefore minimal. The nest situations were such that wandering or escape was impossible for the young bird up to the point of fledging.
The instantaneous growth rate (R), being essentially the percentage increase in weight per day, was calculated using the formula ;

$$R = \frac{\log e\, W_2 - \log e\, W_1}{t_2 - t_1}$$

where **w** = weight and **t** = interval in days.

A similar calculation was carried out for wing growth.

In 1991 Gannet (n=27) chicks were tracked at Kennedy's Naggs, an isolated sub-colony of some 120 breeding pairs, on the top south side of Ailsa Craig. These were weighed and measured weekly until almost 50 days old.

Live, near-fledged young birds (n=48) were also measured and weighed below the cliffs when fledging had been interrupted by falling, misjudgement during wing exercise or when fighting adults displaced nearby young. The exact age and status of these birds was unknown.

In 1993 a small (n=8) sample of newly fledged birds were pursued in a power boat and caught and measured at sea for comparative purposes. These were weighed and measured to compare with study birds and those caught under the cliffs in good condition.

In periods before hatching (12) and in late autumn (4) stomachs of 16 adult birds were examined, and regurgitations of (6) late-fledging juveniles, caught alive or found dead below the cliffs on Ailsa Craig were noted, to try to gain insight into Gannet diet in the non-breeding period. Adults leave the colony soon after the chick fledges and do not return until the following calendar year.

To judge breeding success, free of any possible bias, data were collected at one cliff area, (n = 62 nests), totally undisturbed throughout the season and monitored annually for 3 years. The unit used was "active nests", that is, birds on a nest regularly incubating. The site was monitored weekly from June to October in 1991 and 1993 and from June to September in 1992.

Gannet ringing was first carried out on Ailsa Craig around 1923 but large numbers were ringed from the mid 1960's onwards by Dr A D Brewer and the author. In addition, numbers of chicks were ringed in the late 1960's and early 1970's by the North Solway Ringing Group (1 visit), the North Co. Down Ringing Group (1 visit) and Dr Sarah Wanless (Aberdeen University - during a 4-year period). Only the recoveries held by Clyde Ringing Group have been analysed for this study.

3. 3. Results.

3. 3. 1. *Diet.*

Adults

Of the 12 stomachs from adults obtained in spring 1991 (April and May), six were empty but the other six contained at least one item of identifiable material. In the stomach contents and in the 4 adult autumn (October) regurgitations the only fish involved was Whiting, a species frequently fished at that time of year in the Clyde by the local fishing fleet.

Fledglings

The stomachs of 6 fledglings (i.e. young which have left the nest) found freshly dead in September 1991 each contained between 1 and 3 otoliths of Whiting and bones of the same fish species. In late October 1993 as the few final chicks were leaving the upper part of the colony, four young produced regurgitations immediately prior to departure, comprising 9 fish, all of which were Whiting.

Chicks

Mackerel was the most frequently occurring commercial-sized fish in the diets of the Gannet chicks, although sandeels were numerically commoner. An indication of the general length and weight of fish fed to chicks is presented below (Table 3. 1.).

Table 3. 1. Sizes and weights of fish fed to Gannet chicks from hatching to ca. 50 days based on regurgitations of chicks.

Fish Species (n)	Mean length. mm	S.E.	Mean weight gms	S.E.	Range length mm	Range weight gms
Mackerel (17)	215	21.4	115	18.0	80 - 360	20 - 320
Sandeel (21)	146	10.6	30	8.36	50 - 190	1.5 - 130
Herring (6)	203	19.9	86	16.5	120 - 250	30 - 150
Other (14)	158	3.48	33	5.15	140 - 180	25 - 100

[**Note** : *Measurements of the above were made from entire fish only i.e. scarcely digested.*]

The sandeels taken by Ailsa Gannets were mainly, the Greater Sandeel and to a lesser extent Raitt's Sandeel *Ammodytes marinus*.

Other fish recorded taken by adult Gannets and fed to chicks included small Whiting, Grey Gurnard, Red Gurnard and one small male Lumpsucker, a squat kelp-dwelling species. One squid - *Todarodes sagittatus* was regurgitated by an adult attending a chick.

3. 3. 2. Growth

The growth of chicks in 1991 (n = 27) from hatching to half-grown is shown in Fig. 3.1. (mean weight) , and Fig. 3.2. (mean wing length). Despite time spent measuring and weighing these young, growth was fairly rapid and adult weight (around 3 Kg) was reached at about 30 - 40 days after hatching. At the same age, wing length has reached approximately half the final fledging length. The instantaneous growth rate for the wing (Fig. 3.3.) and weight (Fig.3.4.) of the 27 young can be compared with the rate for the 4 young in 1993. The instantaneous growth rate for wing Fig. 3.5. and weight Fig. 3. 6. of the four chicks from hatching to fledging shows some differences. A marked drop in the growth rate of weight between days 10 - 20 and thereafter a less marked reduction with a further drop in the rate of weight gain around the 77 day period. Rate of weight gain increases slightly before fledging. With respect to wing length, the growth rate peaks at day 15 and thereafter declines, with a slight rise at around the 77 day period before slowing prior to fledging. Towards the point of fledging the increases in weight and a more even wing growth rate. (Fig. 3. 7. weight and Fig. 3. 8. wing.) are perhaps the effects of restored feeding after fasting.

The apparent anomalies in growth between the 27 part-grown chicks and the 4 full-grown, in wing growth rate over similar periods (Fig. 3.3. and Fig. 3.5.) may be attributable to observer bias in that regurgitations collected from the 27 chicks may have hindered growth. Growth of each of the four individual chicks is shown in Fig. 3. 9. (weight) and Fig. 3. 10. (wing length). All four show the same general pattern of growth. Variation in weight can be seen within the final 20 days while wing lengths achieve a certain unity over the same period, perhaps illustrating that wing growth is largely independent of nutrition.

In 1993 the four birds, measured to within a few days of fledging, gave an indication of the final size attained immediately prior to fledging see Fig. 3. 7.(weight) and Fig. 3. 8. (wing length).

Study birds fledged at 90 - 93 days and at a mean weight of 3250 ± s.e.126 gms with mean length of 455 mm ± s.e. 5.17mm, (n=4) up to 5 days before leaving. The heaviest young caught at sea weighed 3600 gms (mean weight 3263 ± s.e.144 gms, n=8) and on land the heaviest fledgling weighed 3830, (mean 3050 ± s.e. 54.9 gms) see Table 3.2.

Table 3. 2. Biometrics of fledgling Gannets ; comparisons between those caught on land , at sea and at the study site.

location	n.	mean	range.	st.dev	SE Mean
	Wing.				
on land	48	469.9	409 - 506	21.10	3.05
at sea	8	466.3	425 - 490	20.20	7.14
study site	4	455.2	443 - 468	10.34	5.17
	Weight.				
on land	48	3050	2100 - 3830	380.1	54.9
at sea	8	3263	2300 - 3600	407.0	144
study site	4	3250	2900 - 3500	252.0	126

Wings of study birds reached a mean of 455 ± s.e. 5.17 mm, (n=4) just before fledging and at sea the longest winged bird was 490 mm (mean 466 ± 7.14mm, see Table 3.2.). Of the birds below the cliffs, the longest wing measured 506 mm (mean 469 ± s.e. 3.05 mm, see Table 3.2.).

There was no statistically significant difference between the wing length and weight of (1) young fledged birds caught on land and (2) fledged birds at sea and (3) those on the study site.(p = 0.375, $F_{2, 57}$ =1.0 for wings, and p = 0.241, $F_{2, 57}$ =1.46 for weights, One-Way ANOVA).

3. 3. 3. Breeding success

Despite the generally inaccessible position of the nest sites in the chosen monitoring area of cliff, some pairs failed through extraneous interference. Pairs lost eggs and young to gulls when adults were fighting over nest material and some young fell or were blown or dislodged from the site by fighting adults well before fledging. Table 3. 3. shows the proportion of active nests that fledged a chick.

Table 3. 3. Gannet fledging success rate from 62 monitored cliff site nests 1991 - 1993.

Year	No of chicks fledging (% of 62 nests)	No failed	Total nests monitored
1991	42 (66%)	20	62
1992	48 (77%)	14	62
1993	32 (53%)	30	62

[There is no statistically significant difference between years (X^2 = 2.646, d.f. 2, P = 0.267)].

3. 3. 4. Dispersal and migration

For a species which makes long migrations towards the equator, Gannets spend longer at the colony than any other seabird. The first birds arrive back on Ailsa Craig from around the first week in January and the final fledglings and adults leave the colony in early November. Fledging takes place from the first day of August. Almost 10,000 Gannets have been ringed on Ailsa Craig, 95 % of which were nestlings. The maps derived from ringing recoveries, Fig. 3. 11. to Fig. 3.17., are arranged according to calendar years after hatching. Shading shows the general area of recoveries both on coasts and at sea. Fig. 3.11. shows the pattern of distribution and mortality in birds fledging from the colony until the end of December in the same year. The trend in movement is entirely southern with some birds moving east into the Mediterranean. In subsequent years the returning birds disperse all around the British coasts and touch on much of coastal northern Europe (Figs. 3. 12. to 3. 14.). By their fourth year many have settled back at the colony but a small percentage have attached themselves to other colonies where they will probably breed. Fig. 3. 15. shows 2 birds ringed as chicks on Ailsa Craig breeding in Norwegian colonies, with a third breeding on the Bass Rock, Lothian. One of the Norwegian breeding birds was subsequently found dead on a beach at Tripoli in Libya. Another bird entering the Mediterranean and moving east was found dead on a beach at Ashdod in Israel. With growing experience, fewer birds die on the wintering grounds. After 10 years of life surviving Gannets usually come to grief around the coasts of the Irish Sea, Eire and south-west Scotland. Several birds up to 22 years old have been controlled breeding in the colony (Fig 3-16) while the oldest Gannet on record was found dead in an oilspill off Holland, 30 years after being ringed as a chick on Ailsa Craig.

3. 4. Discussion

Diets.

The Gannet has evolved a plunge-dive fishing technique through which it can exploit pelagic schooling fish without a reliance on man to bring these to the surface. Gannets readily come to fish discarded from boats but will often ignore fish such as Saithe in preference to more "oily" fish such as Mackerel or Herring, when presented with both at sea (pers.obs). In winter fishing vessels provide easy feeding by means of discards although schooling whitefish such as Whiting are locally abundant in the Clyde and appear to be a major item of diet for Ailsa Craig Gannets. Presumably following fishing vessels has advantages which reduce search time and energy expenditure. On occasion over 5 thousand birds have been counted behind a single fishing vessel offshore.

In the breeding period Gannets appear to concentrate their feeding effort into fish of a relatively high calorific value to feed their young. In the Clyde, these fish usually take the form of Mackerel, Greater Sandeels and Herring, with a few fish of other species and other items occasionally taken (Wanless, 1984). In Table 3. 1., data are similar to that collected by Wanless (1984) on Ailsa Craig during 1974 -1976, with the exception that no sandeel species were then recorded in the diets. There is no commercial sandeel fishery on the Clyde but spawning grounds (sandy substrates) are frequently disturbed or destroyed by trawling for crustaceans and by shellfish dredgers (cockle boats) and suction dredgers, which over a number of years may have the effect of reducing the availability of this species for Ailsa Craig Gannets. Similarly Herring have traditional spawning grounds within the Clyde area and closest to Ailsa Craig are the Ballantrae Banks, south Ayrshire. Nelson (1978b) gives accounts of local fishermen using Gannets on the Clyde to locate

Herring shoals, even until fairly recent times. After many years of overfishing, the controlled fishing of Herring has lead to a recent increase in numbers of that species. In 1991 Herring were plentiful, even being taken by anglers with rod and line from around Ailsa Craig (pers. obs). Herring appeared frequently in the diet of Ailsa Gannet chicks during 1991. Fish commonly taken by anglers around Ailsa Craig are Pollack, Saithe, Ballan Wrasse and Conger Eel, none of which appeared in the diet of Ailsa Gannets in the samples collected during this study. In the Firth of Clyde, migratory Mackerel arrive abundantly in most years around early June, (pers.obs) coinciding with the hatching of young Gannets. The chicks grow steadily over the three months in the nest, and rapidly attain and maintain a greater weight than the adult, before in most cases, losing weight before fledging (Fig 3.5.). Even small chicks of a few weeks old appear capable of swallowing fairly large fish (200 mm +). Discards and spoil from fishing vessels (e.g. particularly small benthic squid and crustaceans) seldom appear in the diet of small to medium-sized chicks.

Growth.

Montevecchi and Vaughan, (1989), suggested that Gannet chicks were adapted to cold conditions with thick down fully grown by 3 weeks old. Heat stress was considered a greater threat to the chick than cold which could be compensated by adult behaviour and coped with more effectively. They also noted that leg musculature functionally matures before flight muscles and is the primary source of thermogenisis. This rapid development in leg musculature also means mobility at an early age and a potential barrier to studying birds physically within large colonies.

Weight of the young reaches a peak at around 60 days after which food is either refused by the chick or reduced in presentation by the adults. Maximum weight of any chick weighed on Ailsa Craig was 3830 gms. Wings grow continuously after hatching until probably even after fledging. Only 3 from 48 young measured below the cliffs reached a wing length in excess of 500 mm, and all study birds fledged around 50 mm less than this. Maximum wing length measured of any young was 506 mm, which approached typical adult length.

Growth patterns can potentially be disrupted by over-handling on the part of the observer. Gannets regurgitated freely, often simply on visual contact with an approaching human. This can be seen in the fluctuations on Figs. 3.3. and 3.4. where collecting regurgitations for analyses probably interfered with growth rate to some extent, although all the chicks fledged. Using the correct technique and equipment however appears to overcome this potential source of error provided that several days of non-interference are left between visits.

Gannet chick weights slowly drop after 70 days, (Figs. 3. 7, and 3.9). Young Gannets are well provisioned and make their first flight in peak condition. This is essential in view of the long migrations undertaken by first-year birds to wintering grounds in coastal West Africa.

Weight increase immediately prior to fledging perhaps offsets a less manoeuvrable flight against advantages in post-fledging survival. The general trend however in gannet chick weight is to slowly drop after 70 days before increasing again after 80 days. The data collected for this study confirm the observations of Nelson (1978) and Wanless (1984) that young are fed right up until the day of departure, and that no deliberate "starvation" period occurs. This was further confirmed by examining birds in late October 1993 on the upper sections of the colony, which regurgitated on approach before taking off on the first flight. At this stage, Whiting was again the only fish found in 6 such regurgitations.

Depending on wind conditions, sustained flight is possible for most birds shortly after fledging (perhaps only a few days). Young pursued at sea in speedboats for ringing have managed to rise from the waves and be briefly airborne in windy conditions, perhaps in strong winds sustained flight is possible immediately after fledging. Gannets on Ailsa have their peak of fledging around the third week in September, a period normally associated with equinoctial gales.

Almost complete data sets on chick growth in Gannets have previously only been obtained by hand-rearing chicks with food regularly presented and *ad libitum*, which may not accurately reflect the natural circumstances (Wanless, 1984). Previous published biometric data on Canadian Gannets given by Godfrey (1979) showed adult males reaching 511 mm and females 503 mm in flat wing length. Poulin (1968) measured birds to 77 days old, measuring the whole wing (ulna to wingtip) and wing from carpal to wingtip (as in this study). The wing growth data are very similar to this study but the weights of Poulin's young birds exceed those of Ailsa Craig at the same age. This may be a function of food abundance. However, wing length should be treated with caution in this context, and weight, in relation to age or size, is probably a better indication of food abundance. For example one of many starving chicks found below the cliffs on Ailsa Craig showed increase in wing and bill length and rapid decrease in weight before death, during a 9 day period (pers.obs).

Post-fledging mortality of Gannets is high. Nelson (1966) calculated that 80% of Bass Rock fledged Gannet chicks die before breeding, at around 4 - 6 years old, although starvation of birds at sea was practically unknown (Nelson, 1978b).

Ricklefs *et al* (1984) considered that the rapid growth of Blue-footed Booby chicks was an indication of good marine productivity, based on a study within the Galapagos Islands where chicks were weighed during a 23 day period, from a 100 day normal cycle (Nelson, 1978a). The Blue-footed Boobies fed close to the colonies and reproductive success was thought to reflect nearshore marine conditions. This assumes a constant or locally abundant supply of high quality fish and therefore little need to forage widely. Gannets regularly forage on the upper Clyde estuary around 60 miles from Ailsa Craig (pers. obs), so that rapid chick growth would not necessarily indicate marine conditions in the immediate vicinity of the island. Few Gannets can be observed feeding naturally close to Ailsa Craig in the breeding period. Williams and Croxall (1990) thought a positive relationship between fledging weight and post-fledging survival (in penguins) was more indicative of marine conditions, given that in "poor" years of food those chicks surviving were all good quality birds. However Gannets, Boobies and certain other seabird species lose weight to varying degrees before fledging, which may probably be related to flight capabilities rather than marine conditions. The entire hatching to fledging cycle in Gannets and Boobies requires examination since food availability may fluctuate within that period.

When making comparisons of weights from pre and post fledged birds, the status of the birds examined must be known. This is often difficult to judge. A bird found at sea near the colony of capture may have been there for some time, or even from another colony further north (all departures are in a southerly direction). Similarly birds found below cliffs, on land, are probably prematurely fledged individuals whose weight may drop considerably but whose wings will still be growing normally. The dead young Ailsa Gannets measured by Okill and Wanless (1986), even freshly dead, may have been at the base of the cliffs for a considerable period or stranded on an upper ledge before falling further and dying. Some ringed birds found below the colony on Ailsa Craig remained up to 8 days ashore before eventually leaving the island. The wing length and weight of the 4 study-site birds all fledged within the parameters of young caught at sea immediately after fledging, indicating that the process of handling the young over a 3 month period did not incur an unacceptable bias in the biometrics (see Fig. 3. 17., A and B).

Distribution and migration

Clearly many young gannets make their first flight insulated by a thick layer of fat and probably with a full stomach. Young Gannets ringed on Ailsa Craig have been recovered in Senegal, West Africa within the first calendar year of their life, as indicated by ringing recoveries. This appears to be around the southern limit of ringed birds from ca. 10,000 ringed as nestlings on Ailsa Craig. From the distribution maps of ringed chicks it is evident that few are found dead or alive anywhere near the colony in their first full summer after hatching. The nearest bird to Ailsa was some 1200 kms away (map. Fig. 3.10.), and Dr Aevar Petersen (pers. comm) reported a similar pattern in Icelandic Gannets ringed on Eldey, where the nearest first year bird was recovered 2,000 kms from the natal colony. It would be of interest to examine data from other Gannetries to ascertain if natal colony avoidance operates post-fledging until the second summer after hatching, in all areas.

Breeding success

Breeding success of Ailsa Craig Gannets appears good with more than half the monitored birds producing a young to fledging during the 3 years of monitoring.

Of the young which hatched, virtually all fledged. Loss of eggs or young from nests has been occasioned by mainly human activities e.g. by low-flying aircraft (Zonfrillo, 1992), which can have serious effects on particular areas of the colony. Eggs and small young are normally lost to gulls when the attending parent is temporarily scared from the nest. Young at any age can be dislodged by fighting Gannets pursuing each other through the colony, many adult and young are killed annually by such activity (Wanless, 1983). Up to 5 % of eggs in one study site in 1991 (n = 120) were infertile. Adults will continue to carefully incubate such eggs into late August. Numbers of young were depressed in 1993 perhaps due to a prolonged very cold wet spring which may have killed early embryos or washed away some eggs. Gannets hatch their egg by standing on top of it and heat is transferred onto the egg via the soles of the fleshy feet. The lower egg surface is possibly open to rapid chilling through a wet or damp nest base. The Gannet has no brood-patch. The breeding success rate on Ailsa Craig (Table 3. 3.) is generally good and compares favourably with data from Norway which showed similar fluctuations, with 60% in 1982, 70% in 1983 and 50% in 1985 at Skarvklakken, (Montevecchi *et al.*, 1987). (At that north Norwegian colony (Fig. 3.15), in 1985, a breeding Gannet was found to have been ringed as a chick on Ailsa Craig six years previous.).

In conclusion, the growing Ailsa colony seems to be healthy, productive and birds appear to have a good food supply.

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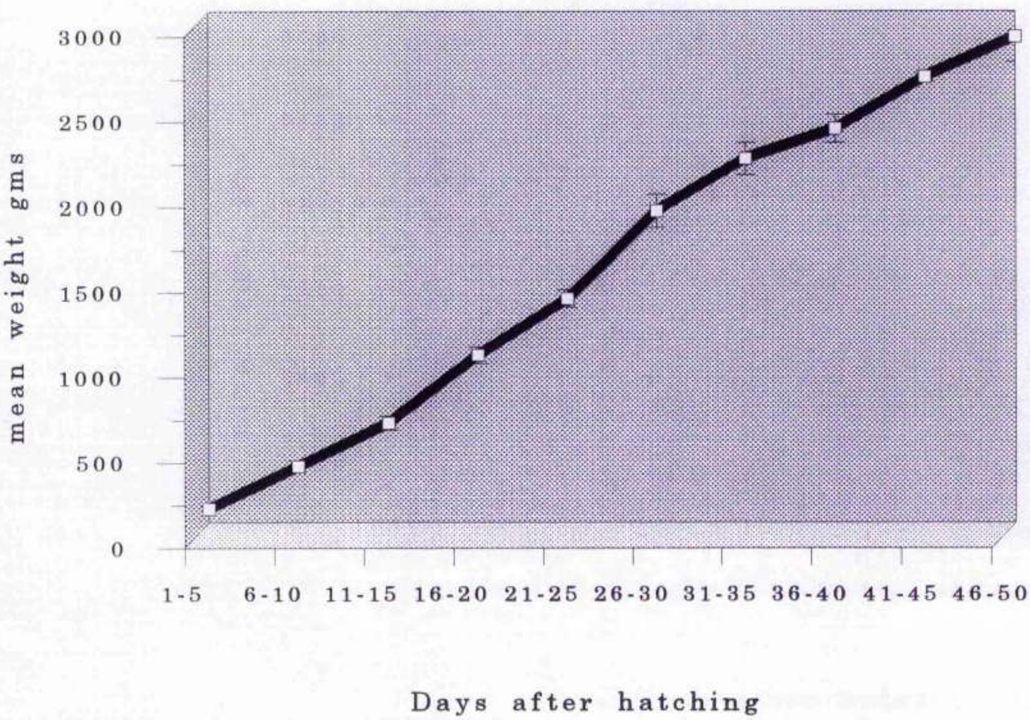


Fig. 3. 1. Mean weight of 27 Gannet chicks (+- s.e.) measured on Ailsa Craig in 1991, in relation to age.

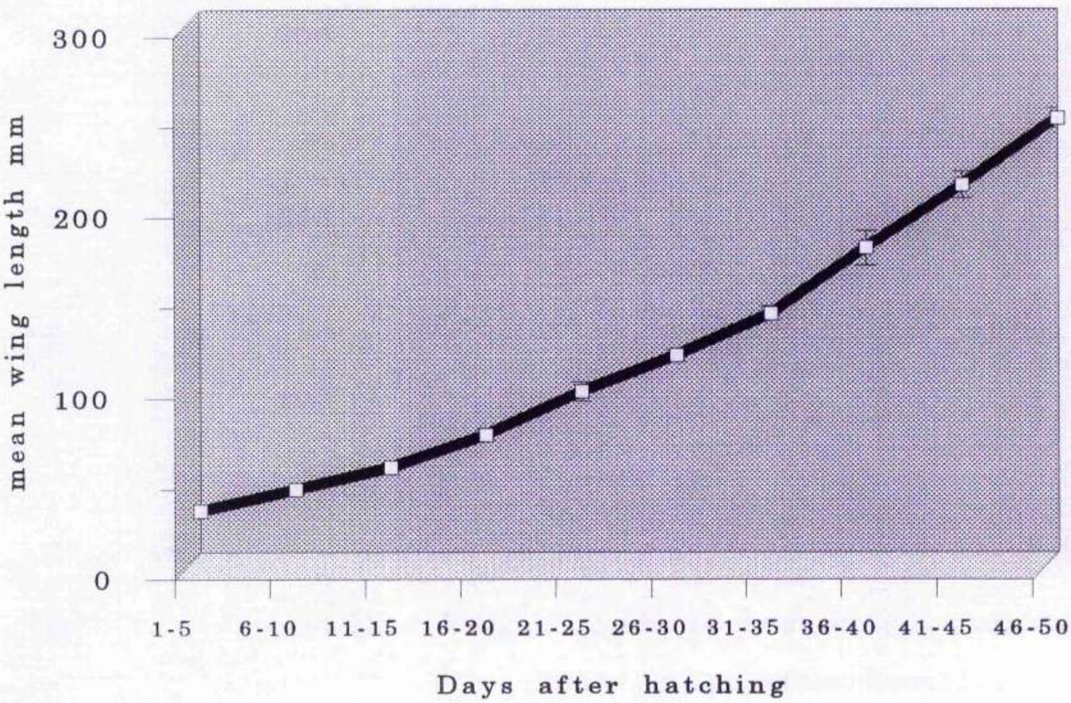


Fig. 3. 2. Mean wing length of 27 Gannet chicks measured on Ailsa Craig in 1991 (+- s.e.) in relation to age.

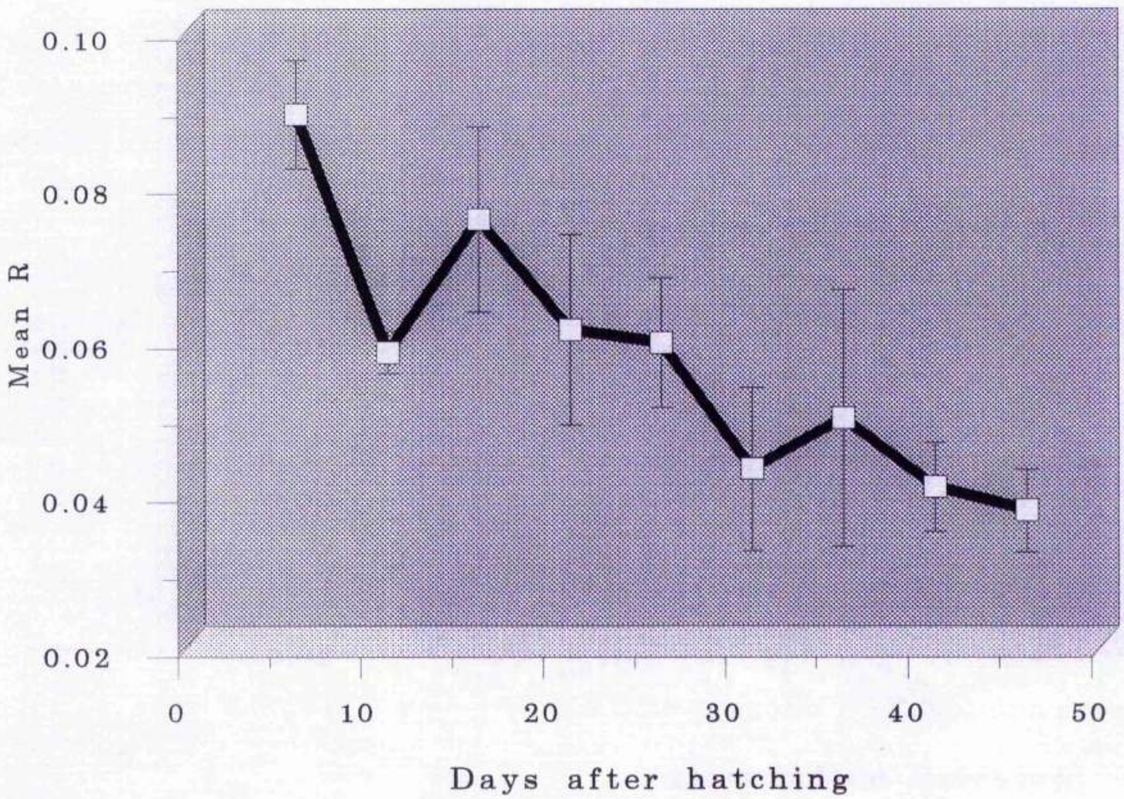


Fig. 3. 3. Mean instantaneous growth rate of the wing of 27 Gannet chicks (+ - s.e.) measured on Ailsa Craig in 1991 until 45 days.

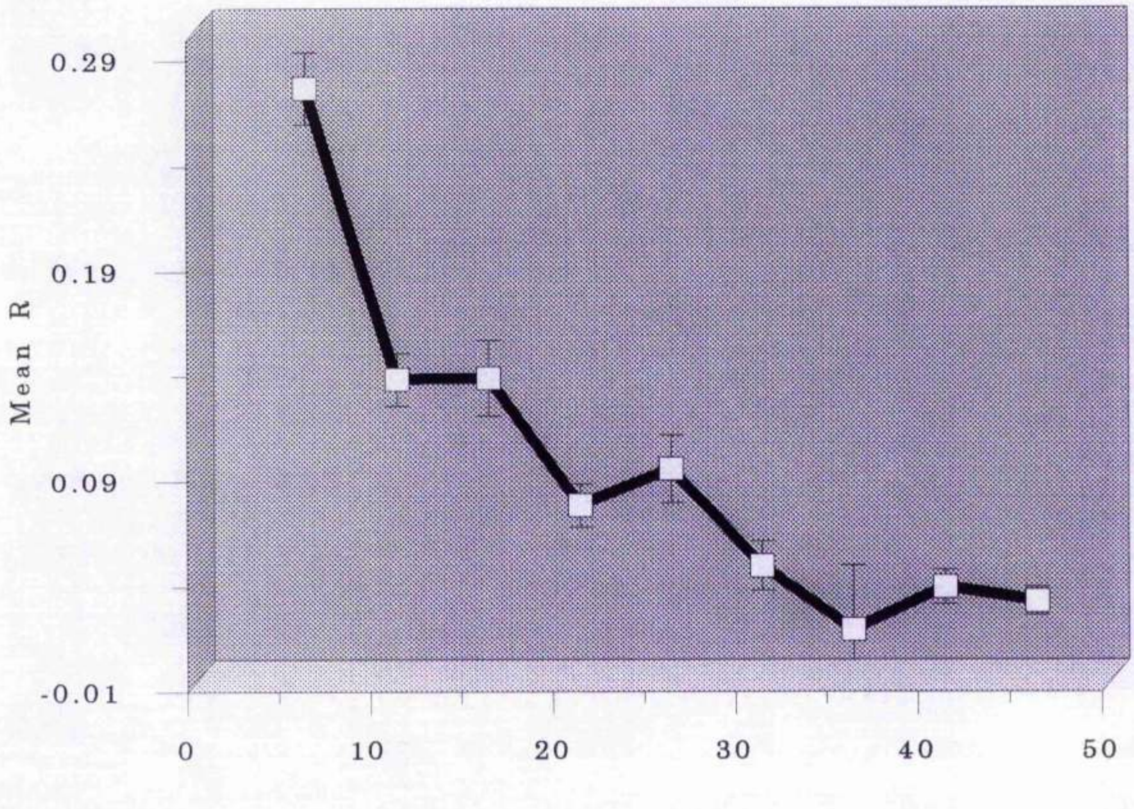


Fig 3. 4. Mean instantaneous growth rate in weight of 27 Gannet chicks (+ - s.e.) measured on Ailsa Craig in 1991 until 45 days.

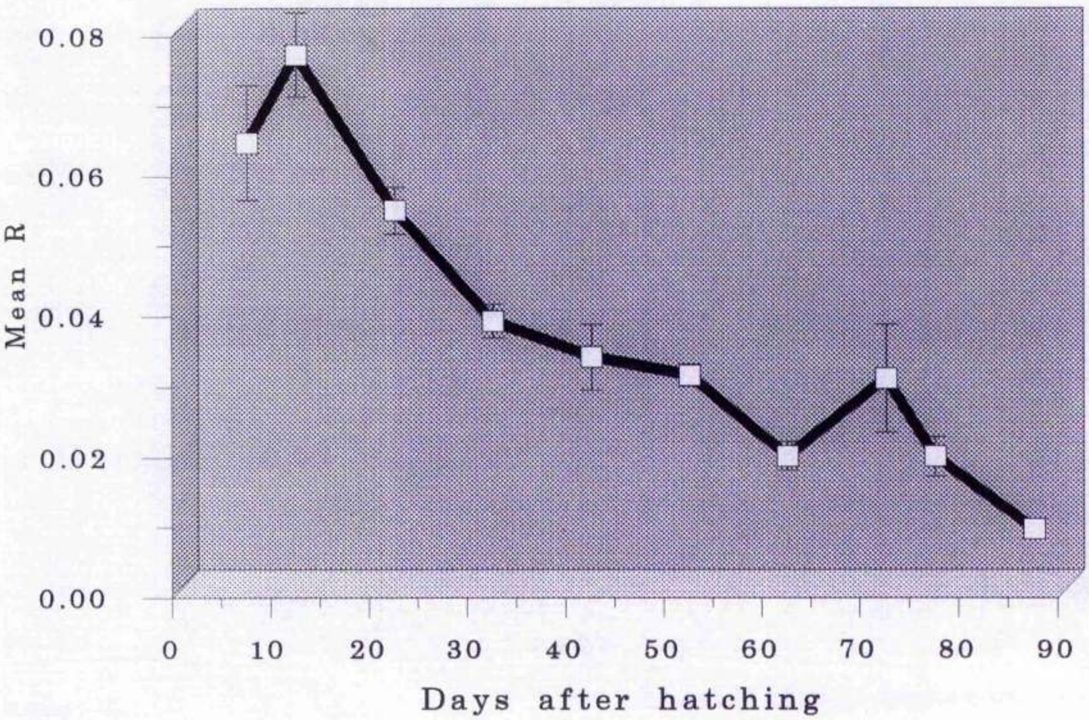


Fig. 3. 5. Mean instantaneous growth rate of the wing of 4 Gannet chicks (+- s.e.) measured on Ailsa Craig in 1993 from hatching to fledging.

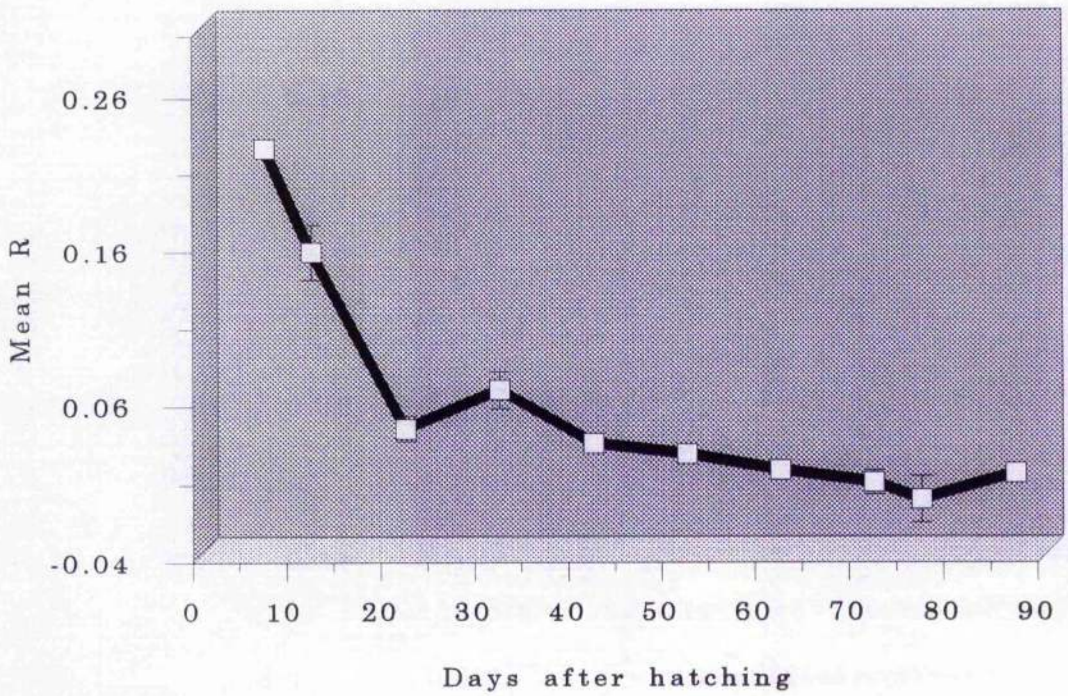


Fig. 3. 6. Mean instantaneous growth rate in weight of 4 Gannet chicks (+ - s.e.) measured on Ailsa Craig in 1993 from hatching to fledging.

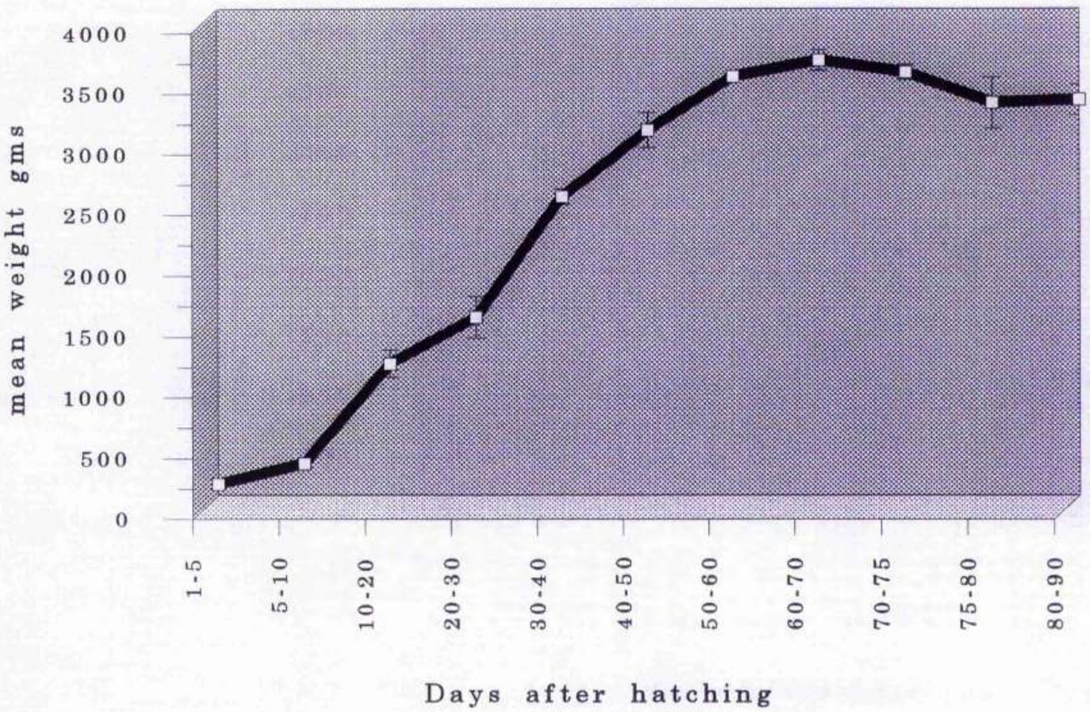


Fig. 3. 7. Mean weight of 4 Gannet chicks (+- s.e.) measured on Ailsa Craig in 1993, from hatching to fledging.

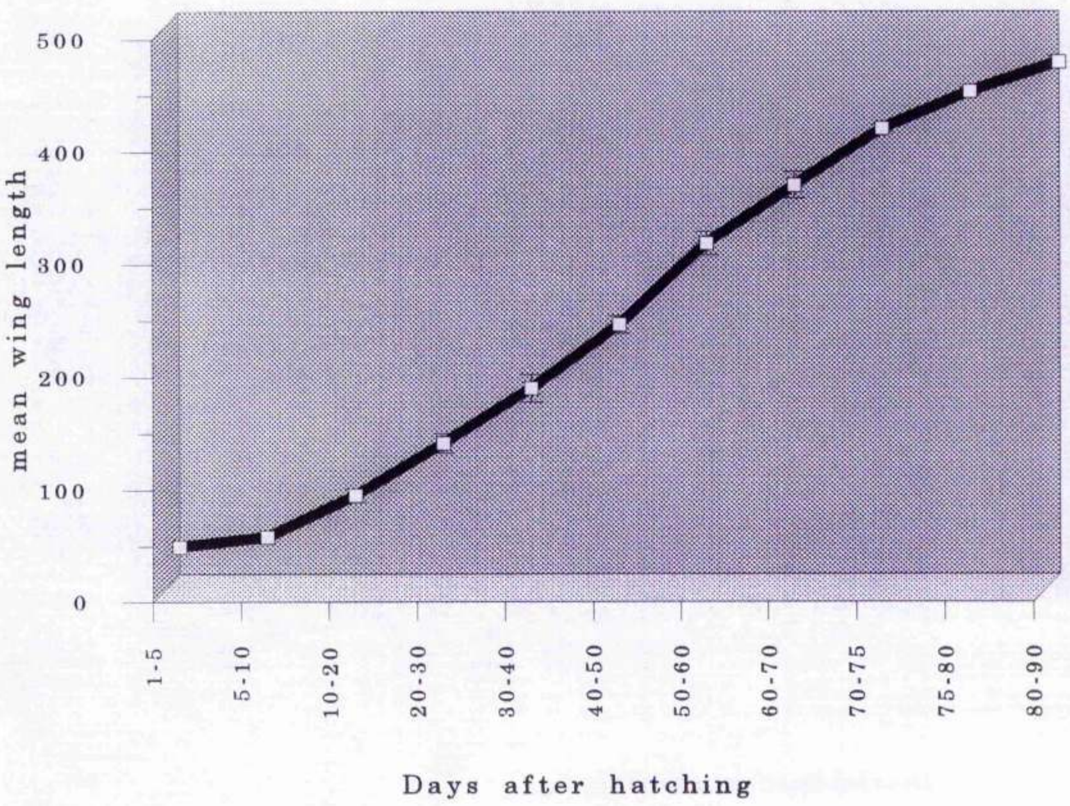


Fig. 3. 8. Mean wing length of 4 Gannet chicks (+- s.e.) measured on Ailsa Craig in 1993 from hatching to fledging.

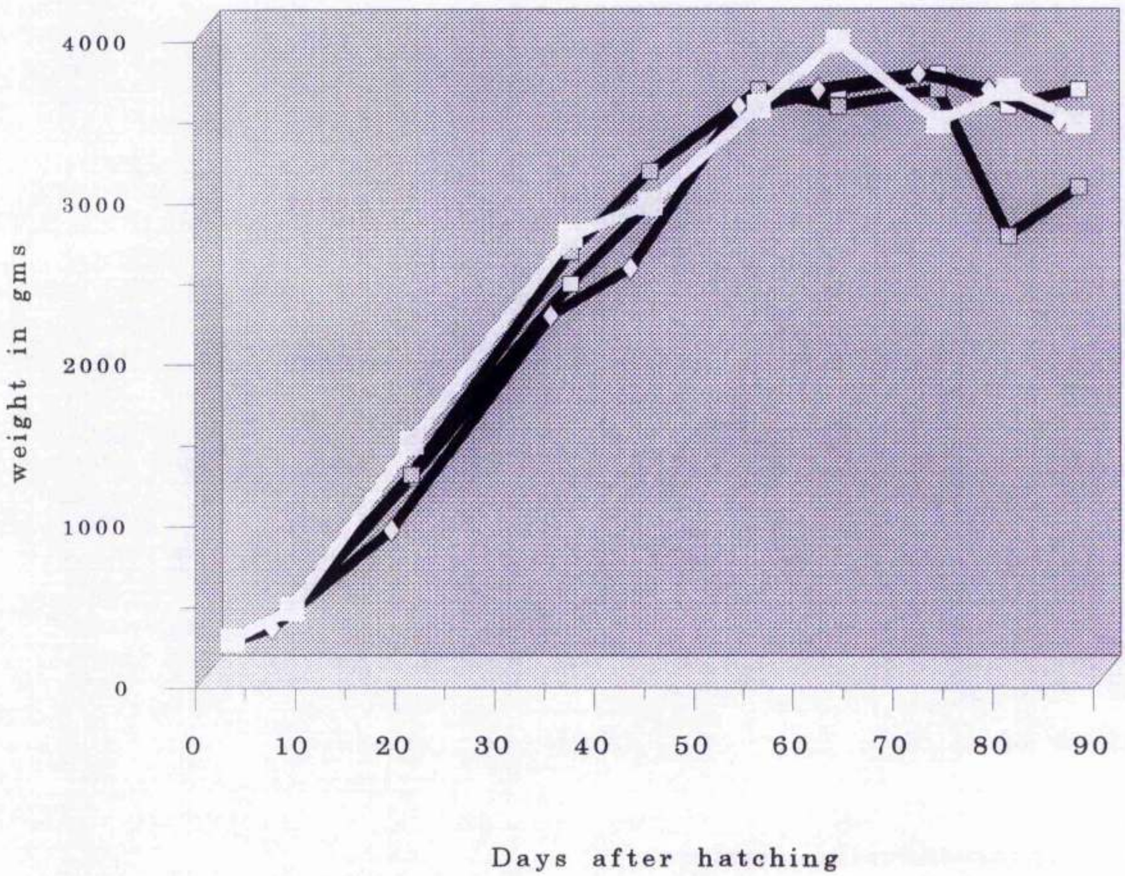


Fig. 3. 9. Weight increase of 4 individual Gannet chicks measured on Ailsa Craig in 1993 from hatching to fledging

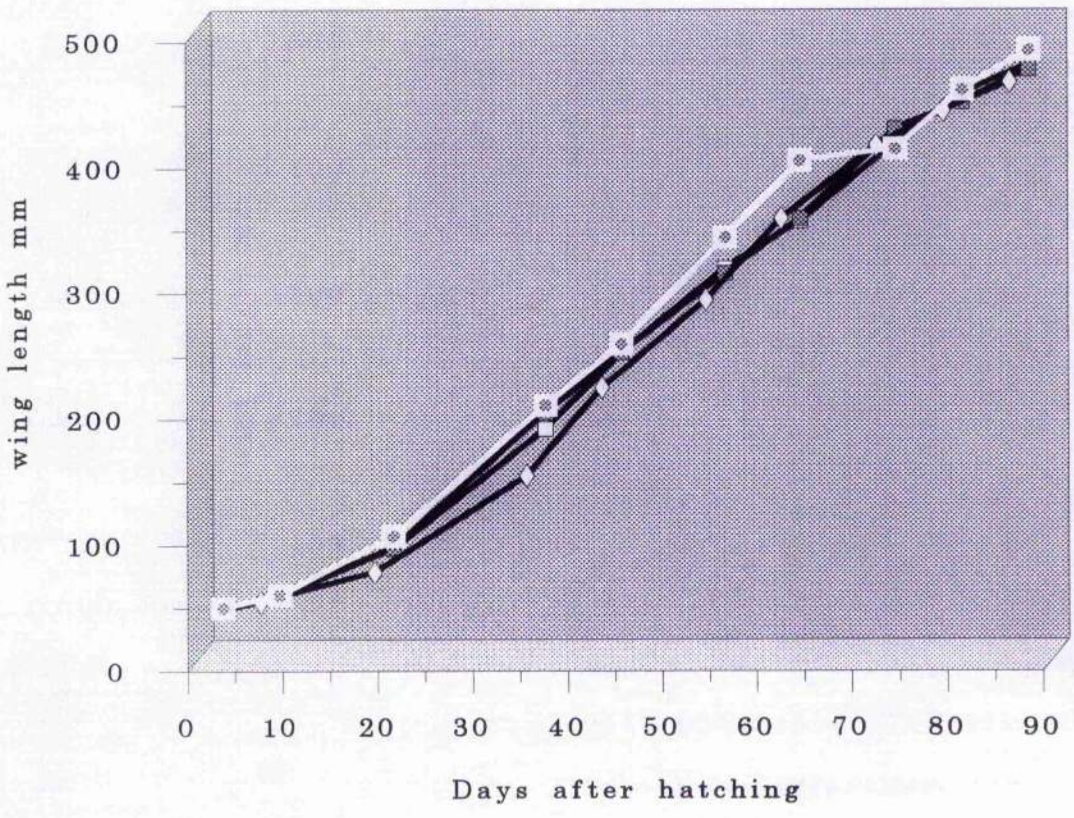


Fig. 3. 10. Wing growth of 4 individual Gannet chicks measured on Ailsa Craig in 1993 from hatching to fledging.

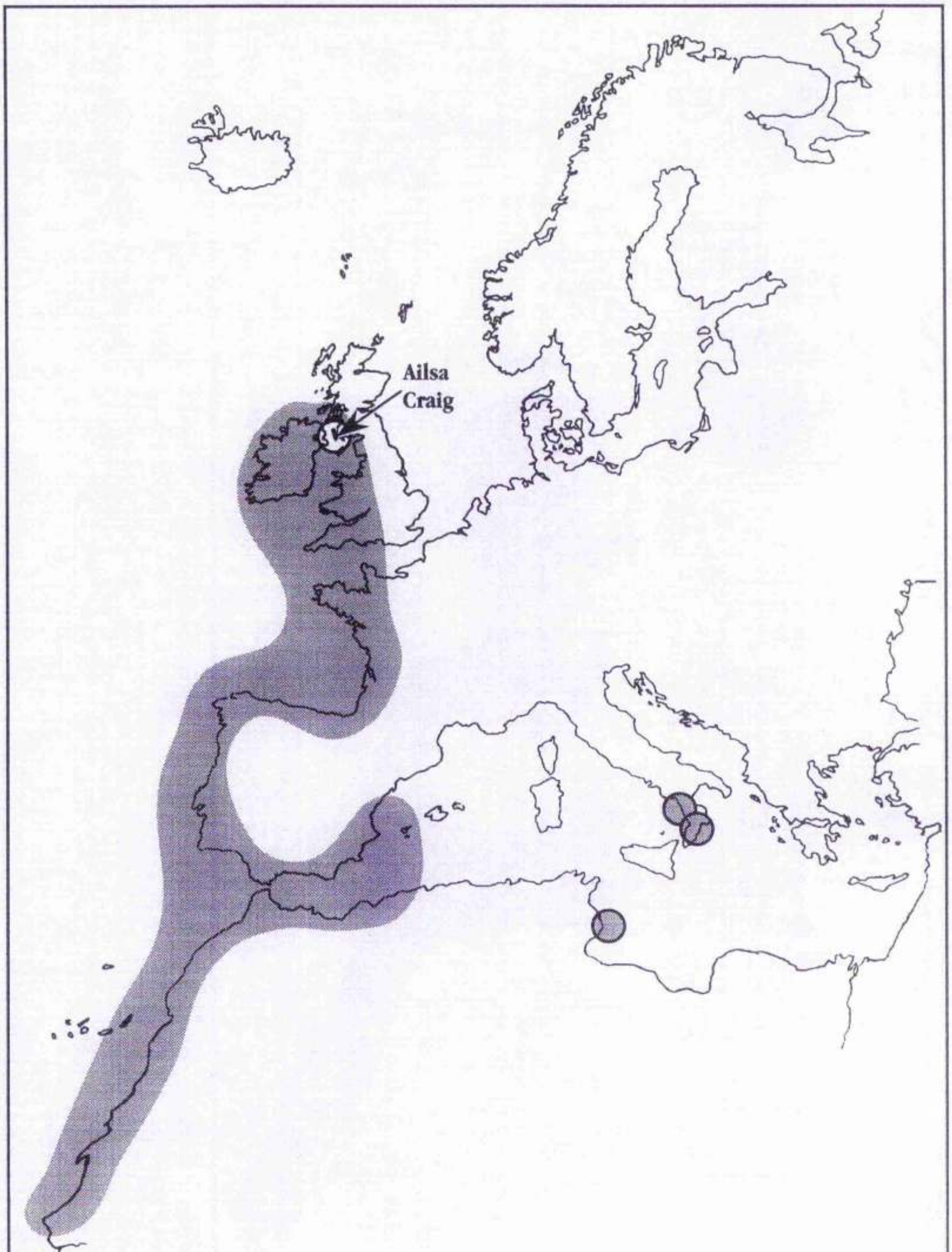


Fig. 3-11 Distribution of 168 Gannet recoveries in first calendar year of life. Shading represents general area of recovery. Shaded dots are individual records.

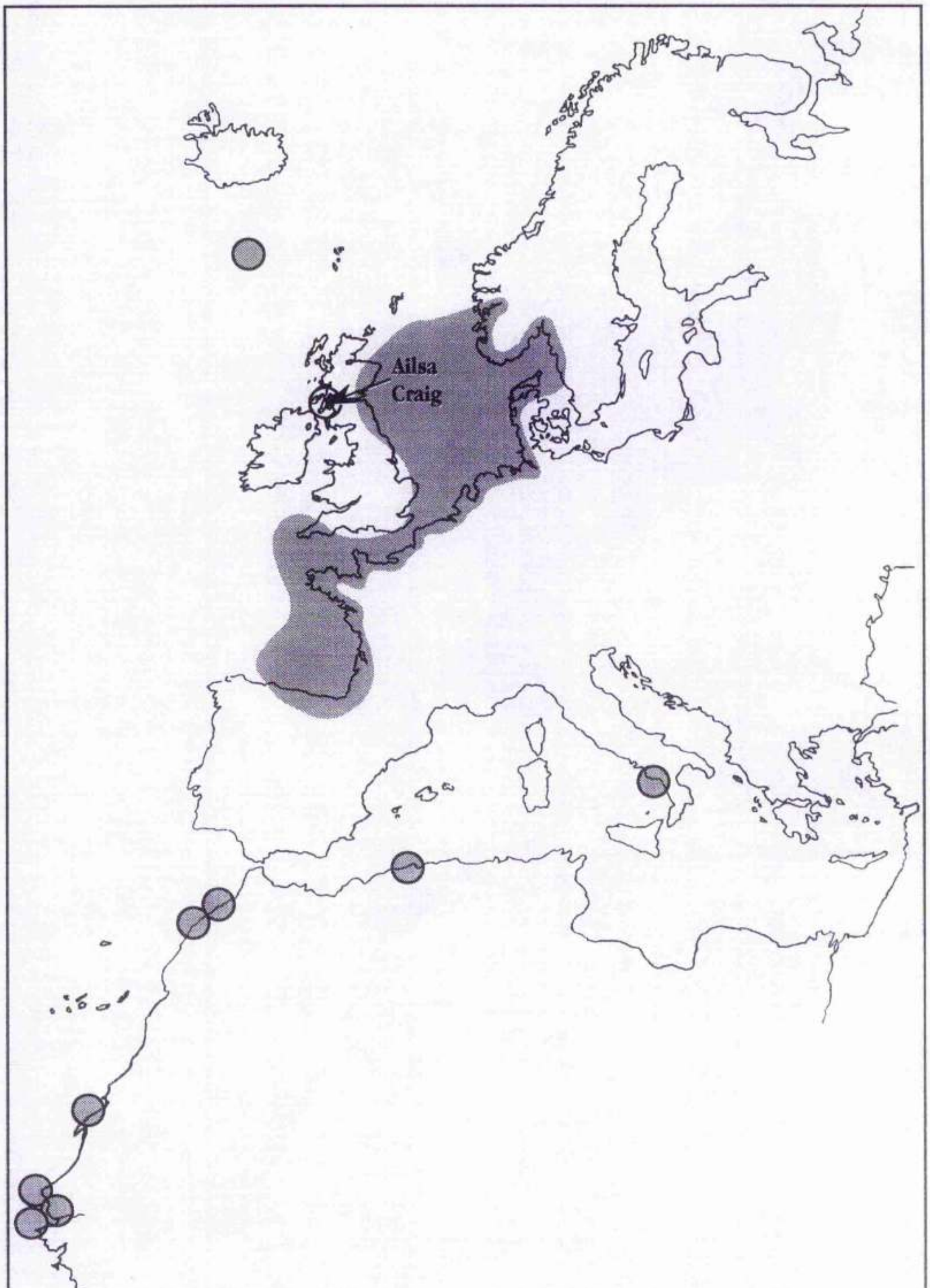


Fig. 3-12 Distribution of 35 Gannet recoveries in second calendar year of life. Shading represents general area of recovery. Shaded dots are individual records. Note absence of recoveries near the natal colony.

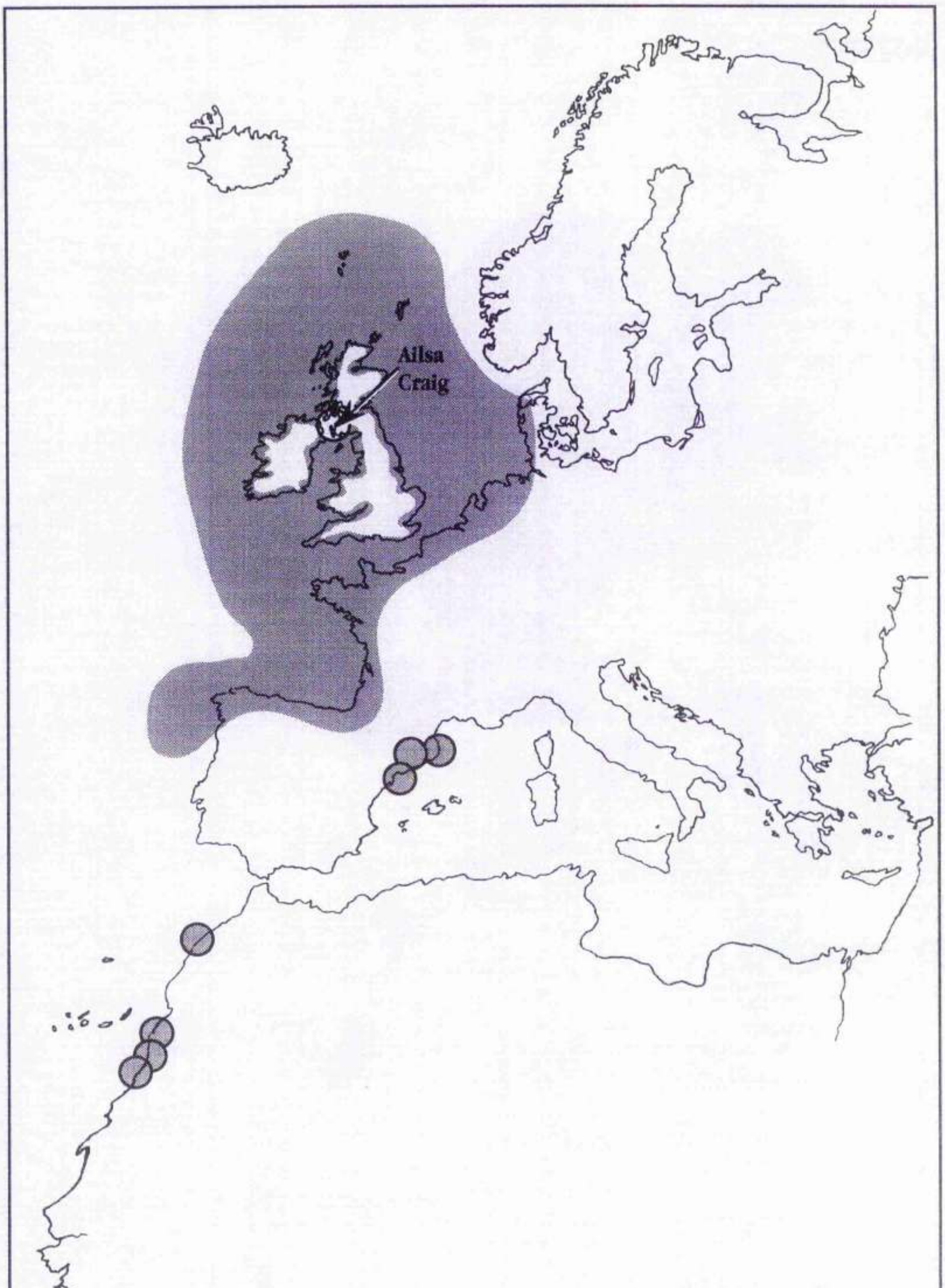


Fig. 3-13 Distribution of 32 Gannet recoveries in third calendar year of life. Shading represents general area of recovery. Shaded dots are individual records.

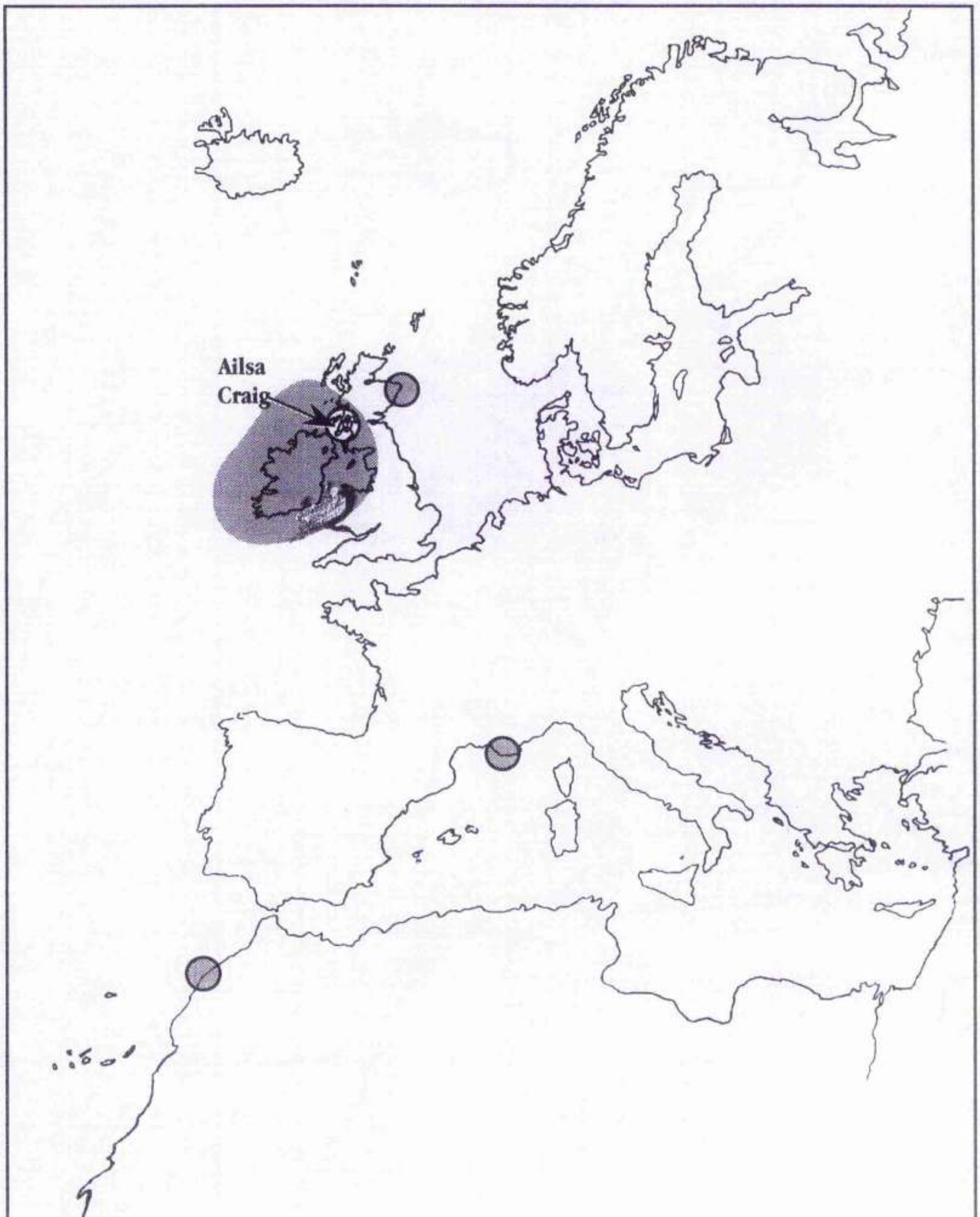


Fig. 3-14 Distribution of 14 Gannet recoveries in fourth calendar year of life. Shading represents general area of recovery. Shaded dots are individual records.

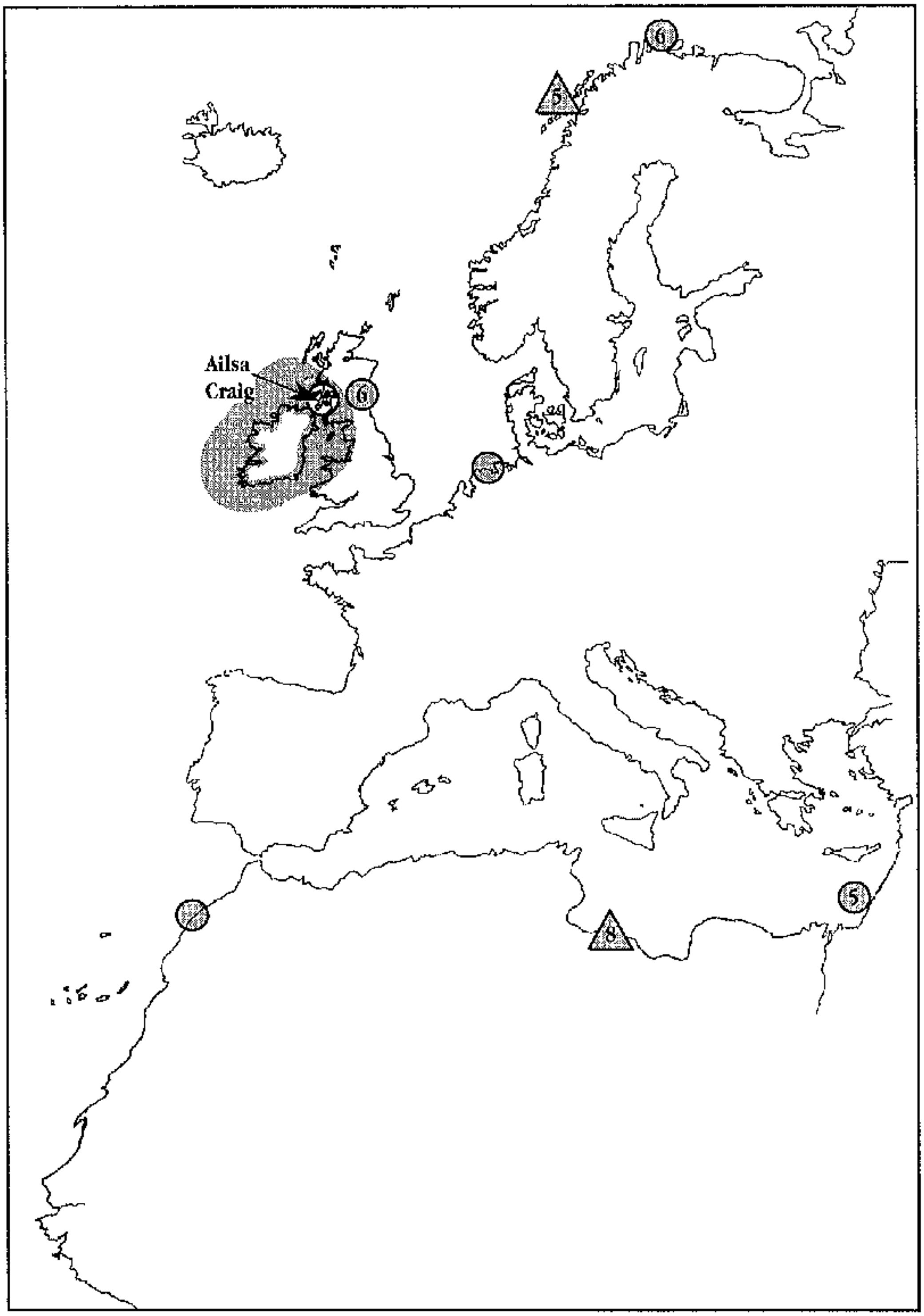


Fig. 3-15 Distribution of 16 Gannets recovered or controlled after 4 years old and under 10 years old. Numbers refer to age of bird found. Shading represents general area of recovery. Shaded dots are individual records and the triangles in Norway and Libya refer to the same bird.

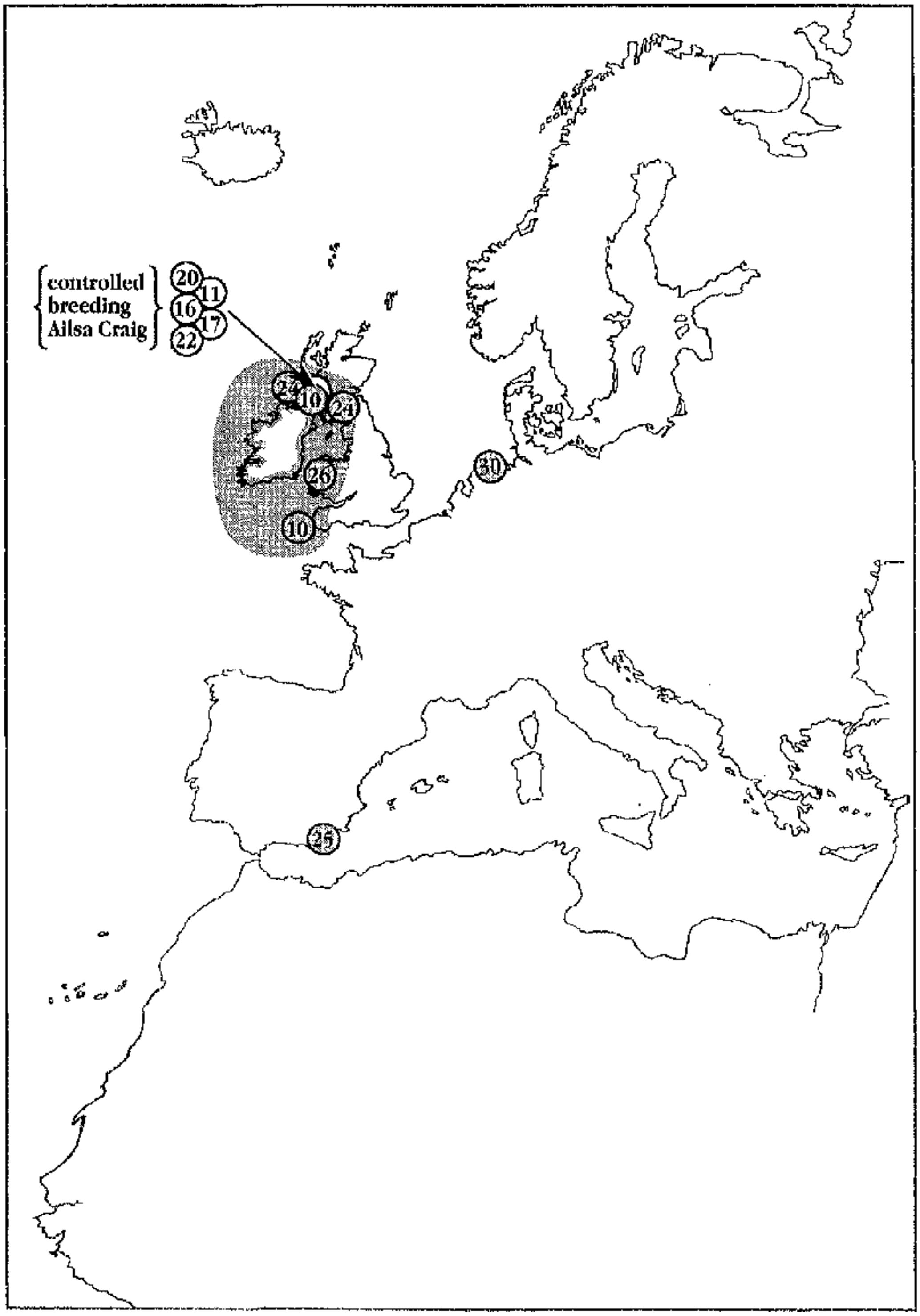
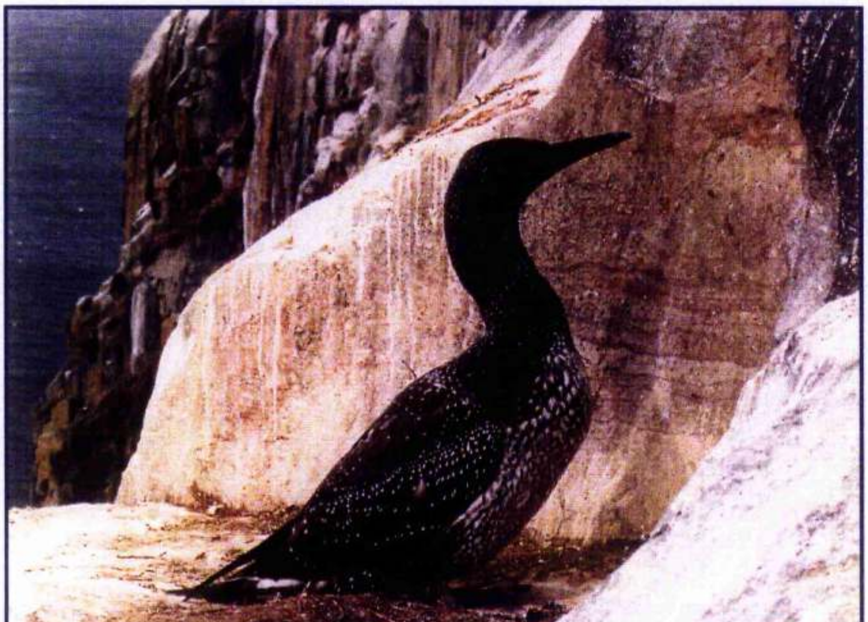


Fig. 3.16 Distribution of 14 Gannets recovered or controlled over 10 years old . Numbers refer to age of bird found. Shading represents general area of recovery. Shaded dots are individual records. (2 recoveries not individually recorded were skeletons of uncertain date).

A.



B.

Fig.3-17 A. Top Half grown Gannet chick.
B. Lower. Same chick as above at 88 days-three days before fledging

Chapter 4.

Diets of adult and chick Herring Gulls *Larus argentatus argenteus* on Ailsa Craig, south-west Scotland

This work was done in collaboration with Manuel Nogales.
[A condensed version of this chapter has been published in SEABIRD. No. 17:1995, 56-63 by *M. Nogales, B. Zonfrillo and P Monaghan*]

4. 1. Introduction

The Herring Gull *Larus argentatus*, is widely distributed over the Holarctic region (Cramp and Simmons 1983), and, although in terms of breeding biology and behaviour, is a relatively well-studied species, its diet has received comparatively little detailed attention over much of its range. There are no published studies from the Firth of Clyde area but Armstrong (Unpublished PhD Thesis - 1992) examined diets of Herring Gulls on Sanda Island. While in the UK as a whole the Herring Gull appears to be in decline (Lloyd *et. al.*, 1991) this does not seem to be the case in the Clyde area. Also in this area, the extent of the population of large gulls in the first half of this century was considerably less than elsewhere in the UK (Monaghan and Zonfrillo, 1986). Some dietary studies have been made in Europe, e.g. Spärck 1951, Ehlert 1961, Harris 1965, Andersson 1970, Spaans 1971, Spitzer 1976, Mudge and Ferns 1982, but there has been little information on the diet of both chicks and adults during the breeding season, (see Spaans 1971; Monaghan 1977). There is also some contradiction, one researcher having concluded that the diet of chicks is similar to adults (Threlfall, 1968), while others have reported the contrary (Ehlert 1961; Spaans 1971).

The aim of this study is to describe the food spectrum of adult and chick Herring Gulls on Ailsa Craig, by analyses of pellets, regurgitations and prey remains during a single season.

4. 2. Methods

Field work was carried out on Ailsa Craig, Strathclyde Region, from 17 May to 6 August 1991. The first chick hatched on 24 May with most hatched by 5 June. Around 2,000 pairs of Herring Gulls breed on the island, mainly on the upper vegetated slopes and screes, but also around the boulder beach below the cliffs surrounding the island. Three study plots were demarcated. The first was below the bird cliffs on rock screes (40 nests), the second was above the cliffs in an area of large boulders (10 nests) and the third was on a more open grassy slope below the summit (20 nests). These areas were chosen to avoid any possible confusion with the nests of Lesser Black-backed Gulls, which were mainly in discreet sub-colonies.

The dietary data of these 70 nests is based on analysis of 408 adult pellets collected around the nests each fifteen day period, 125 regurgitations from 42 chicks, obtained by weekly monitoring of chick growth, and 83 prey remains.

" Prey remains " are here defined as items of food collected at the nest but of uncertain origin being neither pellets from adults nor regurgitations of chicks (for example, remains of mammals or large fish skeletons which may have been delivered or regurgitated at the nest by adults and then pecked clean by chicks or ignored by them). The prey remains found around the nests were removed weekly for studying the variation in the prey selected.

Pellets were collected at 15 day intervals, sealed individually in plastic envelopes, and analysed using a x 8 binocular microscope shortly after collection. Chicks can also produce small pellets at very early ages (Goethe, 1937) Therefore the few, (< 10), very small pellets found during the entire period of the study were excluded from the analyses. After the chicks are older than 4 weeks, they attain a similar body size to adults, but their pellets are usually still much smaller. To avoid any possible confusion as to the origins of the few small pellets they were not itemised. The food composition of the chick regurgitations obtained during the present study (soft food) suggested that the chicks were fed little indigestible material. Two sites near nests at the base of the bird cliffs were those of egg-specialist Herring Gulls. Undeveloped egg contents would not be evident in pellets but fragments of eggshell were recorded in pellets from 15 days after the chicks had hatched.

Data on the food of chicks and adults are only comparable to a certain degree due to the fact that soft-bodied animals, such as earthworms Oligochaeta, marine invertebrates such as some jawless Polychaetes, and discarded fish offal, do not appear in pellets. However, similar studies of Western Gulls by Annett and Pierotti (1989) and of Herring Gulls by

Spaans (1971) concluded that pellets do reflect the adult dietary compositions and they are particularly useful for examining seasonal variation in diet.

The development and growth rate of the chicks from hatching was studied by measuring the wing length and weight each week. Eight chicks were weighed and measured weekly at least 6 times. The term "white fish" used in this study defines mainly Gadoids but also all other discarded commercial species. Where not specified, "meat" is usually that of birds, rabbits and farmed animals.

4. 3. Results

Adult Herring Gulls are omnivorous but there is a marked difference between parental diet and that of chicks (see Tables 4.1, 4.2. and 4.3.). While the food spectrum of the chicks was largely based on white fish and meat, the adult pellets frequently included vegetable material and refuse (inorganic material such as foil, concrete, glass and plastic), two components which were not common in the chick diets.

The main items taken by adults (Table. 4.3.)showed a significantly greater proportion of pellets containing bird meat, coleoptera and vertebrate food in the last 3 periods (3 June - 16 July) than in the first (X^2_3 = 16.18, $p<0.01$ for birds, X^2_3 = 64.68, $p<0.001$ for Coleoptera, X^2_3 = 24.21, $p<0.001$, for all vertebrate matter). In contrast, the frequency of vegetable fibres and refuse varied little throughout the breeding period (Table 4.3). A few distinctive, unworn fish otoliths were identified with certainty during the analysis of the pellets, and these were Gobies *Gobius* sp. (2 otoloiths), Cod (4), Dragonet (7), Whiting (6), Flounder (1) and Mackerel (2). Part of the "bird" remains (4.9 % in frequency of occurrence) were eggshells. Observations showed the remains of 64 eggs near one nest at the base area to be those of Guillemot (39%), Gannet (34%), Razorbill (14%), Fulmar (6%), Kittiwake (5%) and gulls *Larus* spp. (2%). Most of the fish regurgitated by the chicks was muscle tissue which is difficult to identify to species level. Four species were recorded, confirmed by attached distinctive skin and scales: Dragonet, Mackerel, Whiting and Herring.

The results from regurgitation analyses show a marked dietary change in food composition with chicks of 1-2 weeks old, fed fish and worms, chicks of 3-4 weeks old, where the diet showed an equal percentage of meat and fish, and chicks of 5-6 weeks old, where meat was more important than fish (Fig. 1) . These frequencies of occurrence shown a clear, very highly significant difference (X^2_2 = 26.91, p< 0.001). The prey remains seen around the nests reflect the regurgitation data. Invertebrates, marine and terrestrial, were not very important quantitatively in the general context of the chicks' overall diet, appearing mainly during the first two weeks. However their function in the chick development may be crucial. They may provide small but essential quantities of minerals and vitamins necessary for growth.

Table 4.1. Analysis of the diet of herring gull chicks on Ailsa Craig showing percentage occurrence of the different food components identified in the chick regurgitations each week. The first week began on 2 June 1991. (- = zero.)

	Age of chicks (weeks)						
Food	***First***	***Second***	***Third***	***Fourth***	***Fifth***	***Sixth***	***Total***
Fish	68.2	52.2	47.1	40.0	26.1	8.0	39.2
Meat	9.1	21.7	41.2	40.0	60.8	76.0	42.4
Gannet pulli	-	-	-	20.0	4.3	16.0	6.4
Guillemot pulli	-	-	-	-	4.3	-	0.8
Rabbit (only)	-	-	-	-	-	4.0	0.8
Invertebrates							
Crustacea	13.6	4.3	11.8	-	-	-	4.8
Coleoptera	4.5	4.3	-	-	4.3	-	2.4
Lepidoptera	4.5	8.7	-	-	-	-	2.4
Hymenoptera	-	4.3	-	-	-	-	0.8
Cephalopoda	9.1	8.7	-	-	-	-	3.2
Gastropoda	-	-	-	-	4.3	-	0.8
Oligochaeta	13.6	-	-	-	-	-	2.4
Plant Material							
Vegetable matter	-	8.7	-	-	-	-	1.6
Bread	13.6	4.3	-	-	4.3	16.0	7.2
Non-foods							
Rubbish/refuse	-	-	-	-	4.3	-	0.8
Total No of regurgitations examined.	**22**	**23**	**17**	**15**	**23**	**25**	**125**

As the chick develops the percentage of fish in the diet decreases and the percentage of meat increases (Fig.4. 1). The growth curve (Fig.4. 2) shows that the chicks increased in weight on the diet they received during this season and fledged successfully.

Table 4. 2. Analysis of prey remains at nests with chick Herring Gulls on Ailsa Craig showing percentage of occurrence of the different food components detected as prey remains at the nests. The first week began on 2 June 1991.

	Age of chicks (weeks)						
Food	***First***	***Second***	***Third***	***Fourth***	***Fifth***	***Sixth***	***Total***
Fish	80.0	63.6	53.8	45.5	40.0	16.6	48.2
Meat	6.7	36.4	46.2	45.5	60.0	44.4	39.8
Gannet (chicks)	-	-	-	9.0	-	22.2	6.0
Guillemot (pulli)	-	-	-	-	-	5.6	1.2
Razorbill (pulli)	-	-	-	-	-	5.6	1.2
Rabbit (only)	-	-	-	-	-	5.6	1.2
Crustacea	13.3	-	-	-	-	-	2.4
Total Samples	**15**	**11**	**13**	**11**	**15**	**18**	**83**

Table 4. 3. Analyses of pellets from adult Herring Gulls breeding on Ailsa Craig showing percentage occurrence of food and non-foods consumed. The first period began on 20 may 1991. The post-hatch period is in the second 15-day stage.

	15 day period number				
Food	*First*	*Second*	*Third*	*Fourth*	*TOTAL*
Total Mammals	7.2	11.2	5.5	7.1	7.6
Rat	-	3.3	0.9	-	0.5
Rabbit (only)	1.2	3.3	-	-	0.5
Total Birds	7.2	15.7	22.9	24.4	18.6
Poultry	-	3.3	2.8	4.7	2.5
Egg fragments	-	9.0	6.4	3.9	4.9
Nestlings	-	5.6	6.4	11.0	5.6
Total Fish	30.1	15.7	25.7	18.1	22.3
Gadoids	3.6	3.4	9.2	3.9	5.2
Tot. Crustacea	8.4	12.4	7.3	3.9	7.6
Nephrops norv.	6.0	2.2	3.7	2.4	3.4
Cancer pagurus	-	2.2	-	0.8	0.7
Ligia oceanica	1.2	2.2	2.8	0.8	1.7
Total Mollusca	6.0	1.1	1.8	2.4	2.7
Littorina sax.	3.6	1.1	-	-	1.0
Polychaeta	1.2	-	-	-	0.2
Total Insecta	24.1	60.7	74.3	74.0	61.0
Coleoptera	24.1	60.7	74.3	74.0	61.0
Other insects	1.2	2.2	0.9	-	3.9
Total Animal	79.5	87.6	95.4	97.6	91.2
Plant fibres	62.7	73.0	69.7	73.2	70.1
Wheat and Chaff	1.2	2.2	0.9	2.4	1.7
Seeds	2.4	2.2	3.6	-	1.5
Algae	2.4	1.1	-	1.6	1.2
Total Plants	73.5	77.5	77.1	77.2	76.5
Non-foods					
Paper	25.3	18.0	18.1	16.5	19.1
Glass	14.5	10.1	11.0	14.2	12.5
Aluminium foil	15.7	14.6	6.4	14.2	12.5
Plastic	13.3	3.4	2.8	6.3	6.1
Polythene	15.7	15.7	23.9	27.6	21.6
Other items	8.4	-	4.5	6.3	4.9
Total Rubbish	47.0	40.4	46.8	46.5	43.1
Grit	50.6	51.7	23.9	39.4	40.2
Total No of Pellets	**83**	**89**	**109**	**127**	**408**

4. 4. Discussion

The results from the present study show differences in the diet of the adult Herring Gulls and that of their chicks. It appears that parents select foods with the highest possible nutritional value and lowest possible indigestible material to provision their young. These data agree with the ideas of Spaans (1971) and Noordhuis and Spaans (1992) in the Netherlands. Monaghan (1977) saw garbage as second in importance (34% of the regurgitations) in an urban colony, demonstrating the wide adaptability of Herring Gulls to exploit available food supplies in different situations. Observed differences in diet between adult and chicks may be due to non-random feeding by adults. By feeding themselves first, after leaving the nest site during chick rearing, and then gathering foods more suitable to the requirements of the chick the items retained may thus be separated. Observations from the upper study area showed that after adults fed the chicks they consistently washed, preened and then foraged on the littoral zone at the base of the island, the latter pattern governed only by tidal conditions. After a period of around one hour they would regularly fly out to sea. If suitable but large prey were soon caught e.g. a commercial sized fish from a trawler, this could not be immediately fed to the young chick but regurgitated at the nest, and may be the origins of the " prey remains".

The presence of important quantities of fish in the diet Herring Gull chicks has been commented upon by Spaans (1971); Noordhuis and Spaans (1992) and Monaghan (1977). In this study, the progressive change from white fish to meat may be due to various reasons. Firstly, fish and earthworms are food presumably easier for a young chick to digest than a more cohesive substance such as mammal meat. Spaans (1971) postulated that during the digestion of fish bones, substances might be released that are of importance for building the skeleton, the development of which does not terminate until the sixth week. The development of the digestive system in the chick may take time to become sufficiently adapted to handling solid foods. The tendency of switching from fish to meat may correspond with different energetic requirements in the growth rate of the chick. As the chick grows its maintenance requirements will also increase and this may be satisfied with different foods. Herring Gulls do not generally actively catch live commercial sized fish (Witt *et al.*1981) thus most such fish probably originated from scavenging behind fishing vessels. The energy expended in this form of foraging is probably very high and the intra and inter-specific competition is undoubtedly intense. All fish species taken are frequently caught by fishing vessels in the Firth of Clyde during summer, and from their size, all appear to indicate that they are scavenged by the gulls from boats. Observations of birds at the trawlers operating within close range of the island show large numbers of Herring Gulls, Lesser Black-backed Gulls, Great Black-backed Gulls, Kittiwakes and Gannets constantly in attendance. These species assemblages also make up most of the summer scavenging seabirds around trawlers in northern waters, (Hudson and Furness, 1988a).

Hudson and Furness (1988b) found that Herring and Lesser Black-backed Gulls were dominated by their more aggressive competitors, Fulmars, Great Black-backed Gulls and Gannets. After the chicks are approximately three weeks old, energy expenditure may perhaps be reduced by the adults going to the mainland (15 km away) where food can be found more easily. This kind of food is usually meat (processed human food), mainly pork and poultry remains. However part of these types of foods could originate from the frequent passenger ferries which cross the Firth of Clyde, and from Scotland to Ireland. The distance from Ailsa Craig to the mainland is not great. The foraging range of the Herring Gull has been estimated at 40 km (Witt *et al.* 1981) and 30-60 km (Götmark 1984). In Western Gulls, which are similar in size to Herring Gulls, a switch from "garbage" in the pre-hatching period to marine fish after chick hatching was highly significant (Annett and Pierotti 1989). Noordhuis and Spaans (1992) found that Herring Gulls on the Dutch coast switched from bivalves to marine fish for their young, immediately after the hatching of the first chicks, and that birds whose eggs were prevented from hatching showed no dietary change.

The food spectrum of the adults showed them to be omnivorous. The occurrence of young birds as food in the last three periods coincides with the availability of eggs and chicks of most other seabirds on the island. Opportunistic feeding by gulls on resources abundant temporarily has also been mentioned by Andersson (1970) and Götmark (1984). The avian material in the diet was mainly eggshell and chicks, but some bird meat probably originated from the many seabird carcasses on the island. Food specialisation by certain Western Gulls in California showed them selecting Pigeons *Columbia livia* and mice *Mus* sp. (Annett and Pierotti, 1989). Selective predatory behaviour of Herring Gulls has also been described by Rogers (1968), Cleeves (1969) and Kosonen (1983). Only a very few Herring Gulls specialised in egg stealing on Ailsa Craig, and have done so for many years (Gibson, 1951).

An item of food more difficult to explain is the presence of many coleoptera beetles in the adult pellets during the last three periods. These may be specifically sought after by the gulls or may simply reflect their local abundance. The presence of quantities of insects in the pellets may indicate dietary switching after the chicks hatch. Insects are probably consumed immediately after the period when chicks have been fed. Chicks are clearly not fed quantities of insects nor inorganic items, which the adult will continue to consume regularly during the chick rearing period.

The high frequency of vegetable matter (mainly grasses) is also quite difficult to explain because these types of food could be ingested incidentally together with the invertebrates or other soft-bodied items (for instance caterpillars), or may have been consumed deliberately. It is interesting to note that other researchers have found important quantities of vegetable material in the pellets of this species (Rintoul and Baxter, 1925; Someren, 1930; Gillham, 1952; Davis, 1956; King, 1969; Morton and Hogg, 1989; Noordhuis and Spaans, 1992). It may be that material such as grass helps pellet formation for ridding the crop of the indigestible carapaces and legs of many insects, which may irritate the proventriculus. Virtually all grass pellets examined had insect remains intermingled to some extent. Armstrong (1992) found "grass" and grain were major components of the adult Herring Gull diet on Sanda, the former always containing earthworm remains. Sanda has some arable land where gulls could forage and much arable land a short distance away on mainland Kintyre.

The origins of the food of the adults shows a high percentage dependent on man's activities. Much of the food may originate from the rubbish tips near the towns of Ayr, Girvan and Stranraer on the mainland. There are also abbatoirs in the Girvan area, from which much of the meat eaten by adults and fed to chicks may be derived. The use of this feeding strategy has been observed in other parts of the species' range as in the north west of Europe (Monaghan, 1977; Mudge and Ferns, 1982; Lüttringhaus and Vauk-Hentzelt, 1983) or the Mediterranean area (Isenmann 1976; Witt *et al.*, 1981). While soft material digested by adults would not show in pellets, hard material such as insects and inorganic refuse would show in chick regurgitations. The fact that the latter were not important in the chick diet appears to indicate a deliberate decision by the adults on what foods are given to their chicks.

During the breeding period, others researchers have commented that in some areas of Europe, Herring Gulls consumed food mainly of "natural" origin (marine invertebrates, fish, insects, etc.) (Conder, 1952; Meijerin, 1954; Ehlert, 1961; Spitzenberger, 1961; Löhmer and Vauk, 1970; Wietfeld, 1977). This has also been observed in the Atlantic Ocean (Mougin and Stahl, 1981; Hamer *et al.,* 1989) and some areas of North America (Mendall, 1939). Armstrong (1992) found naturally-taken sandeels were of major importance for chicks on Sanda with crustaceans scavenged from trawlers of importance for adults. Sandeels were not observed in the diets of Ailsa gulls. The ingestion of items of non-food such as glass and concrete (some pieces as large as the proventriculus) are presumably an extension of the normal intake of small stones and grit for the gizzard.

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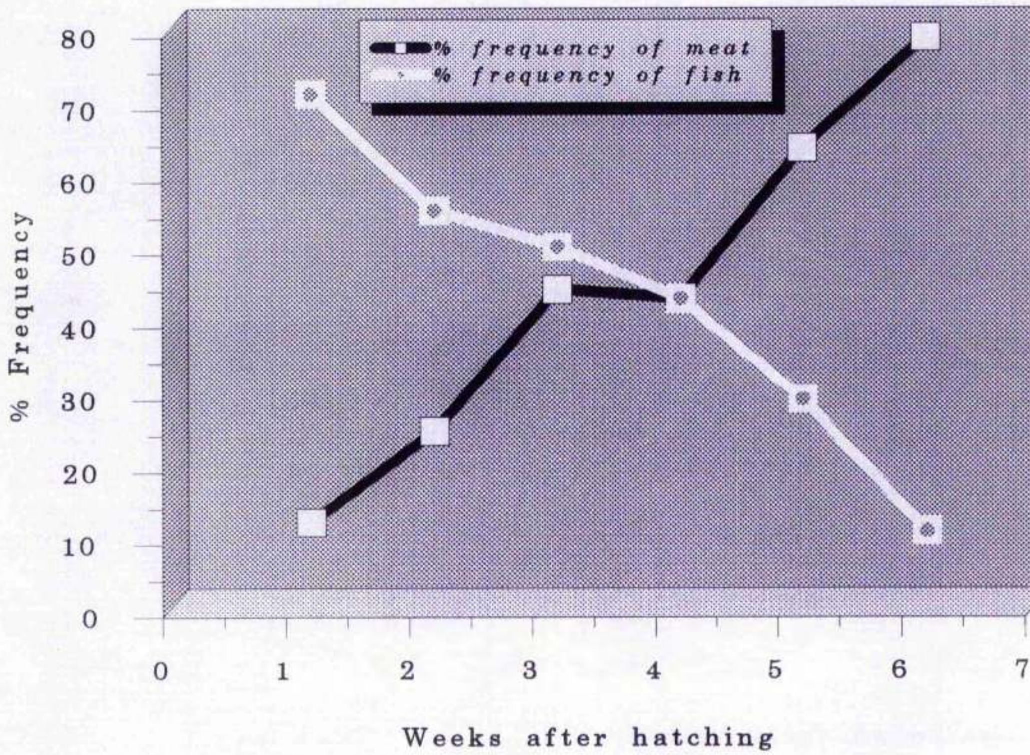

Fig. 4. 1. Meat and fish components in the diet of Herring Gulls on Ailsa Craig in 1991 from weekly analyses of pellets.

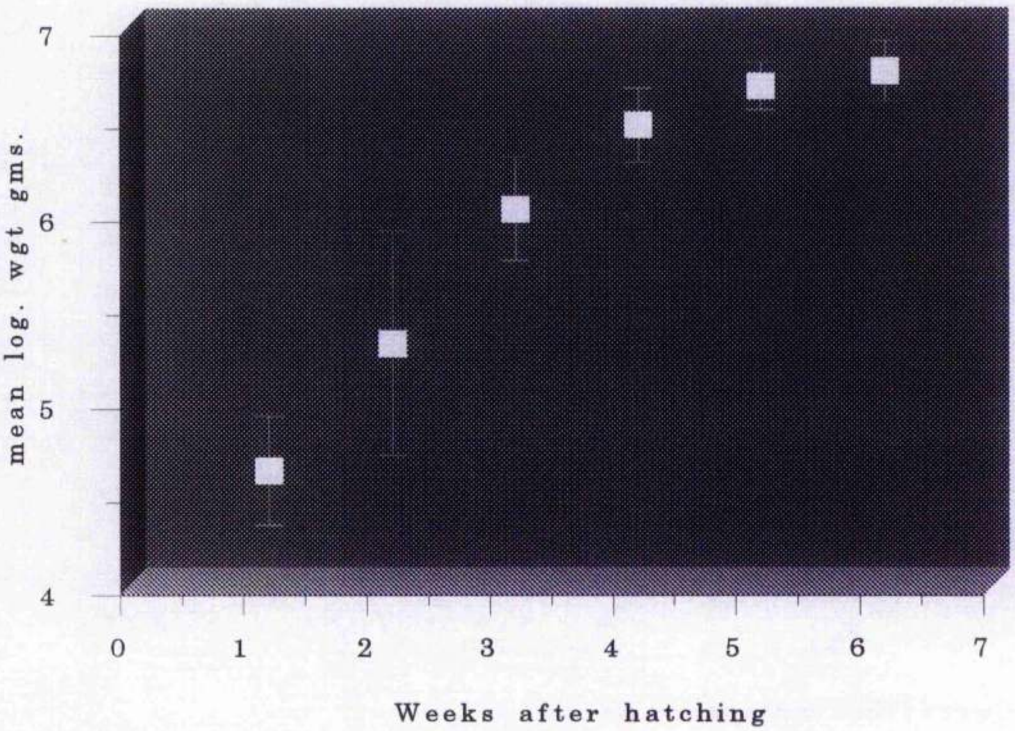

Fig. 4. 2. Growth in weight (+-s.e.) of 8 Herring Gull chicks from hatching to fledging on Ailsa Craig in 1991.

Chapter 5.

Great Black-backed Gull *Larus marinus* diet, chick growth and feeding ecology on Ailsa Craig.

5. 1. Introduction.

Great Black-backed Gulls are the largest of the breeding gulls in Britain and in common with other large *Larus* species are omnivorous. Like skuas, they will force other birds from the size of Kittiwakes up to Gannet, to disgorge food being brought back to the colony for chicks. In northern localities they have been recorded feeding on small pelagic fish and scavenging on the shore (Beaman, 1978). Throughout their range they prey on the chicks of other birds (Taylor, 1985). While in Britain there have been a few detailed studies of food (Harris, 1965; Beaman, 1978; Taylor, 1985; Walker, 1991; Poole, 1995), the growth of chicks has, with perhaps one exception (Harris, 1964), received little attention.

Although one of the largest of gulls, they tend to breed in smaller sized colonies than other *Larus* species, often in sub-colonies or in isolated pairs or small groups within seabird colonies. All three breeding situations can sometimes be observed within one island, and Ailsa Craig provides just such a location. Great Black-backed Gulls are resident on Ailsa Craig throughout the year, although in winter the numbers are much reduced. In the pre-breeding period, territories are set up and defended against conspecifics. Eggs are laid in April and after hatching, young are defended aggressively (Cramp and Simmons, 1983), sometimes with physical contact to the perceived predator, including man (pers.obs).

Within the Clyde area, other than basic monitoring of numbers, no biological studies have been published on the species.

5. 2. Clyde populations.

The overall British population in recent years has remained fairly static (Lloyd *et al.*, 1991), with increases in some areas balanced by declines in others. In areas of decline, human control and botulism were considered to be significant (Lloyd *et al.*, 1991). The largest colonies of Great Black-backed Gulls are in the northern islands of Scotland, in Orkney, and in Ireland.

Despite breeding on a major seabird colony like Ailsa Craig, with many bird-carcasses and young seabirds available to them for food, the number of Great Black-backed Gulls breeding was for many years relatively low and the population perhaps also static through human control (Gibson, 1951; Lloyd *et al.*, 1991). On Ailsa Craig a population increase has been obvious over the past 15 years, rising from 14 pairs in 1969, 50 pairs in 1990 to 85 pairs in 1993 (see Figs. 5.1., and 1.8. in Chapter 1). The greatest increase in numbers occurred however in the two years following the elimination of rats from Ailsa Craig in 1991, when the colony increased dramatically (see Fig. 5. 1.a and Fig. 5. 1. b.).

At other Clyde seabird colonies such as Sanda Island, Kintyre and Little Cumbrae, Buteshire, there has been a recent increase in breeding numbers. The largest Clyde colony is presently that on Little Cumbrae, growing rapidly from 50 pairs in 1985 to over 200 pairs in 1989 (pers.obs). The 1981 Wildlife and Countryside Act may have given some protection to this much persecuted species.

The aim of this part of the study was to examine the diet and reproductive performance of this species which is a small but significant component of the Ailsa Craig avifauna.

5. 3. Methods.

Great Black-backed Gulls occupy three main areas on Ailsa Craig. The upper south slopes, contains a colony of 25 to 30 pairs within a few hectares, smaller scattered groups of a few pairs breed over the rest of the upper parts of the island and isolated nests occur on a newly-colonised (1991) area beneath the rat-free cliffs on the rocky talus slopes. In all, 52 nests were marked and monitored on a 5-day basis during 1992. In 1993, 43 nests were monitored for breeding success. All nests were in close proximity to other gull species. Eggs were measured (length and breadth) with a dial calliper to the nearest tenth of a millimetre and, on the initial visit, weighed to the nearest gram with a Pesola balance. Once hatched, young in each nest were leg-flagged with small strips of different coloured electrician's tape. Measurements of wing and weight of chicks were taken at each visit after hatching using a stopped metal wing rule and Pesola balance. When their legs had developed sufficiently, all birds were ringed and the tape flags removed.

Young were weighed using the spring balance to the nearest 10 gms and the flat and straight wing of chicks was measured to the nearest millimetre using a wing rule.

Food items were collected and cleared from the nest areas at each visit at around 5 day intervals (4 - 7 days in some cases, depending on weather conditions) in 1992. Pellets were collected and stored individually in sealed polythene bags and later analysed using a x8 magnification binocular microscope. Only a very few regurgitations of chicks were examined in situ and the items noted, but too few to be relevant to this study.

In general adult Great Black-backed Gulls produced numerically far less pellet material than Herring Gulls but pellets of a greater size (pers. obs). Pellets cast up away from the immediate nest site could not be included in the analysis because their origin was uncertain. However their contents were noted on a casual basis but showed little variation in material content from those at the immediate nest areas. Chicks were also less prone to regurgitate food than Herring Gull chicks when handled (see Chapter 4). In the pre-hatching period only a few pellets could be located near to the nest - sites usually 3 metres radius, with none at all in the immediate area around the nest which was kept clean. In this period before hatching and until fledging, pellet collection was made at 10 day intervals.

The first hatching date was on 18th May and all chicks had hatched by 6 June. The few regurgitations from chicks were largely observed during the first 10 days after hatching. Beyond that period regurgitations were not common because chicks had perhaps either regurgitated unseen before capture or had become conditioned to handling.

Data on feeding based on pellet analyses are only representative of the dietary spectrum to a certain degree due to the fact that soft-bodied animals and other such material do not appear in pellets. However studies of Western Gulls *Larus occidentalis* in America by Annett and Pierotti (1989) and of Herring Gulls in Holland by Spaans (1971) concluded that pellets do reflect the adult dietary compositions.

5. 4. Identification of eggs and young gulls.

Confusion between gull nests and eggs in mixed colonies might arise when short or single visits are paid to the colony. Misidentification of eggs or young of gulls can be avoided by taking measurements at the nest. There is overlap in the length of Great Black-backed Gull eggs and Herring Gull eggs and only slight overlap in breadth. Nests of Great Black-backed Gulls are also larger in area and usually placed near a rocky outcrop with a commanding view over the surrounding area. Herring Gull nests also tend to be lined with moss rather than the plain grass frequently used by Great Black-backs, although this varies slightly with immediate vegetation. Very small amounts of moss are used in the nest bowl of Great Black-backs. Great Black-back Gull egg measurements were combined from 1992 and 1993. Herring Gull egg dimensions were recorded in 1991 (Table 5.1).

The difference between species for both sets of measurements are statistically very highly significant (t_{176} : t_{181} : $P < 0.001$, for both length and breadth). In most instances, measurement of breadth alone would distinguish over 95 % of all eggs. Most clutches (85%) were of three eggs.

Table 5. 1. Egg dimensions (in mm.) of Great Black-backed Gull and Herring Gull.

Species.	Sample size	Mean Length	Range	S.E. Mean	Mean Breadth.	Range	S.E. Mean
G B-B Gull.	89	76.6	72.5 - 82.3	0.26	53.3	50.5 - 56.4	0.14
H Gull.	97	68.1	61.4 - 78.2	0.33	47.9	43.4 - 51.8	0.16

Downy chicks of Great Black-backed Gulls are always greyer than the fawn chicks of the Herring and Lesser Black-backed Gulls, and the gonys is more angular and deeper at similar ages (pers.obs).

Egg dimensions of Lesser Black-backed Gulls were not measured but in general are close to those of Herring Gulls (68 mm X 47 mm, n = 104; Witherby *et al.*. 1941)

5. 5. Results.

5. 5. 1. *Diet*

In March, during the spring pre-breeding period, the hooves of many lambs were observed strewn around the areas occupied by Great Black-backs in both 1992 and 1993. These areas seldom have Herring Gulls present. The hooves (n= 34) in 1993 all showed evidence of the foot membrane present, indicating that the lambs may have never walked and were probably still-born. The hoof condition was similar to that examined in hill sheep remains from a study of the diet of Hooded Crows (Houston, 1977), in Argyll, Scotland. All of the very few pellets (*n*= 6) found in the colony area in spring revealed also the bones and wool of lambs. This coincided with a late spring and snow-covered hills on the mainland opposite Ailsa Craig, in Ayrshire and Galloway, also on the hill tops on Arran, due north of Ailsa Craig. Malnutrition, illness and starvation account for 80% of lamb mortality in upland areas (Houston, 1977).

Pellets analysed from the breeding sites showing the items in frequency of occurrence in 1992 are shown in Table 5.2. and in Fig. 5.2.

Table 5. 2. Analyses of pellets from adult Great Black-backed Gulls breeding on Ailsa Craig showing percentage occurrence of food and non-food consumed. The first period began on 4 May 1992. The post - hatch period is from the second 10 day stage onwards.

	10 - DAY PERIOD No.						
FOOD	*First.*	*Second.*	*Third.*	*Fourth*	*Fifth.*	*Sixth.*	Total
Mammals							
Rabbit	63.6	5.2	37.5	36.3	33.3	25.0	31.9
Meat.(processed)	-	-	-	4.5	4.5	-	2.0
Birds.							
Chicks - all species.	-	15.7	25.0	59.0	19.0	75.0	30.9
Eider pulli	-	5.2	-	-	-	-	1.0
Guillemot pulli	-	-	-	4.5	4.7	87.5	10.0
Razorbill pulli	-	-	-	-	4.7	-	1.0
Gannet pulli	-	-	6.3	-	-	-	1.0
Gull pulli (H.G.)	-	5.2	12.5	50.0	-	25.0	16.6
Kittiwake pulli	-	-	-	4.5	-	25.1	3.0
Chicken giblets.	-	-	-	4.5	4.7	-	2.0
Pheasant heads	-	-	12.5	13.0	4.7	-	6.2
Unknown birds	-	5.2	6.3	-	-	-	2.0
Fish (Gadoids)							
Whitefish	27.2	68.4	37.5	50.0	19.0	25.0	40.2
Marine Life							
Mollusca - squid	-	-	-	-	-	12.5	1.0
Crustacea	-	-	6.3	4.5	4.3	-	3.0
Echinoderma	-	-	-	4.5	-	-	1.0
Insects							
Coleoptera.	-	-	12.5	-	-	-	2.0
Earthworms	-	-	-	4.5	-	-	1.0
Plants.							
Seeds	-	-	-	4.5	-	-	1.0
Non-Foods							
Paper	9.0	-	-	9.0	9.5	-	5.1
Polythene / foil	9.0	-	-	9.0	9.5	-	5.1
Plastic.	27.2	-	-	-	4.5	-	4.1
No. of Pellets.	**11**	**19**	**16**	**22**	**21**	**8**	**97**

In the pre-hatch incubation period, the first pellets appeared near the nest site. Rabbit featured strongly in the diet during incubation, along with fish and anthropogenic rubbish. Few chicks of other seabirds had hatched at this time. Fish recorded in the pellets were mainly Gadoids, Whiting, *Trisopterus* sp., (probably Norway Pout *T. esmarkii*) and Pollack, here collectively termed "whitefish"; otoliths, in most instances, confirmed species identification.

After hatching, the frequencies changed noticeably with fish becoming a major dietary component and remains of young birds also increasing. Only a few pellets contained rabbit during this period, although rabbit was constantly available. By the third 10 - day period, fish was reduced in the diet, although still a major item. Rabbit and bird meat increased and the first insects and items of marine life, other than fish, appeared. Bird meat and young birds and fish, in the fourth period, were maintained as major items. The diet at this point also broadens to include items scavenged from fishing vessels and items of rubbish of human origin. Rabbit is the most important item in diet in the fifth period but increasing quantities of rubbish are taken by adults. Bird meat and fish are still important items at this time. In the final period, young have fledged but some return to the nest site and are fed by the adults. During this period birds are very frequently taken as food, particularly auk chicks, with fish and rabbit much reduced. This increase in bird meat and reduction in rabbit meat reflects the fledging period of other bird species on the island. Most young rabbits have grown up by the final period and may be a more difficult size for Great Black-backs to kill easily.

5. 5. 2. *Breeding success*

The first Great Black-backed Gull eggs were laid around 20th April (within 24 hrs) in each year. Incubation periods for 6 new-laid marked eggs in 6 clutches were between 27 and 29 days, with a mean of 28 days.

The period from hatching to fledging was between 36 and 47 days for 6 young in 6 broods where the exact date of hatching and first flight was established, the mean was 43 days.

The first young fledged on 7 July in 1992 ; first 1993 fledging date was 8 July. Fledging was accompanied by at least one adult and within a few days some birds - young and adult - had returned to the nest site. A few such flighted young were re-captured. Young sometimes returned intermittently to the nest site for a 5 - 10 day period after fledging, usually with an adult nearby. After that period young were usually seen around the shoreline.

The mean fledging period in 1992 was at 43 days (s.e. +- 1.29, n=7) and in 1993, at 44 days (s.e. 0.80, n=5).

The young "not found" after hatching were initially considered to have been victims of other gulls. However one chick, ringed in 1992, was later reported dead from Northern Ireland in 1993, although it was not located in the colony after the day it was ringed at around 2 weeks old. It would be incorrect therefore to assume that all such "not found" birds were dead, although most may well be. No ringed birds were found among the legs of gull chicks recovered in pellets at any nest in the study areas.

Breeding success was compared between 1992 and 1993 and is summarised in Table 5.3. When eggs laid, clutch sizes, eggs hatching and numbers fledging were compared between years there was no statistically significant difference $X^2 = P < 0.266$, d.f .4.

Table 5. 3. Breeding success of Great Black-backed Gulls on Ailsa Craig in 1992 and 1993.

G B-B GULLS	1992	%	1993	%
No. of nests	52	-	43	-
Total of Eggs laid	144	-	122	-
No. of 2 egg clutches	9	-	6	-
No. of 3 egg clutches	43	-	39	-
Mean clutch size (+-s.e.)	2.82 (0.05)	-	2.86 (0.05)	-
No. Infertile	8	6.0	5	4.0
No. Eggs hatched + (% of those laid)	99	68.0	57	46.7
No. Hatched young known to fledge + (% of those hatched)	62	62.0	38	66.0
No. Young dead at nest + (% of those hatched)	7	7.0	2	3.5
No. Not found - after hatching + (% of those hatched)	30	30.0	17	29.0

Some parents may perhaps lead their chicks from areas where they are disturbed, making finding them again very difficult. Older young, when accidentally disturbed at nest sites, will run well away from the site, but in some cases apparently returned of their own accord. Wandering chicks that resulted from observer disturbance were usually caught and returned to the site manually.

The numbers of young successfully fledging from all nests could not be ascertained because of the wandering behaviour of young thus only those definitely known to fledge are included in Table 5. 3. and this represents the minimum.

5. 5. 3. *Growth*

The instantaneous growth rate in weight of the 16 chicks which were weighed and measured from hatching to fledging is shown in Fig 5. 3. and the wing length in Fig 5. 4. The initial rapid growth pattern slows as adult weight is approached. With wings the initial growth peaks at around 10 days and the rate then slows towards fledging. This initial burst in growth is similar to that of the chick Gannet (Chapter 3). In Fig 5. 5. and 5. 6. the general pattern of wing and weight growth is shown, based on all study nests. In one case only, in 1992, the three eggs laid produced three chicks to the fledging stage. This was the sole instance in the 52 marked nests and nest number 18 may reflect the parental qualities of those adults. Fig. 5. 7. and Fig 5. 8. show growth of the wing length and weight of the three chicks from nest site 18. The growth pattern of the three chicks at this nest can be compared with that of the other study Great Black-backs.

Generally, the three brood weighed lighter than the mean, near to fledging but wing lengths were similar to the mean. Young Great Black-backed Gulls fledge at around 1600 gms, growing from around 70 gms on hatch day.

5. 5. 4. *Dispersal*

Young Great Black-backed Gulls ringed on Ailsa Craig and on Little Cumbrae island in the Firth of Clyde, show them to be relatively sedentary. Most recoveries from the 600 ringed are within the first year of life and are within the Strathclyde region with some birds drifting south into the Irish sea in winter (see Fig. 5. 9.).

Young on Ailsa Craig fledge from early July and are accompanied by their parents. They may briefly return to the nest site for a short spell but thereafter join club roosts with other gulls around the shoreline on the island where they indulge in intertidal foraging. Some young continue to exhibit begging behaviour weeks after leaving the nest site and are sometimes successful in eliciting regurgitated food from the presumed parent. The exact period of independence from the parents could not be ascertained once fledging had taken place, but most birds leave the island after three weeks.

5. 6. Discussion

Eggs

There are data on egg dimensions and food of Great Black-backed Gulls from other studies but little on growth from hatching to fledging. The eggs laid by birds on Ailsa Craig were larger in mean length and breadth than for those on Skomer, Wales (Harris, 1964) but slightly smaller than those on the Calf of Man, Isle of Man (Walker, 1991).

Diets

No published studies appeared to consider the diet of this species outwith the breeding period although the species is more or less present all year round. In spring, Great Black-backed Gulls on Ailsa Craig scavenge sheep carrion in the form of dead lambs from mainland hills (there are no sheep on the island). The unworn hoof condition suggests the lambs are stillborn, and the gulls are exploiting a seasonally available food.

During the incubation period, rabbit forms a major item of food for Great Black-backed Gulls on Ailsa Craig. At that time, young rabbits are emerging from burrows for the first time and are vulnerable to predation. Young small rabbits are swallowed whole (pers. obs). Adult rabbits are also taken but are heavy and difficult to manipulate. On Ailsa most adult rabbits are killed by being lifted briefly from areas near the cliff edge and being dropped to their death 150 metres below (pers. obs). Occasionally rabbits can survive such treatment and fall onto a well vegetated cliff ledge where the deep Red Fescue Grass *Festuca rubra* will break the fall. Rabbits can live some years thereafter in such situations.

At sea, Gannets are sometimes harried, in the manner of skuas, by Great Black-backed Gulls, and are forced to regurgitate food. However there was little evidence of Mackerel or Sandeels (main prey of Gannets) in the Great Black-backed Gull pellets to show that this was widespread.

The hatching chick appears to trigger a dietary switch in the adult birds which is not simply a facet of the seasonal abundance of prey. This reflects similar behaviour to that of Herring Gulls in 1991 when fish and meat were the two main components of diet, decreasing and increasing respectively as the chicks grew (see Chapter 4). Great Black-backs had three major food components in their 1992 diet when breeding on Ailsa Craig (see Fig. 5. 2.). Initially there may be a need to provide fish to the growing chick which will metabolise calcium through the digestion of fish bones, followed by a high protein diet of meat from birds and mammals, many of which appear to be killed or scavenged locally i.e. from Ailsa Craig and immediate surrounding waters. Fish taken were entirely of commercial species or species discarded by fishing vessels and were present in the diet of small young. Beaman, (1978) found a more "natural" diet in Orkney and Shetland with 85 % of birds feeding on surface shoaling sandeels *Ammodytes* sp.. Discards from fishing vessels were also taken. Rabbit was not recorded by Beaman in northern Great Black-backed Gull diets but on Ailsa Craig, rabbit and bird meat were major components of diet for chicks approaching fledging size. Rubbish and non-food items were not important in the diet and a major omission, despite their abundance on the island, was seabird eggs. No egg, even tiny fragments , of any bird species was recorded in the pellets, nor in the vicinity of any nest site. Harris (1965) also found eggs to be unimportant in the diet of Great Black-backed Gulls in Wales. Egg white and yolk would obviously not appear in pellets but eggshell fragments would, and were evident in the pellets of Herring Gulls, (see Chapter 4). Guillemot eggs have been swallowed whole by Great Black-backs at northern colonies (pers.obs) but egging may be a habit of specialist individuals. Young birds were taken as they became available. Initially the chicks of gulls, mainly Herring Gulls, appeared in the diet, followed by those of auks and then Gannets. The latter were young that fell or were knocked from their nest by fighting adult birds, and coincided with their first period of mobility from the nest.

The young of Great Black-backed Gulls on Ailsa Craig were likely to be as vulnerable to nocturnal rat predation as were other ground-nesting species, despite the adult Great Black-backs ability to prey on rats. After rat eradication measures on Ailsa and with no rats to scavenge carcasses, food, in the form of carrion, became abundant for gulls. No Great Black-backed Gull nests were ever found below the cliffs, in an area of many bird carcasses but also many rats, prior to 1991. Since rat eradication three pairs have nested annually below the cliffs.

The frequent placement of Great Black-backed Gull nests beside a prominent rock or boulder may be to ensure a commanding view of activity in Herring Gull colonies as well as to watch for approaching danger. Most sub-colonies of Herring Gulls adjoining or surrounding the nests of Great Black-backs lost many young to their larger neighbours. In colonial and sparse sites, the missing chicks of Great Black-backs may have been lost to Herring Gulls. There was no evidence from pellet analyses of birds preying on conspecifics, although this may indeed occur when chicks are small.

The largest Great Black-backed Gull colony presently on the Clyde is on Little Cumbrae island which also holds large numbers (thousands) of breeding Herring and Lesser Black-backed Gulls. Great Black-backs may rely on other gull species providing a supply of their young to allow them to raise their own chicks. It was notable on Ailsa Craig that in all the pellets and regurgitations examined in 2 years, only one Eider Duck chick was found. Eiders breed on Ailsa (around 35 pairs) and each nest produces 4 - 6 young.

Many of the items of food are to be expected but the frequent occurrence of Pheasant heads in pellets is perhaps surprising. Pheasants are reared for shooting at sporting estates on the nearby Ayrshire mainland. Pheasant heads occurred regularly in diets in 1992 and 1993. No other part of the bird could be located in pellets or regurgitations and a few were regurgitated virtually undigested at roost sites. The birds are presumably exploiting a man-provided source or perhaps regularly finding remnants of fox or raptor kills. It is doubtful that adult Pheasants are being killed and only heads eaten by Great Black-backed Gulls.

From the upper slopes of Ailsa Craig it was possible to view adult Great Black-backed Gulls flying out to sea and landing several kilometres offshore. They did not appear to feed from the sea surface but waited until other species including gulls and Gannets were returning towards the island. They would then intercept the bird in flight and force it to regurgitate, in a similar manner to skuas, although in a less manoeuvrable fashion. This may be a good way of obtaining the vital fish for small chicks. The gulls may be able to detect the behaviour of the returning birds (e.g. the direct purposeful flight) or the bulging crop since not every bird that passed was intercepted. Gannets also have the habit of carrying seaweed (mostly Bladder-wrack) in their bill back to their nests at all times of year, even when their young have almost fledged. This material is often delivered to the nest and immediately blown away in the wind. The seaweed carrying probably has a social function but may also disguise the crop content and avoid confrontation by Great Black-backed Gulls or, further north, skuas. Birds observed carrying nesting material were not intercepted by Great Black-backed Gulls.

For many other seabird species Great Black-backs will dominate and not just rob but kill. Adult auks, young Kittiwakes and Manx Shearwaters, at some colonies, are killed on land and at sea (Beaman, 1978; Harris 1965; Taylor 1985). On Ailsa, newly-fledged Herring Gulls were also seen to be attacked and killed by Great Black-backs when just offshore.

Fledging

In 1992, around 30% of Great Black-backed Gulls on Ailsa Craig appear to raise only one chick per annum. The same percentage, 30%, can raise two and almost 40% fail to raise any young, but only one pair of 52 studied managed to raise three young to the fledging stage. There are few data on broods from other colonies for comparison.

The individual abilities of parents to raise young have consequences for breeding success. Some Great Black-backs defend their nests with extreme aggression and will make physical contact with creatures such as humans, many times their own size. At least 2 such birds were active on Ailsa Craig. Some birds showed no aggression at all, other than by calls. Most birds made close swoops at the individual perceived threatening the nest or young.

Other factors, such as the laying of larger than average eggs may also improve offspring quality and may reflect parental quality directly (Williams, 1993). Such theories did not apply to the only pair which managed to raise three young to fledging on Ailsa. The adults at nest site No. 18 were not particularly aggressive towards the observer when at the nest site and the three eggs laid were in fact below both the mean length and breadth calculated for the 89 eggs measured. This particular nest site was set on the fringes of the colony area, beside a large rock and within 50 m of several similar sites, which were at a slightly lower level. Williams (1993) also argued that smaller eggs laid earlier in the year may hatch sooner and give a survival advantage in that way. Larger eggs may equate with bigger, fitter young in the post-fledging period (Williams, 1993). However nest No.18 was by no means the earliest nest to hatch young. Physical location of nest sites may give an advantage perhaps not yet fully explained. Extrinsic rather than intrinsic factors may aid the successful breeding of Great Black-backed Gulls and perhaps warrants further investigation. Being able to regularly observe potential food items (such as other gull chicks or young rabbits) is perhaps an advantage which Great Black-backed Gulls more than other species have learned to exploit.

5. 7. References

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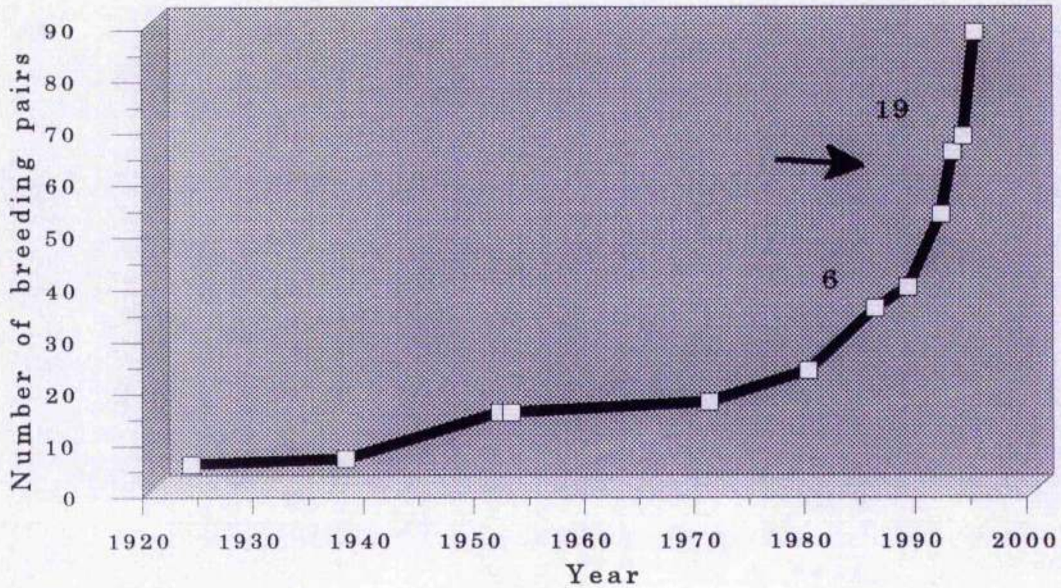

Fig. 5. 1. a. Numbers of breeding pairs of Great Black-backed Gulls on Ailsa Craig. The arrow marks the year when rats were eradicated. Numbers show average percentage annual change in population (1980 - 1990 & 1990 - 1993).

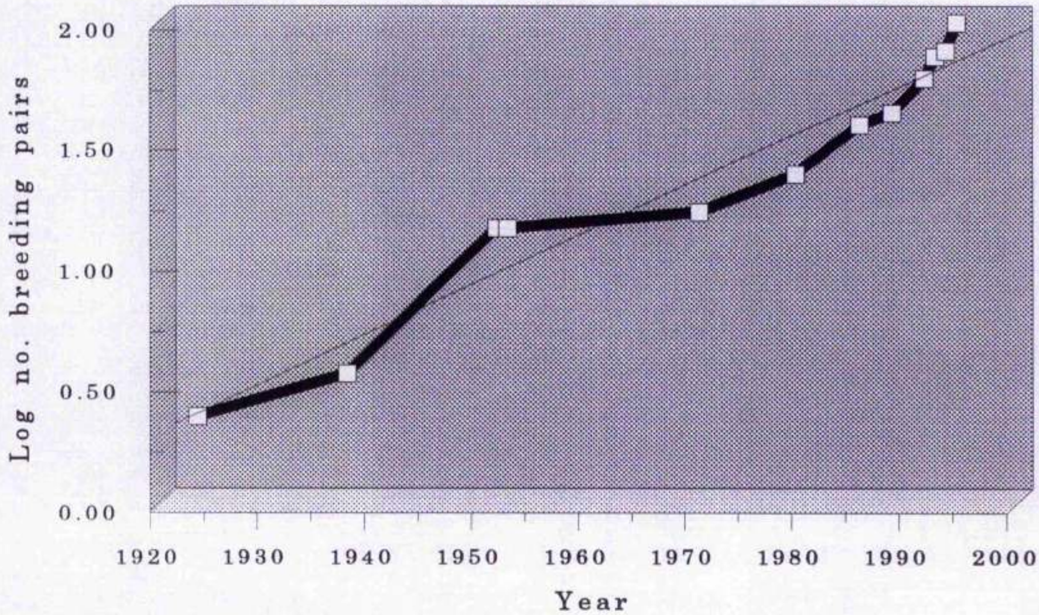

Fig. 5. 1. b. Logarithmic scale of the numbers of breeding Great Black-backed Gulls on Ailsa Craig. *(y = -39.1389 + 2.05E-02X, r^2 = 0.9417. P= <0.0001)*

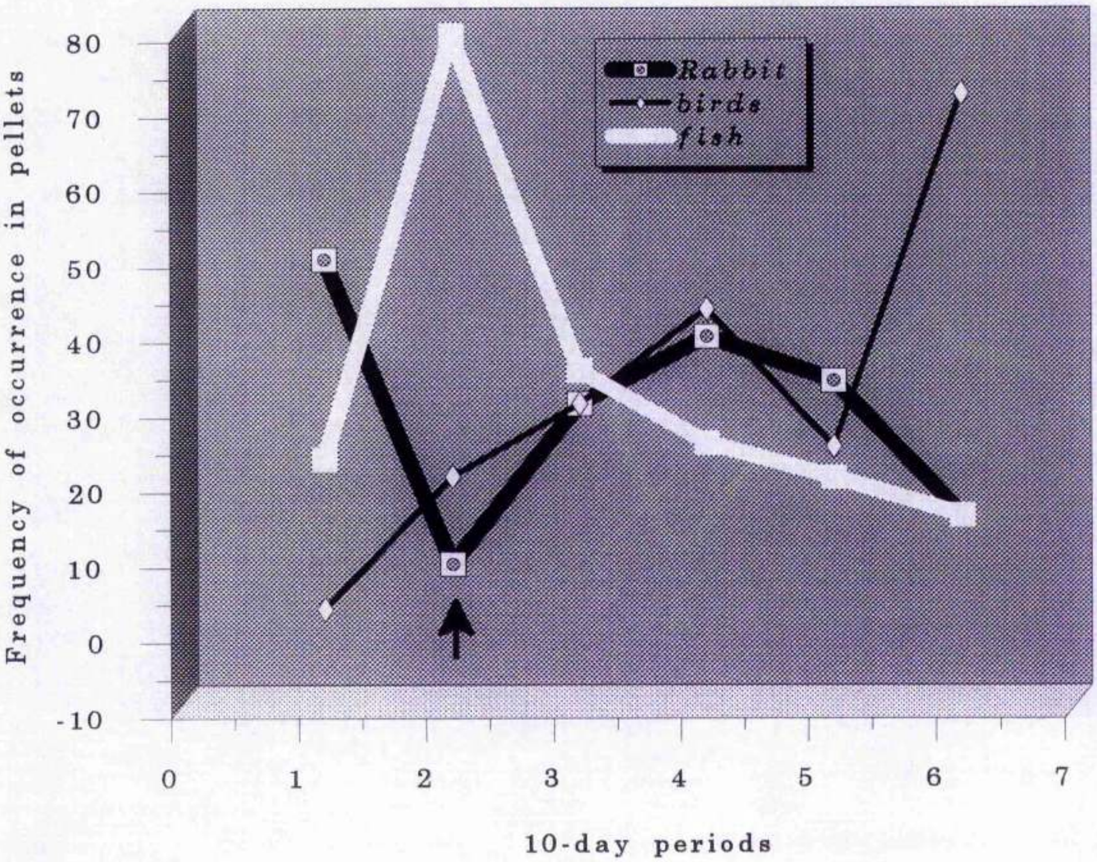

Fig. 5. 2. The three principal components in 97 Great Black-backed Gull pellets during the breeding period on Ailsa Craig. The arrow marks the mean date of first hatching.

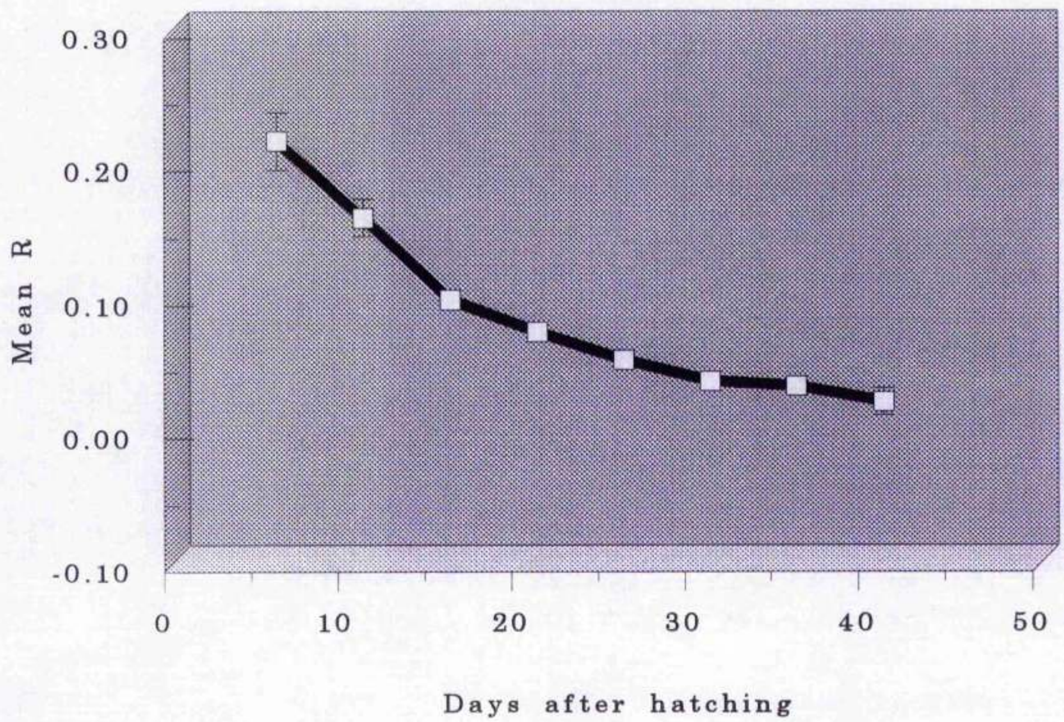

Fig. 5. 3. Mean instantaneous growth rate of weight of 16 Great Black-backed Gull chicks (+-s.e.) weighed from hatching to fledging in 1992.

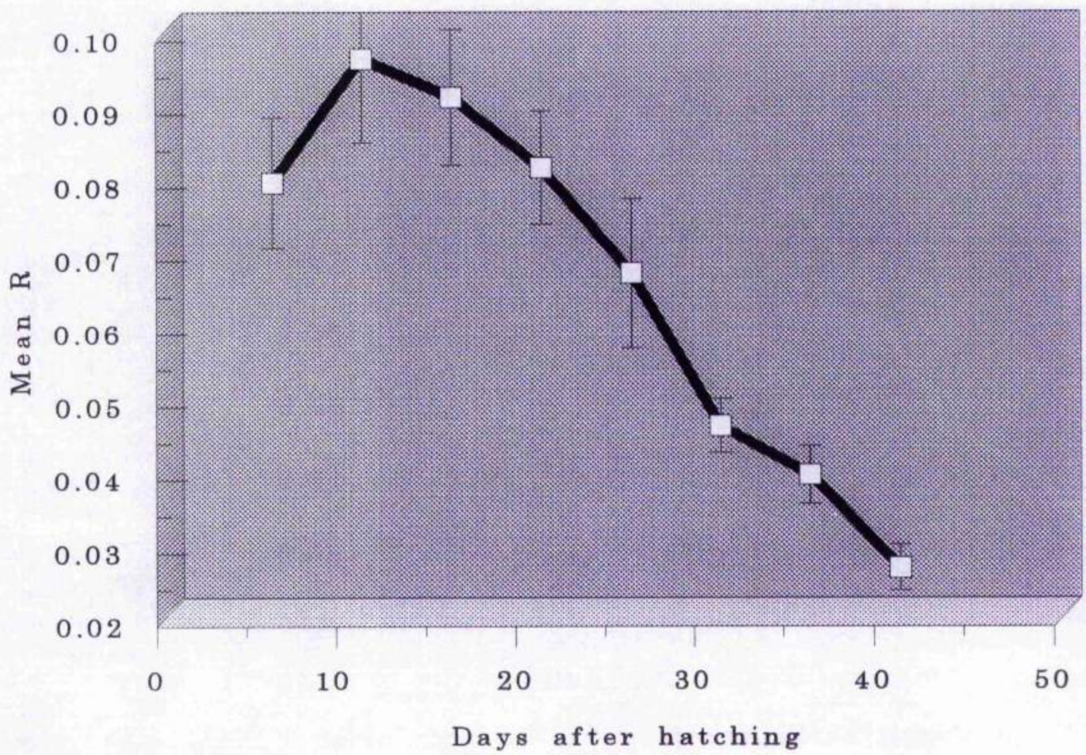

Fig. 5. 4. Mean instantaneous growth rate of wing length of 16 Great Black-backed Gull chicks (+-s.e.) measured from hatching to fledging in 1992.

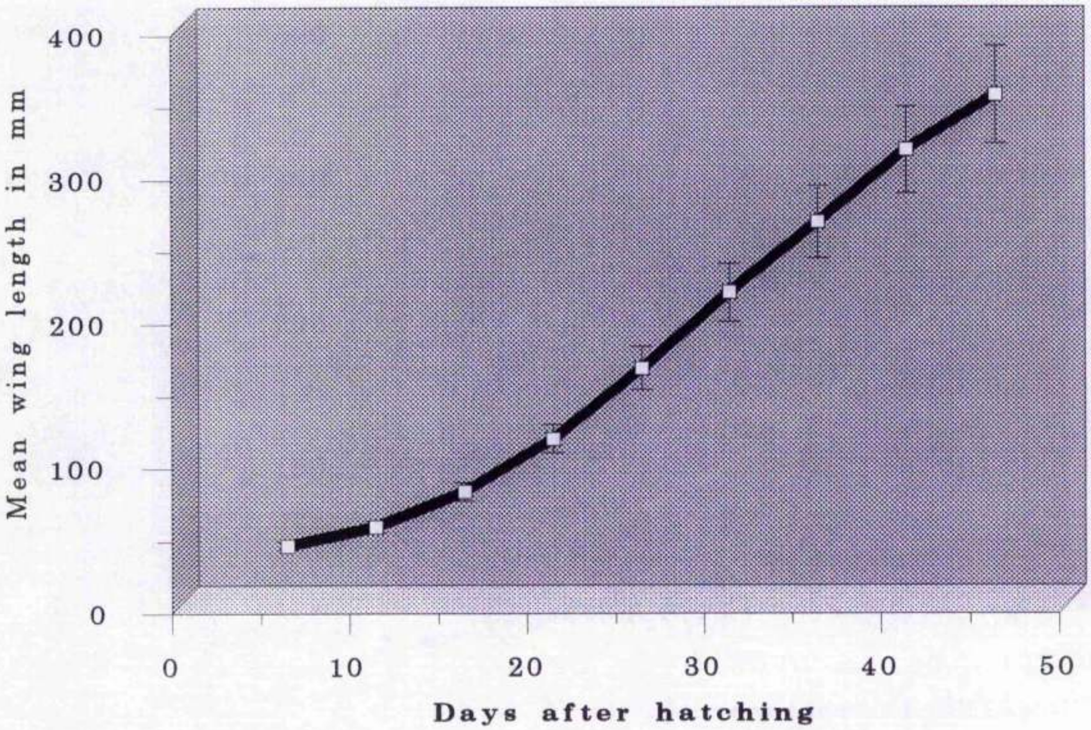

Fig. 5. 5. Mean wing length (+- s.e.) of 16 Great Black-backed Gull chicks measured from hatching to fledging in 1992.

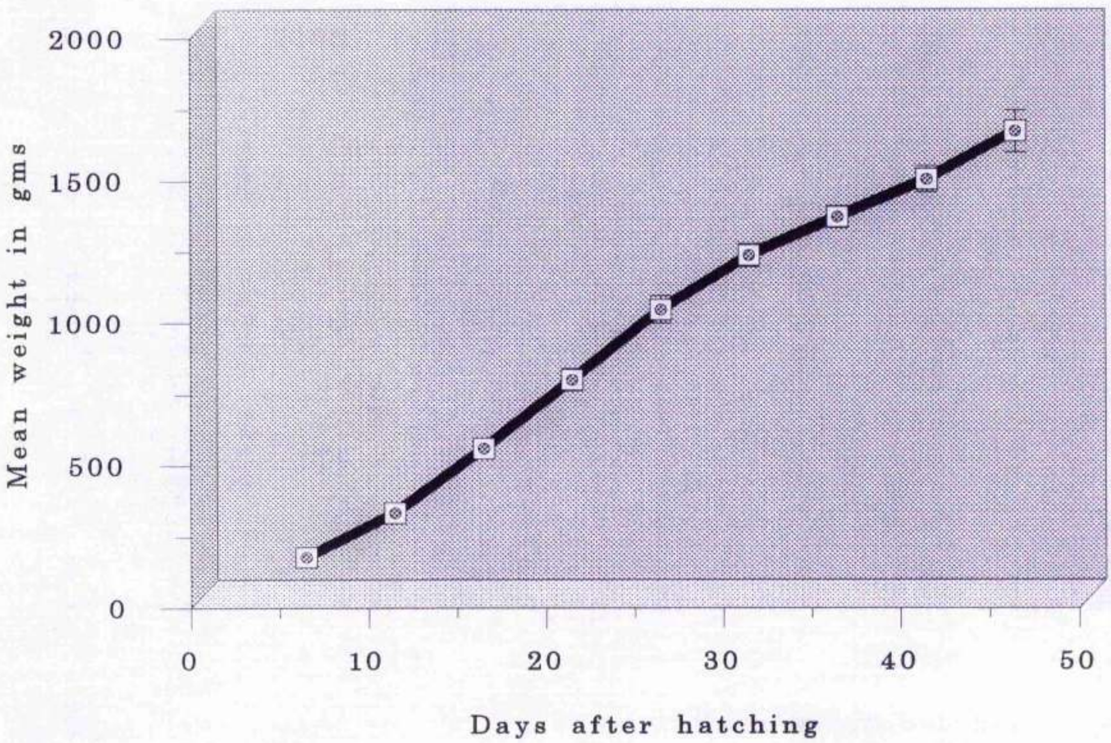

Fig. 5. 6. The mean (+-s.e.) growth in weight for 16 Great Black-backed Gull chicks from hatching to fledging in 1992

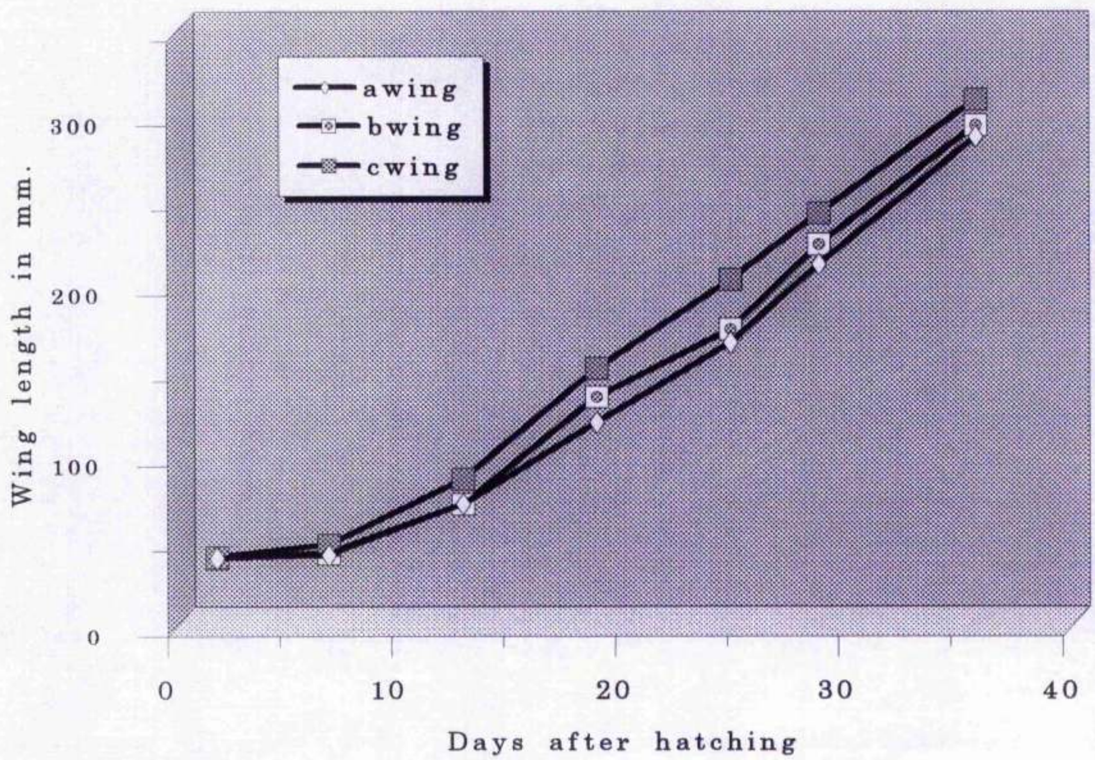

Fig. 5. 7. Growth of wing length of Great Black-backed Gull siblings at nest No. 18 from hatching to fledging on Ailsa Craig in 1992.

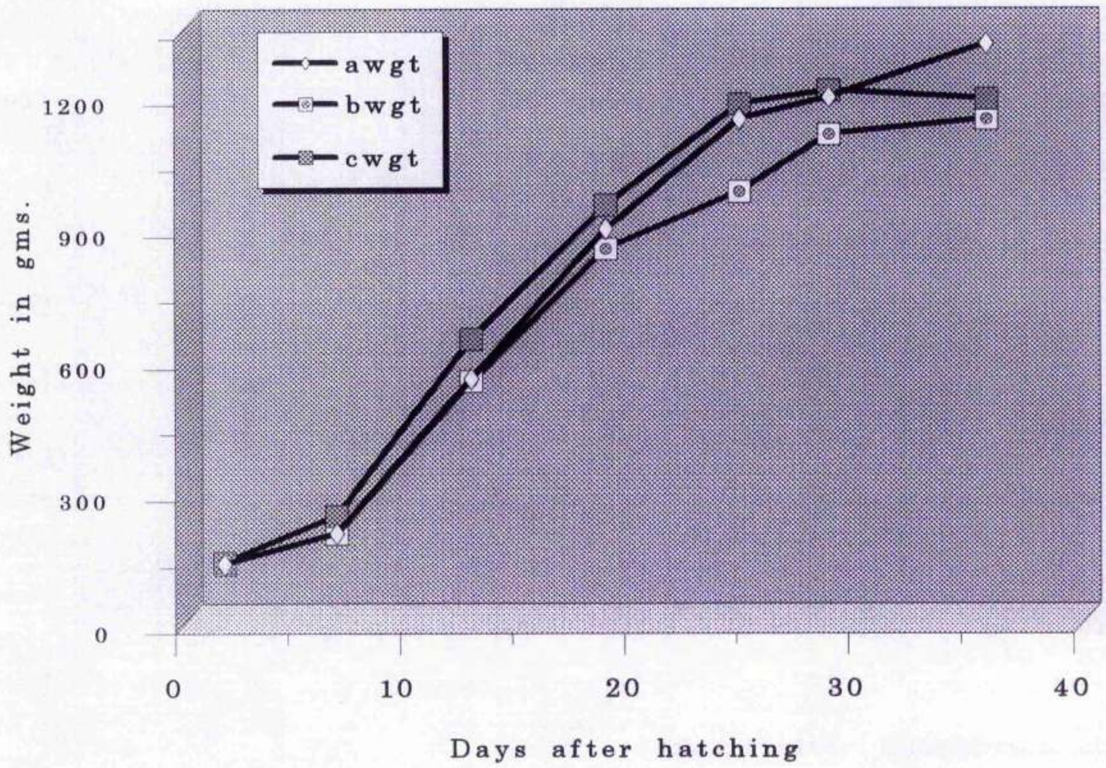

Fig. 5. 8. Growth in weight of Great Black-backed Gull siblings at nest No.18 from hatching to fledging on Ailsa Craig in 1992.

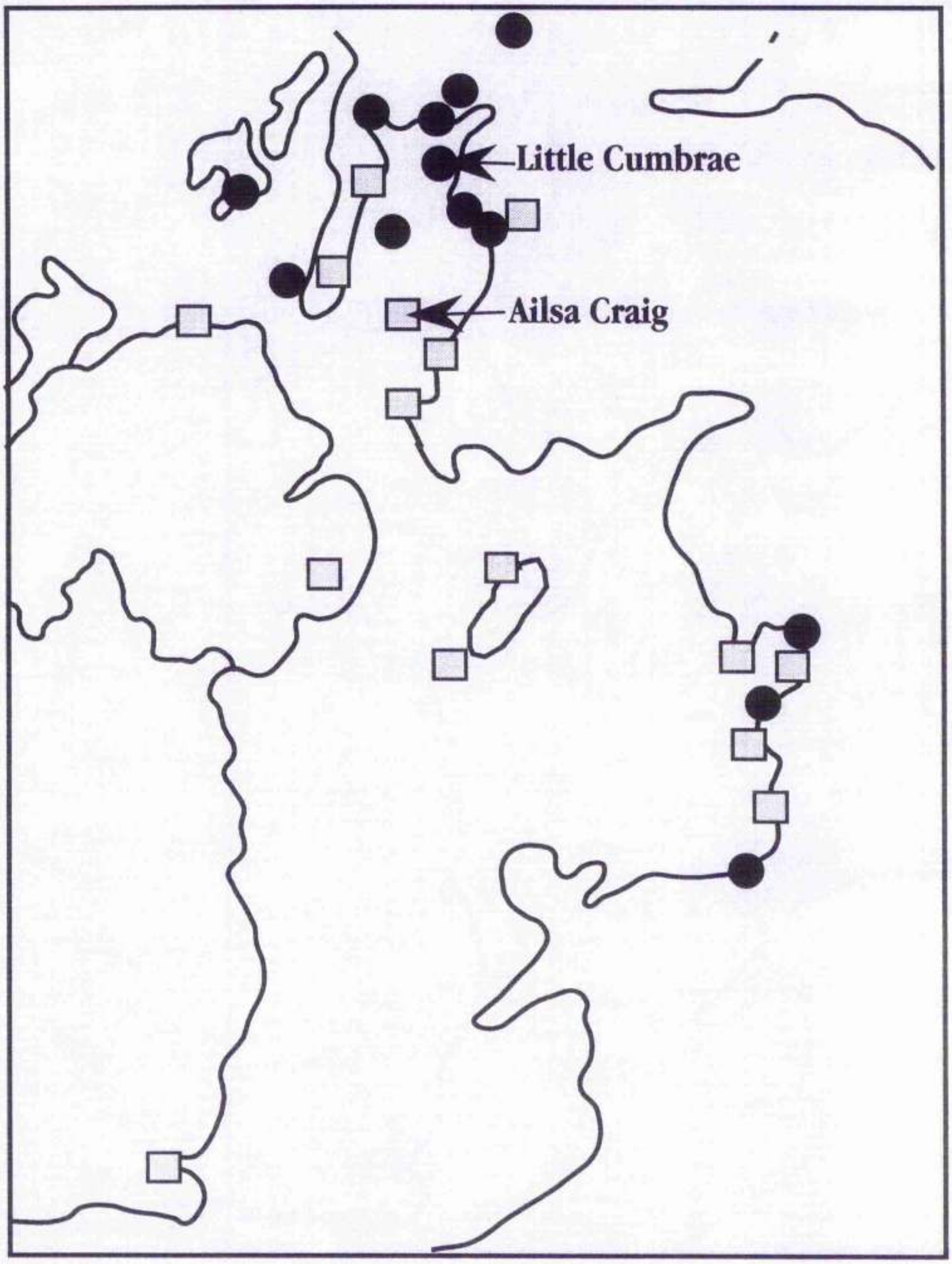

Fig. 5.9 Recoveries of Great Black-backed Gulls ringed on Little Cumbrae (solid circles) and Ailsa Craig (open squares).

Chapter 6

The Kittiwake *Rissa tridactyla*, on Ailsa Craig - aspects of breeding success, feeding ecology, and chick growth.

6. 1. Introduction

Breeding success in Kittiwakes, as in other seabirds, is often linked to food availability; breeding failure, in particular, can result from the effects of natural circumstances altering prey abundance or those induced by man in causing fundamental changes to the marine environment (Harris and Wanless, 1990; Danchin, 1992). The annual breeding performance of Kittiwakes, like that of other surface feeding seabirds appears to be relatively sensitive to changes in the marine environment (Monaghan, 1992), and their reproductive performance reflects changes in food availability (Galbraith, 1983; Harris and Wanless, 1990; Aebischer *et al.,* 1990; Danchin, 1992; Hamer *et al.*, 1993). This is likely to be partly because, being surface feeders, the proportion of prey population available to them is less than for diving species. Secondly, their relatively long life span and low reproduction rate means they are likely to sacrifice annual reproductive performance in favour of maximum survival, as is the case for other surface feeding seabirds (Monaghan *et al.*, 1989). Kittiwakes have an annual average survival rate of around 78% for adult males and 82% for adult females (Aebischer and Coulson, 1990). They have a moderate life span; Hatch *et al.*, (1993a) calculated an average life expectancy of 13 years for Kittiwakes (subspecies *R. t. pollicaris*) in Alaska. For this reason, in evaluating the health of the marine environment around Ailsa Craig, it was considered important to collect data on Kittiwake breeding performance. However it must be borne in mind that growth of seabird chicks and fledging success may be influenced by human disturbance or interference as well as by marine conditions and parental quality (Coulson and Porter, 1985; Hatchwell, 1989; Harris and Wanless 1990; Calvo and Furness, 1992; Lyngs, 1994).

This chapter examines breeding success, diet, growth and timing of fledging in Kittiwakes on Ailsa Craig. Ailsa Craig holds most of the Firth of Clyde's breeding Kittiwakes with around 3,000 occupied nests counted in 1988, using standard counting methods (Chapter

1). In addition to the Ailsa population, around 70 pairs nest on the Sanda Islands, Kintyre (Maguire, 1981) and a single pair bred in Troon Harbour, Ayrshire in 1991.

6. 2. Methods

Physical handling of seabirds such as Kittiwakes for study may in itself cause disruption in the growth patterns of young. When handled, seabird chicks usually regurgitate and may thus lose weight or perhaps be stressed or otherwise prevented from being fed, however briefly, thus affecting growth (e.g. Hatchwell, 1989; Lyngs, 1994). Human interference with species that are experiencing food shortage and having difficulty raising their brood may therefore also precipitate breeding failure. The observer may simply be studying or recording the effects of his or her own level of interference. It is therefore important to examine the magnitude of the disturbance effect, which can be done by comparing chicks handled and those previously untouched. Comparative data on such undisturbed birds at the moment of fledging tends to be lacking in the literature due to logistic problems (Calvo and Furness, 1992). Well grown Kittiwake chicks on open sites may fledge prematurely when approached by humans, to their immediate detriment or, in the longer term, to the detriment of their future life expectancy (Coulson and Porter, 1985). Often it is at just this stage when grown chicks are at their most vigilant and, when at sea or able to fly, they are very difficult if not impossible to catch.

Because of the mainly inaccessible nesting situations on Ailsa Craig, Kittiwakes cannot be closely studied without causing unacceptable disruption. Sophisticated climbing equipment would be required and sites cannot be observed from adjacent vantage points owing to the overhang and height involved. All nests can only be viewed from below. However, studies of breeding activity and attendance are still possible to a limited extent simply by observation. Some limited opportunities were available at certain stages of the breeding cycle when adult and young birds at a few sites (6 to 10) could be handled to record wing lengths and weights, or when faecal debris could be collected for analyses. The latter is due to the presence of a boulder-beach surrounding Ailsa Craig and which allows relatively easy access to the cliff-base below the nest sites at certain tidal stages and possible capture of any new fledglings which land there. However the data that were collected were limited and no complete chick growth curve could be obtained for this species on Ailsa Craig.

In this study, Kittiwakes were monitored at two main sites on Ailsa Craig, one facing due north above the Swine Cave (circa 56 nests ±5) and 20 - 40 metres above sea level, and the other around 150 metres away but facing due west on the Barestack (circa 65 nests ±9), a vertical overhung cliff site 215 metres above sea level in total height. Both sites were directly above a boulder beach (see map Fig 1.2, Chapter 1). Nests at both sites could only be observed from below, thus laying dates were unobtainable directly since eggs could not be viewed. A third site was used intermittently. Dates of hatching could be estimated from accumulations of eggshells found below the nesting cliffs and from size of young when visible from below. The eggshells, particularly early finds, may not always be as a result of normal hatching but may sometimes be from gale-blown or abandoned nests. However many later eggshells appear to show evidence of natural hatching. Egg shape may give an indication of the age of breeding females (Coulson, 1963) but entire eggs were seldom found. From laying to fledging takes 10 weeks (Coulson and White, 1958) - 27 days incubation and 43 days to fledging. In 1991, nests at 3 accessible points on the cliffs away from the study areas provided some data on chick growth and diet, but, because of poor breeding success, the sample sizes were small and most chicks died long before fledging. In view of this no further attempts were made to disturb the few accessible breeding birds or examine eggs. However, chicks also died in several areas of cliff where no human disturbance took place.

Growth rate was calculated using the instantaneous growth rate formula -

$$R = \frac{\log e\, W_2 - \log e\, W_1}{t_2 - t_1}$$

where **w** = weight and **t** = interval in days.

Coulson and White (1958), Pearson, (1968), Ricklefs, (1973) and Galbraith, (1983), used the percentage growth of the asymptotic weight as a factor to provide an index of absolute growth rate. However no asymptotic weight was obtained for Kittiwakes on Ailsa Craig during this study.

Six newly-fledged Kittiwake young that were caught immediately following their first flight were weighed and measured in 1993. These were compared with 11 breeding adults caught away from the two monitored plots. All measurements were taken with a 500 mm wing rule and weights with a 500 gm spring balance. Wings were measured maximum chord to the nearest mm and weights to the nearest gram..

Counts of birds present at the Swine Cave site (56 ± 5 regularly monitored nests) during seasons 1989, 1990 and 1991, were made every 10 to 15 days from early May. When small young were visible, (late June onwards) nests were checked 4 or 5 times per week but daily when close to fledging, and the number of chicks that eventually fledged recorded. Breeding success was calculated from the number of chicks that fledged from the total of occupied active nests in the combined study plots. Fledging success was also recorded in 1988, 1992 to 1994 and 1995. Hatching appeared reasonably synchronous most years, centred around late June into mid July (estimated from eggshell numbers below nests) in all years. The overall breeding success recorded during 1988 - 1993 was recorded for nests failing, rearing 1 and rearing 2 young.

Some data on Kittiwake arrival at Ailsa Craig were collected from 1986 onwards; this took the form of monitoring counts at sea from October to January (this may or may not involve only Ailsa breeding Kittiwakes but indicates presence of birds in proximity to the colony). Hourly checks were carried out from 20.30 until 02.00 hrs. in March 1993 to check for colony attendance. Observations on the pre-breeding behaviour were made during March and April.

Two dawn to dusk watches were made on six nests at one Kittiwake site (Swine Cave) in 1991 to estimate feeding frequency. Pre-breeding diet of adults was studied from faecal analyses collected from below the breeding cliffs in March, when nests were first occupied. Each dropping was individually bagged in a sealed plastic bag and analysed within 24 hours of collection. The remains were softened in water and viewed under a X8 binocular microscope on the island and were compared with entire examples of crustaceans found in the foregut of 3 adult Kittiwakes, while still relatively undigested, killed by a Peregrine Falcon at dawn.

6. 3. Results

6. 3. 1. *Annual cycle of Kittiwakes on Ailsa Craig*

Based on observations over an 8 year period from 1986, adult and juvenile plumage Kittiwakes are present at sea in small numbers (up to 10) around Ailsa Craig in winter. In March each year virtually all nest sites on Ailsa Craig were occupied (e.g. 848 sites on Barestack in 1991, photographic count) but there are periods of non-attendance, when the entire colony is temporarily deserted. This continues during April and into May. Return to nest sites is synchronous and there is much vocalisation. Cold, wet spring weather usually means no Kittiwakes ashore on Ailsa Craig for several days but as daylight increases then the days ashore also increase, and, like Fulmars, from dawn to dusk will be spent at the colony with little daylight time apparently devoted to feeding. During March and into April, the colony on Ailsa is deserted at night (pers. obs.). At twilight the entire Ailsa Kittiwake population is very vocal, with periods of behaviour when all birds present depart from the cliffs in a single flock and fly out to sea only to return a few minutes later. Eventually, sometimes when quite dark, the birds were observed to leave and head due north from Ailsa Craig towards the island of Arran. Hourly checks on 23rd March 1993 from dusk (circa 20.30 hrs. until 02.00 hrs.) revealed that no Kittiwakes were present at any nest site within the major breeding areas, and none seen at any other breeding area viewed on the island.

On Ailsa Craig eggs appear to be laid starting late May into June (calculated from eggshells found below sites after hatching, following four weeks incubation (Coulson and White, 1958) - earliest 14 June, but most around mid July). Kittiwakes on Ailsa Craig which is at 55°15′ N generally appear to breed about a month later (based on first fledging dates) than in colonies in eastern Scotland in the North Sea, such as Isle of May, Fife, at roughly similar latitudes 56°11′ N, (Harris, 1987; pers.obs.).

Hatching of young is mainly from late June into July (estimated from size of visible young ; for growth of chick plumage with age - see Maunder & Threlfall, (1972)). Over the period of this study many young died within two weeks of hatching or nests failed at the egg stage (see below). In years when some young have been produced and survive to fledging, the earliest fledging date recorded was 9 August, in 1992 and 10 August in 1993. The few later birds fledge into early September with the latest recorded leaving on 5th September 1992. Some adults (and young) rest on the shores around Ailsa into mid September, after which period they depart and do not return until the following spring.

6. 4. Breeding success

Breeding success (number of chicks fledging per active nest) during a 7 year period was very low, with some years almost zero over the entire colony (Table 6. 1. shows average breeding success based on the combined study plots). For the two sites monitored closely, fledging success differed between them within years (Table 6.2). For example 0 at Swine Cave and 0.03 chicks fledged per nest at Barestack in 1988, and in 1990 a similar picture with 0 at Swine Cave and 0.12 at Barestack.

Table 6. 1. Summary of breeding success of combined study plots.

Year	Chicks fledged per nest (mean)	Samples size a.o.n's.*	No. of plots
1988	0.03	561	3
1989	0.08	107	2
1990	0.12	139	3
1991	0.22	118	2
1992	0.29	128	2
1993	0.37	131	2
1994	0.40	124	2

**A.O.N. = apparently occupied nest..*

The proportion fledging 0, 1 and 2 chicks is given in Fig. 6.1. The proportion failing to fledge any young remained high at between 60% - 80%. When the numbers failing, raising broods of 1 and 2 chicks and the total number of chicks produced is compared between years there is a highly significant difference, $X^2 = 34.64$, $P = < 0.005$ d.f.=16.

When the number of fledged chicks per nest (here taken as breeding success) was examined in relation to the mean monthly sea surface temperatures for the Clyde, there is a highly significant negative correlation for the three months spanning the breeding period (May, June and July - Fig. 6. 2.). $P = 0.01$ in each month [Pearson's correlation for May = -0.939, June = -0.937 and July = -0.946] (Mean sea surface temperatures at the University Marine Biological Station, Millport, provided by Dr P. Barnett, pers.comm).

When the frequency of chick production (Table 6.2.) is compared between the two sites over the years 1988 to 1995 there is a significant difference (T=8, P<0.05, Wilcoxon test for matched pairs). Complete failure to raise any chicks was recorded in 1988 and 1990 at the Swine Cave site. The Barestack site produced some young during the same years but numbers were overall low.

Table 6. 2. Frequency of Kittiwake young fledged from breeding sites at Swine Cave (ca. 56 nests ± 5) and Barestack (ca. 65 nests ± 9), 150 metres apart on Ailsa Craig.

Year	Swine Cave	Barestack
1988	0	23.0
1989	3.5	18.4
1990	0	23.0
1991	25.0	38.7
1992	26.7	15.3
1993	14.2	61.5
1994	7.1	76.9
1995	50.0	86.1

6. 5. Chick feeding and growth

6. 5. 1. *Chick provisioning*

Of around 20 chicks handled for ringing during 1990 - 1993, all regurgitated sandeels, mostly of the 0-group size. Breeding success was poor during this period (see Table 6.1). During the two dawn to dusk watches at Swine Cave, (59 nests) on 26 and 30 July 1991, 8 of the 16 chicks were apparently unfed on both days and two others died on the nest during the period of watch. Three nests with chicks showed long periods when chicks were not fed and long spells where neither parent was present at on near the nest. Average feeding intervals are given in Table 6.3.

Table 6. 3. Periods between feeds for 6 Kittiwake nests with chicks on two dates in July 1991.

Date	Average interval between feeding	No. of feeds from 05.00hrs to 23.30hrs
26 July 1991	07hrs 50 mins	4
26 July 1991	05hrs 45 mins*	4
26 July 1991	16hrs 03mins	2
30 July 1991	16hrs 00 mins	2
30 July 1991	02hrs 45 mins*	6
30 July 1991	04hrs 10 mins	4

Overall mean = 8hrs 45 mins. S.E. =144 mins. * = same nest

Only one nest of the above raised a single chick to fledging, (that with an asterisk, which notably had the shortest feeding interval). Adults with dead chicks attended them for over a week after the death of the chick. In addition, the final nest check at 22.30 hrs. on 26 July showed that, of the 16 nests with chicks (approx. 20 days old) present on them, 11 (69%) were unattended - both adults having gone to sea at the onset of dark. On 21 July, 9 nests (57%) were unattended during the night (23.30 hrs to 03.00 hrs on 22 July) while on 30 July only 6 (40%) nests were left unattended by both adults at 22.30 hrs.

In all only 14 chicks fledged from the 56 nests at the Swine Cave site in 1991. Nearby Barestack site fared much better (although still generally poor) with 24 young fledged from 62 nests.

6. 5. 2. *Chick growth*

Because of inaccessibility and high mortality, no sample of Kittiwake chicks could be measured from hatching to fledging on Ailsa Craig therefore growth curves could not be obtained for this species during the period of this study. Only three individual Kittiwake chicks at an accessible site (Stranny Point) were measured twice only - at a 20 day interval in 1991; the long interval ensured that disturbance through handling was kept to a minimum (Fig. 6.3 and Fig 6.4). Using the growth rate formula described in the methods, the instantaneous growth rates for the three chicks during this 20 day period were R = 0.0247. 0.0407 and 0.0463 for weight and R = 0.0567, 0.0643 and 0.0317 for wing length respectively. Precise hatching dates for these chicks were not recorded. The three measured chicks fledged successfully but their three siblings all died shortly after hatching.

A small sample (n=6) of newly-fledged Kittiwake chicks was caught following their first flight. The biometrics are given in Table. 6.4. and biometrics of a sample of breeding adults are given for comparison. The adults caught at the nest could not be sexed according to head + bill measurements (Baker, 1993), both individuals at the nest having longer measurements than for females cited in the published criteria for sexing (Coulson *et al.*, 1983), but perhaps in most instances the larger of a pair will probably be male (Cramp and Simmons, 1983).

Table. 6. 4. Biometrics of newly fledged (Juv.) and breeding (Ad.) Kittiwakes on Ailsa Craig.

Kittiwakes	Sample size	Mean.	St Dev.	SE Mean	Min.	Max.
Ad. wing length (mm)	11	300.3	24.9	7.51	230	317
Ad. weight (gms)	11	357.7	53.9	16.3	280	490
Juv.wing length (mm)	6	249.1	14.1	5.7	232	275
Juv. weight (gms)	6	285.0	40.9	16.7	240	340

Since many of the nests of Kittiwakes failed, it is not known whether these weights are above or below that for successful breeding birds on Ailsa Craig. These are presumably the birds best able to cope with poor feeding conditions and may not be representative of the colony as a whole.

6. 6. Pre-breeding diet of adult Kittiwakes.

In March the rocks beneath the Kittiwake breeding cliff on Ailsa Craig are coated in pink/red pigmented droppings (only Kittiwakes are involved at the time and at this site). The contents of the droppings can be viewed easily following collection with a low-power binocular microscope. The contents of 43 droppings were examined in 1990 and 50 in 1992. The sole species involved was the euphausiid decapod crustacean *Meganyctiphanes norvegicus* with each dropping composed of many euphausiid crustacean remains.

A further three spring Kittiwakes were found freshly dead (2 in March 1990, 1 in February 1992) from Peregrine kills and the intact gut contents were removed. Each contained 35, 26 and 4 entire examples of *Meganyctiphanes norvegicus*. [All examples identified using Allen (1967) and later confirmed by Prof. J. Allen, Universities Marine Biological Station, Millport, Great Cumbrae].

The only items of diet from adult breeding (on eggs) Kittiwakes were recorded on 28 June 1991 when 2 birds each regurgitated a small fish, either Sprat or young Herring, each 60 and 150 mm in length and 10 and 15 gms respectively.

6. 7. Discussion

Fledging success.

The nest situations of Kittiwakes on Ailsa Craig may be an important factor influencing breeding success. Despite the two Ailsa study plots being less than 150 metres apart they had, in some years, quite different breeding success (see Table 6.2). In most years at least a few young fledged from each site. Since the birds would have the same foraging area available, this presumably relates to either differences in the breeding sites or in the quality of birds nesting there. The effects of wind direction and particularly rain can make breeding situations good or bad and affect attendance patterns particularly for exposed-site nesting seabirds such as auks and Kittiwakes (Slater, 1980; Danchin, 1992).

Different patterns of breeding success between Kittiwake colonies in the same year has been noted elsewhere, though much farther apart. In Norway, Barrett and Runde, (1980) at colonies hundreds of kilometres apart, found their west Norway colony had a much lower breeding success rate than two north Norway colonies when directly compared. Similarly, Walsh and McGrath (1989) found that colonies of Kittiwakes less than a few kilometres apart in southern Ireland had differing breeding success within years, perhaps as a result of utilising different foraging areas.

The temporal pattern of breeding on Ailsa Craig seems later than at other colonies. First fledging in the Waterford area of southern Ireland was recorded between 26 June in the earliest year (1983) and 24 July in the latest year (1984) (Walsh and McGrath, 1989). This is more than two weeks earlier than the earliest first fledging on Ailsa Craig (9th August) recorded during this study. At North Sea colonies first fledging is regularly around a month earlier than on Ailsa Craig (Coulson and White, 1958; Harris, 1987). Belopol'skii (1957) gives slightly later - between mid and late July - as the first fledging period for Barents Sea Kittiwakes. The Ailsa birds first fledge around the same time as those studied by Gaston (1988) from near Baffin Island, Canada at 62 ° N (calculated from laying dates provided). In the Faroe Islands and Norwegian Sea, Kittiwakes also appear to fledge later with 11% of birds at sea seen in July being juveniles and 52% juveniles in August rising to 86% in September (Danielsen *et al.*, 1990). The September count by then probably may have included birds from elsewhere.

Inter-colony variation in Kittiwake breeding success has been observed on North Sea coasts (Coulson and Thomas, 1985a) and makes an interesting comparison with Ailsa Craig. Coulson and Thomas, (1985a) found that chicks fledged per pair increased with parental experience between the ages of 4 - 9 years, reaching a peak during this period. After 10 years breeding, success declined with age. A minority of birds bred intermittently, although most continued to breed for the remainder of their lives. Pairs breeding at the centre of a colony fledged chicks 11 % higher than those breeding on the edge. Between 1954 and 1983 chicks fledged per pair varied between 0.94 and 1.61, much higher than at any recent period on Ailsa Craig. For Alaskan Kittiwakes, Hatch *et al.*,(1993b), reported a mean annual productivity rate of 0.168 chick per nest from 1983 to 1991, nearer to the rate recorded from Ailsa Craig during this study period (0.215 chick per nest over seven years). Alaskan and east Siberian Kittiwakes *R. t. pollicaris* are however morphometrically larger than those in Scotland, have a different juvenile plumage and have a well developed hind toe and claw (Ilyichev and Zubarkin, 1988; pers.obs.) and may therefore differ ecologically e.g. in prey size selection. At North Shields, east England, mean productivity ranged between 1.1 and 1.4 chicks per pair spanning a 31 year period (Coulson and Thomas, 1985b). I can however find no data to support differential rates of productivity from scattered colonies as being linked either to phenotypic variation or as a consequence of genetic modifications between populations or subspecies. With such low success on Ailsa, declines in breeding numbers should be noticeable but no census has been carried out since the last national survey (Lloyd *et al.*, 1991).

While 15% of breeding Kittiwakes in north east England laid 3-egg clutches (Coulson and Thomas, 1985a), on Ailsa Craig, no brood of 3 young Kittiwakes has been observed in 10 years (pers.obs). Walsh and McGrath (1989) had some broods of 3 young among their successful breeding pairs in southern Ireland. Coulson and Thomas (1985a) concluded that between 25 - 33% of variation in several aspects of breeding success in North Sea Kittiwakes was attributable to consistent differences between female parents, and perhaps also males. Parental quality plays a role in chick growth and breeding success in Kittiwakes (Coulson and Porter, 1985). The failure in many Ailsa Kittiwake nests may therefore be affected by young inexperienced parents that cannot find adequate food during chick rearing while their older neighbours can and do raise young successfully even in years of seemingly relatively poor food supply. This may also account for the differences between the Ailsa plots.

The intervals between feeding chicks by Ailsa Craig Kittiwakes show some inordinately long foraging periods such as 16 hours. Chicks receiving only two provisioning visits by their parents in a day usually died. In 1991 it was obvious from observing nests over an

18 hour period that many birds struggled to find enough food for their young. Hamer *et al.* (1993) found that Kittiwake foraging trips were up to 44 hours duration in 1990 and a maximum of 20 hours duration in 1991, from sites on the Shetland Islands. On Shetland in 1991 most trips were of 2-3 hours duration while in 1990 trips of 6-10 hours were frequently logged. Sandeel stocks in Shetland were estimated to be ten times higher in 1991 than in 1990 and thus the long trips were associated with poor food supplies near the colony. Coulson and Johnson (1993) also found daytime absence at their North Sea study colony. Coulson and Johnson (1993) gave daytime foraging data of 3-4 hours and overnight trips of 4-5 hours from birds feeding chicks at North Shields, covering a 16 year period. In years of poor food supply, up to 50% of chicks were left unattended by day at Isle of May (Wanless and Harris, 1989) and similarly in west Norway (Barrett and Runde 1980), and in Shetland when food was poor (Hamer *et al.*,1993), increasing the risk of predation. Food shortage was thought responsible for the low adult attendance and poor breeding success at North Sea colonies (Harris and Wanless, 1990).

Many studies fail to acknowledge the effects of human disturbance and interruption on study species (Calvo and Furness, 1992) but the effects may be considerable. Galbraith (1983) disturbed Kittiwakes on a daily basis on the Isle of May, dye-marked birds and collected 147 regurgitations from 21 chicks during June and July. Despite reasonably good food supplies, Kittiwakes in his study area were absent from the nest at night perhaps suggesting that in this case nocturnal foraging was precipitated by persistent human interference. At a Kittiwake colony in Atlantic France, where birds were disturbed daily, Cadiou and Monnat, (1996) recorded increasing non-attendance of chicks with chick age, similar to that described by Galbraith (1983) but this also occurs in the absence of disturbance. Nocturnal foraging also occurs in the absence of human disturbance, as at Ailsa Craig. Predation of chicks would probably be restricted during the night, although the larger gulls appear also to be occasionally nocturnally active on Ailsa Craig (pers.obs). Most Ailsa Kittiwakes with chicks left their nests regularly at night and some did not re-appear until after dawn. These birds were undisturbed by human intervention at the nest but apparently had difficulty finding enough food for their young and perhaps also themselves. Nocturnal attendance varied on Ailsa Craig with between 40% and 69% (over a 5 hour period) of chicks left unattended during a year of poor breeding success. This absence is usually attributed to nocturnal foraging by adult birds. Kittiwakes often appear to feed nocturnally at moored trawlers just off Ailsa Craig (pers.obs), which may perhaps help avoid interspecific competition around fishing vessels, where they are often at the bottom of the "pecking order" (Furness *et al.*, 1992). Barret and Runde (1980) recorded 65% of chicks unattended in Norway, but considered that exceptional. However there is little darkness at high latitudes in summer so there may be little to be gained in developing such a pattern. Coulson and Johnson (1993) examined a series of data on attendance patterns during years of good breeding success in north-east England. They found over 30% of well-grown chicks were unattended during the night from 2200 hrs to 0500 hrs. If human disturbance was not a precipitating factor, then an increasing depth of phytoplankton growth in the shallower southern part of the north sea might inhibit diurnal surface swarming of sandeels (see below). Nocturnal feeding may be for the benefit of adult Kittiwakes only, with perhaps an emphasis on bioluminescent organisms such as are taken in the pre-breeding period. Adult diet after nocturnal foraging trips requires further investigation.

Adult weight

The mean adult weights given in Table 6.3. are slightly higher than those recorded in north-east England - 354 gms (Coulson and White 1958) and the Farne Islands - 350 gms (Pearson, 1968), but are lower than those from Norway - 375 gms (Barret and Runde, 1990), Barents Sea - 407 gms (Belopol'skii,1957) and from birds rearing one and two broods on Isle of May, east Scotland - 395 gms and 365 gms respectively (Galbraith, 1983). Adult Kittiwakes breeding on Ailsa Craig probably found difficulty in recent years maintaining their own body weight when fish are generally scarce and chicks consequently suffer high mortality. On Ailsa the absolute chick growth parameters over the same period of time after hatching are similar to that for Norwegian Kittiwakes and those of single brood Kittiwakes on the Isle of May, Fife, and a brood of three in north-east England, reaching around 350 gms after approximately 25 days (see Fig 2 in Barrett and Runde, 1980; Fig 5 in Galbraith, 1983; Fig 1 in Coulson and Porter, 1985.). Comparing absolute weights may be an academic exercise since Kittiwakes exhibit a clinal size variation with Norwegian and northern birds intrinsically bigger than those from central Scotland and north-eastern England (Coulson and White, 1958; Tatarincova and Shklyarevich, 1978; Galbraith, 1983; Coulson *et al.*, 1983; Barrett *et al.*, 1985).

Chick growth

At North Shields, north-east England, Coulson and White (1958) found no evidence of a distinction between the growth rates of first and second hatched chicks over a four year period when data were collected. Presumably feeding conditions were much better at that time than those experienced on Ailsa Craig during this study when breeding success was generally poor (see Table 6.1.). Coulson and Johnson (1993) thought feeding conditions for Kittiwakes good from 1968 to 1974 at the same North Shields area. From the three nests hatching two young examined on Ailsa Craig the second young died shortly after hatching in each case. More chick growth data are required for Kittiwakes on Ailsa Craig.

Overall it appears that the sea area around Ailsa Craig where the birds forage may be subject to a fluctuating food supply making it at times difficult for Kittiwakes to raise young but the habitat for nest sites is evidently still ideal. Falling out of synchrony with seasonally dependable prey species clearly creates problems for most breeding Kittiwakes on Ailsa Craig and perhaps also elsewhere.

Diets

Diets of British Kittiwakes in the winter period, when at sea, are largely unknown. Foraging occurs at fishing vessels (Erikstad, 1990), but Kittiwakes have difficulty competing with the larger gulls (Furness *et al.*, 1992). Small numbers of Kittiwakes sometimes frequent the Clyde harbours and shores on the nearby mainland in winter. These numbers are similar to those observed at sea (Stone *et.al.*, 1995) although the Ailsa area has more birds at sea than any location between Mull to the north and north Wales to the south. However much greater numbers are sometimes recorded on the upper Clyde and around Arran, e.g. 150 at Coulport, Dunbartonshire in January, 420 Whiting Bay, Arran in October 1995 (Gibson, 1997). These birds may or may not be from Ailsa Craig or Sanda. Ringing recoveries of two adult Kittiwakes from Ailsa Craig indicate no long movements but wintering in the northern Irish Sea (pers.obs). Although they can often be observed around offshore fishing vessels, adult Kittiwakes do not come to land on Ailsa until late February. At this time of year, little interaction was observed in this study when birds were on the sea, such as the courtship reported by Daniels *et al.* (1994). Most birds rafted on the sea in short spells in daylight, less than a kilometre out from the cliffs and usually in calm conditions.

Kittiwakes on Ailsa Craig during the breeding period feed sandeels to their young. I have recorded no other species from regurgitations of chicks. This is also the staple diet for the species in many locations at the same time of year (Pearson, 1968; Galbraith, 1983; Gaston, 1988; Danchin, 1992; Hamer *et al.*, 1993), few other fish species being involved. Belopol'skii (1957) listed Capelin, sandeel, Herring, Cod, Polar Cod and Sticklebacks as fish taken by Kittiwakes in the Barents Sea during the breeding season. He also noted crustaceans, small amounts of molluscs and echinoderms as well as insects and berries, the last three being of little significance. Erikstad (1990) recorded mainly fish and a few squid in the diets of birds shot at sea in March, also on the Barents Sea, which probably reflects proximity to a fishing fleet.

The pre-breeding diet of Kittiwakes has seldom been studied, with what little is known coming from colonies outwith the British Isles (Cramp and Simmons, 1983). Erikstad (1990) did not record crustaceans in his sample of birds taken in daylight at sea in March. However in the pre-breeding period and probably over winter in general, euphausiid shrimps (in the Clyde, *Meganyctiphanes*) are probably regularly taken at night. The pink coloration of the Kittiwake droppings observed below the colony at Ailsa Craig is derived from *Carotin* pigments in this crustacean, which is concentrated particularly in the eye lenses (Mauchline, 1959). As described in Chapter 2, *Meganyctiphanes* forms a major biomass in the deep waters surrounding Arran in the Firth of Clyde (Mauchline 1959, Adams 1986). It surface-swarms at night, mainly over winter, is bioluminescent and offers a major dependable foodsource for Kittiwakes at this time of the year, declining with increasing daylight after the vernal equinox (Mauchline, 1959; Conway, 1973; Adams, 1986). This foodsource appears to differ from that of the breeding period when the diet of Kittiwakes switches mainly to fish. Even if available in the breeding period euphausiids may not be easily digested by chicks. *Thysanoessa innermis* is the winter euphausiid usually taken by more northern Kittiwakes (Cramp and Simmons, 1983), (and those on Isle of May, Fife - pers.obs.), but this species is uncommon in the Clyde area (Prof. J. Allen. pers. comm.). Euphausiid crustaceans require a minimum water column of 120 metres in which to reproduce (Mauchline, 1959) which clearly restricts their distribution.

The surface feeding method of Kittiwakes ensures no direct natural access to food more than perhaps a metre at most below the surface. Belopol'skii (1957) stated that the Kittiwake may dive up to a metre after prey but most of its food is collected from the surface. Kittiwakes therefore rely on surface swarming of sandeels or other small fish in summer, switching to this foodsource from crustaceans in spring. This presumably reduces the proportion of fish biomass available at any one time. Little is known of the seasonal dietary switching in seabirds although dietary switching after hatching in gulls has been reported elsewhere (Annett and Pierotti, 1989; Noordhuis and Spaans, 1992). In some years the surface swarming of sandeels does not apparently occur with any regularity during the chick rearing phase. This dearth of sandeels at the sea's surface at a critical period may be due to hydrological changes, perhaps also plankton abundance or overall distribution. The food-web fuelling sandeel reproduction is well known on the Clyde. Clyde sandeels feed on a small planktonic Copepod crustacean *Calanus finmarchicus*, (pers. obs.- from fresh sandeel dissections) which Adams (1986) investigated in the Clyde. *Calanus* is an abundant and important organism in the Clyde ecosystem, being food for many higher organisms including fish. Its seasonal fluctuations are often at a low on the Clyde just as Kittiwake young hatch on Ailsa Craig. *Calanus* feeds on diatomic phytoplankton which "blooms" annually near to the surface according to increasing temperature (see Salomonsen, 1955). In the Clyde, this cycle may govern the surface swarming of sandeels. The highly significant negative correlation between mean monthly sea surface temperature during May, June and July and Kittiwake breeding productivity suggests that differences in the food availability may be involved in the poor breeding success. The decreasing sea surface temperature over the study period from 1988 to 1993 coincides with improved Kittiwake chick production. When surface temperature is high then the copepods on which the sandeels feed can browse at a greater trophic depth, which in turn allows sandeels and other small fish to feed at a marginally deeper trophic level, effectively eliminating predation by Kittiwakes. Aebischer *et al.* (1990) reported long-term links between Kittiwake breeding performance over many years and changing marine conditions. There was a remarkable similarity shown between patterns of phytoplankton production, zooplankton and Herring abundance, and the pattern of westerly weather in the north Atlantic. Sea surface temperatures should be examined in relation to Kittiwake breeding success at other colonies to confirm that the two are linked at other than a local level, since the Ailsa data, while suggestive, is of course also a co-incident time series (see below). The Clyde is a relatively "protected" sea area and may be subject to greater temperature fluctuations than more open sea areas. More data would be required to confirm if this scenario is operating in the Clyde over the long term. Sea surface temperature is important in that it fuels the diatom and copepod cycle (Adams, 1986; Daly and Smith, 1993). A warm spring will set the cycle off prematurely while an excessively cold spring might retard production. A cool spring, warming gradually as the season progresses is perhaps the ideal, producing enough diatoms to feed copepods within the first few hundred millimetres of the sea's surface, resulting in access to sandeels by Kittiwakes. *Calanus* has no significant control over phytoplankton biomass accumulation (Daly and Smith, 1993). The entire diatom-copepod cycle may take only a few weeks to quickly build in rapidly warming weather. The timing of the cycle will perhaps also influence laying dates of Kittiwakes on Ailsa Craig. It is interesting to note that in the Barents Sea, Kittiwakes were observed feeding directly on swarms of *Calanus finmarchicus* with one bird having about 800 in its stomach (Belopol'skii, 1957). However, *Calanus* has not been recorded in Kittiwake diets from Ailsa Craig. Gaston, (1988) recorded crustacea and a few other marine invertebrates in the diets of Kittiwake chicks near Baffin Island, Canada.

It must be emphasised again that the correlation in Fig 6. 2. is a time series, since both Kittiwake breeding success and temperature have changed in parallel across the years. Thus no direct causative link has been established and other factors may be involved. For example the effects of marine pollution, sea current changes or salinity levels might suppress the surface reproductive rates of the planktonic organisms upon which sandeels and other small or larval fish may feed. Unfortunately most seabird studies have concentrated on the effects rather than causes of marine organism fluctuations. If sea temperature changes alter the reproductive rates of planktonic organisms this will in turn alter the breeding synchrony of Kittiwakes with their food supply. It may take many years to adjust breeding regimes to fit altering marine conditions. Clearly the Kittiwake - Sandeel - Copepod - Diatom food-web shown from Ailsa Craig deserves further investigation.

Other studies have found a link between sea-surface temperature and seabird breeding performance. Cunningham and Moors (1994) linked the decline in Rockhopper Penguins *Eudyptes chrysocome* at Campbell Island, New Zealand to rising sea surface temperatures since the 1940's. In the case of a deep-diving krill / fish feeder it presumably increases the time spent searching for food. Terrestrial factors involved in the Penguin's decline were ruled out, although rats and cats were also present on the island. Presumably the penguins feed nocturnally and lose visual contact with their luminescent prey when it fails to come above a certain trophic level. Agitation by wave action at the sea's surface plays a part in the luminescing of euphausiids (Mauchline, 1959). The fluctuating productivity of Kittiwakes on Ailsa Craig may therefore be directly related to food accessibility influenced thus by temperature resulting in asynchrony with traditionally dependable food supplies during chick rearing. Harris and Wanless (1990) and Monaghan (1992) have also linked changes in sea temperature to sandeel abundance, and thereby breeding performance, of North Sea Kittiwakes.

Changes in fish numbers or behaviour may also be occasioned by fishing activity, particularly trawling. Studies in Shetland, where sandeels are fished commercially, showed that seabirds worked much harder in poor years than in years of sandeel abundance (Hamer *et al.*, 1993; Uttley *et al.*, 1994; Monaghan *et al.*, 1994). Foraging trips of around 10 hours duration in Kittiwakes were common in poor conditions, reducing to 2-3 hours in good years (Hamer *et al.*, 1993). The circumstances may be somewhat different on the Clyde where sandeels have never been fished commercially. With such low breeding success rate for several years, it appears that Kittiwakes are apparently unable to utilise other possible foodsources when feeding chicks e.g. inshore invertebrates, and lose many of their young through starvation in years when sandeel availability is low. In Norway, Barrett and Runde (1980) found their west Norwegian Kittiwake chicks poorly fed. They grew more slowly than chicks at more northern Norwegian colonies and many chicks died at a lighter weight than those surviving, suggesting starvation. Chick survival in Norway was found to be independent of brood size, hatch sequence and egg size (Barrett and Runde, 1980). West Norway is influenced by the warmer waters of the Gulf Stream (Hardy, 1956).

6. 8. References

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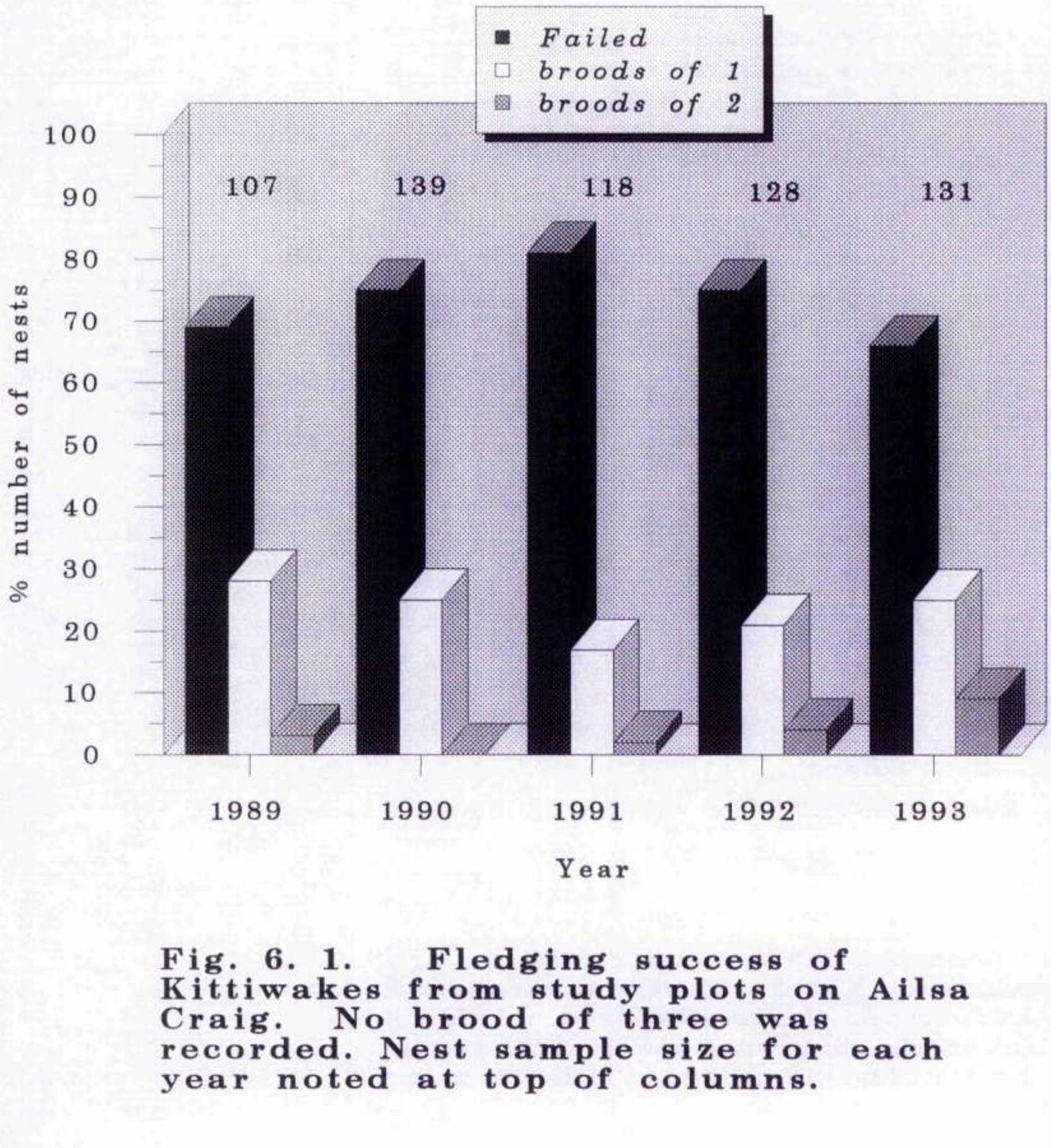

Fig. 6. 1. Fledging success of Kittiwakes from study plots on Ailsa Craig. No brood of three was recorded. Nest sample size for each year noted at top of columns.

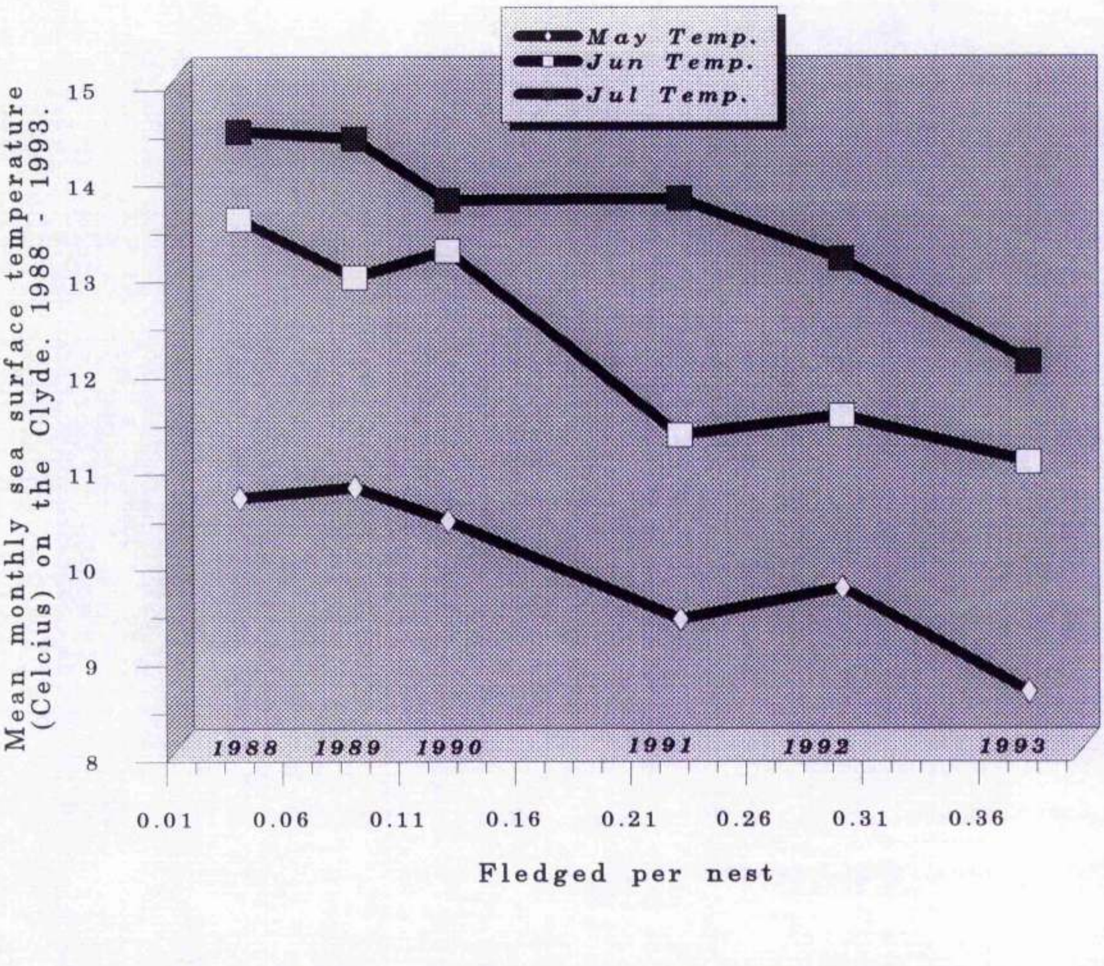

Fig. 6. 2. Average breeding success of Ailsa Craig Kittiwakes in relation to sea surface temperature on the Firth of Clyde 1988 - 1993. [Pearsons correlation, May -0.939, June -0937 and July -0.946 (P=0.01 in each month)].

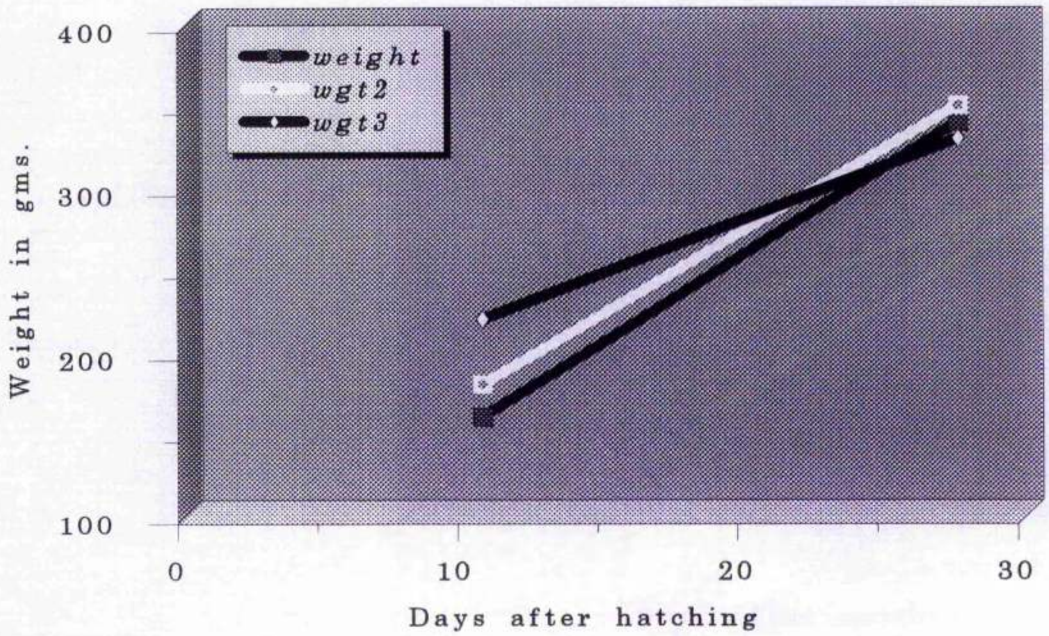

Fig. 6. 3. Growth in three individual Kittiwake chick weights from three different nests, each measured twice in July 1991.

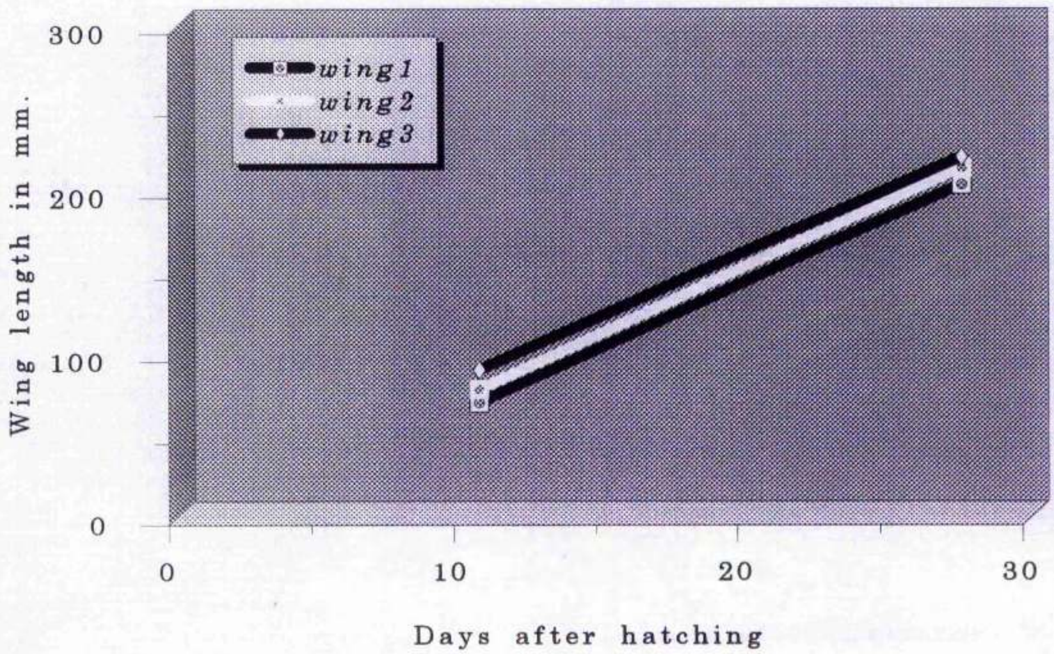

Fig. 6. 4. Growth in three individual Kittiwake chick wings from three different nests, each measured twice in July 1991.

Chapter 7

Guillemot *Uria aalge albionis* on Ailsa Craig - aspects of breeding biology, diet, chick growth and population trends.

7. 1. Introduction

Guillemots constitute an important component of the seabird community on Ailsa Craig. Guillemot breeding numbers in 1988 were 4,000 pairs using standard counting methods. Sanda Island, 25 kms distant is the nearest colony to that on Ailsa, (see Chapter 1, Fig 1.) and numbers there have risen in recent years (Maguire, 1981). In the Clyde overall, the populations are increasing for Guillemot and decreasing for Razorbill (see Chapter 1, Fig. 1.10.).

Guillemots on Ailsa Craig belong to the small southern *albionis* race. During the pre-laying period on Ailsa Craig, auks are susceptible to disturbance even simply through visual contact with humans. In the pre-breeding period vast numbers of Guillemots in particular, will spill from cliffs and fly out to sea simply through visual contact even at a distance of 100's of metres (pers.obs). At the egg-laying period, eggs are sometimes dislodged and lost through this response to human intrusion. Once incubation commences birds appear to become more tolerant and sometimes allow close approach, however chicks may become agitated and mobile from an early stage.

Because of their nesting situations on Ailsa Craig, Guillemots cannot be closely studied without causing excessive disruption, premature fledging and in addition sophisticated climbing apparatus would be required. Breeding activity however can be studied largely by observation and when opportunities arise, as at fledging, when young birds may be handled to record wing lengths and weights. The boulder-beach surrounding Ailsa Craig provides an opportunity for this information to be collected when young land there before reaching the sea.

Data on weight and measurements of birds which have just fledged are important in that many seabirds frequently lose weight as well as gain weight before taking their first flight and auks "fledge" at an extremely early age. Often it is at just this stage when ready-to-fledge chicks are at their most unapproachable and, when at sea and able to dive, are very difficult if not impossible to catch. It is also important to know therefore if chick growth is being influenced or otherwise affected either by human disturbance and / or marine conditions (Hedgren, 1981; Hatchwell, 1989; Harris and Wanless, 1984, 1990; Lyngs, 1994.). Furthermore, weights and measurements of newly fledged birds, unaffected by human interference during their growth, are therefore desirable for comparison with study birds which are disturbed during data collection. Date of fledging can be easily recorded but data on such birds at the precise moment of fledging in Britain tends to be lacking in the literature and is here presented for Guillemot.

Because of their fewer numbers and similar inaccessibility on Ailsa Craig, the small amount of data on Razorbills is summarised and presented in Appendix III for comparative purposes.

7. 2. Annual cycles of Auks on Ailsa Craig

Guillemots and Razorbills are frequent in the sea around Ailsa Craig outwith the breeding season. Although many of these winter birds are probably immature, many are adult, and only a few may be from the colonies on Ailsa and Sanda in the Clyde. There are no ringing recoveries of Ailsa birds in winter from the Clyde and very few from the rapidly growing colony on Sanda, where almost four thousand have been ringed (Clyde Ringing Group data). Ringed Guillemot young (mainly from Sanda) are found dead much further afield in their first year - south to the Bay of Biscay and north to Norway, Faroe Islands and into the North Sea (I. Livingstone pers.comm.).

The first adult Guillemots ashore are back on the cliffs of Ailsa Craig sporadically in late December, but only briefly and normally around dawn. By February visits become more frequent. Eggs are laid from mid May into June. When fledging, young are called at dusk by the parent to the sea during late July and all swim rapidly away from the island. Young appear to fledge at around 20 days after hatching. Even at dusk, some larger gulls are frequently predators of the fledglings (see Chapters 4 and 5).

Young are then reared at sea and their distinctive whistling calls and the adult's growl can be heard on calm days into November. Well-grown young have been observed begging for fish during this period (pers.obs). It is probable that after November they become totally independent of the parent. The parent and young observed at this period are probably not from Ailsa Craig [One young Razorbill found dead at this time of year was ringed on the Shiant Islands, Outer Hebrides].

7. 3. Guillemot numbers in the Clyde

Guillemots on Ailsa Craig have declined over the long-term since counts were first made in the 1950's but the population had stabilised by the early 1980's (Monaghan and Zonfrillo, 1986). The increase in Guillemot numbers on the Sanda Islands, only 25 km distant from Ailsa Craig, during the late 80's and early 1990's indicates a reasonable food supply available in the Firth of Clyde (See Chapter 1). In a period of only 4 years 100 pairs had risen to over 1500 breeding pairs in 1991.

7. 4. Methods

7. 4. 1. *Guillemot data collection*

Weights and measurements of Guillemot chicks came from two sources on Ailsa Craig, a) - 40 fresh dead young from a kill of over 100 young precipitated by a low-flying aircraft incident on 21 July 1992 (Zonfrillo, 1992) and b) - from 12 living young intercepted while making their first flight during 25 - 28 July 1993. In the latter situation young were picked up while fledging at dusk.. Fledging on Ailsa Craig occurs as follows. The adult on the sea calls continuously to the chick which calls excitedly in return and eventually leaps from the cliff, performing a "controlled" descent on rudimentary wings only 70 mm in length. Frequently the chick will try to follow the adult directly from the ledge to the sea. Remarkably, those which do not splashdown directly onto the sea crash onto the rocks at low tide. Not one chick from 30 + fledglings observed falling onto rocks was killed during this type of descent. The Guillemot ledges studied are on the 215 metre high Barestack cliff on the north-west of Ailsa Craig. In previous years all fledglings behaved in a similar way and immediately scrambled over the large boulders at low tide to join the adult at sea just offshore. At high tide virtually all young splashdown directly onto the sea which is only a few metres from the base of the cliffs. The combination of low-tide, good weather conditions and young at the right age allows data to be gathered on these young Guillemots at precisely the moment of fledging.

Once processed, young were manually thrown high onto the sea to where adults were continuously calling, and all were successfully re-united with their parent. Direct observation showed that the splash of the young hitting the water appeared to help the adult in locating the calling chick. Those placed gently onto the water became somewhat disorientated among the exposed kelp and took much longer to re-unite with their parent.

When chicks make a descent which is uncontrolled or in panic they are mostly killed through head injuries. Very few survive this sort of unpremeditated jump as occurred in July 1992, and as previously mentioned. Most nest ledges are around 80 - 100 metres above sea level. In the disastrous low-flying aircraft incident on 21 July 1992, over 120 chicks were killed by being panicked from the breeding ledges by a light aircraft which came very low over the island (Zonfrillo, 1992). Many were near to fledging (see Fig. 7.1) but the rapidity and haphazardness of the jump clearly caused death, mainly through head injuries. 40 of these chicks were collected and dissected and their measurements recorded (Table 7.1.). These were later compared with live caught fledglings in 1993.

Both living and fresh dead young were measured with a 300 mm wing rule to the nearest mm and weighed with a 500 gm spring balance to the nearest gm. The fledging auks were measured under torchlight immediately below the colony and all measurement made as quickly as possible to ensure safe fledging and rapid reunion with the calling parent.

7. 4. 2. Diets

Food of both auk species, carried by adults to feed chicks, was noted on 3 occasions in July from birds assembling 50 metres offshore in windy conditions before flying up to the nest sites. Sizes of prey items were estimated in comparison with the average length of head and bill for both species. For Razorbill diet see Appendix III.

7. 5. Results

7. 5. 1. *Fledglings*

As mentioned above no Guillemot chicks on Ailsa are easily accessible during their brief period on the cliffs after hatching. Their growth rate on Ailsa Craig thus remains to be recorded. Table 7. 1. gives the measurements of undisturbed living and dead Guillemot chicks collected from under the fledging cliffs. The precise age of the chicks was unknown, but clearly similar in the two groups as illustrated by their size. The chicks which died through disturbance by aircraft were very close to natural fledging which tends to be highly synchronous in Guillemots (Hedgren, 1981).

Table 7. 1. Measurements of Guillemot chicks killed following disturbance by aircraft and those fledging successfully.

Chicks dead	**n**	**Mean**	**St.Dev**	**Min**	**Max.**
Wing	40	70.5	6.02	51	83
Bill	40	20.2	1.00	18.1	21.9
Weight	40	220	20.20	170	260
Chicks alive					
Wing	12	71.5	5.4	60	80
Bill	6	18.3	1.36	15.8	19.4
Weight	12	224	21.5	170	250

The differences however, between the dead and living chicks for wing length and weight are not statistically significant (Two-sample t-test ; $p = 0.59$, d.f. 50, for wings, and $p=$ 0.26 d.f. 50, for weights). The disturbed chicks appear to have been slightly smaller and therefore possibly slightly younger than those fledged naturally. Of the 40 dead chicks only 1 stomach contained food remains, viz. 2 small Whiting otoliths and that chick was the smallest measured, and probably the youngest, with a wing length of 51mm and a weight of 180 gms. For comparison with chick biometrics, two adult Guillemots hand-caught on Ailsa Craig weighed 870 gms and 760 gms respectively with wings 202mm and 200mm, and bills 47.3mm and 46.8mm. The wing lengths lie near those at similar latitudes elsewhere in Europe (Hope Jones, 1988).

7. 5. 2. *Diets*

Ailsa Guillemots feed their young mainly on small Clupeid fish such as Sprat and also Sandeels *Ammodytes* sp., caught by underwater pursuit. Small Gadoid *Trisopterus* fish - probably Norway Pout *T.esmarkii*, are also taken.

The prey items identified and their approximate sizes are given from 35 observations in early July 1992 (Table 7.2).

Table 7. 2. Size range of prey selected by Guillemots derived from observations of birds at sea below the colony.

Prey species	Size range (mm)	n.
Clupeids (Herring and Sprat)	0 - 50	4
	50 - 100	10
Sandeel (*Ammodytes* sp.)	0 - 50	2
	50 - 100	8
	100 - 150	4
Gadoids(*Trisopterus* sp)	50 - 100	7

7. 6. Discussion

Diets

During the breeding period, auks and Kittiwakes on Ailsa Craig feed sandeels to their young. The methods of feeding (diving in auks, surface feeding by Kittiwakes) ensure no direct competition. The auks however are apparently in competition with each other for the same prey species but not for nest sites, with Guillemots nesting in open exposed sites and Razorbills nesting mainly in sheltered or covered sites..

For Guillemot on Ailsa, food supply appears adequate, taking small to medium sized prey (Table 7.2.). The young auks, however are only present for a few weeks after hatching before going to sea with the parent. There are no data to assess their post-fledging survival. Unlike Kittiwakes (Chapter 6), Guillemots appeared to have had little problem finding suitable small fish to provision their young. Adult sandeels are frequently taken and along with young Herring probably provide the food of highest calorific value available to Guillemots in the breeding period (Harris and Hislop, 1978).

Fledging

The time spent on the cliffs after hatching appears critical for young auks. Harris *et al.* (1992), found survival increased with early fledging, data from young fledging within a 2 -3 week difference during a 6 year period of study, and that no chick showed body condition to have a demonstrable effect on post-fledging survival from birds on Isle of May, Fife.

Young Guillemots fledge with rudimentary wings, grown enough to give a controlled descent to the sea or rocks below the colony, but not for sustained flight. An adaptation perhaps evolved for a cliff nesting species, but retained even when low non-cliff sites are utilised for breeding. At fledging, the skeleton contains no calcified bones and the longer chicks are on the cliffs the greater the chance they may have of injury at fledging through bone consolidation. It is also argued that while ashore after hatching, there is increased risk of predation by gulls, skuas or raptors (presumably on exposed sites) (Barrett, 1984) and that adults find it more energetically costly to commute between feeding grounds and the colony. It is therefore thought beneficial for the adult to take the chick to sea at the earliest opportunity.

Hatchwell (1991) found no differences between or within two different three year periods in the 1970's and 1980's on hatching weight, growth rate or fledging weight of chicks on Skomer Island, Wales. Differences were evident only in provisioning rate and food supply. Guillemot young fledging from Ailsa Craig were lighter in mean weight than those fledging at other colonies (see below). This may point to food shortage or to the birds being intrinsically smaller. Hope-Jones (1988) showed a north to south cline in European Guillemot biometrics with bigger birds to the north of their range so one would expect the Ailsa birds to be marginally bigger than those further south, not smaller. Hedgren (1981) recorded mean fledging weights from a vast sample of 13,841 young in the Baltic during 1972 to 1976. The mean weight of 253.9 gms was heavier than the heaviest to fledge naturally from Ailsa Craig (at 250 gms). However the range was from 150 gms to 350 gms, which encompasses the weights of Ailsa young. Hedgren and Linman (1979) also found Baltic Guillemot young to decrease in fledging weight after peak of fledging. They also found that re-laid eggs were 6% smaller than originals but hatch weight was similar to eggs of original size. Young were ashore for a mean of 19 days after hatching and were fed only Sprats. Late young had a lower growth rate than "normal" young and decreased availability of food was thought responsible. It is not known to what degree of disturbance the birds were subjected while data was gathered . Hedgren (1981) noted that fledging was highly synchronous with 82% fledging at + 5 days from the mean.

Approaching fledging it is likely that adult Guillemots do not feed their chick for perhaps 24 hours or more to encourage it to make the decisive jump (gut contents of n=40 dead chicks examined). This period is accompanied by much vocalisation between chick and parent. Stomachs of all but one of the young killed when at the near-to-fledging stage on

Ailsa Craig were empty, suggesting this may be the case. It may also be argued that they were undernourished although there was little supporting evidence. The site and habitat conditions in most auk studies are not adequately described to relate the point of fledging to the immediate habitat conditions. However the Ailsa sample size is perhaps too small to draw any valid conclusions. More data are required on the weights at which young auks fledge from different nesting sites within and between colonies.

While wing and feather growth may be independent of weight, deliberate temporary starvation may delay development of bones.

Timing of fledging

Guillemots, like Kittiwakes, on Ailsa Craig fledge later than birds on the east coast of Scotland. Auks on Ailsa Craig consistently fledge around the end of July from 20th - 31st. Harris and Wanless (1984) had chicks all fledged from a study plot on Isle of May, Fife on 4 July. Hatchwell (1989) records fledging at 14 July on Skomer, Wales. Ailsa birds may therefore lay later.

Guillemots may move or switch colonies, perhaps depending on disturbance levels (human and / or aircraft). The rise in numbers of Guillemots on the Sanda Islands (25 kms distant from Ailsa Craig) from less than 100 to over 1500 during the past decade perhaps might involve colony switching or an upsurge of young birds of breeding age which are not absorbed into established larger colonies such as Ailsa Craig.

Once at sea, Guillemots and probably Razorbills attend the young for many months. I have heard the whistling calls of young Guillemots off Ailsa Craig in early November (these birds may or may not be from Ailsa Craig). By December and January the first birds return temporarily and infrequently to the nest sites vacated since early August. Slater (1980) found wind speed was a factor in the numbers of birds present at east coast breeding cliffs. On stormy days on Ailsa Craig during the breeding period, auks spent periods of up to 30 minutes on the sea below the colony before flying up to the breeding ledges. In gale-force conditions up to 6 adults in one day were killed when attempting to land, surprisingly no chicks or eggs were found on the rocks below the ledges.

Provided the young does not strike its head when fledging onto rocks, there can be little damage to the cartilaginous skeleton during a controlled and premeditated fall or flutter by the chick. When the fall is through panic, or being swept from the ledges by fighting adult conspecifics or even the parent, the chances of an uncontrolled descent are increased to the point where few appear to survive such a fall. The plastic quality of the sternum, which is very long in auks compared to other seabirds, will absorb the impact of most controlled falls when fledging. Many large colonies of auks fledge onto exposed tidal rocks beneath the breeding cliffs e.g. at Handa Island, north-west Scotland, the largest British colony.

When comparing the growth rates of a number of bird species, Rickefs (1973) found precocial Guillemot chicks grew slower than other semi-precocial auks when at 15% of adult weight. When at 20% of adult weight (i.e. near to fledging) Guillemot chicks were only 25 - 50 % of semi-precocial alcids. The slow growth rate, in this instance, may be an adaptive function which Ricklefs tended to generally dismiss.

Studies of young auks should in future specifically relate the comparative breeding habitat peculiarities with the age or time of fledging. Ydenberg (1989) and Ydenberg et al.,(1995) studied the juvenile life-histories of the Alcidae. Nestlings of faster growing Alcids fledged younger and heavier than slower growers, and those hatched later fledged younger and lighter in mass. Moreby and Ydenberg (1997) found a relationship between provisioning rates and level and steep habitats in Cassin's Auklets which tended to contradict the general predictions of the Alcidae model. Few comparative studies also take account of size differences in auk populations (Hope Jones, 1988), relating this to fledging weights or wing lengths. Together these factors may explain the lightness at which chicks fledge from the cliffs of Ailsa Craig coupled with their longer wings. A lighter weight chick may better survive fledging from cliff sites not directly above the sea and where contact with rocks below is guaranteed.

Disturbance

Harris and Wanless (1984) examined the effects of human disturbance on young Guillemots choosing a much disturbed group and a little disturbed group for comparison on Isle of May, Fife. Hatchwell (1989) similarly compared groups of young subjected to varying degrees of disturbance on Skomer Island, Wales. Disturbance when extreme can lead to mass death (Zonfrillo, 1992) but to what effect does lesser degrees of disturbance have on auks, adults of which can be disturbed from their breeding sites simply by visual contact with humans ? The dilemma in handling birds to generate data may be offset by the usefulness of that data if handling has a significant effect on the birds, e.g. on the weight at which they fledge. Remote operating balances are probably required for accurate growth rate data with minimal human disturbance. In the studies by Harris and Wanless (1984) and Hatchwell (1989) the definitions of "disturbance" vary between "much disturbed" and "once disturbed". However "undisturbed" birds of Harris and Wanless (1984) were in fact disturbed several times before fledging while those of Hatchwell (1989), defined as "undisturbed" or "totally undisturbed" were disturbed once prior to fledging, perhaps enough to influence fledging.

Harris and Wanless (1984) and Lyngs (1994) found disturbance had a significant effect on the weight at which young Guillemots and Razorbills fledged and Hatchwell (1989) had similar results with young Guillemots departing earlier and lighter and growing more slowly than once-disturbed young. The Harris and Wanless (1984) data on fledging makes interesting comparison with the Ailsa Craig birds (Table 7. 1.), none of which were handled prior to being caught at the moment of fledging. In their study, both categories of birds, disturbed and undisturbed (less disturbed) weighed slightly heavier in the mean than those fledging from the cliffs of Ailsa Craig, even for the most disturbed birds on the Isle of May this difference remained (229.9 gms. c.f. 224.0 gms, n = 11, 12 respectively). Paradoxically, the wing lengths showed a reverse correlation, with the lighter Ailsa birds having a longer mean wing length than even the least disturbed birds on Isle of May (67 mm c.f. 71 mm, n = 8, 12 respectively). Thus the genuinely totally undisturbed birds on Ailsa Craig fledge lighter in mean weight and longer in mean wing length than those subject to varying degrees of disturbance on Isle of May. These weights in turn are lighter than those from the Baltic given by Hedgren (1981) and mentioned above. The discrepancies of the Ailsa birds may be that they were older and in poor condition although the upsurge in breeding numbers of Guillemots on nearby Sanda Island suggest that food was not scarce, perhaps even locally abundant. Given that wing length grows independently of nutrition, the wing length at which the young fledge may therefore be more important than the weight. This could be because a suitably controlled descent from high cliffs requires wings of a certain length and in turn the longer wings aid survival by giving the young an advantage in swimming underwater - to avoid predators, marine and avian, or in learning the skill of food collection.

7. 7. References

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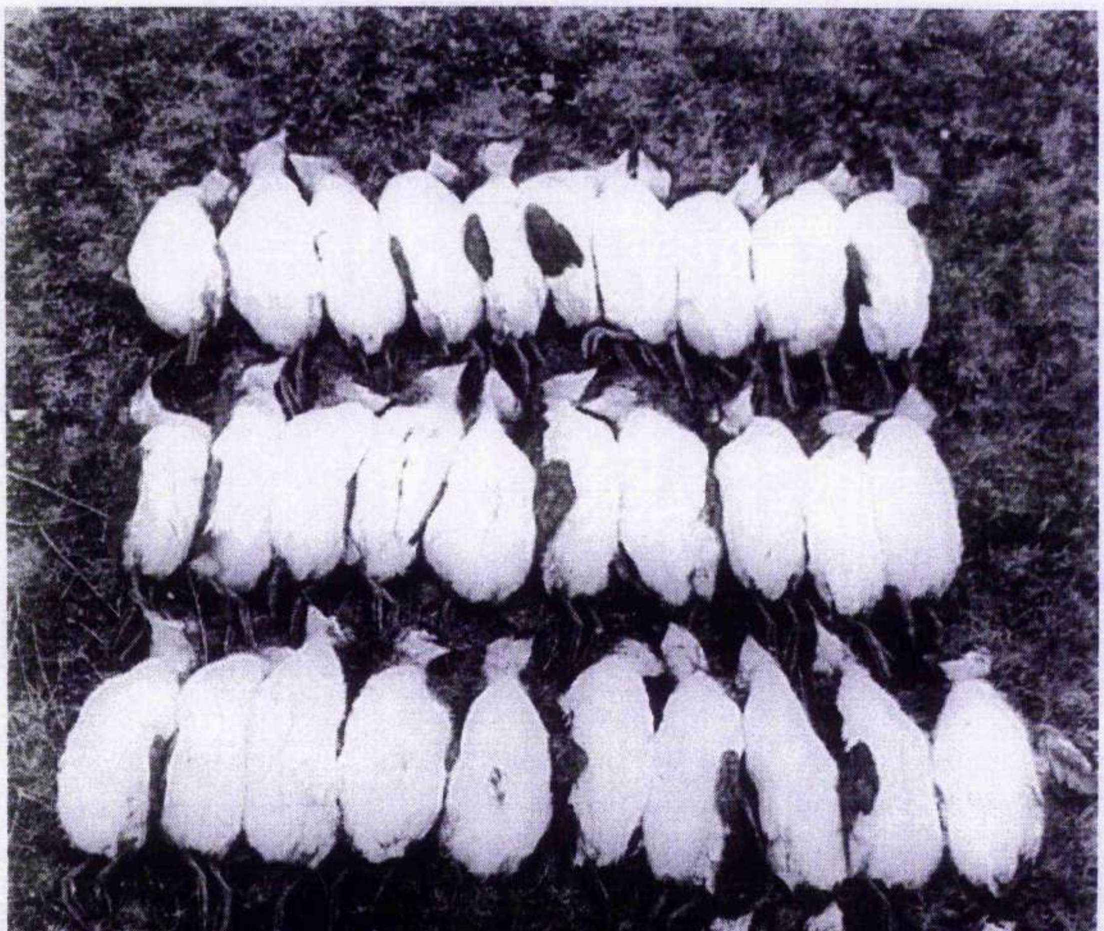

Fig. 7.1 Guillemot chicks killed as the result of a low-flying aircraft incident over Ailsa Craig in July 1992.

Chapter 8.

Colonisation, ecology and eradication of the Brown Rat *Rattus norvegicus* on Ailsa Craig

8. 1. Introduction

8. 1. 1. *Historical perspective*

Both the Brown Rat and the Black Rat are introduced species to most of Europe. Their origins are fairly well documented. The Black Rat arrived in the British Isles via the ancient trade routes from South East Asia probably around the eleventh century; the Brown Rat arrived much later, around the year 1728, via shipping from present day Russia (Corbet and Southern, 1977). While the Black Rat has largely died out over much of its former range in northern Europe, the Brown Rat has spread, sometimes ousting the Black Rat in the process. The specific name of the Brown Rat is a misnomer, having arrived in Norway much later than in the British Isles and not *vice versa*. In Scotland, the Brown Rat spread rather slowly, and by 1855 was described as "recently introduced " in some remote areas (Matheson, 1962).

The Brown Rat has now spread over virtually all of the Scottish mainland and, through the agency of man, to many islands, large and small. Their impact on the island ecosystems has been little studied. Indeed most studies of Brown Rats have been on agricultural land or on rubbish tips where their existence is almost wholly parasitic of man. The Brown Rat lives more outside rather than inside buildings, unlike the Black Rat, but carries diseases equally as noxious. Broom (1958) showed 43% of Brown Rats to be carriers of leptospirosis, but other diseases transmissible to man such as salmonella, lymphocytic choriomeningitis and toxoplasmosis have also been isolated in British rats. Elsewhere plague and typhus are carried by Brown Rats but are less likely to affect man from this source because of the rodent's ecology than are the same diseases when carried by Black Rats.

8. 1. 2. *Summary of rat behaviour and ecology*

Brown Rats feed mainly nocturnally and usually within a short radius (12 m) of their burrows (Davis *et al.*, 1948), but in agricultural land foraging trips of over 660 m have been recorded by radio tracking (Taylor, 1978). Brown Rats swim and dive well and will forage on beaches at coastal sites. Where the environment is undisturbed, unfamiliar objects, such as spring loaded cage-traps or snap traps tend to be avoided for at least 48 hours (Shorten 1954; Barnet 1963; this study). Brown Rats also climb very well and can easily ascend vertical cliffs. Almost anything will be eaten or chewed, including inorganic items such as plastic. Protein-rich or starch-rich foods are preferred (Corbet and Southern, 1977). Large items of food are usually gnawed to a size where they can be carried away to a place of safety and devoured. Animal carcasses may be dragged down burrows or under rocks where they may be eaten at leisure and defended from competitors.

Female Brown Rats rarely produce more than 5 litters per year, and average 7 - 8 offspring per litter. Female offspring usually are sexually mature at 11 weeks old, and in areas where food supplies are seasonal, breeding usually takes place in summer and autumn. Life expectancy is short. Among young rats in saturated populations, Davis (1953) calculated a mortality rate of 99%. Adult mortality was calculated at over 90% per annum. Few rats will therefore live for more than a year. Population changes tend to involve highest numbers in autumn and early winter with lowest numbers in spring. In the northern hemisphere this trend will closely follow seasonal abundance of food and gradual lowering of temperature at the onset of winter. The dynamics of rat populations can therefore be of the "boom and bust" type; numbers increase then crash when food ceases to be available. Such population changes are particularly marked on remote islands where food may only be abundant on a seasonal basis (Atkinson, 1985).

8. 1. 3. *Rats as seabird predators*

Atkinson (1985) has implicated rats in the decline and, in some cases, extinction of seabirds, landbirds and other animal populations on several of the world's oceanic islands. Some of the world's rarest seabird species are currently under threat of extinction from the effects of rat predation. In many situations past attempts have been made to eradicate rats, but with modern, more potent poisons, the results are now more likely to be successful.

The drastic effects that rats can have on island bird populations are well documented. A few such examples are from the Midway Island group, in the Pacific, where rats reduced the endemic Bonin Island Petrel from half a million pairs to the present 5,000, and the Wedge-tailed Shearwater from 62,000 in 1945 to 2,000 at present (Woodby, 1988). On Madeira, in the north Atlantic, the endemic Freira Petrel, which sub-fossil remains show was found at many sites over the island, is presently reduced to 8 known breeding pairs in 1993 (Zino, pers.comm.). In the Galapagos Islands, the Dark-rumped Petrel is currently threatened by rats (Cruz and Cruz, 1987) and in Bermuda the endemic Cahow has been brought back from the verge of extinction by a massive and prolonged campaign mainly directed against rats (Wingate, 1985).

In New Zealand, where the endemic flora and fauna appear to have suffered more from the ignorance and stupidity of European settlers than almost anywhere else, the seabirds have been hard hit by rats (Imber, 1975). In a study of the Grey-faced Petrel, Imber (1976) found that although breeding in large numbers, the fledging success was practically zero and the colony was increasing in size purely through immigration. Rats were responsible for the annual extermination of the petrel chicks, and once the rats were eradicated, the fledging success of the young birds was good. In virtually all of the previous examples, the birds nest in burrows, which makes their eggs and young particularly vulnerable. In Europe, Møller (1983) found that rats on some Danish Islands were preying upon young Larids (gulls and terns), surface nesters, which either deserted or switched their breeding colonies in an attempt to avoid rats. However, the new colonies were eventually found and exploited by the rats, causing further shifts in breeding sites.

8. 1. 4. *Colonisation of Ailsa Craig and predation of seabirds by rats*

While much attention has been focused on the problems of seabird islands and rats within the past 15 years, it is not a recent phenomenon. In 1889 a dog belonging to one of the lighthouse keepers on Ailsa Craig killed a Brown Rat at the head of the jetty (Campbell, 1892). It was the first seen on the island. At the time a ship delivering coal was at the jetty supplying the recently built lighthouse with coal for conversion to gas for fuelling the light, (a practice which ceased around 1910, when the light was converted to paraffin). This was certainly the first rat recorded on Ailsa Craig, which had been inhabited, albeit seasonally, since at least the 12th century. Lawson (1895) had noted the absence of rats in the first edition (1888) of his book on the island's natural history, but by the second edition commented on their abundance. Several large ships came to grief on the rocks and reefs surrounding Ailsa Craig in the latter part of the last century. Major catastrophes included the *Duke of Edinburgh* in 1870, the *Clan Campbell* in 1881, the *Austria* in 1884 and the *Pennon* in 1889 (Moir and Crawford, 1988). Following the first two of these wrecks, which involved loss of life, the Commissioners of the Northern Lighthouses were petitioned, resulting in the construction of the Ailsa Light in 1883. The light became operational in 1886. Rats had only to swim ashore from any of the wrecked vessels to find probably a better food supply than that on board ship.

Like the Norse-Gaels who colonised St Kilda and lived on its seabirds in a generally self-sustaining way until the 1920's, Ailsa Craig had similar inhabitants. These were mainly the Girvan family who were tenants of the island from at least the mid 19th century, part fishing, part crofting and who seasonally exploited the seabird colony (Gibson, 1955; J Girvan, pers. comm.). The Girvan family, along with the lighthouse keepers, their families, and granite workers lived as a community on Ailsa Craig until the 1950's. Long before then, the Ailsa rats had become a problem. Campbell (1892) provides some limited quantitative data, having interviewed the lighthouse keepers then resident. On 11 December 1889, it was noted that 48 rats had been killed..." yet there seems to be plenty more about the place". In spring 1890 it was noted that a rat weighing 18 ounces (540 gms) had been killed, and that ... " it is not safe to put your hand into a hole for a Puffin, for the chances are that you will get a rat instead". Such a heavy individual was perhaps a pregnant female. By November of that year the autumn increase in rats had lead to a lightkeeper's dog killing 59 in one day on the west side of the island (under the Gannetry). Rabbits were being eaten in their snares by the rats and even the vast bird colonies were being decimated ..." The eggs and young of the sea-fowl also paid large tribute to the omnivorous rodent, so much so, that fewer young, I believe, were reared than has ever been the case before." From 1st October to the end of December 1890, the lightkeepers killed over 900 rats. Around the dwellings a dog killed 100, and 300 were killed in a month ..." yet they seem as plentiful as ever." The rats had clearly spread from below the cliffs and around the houses to occupy all habitats on the island, " They are all over the island, from the very top down to the water's edge." This situation remained until 1991. Campbell summed up his comments by concluding, " It is difficult, if not impossible, to suggest a cure but if any such can be found there is no more favourable spot on which to operate, for the Craig,... cannot, unless by a chance similar to their introduction... receive any outside accession to their numbers."

The rats were also threatening the livelihood of the tenants who relied on the seabirds and rabbits as a major source of income. Apart from eating the young and eggs of most seabirds, the rats would also have found the many Gannet carcasses below the cliffs a favourable foodsource. These are adult and young birds that have died from falling. Adult Gannets do so when fighting and young of all ages fall when adults knock them off accidentally or, when larger, during wing exercising in windy weather. Wanless (1983) estimated over 600 Gannets, young and old, dying in the course of a season below the cliffs. The Puffin colony on Ailsa Craig, formerly described as in "bewildering numbers... so great that they darkened the sky" (Gray, 1871), had been so ravaged by rats that by 1934 their numbers were few, McWilliam (1936) described them then as "...practically extinct".

Burrow nesting seabirds such as Puffins and petrels are very susceptible to rat predation. One of the major benefits from nesting in burrows is generally held to be the avoidance of predators, usually avian. Often this means that both adults can temporarily abandon the young chick and go to sea; this makes the young particularly vulnerable to rat predation. In contrast, surface nesting petrels such as the Fulmar, which probably descended from a burrow-nesting ancestor, will routinely attend the chick for around 10 days after hatching before leaving it during foraging trips. By this age the proventricular oil capacity of the chick has developed enough to act as a defensive or offensive form of protection. Chicks either in burrows or unattended on the surface are therefore vulnerable to rat predation.

However no major steps were taken against the rats on Ailsa Craig until 35 years after they were first seen on the island.

8. 1. 5. *Early attempts to control rats*

The invasion of Ailsa Craig by Brown Rats, and the damage they caused, prompted perhaps the first-ever attempts at rat control on a seabird island anywhere in the world. With the growing awareness of the value of conservation, and the passing of Acts of Parliament to protect wildlife, Glasgow members of the then embryonic Royal Society for the Protection of Birds took up the gauntlet thrown down during a Parliamentary session in 1924, when questions were asked in the House of Commons as to what could be done to save the Ailsa seabirds from rats (Anon., 1924). This bold step stimulated concerned individuals into action. The then not inconsiderable sum of £160.00 was spent on rat poison for the effort in rat eradication by the Glasgow branch of the Royal Society for the Protection of Birds (RSPB, 1924 and 1925). The money and effort helped reduce the numbers of rats on the island considerably. The poison used however (Ratolin) was not wholly effective and poisoning activity was mainly around the lower inhabited parts of the island. Many, but not all, rats were killed, (RSPB, 1925) and those surviving slowly increased their numbers once more.

8. 1. 6. *Rat and seabird interactions on Ailsa Craig and elsewhere in the Firth of Clyde*

Detailed studies undertaken during 1989 and 1990 of the breeding success of seabirds on Ailsa Craig (see Chapters 2 - 7) showed that Fulmars and Gulls in particular appeared to suffer heavy losses at the egg and chick stage. Many Fulmar eggs went missing and all hatched chicks were similarly lost (Fig. 8.1., and Fig. 8.2.). Counts and ringing efforts similar to those on the Clyde were simultaneously conducted at two colonies on the Forth, at Isle of May, Fife, (Fig. 8.3.), circa 50 - 90 breeding pairs (1979-1988 counts), and at Tantallon Castle (East Lothian) circa 120 breeding pairs (1988 count), and showed a completely different picture. Most Isle of May Fulmars for example hatched eggs (only a few lost to gulls) and raised chicks to fledging (Fig. 8. 3.) as did the Tantallon Fulmars. (Data collected by the author).

Reasons for the failure of Fulmars to raise young to the fledging stage at most Clyde colonies were not obvious. Since the circa 300 pairs of Fulmars on Sanda Island, off the Mull of Kintyre and 25 km distant from Ailsa, were capable of regularly raising young to the fledging stage, (Clyde Ringing Group data), it suggests that the Fulmars were experiencing land-based rather than sea-based difficulties. Sanda Island has neither rats nor rabbits, and also has breeding Manx Shearwaters, Storm Petrels Black Guillemots and Puffins - all burrow-nesters. Habitat on several of the smaller Clyde islands appears perfect for burrow-nesting species, although only a very few have them present.

8. 1. 7. *Evidence of rat predation*

In general, direct evidence of rat predation is very difficult to obtain. Most rat activity is nocturnal. However, gnawed carcasses, rat droppings and a complete lack of obvious predation at or near a formerly active nest site (no corpse or plucked feathers) is good circumstantial evidence of rat activity in a bird colony. Detailed studies must be made to ascertain the circumstances of chick loss and to differentiate between scavenging and active killing by rats. Rats are seldom if ever seen in the act of predation, although on

Ailsa Craig they could frequently be found scavenging bird carcasses, even in daylight. These may or may not have been killed by the rats themselves.

Rat predation was evident at the Rotten Nick study site. A dismembered Fulmar chick which had been alive less than 8 hours earlier was found down a rat hole with the leg-ring jammed in a rock crevice, preventing most of the carcass from being dragged further down under the rocks. At other Fulmar nest sites, regurgitated oil coated the immediate rocks at the site and small fragments of wing feather and tissue from internal organs e.g. heart and liver was evident on the site. The carcass showed rat gnaw marks and it was evident that rats were actively killing the young birds. Fig 8. 4., shows the pattern of loss of Fulmar chicks from the study site. Predation by birds such as gulls and Ravens can generally be distinguished from that of rats. The birds always removed eggs or chicks from the nests to a site nearby and never broke or dismembered and devoured them on the spot. Spring-loaded cage traps baited with bird meat (from a dead Gannet) and placed on the cliff ledges - 80 m above sea level - beside the Fulmar sites proved that rats were indeed active in the area. Traps were ignored for three to five days or more before eventually being entered by rats. Traps set at ground level were more quickly sprung (usually overnight) suggesting that the rats living on the upper ledges were very suspicious of unfamiliar objects placed in their territories.

Gull chicks simply vanished from around the nest sites. These were usually less than 14 days old and a few part-eaten corpses under boulders showed gnaw marks to legs and cranium, with most tissue in between these areas removed completely. In 1989, 72 monitored Herring Gull clutches, comprising 194 eggs, produced only 11 fledged young. Gull chicks are precocious, brooded for only a few days after hatching and then are able to shelter from heat and rain by going under rocks and boulders, usually within a few metres of the nest. Adult Herring Gulls attend the chicks by day but at night when chicks were under rocks or in holes these would be vulnerable to rats, even with the adult close by. From around 2000 pairs of breeding gulls on the island the pre-dispersal, post-fledging roost sites on the island in 1989 and 1990 showed around 300 juvenile birds (Fig 8.5.), when perhaps three times that number could reasonably be expected.

After autumn dispersal of seabirds, rats have to rely on a more frugal diet. In winter most vegetation has died down, insects are hard to find and dead rabbits are the only regular source of meat for at least two months. Gulls continue to roost on the upper parts of the island throughout winter and their regular production of pellets appears to have been a foodsource for rats in these localities. Pellets were regularly found under rocks alongside rat droppings and in rat burrows. Pellets and regurgitations frequently included the part-digested regurgitated legs of poultry and complete plastic bags of chicken giblets which rats could easily open.

Droppings (10) of Ailsa rats from different parts of the island were collected and analysed to ascertain the types of foods taken in winter. These showed a fairly predictable diet of plant material, molluscs and insects, depending on their location. (Data via Rentokil laboratories, East Grinstead).

Following preliminary discussions between interested parties it was agreed that complete rat eradication, if possible, would be of benefit to the seabirds and the island in general. The Ailsa Craig Working Group was therefore formed in November 1989 to investigate and oversee a proposed rat eradication project and comprised The Most Hon. The Marquess of Ailsa, O.B.E. (Chairman), Dr P Monaghan (Glasgow University), Mr G Hancock (Kelvingrove Museum), Mr G Houston (Rentokil Ltd), Mr D Smith (Clyde Ringing Group), Mr J Burlison (Scottish Natural Heritage) and the author Mr B Zonfrillo (Glasgow University).

8. 2. Methods

8. 2. 1. *Pilot studies*

Pilot studies commenced in 1990 to answer some fundamental questions before undertaking any major eradication work.

8. 2. 2 *Choice of suitable poison*

There are several modern, highly effective rat poisons currently available. Some are very rapid. others cumulative. Fast acting poisons can cause death almost instantaneously and in such cases the animals die above ground, usually after convulsions, and are then available to scavenging birds. Warfarin is cumulative and the animals usually die in the burrow, in a torpor, with no convulsions. Warfarin is a mammalian poison and whilst not amongst the most potent of poisons, it was thought to be the least harmful to any other indigenous vertebrates, should they receive a dosage. In the field the use of Warfarin would mean most rats would die underground, thus lessening further any possible risk of secondary poisoning to non-target species.

Warfarin is a vitamin K inhibitor and works cumulatively as a decoagulent, causing internal haemorrhaging. It was essential to establish whether the Ailsa rats would consume the Warfarin-impregnated grain (a food never available to them on the island) and if they were resistant to Warfarin. It was also essential to devise a rat monitoring programme for before and after baiting. Warfarin usually manifests itself in rats after 3-5 days following ingestion. Distribution of poison was therefore to be executed such that rats could find it and when found, have enough to eat to cause death.

In spring 1990 Rats were presented with Warfarin-impregnated whole-wheat bait (500 ppm) in bait boxes, as supplied by Sorex Ltd, Widnes, England, on the Rotten Nick study site. The rapid uptake of bait showed that the rats were susceptible to Warfarin and that they would clearly readily devour the grain.

8. 2. 3. *Censusing rats*

Rats are very difficult to census. However an index of activity, and thereby abundance, is given by the use of chewsticks, i.e. wooden spatulas smeared with edible substances and firmly set at random, in known and unrecorded territories, around the island. To test for palatability, cage-trapped Ailsa Craig rats were each given three spatulas each smeared with edible material. The first was Bovril, a concentrated meat extract, the second honey and the third margarine. Both Bovril and honey were totally ignored and remained untouched after several hours. Margarine, on the other hand was rapidly licked off and the saturated wood chewed exactly to where it was unstained by the fat.

The extent to which chewsticks are used thus provides evidence of rat activity in the areas where they are deployed. When chewsticks were set on and around the base of the cliff area at Rotten Nick they did indeed clearly show activity. Chewsticks however do not measure abundance quantitatively, but give an indication of rat presence and presumably absence.

8. 2. 4. *Initial Baiting*

In spring 1990, 10 rats were trapped and weighed giving a mean weight of 260 gms, (s.e. 12.1; range 200 - 320 gms), considerably lower than the 500 gms given in the literature for the species (Corbet and Southern, 1977). It was found that 6 -10 rats could be cage trapped in any area of known rat activity over a period of three weeks and the quantities of poison required were determined on the basis of a calculated over-estimate. A trial baiting was carried out on the Rotten Nick ledges, in spring of 1990 using two bait-boxes each filled and replenished regularly with 1 kilo of Warfarin during April and May. This resulted in the area being rat-free (no chewstick activity recorded) by June. The number of eggs laid by Fulmars at this site had been fairly stable over the years (around 15) but only one young reached fledging in six years of monitoring the site (Fig 8. 2.). In contrast, for the 6 Fulmar eggs which hatched at this site in 1990, all fledged successfully (Fig 8. 2.).

Chewsticks (20) were set on and below the baited cliff ledges and monitored at least weekly from June onwards. Not until late August did any lower stick show signs of being chewed, and thus the ledges and basal area were probably gradually re-colonised by dispersing young rats, following the increase in Gannet carcasses available in late summer from below the nearby cliffs.

8. 2. 5. *Deployment of poison*

Warfarin rodenticide was supplied by Sorex Ltd in the form of whole wheat grains pressure-impregnated (500 ppm) and having an edible blue-black dye and palatability agent added. Total used in 1991 - 3 Tonnes, in 1992 - 2.5 Tonnes and in 1993 - 0.5 Tonne. Warfarin was transported to the island and the bags dropped on the upper slopes by means of a Royal Navy "Sea King" helicopter from 819 Search and Rescue Squadron at HMS Gannet, Prestwick, Ayrshire, at pre-determined drop zones and at a time of year when bird activity was low, to avoid disturbance. Bait was stored under tarpaulins until ready for use when it was transferred into plastic buckets and distributed using plastic scoops. Each scoop would carry at least 200 gms. Rubber gloves were used to prevent the blue-black dye from the bait impregnating hands. Chalk marks were made along the talus slopes on prominent boulders to indicate that poison had been distributed in that area and to avoid double-dosage. Poison was placed, wherever possible, well under rocks or deep in holes to avoid easy access by non-target species. The species thought most vulnerable to the effects of secondary poisoning, e.g. gulls and Raven were monitored for breeding success.

Five helpers were used to make the initial distribution, and these had been previously briefed by Mr. G. Houston of Rentokil Ltd., on how to handle and use the poison safely, and its effects on human and other animals. On the first baiting phase, mid March - April 1991, an additional 14 helpers spent one day (23 March 1991) distributing bait. These were from Scottish Natural Heritage, Glasgow University and the Clyde Ringing Group. Most helped on the upper slopes but the area under the west cliffs was baited with the use of an inflatable "Zodiac" to transport bait by sea to the areas where it was required. When most areas of the island in which rats had been proven active were adequately baited, (around 75% of the landmass), coverage was deemed to be satisfactory. Only certain areas of inaccessible cliff and ledges were left without bait.

Baitboxes, made of timber, were used in areas where rat activity was noted but where no suitable cover for bait laying could be found. These were constructed to monitor baiting mainly on exposed ledges. The box was a simple container, size 450mm x 350mm x 200mm deep, with an entrance and exit hole 100mm wide x 200mm deep and a "manger" area inside to contain the bait. This was replenished when bait had been devoured. The baitboxes could hold up to 5 kilos of grain. Margarine was smeared around the entrance holes of the boxes to attract the rats and reduce any scent of humans, and to try and make the rats accept the box in their territory sooner. In all, six baitboxes were utilised. Back-up baiting with 2.5 tonnes Warfarin, using the same methods and materials, was done over the winter of 1992 to eliminate possible survivors. All bags, scoops and other materials in contact with the Warfarin were burnt after each baiting session.

Bait was initially distributed in March and into April when rat numbers were thought to be at their lowest. The important overall aim in baiting was to attempt getting a few kilos of Warfarin, at least, into every area where rats were known to be active. The basal areas, cliff ledges and upper slopes, particularly at the gull roosts were especially targeted as were "shelter stones" where rats had accumulated large quantities of droppings either through marking territories or where food was regularly devoured. These stones were large and sometimes formed small caves which rats found attractive. Herring Gulls frequently nested in or near these sites during the breeding period.

8. 2. 6. *Monitoring*

It was essential to devise a rat monitoring programme for before and after baiting had taken place. Before baiting, 200 chewsticks were set around the island and checked daily during October 1990 and March 1991. Monitoring of chewsticks and baitboxes was done initially on a daily basis, when weather permitted. Two weeks after baiting was completed in mid April, some 600 in total chewsticks smeared with rancid margarine had been set around the base of the island, on the upper slopes, and on the accessible seabird ledges, and monitored. All that had been previously set were replaced. After daily monitoring during May and June of 1991, the 600 chewsticks were monitored weekly.
Around the base of the island and near to habitation, daily checking was continued on a casual basis over the remainder of the period until October 1993. Other direct evidence of rat activity was obtained by monitoring carcasses for evidence of gnawing, looking for fresh droppings under stones and making nightime walks around the base with a flashlight to look for foraging rats, until October 1993. Monitoring during and after 1992 was done on a monthly basis with roughly the same number of chewsticks checked (some loose chewsticks were pulled up by gulls and built into their nests in spring).

Monitoring also included the breeding success of seabirds preyed upon by rats (see previous chapters for methods) and the success of species such as large gulls was estimated from the numbers of chicks fledging .

8. 3. Results

8. 3. 1. *Rat activity*

Prior to baiting , after only 5 days every one of 200 set chewsticks was chewed to some degree, some being completely reduced to "sawdust". Rat activity was noted at one chewstick from the first 210 set immediately after baiting on 13 April 1991 to check progress with poisoning. The area was quickly treated with further poison. From 16 April 1991 onwards until October 1993, no chewstick was chewed anywhere on the island, and of the final total of 600 chewsticks set up by May 1991 and later monitored, none was chewed or showed any evidence of rat activity, where formerly all had been eaten (Fig. 8. 6.). Most rats appeared to die underground, only 4 were found dead above ground post-baiting, lessening further any possible risk of secondary poisoning to non-target species.

The last live rat seen on Ailsa Craig was on 15 April 1991, near the summit.

Rat was noted as an item in the pellets of Herring Gulls in early May, but these may have been recently scavenged on the island or come from the mainland, where much of this species' food originates.

With no evidence of rats from chewsticks it was possible that most, if not all, rats had been eradicated before the end of May 1991.

8. 3. 2. *Non-target species*

Of the other animals indigenous to the island the reptiles, Common Lizard and Slow Worm, and mammal, Pygmy Shrew, were not thought vulnerable to the poison, being almost exclusively insectivores. Rabbits however were thought vulnerable, but expendable, being a deliberate introduction of man and generally damaging to the island by destroying vegetation and precipitating soil erosion. Evidence showed after baiting that rabbits had been considerably reduced by the effects of Warfarin set for rats.

Where rabbits were scavenged by gulls, it was noted that the gut tract had been removed and not eaten. This was confirmed by placing a dead Warfarin-killed rabbit in an open area and observing the gull's method of dealing with the corpse. Great Black-backed Gulls fed on young and adult rabbits (see Chapter 5) but in two years of study there were no obvious effects to either the adult birds or their offspring, which fledged successfully, indeed the breeding Great Black-backed Gull numbers increased. The Warfarin uptake by rabbits was evident in the droppings which changed colour due to the inbuilt dye.

8. 3. 3. *Evidence of success*

Evidence of rats, or the lack of them, was monitored by as many means as possible to assess the success of the project. Categories of evidence fell into two main forms - Positive and Negative.

8. 3. 4. *Negative monitoring*

Negative monitoring (i.e. absence of an effect), showed no chewsticks chewed, no bird carcasses gnawed, no fresh rat droppings anywhere searched, bait uneaten in baitboxes and no sighting of rats by day or night. In April 1989 a fresh dead Gannet was laid out under the south cliffs (under a large flat rock to prevent gulls scavenging). In two days it had been opened by rats, in 5 days most flesh from legs, feet, pectoral muscle and head had gone and by 12 days all that remained was cleaned bones and feathers. In April 1991 the exercise was repeated and another fresh Gannet carcass was laid out in the same area shortly after baiting. This was monitored daily for 3 weeks and no sign of rat activity was found. Regular weekly monitoring thereafter showed that by June 1991 the corpse had effectively mummified, being completely intact. There were few other carcasses in the area available for scavenging at that time and it was a strong indication that baiting had been effective. Of circa 800 Gannet corpses checked over the next two years, none showed chew marks to feet.

8. 3. 5. *Positive monitoring*

Positive monitoring (i.e. increased productivity of plants and animals), for evidence of rats commenced almost immediately after the spring baiting of 1991, when the first seabird eggs were laid. In general vegetation became more luxuriant, due to the elimination of rats and rabbits (Zonfrillo, 1994).

For plant species such as the Tree Mallow, the seed heads of which had suffered from rat activity, no immediate effect was noticeable, since it is a biennial. However in 1991 and 1992 its cliff-site plants produced abundant seed and much of the area below the cliffs had by 1993 many new Tree Mallow plants emerging, (Fig 8.7.). The Sea Radish, also largely confined to cliff sites, spread and provided a dense growth, beneficial to insects and caterpillars. This *Brassica* is a major foodsource for many butterfly and moth species.

The growth rate of plants following the elimination of both rats and rabbits may be shown by comparing the best specimens of two common plants, Sheep's Sorrel and Self-heal collected from the same areas before and then after grazing pressure had been removed (Table 8. 1.). Growth after poisoning in 1991 was luxuriant but in the following two years, returned to a more normal, intermediate form of both species. In general plant communities rapidly recovered and many grasses, for example, flowered and produced seed for the first time in decades. Previously only species which were poisonous to rabbits and rats proliferated.

Table 8. 1. Maximum heights (from root to apex) of Sheeps Sorrel and Self-heal plants before and after rat baiting.

Sheeps Sorrel		*Self-heal*	
	Max. height in mm.		
Before 1991	**1991**	**Before 1991**	**1991**
130	230	70	380
94	290	70	383
170	240	75	280
45	254	73	260

N.B. *(The above specimen records are deposited in the Herbarium of Glasgow University.)*

The vegetation on the ledges also grew more robustly and many Fulmar sites formerly exposed to gulls were sheltered by the new vegetation growth.

Following the first baiting in 1991, the majority of species apparently affected by rat predation raised young to the fledging stage. The numbers of successful gull nests were estimated from the numbers of young assembling at pre-dispersal, post-fledging roost sites around the island. The peak counts of young gulls before and after rat eradication show a rapid improvement in the fledging success rate. The Herring gull population was estimated to be stable during this period, but the Lesser Black-backed Gulls showed a marked decline in breeding numbers. Despite the latter, the overall numbers of young gulls showed a vast increase (Fig 8. 5.).

The Fulmars which hatched young also showed a remarkable improvement going from 100% failure to 100% success (Fig. 8. 2.).

8. 4. Colonisation and prospecting by burrow-nesting species

Since baiting commenced generally in 1991, three burrow-nesting bird species have colonised Ailsa Craig. Two were frequently seen around the island in past years, but never recorded breeding, these were Black Guillemot and Shelduck. Both were discovered on eggs in summer 1991 and bred successfully in 1992 and 1993. The third species was Wheatear, a frequent passage migrant but again, never proven to have bred on Ailsa. In 1992 and 1993 one pair bred successfully, raising 3 and 4 young in each year.

The Puffin, which had formerly bred in vast numbers on Ailsa, also made a re-appearance. One was seen ashore entering a suitable cliff crevice in 1991, a week later a corpse of this species was found killed by the Peregrine Falcon. The site was never re-occupied. In 1992 none was ashore but at sea numbers of prospecting birds in groups of 5 or 6 were evident just offshore. In 1993 these reached a peak of 19 together and a site near to the first was prospected by an individual Puffin, (Fig. 8.8.). Unfortunately 10 Puffins were killed by the Peregrine and no positive evidence of breeding was obtained. From the skulls of the 10 dead birds, it was evident that these were 2-3 year old, (by bill shape and grooves - as per Harris, 1984), and would not have bred in any event. However the process of re-colonisation of Ailsa Craig by Puffins appears to have commenced. The Peregrine, which normally has a very poor breeding record on Ailsa Craig because of site competition with Raven and Fulmars, managed to raise young in 1993.

During June 1991 two dead Manx Shearwaters were found on the island, again a species frequent offshore but with no history of ever having bred on Ailsa Craig. This nocturnal species has prospected the island for many years, as calls have been heard most calm nights during July and August. The two dead birds ashore strongly suggested a serious breeding attempt. Figure 8.9., shows the increase in prospecting and actual breeding of burrow nesting species on Ailsa Craig.

The species thought possibly vulnerable to the secondary effects of Warfarin poisoning proved to have fared well. Ravens raised broods of 4 - 5 young during 1991 - 1993, showing no obvious effects through brood size reduction from secondary poisoning.

8. 5. Discussion

This study has shown that even in the most difficult terrain, large populations of alien Brown Rats can, at the very least, be rapidly reduced. An inexpensive but highly effective method of monitoring rat activity (or presumed absence) is available through the use of chewsticks (see Fig. 8.6 and photo Fig. 8. 10). The breeding success for vulnerable seabird species will show a rapid response, given that sea-based factors, such as prey abundance and availability remain substantially unchanged.

Monitoring to ascertain that all rats have been eliminated must be done following baiting operations. This can be summarised by negative and positive indicators.

Monitoring before and after baiting

Negative monitoring was the absence of effects formerly evident. It included -

a lack of chew marks on the chewsticks,

lack of gnaw marks on bird carcasses,

lack of fresh rat droppings ,

lack of uptake of poison bait and

lack of physical sightings.

Positive monitoring included the increase and improvement in parameters formerly held low by rats. It included -

breeding success of birds formerly eaten by rats,

colonisation or re-colonisation of the island by burrow nesting bird species,

recovery and growth of vegetation, particularly in areas where rats were causing destruction,

effects on populations of other vertebrates and invertebrates through improved habitat quality and, - exploitation of available carcasses by scavenging bird species.

It was particularly noticeable that scavenging for carcasses ceased. The fleshy feet of dead Gannets were frequently the first chewable material for rats encountering a fresh dead corpse. Monitoring showed these remaining intact until mummified after baiting. Gull-scavenged corpses of seabirds and rabbits usually finish with the skin exposed i.e. inside-out, and with feet always intact. Rats were capable of killing Fulmar chicks of over 1 kg in weight and probably the live, unguarded young of all species under that weight are potentially vulnerable to rat predation. Adult birds of all but the smallest species are probably immune to rat predation unless in exceptional circumstances.

The late autumn die-off of fallen and injured young Gannets would have meant an abundance of meat and fat for any surviving rats and a rapid increase in their numbers. The basal areas of Ailsa Craig were particularly well-monitored and no evidence of such activity was found..

Modern poisons and methods of bait distribution and post-kill monitoring also heightens the prospect of a successful outcome. It is essential to monitor both before and after baiting takes place.

Avoiding disasters.

Damage to indigenous non-target species can be avoided but it is first essential to know exactly which species of important flora and fauna are at risk. Thorough surveys are a pre-requisite to rat eradication. While on Ailsa Craig no non-target species except rabbit was thought immediately vulnerable, other islands may have particular situations where alternative arrangements to temporarily remove and re-introduce species might be necessary. Each island situation would have to be assessed independently. Where rare flora have colonised islands and depend on short-cropped turf then a more ecologically "friendly" species such as pinioned geese, replacing rabbits and rats, should be considered. Declaring an eradication project successful takes time and the longer the evidence remains negative the stronger will be the belief in success. Confidence increases with the passage of time and three years of negative evidence is perhaps a minimum for post-kill monitoring. Comparative data from other islands would be useful in assessing this aspect of rat eradication.

While elimination of rats from islands has immense conservation value, legislation is probably required to ensure that shipping is constantly checked for rat infestations. At present there does not appear to be any such activity undertaken. Rats join ships of all sizes mainly at ports and docks by climbing mooring ropes. Compulsory rope guards (cones or other devices) should be enforced to ensure anti-rat precautions are taken at source. A high standard of hygiene (provision of commercially available poison) on all sizes of ships should be encouraged to prevent transportation of rats to islands whether deliberately or accidentally.

A list of major seabird islands with rats present should be drawn up for a national programme of systematic rat eradication to be initiated. Under Economic Community wildbird directives, many seabird species require to be conserved and protected such that governmental backing for such proposals should be forthcoming.

On the National Nature Reserve of Rhum, Inner Hebrides, Thompson (1987) studied the effects of rats on the vast Manx Shearwater population breeding in burrows on inland mountaintops. She found that in such situations rats had little effect, probably through an extremely low survival rate at altitude over winter, which meant re-colonisation of the area on an annual basis and at a time of year after most birds had bred successfully. However, shearwaters reputedly bred at lower altitudes on Rhum and in such situations appear to have been virtually eliminated by rats.

Rebuilding ecosystems.

The model from this study for rat eradication from seabird islands shows that rat numbers can be quickly decimated, vegetation will improve, breeding success of vulnerable species changes rapidly, lost or absent species vulnerable to rat predation will colonise under suitable conditions and adequate monitoring methods will ascertain evidence of rats, or the lack of them. The ecosystem will in essence return to "normality".

The methods and materials are now available for the execution of such a programme to conserve important fauna and flora. Ecosystems will re-generate rapidly when alien predators and grazing pressures are removed. Lizards, Slow Worms and Pygmy Shrews all became more frequently sighted on Ailsa Craig following the elimination of rats, suggesting competition or predation was previously constraining their numbers.

From initial baiting in spring 1991 until regular monthly monitoring for rats ceased in October 1995, no evidence of rats persisting on Ailsa Craig has been forthcoming. At time of writing (September 1997) there is still no evidence that rats still exist on Ailsa Craig. Given that few rats live longer than 3 years in the wild, the eradication of the Brown Rat on Ailsa Craig appears to have been a complete success.

8. 6. References

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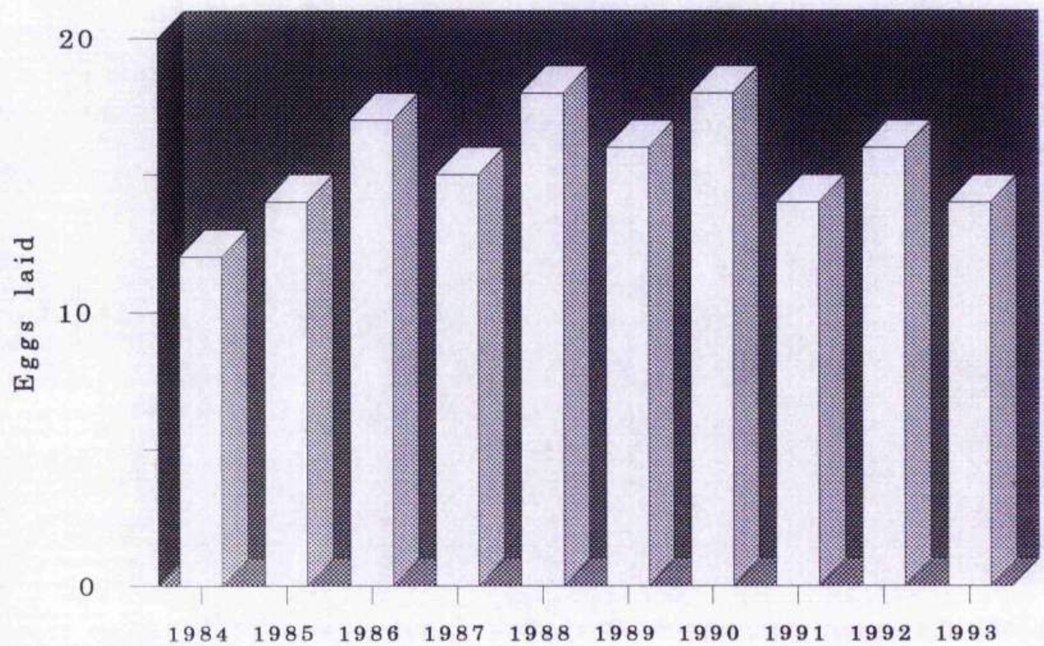

Fig. 8. 1. Number of Fulmar eggs laid annually at Rotten Nick study site, Ailsa Craig from 1984 to 1993.

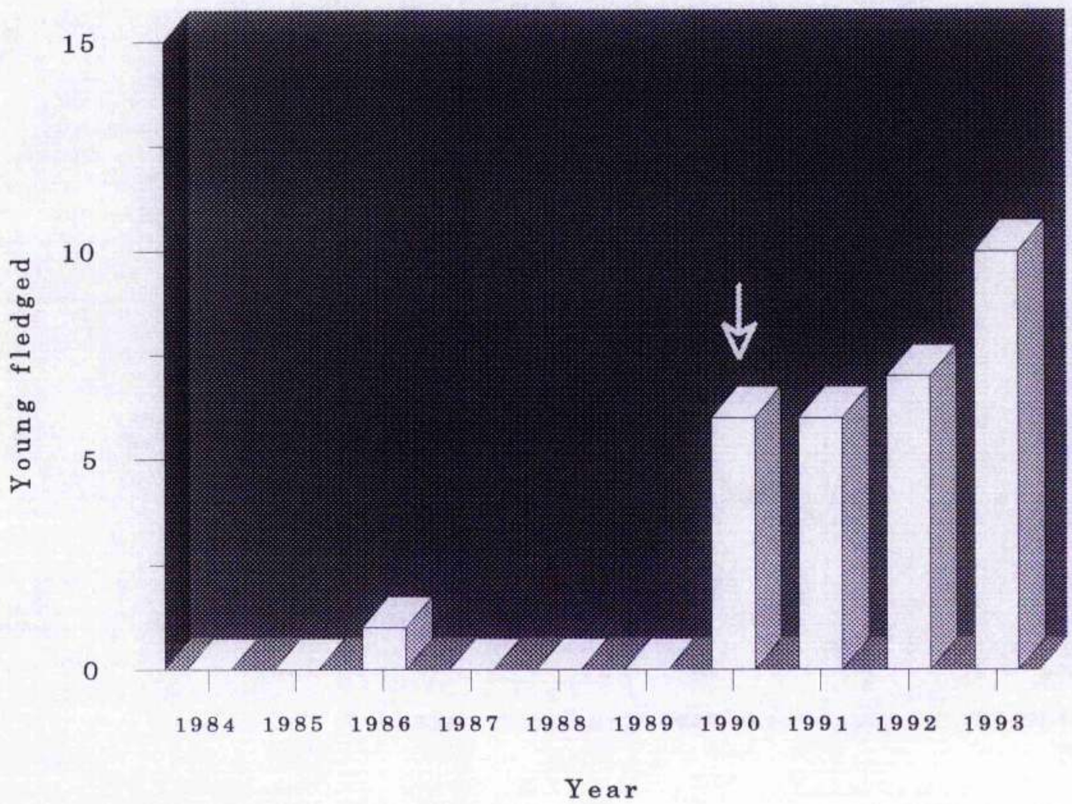

Fig. 8. 2. Number of Fulmar chicks fledged from Rotten Nick study site, Ailsa Craig. The arrow marks year of rat baiting pilot study.

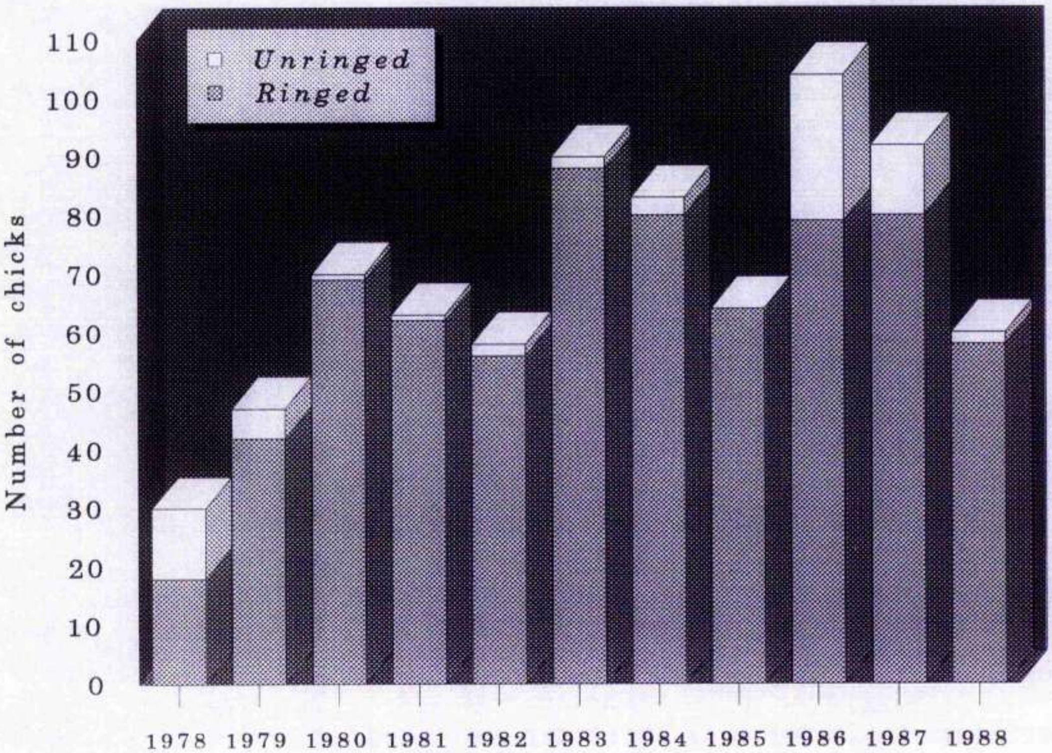

Fig. 8. 3. Number of young Fulmars ringed and unringed on Isle of May, Fife at fledging time. Data represents all known chicks on the island.

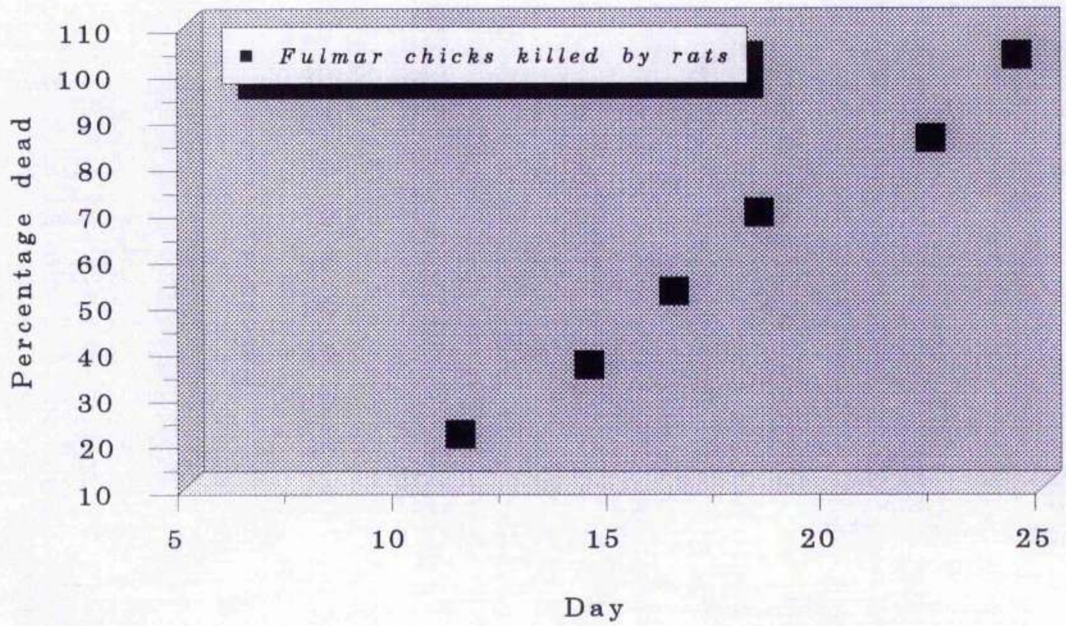

Fig. 8. 4. Percentage mortality of 6 Fulmar chicks in days after hatching on study site at Rotten Nick, Ailsa Craig in July 1989.

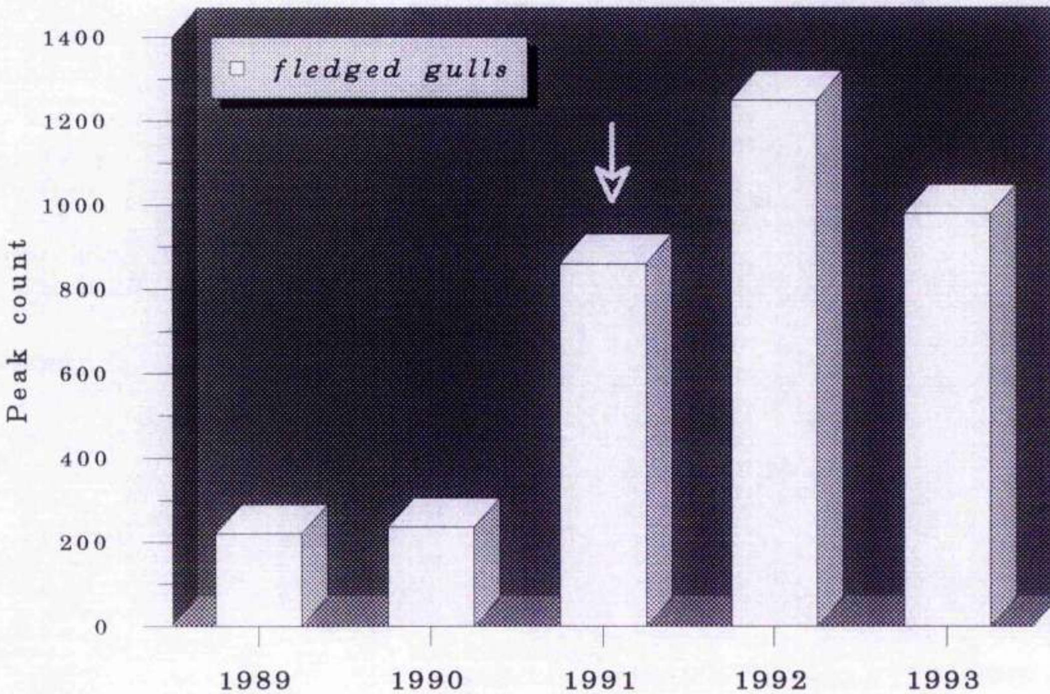

Fig. 8. 5. Annual counts of post-fledging, pre-dispersal juvenile gulls at roosts on Ailsa Craig. The arrow marks year of rat eradication.

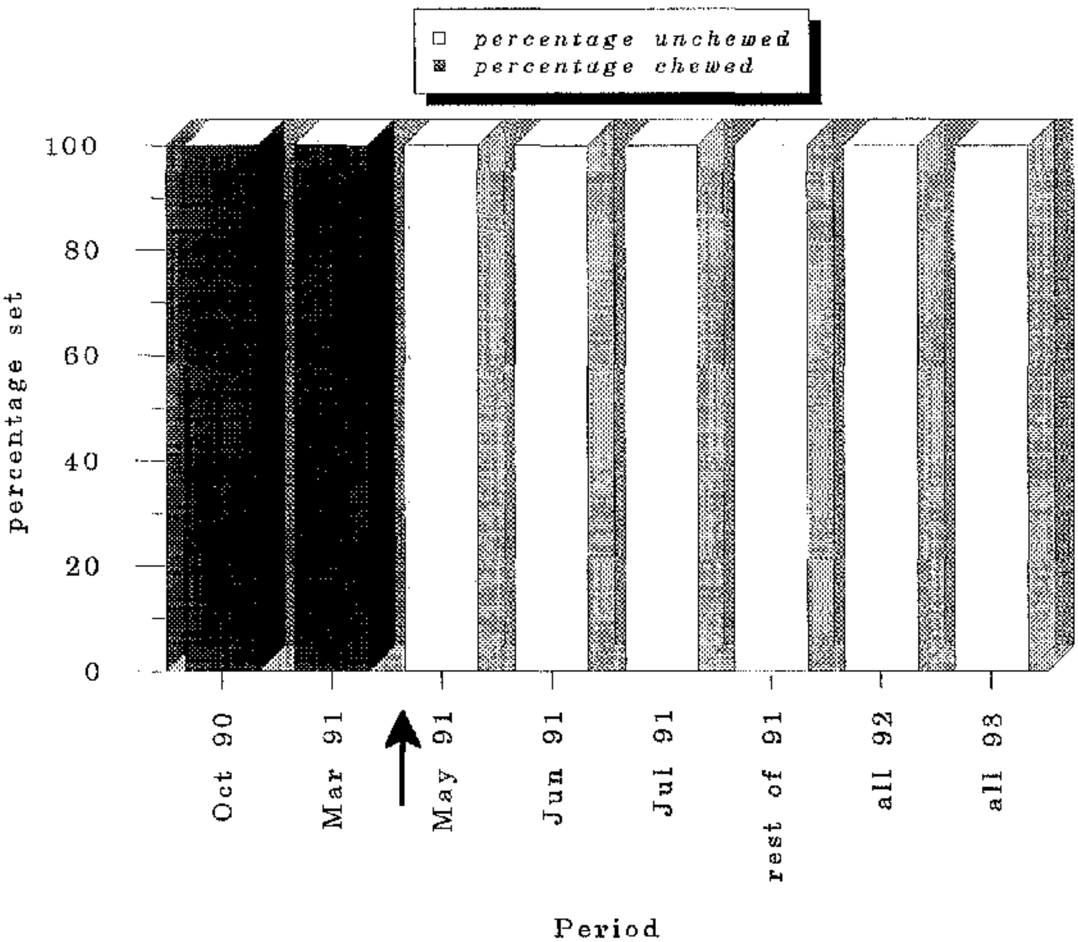

Fig. 8. 6. Rat activity revealed by chewsticks before and after baiting. The arrow marks the period when bait was first generally distributed.

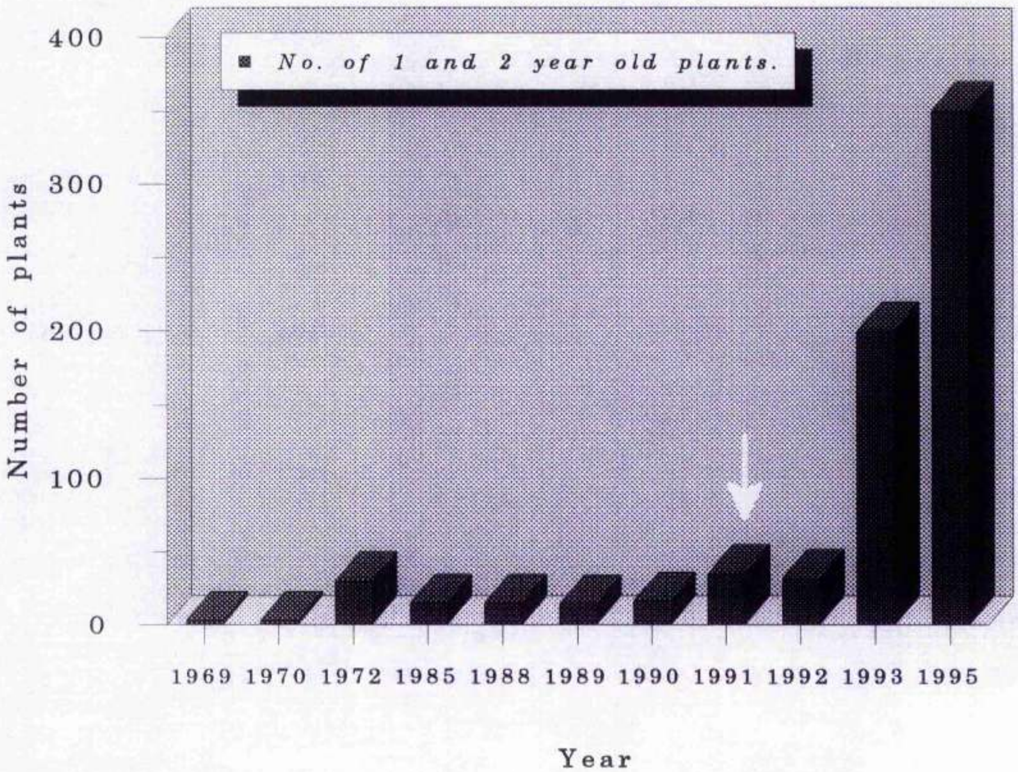

Fig. 8. 7. Increase in numbers of biennial Tree Mallow plants on Ailsa Craig. The arrow marks the year of rat baiting. Pilot baiting of rats was done in 1990 at the same site.

Fig. 8. 8. Numbers of Puffins recorded in groups around Ailsa Craig. The arrow marks the year of rat eradication.

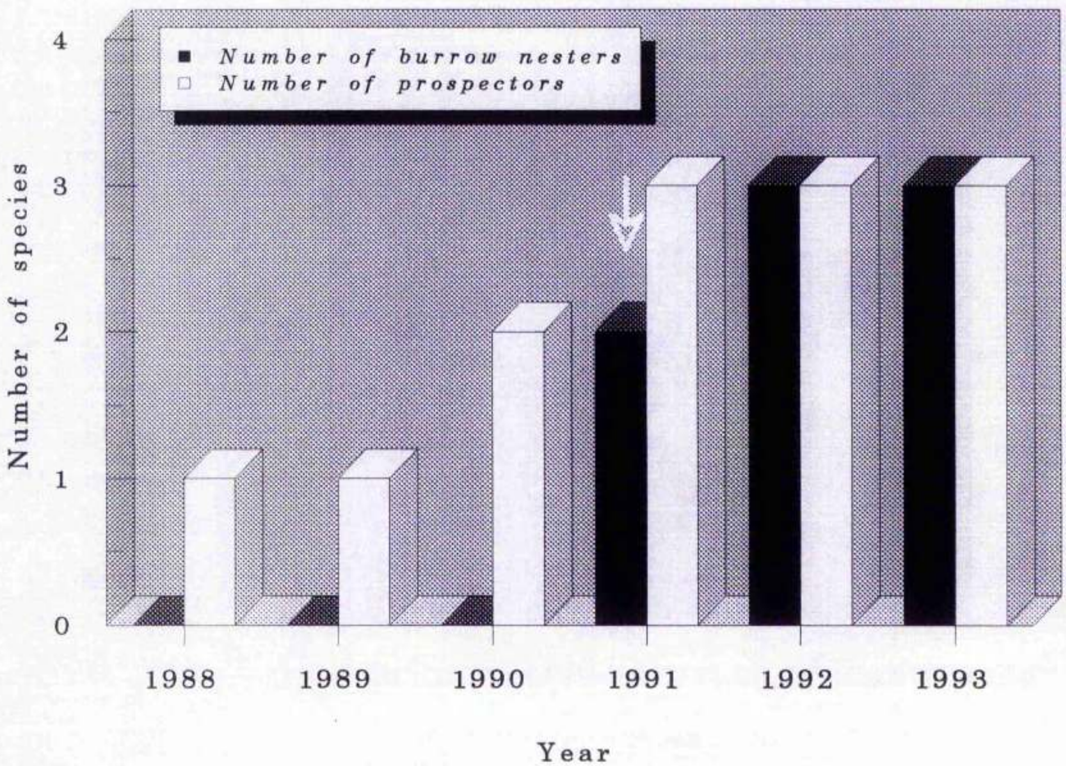

Fig. 8. 9. Colonisation of Ailsa Craig by burrow or hole-nesting species after rat eradication. The arrow marks the year of rat baiting.

A.

B.

Fig. 8.10 A. Top. An inexpensive method of monitoring rat activity on Ailsa Craig. Equipment includes wooden spatulas (chewsticks), Margarine, Pin hammer and marker pen.

B. Lower. Chewstick showing rat gnawmarks one day later.

Appendix I.

Species of birds, mammals, reptiles and fish mentioned in the texts.

Seabirds.

Rockhopper Penguin *Eudyptes chrysocome*

Fulmar *Fulmarus glacialis*

Manx Shearwater *Puffinus puffinus*

Wedge-tailed Shearwater *Puffinus pacificus*

Cory's Shearwater *Calonectris diomedea*

Sooty Shearwater *Puffinus griseus*

Balearic Shearwater *Puffinus mauretanicus*

Grey-faced Petrel *Pterodroma macroptera gouldi*

Bonin Island Petrel *Pterodroma hypoleuca*

Cahow *Pterodroma cahow*

Dark-rumped Petrel *Pterodroma phaegopygia*

Freira Petrel *Pterodroma madeira*

Leach's Storm-petrel *Oceanodroma leucorhoa*

Storm Petrel *Hydrobates pelagicus*

Gannet *Morus bassanus*

Blue-footed Booby *Sula nebouxii*

Cormorant *Phalacrocorax carbo*

Shag *Phalacrocorax aristotelis*

Shelduck *Tadorna tadorna*

Arctic Tern *Sterna paradisaea*

Common Tern *Sterna hirundo*

Sandwich Tern *Sterna sandvicensis*

Roseate Tern *Sterna dougalii*

Little Tern *Sterna albifrons*

Lesser Black-backed Gull *Larus fuscus*

Herring Gull *Larus argentatus*

Western Gull *Larus occidentalis*

Great Black-backed Gull *Larus marinus*

Common Gull *Larus canus*

Kittiwake *Rissa tridactyla*

Black-headed Gull *Larus ridibundus*

Iceland Gull *Larus glaucoides*

Glaucous Gull *Larus hyperboreus*

Great Skua *Catharacta skua*

Arctic Skua *Stercorarius parasiticus*

Razorbill *Alca torda*

Guillemot *Uria aalge*

Puffin *Fratercula arctica*

Black Guillemot *Cepphus grylle*

Little Auk *Alle alle.*

Cassin`s Auklet *Ptychoramphus aleuticus*

Landbirds

Pheasant *Phasianus colchicus*

Chicken *Gallus domesticus*

Peregrine Falcon *Falco peregrinus*

Wheatear *Oenanthe oenanthe*

Raven *Corvus corax*

Hooded Crow *Corvus corone cornix*

Mammals.

American Mink *Mustela vison*

Ferret *Mustela putorius*

Pygmy Shrew *Sorex minutus*

Brown Rat *Rattus norvegicus*

Black Rat *Rattus rattus*

Rabbit *Oryctolagus cunicularia*

Feral Goat *Capra hircus*

Raccoon *Procyon lotor*

Badger *Meles meles*

Feral cat *Felix domesticus*

Grey Seal *Halichoerus grypus*

Common Seal *Phoca vitulina*

Minke Whale *Balaenoptera acutorostrata*

Common Porpoise *Phocoena phocoena*

Reptiles

Common Lizard *Lacerta vivipera*

Slow Worm *Anguis fragilis*

Fish

Mackerel *Scomber scombrus*

Greater Sandeel *Hyperoplus lanceolatus*

Raitt's Sandeel *Ammodytes marinus.*

Sprat *Sprattus sprattus*

Herring *Clupea harrengus*

Capelin *Mallotus villotus*

Grey Gurnard *Eutrigla gurnardus*

Red Gurnard *Aspitrigla cuculus*

Lumpsucker *Cyclopterus lumpus*

Cod *Gadus morhua*

Polar Cod *Boreogadus saida*

Whiting *Merlangius merlangus*

Pollack *Pollachius pollachius*

Saithe *Pollachius virens*

Norway Pout *Trisopterus esmarkii*

Ballan Wrasse *Labrus bergylta*

Conger Eel *Conger conger*

Stickleback *Gasterosteus aculeatus*

Gobies *Gobius* sp.

Dragonet *Callionymus lyra*

Flounder *Platichthys flesus*

Appendix II

Flowering Plants and Ferns on Ailsa Craig

* = specimen in herbarium of Glasgow University Botany Dept.
(*) = brackets denotes old specimen record)

Ferns

Common Polypody *Polypodium vulgare**
Interupted Polypody *Polypodium interjectum**
Hybrid Polypody *Polypodium (interjectum x vulgare) = mantoniae**
Bracken *Pteridium aquilinum**
Hart's tongue Fern *Phyllitis scolopendrium**
Black Spleenwort *Asplenium adiantum-nigrum**
Sea Spleenwort *Asplenium marinum**
Maidenhair Spleenwort *Asplenium trichomanes**
Wall-rue *Asplenium ruta-muraria**
Lady Fern *Athyrium filix-femina**
Scaly (Male) Fern *Dryopteris affinis (filix-mas)**
Broad Buckler-fern *Dryopteris dilatata**

Flowering Plants

Marsh Marigold *Caltha palustris**
Meadow Buttercup *Ranunculus acris**
Creeping Buttercup *Ranunculus repens**
Lesser Spearwort *Ranunculus flammula* (*)
Long-headed Poppy *Papaver dubium**
White Fumitory *Fumaria capreolata**
Small Nettle *Urtica urens**
Stinging Nettle *Urtica dioica**
Babington's Orache *Atriplex glabriuscula**
Common Orache *Atriplex patula**
Blinks *Montia fontana**
Balearic Sandwort *Arenaria balearica**
Common Chickweed *Stellaria media**
Common Mouse-ear *Cerastium fontanum**
Sea Mouse-ear *Cerastium diffusum**
Procumbent Pearlwort *Sagina procumbens**
Annual Pearlwort *Sagina apetala**
Sea Pearlwort *Sagina maritima**
Rock Spurry *Spergularia rupicola**
Sand-spurry *Spergularia rubra (*)*
Red Campion *Silene dioica**
Sea Campion *Silene uniflora**
Redshank *Polygonum maculosa**
Knotgrass *Polygonum aviculare**
Sheep's Sorrel *Rumex acetosella**
Common Sorrel *Rumex acetosa**
Curled Dock *Rumex crispus**
Broad-leaved Dock *Rumex obtusifolius**
Thrift *Armeria maritima**
Beautiful St John's Wort *Hypericum pulchrum**
Tree Mallow *Lavatera arborea**
Common Violet *Viola riviniana**

Marsh Violet *Viola palustris* *
Aspen *Populus tremula**
Thale Cress *Arabidopsis thaliana**
Common Yellow Rocket *Barbarea vulgaris**
Cuckoo-flower *Cardamine pratensis**
Hairy Bitter-cress *Cardamine hirsuta* *
Whitlow Grass *Erophila verna**
Scurvy-grass *Cochlearia officinalis**
Shepherd's Purse *Capsella bursa-pastoris**
Rape *Brassica napus**
Sea Radish *Raphanus maritimus**
Heather (Ling) *Calluna vulgaris**
Bell-heather *Erica cinerea**
Blaeberry *Vaccinum myrtillus**
Scarlet Pimpernel *Anagallis arvensis**
Pennywort *Umbilicus rupestris**
English Stonecrop *Sedum anglicum**
Bramble *Rubus fruticosus septentrionalis**
Bramble *Rubus fruticosus polyanthemus**
Bramble *Rubus fruticosus ulmifolius**
Common Tormentil *Potentilla erecta**
English Tormentil *Potentilla anglica**
Wild Strawberry *Fragaria vesca**
Parsley Piert *Aphanes arvensis**
Dog Rose *Rosa canina**
Bird's foot Trefoil *Lotus corniculatus**
Bush Vetch *Vicia sepium**
Narrow Leaved Vetch *Vicia sativa ssp. nigra**
Spring Vetch *Vicia lathyroides**
White Clover *Trifolium repens**
Lesser Yellow Trefoil *Trifolium dubium**
Hop Trefoil *Trifolium campestre**
Long-Fruited Willowherb *Epilobium obscurum**
Broad-leaved Willowherb *Epilobium montanum**
Rose-bay Willowherb *Chamerion angustifolium**
Heath Milkwort *Polygala serpyllifolia**
Dove's foot Cranesbill *Geranium molle**
Herb Robert *Geranium robertianum**
Common Storksbill *Erodium cicutarium**
Ivy *Hedera helix**
Marsh Pennywort *Hydrocotyle vulgaris**
Hemlock Water-dropwort *Oenanthe crocata**
Ground Elder *Aegopodium podagaria**
Fool's Parsley *Aethusa cynapium**
Wild Angelica *Angelica sylvestris**
Bugloss *Anchusa arvensis**
Common Forget-me-not *Myosotis arvensis**
Dead Nettle *Galeopsis tetrahit**
Intermediate Dead-Nettle *Lamium confertum**
Wood Sage *Teucrium scorodonia**
Self-heal *Prunella vulgaris**
Wild Thyme *Thymus arcticus praecox**
Water Starwort *Callitriche platycarpa**
Great Plantain *Plantago major**
Ribwort Plantain *Plantago lanceolata**
Buck's Horn Plantain *Plantago coronopus**
Ivy-leaved Toadflax *Cymbalaria muralis**
Common Speedwell *Veronica officinalis**

Germander Speedwell *Veronica chamaedrys**
Thyme-leaved Speedwell *Veronica serpyllifolia**
Wall Speedwell *Veronica arvensis**
Persian Speedwell *Veronica persica**
Sheep's Bit *Jasione montana**
Heath Bedstraw *Galium saxatile**
Goosegrass *Galium aparine**
Elder *Sambucus nigra**
Honeysuckle *Lonicera periclymenum**
Devil's-bit Scabious *Succisa pratensis**
Lesser Burdock *Arctium nemorosum (minus)**
Slender Thistle *Carduus tenuiflorus**
Spear Thistle *Cirsium vulgare**
Creeping Thistle *Cirsium arvense**
Nipplewort *Lapsana communis**
Smooth Cat's Ear *Hypochoeris radicata**
Spiny Sow-thistle *Sonchus asper**
Common Dandelion *Taraxacum officinale argutum**
Common Dandelion *Taraxacum officinale uniquilobum**
Common Dandelion *Taraxacum officinale dahlstedtii**
Common Dandelion *Taraxacum officinale vastisectum**
Golden-rod *Solidago virgaurea**
Daisy *Bellis perennis**
(Ailsa Craig) Hawkweed *Hieracium sp. Nov.* * (D.McCosh *pers.com*).
Yarrow *Achillea millefolium**
Common Ragwort *Senecio jacobaea**
Scentless Mayweed *Tripleurospermum maritimum**
Coltsfoot *Tussilago farfara**
Hardheads *Centaurea nigra**
Toad Rush *Juncus bufonius**
Bulbous Rush *Juncus bulbosus**
Soft Rush *Juncus effusus**
Compact Rush *Juncus conglomeratus**
Hairy Woodrush *Luzula pilosa**
Greater Woodrush *Luzula sylvatica**
Field Woodrush *Luzula campestris**
Common Mud-rush *Isolepis setacea#*
Red Fescue *Festuca rubra**
Sheep's Fescue *Festuca ovina**
Rye-grass *Lolium perenne**
Squirrel-tail Fescue *Vulpia bromoides**
Annual Meadow Grass *Poa annua**
Narrow-leaved Meadow Grass *Poa angustifolia**
Smooth Meadow Grass *Poa pratensis**
Rough Meadow Grass *Poa trivialis**
Cock's Foot *Dactylis glomerata**
Crested Dog's-tail *Cynosurus cristatus**
Soft Brome Grass *Bromus hordeaceus**
False Oat *Arrhenatherum elatius**
Yorkshire Fog *Holcus lanatus**
Creeping Soft-grass *Holcus mollis**
Wavy Hair-grass *Deschampsia flexuosa**
Early Hair-grass *Aira praecox**
Silvery Hair-grass *Aira caryophyllea**
Sweet Vernal-grass *Anthoxanthum odoratum**
Brown Bent *Agrostis canina**
Common Bent *Agrostis tenuis**
Creeping Bent *Agrostis stolonifera**

Marsh Fox-tail *Alopecurus geniculatus**
Slender Hair-Grass *Koeleria macrantha**
Couch Grass *Elytrigia repens**
Two-row Barley *Hordeum distichon**
Wheat *Triticum aestivium* *
Blue-bell *Hyacinthoides non-scripta**
Orchid sp. *Dactylorhiza sp* (*)

Garden Escapes

Mind-your-own-business *Soleirolia soleirolii* *
Rhubarb *Rheum (rhaponticum)*
Daffodil *Narcissus pseudo-narcissus - (var).**

Appendix III

Aspects of Razorbill ecology *Alca torda* on Ailsa Craig

[See also Chapter 7 - Guillemots]

Population

Around 1,000 pairs of Razorbills breed on Ailsa Craig (pers.obs, 1987 count.).
Razorbill numbers increased on Sanda over the past decade, but not as dramatically as Guillemots, while on Ailsa Craig numbers remained fairly stable (see Chapter 1).

Young Razorbills

Only limited data were collected on Razorbills due to the position of nest sites (on cliffs above boulder scree) and their general inaccessibility. Two young Razorbills were monitored in a cave site on the cliffs and some growth-rate data were obtained (Fig. III.1). Fledging young Razorbills were much scarcer than Guillemot chicks at the Barestack, due to lack of nesting holes in the immediate area of cliff above, thus only 3 were caught. Nearly all Razorbill chicks must make a descent onto hard ground when fledging on Ailsa Craig since most of the nest sites are in crevices and holes away from the vertical cliff faces over the sea and some tens of metres horizontally from the high tide mark. Biometric data were collected as for Guillemot.
Most Ailsa Razorbills are inaccessible but avery few can be reached with care. Growth rate was noted for two Razorbill chicks in a cliff-cave situation and were observed during an 11 day period, during which they were weighed and measured three times. One chick was estimated to be 2 days old, the other 4 days old when first weighed and measured. Four days later one chick had almost doubled its weight and the other had lost 10 gms. After 11 days, the larger chick had fledged and the second had lost 20 gms weight from when last weighed (Fig. III.1). It fledged successfully. A successful fledged Ailsa Razorbill chick below Barestack had wing length 75mm and weighed 140 gms. For comparison with adult biometrics, two live adult breeding Razorbills weighed 650 gms and 640 gms and had wings 205mm and 208 mm respectively in length. The wing length of fledging chicks is therefore around a third that of the parents.

Diets

Razorbills provided their young with only Sandeels - no other species of fish was recorded. A few sandeels were very large (possibly *Hyperoplus* ?) and would have proved difficult for a small chick to swallow. Most of the 18 observations were of birds on the sea immediately below the cliffs, where they congregated prior to flying up to the nest sites. The sea conditions were usually rough to elicit this behaviour, but when calm, the birds flew directly onto the nest site. Unlike Guillemots, Razorbills sometimes carried more than one fish.

Table III.1. Length of fish taken by Razorbills to feed chicks. All were Sandeel species.

Species	Estimated Fish length	Number
Sandeels (*Ammodytes* sp.)	0 - 50	12
	50 - 100	8
	100 - 150	6
	150+	2

Chick disturbance and weight loss

Lloyd (1979) handled Razorbill eggs for measurement and weighed and measured chicks on a daily basis and also caught adults. Only 7% of chicks which hatched failed to fledge. Weight of young Razorbills increased until day 14 in all chicks and most to the day of fledging, but 56% decreased in weight by a mean of 10.5 gms the day before fledging. As with Guillemots, Lloyd (1979) found earlier Razorbill chicks fledged at a heavier weight than later hatched chicks.

Lyngs (1994) documented chick growth on a Danish island and found "handled" chicks departed at around 212 gms, considerably heavier than those on Ailsa Craig (140 gms). This may indicate a physically larger population.

It appears that, like petrels, young Razorbills lose weight before fledging, and post-fledging they obviously gain weight once more. This pre-fledging weight loss is evident from some colony data presented by Barrett (1984), although other colony data reported in the same paper showed continuous weight gain and a much longer period ashore.

From the two Razorbill chicks measured over a 10 day period a weight loss at fledging was evident (Fig. III.1). Barrett (1984) showed some Razorbill young losing weight at fledging while others at different colonies continued to grow.

The weight loss in young Razorbills may parallel the lack of food in the stomachs of the young Guillemots at the approach to fledging (Chapter 7).

Pennington *et al.* (1990) noted differences in the weight and wing relationship of Razorbill chicks from north Shetland and Fair Isle. However they thought food availability might have been responsible without examining disturbance levels, population differences, micro habitat at fledging and the age at which each chick was near to fledging.

Further data on Razorbills on Ailsa Craig are required to put the small contribution here presented into context.

References

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Lloyd, C.S. 1979. Factors affecting breeding of Razorbills *Alca torda* at Skokholm *Ibis.* 121: 165 -176.

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Pennington, M.G., Osborn, K. and Harvey, P.V. 1990. Differences in weight:wing length relationships of Razorbill chicks at Hermaness and Fair Isle in 1989. *Scottish Birds* 16. 33-34.

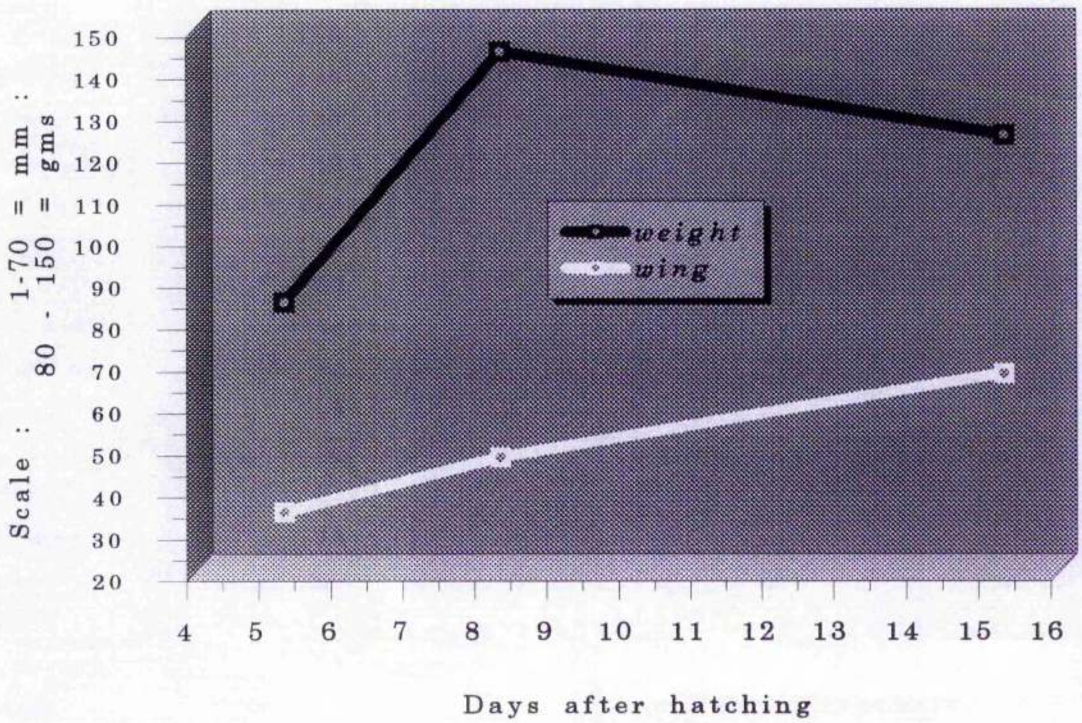

Fig.III. 1. Growth in weight and wing length of a Razorbill chick. Fledging was at 20 days.

Final Discussion.

The complex interactions between seabirds, their prey and the habitats they occupy at different times of year span several biological disciplines. To understand the ecology of seabirds that breed in mixed colonies within one island habitat requires investigation into not just the birds themselves, but also the availability and abundance of their prey, factors affecting their breeding success, the geology and oceanography of their marine habitat, climatic influences and the competition seabirds encounter when breeding and foraging.

Ailsa Craig has a diverse seabird population but is most noted for being a major Gannet colony. Unlike volcanic and basaltic oceanic islands, the granite of Ailsa Craig erodes very slowly (in geological terms) thus breeding sites are relatively stable. While other Gannetries of similar numbers to Ailsa appear to have little scope for further physical expansion - e.g. Bass Rock, Grassholm and Little Skellig, this is not the case on Ailsa Craig. It has the potential to be the largest single colony in the British Isles, given that the St Kilda Gannetry covers four distinct island-rocks but is counted as one colony. Other Gannetries do not appear to have as diverse a flora and fauna as Ailsa Craig, indeed Bass Rock and Grassholm now scarcely have any areas of open vegetation at all.

The habitats within the island are diverse - bare vertical cliff ledges, steep vegetated slopes, boulder screes, earthy soil for burrowing, an inter-tidal zone of boulder beach (important for local foraging, but missing on many steep oceanic islands) and of a height (1,114 feet) that produces localised wind and weather conditions. It is also relatively remote (15 km) from the UK mainland and other island influences. Consequently it has a diverse seabird fauna, with ten species now breeding regularly

Fuelling a seabird colony such as that on Ailsa Craig must require reliable food supplies to be obtainable within reasonable flying distance from the colony. Four fish species are particularly important in the diet of breeding seabirds in the Clyde area. These are Mackerel, Whiting, sandeels and Norway Pout (the latter a common non-commercial discard from trawling activity on the Clyde and taken frequently by gulls). In addition Herring, especially young fish, and Euphausiid crustaceans are also important for some seabirds outwith the breeding season. Mackerel is a migratory species and their presence in the Clyde coincides with the hatching period of Gannets and they remain present until the young fledge. Fledgling Gannets leave the cliffs unaccompanied by their parents and rapidly move south, reaching north African waters in about two weeks. This southward movement in autumn may track Mackerel movements but also takes the young birds into productive waters such as the Bay of Biscay and southwards to the west African coast where they spend their first winter. Little is known of the prey species taken by Gannets in their wintering areas but doubtless the higher ambient temperature assists survival while the young birds learn to forage successfully.

Depending on the size of the seabird, all or some of previously mentioned fish can become food for the seabird and its chick or chicks. Gannets will take large pelagic fish but will equally take smaller adult sandeels in large numbers. Such a wide range of prey size buffers Gannet breeding success from fluctuations in any particular prey species; their numbers continue to increase steadily on Ailsa Craig over the years. On the other hand a smallish seabird such as the Kittiwake is more specialised, being locked into one or two fish species to feed its young and when these do not become available, for whatever the reason, breeding success is poor through inability to exploit alternative food sources. Seabirds sensitive to marine changes such as the Kittiwake may be used as an indicator of changes in their prey populations by monitoring their breeding numbers, diet, body condition and patterns of behaviour (Monaghan, 1996). Unfortunately, once a fish stock crashes, little or no effort is put into monitoring the stock recovery by the fishing industry.

The scarcity of fish at vital periods of the seabirds breeding cycle is often a man-induced phenomenon. It may be caused simply by over-fishing - removal of more fish from the local ecosystem than can be replaced naturally through reproduction or migration. Or it may involve longer term influences such as pollution, climatic changes or disruption to the marine habitat through harmful operations such as trawling or clam-dredging. While discards from the fishing industry may have beneficial effects on survival of some seabird species, in the long term it must be counter-productive. The law of diminishing returns decrees that in the end the fish will run out and any benefits will be countered by rapid and massive mortality, especially for species that have conditioned themselves to rely on this source of food. Reduction or specialisation in fishing effort and thus decline in discards might help preserve fish stocks but it will probably mean a decline also in those bird species most vulnerable to surface availability of small fish. In the North Sea alone, some 320,000 tonnes of fish discards have been calculated as available to certain seabirds on an annual basis (Camphuysen *et al.* 1995). There is now little " balance of nature " in the marine ecosystem. Unfortunately the fishing industry is governed through economic and political directives which lack foresight and preside over their own self-destruction.

Man has not only effected fundamental changes in the marine ecosystem but has created threats to seabirds on land through the transportation and release of alien mammals into seabird habitats (Atkinson, 1985). Ailsa Craig was perhaps a prime example. In Victorian times(1800's) Goats, Badgers and Racoons were released onto the island "...to see how they would do..." (Lawson, 1896). The latter two died out within a season or two simply because they could not survive the periods when seabirds were absent. It was noted however that the Racoons did "wreak havoc" amongst the seabirds in summer. The goats were eventually shot out. For more adaptable species such as rats, seabird colonies can sustain them. Their alternative foods mean that they, albeit in much reduced numbers, can survive the winters until the seabirds return. Many man-affected islands also have rabbits which not only survive well but create soil erosion and provide winter food for rats. American Mink are also particularly destructive in seabird colonies and are a relatively new alien species on the scene (Craik, 1994). On mainland estates, gamekeepers know little of their behaviour and how to deal with them. Their spread to seabird islands should make them a subject of intensive and active campaigns of destruction. Fortunately they have not reached Ailsa but they are common on Bute, Arran and Great Cumbrae and have recently reached Sanda (in 1996). In future it must be acknowledged that either we live with decreasing seabird populations or take active steps to ensure their survival.

Where fragile ecosystems are invaded by alien mammals their biodiversity is reduced. This begins with the extinction of burrow nesting bird species but surface nesters are also suppressed or much reduced in reproductive performance. Vegetation also suffers, nutritious seeds and roots are eaten by rats and rabbits, halting reproduction and preventing the laying down of humus layers for the future build up of soil depth. Burrowing also starts the processes of soil erosion which is extremely difficult to reverse. Plants on islands with rats and rabbits present often have their last refuges on sheer cliffs or inaccessible ledges. Here thankfully they act as seed banks should conditions alter in future. The plants listed in Appendix II provide a snapshot of the vegetation present on the island during the period of this study. Should rabbits be removed then major changes will evolve in the plant communities of the island in the years ahead (Zonfrillo, 1994). This may also have knock-on effects for the breeding habitat of certain seabirds.

Seabird size or mass may be in itself a method of countering predators and it was noticeable on Ailsa that large powerful birds such as Gannets were completely unaffected by rats. Modern poisons and methodologies in dealing with rats on seabird islands can lead to their eradication and the rebuilding of the island ecosystems. In the longer term this results in increased in biodiversity. Since rats will not leave islands of their own accord and rarely die out, it should be obligatory that man, whose agency transported them to the islands in the first place, removes them. Only when this responsibility is accepted will the destruction created on many seabird islands be reversed.

The Clyde sea area has undergone something of an ecological transformation over the past few decades, partly through the dismantling of heavy industry. This has lead to fewer ships and consequently fewer oiling incidents at sea. The oil terminal at Ardrossan in Ayrshire created a scenario where the tanks of ships importing oil were flushed out as the ships left the Clyde. Despite legislation this sometimes still occurs but oil is no longer imported to the same extent since its discovery and extraction from offshore Scotland. Legislation on the discharge of sewage and chemical pollutants at sea has also helped clean up the ecosystem. Modern techniques using seabird tissues, eggs and feathers can now indicate levels of pollutants in both the birds and their environment (Furness and Greenwood, 1993). It is fair to say that the Clyde has never been "cleaner" in the past 100, if not 200, years than it is at present. Provided their breeding islands are kept free of alien predators such as rats and mink, seabirds should consequently benefit as fish become more abundant, pollution is reduced to insignificance and commercial fishing much better managed than at present.

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Many people made my work on Ailsa Craig both possible and enjoyable. My sincere thanks are due to the present Marquess of Ailsa and his late father who not only funded the pilot studies for eradication of rats but chaired every meeting held to oversee progress of the rat eradication work. His permission to carry out research work on the island enabled this study to take place. Lord David Kennedy also allowed storage of bait at his farm. Mr D. G. Gray the factor of Cassillis estate ensured financial matters ran smoothly. John Burlison, and his team at South-west Scottish Natural Heritage helped enormously with the general smooth running of the rat eradication project over the years.

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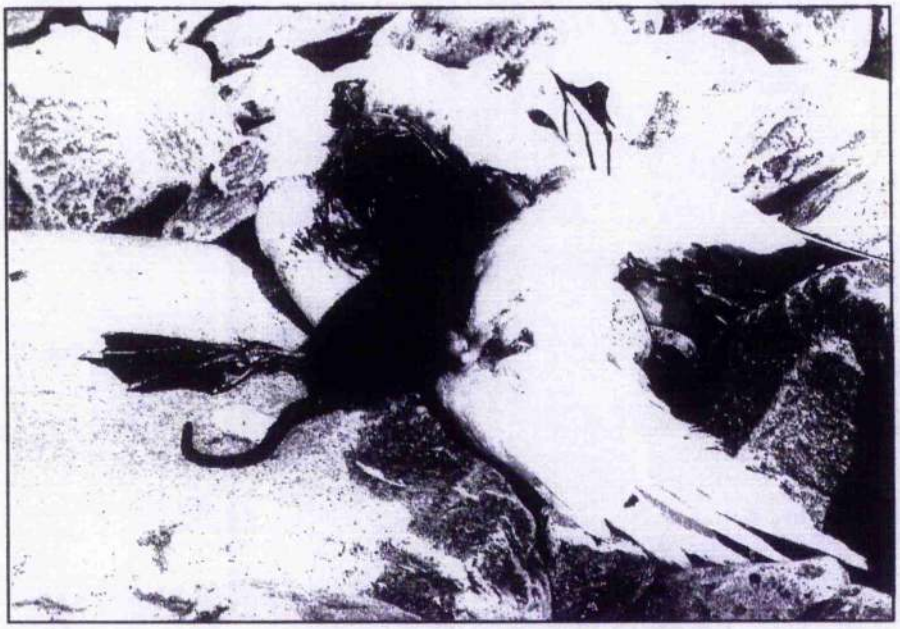
Epilogue



Brown rat scavenging Gannet carcass - note gnawed feet. Ailsa Craig, August 1989. (B.Z.)

From ***Four Preludes on Playthings of the Wind***

Part 4.

The feet of the rats
scribble on the doorsills;
the hieroglyphs of the rat footprints
chatter the pedigree of the rats
and babble of the blood
and gabble of the breed
of the grandfathers and great-grandfathers
of the rats

Carl Sandburg (American) born 1878.