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### *Breeding success of, & habitat use by, eider ducks*

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BREEDING SUCCESS OF,  
& HABITAT USE BY,  
EIDER DUCKS

Richard J. Wilson

Submitted as part of the requirements for the  
degree of Master of Science (Advanced Course in Ecology) at  
the University of Durham, 1990.



23 SEP 1992

## ACKNOWLEDGEMENTS

I should like to thank my supervisor, Dr. J. C. Coulson, for his help and advice throughout the completion of this thesis; Simon Cooter, the Coquet Island warden, for the collection of data regarding Eider duck clutch size and the use of the island's shores by Eider ducklings; and finally my parents for their help in ferrying me to and from the study area.

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ABSTRACT

The study covers several facets of the ecology of the Eider ducks of the Northumberland coast between Hadston Carrs and Craster between 9 May and 1 August 1990. Special attention was given to the breeding success of the Coquet island population.

Nesting success is high, in excess of 90%, however fledging success is low (<6%) due to high duckling mortality. Starvation and large gull predation are believed to be the media responsible.

The uneven distribution of ducklings along the coast is due to differing food availability and the ability of ducklings to take different sized prey items as they mature.

It was found that both duckling group size and the number of ducklings per attendant female fell as the ducklings aged, reflecting the over-riding importance of duckling mortality in determining these statistics. Significant relationships were also found between duckling activity and duckling age; duckling activity and sea surface roughness; and duckling activity and time relative to low tide.

Adult birds are shown to have a feeding pattern determined by the tidal cycle (feeding was not related to the time of day).

The spatial variation in adult bird numbers reflects differing distance from the Coquet Island breeding centre and the relative availability of suitable feeding habitat. It is concluded that the adult birds attending young in

Amble harbour are in a sub-optimal feeding environment.

Fluctuations in overall population and sex ratio in the study area, are due primarily to the female's role as egg incubator. The differences in the pattern of fluctuation between the northern and southern halves of the study area are a reflection of distance from the breeding centre on Coquet Island.

An overall, non-breeding season, sex ratio of 1.17 was found.

## INTRODUCTION

The Eider (*Somateria mollissima*) is a wholly coastal and marine species breeding in White Sea, Baltic and Atlantic waters extending south to Brittany in France. The species is largely sedentary in Britain with movements over 200km being rare (Cramp *et al.*, 1977).

Feeding largely on molluscs, such as the Mussel (*Mytilus edulis*) and to a lesser extent crustaceans, echinoderms and flatfish, the Eider enjoyed its major phase of expansion in the British Isles towards the end of the 19th century as it began to benefit from protected status (Cramp *et al.*, 1977).

The species shows marked sexual dimorphism, the male in breeding plumage being an unmistakable patchwork of black and white markings, the female a uniform brown.

The entitled aspects of Eider duck ecology have been studied in the past. For instance Goudie and Ankney's (1988) study of habitat use by seaducks wintering in S.E. Newfoundland analysed shoreline substrate preferences ; and Minot (1980) studied both this, and how tide and time of day affected Eider activity, in particular feeding behaviour.

However it is duckling survival that has been the subject of greatest attention, for instance Munro and Bedard (1977), Mendenhall (1979), Cooke (1982), Swennen (1983 & 1989) and Mendenhall and Milne (1985) all considered various aspects of duckling survival.

Clearly a single season study cannot hope to cover all these areas in great detail, but by studying a different



Eider population in different environmental conditions it may be possible to give some indication as to the general applicability of the above researchers' conclusions.

The study itself was centred at Amble on the Northumberland coast and used breeding associated with Coquet Island. The research in its entirety was carried out between Hadston Carrs (GR 284009) and Craster (GR 259199). More specifically the data regarding the timing of adult feeding were collected from the coastguard look-out point (GR 286003) to the south of Amble. This point was selected for its convenience relative to where the author was living, and for its remoteness from the environs of Amble harbour and Amble sewage outfall, two potentially strong sources of anthropogenic interference with the Eiders' normal activity rhythms.

The study covers three main facets of Eider duck ecology:

- 1) The distribution of adult Eiders and ducklings.
- 2) The nature of duckling mortality.
- 3) The timing of adult feeding (diurnal & tidal).

However attention will also be given to some more detailed aspects of, in particular, the ducklings' ecology. Namely, their preferred feeding substrate; how their time budget alters as they mature; how, if at all, their activity varies with the stage of the tidal cycle or the roughness of the sea surface; and, in relation to duckling group size, does it alter with age and are there relatively more or fewer ducklings per attendant female as the ducklings mature.

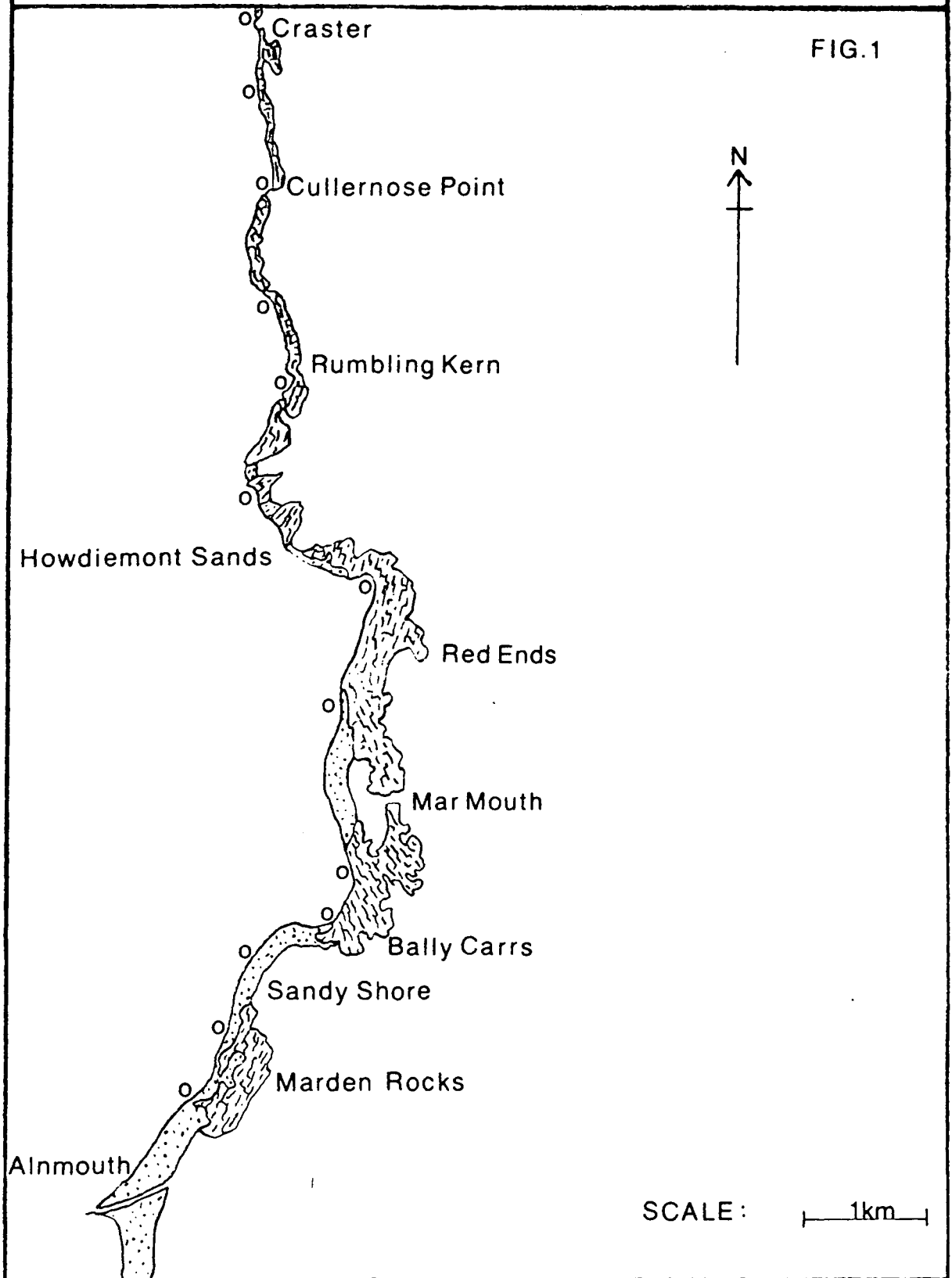
The fluctuations in the adult population and the sex ratio therein will also be considered.

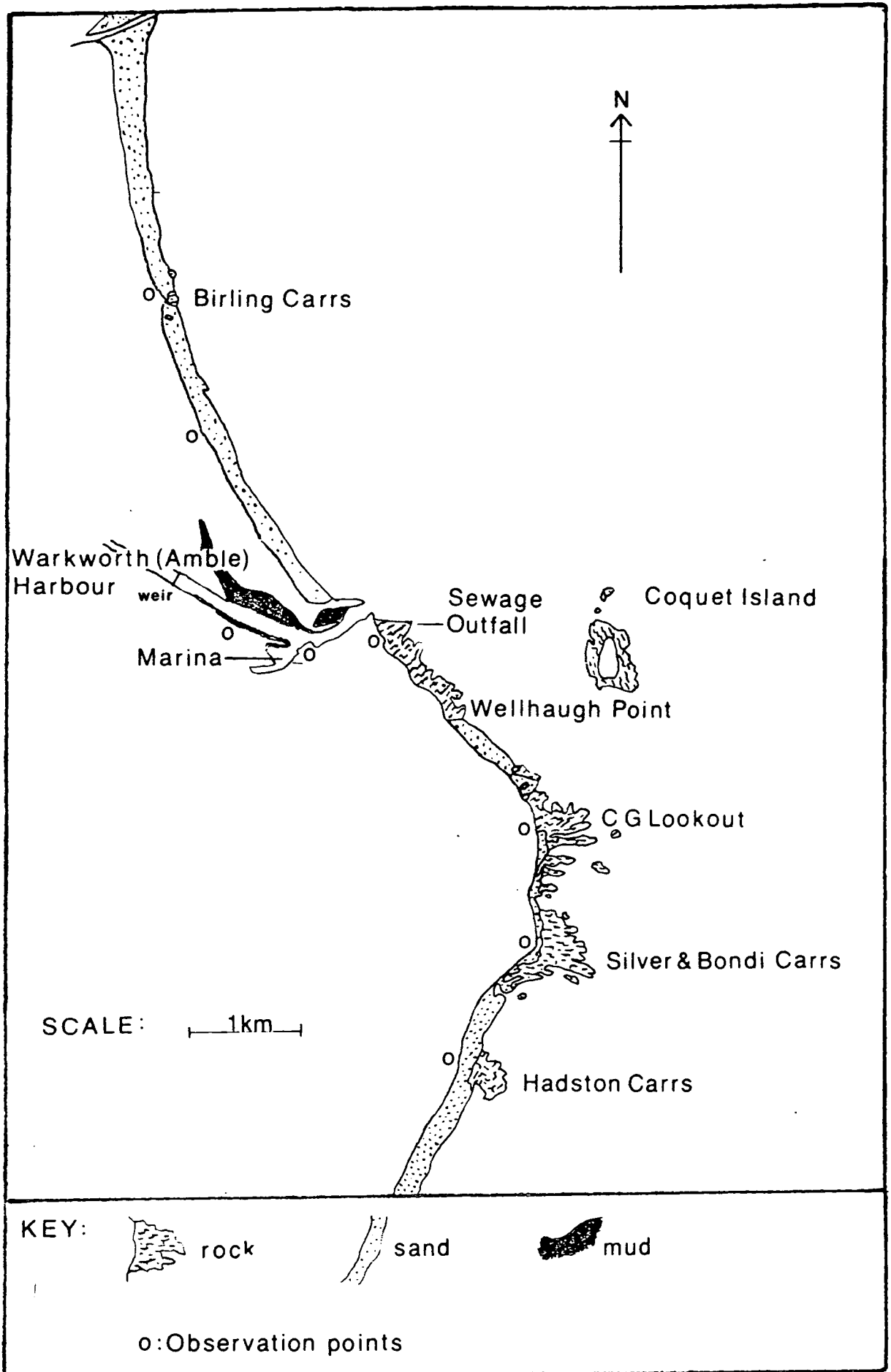
Besides being the basis of the author's degree thesis, the research will be used as background material for a report to the Nature Conservancy Council, which will make recommendations for enhancing the area's duckling survival rate.

STUDY AREA

Source: OS Landranger 81

FIG.1





## METHODS

The equipment used in this study comprised a SWIFT ZOOMSCOPE (15-60x 60mm) and 10x50 binoculars.

The methods employed can be conveniently split into three sections, namely those used to determine the distribution of adults and ducklings; those used in the assessment of duckling survival; and finally those used to assess the timing of adult feeding.

### ADULT AND DUCKLING DISTRIBUTION & DUCKLING SURVIVAL

The preferred feeding areas of adults and ducklings and their populations were determined by walking the study area from Hadston Carrs to Craster as often as possible (usually 2-3 times per week), and counting the populations of adults and ducklings found. At the same time the nature of the habitat in which the ducklings were found was noted. However due to the length of the coastline involved (>25km), the area had to be surveyed in two parts i.e. Birling Carrs to Hadston Carrs (GR 254078 - 284009) covered on twenty-two occasions, and Alnmouth to Craster (GR 247105 - 259199) covered on twenty occasions. Within each 'half' of the study area viewing points were selected to maximise the area visible and to ensure complete coverage (see Fig. 1).

The choice of Craster as the northern limit of the study area was principally a practical consideration in that to cover a larger area on foot would have been impossible. However, that ducklings from Coquet Island did get so far

north was demonstrated on one occasion when a brood/creche swam the whole distance from Marden Rocks to Craster as the author walked the same distance. That ducklings go no further than Craster cannot be proven, yet it seems likely that the numbers doing so will be small. Moreover, it is known that a few pairs of Eiders do in fact breed on the mainland to the north of Craster around Dunstanburgh Castle and thus to survey this area would have led to the impossibility of trying to separate the few Coquet ducklings from the few local ducklings. It is hoped that by stopping at Craster such complications could be avoided or at least made insignificant. Similarly, that Farne Island ducklings were not drifting southwards into the study area could not be proven in the time, or with the manpower available. However previous work (Coulson, pers comm) involving marking of ducklings from the Farnes showed that they only got as far south as Embleton (approximately 1.5 miles north of Dunstanburgh castle).

It quickly became clear that the ducklings were easier to see in some areas at certain tidal conditions. For instance at low tide in Amble harbour when the ducklings moved onto and across the exposed mud to feed; and at high tide between Marden Rocks and Howdiemont Sands, when the area of rock pools and seaweed encrusted rocks, into which the birds could disappear, was much reduced. Hence, whenever possible, counts were timed to coincide with these stages in the tidal cycle.

To assess duckling survival an age categorisation of ducklings is required. <sup>Milne (1985)</sup> developed the

following age categorisation based on 130 newly hatched ducklings in eight broods:

Age categories and physical description	Extremes of observed ages (days)	Median (days)
1a Rotund, blackish	0-10	3
1b Slimmer, pale brown	5-25	12
2 Distinct neck	10-40	25
3 First feathers (scapulars & flanks)	25-49	40
4 Feathers on head and flanks - Fledging	40-84	65

#### TIMING OF ADULT FEEDING

In the case of the feeding habits of adult birds it was impossible to watch the whole Eider duck population, or even a sizeable proportion of it, for a whole day. Further, while it may be possible to watch a single bird for a whole day this assumes that the chosen bird is 'typical' of the whole population and, moreover, that the chosen day is typical of all other days. A more generalised indication of feeding activity is required that aggregates the behaviour of several, if not several hundred, individuals through changing weather, and in this case especially, changing tidal conditions. A feeding index was developed to do this.

To calculate the feeding index, a group of ten birds is selected and then watched for 30 seconds, the number of individuals observed to engage in feeding activity

in that period is noted. The process is repeated ten times over a period of ten minutes. After a five minute break (to give the author a rest), another ten observations are made. Four such data sets were thus taken within one hour. The proportion of birds observed to have fed in those four counts is the feeding index for that hour.

This process was repeated every other hour from 0530 to 2030, giving eight feeding indices for any one day, namely:- 0530-0630; 0730-0830; 0930-1030; 1130-1230; 1330-1430; 1530-1630; 1730-1830; 1930-2030.

As many individuals as possible were included within each hourly sample. Given that the population visible from the look-out rarely, if ever, totalled 400 (the number sampled in one hour) it is likely that virtually all visible individuals would have been sampled and thus the method gives results which were representative of the real situation.

## STATISTICAL TREATMENT

By and large graphical presentation was all that was required to allow analysis of the data. However, in the sections relating to 'DUCKLING GROUPS' and to 'OTHER ASPECTS OF DUCKLING ECOLOGY' statistical tests were used.

In the former case this comprised the use of the Student t-test to see if there were significant differences in mean group size and mean dependency ratio (number of ducklings per attendant female) between successive age categories of ducklings. In both instances the data was not normally distributed and was thus log transformed before analysis was carried out.

In the latter case the two sample Chi-squared test was used to analyse, in turn, how the activity of the ducklings was related to their age; the stage of the tidal cycle; and the roughness of the sea surface. In the last case, only those ducklings which were outside Amble harbour were included in the test as those within the harbour were effectively sheltered from, and could thus behave independently of, the general sea-surface conditions. The identification of sea-surface conditions as 'flat', 'slight', 'moderate' or 'rough' was purely subjective and not based on quantitative criteria. Similarly the difference between 'shallow water' and 'deeper water' is subjective, ducklings generally being ascribed to the latter category if more than a few metres (@ 5m) off shore.

When carrying out the chi-squared tests the author was faced with the problem of deciding whether to take the

individual duckling or the duckling group as the base data point. To use the former would assume that all the individuals within a group of ducklings was behaving independently of all the others, and five minutes of observation is enough to prove that this is not the case. Conversely, to take the group as the base data point would mean that a lone duckling would have the same weight, within the test, as a group of 30.

The only solution was to carry out tests on the basis of both assumptions and only in those instances where the results concur take them to be reliable.

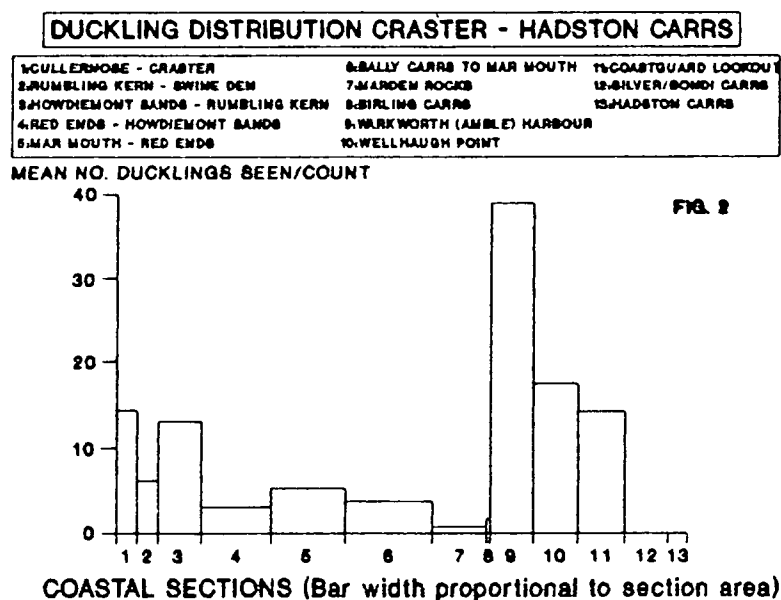
In all statistical tests significance was accepted if the probability level fell below 0.05 (i.e.  $p < 0.05$ ).

## RESULTS

### DUCKLING DISTRIBUTION

In the following text it should be noted that the numbers referring to coastal sections are not necessarily interchangeable between graphs. A key to the sections is provided on each individual graph.

Figure 2 illustrates the distribution of ducklings in the study area. Only those sections that contain shore types which were extensively used by the ducklings are shown. Such areas include seaweed covered rock, bare rock and mud and these together accounted for 95% of all inshore duckling observations.



The width of each section bar is proportional to the area of useful habitat within each section between M.H.W. and M.L.W. The total useful area is 2.9875km<sup>2</sup> and is divided between the sections as shown thus:

COASTAL SECTION	AREA
CULLERNOSE - CRASTER	0.1025 km <sup>2</sup>
RUMBLING KERN - CULLERNOSE	0.1150 km <sup>2</sup>
HOWDIEMONT SANDS - RUMBLING KERN	0.2250 km <sup>2</sup>
RED ENDS - HOWDIEMONT SANDS	0.3650 km <sup>2</sup>
MAR MOUTH - RED END	0.3925 km <sup>2</sup>
BALLY CARRS - MAR MOUTH	0.4625 km <sup>2</sup>
MARDEN ROCKS	0.2825 km <sup>2</sup>
BIRLING CARRS	0.0225 km <sup>2</sup>
WARKWORTH (AMBLE) HARBOUR	0.2250 km <sup>2</sup>
WELLHAUGH POINT	0.2300 km <sup>2</sup>
COASTGUARD LOOK OUT	0.2425 km <sup>2</sup>
SILVER/BONDI CARRS	0.2250 km <sup>2</sup>
HADSTON CARRS	0.0975 km <sup>2</sup>

Table 1

Of the above, only the harbour (Fig 2, section 9) is characterised by mud.

Figure 2 illustrates that the harbour is the most used section of the study area, with sections 10 (Wellhaugh Point), 1 (Cullernose - Craster), 11 (Coastguard lookout) and 3 (Howdiemont Sands - Rumbling Kern) being less than half as well used.

Within the harbour, the ducklings principally used the main channel, from the dockyard upstream to 50-100m below the weir, and the extensive mud banks to the north of the main channel opposite the yacht club.

Table 2 illustrates the intensity of use of each section (the values are obtained by dividing the "mean number of ducklings seen per count" by the area of useful habitat in each section). Amble harbour appears as the most intensively used section, with the area between Cullernose and Craster a close second.

COASTAL SECTION (FIG 2.)	(DUCKLINGS/COUNT) /km <sup>2</sup>
1 CULLERNOSE - CRASTER	140.60
2 RUMBLING KERN - CULLERNOSE	54.73
3 HOWDIEMONT SANDS - RUMBLING KERN	58.40
4 RED ENDS - HOWDIEMONT SANDS	8.70
5 MAR MOUTH - RED ENDS	13.64
6 BALLY CARRS - MAR MOUTH	8.18
7 MARDEN ROCKS	2.92
8 BIRLING CARRS	76.18
9 WARKWORTH (AMBLE) HARBOUR	172.70
10 WELLHAUGH POINT	75.98
11 COASTGUARD LOOK OUT	61.66
12 SILVER/BONDI CARRS	0.00
13 HADSTON CARRS	0.00

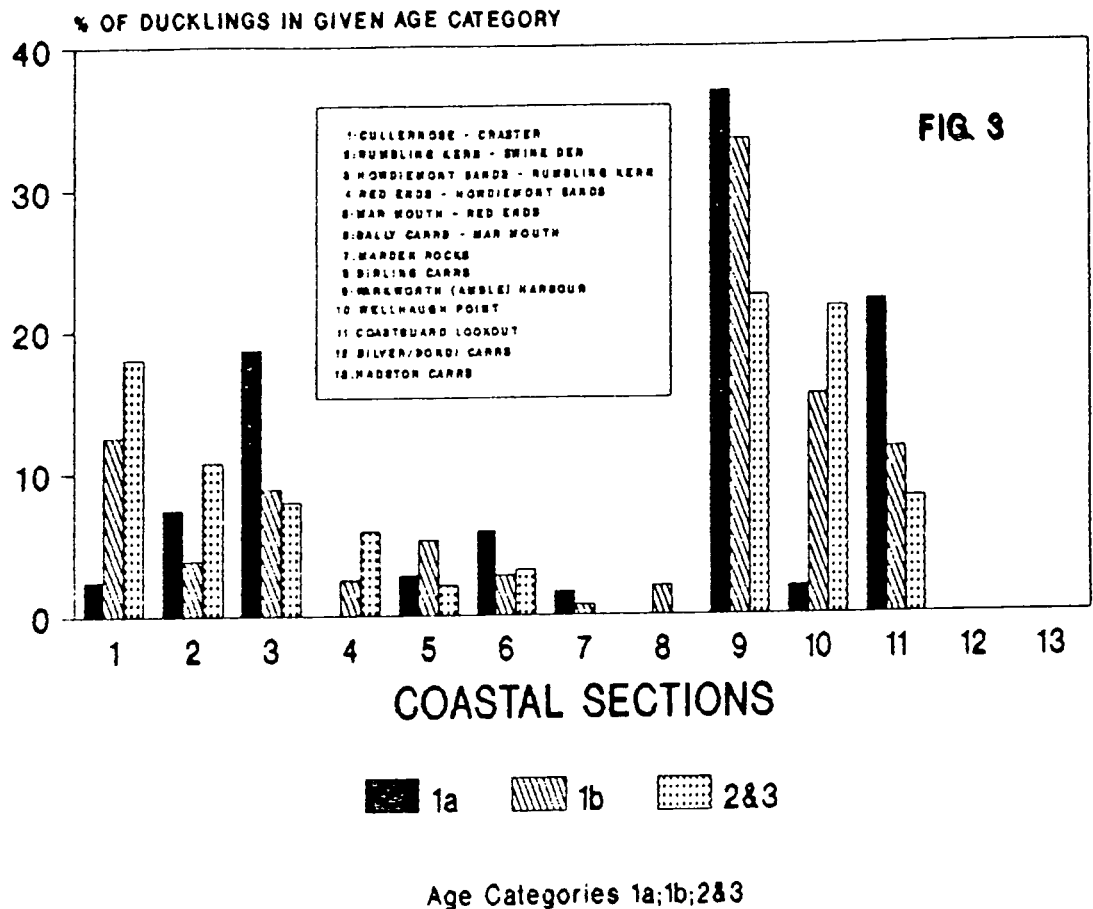
Table 2

Figure 2 contains only field data collected during approximately the first half of the ducklings' growth (9/5 - 12/7 with one additional visit on the 1/8) thus areas favoured by the ducklings in the latter stages of their growth will be somewhat under-represented. However since this first half of the growth is the time of high mortality, the early habitat choice is of particular importance.

Figure 3 illustrates the changing distribution of ducklings as they grow. Age categories 2 and 3 have been combined due to their relatively small size.

The areas between Howdiemont Sands and Rumbling Kern (Fig.3, section 3); around the Coastguard look out point to the south of Amble (Fig.3, section 11); and, most importantly Amble harbour (Fig.3, section 10) are favoured by ducklings of age categories 1a and 1b. It was notable that the additional count carried out on 1 August revealed no ducklings in Amble harbour. On this date all observed ducklings were in age category two or above.

## DISTRIBUTION OF DUCKLINGS BY AGE GROUP



Furthermore the recently constructed marina within Amble harbour is little used by ducklings (only 2.8% of all 'in-harbour' observations).

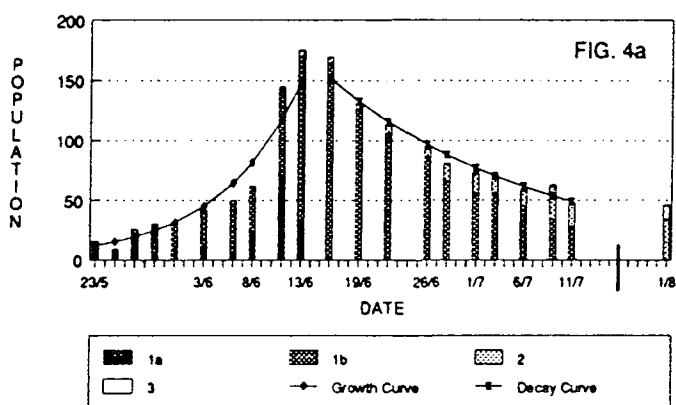
Figure 3 also indicates the existence of areas favoured by older ducklings such as the rocks between Wellhaugh Point and the mouth of Amble harbour (Fig 3, section 10), and the area between Cullernose Point and Craster (Fig 3, section 1).

## DUCKLING MORTALITY

The growth and decline of the duckling population, its age structure and the overall mortality are shown in Figures 4 & 5.

### EIDER DUCKLING POPULATION DYNAMICS

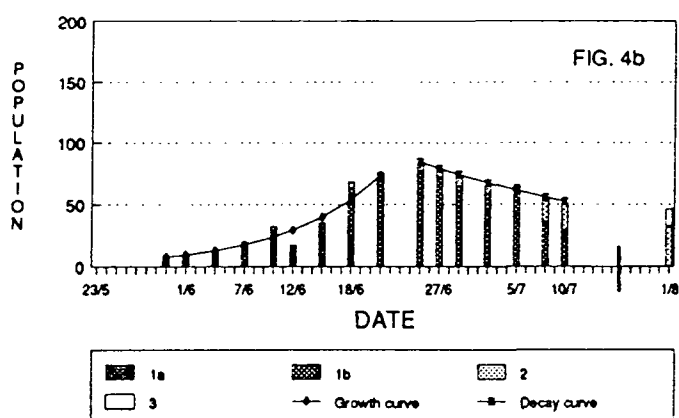
HADSTON CARRS - BIRLING CARRS



Ducking age categories 1a,1b,2,3

### EIDER DUCKLING POPULATION DYNAMICS

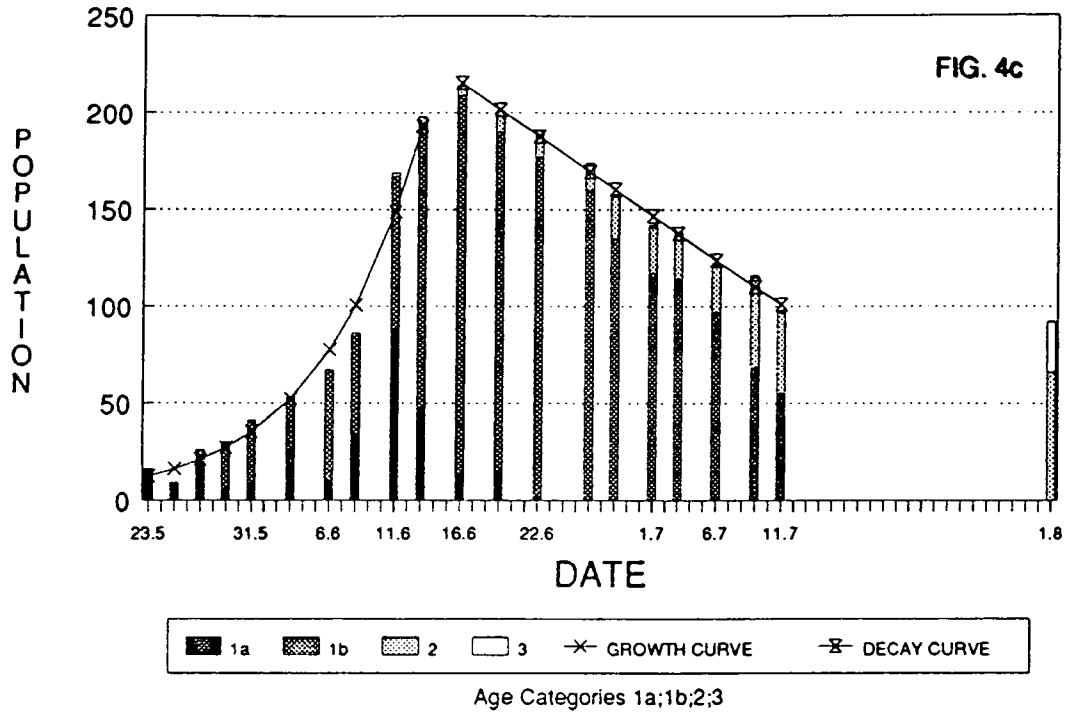
ALNMOUTH - CRASTER



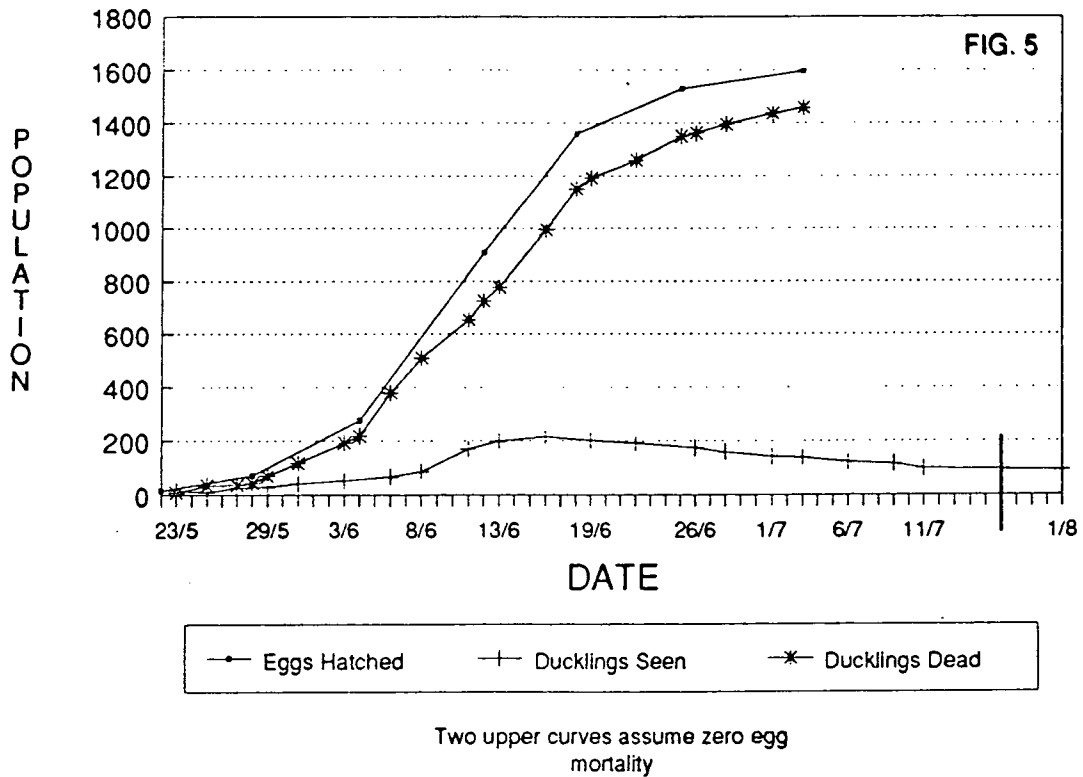
Age Categories 1a;1b,2;3

# EIDER DUCK POPULATION DYNAMICS

HADSTON CARRS - CRASTER



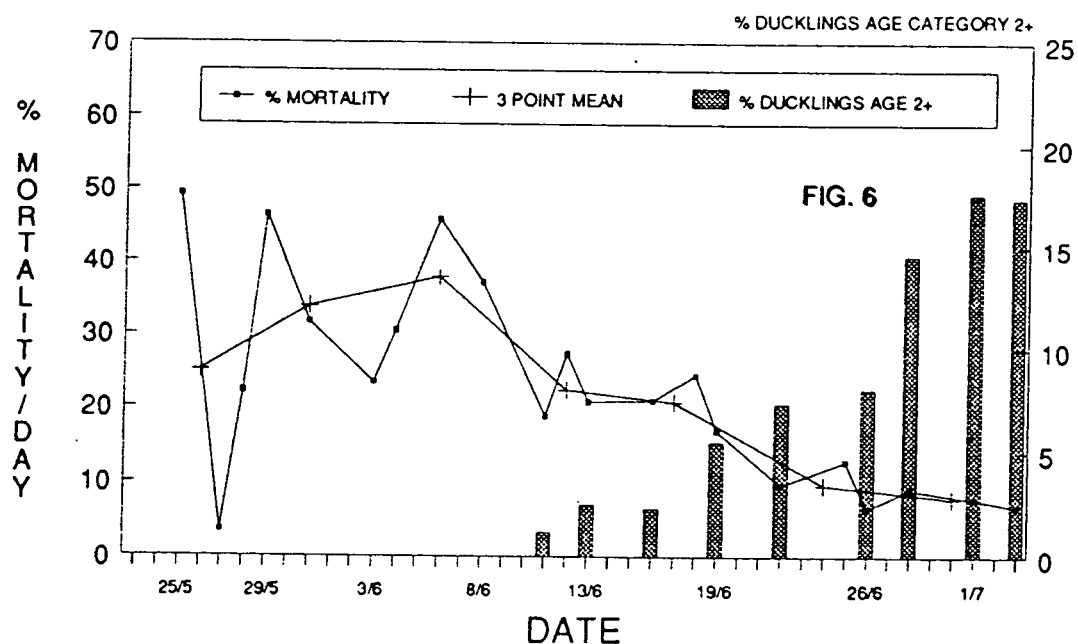
# EIDER DUCKLING MORTALITY



The vast majority of mortality occurs prior to the ducklings reaching age category 2, while those ducklings reaching this age have a relatively good chance of surviving to maturity. This is illustrated by both Figures 4c and 6, in the former is depicted the death of only six ducklings between 11 July and 1 August (when all the ducklings were in, or fast approaching, age category 2 or above). Conversely in the three weeks prior to 11 July approximately 100 ducklings are known to have died. The latter graph, Figure 6, shows the relationship between the mortality rate per day and the percentage of ducklings in the population in age category 2 or above.

## % DUCKLING MORTALITY/DAY

### HADSTON CARRS - CRASTER



Again the drop in mortality rate as the ducklings mature is seen. It should also be noted that the mortality rate per day in the early part of the season, as represented in Figure 6, is probably too low simply because in order for a duckling to contribute to this figure it must have been observed on at least one occasion. However the youngest ducklings die at such a rapid rate that some are undoubtedly never counted.

As the data for Figures 4a and 4b was collected on different days, an indication of the overall population changes could only be gained by combining the two data sets. Figure 4c is the result and is derived by interpolating between the count dates for the area between Alnmouth and Craster on to the dates on which counts were carried out between Hadston Carrs and Birling Carrs, and then adding the former to the latter (this technique has also been applied, using the relevant data, to construct Figures 5, 6 & 10c). This gives an accurate impression of the day to day change in numbers for the whole study area. However in doing so, the true nature of the population dynamics are hidden, especially in the decline phase of the graph where an apparently linear decline (Fig. 4c) hides two exponential curves (Figs. 4a & 4b).

From counts of sitting females provided by the Coquet Island warden (and assuming an incubation period of 27 days [Cramp, 1977]) it is calculated that 420 females bred on the island this year. Thus in order to replace the loss due to adult mortality, 10% per annum (Coulson, 1984), 42 female ducklings would have to survive to maturity. On 1

August, 92 ducklings remained. Assuming a sex ratio of 50/50 this means 46 female ducklings were still alive, but as it takes two years to reach sexual maturity clearly in 1990 too few ducklings have survived.

At an average clutch size of 3.8 (Coulson, pers. comm.), and given a total of 420 clutches this means 1596 eggs were laid. Thus by 1 August the eggs and ducklings had suffered an overall mortality of 94%.

There was no evidence to suggest that this year's toxic bloom of Dinoflagellates in the North Sea had a detrimental effect on duckling (or adult) survival.

#### DUCKLING GROUPS AND CRECHES

Student t-tests were carried out on two facets of duckling groups, namely how group size changes with age and how the number of ducklings per attendant adult (the 'dependency ratio') changes with age. Both showed significant declines between successive age groups (see below & Appendix 1). The only exception being between age categories 2 and 3 when the dependency ratio was considered.

It should be noted that these results reflect significant (or non-significant) changes in the LOG of the mean creche size and mean dependency ratio.

Age Categories	Creche Size		Dependency Ratio	
	t	p	t	p
1a v. 1b	3.28	<0.001	5.03	<0.001
1b v. 2	5.27	<0.001	3.42	<0.001
2 v. 3	2.82	0.011	1.71	0.10

### OTHER ASPECTS OF DUCKLING ECOLOGY

Chi-squared analysis of duckling activity in relation to age category shows only three clear trends, firstly that there is a significant variation in activity with age (GROUPS: chi-squared = 76.57,  $p < 0.001$ . INDIVIDUALS: chi-squared = 630.93,  $p < 0.001$ ), and that this variation is largely comprised of an increasing level of feeding in deeper water as the ducklings age, with a concurrent decrease in the level of feeding in shallow water. These patterns are consistent whether groups or individual ducklings are used as the unit of data.

The consideration of how duckling activity is related to the tidal cycle shows that when the group is taken as the unit of data no significant relationship is found (chi-squared = 28.39,  $p > 0.10$ ). However when individual ducklings are taken as the individual unit of data, significance is achieved (chi-squared = 327.06,  $p < 0.001$ ). The only clear pattern is a greater propensity to rest close to high tide, and a tendency to feed on land to a greater extent than expected around mid-tide.

Finally, chi-squared analysis of the relationship between duckling activity and sea-surface roughness finds significant relationships with both groups and individuals as the base data point (GROUPS: chi-squared = 29.30,  $p < 0.001$ . INDIVIDUALS: chi-squared = 161.39,  $p < 0.001$ ). In this instance we find less feeding than expected in shallow water in flat conditions and rather more than expected in

moderate-rough conditions, the reverse being true for deep water. Furthermore there is less swimming than expected in open water in moderate to rough conditions, and more than expected in slight conditions.

The data for all the above tests is shown in appendix 2.

### ADULT FEEDING

The results of the counts to determine the timing of adult feeding are shown individually and collectively in Figures 7 & 8 (see also Appendix 3).

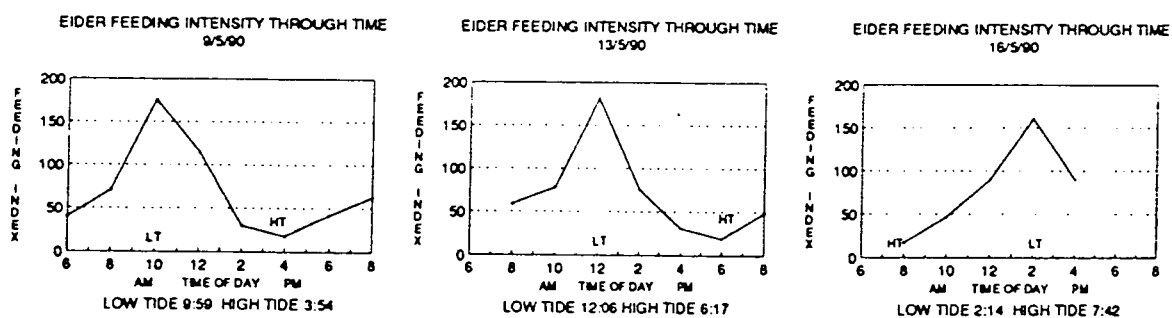
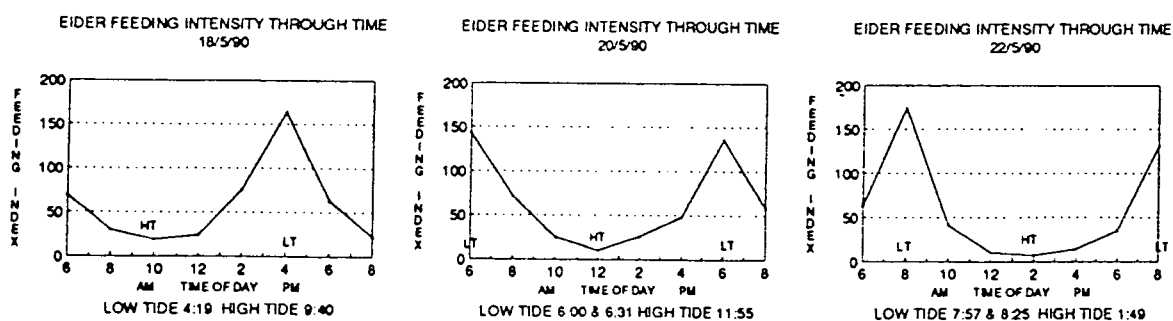
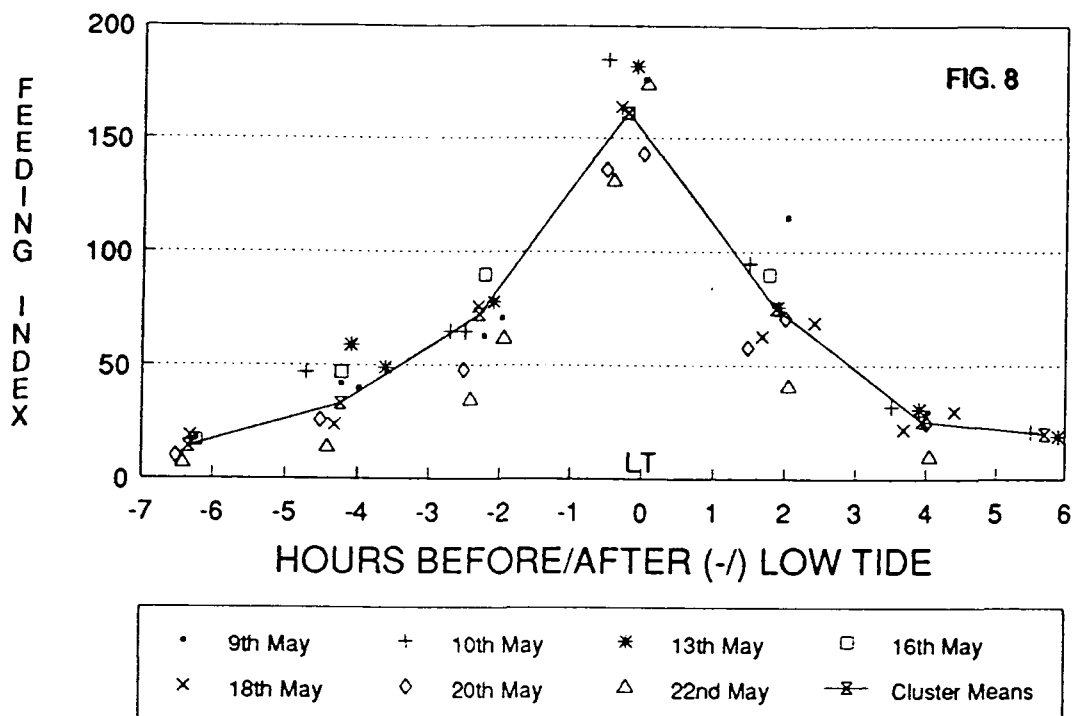


FIG. 7



## EIDER DUCK FEEDING v. TIDE RELATIONS



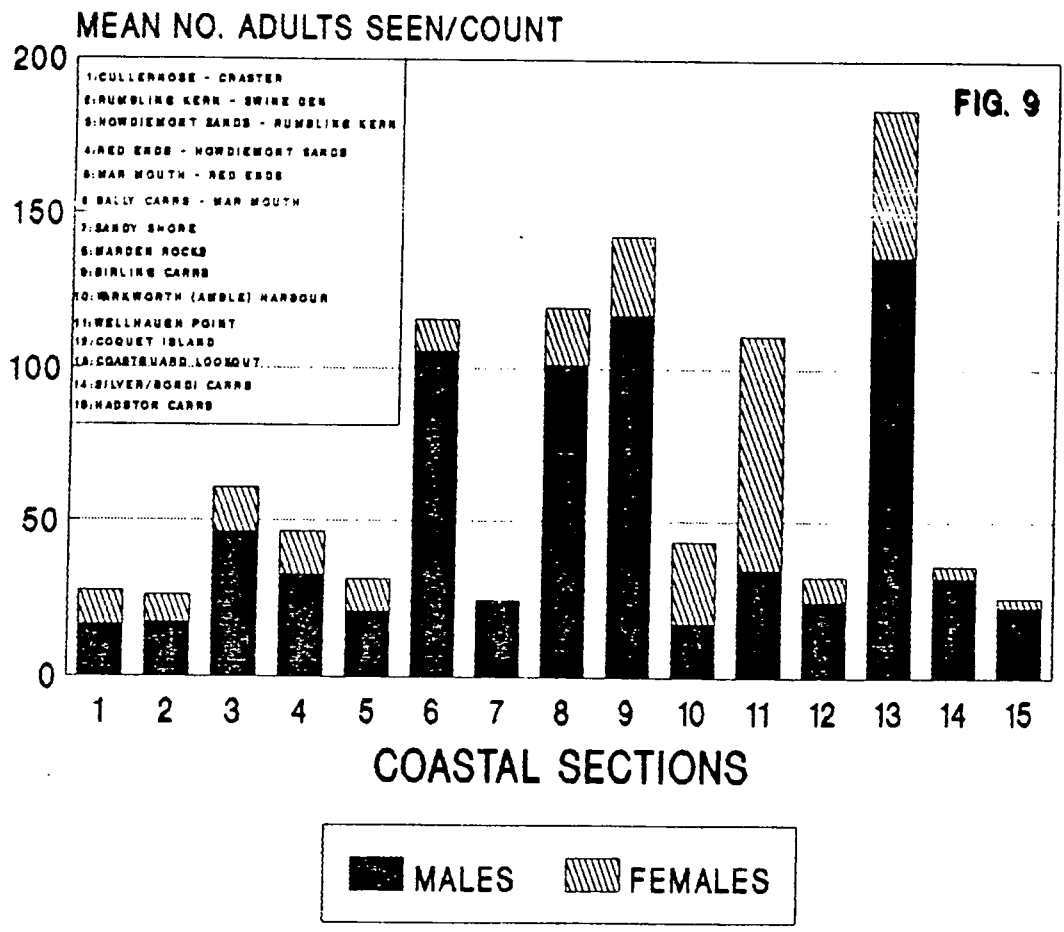
There is a clear peak in feeding at low tide and a corresponding trough at high tide. This pattern is repeated irrespective of when low and high tide fall during the day. Furthermore, if two low tides occur within the daylight period then two peaks of feeding activity are recorded.

The adults fed both in the water and on the rocks at the water's edge. Pecking, dabbling, upending and diving were all used as feeding techniques.

ADULT DISTRIBUTION

As shown in Figure 9, there is a general increase in numbers down the coast towards Coquet Island and the onshore area opposite around the coastguard lookout point. Only areas: 7, Sandy Shore (Fig. 9); 10, Warkworth (Amble) harbour (Fig. 9); and 12, Coquet Island (Fig. 9) deviate from this trend. However as it is known that there were c420 nests on the island this year, the bar on Figure 9 for Coquet Island must be largely meaningless.

**ADULT BIRD DISTRIBUTION**



To the south of Coquet Island i.e. Silver/Bondi and Hadston Carrs there is a very rapid drop in numbers and no birds were seen in the body of Druridge Bay.

A second feature of the graph is the preponderance of male birds. However there are two exceptions to this general situation i.e. Warkworth (Amble) harbour (Fig.9, section 10), and the rocks around Wellhaugh Point (Fig.9, section 11), where females are in the majority.

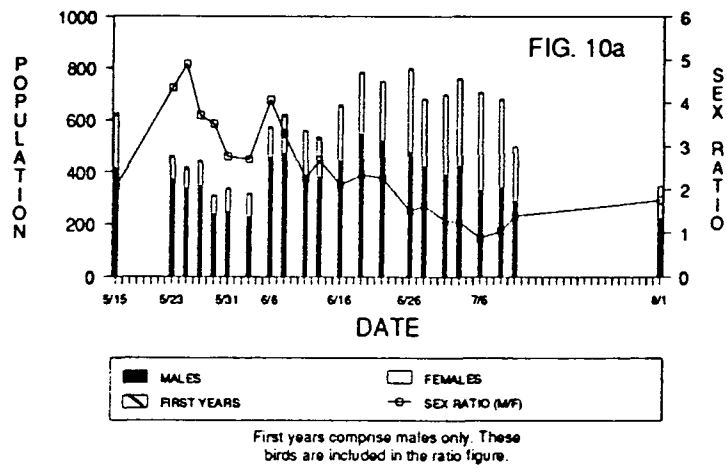
#### ADULT SEX RATIOS AND POPULATION FLUCTUATION

Figures 10a,b & c show the sex ratio (male/female) of adult Eiders in the study area (see Appendix 4). The picture is one of a peak in the ratio, at the height of the incubation period (@25/5) of 5.56, followed by a decline to just 1.17 on 1 August. However this pattern hides more or less severe fluctuations in the ratio figure especially in the northern 'half' of the study area.

The graphs also indicate the variation in the overall numbers seen within the study area (see Appendix 4). In this case a minimum of 674 birds is reached at the height of the incubation period, followed by a steady rise in numbers to 1296 on 26 June. This pattern, as opposed to that of the sex ratio, is more consistent in the two halves of the study area although again the northern 'half' fluctuates quite widely from day to day.

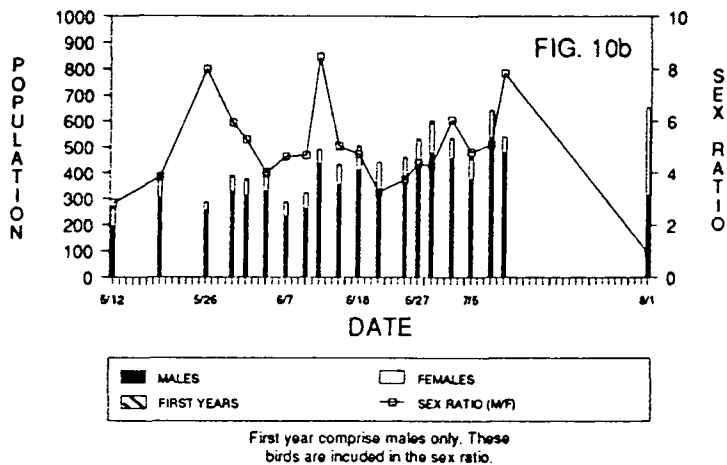
DRAKE/DUCK SEX RATIO AND POPULATION

HADSTON CARRS - BIRLING CARRS



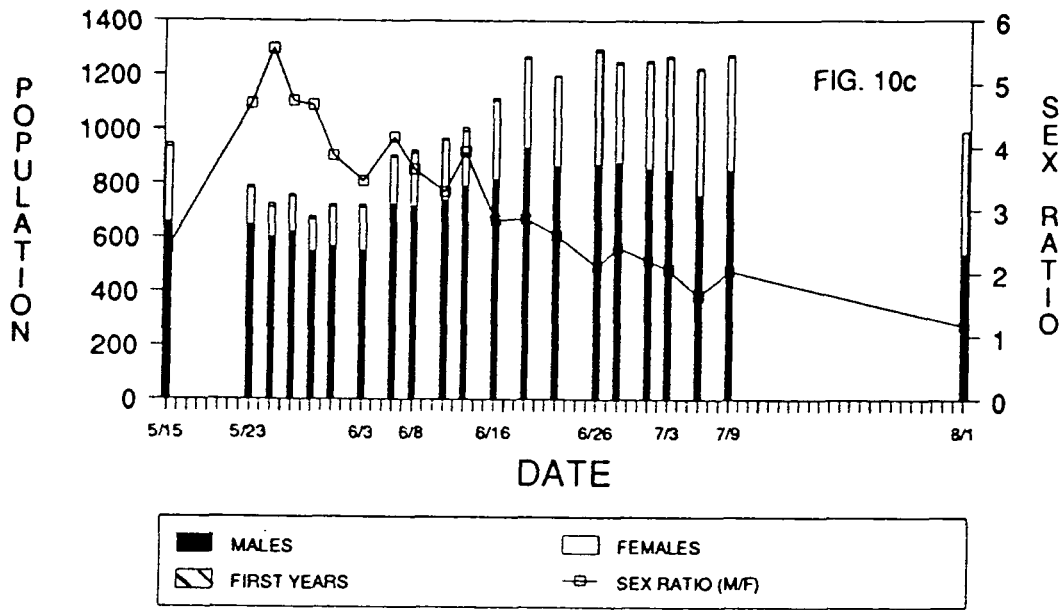
DRAKE/DUCK SEX RATIO AND POPULATION

ALNMOUTH - CRASTER



# DRAKE/DUCK SEX RATIO AND POPULATION

## HADSTON CARRS - CRASTER



First years comprise males only. These birds are included in the ratio figure.

## DISCUSSION

### DUCKLING DISTRIBUTION

Although all the ducklings of the study area are hatched on Coquet Island most of them leave immediately after hatching, and cross the kilometre or so of open water to the mainland. This is reflected in the small number of ducklings seen by the island's warden around its shores (a maximum of 58 on 18 June).

While Figure 2 illustrates that Amble harbour is the most important area in terms of how many ducklings use it, Table 2 shows that the area between Cullernose and Craster is almost as attractive a habitat to ducklings. However for the conservation of the local population it is clearly the mud flats of Amble harbour that are most important. Figure 3 identifies the existence of three 'nursery areas' where the young occur and feed for the first few weeks of their life, Amble harbour again being principal amongst these.

The lack of usage by Eiders of the newly constructed marina in Amble harbour does not reflect human disturbance through the use of the marina by boating enthusiasts *per se* (indeed the open river channel was probably disturbed to a greater extent by the comings and goings of boats and their crews than the marina itself). Rather, the marina is now an area of relatively unsuitable habitat for ducklings with only very restricted areas of mud becoming available at low tide due to the artificially

created and steeply sloping sides of the marina basin. It is possible that chemicals derived from the boats have killed the fauna on and in the mud and this should be examined.

The uneven use of the coastline by ducklings, depicted in Figures 2 & 3, in part reflects availability of food, as Cantin, Bedard and Milne (1974) found on the St. Lawrence estuary in July, the number of ducklings per unit area was directly related to food densities (ranging from 34 ducklings/km<sup>2</sup> up to 162/km<sup>2</sup> - results not too dissimilar to those shown in Table 2). It also points to the relative abilities of younger and older ducklings to cope with different sized prey items. Young ducklings take polychaetes such as *Nereis diversicolor* and *Arenicola marina*; young or small crustaceans such as *Crangon crangon* and *Gammarus* sp. (Swennen, 1989) and small molluscs such as *Hydrobia jenkensi* (Coulson, pers. comm.) which abound in the typically estuarine muds of Amble harbour. The attraction of this habitat to ducklings is revealed by chi-squared analysis which in comparing the various substrata available to the ducklings for feeding shows that significantly more ducklings than expected used mud as a feeding habitat (Chi-squared : 68.05 {groups}, 277.05 {individuals} p<0.001). Another element of the diet for the first two weeks of life is insects, especially the Bibionidae (Cantin, Bedard and Milne, 1974). These authors also indicate the importance of *Littorina* spp., a gastropod, which can comprise 30 - 97% of the ducklings' diet, the figure increasing with age. They also note an increase in the size of the *Littorina* spp. taken as the

ducklings aged (although this could simply reflect a coincidental increase in the availability of larger *Littorina* spp.). Furthermore, ducklings above the age of three weeks are able to cope with 2-3cm. long mussels (*Mytilus edulis*) (Swennen, 1989). Both mussels and *Littorina* spp. thickly encrusted the rocks around and to the north of Wellhaugh Point, with the latter also being abundant between Cullernose and Craster.

The concentration of older ducklings between Wellhaugh Point and Amble harbour mouth is closely associated with Amble sewage outfall, and it may be that the localised nutrient enrichment of the sea-water due to this and possibly to the discharge of the nearby River Coquet into the sea leads to the area's beneficial nature for ducklings.

Young ducklings, within their first few days of life, need to drink low salinity or fresh water (Swennen, 1989), however Swennen also noted that they seem to be very efficient at finding even small quantities in shells, small seepages and drains. Such sources, and others (including fresh water rock pools, home to healthy tadpoles), were relatively common along the whole coastline and thus the availability of fresh water is probably not important in determining duckling distribution in this instance.

On the other hand, while availability and suitability of food are of great importance in determining duckling distribution other factors such as freedom from disturbance; availability of shelter and loafing areas; tradition; the presence or absence of predators; and the

proximity of the nearest nesting habitat may all be of importance as well.

#### EGG MORTALITY

Prior to a discussion of duckling mortality, mention should be made of the potential for egg losses if assumptions concerning its magnitude are to be accepted.

There exists the apparent paradox that while large gulls (*Larus marinus*; *Larus argentatus*) and crows (*Corvus* spp.) appear to be the main predators of Eider eggs (Reed, 1964; Choate, 1967; Gotmark & Ahlund, 1986) and rates of egg loss may reach levels as high as 30% (Gerasimova & Baranova, 1960), with a figure of 70% variously recorded (Paynter, 1951; Guignion, 1967; Clark, 1968; Bourget, 1970), nonetheless Eiders seem to derive some benefit from nesting in gull colonies. It appears that the gulls unintentionally protect the Eiders from predators external to the colony such as other gulls and crows (Bourget, 1973) and mammals (Swennen, 1989). As Gotmark & Ahlund (1986) state:

"...the proportion of Eider nests destroyed by predators was significantly lower within than outside gull colonies...We suggest that the colonies, to some extent, protected Eider nests against predation."

It seems that the females' habit of rarely if ever

leaving the nest (Anderson, 1975), once incubation has begun is adequate protection against direct attack by avian predators (Swennen, 1983). However:

"...the absence of mammalian predators appears to be the most important pre-requisite (for high nesting success) as mammals may be dangerous for the adult bird" (Gotmark & Ahlund, 1986)

The same has been found by Hilden (1964) and Larson (1960). Swennen (1983) points to whole colonies being destroyed by the Red Fox (*Vulpes vulpes*) and the Arctic Fox (*Alopex lagopus*). Such predators, and indeed man, pose a real threat to the incubating female, she is forced to leave the nest thereby leaving it open to all potential predators. Van Dobben (1934 & 1937) observed 20% egg loss on Vlieland to Herring Gulls as the result of human disturbance. Grenquist (1959) and Hilden (1964), also showed the influence of man on clutch predation.

A realisation of the above has important consequences for the conservation of the Eider. For instance in S.W. Sweden:

"...the breeding population has increased markedly, even more than the gulls. Thus, predation on eggs... by gulls has no serious negative influence on the population level of the Eider, and cannot be used as an argument for the reduction of gull populations." (Gotmark & Ahlund, 1986).

Similarly in Vlieland nesting success has increased to more than 90% despite an increase in the gull population from 3,000 to 10,000 pairs. This in fact reflects a lack of disturbance by man (Swennen, 1989).

In the present study no data were recorded concerning egg depredation on Coquet Island, however it is very low. The only potential predators are the big gulls, and in the early 1970's, when their population reached a maximum of over 130 pairs, the number of Eider clutches involved in egg predation was less than 4% (Coulson, 1984). Today the numbers of gulls are far lower having been subjected to a culling programme by the R.S.P.B. who own the island. Yet, more importantly there are no ground predators on the island and, moreover, the island is closed to the general public thus minimising disturbance of the incubating females. In the results section I refer to egg loss as being less than 10% however the figure is probably closer to 2 or 3%

Apparently Coquet Island's only short-coming as far as egg survival is concerned is a lack of vegetative cover, which has been shown to increase predation (Lewis, 1959; Choate, 1967). However, Bourget (1970) managed to overcome this problem by providing artificial shelters thereby doubling nesting success.

### DUCKLING MORTALITY

The figure of 94% duckling mortality by 1 August is high, moreover this figure will inevitably increase before the remaining birds fledge, and rise further before they reach breeding status in two years time. However such a level of mortality is common to many similar studies on Eiders. Indeed Vermer (1968) noted a death rate of 100%, while Swennen (1989) noted that:

" Up to 99% of ducklings may disappear during the first 10 days after hatching."

Mendenhall & Milne (1985) in their 13 years of study in N.E.Scotland showed survival from hatching to fledging averaged 10.4%. While work by Swennen, Duiven & Reyriink (1979) on Vlieland indicated that:

" In the years 1975 - 1977 the mortality rate due to natural causes exceeded 98%. In 1978 mortality was noticeably lower, down to about 70%."

This, in turn, highlights another characteristic feature of Eider duckling mortality. While in most years, as in the present study, survival is barely enough or is actually insufficient to replace the annual loss to adult mortality (10.5% around Coquet (Coulson, 1984); 20% in Denmark (Paludan, 1962); 39% in N.W.Europe (Boyd, 1962)), occasionally there are 'good' years in which a high

proportion of ducklings survive. As Mendenhall & Milne (1985) found fledging success varied from 0.5 to 55% between 1961 - 1974.

The primary cause of duckling mortality has, in most instances, been found to be large gull predation (principally Herring and Great Black-backed Gulls). For instance Mendenhall & Milne (1985) found that predation, largely by Herring Gulls, accounted for 96% of all mortality in 1974; for Vermer (1968) the figure was 100% and similar findings have been made by Mennes & Swennen (1976) and Swennen *et al* (1979).

Thus, although little direct evidence of gull predation is available in this study (only 4 instances of Herring Gulls (Larus argentatus) and Great Black-back Gulls (Larus marinus) swooping unsuccessfully on groups of ducklings), it seems likely from the magnitude and timing of the mortality (almost exclusively in age category 1), that this was in fact the cause.

Recent work by Swennen (1989) in the Netherlands, however, suggests gull predation is merely a proximate reflection of the moribund state of ducklings, a state ultimately caused by starvation. As the ducklings weaken through lack of food they become less responsive to their guardians alarm calls, spread out more while feeding, and so become more susceptible to predation.

As the ducklings grow the range of food they can handle increases, thus they find it increasingly easy to avoid starvation. Moreover their increased size in itself makes predation less likely. Consequently the predation and

mortality rate drops through the season (Mendenhall & Milne, 1985), a pattern clearly seen in this study in Figure 6.

Mortality due to other causes is, per force, relatively rare although Mendenhall & Milne (1985) did find that:

" 25 - 40% of mortality during the second week of life was from renal coccidiosis *Eimeria somateriae*"

and also that all dead birds aged between 5 and 18 days had severe kidney damage as a result of the disease.

Swennen (1989) found physical wounds and ectoparasites on less than 1% of ducklings and thus these may be dismissed as significant causes of death in the present study, and while Mendenhall and Milne (1985) found a correlation between poor weather and death rate it seems likely that the former has its effect through the medium of starvation, and hence predation, by making foraging more difficult.

In the case of the Coquet Island population, the average survival rate of ducklings needs to be higher than in 1990 if the population is going to be sustained. The possibility that feeding sites for ducklings have deteriorated or become too small needs investigating.

### DUCKLING GROUPS & CRECHES

Creches are a well known feature of eider duck ecology. They form shortly after nest exodus and may last until fledging, although exchange of ducklings has been observed both in this study and others (Munro & Bedard, 1977; Swennen, 1989). The encounters which lead to creche formation may be caused by alarm, predation or simply the mutual attraction of the ducklings (Munro & Bedard, 1977). The consensus is that this behaviour leads to a distinct survival advantage for the ducklings (Munro, 1975; Patterson, Gilboa & Tozer, 1982).

Swennen (1989) found that between good and bad years for duckling survival the average number of young per attendant female dropped from 3.3 to 2.1. In this study, a bad year, the figure is 2.6. However this figure includes fewer sightings of older duckling groups due to lack of time available for collecting field data. Older duckling groups are significantly smaller than younger duckling groups, and hence the 2.6 figure is artificially high.

The drop in mean group size between each successively older age category of ducklings suggests that the mortality of the ducklings is of over-riding importance in determining group size, and that there is no optimum group size which ducklings strive to attain. It is also in accord with Munro & Bedard (1977) who found that as ducklings get older they show greater aggression to foreign ducklings, thus preventing further creche formation.

Moreover they suggest that once creches are established in the rearing area they have "remarkable stability".

The drop in mean dependency ratio between each successive age category reflects the increasing aggregate mortality of ducklings over time. There was no evidence of females joining groups as the latter aged ( a total of 216 females attended the first 100 group sightings; a total of 200 attended the last 100 group sightings).

#### OTHER ASPECTS OF DUCKLING ECOLOGY

By and large the relationships found have simple explanations. The observed increase in feeding in deeper water as the ducklings age points to them overcoming physiological barriers to diving, presumably at about the age of 2 - 3 weeks they develop the strength to overcome their natural buoyancy. Clearly the ability to feed by diving in deep water obviates the need to feed by dabbling in shallow water.

Similarly the greater propensity for resting at high tide simply demonstrates the exclusion of ducklings from their feeding grounds by the flooding tide, this especially being the case in Amble harbour where the whole of the mudflats are covered at high tide. Why ducklings should choose to feed more than expected on land around mid-tide is not so obvious, although it is likely that it reflects the relative ease with which certain types of food

may be acquired when covered with water or exposed, and the distribution of those food types between low and high tide.

The observed increase in feeding in shallow water as sea surface conditions roughen clearly points to the increased cost, in terms of energy it requires, of feeding in difficult conditions. A similar argument can be used to explain why there is less open water swimming in rougher sea conditions.

The behaviour of the ducklings while feeding was not quantitatively studied for this report, however some qualitative comparisons with other workers findings may be made. Swennen (1989), working on the intertidal flats around the West Frisian islands, found that at high tide the ducklings and their guardian females rest close to the water, at low tide appearing, to forage over the flats. Similarly, in Amble harbour the ducklings only fed at low tide. At high tide their whereabouts were generally unknown although on two occasions ducklings could be seen resting in the saltmarsh vegetation above the high water mark to the north of the main channel.

Swennen (1989) also noted that the ducklings feed independently of the attendant females' behaviour. In the present study although the ducklings did occasionally feed when the adults did not, the latter were always in close attendance and rarely, and then only for short periods, did the author observe the young to be out of the water while attendant females were swimming or vice versa.

### ADULT FEEDING

Although no analysis of diet was carried out for this study it seems that, from previous research, the adult Eider is constrained more by what is available than by any dietary specialisation. Cramp et al (1977) list *Mytilus edulis*, *Littorina* spp., crabs, Echinoderms, fish and Herring's eggs, to which may be added algae, *Gammarus oceanicus*, *Nereis virens* (Cantin, Bedard & Milne, 1974) and fishing offal (Cavallini, 1988).

Cantin, Bedard & Milne's (1974) study of Eiders in the St. Lawrence estuary shows how the diet of those females attending ducklings changes over the summer season. In May 40% of the diet is Herring eggs, with some *Nereis virens* and some algae also taken. Later that month and into June, *Nereis* becomes the dominant item while *Littorina* spp. and amphipods appear in the diet. By the end of June Herring eggs have disappeared from the diet and *Nereis* spp. is still more important. Finally by late July *Littorina* spp. dominates the diet and amphipods also increase in importance.

The pattern of peaks in feeding activity at low tide (Figs.7 & 8) concurs with previous research (Bent, 1925; Marriot, 1966; Player, 1971; Minot, 1980) who report that:

" In areas where the tidal range is large the activity rhythms of Eiders have been reported to be strongly

tide dependent." (Cavallini, 1988)

In this particular study this pattern clearly reflects the increasing accessibility of the birds' feeding grounds (shellfish rich rocks and rock-pools) as the tide fell. No concurrent pattern of feeding associated with the time of day was found. Thus in this instance of the two factors 'need to feed' and 'ease of feeding' the latter is of overriding importance.

Milne (1963) and Gorman (1970a) found a similar situation in the Ythan estuary where the Eiders fed on the mussel beds at the seaward end of the estuary at low tide and roosted at high tide.

#### ADULT DISTRIBUTION

The increasing numbers of adult birds towards Coquet Island (Fig. 9) reflects it being the main breeding centre in the area.

The blips in this trend in the "Sandy Shore" area, Amble harbour, and Coquet Island itself (sections 7, 10 & 12 Fig. 9) can be ascribed to unsuitability of habitat in the former two cases i.e. sand and mud respectively, and in the latter case to the distance separating the observer from the birds and the topography of the island.

The conclusion that mud is a sub-optimal feeding habitat for adult birds suggests that those females

attending ducklings in Amble harbour are under some stress. This may indeed be the case, however in terms of their lifetime contribution to the species gene pool, the attempt to ensure that their ducklings survive by taking them to their preferred feeding habitat, may represent optimal behaviour. The fact that not all ducklings are taken to Amble harbour suggests that beyond a certain population level competition between ducklings reduces the area's profitability. Furthermore, beyond a certain age, the ducklings' increasing breadth of diet means that the harbour is no longer the optimal feeding habitat.

It seems likely that the recorded drop in adult numbers at Silver/Bondi and Hadston Carrs reflects the fact that the areas were lower relative to sea level and so provided less opportunity for feeding and resting, and hence were less attractive to the Eiders. Furthermore it seems probable that much of the rest of the variation in numbers between coastal sections can be put down to spatial (Table 1) and temporal habitat restriction.

The numerical dominance of males during the breeding season (Fig. 9) simply points to the females' role in egg incubation. Amble harbour, in being an exception to this confirms its use as a nursery for young ducklings (only adult females attend the ducklings), the case of the area around Wellhaugh Point though is harder to explain. Figure 3 illustrates that the area is amongst those most favoured by older ducklings, however the numbers of adult females seen far exceeds those directly associated with duckling groups. Moreover while the nearby Amble sewage outfall is a feature

that distinguishes this part of the study area, there is no reason to suspect that this in any way directly differentiates between males and females. What seems most likely is that the presence of ducklings and their associated female guardians for some reason attracts other females. It is notable also that in general the male and female birds formed single sex flocks even after the numbers of females on shore began to rise towards the end of the breeding season. Thus once a largely female flock had become established, in one particular area, then the imbalance became self perpetuating.

#### ADULT SEX RATIOS & POPULATION FLUCTUATION

The coincident maximum sex ratio (male/female) and minimum population point to the females' role as incubators, which on the basis of Figures 10a-c must have reached its peak in the last week of May (probably between the 25th and 29th). This ties up with counts of sitting females carried out by the Coquet Island warden who achieved a maximum of 376 on 29 May. One week earlier (22/5) the figure had been 358, whilst a week later (6/6) it was only 303, suggesting that the actual peak lay between 22 and 29 May.

The drop in female numbers outlined above has, in other studies (Milne, 1974), been used as a measure of the

fact that some females have finished incubating before the latest ones begin, thus both are low compared to the figure of 420 pairs calculated on the basis of the sitting female counts in conjunction with a consideration of the incubation period.

Figures 10a-c also record a drop in the number of males contemporaneously with the drop in female numbers, this reflects the males' role in protecting the nest and the female while the latter is laying. Thereafter the female remains alone at the nest (Cramp, 1977).

The differences between the two halves of the study area can probably be explained by their relative distance from the breeding centre on Coquet Island. For instance the generally lower male/female sex ratio in the south presumably reflects the greater number of females one would expect to see closer to the breeding grounds, and it may be that as the females (and ducklings) leave the island at least some of the males are forced to leave the immediate area as competition for food increases. This reduces the male/female ratio in the southern half of the study area but keeps it higher for longer in the northern half (see Figs. 10a,b).

The overall sex ratio for the local population, outside the incubation period, of 1.17 (1.16 Coulson, 1984) has comparisons elsewhere. Milne (1974) on the Ythan estuary found that males constituted 52.4 - 55.3% of the population between 1961 and 1970 (male/female ratio = 1.10 - 1.24).

Figures in the area from the Wadensee to the Baltic vary enormously from females dominating in the ratio 63:37 in the

~~10a, b)~~.

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Figures in the area from the Wadenzee to the Baltic vary enormously from females dominating in the ratio 63:37 in the small Valassaaret colony (Hilden, 1964); to equality in the Vlieland population (Hoogerheide & Hoogerheide, 1958); to a male domination of 55:45 in the Waddenzee in winter (Swennen, Duiven & Reyrink, 1979).

However when the Baltic/Waddenzee population is considered as a whole:

"...the figures seem to indicate a slight dominance of males (55 - 60%)."

i.e. 1.22 - 1.50 males for every female.

It is proposed by Swennen, Duiven & Reyrink (1979) that this imbalance sets in while the birds are still ducklings, when it appears females are more susceptible to disease than males. In the Vlieland colony, of 1134 captured ducklings aged 6 - 9 weeks, 54.2% were male after the sex ratio at hatching was shown to be not significantly different from unity.

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APPENDIX 1: STUDENT T-TEST ANALYSES.  
(In all cases data logged to normalise distribution)

MEAN DUCKLING GROUP SIZE v. AGE CATEGORY

Age Categories	Mean	t-value	D.o.F.	p
1a	1.753	3.28	65.5	0.0017
1b	1.378			
1b	1.378	5.27	271.7	0.0000
2	0.969			
2	0.969	2.82	20.3	0.011
3	0.553			

MEAN DEPENDENCY RATIO v. AGE CATEGORY

Age Categories	Mean	t-value	D.o.F.	p
1a	1.192	5.03	71.6	0.0000
1b	0.741			
1b	0.741	3.42	220.5	0.0007
2	0.491			
2	0.491	1.71	17.3	0.10
3	0.120			

APPENDIX 2: CHI-SQUARED ANALYSES

ACTIVITY v. AGE CATEGORY (Duckling Groups)

	1a	1b	2	3	
Feeding (shallow water)	19 15.877 0.61	125 111.526 1.63	23 36.401 4.93	3 6.196 1.65	Observed Expected Chi-sq.
Feeding (on land)	3 3.082 0.00	29 21.649 2.50	0 7.066 7.07	1 1.203 0.03	Observed Expected Chi-sq.
Feeding (deeper water)	0 3.175 3.18	7 22.305 10.50	24 7.280 38.40	3 1.239 2.50	Observed Expected Chi-sq.
Preening/ Resting	7 9.620 0.71	66 67.572 0.04	24 22.055 0.17	6 3.754 1.34	Observed Expected Chi-sq.
Swimming/ Walking	12 9.246 0.82	61 64.948 0.24	23 21.198 0.15	3 3.608 0.10	Observed Expected Chi-sq.

CHI-SQUARED = 76.57 D.o.F. = 12 p < 0.001

ACTIVITY v. AGE CATEGORY (Individual Ducklings)

	1a	1b	2	3	
Feeding (shallow water)	150 132.067 2.44	836 769.941 5.67	58 131.618 41.18	4 14.375 7.49	Observed Expected Chi-sq.
Feeding (on land)	24 36.671 4.38	266 213.791 12.75	0 36.546 36.55	1 3.991 2.24	Observed Expected Chi-sq.
Feeding (deeper water)	0 17.012 17.01	27 99.181 52.53	98 16.955 387.40	10 1.852 35.85	Observed Expected Chi-sq.
Preening/ Resting	47 55.700 1.36	311 324.727 0.58	73 55.511 5.51	11 6.063 4.02	Observed Expected Chi-sq.
Swimming/ Walking	73 52.550 7.96	274 306.360 3.42	64 52.371 2.58	6 5.720 0.01	Observed Expected Chi-sq.

CHI-SQUARED = 630.93 D.o.F. = 12 p < 0.001

ACTIVITY v. TIME RELATIVE TO LOW TIDE (Duckling Groups)  
(Time in hours.minutes)

	0-0.59	1-1.59	2-2.59	3-3.59	
Feeding (shallow water)	61 60.376 0.01	41 41.289 0.00	24 23.371 0.02	16 16.749 0.03	Observed Expected Chi-sq.
Feeding (on land)	13 11.651 0.16	5 7.968 1.11	9 4.510 4.47	4 3.232 0.18	Observed Expected Chi-sq.
Feeding (deeper water)	13 12.005 0.08	14 8.210 4.08	3 4.647 0.58	3 3.330 0.03	Observed Expected Chi-sq.
Preening/ Resting	34 36.367 0.15	20 24.870 0.95	14 14.077 0.00	10 10.089 0.00	Observed Expected Chi-sq.
Swimming/ Walking	34 34.601 0.01	26 23.663 0.23	10 13.394 0.86	10 9.600 0.02	Observed Expected Chi-sq.
	4-4.59	5-5.59	6.00+		
Feeding (shallow water)	12 12.465 0.02	12 11.296 0.04	5 5.453 0.04		Observed Expected Chi-sq.
Feeding (on land)	1 2.405 0.82	1 2.180 0.64	0 1.052 1.05		Observed Expected Chi-sq.
Feeding (deeper water)	0 2.478 2.48	1 2.246 2.45	0 1.084 1.08		Observed Expected Chi-sq.
Preening/ Resting	8 7.508 0.03	10 6.804 1.50	7 3.285 4.20		Observed Expected Chi-sq.
Swimming/ Walking	11 7.144 2.08	5 6.474 0.34	2 3.125 0.41		Observed Expected Chi-sq.

CHI-SQUARED = 28.39 D.o.F. = 24 p > 0.10

ACTIVITY v. TIME RELATIVE TO LOW TIDE (Individuals)  
(Time in hours.minutes)

	0-0.59	1-1.59	2-2.59	3-3.59	
Feeding (shallow water)	457 398.542 8.58	200 216.648 1.28	163 166.097 0.06	89 120.962 8.45	Observed Expected Chi-sq.
Feeding (on land)	99 110.138 1.13	41 59.871 5.95	99 45.901 61.43	44 33.428 3.34	Observed Expected Chi-sq.
Feeding (deeper water)	46 51.095 0.51	44 27.775 9.48	9 21.294 7.10	32 15.508 17.54	Observed Expected Chi-sq.
Preening/ Resting	120 167.289 13.37	93 90.939 0.05	68 69.720 0.04	39 50.774 2.73	Observed Expected Chi-sq.
Swimming/ Walking	161 155.935 0.16	102 84.766 3.50	29 64.987 19.93	64 47.328 5.87	Observed Expected Chi-sq.
	4-4.59	5-5.59	6.00+		
Feeding (shallow water)	67 64.543 0.09	66 64.092 0.06	11 22.116 5.59		Observed Expected Chi-sq.
Feeding (on land)	5 17.837 9.24	3 17.712 12.22	0 6.112 6.11		Observed Expected Chi-sq.
Feeding (deeper water)	0 8.275 8.28	4 8.217 2.16	0 2.835 2.84		Observed Expected Chi-sq.
Preening/ Resting	36 27.092 2.93	50 26.903 19.83	36 9.283 76.89		Observed Expected Chi-sq.
Swimming/ Walking	35 25.253 3.76	19 25.077 1.47	2 8.653 5.12		Observed Expected Chi-sq.

CHI-SQUARED = 327.06 D.o.F. = 24 p < 0.001

ACTIVITY v. SEA SURFACE CONDITIONS (Duckling Groups)

	FLAT	SLIGHT	MODERATE	ROUGH	
Feeding	18	56	27	4	Observed
(shallow	26.417	57.516	19.061	2.006	Expected
water)	2.68	0.04	3.31	1.98	Chi-sq.
Feeding	4	8	7	0	Observed
(on land)/	4.780	10.408	3.449	0.363	Expected
Walking	0.13	0.56	3.66	0.36	Chi-sq.
Feeding	12	14	1	0	Observed
(deeper	6.793	14.790	4.901	0.516	Expected
water)	3.99	0.04	3.11	0.52	Chi-sq.
Preening/	29	45	16	1	Observed
Resting	22.895	49.847	16.519	1.739	Expected
	1.63	0.47	0.02	0.31	Chi-sq.
Swimming	16	49	6	1	Observed
	18.115	39.439	13.070	1.376	Expected
	0.25	2.32	3.82	0.10	Chi-sq.

CHI-SQUARED = 29.30 D.o.F. = 12 p < 0.001

ACTIVITY v. SEA SURFACE CONDITIONS (Individuals)

	FLAT	SLIGHT	MODERATE	ROUGH	
Feeding	92	282	126	43	Observed
(shallow	121.621	290.458	110.174	20.747	Expected
water)	7.21	0.25	2.27	23.87	Chi-sq.
Feeding	32	92	60	0	Observed
(on land)/	41.212	98.424	37.333	7.030	Expected
Walking	2.06	0.42	13.76	7.03	Chi-sq.
Feeding	48	62	3	0	Observed
(deeper	25.310	60.445	22.928	4.318	Expected
water)	20.34	0.04	17.32	4.32	Chi-sq.
Preening/	119	167	89	10	Observed
Resting	86.232	205.942	78.116	14.710	Expected
	12.45	7.36	1.53	1.51	Chi-sq.
Swimming	49	209	30	5	Observed
	65.626	156.730	59.449	11.195	Expected
	4.21	17.43	14.59	3.43	Chi-sq.

CHI-SQUARED = 161.39 D.o.F. = 12 p < 0.001

APPENDIX 3: FEEDING INDEX DATA

DATE: 9/5/90      LOW TIDE: 0959      HIGH TIDE: 1554

TIME	FEEDING INDEX
0530 - 0630	40
0730 - 0830	71
0930 - 1030	176
1130 - 1230	115
1330 - 1430	30
1530 - 1630	18
1730 - 1830	42
1930 - 2030	63

DATE: 10/5/90      LOW TIDE: 1030      HIGH TIDE: 1629

TIME	FEEDING INDEX
0530 - 0630	RAIN
0730 - 0830	65
0930 - 1030	185
1130 - 1230	95
1330 - 1430	32
1530 - 1630	21
1730 - 1830	47
1930 - 2030	65

DATE: 13/5/90      LOW TIDE: 1206      HIGH TIDE: 1817

TIME	FEEDING INDEX
0530 - 0630	FOG
0730 - 0830	59
0930 - 1030	78
1130 - 1230	182
1330 - 1430	76
1530 - 1630	31
1730 - 1830	19
1930 - 2030	49

DATE: 16/5/90      LOW TIDE: 1414      HIGH TIDE: 0742

TIME	FEEDING INDEX
0530 - 0630	RAIN
0730 - 0830	17
0930 - 1030	47
1130 - 1230	90
1330 - 1430	161
1530 - 1630	90
1730 - 1830	RAIN
1930 - 2030	RAIN

DATE: 18/5/90      LOW TIDE: 1619      HIGH TIDE: 0940

TIME	FEEDING INDEX
0530 - 0630	69
0730 - 0830	30
0930 - 1030	19
1130 - 1230	24
1330 - 1430	76
1530 - 1630	164
1730 - 1830	63
1930 - 2030	22

DATE: 20/5/90      LOW TIDE: 0600      HIGH TIDE: 1155  
1831

TIME	FEEDING INDEX
0530 - 0630	143
0730 - 0830	71
0930 - 1030	25
1130 - 1230	10
1330 - 1430	26
1530 - 1630	48
1730 - 1830	136
1930 - 2030	58



APPENDIX 4: SEX RATIO AND POPULATION FLUCTUATIONS

(HADSTON CARRS - BIRLING CARRS)

DATE	MALES	FEMALES	1ST YEARS	TOTAL	SEX RATIO
15/5	414	204	7	625	2.06
23/5	370	86	4	460	4.35
25/5	338	71	10	419	4.90
27/5	346	94	3	443	3.71
29/5	237	69	5	311	3.51
31/5	245	90	3	338	2.76
3/6	227	86	4	317	2.69
6/6	456	113	4	573	4.07
8/6	470	145	7	622	3.29
11/6	385	172	3	557	2.25
13/6	380	145	8	533	2.68
16/6	440	213	6	659	2.09
19/6	545	235	4	784	2.34
22/6	518	230	2	750	2.26
26/6	476	319	4	799	1.50
28/6	420	259	2	681	1.63
1/7	390	307	3	700	1.28
3/7	421	337	3	761	1.26
6/7	329	376	2	707	0.88
9/7	342	335	5	682	1.04
11/7	289	209	1	499	1.39
1/8	221	117	-	338	1.89

(ALNMOUTH - CRASTER)

DATE	MALES	FEMALES	1ST YEARS	TOTAL	SEX RATIO
12/5	195	70	4	269	2.84
19/5	302	80	6	388	3.85
26/5	255	32	1	288	8.00
30/5	328	56	4	388	5.93
1/6	312	60	5	377	5.28
4/6	329	83	3	415	4.00
7/6	234	51	2	287	4.63
10/6	264	57	2	323	4.67
12/6	437	52	3	492	8.46
15/6	357	72	5	434	5.03
18/6	411	88	4	503	4.72
21/6	338	104	0	442	3.25
25/6	360	97	4	461	3.75
27/6	429	99	4	532	4.37
29/6	478	114	9	601	4.27
2/7	455	76	4	535	6.04
5/7	375	79	4	458	4.80
8/7	533	106	4	643	5.07
10/7	478	61	1	540	7.85
1/8	314	339	-	653	0.926

(OVERALL)

DATE	MALES	FEMALES	1ST YEARS	TOTAL	SEX RATIO
15/5	655	278	12	945	2.40
23/5	645	139	7	791	4.69
25/5	600	110	12	722	5.56
27/5	619	132	5	756	4.73
29/5	547	119	8	674	4.66
31/5	565	148	8	721	3.87
3/6	550	161	8	719	3.47
6/6	722	175	6	903	4.16
8/6	714	198	9	921	3.65
11/6	736	225	6	967	3.30
13/6	790	204	12	1006	3.93
16/6	815	290	11	1116	2.85
19/6	932	328	7	1267	2.86
22/6	862	332	3	1197	2.61
26/6	871	417	8	1296	2.11
28/6	874	366	9	1249	2.41
1/7	853	392	9	1254	2.20
3/7	849	414	7	1270	2.07
6/7	757	464	6	1227	1.64
9/7	848	419	8	1275	2.04
1/8	535	456	-	981	1.17

(OVERALL)

DATE	MALES	FEMALES	1ST YEARS	TOTAL	SEX RATIO
15/5	655	278	12	945	2.40
23/5	645	139	7	791	4.69
25/5	600	110	12	722	5.56
27/5	619	132	5	756	4.73
29/5	547	119	8	674	4.66
31/5	565	148	8	721	3.87
3/6	550	161	8	719	3.47
6/6	722	175	6	903	4.16
8/6	714	198	9	921	3.65
11/6	736	225	6	967	3.30
13/6	790	204	12	1006	3.93
16/6	815	290	11	1116	2.85
19/6	932	328	7	1267	2.86
22/6	862	332	3	1197	2.61
26/6	871	417	8	1296	2.11
28/6	874	366	9	1249	2.41
1/7	853	392	9	1254	2.20
3/7	849	414	7	1270	2.07
6/7	757	464	6	1227	1.64
9/7	848	419	8	1275	2.04
1/8	535	456	-	981	1.17

