Population change & breeding biology of the Arctic Tern (Sterna paradisaea) in Shetland 1986

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by

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CONTENTS

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INTRODUCTION

Most British work on Arctic Tern (Sterna paradisaea) biology has been carried out on either the Farne Islands or Coquet Island in Northumberland, and all was undertaken during favourable breeding conditions, (Springett 1967; Langham 1968; Pearson 1968; Horobin 1971; Dunn 1972; Coulson and Horobin 1976).

Springett (1967) studied Arctic Terns on Inner Farne, looking in particular at chick mortality and its relation to the biology of the beetle Necrophorus investigator. He found the curve of daily weight increase in chicks to be sigmoid and daily weight increase to be approximately linear at 7.2g per day from Day 3-13. Calm weather decreased the daily weight increase of all chicks but rain and temperature had no effect. He concluded that in years of favourable weather and adequate food supply adult terns may rear two chicks successfully but in adverse conditions only the first hatched survive.

Langham (1968) investigated the comparative biology of four closely related species of terns nesting in close proximity on Coquet Island. Common (Sterna hirundo), Arctic, Roseate (S.dongalli) and Sandwich Tern (S.sandvicensis) breeding biology was studied to find out whether any species competed for a common resource. Langham found that the third hatched (most likely) and second hatched chicks died of starvation in the first week because one parent was stimulated to brood and the second parent could not obtain sufficient food for all chicks. In years of abundant food, mortality was much lower. The effect of weather on the feeding of terns was studied by recording the daily weight increases of chicks under various climatic conditions. Wind speed was the most important factor analysed affecting Roseate and Common but hardly affecting Arctic Terns. Rain always had a depressive effect on the growth of these three species. Sunshine had a variable effect on Common and Roseate Terns but a consistent positive effect on the average weight increase of Arctic Tern chicks. The food of different species was examined and it was found that for Common Terns less than 30% of the chicks' diet was sand eels (Ammodytidae) but for Arctic Tern chicks over 60% of their diet was sand eels. The sizes of fish taken were not significantly different. Significant differences in the areas in which species fished were found. Arctic Terns were found to feed mainly offshore which may indicate areas for their preferred prey sand eel, whereas Common and Sandwich preferred Herring (Clupea harengus) and Sprats (C. spattus) and fed inshore.

In 1968 Pearson concluded his work concerning the feeding biology of ten species of seabirds (including Arctic Terns) on the Farne Islands. He found that sand eels were the most important fish taken by all except the Cormorant (Phalacrocorax carbo). Young Saith (Pollachius virens) and Codling (Gadus morrhua), (Gadidae) and young Herring and Sprats were also important in the diet of most species. The growth curves of increase in weight and winglength with age were calculated for ten species including Arctic Terns. Estimates were made of the amounts of food required for maintenance and the amounts of food required for growth of chicks under laboratory conditions.

Horobin (1971) and Coulson and Horobin (1976) worked on Inner Farne from 1965 to 1968 researching the breeding biology of Arctic Terns, concentrating in particular on adults of known age. Egg laying was found to peak in the first week of June and mean clutch sizes showed a seasonal decline. Laying, hatching and growth statistics were studied, chicks were found to grow at a constant rate from Day 3 to 13 (6.8g) and to attain adult weight at Day 14. Provisioning rates and fish sizes were also given. The main causes of chick mortality were found to be exposure and starvation and these increased towards the end of the season and were highest in vegetated areas; 66% of chick mortality took place within three days of hatching. The mean daily growth rate of chicks from parents over nine years old (7.5 +/- 0.4g) was greater than from any other age group. In 1966 23% of eggs produced fledged chicks; with 37% in 1967 and 10% in 1968.

Dunn (1972) studied the feeding biology of four species of tern on Coquet Island, and found that Arctic and Roseate Terns usually foraged offshore, Sandwich Terns inshore and Common Terns used both. The effects of windspeed and sea condition on feeding were studied for Sandwich and Common Terns. Windspeed was the most important environmental factor affecting chick growth.

Breeding success for the Farne Islands and Coquet Island from 1961 to 1970 are given in Table 9. In all years breeding success was over 0.5 chicks fledged per pair, with over 0.9 per pair fledging in 1967 and 1968 on Coquet Island.

There exists, therefore, a wealth of information on the breeding biology of the Arctic Tern in Northumberland. Information on clutch sizes, chick growth rates, prey type, size and breeding success from years of good breeding conditions are available for comparison with data collected in Shetland during an unproductive year.

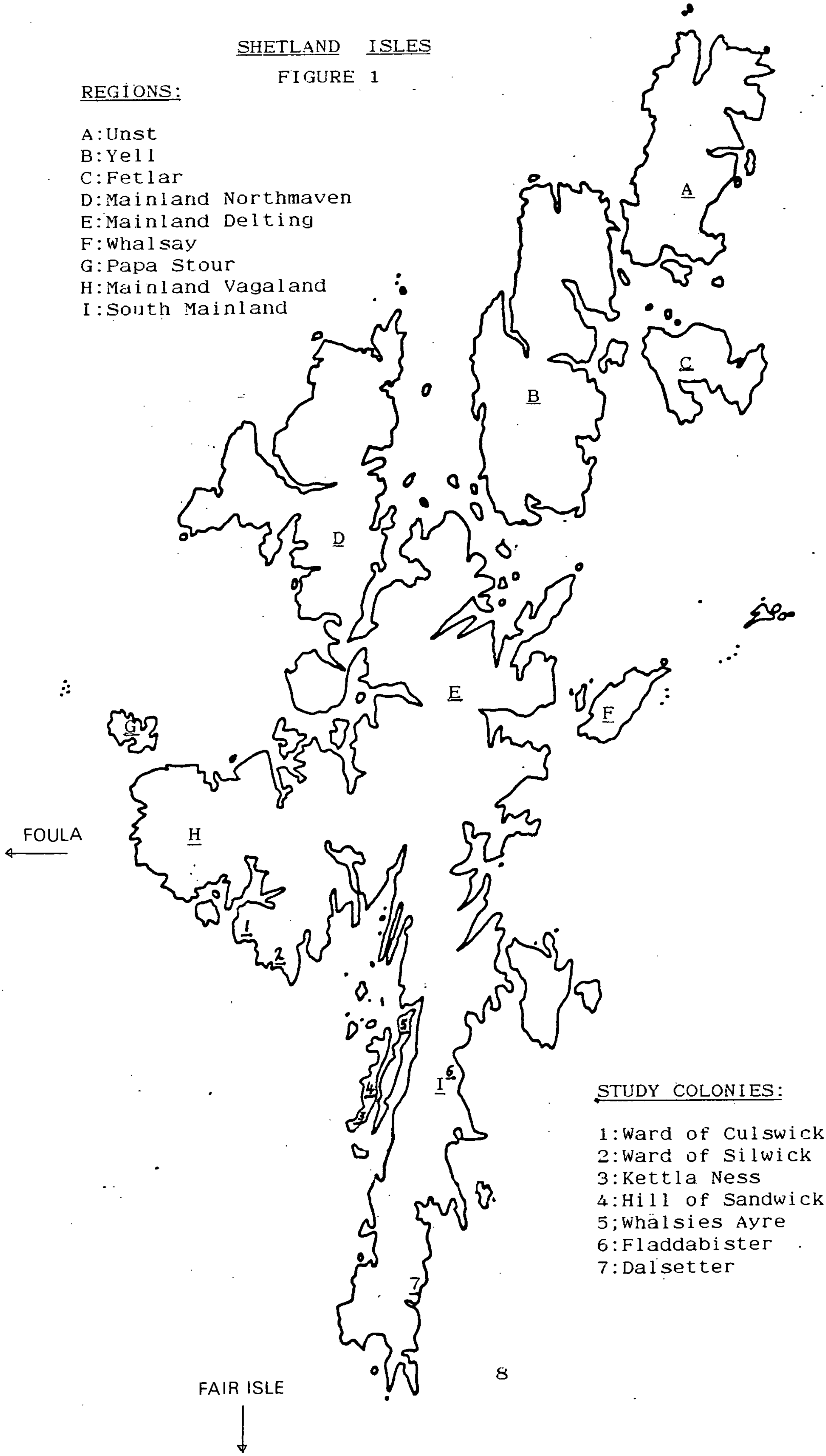
There has been little work on Arctic Tern breeding biology in Shetland although nearly 42% of the British population bred there in 1980. This was revealed by an extensive survey which found nearly 32000 pairs in 1980 (Bullock and Gomersall 1981). Additionally 1014 pairs of Commom Tern were found at 87 colonies. They also recorded clutch sizes for both species and population trends and colony tenacity are discussed.

In the period 1978 to 1981 large scale colony desertions, inter-colony shifts and breeding failures often involving the deaths of large numbers of unfledged young were reported (Shetland Bird Reports 1979-1981; Bullock and Gomersall 1981). Ewins (1983;1985) studied breeding Arctic Terns from 1982 to 1984 chiefly on the island of Mousa (South Mainland) to obtain information on clutch size, growth curves, diet and mortality of chicks in an attempt to investigate recent reproductive failures. The Shetland growth data covers poor and productive years. The 1982 and 1983 seasons were reported to have been productive, with a fledging rate of approximately 0.71 per pair from 1024 pairs on Mousa in 1983. The breeding season of 1984 was poor, with a fledging rate of approximately 0.08 per pair from a sample of 1309 pairs on Mousa (Ewins 1985).

The Shetland data covers both poor (1978; 1980; 1984; 1985) and productive years (1981; 1982; 1983). It therefore provides additional material for comparison with the results of the present study which aims to assess the success of the breeding season in Shetland 1986, and to compare the status of selected colonies with Bullock and Gomersall's 1980 data. Ten study colonies were chosen to investigate breeding in detail, with particular emphasis on growth data. This data is compared to both Farne/Coquet Island and earlier Shetland breeding biology data.
A number of reasons have been suggested why Arctic Terns have been unproductive in recent years in Shetland. In 1978 adverse weather conditions were blamed for the desertion of chicks in many colonies (Richardson 1979). Ewins considered the possibility that as in higher latitudes, in some years of adverse conditions birds either do not breed or else abandon nesting attempts but occasionally experience favourable years and breed well. Arctic Terns are long lived birds and if they were in poor breeding condition may abandon nesting instead of risking themselves.

The breeding season of terns is closely synchronised with the seasonal surface appearance of sand eels (Pearson 1968). The unpredictable appearance of such shoals from season to season could be a cause of local colony shifts, and the absence of shoals may cause widescale desertions, such as those reported in 1979 and 1980 (Bullock and Gomersall 1981). The general impression in Shetland is of the progressive disappearance of smaller fish from inshore waters and this is popularly attributed to commercial exploitation which has increased steadily during the 1970's and 1980's (Bullock and Gomersall 1981).

The recent increase in U.K. landings of sand eels has been restricted to Scotland where a fishery based on stocks around the Shetlands began in 1974. Landings in Shetland increased steadily from 7546 tonnes in 1974 to 46650 tonnes in 1981 with a drop in 1979 when 13404 tonnes were landed. Recent workers in Shetland have recommended that the effects of commercial fishing on the Arctic Terns and their main food resource should be monitored closely.


SHETLAND ISLES
FIGURE 1
REGIONS:
A:Unst
B:Yell
C:Fetlar
D:Mainland Northmaven
E:Mainland Delting
F:Whalsay
G:Papa Stour
H:Mainland Vagaland
I:South Mainland
A
B
C
D
E
F
G
H
I
FOULA
FAIR ISLE
1
2
3
4
5
6
7
STUDY COLONIES:
1:Ward of Culswick
2:Ward of Silwick
3:Kettla Ness
4:Hill of Sandwick
5;Whalsies Ayre
6:Fladdabister
7:Dalsetter

STUDY AREA

Sites all over Shetland were visited between 28 May and 31 July 1986. A total of ten study colonies were chosen for detailed study, all of which were situated on Mainland or Burra Isle to enable frequent visits to be made.

On the eastern side of Mainland two colonies were selected. Dalsetter, an area of aproximately 16 hectares situated at 59°55'N, 1°17'W and Fladdabister, 15 hectares situated at 60°05'N, 1°13'W. On the western side of Shetland, Ward of Culswick (60°12'N, 1°31'W) and Ward of Silwick (60°10'N, 1°28'W) were used from the Mainland Vagaland region. Burra Isle is situated just off of the western side of Mainland and is included in Bullock and Gomersall's South Mainland region. Five colonies were used on West Burra, four discrete sites at Kettla Ness (60° 02'N, 1°21'W) named "Main", "Lower", "Marsh" and "New" and Hill of Sandwick (60°04'N, 1°20'W). One colony was selected from East Burra and this was Whalsies Ayre (60° 06'N, 1°18'W). The location of study colonies is shown on Figure 1 and colony details are given in Table 11.

BREEDING POPULATIONS

METHODS

In 1980 Bullock and Gomersall made a comprehensive survey of all Arctic Tern colonies in Shetland. They recorded 396 colonies with an estimated total of 31794 pairs, which they broke down into totals for the major island groups.

In 1986, 72 (19.7%) of the original colonies known in 1980 were visited and estimates of numbers of breeding pairs made from "first flushing" counts, using methods given by Bullock and Gomersall (1981). These were then compared to 1980 figures for the same colonies to measure changes in colony size. This is broken down further into the colonies surveyed again (and includes six new colonies) for each island group in Table 1.

Coverage was poorest on Yell (5.5%) and Mainland Delting (6.4%), and best on the smaller islands of Papa Stour, Mousa, and Fair Isle (all 100%). South Mainland had the next best coverage with 45.1%. No colonies were visited on Unst or Mainland Northmaven. It is unlikely that any large colonies were missed because suitable areas (including Unst and Mainland Northmaven) were covered by teams of fieldworkers conducting other surveys. No large colonies were reported by these fieldworkers although one smaller one was brought to my attention.

All sites (excluding Yell colonies) were revisited later in the season but no large influx had occurred after the initial count. The colonies surveyed in 1986 are shown with the comparative 1980 figures in Table 2. When making a comparison it is assumed that all breeding seasons were subject to the same conditions, therefore the yearly population changes are only suggested figures. Nevertheless the changes give an indication of the current status of Shetland's Arctic Terns.

RESULTS

The sample colonies had 15925 pairs in 1980 which was 50.1% of the total nesting in 1980. In 1986, including six new colonies, 4195 pairs were counted in the colonies, which represents 26.3% of the 1980 value.

Table 1 gives the population changes and the percentage change per year estimated from surveys in 1980 and 1986, for each island group.

Shetland as a whole has decreased at a rate of 19.9% per year. The general trend is that breeding populations, that is, the number of breeding pairs, have decreased between 1980 and 1986. Decreases vary from an estimated 0.3% per year over six years for South Mainland (not including Mousa), to 43.3% per year for Mousa. Papa Stour shows the third greatest decrease, one of 37.3% per year, though this relies upon counts made on 4 July. The only island to have increased in population is Fair Isle, which expanded from two pairs in 1980 to 103 pairs in 1986.

Six new colonies were found in 1986. Two were located in

Fair Isle's expanding population, on Bu Ness (50 pairs) and by the south lighthouse (20 pairs). A colony of 29 pairs was found at Ward of Culswick, and one of 6 pairs at Ayre of Deepdale, both in Mainland Vagaland. The new colony of 49 pairs at Grunasound (South Mainland) was reported as present in 1985. The only new colony of reasonable size was at Fladdabister (South Mainland). A total of 368 pairs made this the second largest colony found in 1986 and it was used as a study colony. A total of 23 of the 1980 colonies were not used by breeding terns in 1986.

TABLE 1: POPULATION CHANGES 1980 TO 1986

Island group	Number of pairs ---1980	1986-	% 1980 pop. in 1986	% change per year	Sample no. of colonies -1980	1986-	% 1980 colonies in 1986
Yell	637	27	4.2	-41.0	55	3	5.5
Fetlar	1346	186	13.8	-28.1	25	6	24.0
Papa Stour	4394	267	6.1	-37.3	21	21	100.0
Mainland Vagaland	931	221	23.7	-21.3	48	8	16.7
Mainland Delting	173	156	90.2	-1.7	78	5	6.4
Whalsay	832	531	63.8	-7.2	37	8	21.2
South Mainland	2146	2112	98.4	-0.3	45	17	37.8
Mousa	1264	42	3.3	-43.3	6	6	100.0
S.Mainland inc. Mousa	3410	2154	63.2	-7.4	51	23	45.1
Foula	4200	550	13.1	-28.7	3	1	33.3
Fair Isle	2	103	5150.0	+192.9	1	3	300.0
Total	15925	4195	26.3	-19.9	51	23	45.1

TABLE 2: ESTIMATED NUMBER OF BREEDING ARCTIC TERNS AT SAMPLE COLONIES 1980 & 1986

Region Colony	Estimated No. of pairs 1980	1986	Date of count	No. of visits
			------1986----	
YELL				
Migga Ness	100	18	6 June	1
Vatsetter	120	9	6 June	1
Litla water	417	0	5 June	1
FETLAR				
Upper Trona Mires	96	14	6 June	3
Lower Trona Mires	171	7	6 June	3
Kegga	137	18	6 June	3
Cruss	12	80	29 May	3
Brough Plough	382	6	5 June	3
Stivla	548	61	29 May	3
MAINLAND DELTING				
Green Isle	60	101	26 June	1
Loch of Houland	34	9	1 June	3
Ribbans	31	8	18 July	3
S. Holm of Gletness	38	4	1 June	3
Hamnavoe	10	34	23 July	1
PAPA STOUR				
The Creed	130	0	4 July	1
North Ness W.	160	0	"	1
North Ness E.	68	40	"	1
Geubery	15	0	"	1
Gardie N.	600	76	"	1
Robie's Noost	50	0	"	1
Gorda Water E.	15	40	"	1
Gorda Water W.	205	0	"	1
Quida Ness	103	25	"	1
Cullavoe E.	55	0	"	1
Cullavoe Dale	205	84	"	1
Sholma Wick	240	0	"	1
Hundsetts	65	0	"	1
Little Virda Field	1026	2	"	1
Lochs of Aeshia	513	1	"	1
Christie's Hole	103	0	"	1
Dutch Loch	34	0	"	1
Mauns Hill W.	205	0	"	1
Mauns Hill SW.	240	0	"	1
Mauns Hill S.	205	0	"	1
Hamna Voe N. beach	157	0	"	1
MAINLAND VAGALAND				
Hill of Swartagill	92	0	19 June	1
Ward of Culswick	390	51	2 June	8
Ward of Silwick	38	74	30 June	6
Sotersta Culswick	362	15	2 June	3
Hill of Culswick	0	29	2 June	3
Bridge of Walls	24	35	25 June	2
Greenvale Reawick	25	11	19 June	2
Ayre of Deepdale Reawick	0	6	19 June	2

Region Colony	Estimated No. of pairs 1980	 1986	Date of count ------1986----	No. of visits
(cont.)				
WHALSAY				
Hunder holm	52	19	26 June	1
Wether holm	75	25	"	1
Houb Kirkness	54	76	"	1
Inner holm of Skaw	104	38	"	1
Holm of Sandwick	22	290	"	1
Mooa	151	20	"	1
East Linga	301	58	"	1
Grif skerry	73	5	"	1
SOUTH MAINLAND				
Grutness	765	55	13 July	10
Noss Hill Spiggie	64	0	8 June	2
Uradale	12	14	9 June	5
Hogaland spit	1	6	31 May	3
Kallee Ness	24	15	31 May	2
Whalsies Ayre	22	119	14 June	10
Symbister Ayre	118	22	22 June	6
Holm of Houss	22	30	29 July	1
Kettla Ness (4 sites)	1	262	15 June	25
Hill of Sandwick	10	176	26 June	20
Papa	103	432	15 June	3
Pund Point	4	0	31 May	2
Dalsetter	903	551	29 May	18
Fladdabister	0	368	23 June	30
Grunnasound	0	49	8 June	5
Trumba	92	0	13 June	1
MOUSA				
N. Isle	602	21	28 May	2
Midfield	315	21	"	2
Muckle Bord	213	0	"	2
Muckle Bord	28	0	"	2
Green Head	23	0	"	2
Green Head	83	0	"	2
FOULA				
Airstrip	4200	550	4 June	1
FAIR ISLE				
N. Haven stack	2	33	25 July	1
S. lighthouse	0	20	"	1
Bu Ness	0	50	"	1
TOTAL	15093	3564		

BREEDING BIOLOGY AT STUDY COLONIES

METHODS

The ten study colonies were visited frequently to monitor the breeding season at each one. Observations of predation within the colonies were noted, as well as dates of desertion.

At each colony a random sample of nests were marked. These were monitored daily enabling timing of clutch completion to be determined and a valid figure for mean clutch size to be obtained. A clutch was considered to be complete if three days elapsed without an increase in clutch size. Horobin (1970) gives the mean interval between laying as 46.2 ± 4.6 hours. Predated nests were discounted from the sample. Standard Chi-squared tests were applied to clutch size data.

Laying dates were obtained from marked nests and by back tracking 22 days from known hatching dates. Combinations of known and estimated hatching dates for all colonies enabled the frequency distribution of hatchings to be plotted. This can be compared to the distribution of hatching dates given by Ewins (1983) for Shetland 1982.

The lengths and breadths of 138 eggs were measured. Chick mortality was recorded daily, the dead chicks being aged by wing length and removed from the colony on each visit.
The breeding success of each colony was determined from

fledging rates.

Information on the breeding success of Kittiwakes (Rissa tridactyla) was obtained from the 1986 Seabird Colony Register.

Weather conditions were noted at each visit and records were provided by the Lerwick Meteorological office.

RESULTS

TIMING OF BREEDING

Table 6 gives the first egg dates for Shetland, and Table 5 the timing of breeding in 1986 compared to 1982. Egg laying was later in 1986 than all previous years with records. The hatching dates were synchronous, with 60% of chicks hatching in the five day period 25-29 June 1986 this compares to 62% of chicks hatching in the four day period 18-21 June 1982 (Table 5). The date of maximum hatching was 27 June compared to 19 June in 1982.The median hatching date (by which time 50% of chicks have hatched) was 27 June compared to 20 June in 1982. (Figure 2).

The secondary peak of hatching in 1986 was small and occurred 13 days after the date of maximum hatching compared to an 8 day lapse in 1982. In both cases secondary peaks probably represent the hatching of replacement clutches.

May 1986 was a cool and wet month. The mean maximum temperature was 10.7°C and the mean minimum temperature was 6.1°C. Rainfall totalled 105.7mm and the mean wind speed was 14.5 knots.

MEAN CLUTCH SIZES

Table 3 gives the mean clutch sizes and the dates they were obtained, for eight Mainland colonies in 1986. The samples used to determine mean clutch sizes did not include nests which had been predated. Mean clutch size varied from 1.22 (n=27) at Kettla Ness Main to 1.71 (n=21) at Whalsies Ayre.

The mean clutch size for Shetland as a whole was 1.49 (n=350). This comprised of 181 single egg clutches (51.7%) and 165 clutches of two (47.1%). Only four clutches of three were found (1.1%), (Table 4a). The mean clutch sizes for different geographical areas and their Chi-square significances compared to 1986 are given in Table 4b.

A sample of eggs were measured and found to be very similar to those measured by Horobin (1971) on the Farne Islands during a successful breeding season (Table 7).

MORTALITY

Very few dead chicks were found at colonies other than Fladdabister, because of smaller numbers of pairs and because very few eggs hatched. This is reflected in the ringing totals for each colony (Table 11). Of a total of 237 chicks ringed, 168 (70.9%) were at Fladdabister.

At Fladdabister 51 chicks were found dead and many more were scavanged by predators. Of 169 chicks ringed only three are known to have fledged. A further 115 minimum must therefore have died. A total of 9.75 hours between 23 June and 15 July was spent watching the colony from a hide. Watches were at any time of the day between 0430 hours and 2230 hours B.S.T.. A total of 13 successful forays by predators into the colony to scavange apparently dead chicks were recorded. Three species were involved: Common Gull (_Larus canus_) 62% of forays; Herring Gull (_Larus argentatus_) 23%; and Arctic Skua (_Stercorarius parasiticus_) 15%. Approximately ten pairs of Common Gulls and two pairs of Arctic Skuas were nesting just outside the colony. No live chicks were seen to be predated.

The ages of dead chicks recovered at Fladdabister (estimated from wing length) were as follows:- 0-5 days: 37; 6-10 days: 11; 10+ days: 3. The oldest chicks recovered dead were three, eleven day olds. However some older chicks (13,14 and 16 days) were ringed three to six days before the colony was abandoned and are presumed to have died as they were too young to have fledged. Figure 3 shows the ages of detected death (for all colonies).

In 1986 there was a small peak of mortality (9.5%) on 29 June and then a drawn out peak from 3 to 8 July involving 69.8% of known mortality (Fig 2). The median hatching date for all colonies in 1986 was 27 June.
In 1983 and 1984 peak mortality occurred between 26 to 30 June (58% in 1983, 51% in 1984) and median hatching dates were 20 June 1983 and 23 June 1984 (Ewins 1985). Figure 2

gives the frequency distribution of hatchings and nestling mortality for Shetland 1986. Only two dead adults were found, and both had been dead for some time.

BREEDING SUCCESS

The fledging rate for Shetland as a whole is 0.0266 per pair, from a sample of 1900 pairs. The number of fledglings from each colony are given in Table 8. In 1986 a minimum of 43 chicks fledged from eleven colonies. Another nine were processed when close to flying but were not seen subsequently. This gives a total of 52 from 1900 pairs, not including any relaid clutches which may have been successful (some pairs on Fair Isle still had chicks into August). The breeding success for earlier years is given in Table 9.

Nine of the eleven colonies where chicks are known to have fledged were colonies of fewer than one hundred pairs (Table 10). Of these, six were in the range of 1-30 pairs. Only one medium sized colony (119 pairs) and one larger colony (382 pairs) fledged young. The highest fledging rate was 0.67 per pair and this was recorded in the smallest colony which had only six pairs. Conversely the lowest fledging rate of 0.008 per pair was at the largest colony of 382 pairs.

Table 11 shows the breeding season details of the ten study colonies.

Of the ten, six failed completely and the four at which chicks did fledge had fledging rates of 0.008 to 0.255 per pair.

The first large colony to fail was Dalsetter. One area of this 700 pair colony was chosen for nest marking. Arctic Skuas frequently quartered the colony looking for eggs, especially when the terns were flushed. Predation of eggs was noted on a number of occasions. Desertion of the marked portion of the colony began on the 11 or 12 June. Over half the nests had lost all eggs on 12 June but some adults were still present. By 13 June the marked area was deserted and all eggs had gone. The rest of the colony steadily declined and by 7 July the last 30 pairs (including some pairs re-laying) had deserted eggs. Only two chicks were seen and both are presumed to have died shortly afterwards. Dalsetter failed because of egg predation.

The second largest colony, Fladdabister, appeared to be progressing well, with eggs and chicks up to fledging age. However, numbers of adults dropped rapidly from 13 June, and the colony was deserted by 17 June. Egg predation was observed only once, but dead chicks were scavenged frequently. No live chicks were seen to be predated. Failure was due to the death of chicks, caused by starvation.

Four discrete colonies were located at Kettla Ness. The "Marsh" site had a peak of laying around 12-15 June, but heavy egg predation occurred on the 15-16 June causing failure by the time of the subsequent visit on 21 June. Kettla Ness "New" colony failed during the incubation stage, with only one chick hatching. At the other two Kettla Ness colonies, "Main" and "Lower", chicks hatched but all died in their first week of life with only one exception. Both colonies decreased as chicks died and the parents abandoned breeding. Failure was due to chick starvation.

Hill of Sandwick was a healthy colony of approximately 110 pairs at the time of desertion. Chicks up to 17 days old and clutches nearing the end of incubation disappeared on 9 or 10 July. Two sheepdogs were roaming around the area investigating nests on 10 July and these are presumed to have caused abandonment.

Whalsies Ayre colony increased in size from 30 May (45 pairs) to 14 June (119 pairs). Many of these birds did not settle down to breed and numbers rapidly fell to 70 pairs on three small areas by 18 July. The birds on two of the small areas of activity failed during incubation and at the third only four well grown chicks were found and ringed, all of which fledged. The poor fledging rate per pair was due to the predation of eggs.

At both Ward of Culswick and Ward of Silwick colonies were present all through the breeding season. Few chicks were found despite regular searches. At Culswick 23 chicks were ringed and 13 fledged and at Silwick five chicks were ringed and all of them fledged. At Culswick there were approximately ten pairs of Arctic Skuas in the vicinity and this species frequently patrolled the colony and loafing area. Additionally one Common Gull was observed to predate an egg or chick. It can be assumed that most pairs failed at the incubation stage.

The breeding success of Kittiwakes was 0.79 per pair in 1986 and is given in Table 12. The breeding colonies were located at Sumburgh Head, S. Mainland (59° 51'N., 1° 15'W.); Troswick Ness, S. Mainland (59° 56'N., 1° 15'W.) and Esha Ness, Mainland Vagaland (60° 30'N., 1° 35'W.).

FIGURE 2: FREQUENCY DISTRIBUTIONS OF ARCTIC TERN HATCHINGS AND NESTLING MORTALITY, SHETLAND 1986

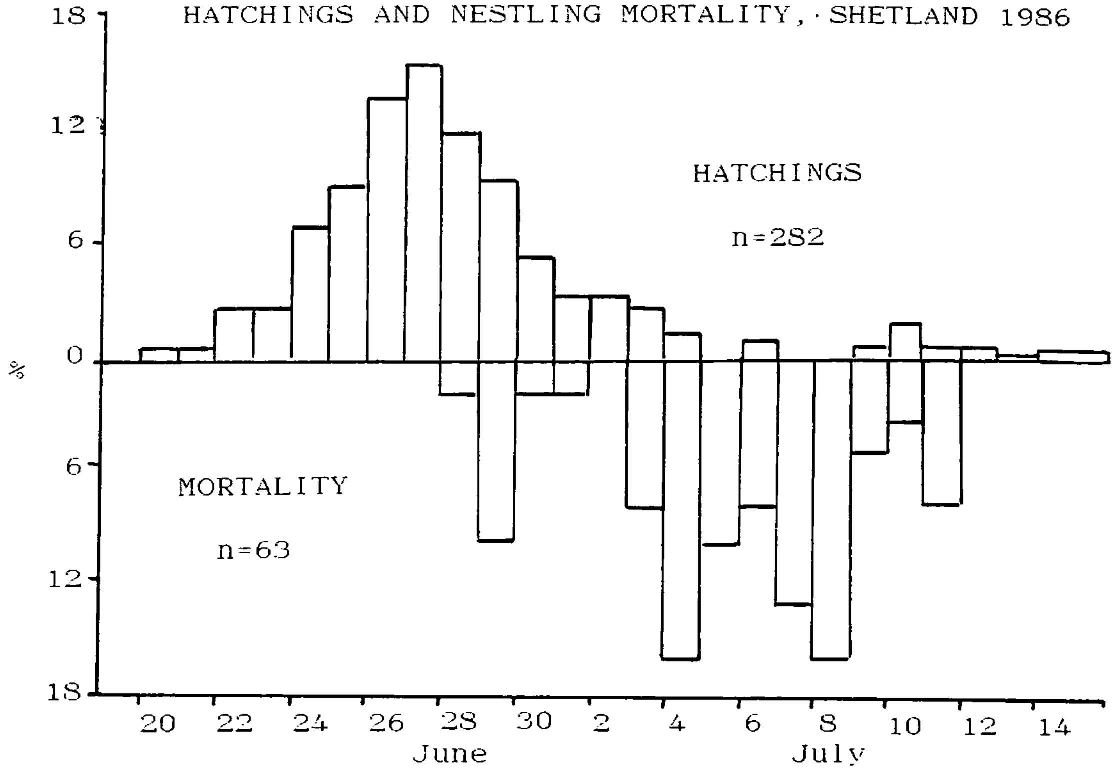


FIGURE 3: FREQUENCY DISTRIBUTION OF AGES OF DEATH OF ARCTIC TERN CHICKS, SHETLAND 1986

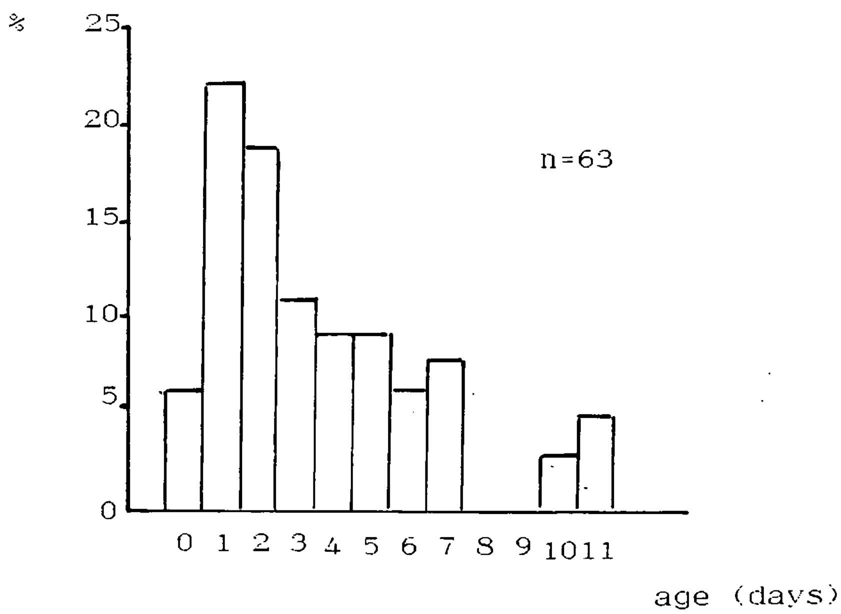


TABLE 3: CLUTCH SIZES, SHETLAND 1986

Colony	Date	c/1	c/2	c/3	n	Mean clutch size
Dalsetter	8 June	18	9	0	27	1.33
Whalsies Ayre	14 June	6	15	0	21	1.71
Fladdabister	15 June	23	33	1	57	1.61
Papa	15 June	19	43	2	64	1.69
Kettla Ness Main	22 June	21	6	0	27	1.22
Ward of Culswick	25 June	27	19	0	46	1.41
Hill of Sandwick	26 June	53	33	1	87	1.40
Kettla Ness Lower	28 June	14	7	0	21	1.33
Total		181	165	4	350	1.49

TABLE 4a: COMPLETED CLUTCH SIZES, SHETLAND

Year	c/1	%	c/2	%	c/3	%	n	Mean	Source
1980	77	17.0	317	70.0	59	13.0	453	1.96	B&G(1981)
1982	27	8.8	193	62.9	87	28.3	307	2.20	Ewins(1985)
1986	181	51.7	165	47.1	4	1.1	350	1.49	Present

TABLE 4b: CHI-SQUARE TESTS ON MEAN CLUTCH SIZE 1986 COMPARED TO OTHER YEARS

Year	Area	Mean clutch size	Chi-square value	Degrees of freedom	Significance
1961	Inner Farne	1.85	119.9	1	P<0.001
1962	"	1.61	14.9	1	P<0.001
1963	"	1.75	62.2	1	P<0.001
1964	"	1.76	77.7	1	P<0.001
1966	"	1.66	20.2	1	P<0.001
1967	"	1.68	24.8	1	P<0.001
1968	"	1.42	2.7	1	P>0.95
1971	Spitsbergen	1.70	19.7	1	P<0.001
1977	S.W.Finland	2.03	183.8	1	P<0.001
1980	Shetland	1.96	109.1	1	P<0.001
1982	"	2.20	137.3	1	P<0.001

TABLE 5: TIMING OF BREEDING OF ARCTIC TERNS, 1982 & 1986

Year	n	Date of maximum hatching	First Peak	Second Peak	Number of days after first peak	Range of Hatching	Median hatching date
1982	271	19 June	18-21 June 62%	27 June	8	14 June- 6 July 23 days	20 June
1986	282	27 June	25-29 June 60%	10 July	13	20 June- 15 July 26 days	27 June

TABLE 6: FIRST EGG DATES FOR ARCTIC TERNS, SHETLAND

Year	First egg date
1975	24 May
1976	27 May
1977	23 May
1978	21 May
1980	28 May
1981	26 May
1982	23 May
1986	28 May

TABLE 7: MEAN LENGTHS & BREADTHS OF ARCTIC TERNS EGGS, SHETLAND

<table>
<tr><th>Category</th><th>Sample 1966-68</th><th>n</th><th>Sample 1986</th><th>n</th></tr>
<tr><td>c.1</td><td>l. 40.48 ± 0.16mm
b. 29.10 ± 0.08mm</td><td>462</td><td>l. 40.40 ± 0.2mm
b. 29.10 ± 0.1mm</td><td>82</td></tr>
<tr><td>c.2/1</td><td>l. 40.46 ± 0.26mm
b. 29.14 ± 0.11mm</td><td>189</td><td rowspan="2">l. 40.00 ± 0.3mm
b. 29.10 ± 0.1mm</td><td rowspan="2">56</td></tr>
<tr><td>c.2/2</td><td>l. 39.78 ± 0.26mm
b. 28.76 ± 0.12mm</td><td>169</td></tr>
</table>

TABLE 8: BREEDING SUCCESS OF ARCTIC TERNS, SHETLAND 1986

Colony	Number of pairs	Number fledged	Fledging success per pair
Fladdabister	368	3	0.0082
Ward of Culswick	51	13	0.2550
Ward of Silwick	74	5	0.0675
Symbister Ayre	22	4	0.1818
Whalsies Ayre	119	4	0.0336
Reawick	6	4	0.6666
Deepdale Reawick	11	3	0.2727
Holm of Houss	30	1	0.0333
Hogoland	14	1	0.0714
Uradale	14	6	0.4285
Fair Isle	83	8	0.0964
Others	1108	0	0.0000
Total	1900	52	0.0266

TABLE 9: BREEDING SUCCESS OF ARCTIC TERNS

Year	Fledging Success	n	Area	Source
1961	0.67	63	Inner Farne	Springett (1967)
1963	0.62	253	Inner Farne	Springett (1967)
1964	0.86	320	Inner Farne	Springett (1967)
1965	0.83	87	Coquet Island	Langham (1968)
1966	0.78	89	Coquet Island	Langham (1968)
1966	0.52	143	Inner Farne	Horobin (1971)
1967	0.90	125	Coquet Island	Langham (1968)
1967	0.79	239	Inner Farne	Horobin (1971)
1968	0.62	103	Inner Farne	Horobin (1971)
1968	0.93	399	Coquet Island	Dunn (1972)
1969	0.90	292	Coquet Island	Dunn (1972)
1970	0.75	235	Coquet Island	Dunn (1972)
1983	0.71	1054	Mousa	Ewins (1985)
1984	0.08	1309	Mousa	Ewins (1985)
1986	0.03	1900	Present study	

TABLE 10: COLONY SUCCESS & ITS RELATION TO SIZE, SHETLAND 1986

Colony Size (pairs)	No. of successful colonies	No. of chicks fledged	% of chicks fledged
0-99	9	44	84.6
100-499	2	8	15.4
500+	0	0	0.0

TABLE 11: STUDY COLONIES, SHETLAND 1986

Colony	Maximum pairs	Chicks ringed	Chicks found dead	Chicks fledged	Date failed
Dalsetter	556	2	0	0	7 June
Kettla Ness Main	142	3	1	0	13 June
Kettla Ness Lower	55	8	2	0	15 June
Fladdabister	382	168	51	3	17 June
Kettla Ness Marsh	103	0	0	0	24 June
Kettla Ness New	38	1	0	0	8 July
Hill of Sandwick	176	23	3	0	11 July
Ward of Silwick	74	5	0	5	-
Ward of Culswick	51	23	0	13	-
Whalsies Ayre	119	4	0	4	-

TABLE 12: BREEDING SUCCESS OF KITTIWAKES, SHETLAND 1986

Area	Number incubating	Number fledged	Fledging success per pair
Sumburgh Head	234	151	0.65
Troswick Ness	133	149	1.12
Eshaness	99	69	0.70
Total	466	369	0.79

GROWTH

METHODS

At the study colonies chicks were ringed to enable identification of individuals. Chicks of known age were required for determining growth rates, and were ringed as close to hatching (Day 0) as possible. This was possible for chicks which hatched from marked nests as these were monitored daily. Eggs which were due to hatch the following day were identified by the starring and chipping of the eggshell. Chicks which were still wet, and lying in the nest scrape or adjacent to broken eggshell were identified as Day 0 chicks. Chicks were measured at ringing and on each subsequent recapture. Wing lengths were measured to the nearest mm (maximum flattened chord, excluding the downy tips to the remiges), and chicks were weighed accurate to 1.0g using an Ohaus electronic balance. Daily colony visits were made to ring and recapture chicks. Visits were made at the same time of day to reduce biases due to diurnal variation in provisioning rates. Approximately 35 to 45 minutes were spent in the colony, except during cold, windy and wet conditions when visits were shortened. Disturbance was kept to a minimum at all times.

To obtain information on growth rates attempts were made to capture and measure chicks on consecutive days. Difficulty was experienced in recapturing chicks due to a high death rate and because of a tendancy for chicks to wander considerable distances and hide themselves in the dense vegetation (mainly _Calluna vulgaris_ and _Nardus stricta_). The two colonies with the thickest vegetation were at Fladdabister where the majority of the ringing was done and at Whalsies Ayre. Very few chicks were caught at the study colonies which failed at the incubation stage.

A total of 37 chicks were ringed at Day 0 and therefore of known age. These were measured a total of 62 times. The wing length measurements of known age chicks were compared to known age wing lengths reported by Pearson (1964) from the Farne Islands and Ewins (1985) for Shetland. The 1986 wing lengths showed a significant correlation with both ($r=0.99$, 10 d.f., $P<0.001$). Therefore chicks not ringed at hatching were aged from their wing length.

Measurements of the mean daily weight increase were used to investigate chick growth rates. These were calculated by three different methods. Firstly by using the weight increase of known age chicks. Secondly by using the weight increase of chicks captured twice in the period of approximately constant weight increase, and thirdly by using chicks older than five days (aged from wing length) but only caught once. This was done by taking the mean wing length at hatching (Day 0) which was 17.1 ± 0.1 mm (n=37) and the mean weight at hatching which was 13.1 ± 0.6g (n=37), and calculating the daily increment up to the day of capture. To obtain the mean daily increase, the change in weight was divided by one less than the number of days in between, to allow for Day 0 when there is little or no increase. The mean daily weight increase for all three methods were as follows:-

1) 6.0 ± 0.31g (n=22).

2) 6.0 ± 0.45g (n=18).

3) 6.2 ± 0.23g (n=33).

Results from all three methods were compatible and therefore pooled. The mean daily weight increase was calculated from measurements of chicks not later found dead, for Fladdabister and for all the other colonies combined.

RESULTS

The mean increase in wing length was approximately linear from Day 4 to 20 (Figure 4) with an average daily increment of 8.06 ± 0.21 mm between Day 4 and 14. This compares to an average daily weight increase from Day 4 to 14 of 8.2mm reported by Ewins (1985) for Mousa 1983. The average daily increment between Day 2 and 22 was 7.23 ± 0.21mm, which compares to 7.4mm for the Farne Islands (Pearson 1964).

The mean daily weight increase for Day 1 to 18 was 5.55 ± 0.22g (n=99) for Fladdabister, and 6.71 ± 0.16g (n=35) for all other colonies. At Fladdabister between Day 1 and 9 the average daily weight increase was 6.12 ± 0.21g (n=64) but this dropped to 2.79 ± 1.27g (n=7) for Day 10 to 23 (Figure 5). For the other colonies, the mean daily weight increase between Day 1 and 9 was 6.76 ± 0.26g (n=21). Only one chick was sampled for the period Day 10 to 23 and this had a mean daily weight increase of 6.2g.

Figure 6 presents the plots of weight against wing length for 247 chick measurements at Fladdabister. This can be compared to the plot for Mousa in a year of high productivity, 1982 (Ewins 1985). The plot for Fladdabister has considerably more scatter than the Mousa data. A band containing 95% of the Mousa points has been superimposed onto the Fladdabister plot in Figure 6. No points occur above the band but 35% fall below it, indicating that many of the chicks were underweight for their age (wing length). The percentages of points within and below the band for each ten mm of wing length are given in Table 13.

The distribution of daily weight increase for chicks at all colonies is given in Figure 7.

FIGURE 4: GROWTH CURVE FOR OF MEAN WING LENGTH FOR ARCTIC TERN CHICKS AT FLADDABISTER 1986

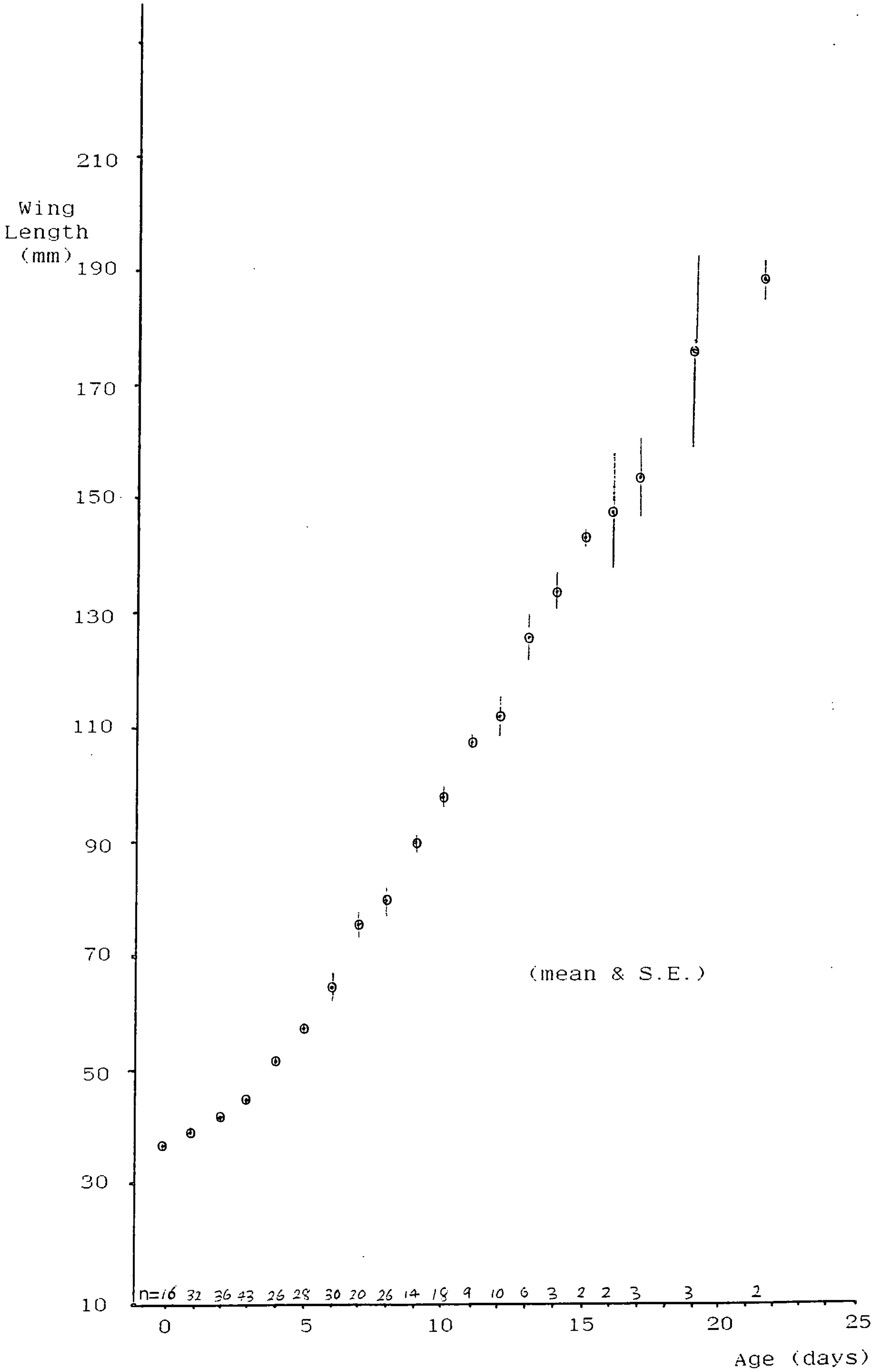


FIGURE 5: GROWTH CURVES FOR FLADDABISTER, OTHER COLONIES IN 1986 AND FARNE ISLANDS IN 1967

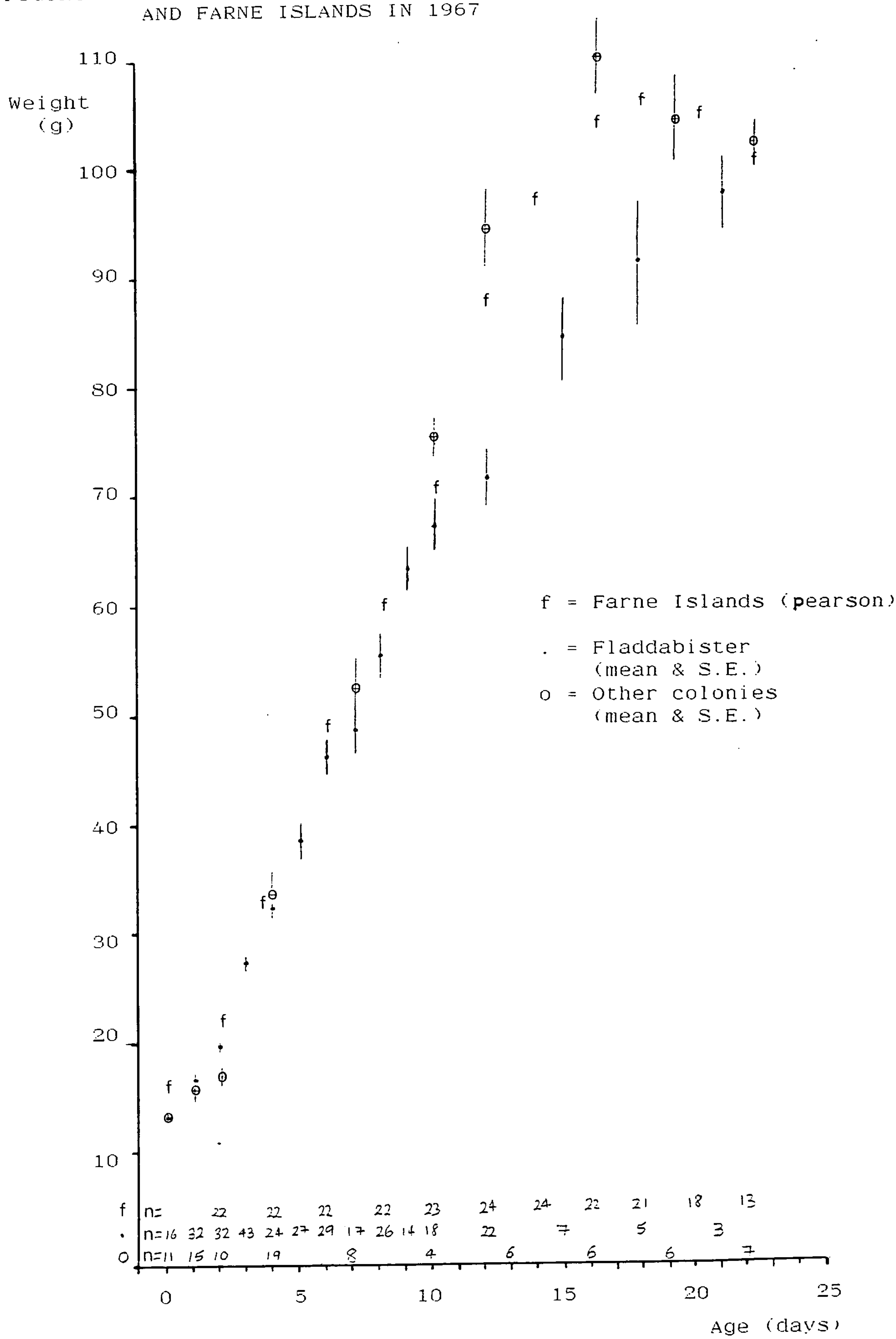


FIGURE 7: DISTRIBUTION OF DAILY WEIGHT INCREASES FOR ARCTIC TERN CHICKS, SHETLAND 1986

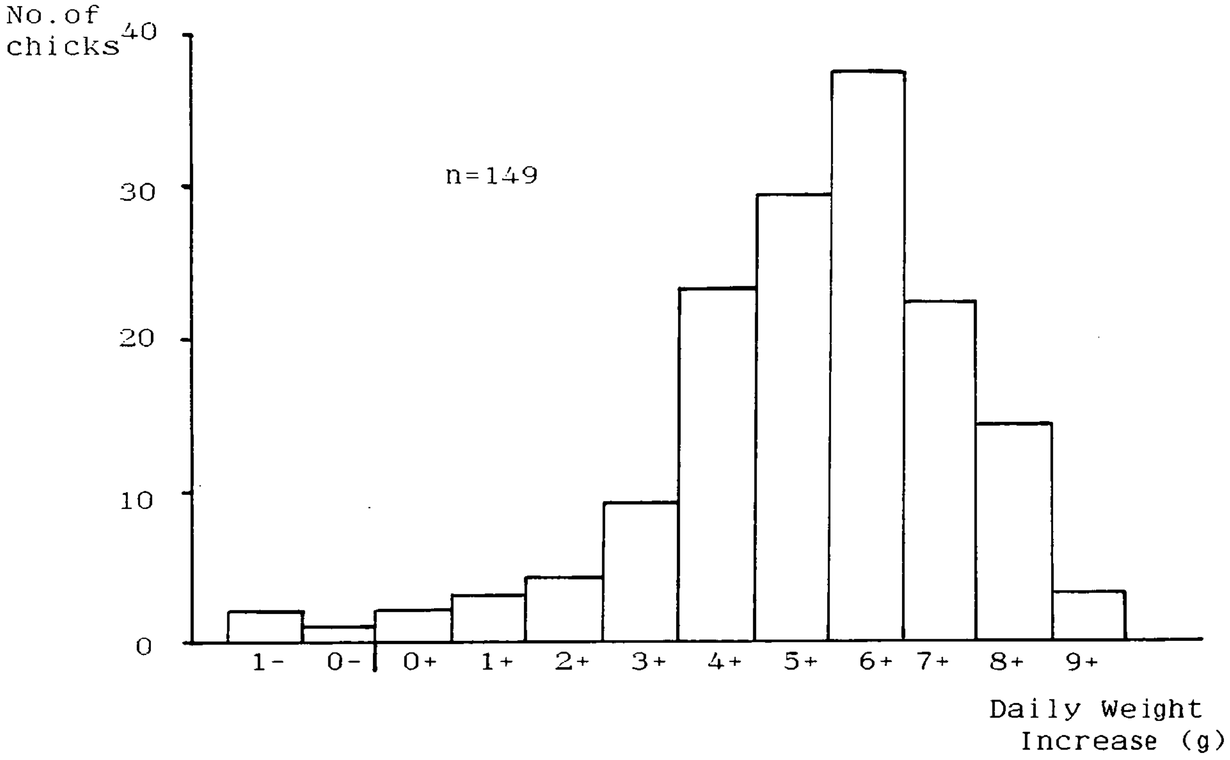


FIGURE 6: WING/WEIGHT PLOT FOR ARCTIC TERN CHICKS
AT FLADDABISTER 1986

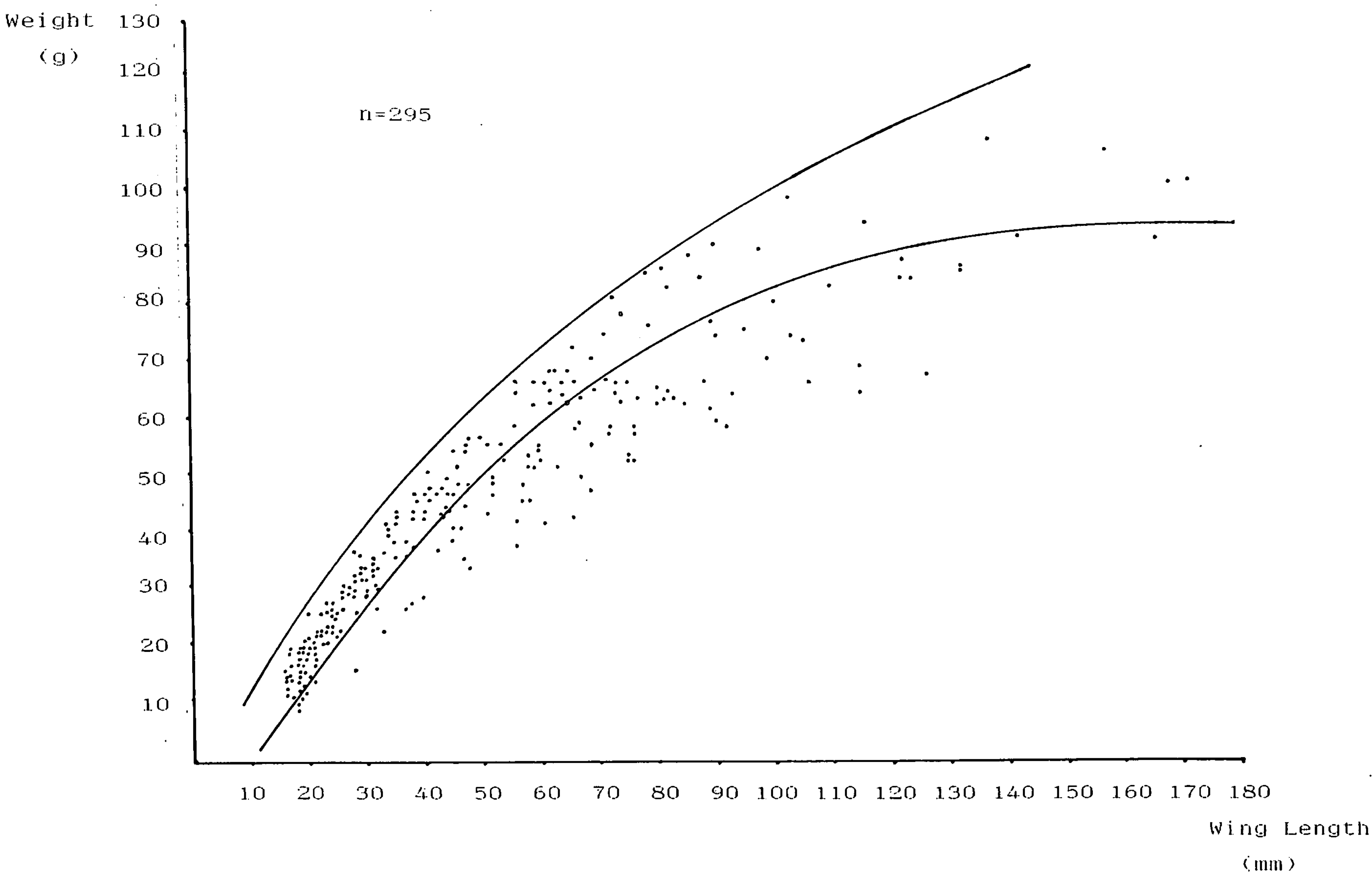


TABLE 13: COMPARISON OF WING - WEIGHT PLOTS
1982 MOUSA & 1986 FLADDABISTER

Wing length (mm)	No.of points in wing length	Points within 1982 band		Points below 1982 band	
		No.	%	No.	%
10-19	27	23	85.2	4	14.8
20-29	48	46	95.8	2	4.2
30-39	33	29	87.9	4	12.1
40-49	30	22	73.3	8	26.7
50-51	22	9	40.9	13	59.1
60-69	26	13	50.0	13	50.0
70-79	18	5	27.8	13	72.2
80-89	13	4	30.8	9	69.2
90-99	8	2	25.0	6	75.0
100-109	6	1	16.7	5	83.3
110-119	4	1	25.0	3	75.0
120-129	4	0	0.0	4	100.0
130-139	3	1	33.4	2	66.6
140-149	1	0	0.0	1	100.0
150-159	1	1	100.0	0	0.0
160-169	2	1	50.0	1	50.0
170-179	1	1	100.0	0	0.0

DIET

METHODS

Prey species and sizes were determined from observations of adults returning to the colonies from feeding areas. Terns were carrying fish either for courtship or for feeding chicks. Prey length was estimated as a fraction of the head to bill length of the returning tern. The mean length from the bill tip to the rear of the black head feathering on six fresh corpses measured by Ewins in 1982 was 9.1cm. Prey species were grouped into three size classes, small (1 to 5cm), medium (6 to 10cm) and large (over 10cm).

The majority of fish brought in were either sand eels or Saith, a gadoid. Some prey items were clupeids (Herring and Sprat) but their species was not identified. In some cases clupeids and gadoids could not be separated and these two groups of fish have been pooled but refer mainly to Saith. Fish of unknown identity were grouped as "other fish". One three-spined stickleback (*Gasterosteus aculeatus*) and one ten-spined stickleback (*G. spinachia*) were found in the colonies. The few unidentified non-fish items were mainly crustaceans and these were grouped under "item".

Details of the landings of sand eels in Shetland were obtained from the Department of Agriculture Food and Fisheries.

RESULTS

Table 15 and Figure 8 give the composition of prey species brought into Fladdabister by Arctic Terns. Numbers of sand eels show a steady decline from 27 June to 15 July. There is a significant negative correlation between the percentage of sand eels in the sample and the date of the sample ($r=0.80$, 14d.f., $P<0.001$). Generally, over 50% of each sample before 7 July were sand eels and less than 50% afterwards. The number of sand eels compared to other prey before and after 7 July is significantly different (Chi-sq. $=125.5$, 1d.f., $P<0.001$).

Gadoids/clupeids were brought into Fladdabister at an approximately stable rate throughout the season, there was no significant correlation between percentage of the sample and the date ($r=0.35$, 14d.f., $P>0.1$). As a consequence of the decline of sand eels in the samples, the percentages of "other fish" show a complementary increase over the period. Unidentified "items" were brought into the colony at a minimal level throughout ($r=0.05$, 14d.f., $P>0.1$).

Over the period 27 June to 15 July sand eels formed 49% and gadoids/clupeids formed 33% of the observed diet, "other fish" formed 15%, and "items" 2% of the diet.

The sizes of prey items at Fladdabister bave been grouped for analysis (Table 14 & Figures 9,10,11).

At Fladdabister 416 (57%) of the 729 sand eels observed were small, and 64 (8.7%) were large. Numbers of small sand eels declined at a steady rate throughout the sampling period 27 June to 14 July which is a negative correlation ($r=-0.90$,14d.f.,$P<0.001$). Medium sized sand eels increased at a complementary rate, ($r=0.94$,14d.f.,$P<0.001$), but large ones were scarce and the increase was not significant ($r=0.42$,14d.f.$P>0.1$).

A total of 497 gadoids/clupeids were observed, 346 (70%) of which were estimated to have been medium in size. Of the others, 15% were small and 15% large. Sizes were approximately constant from 27 June to 15 July. Small fish decreased significantly over the period ($r=-0.48$,,13d.f.,$P<0.1$), medium fish increased but not significantly ($r=0.26$,13d.f.,$P>0.1$) and large fish increased significantly ($r=0.512$,13d.f.,$P<0.1$).

At Fladdabister the majority of "other fish", 15% of 227, were classed as small, 24% medium and 9% large. Large fish decreased at an insignificant rate ($r=-0.45$,11d.f.,$P>0.1$) between 2 and 15 July. Medium fish decreased significantly ($r=-0.85$,11d.f.,$P<0.001$) and small fish increased significantly ($r=0.78$,11d.f.,$P<0.01$).

Of 36 "items" 34 (94%) were small and one medium and large were recorded.

The main trend is of a steady decline in the number of sand eels, complemented by an increase in the number of "other fish" captured by Arctic Terns, and observations in other areas follow this same apparent pattern. Samples of prey size and composition from Mainland Vagaland, South

Mainland, Burra Isle, Papa Stour and Fair Isle are given in Appendices 1 and 2.

Figure 12 shows the commercial fishing landings of Shetland sand eels from April to July 1986. It is not known whether any sand eels fished from Shetland waters were landed elsewhere. The Shetland landings show a decreasing trend of 37.6% per week from the peak landing of 1787.7 tonnes for the week ending 17 May to a low of 65.5 tonnes for the week ending 5 July. This data therefore backs up the apparent trend of declining sand eels shown by the Arctic Tern prey samples.

On only three occasions were adults observed hawking for insects over land though no insects were seen to be fed to chicks.

FIGURE 8:. COMPOSITION OF PREY AT FLADDABISTER 1986

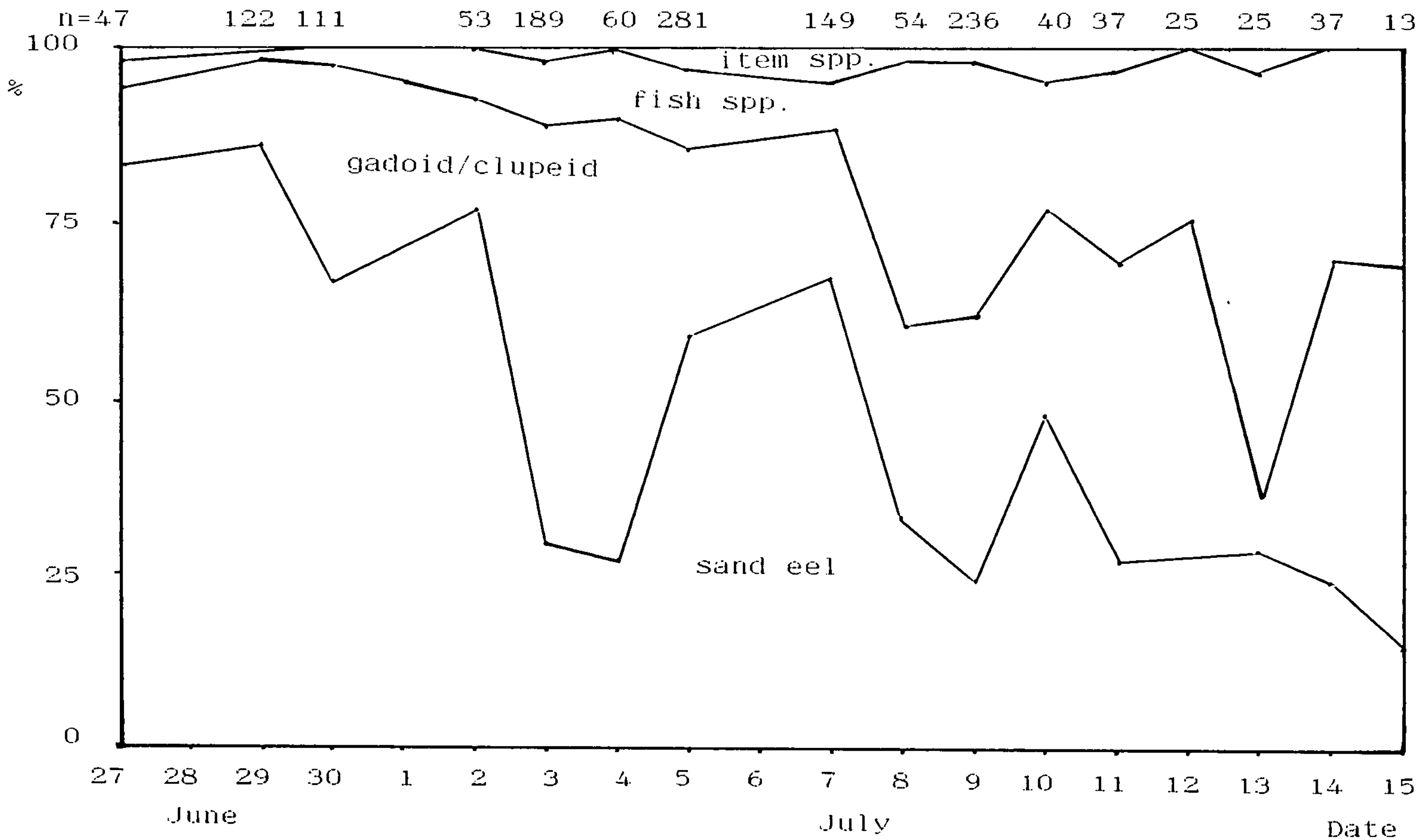


FIGURE 9: SIZE COMPOSITION OF SAND EELS AT FLADDABISTER 1986

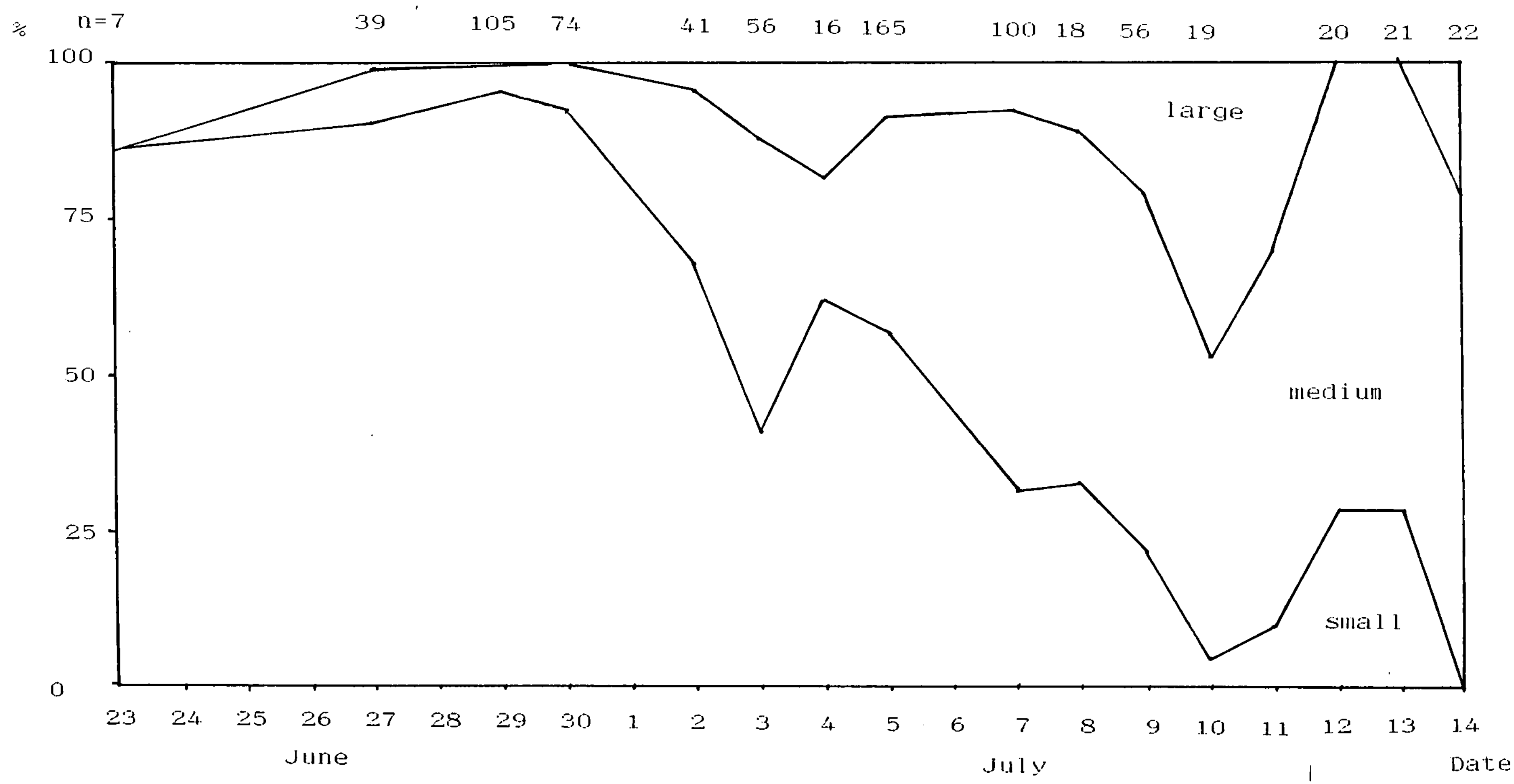


FIGURE 10: SIZE COMPOSITION OF GADOIDS/CLUPEIDS AT FLADDABISTER 1986

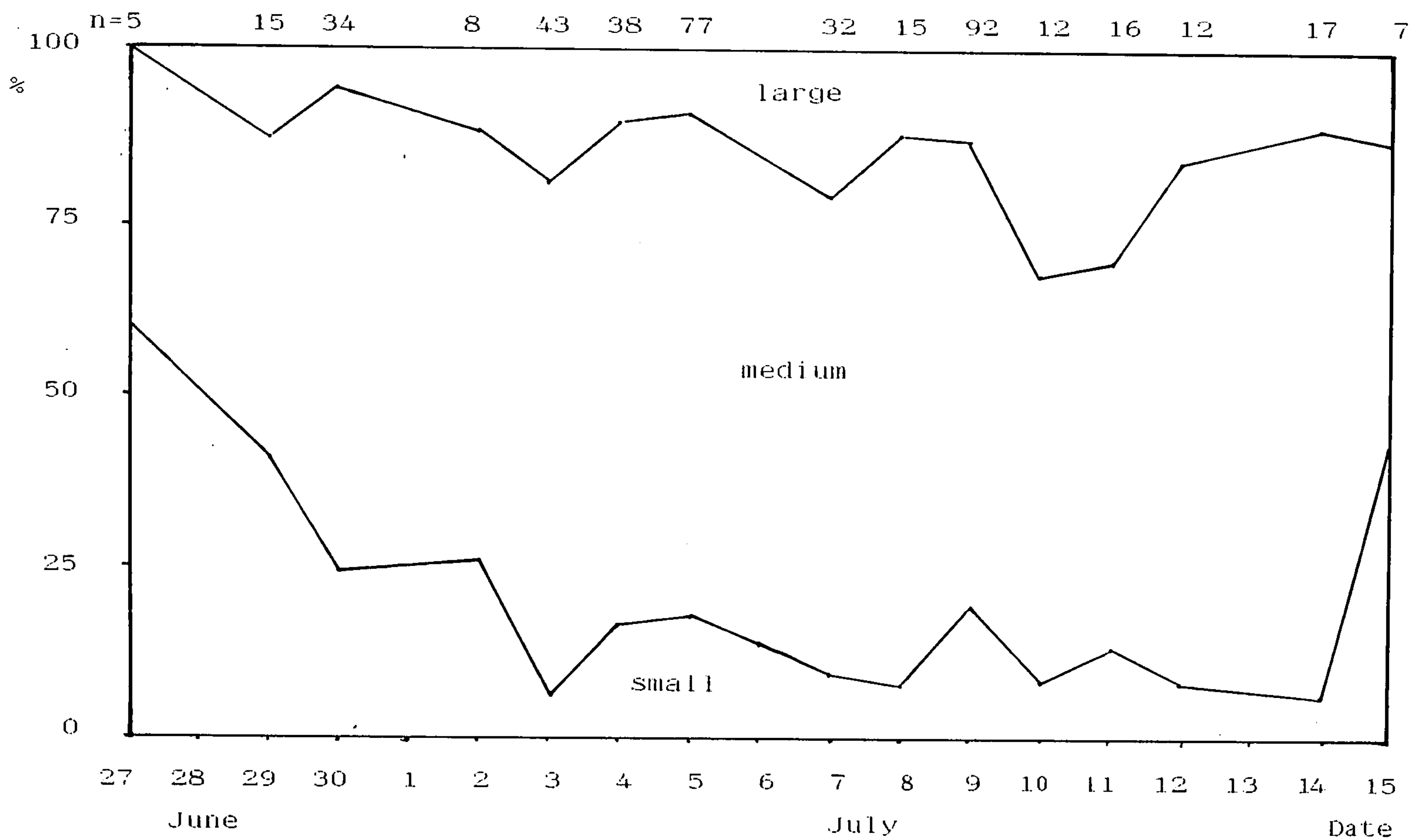


FIGURE 11: SIZE COMPOSITION OF "OTHER FISH" AT FLADDABISTER 1986

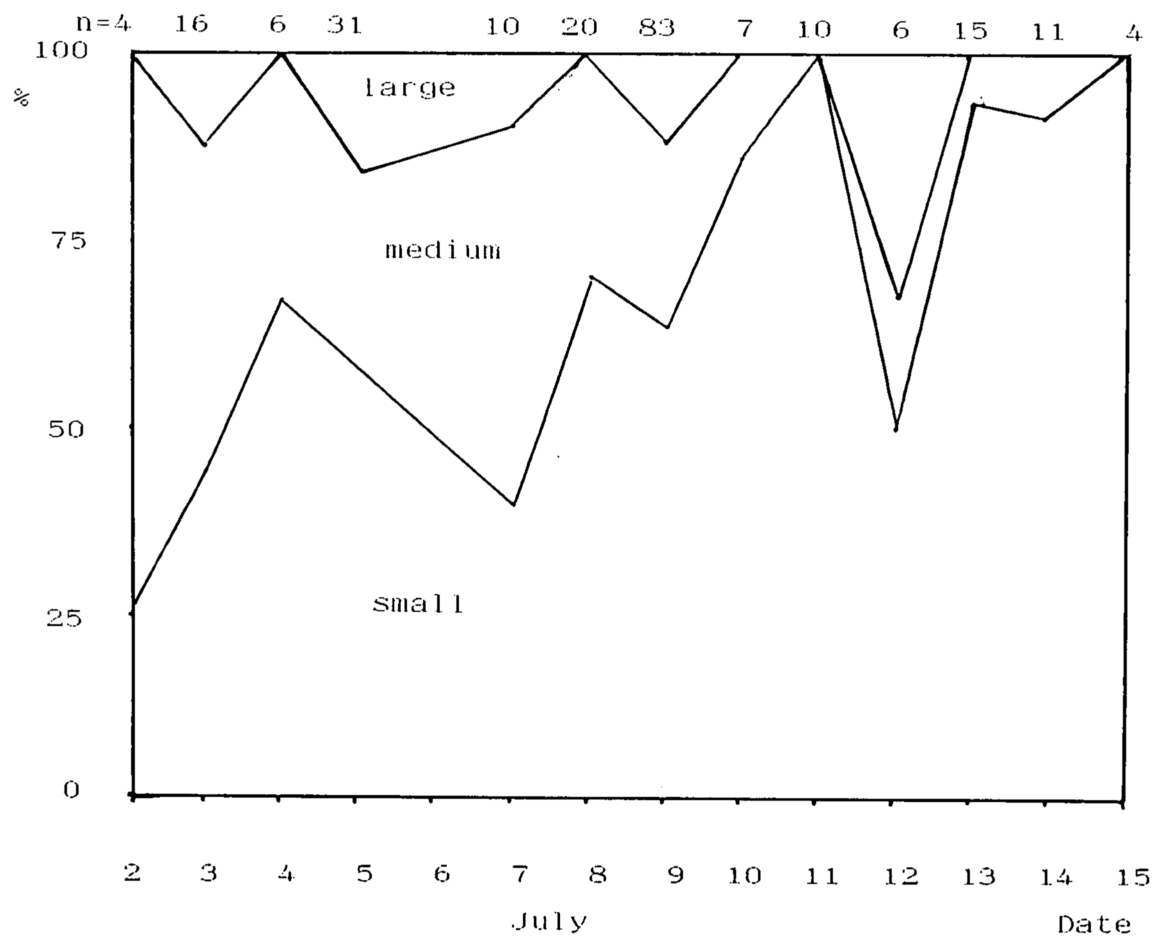


FIGURE 12: LANDINGS OF SAND EELS IN SHETLAND PER WEEK 1986

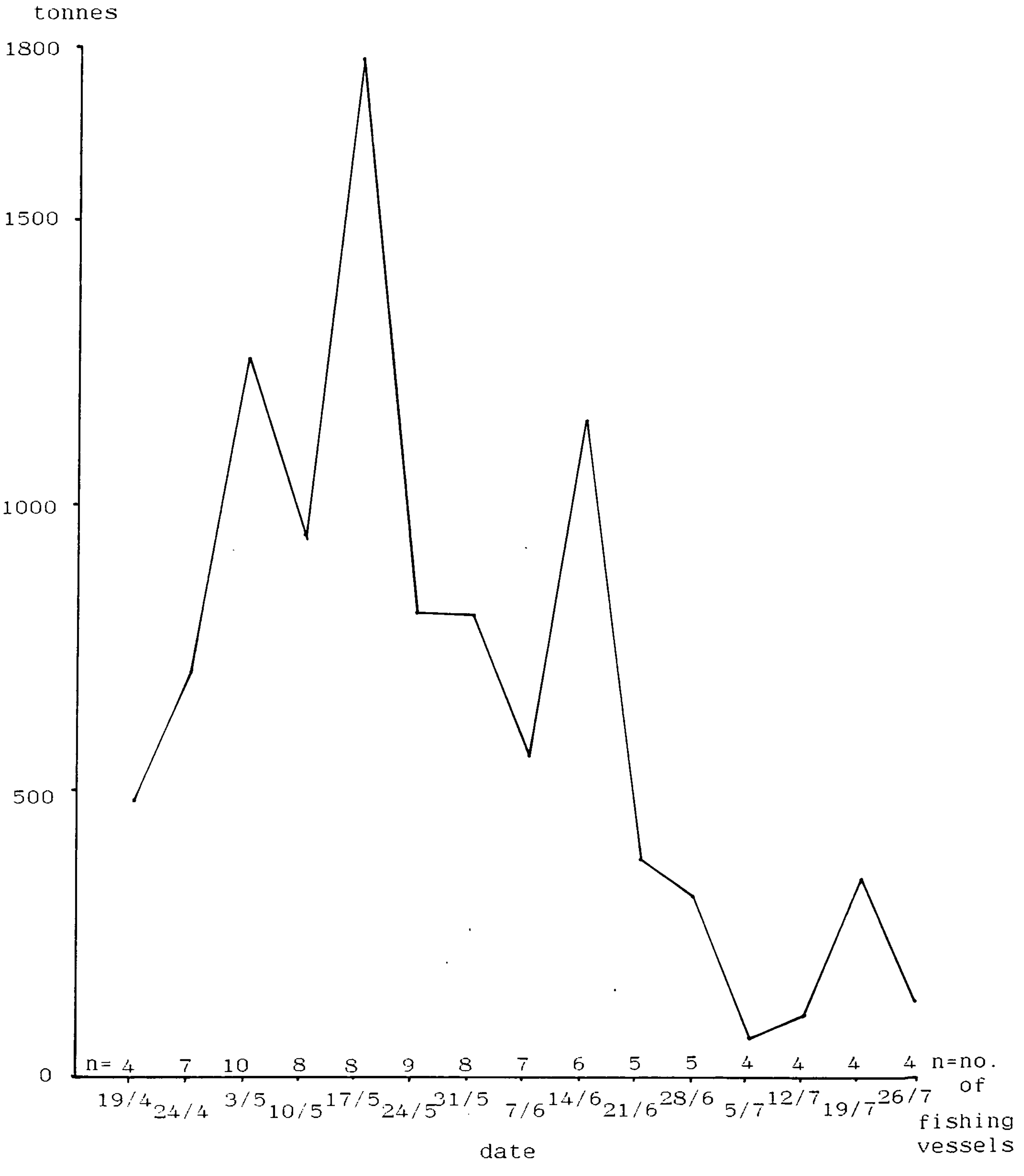


TABLE 14: COMPOSITION OF DIET, SHETLAND 1986
FLADDABISTER

Date	Sand Eel No.	Sand Eel %	Gadoid/Clupeid No.	Gadoid/Clupeid %	Fish spp. No.	Fish spp. %	--Item-- No.	--Item-- %	n
27 June	39	83.0	5	10.6	2	4.3	1	2.1	47
29 June	105	86.1	15	12.3	2	1.6	1	2.1	122
30 June	74	66.6	34	30.7	0	0.0	3	2.7	111
2 July	41	77.4	8	15.1	4	7.5	0	0.0	55
3 July	56	29.6	113	59.8	16	8.5	4	2.1	189
4 July	16	26.7	38	63.3	6	10.0	0	0.0	60
5 July	165	58.7	77	27.4	31	11.0	8	2.9	281
7 July	100	67.1	32	21.5	10	6.7	7	4.7	149
8 July	18	33.3	15	27.8	20	37.0	1	1.9	54
9 July	56	23.7	92	39.0	83	35.2	5	2.1	236
10 July	19	47.5	12	30.0	7	17.5	2	5.0	40
11 July	10	27.0	16	43.3	10	27.0	1	2.7	37
12 July	7	28.0	12	48.0	6	24.0	0	0.0	25
13 July	7	28.0	2	8.0	15	60.0	1	4.0	25
14 July	9	24.3	17	46.0	11	29.7	0	0.0	37
15 July	2	15.4	7	53.8	4	30.8	0	0.0	13
Total	731	49.1	496	33.3	227	15.2	36	2.4	1490

TABLE 15: SIZE & COMPOSITION OF DIET, FLADDABISTER, SHETLAND 1986

Date	---Sand Eel--				Gadoid/Clupeid				--Fish spp.--				----Item-----			
	sm.	med.	lge.	n	sm.	med.	lge.	n	sm.	med.	lge.	n	sm.	med.	lge.	n
27 Jun	35	3	3	39	3	2	0	5	1	1	0	2	1	0	0	1
29 Jun	99	5	0	104	6	7	2	15	2	0	0	2	0	0	0	0
30 Jun	68	6	0	74	8	24	2	34	0	0	0	0	3	0	0	3
2 Jul	28	11	2	41	2	5	1	8	1	3	0	4	0	0	0	0
3 Jul	23	26	7	56	7	83	23	113	7	7	2	16	2	1	1	4
4 Jul	10	3	3	16	6	28	4	38	4	2	0	6	0	0	0	0
5 Jul	93	58	14	165	13	57	7	77	18	8	5	31	15	0	0	15
7 Jul	32	60	8	100	3	22	7	32	4	5	1	10	7	0	0	7
8 Jul	6	10	2	18	1	12	2	15	14	5	1	20	1	0	0	1
9 Jul	11	33	12	56	5	55	32	92	53	20	10	83	5	0	0	5
10 Jul	1	9	9	19	1	7	4	12	6	1	0	7	2	0	0	2
11 Jul	1	6	3	10	2	9	5	16	10	0	0	10	1	0	0	1
12 Jul	2	5	0	7	1	9	2	12	3	1	2	6	0	0	0	0
13 Jul	2	5	0	7	1	1	0	2	14	1	0	15	1	0	0	1
14 Jul	0	7	2	9	1	14	2	17	10	1	0	11	0	0	0	0
15 Jul	0	2	0	2	3	3	1	7	4	0	0	4	0	0	0	0

DISCUSSION

The overall rate of decline in the number of pairs of Arctic Terns breeding in Shetland between 1980 and 1986 was 19.9% per year.

The annual mortality rate of breeding adult Arctic Terns obtained on the Farne Islands between 1952 and 1954 by Cullen (1957) was 13.6%. Coulson and Horobin (1976) used two methods to obtain rates of 13.3 + 2.0% and 12 + 0.3% for the Farne Islands between 1966 and 1967. The estimated rate of decline for Shetland approximates to, but exceeds, the decline which would be expected if there was no recruitment into the colonies. Some terns must therefore be opting out of breeding.

The results of declining numbers of breeding pairs for each Island group show a geographical trend. Northern and western regions and outlying islands have decreased at an average of 31% per year compared to 5% per year for southern and eastern regions.

There is a trend among the 78 individual colonies surveyed that larger colonies decrease proportionatly more in size than smaller ones. In 1980, there were 38 colonies in the size range 0 to 99 pairs. Of these, 58% had decreased in size by 1986. Twelve of these colonies were not being used in 1986 but five new colonies in this size range were found. The size range 100 to 499 pairs included 26 colonies of which 96% had decreased in size. One new colony was found and ten had been abandoned. All eight of the large colonies (each over 500 pairs) had decreased in size. One had been abandoned.

In 1986 the breeding season was approximately eight days later than in the productive year of 1982, suggesting that adults were in sub-optimal condition. An alternative explanation, however, is that the spring weather was cold and wet compared to a good spring in 1982. However, cool spring weather is probably not of importance to this species as it breeds successfully at higher latitudes.

The mean clutch size for Shetland in 1986 is significantly lower than the 1980 and 1982 Shetland means, the 1961-1967 Coquet/Farne Island means, the 1970 Spitzbergen (Bengston 1971) and the 1976 S.W. Finland (Belopol'ski 1977) means. There is no significant difference between the 1986 mean and the 1968 mean for Inner Farne. This is because of the 1968 "Red tide" (a dinoflagellate bloom which produced a highly toxic substance causing paralytic shell-fish poisoning in man) which reduced both the clutch size and the breeding success in 1968 (Horobin 1971).

In 1980 and 1982 the percentage of clutches of three were 13% and 28.3% respectively. In 1986 this figure was much lower at 1.1%. Two was the commonest clutch size in 1980 and 1982 but in 1986 there were almost equal numbers of one and two egg clutches. This has resulted in the low mean clutch size and indicates that in 1986 Arctic Terns were in poor breeding condition.

The average daily weight increase of chicks at Fladdabister was approximately constant at 6.12 ± 0.21g (n=64) from Day 1-9, which is very similar to the growth rates for normal years. However, the mean daily weight increase from Day 10-23 was only 2.79 ± 1.27g (n=7). The low sample size reflects the proportion of chicks which were dying before this age. This trend does not match the "other colonies", where the mean growth curve increases in a linear manner between Day 4 and 14 and then declines gradually with a period of weight fluctuation just prior to fledging. This closely matches the situation on Coquet and the Farne Islands 1961-1970, and on Mousa in 1983.

For the first few days after hatching a chick's demand for food is not very great. Pearson (1964) estimated that chicks require 1g of food per 3.5g of body weight for maintenance each day. However, as they increase in age and in body weight their demand for food increases rapidly. At the age of nine days chicks are in their period of fastest growth and greatest food demand. The slow growth rate of chicks older than nine days occurred during the period of greatest food demand and therefore indicates a food shortage.

Peak mortality of chicks was in the period 3 to 11 July. Although this follows peak hatching and mortality is expected, it was higher than expected. The weather for this period was normal for July, suggesting that this was not the prime cause of mortality. As expected the majority of chicks (78%) died before they were six days old. At this age chicks have not fully developed their thermoregulatory mechanism and are more vulnerable to cold, wet weather.The corresponding figures for Day 0-5 mortality in 1983 and 1984 were 92% and 97% respectively (Ewins 1985). In 1986 large numbers of chicks died after their first week. More chicks were dying therefore, of causes other than from thermoregulation problems and this suggests that death was attributable to starvation. At Fladdabister adults deserted live young and three nests were found with dead chicks huddled together, an indication of parent death or desertion.

Terns experienced difficulty in breeding and colony failures all through the season. The severe egg loss which was a feature of the earlier failing colonies such as Kettla Ness Marsh (24 June) and Dalsetter (7 July), is likely to have been caused by Arctic Skuas increasing the amount of time spent foraging for eggs. Arctic Skuas rely heavily upon robbing Arctic Terns carrying fish and therefore, a food shortage affecting terns would also put pressure on Arctic Skuas. A consequence of this was that Arctic Skuas put more effort into egg predation in tern colonies. Additionally, if terns were having to spend a greater proportion of their time foraging, there would be fewer terns protecting the colony from such predation. A recurring feature of the "first flushing" counts at many colonies was that Arctic Skuas would fly in and begin searching for eggs. Although the predation of eggs, particularly before incubation has begun, is a normal occurrence, it is interesting to note that it occured on all visits to Dalsetter (which hatched few chicks and failed on 7 July), and not at all at Fladdabister which hatched many chicks but had failed by 17 July. At Hill of Sandwick colony desertion was caused by two sheepdogs. Arctic Terns are ground nesting birds and are therefore at risk from ground predators which can, as in this case, wipe out whole colonies. Desertion due to heavy chick mortality occurred at Fladdabister and Kettle Ness Main.

The first colony failures were caused by heavy Arctic Skua egg predation and this was followed by disturbance from dogs. However colonies which survived these factors still failed, the later desertions being caused by chick starvation and death. Thus, colony failures were not caused by a single factor, but by a whole series of factors.

In 1986 the breeding season on Shetland was disastrous with a fledging success of 0.027 per pair for 1900 known pairs. On Coquet and the Farne Islands in all years between 1961 and 1970 breeding success was over 0.5 per pair. Breeding success on Mousa was estimated as 0.71 per pair for 1054 pairs in 1983 but only 0.08 chicks fledged per pair for 1309 pairs in 1984. Both 1981 and 1982 were reported by Ewins (1985) to have been productive years but no figures were given. In 1986 small colonies had a higher breeding success than larger ones. This is contrary to normal expectations that terns in larger colonies are better able to protect themselves, and that social stimulation causes greater synchronousy and therefore more successful breeding.

All the evidence for the unproductive breeding season points to a chronic shortage of suitable food all through the season:-

1) Late breeding season;

2) Low mean clutch size;

3) High chick mortality;

4) Low growth rate of chicks during their period of greatest food demand;

5) The high proportion of chicks which are under weight as shown by the wing/weight plot;

6) Low fledging success;

7) Colony desertions all through the season;

8) Decline in sand eels brought into the colony by adult terns;

9) Decline in the number of sand eels landed by Shetland fishing boats.

Although the breeding season was an unproductive one, some terns did succeed in rearing chicks. These chicks hatched in both the early and late periods of the hatching range. The successful adults must have followed a breeding strategy which made them more efficient than the others, perhaps due to them being older and more experienced. Coulson and Horobin (1976) found that breeding success was higher in older terns (over eight years old).

Sand eels formed 49% of the observed diet throughout the season, which is lower than the 97% observed on Mousa, in 1984. Sand eels declined over the breeding season. Small sand eels declined at a greater rate than larger ones. This could be because small sand eels had grown but is more likely to be due to a reduction in numbers because of the overall decline. The decrease in small sand eels means that adult terns are forced to either spend longer searching for small fish or take larger fish, which has a detremental effect on the feeding of young chicks, because they cannot swallow large prey items.

Gadoids/clupeids were taken at approximately the same rate all season in 1986 when they formed 33% of observed diet. They were utilized more than in 1983 when they formed 20% of the diet in the early nestling period and 3% in the late nestling period. The main gadoid species fished was Saith, which has a lower calorific value than sand eels (5.1 Kj/g compared to 6.5 Kj/g, Harris and Hislop 1978) resulting in a poorer diet.

Pearson (1964) found that Arctic Terns prefered sand eels and fished up to 20 km offshore to catch them. The decline in sand eels in 1986 caused an increase in the number of "other fish" caught. Thus, there is an increasing importance being put on a food source which is not preferred, a consequence of which is the low growth rates and high mortality of chicks.

In 1986 the decrease of sand eels caught by Arctic Terns coincided with the continued low levels of sand eel landings by fishing boats. It is therefore possible that there was a shortage of sand eels for both fishermen and terns alike.

Kittiwakes have a feeding range of 55 km and are potentially able to feed over an area about ten times greater then that utilized by terns beeding in the same locality (Pearson 1964). In 1986 Kittiwakes had a better breeding season than Arctic Terns, with an average of 0.79 chicks fledging per pair (n=466). The relatively higher breeding success of Kittiwakes indicates that they were not under as much pressure from food shortage as Arctic Terns. Kittiwakes have larger foraging ranges and do not rely so heavily upon the inshore shoaling of sand eels. This indicates that the food shortage was more severe in inshore waters around Shetland.

Recommendations:

1) That a full breeding survey is undertaken to confirm the overall decrease in breeding pairs indicated by this study.

2) Further research is undertaken into the breeding of terns related to the ecology of the fish species on which they depend.

3) A detailed study is made of provisioning rates of Arctic Tern chicks throughout a successful season.

4) Further study of the ecological effects of commercial fishing on all North Sea fish stocks.

SUMMARY

Research on Arctic Tern breeding biology on the Farne Islands is reviewed.

A survey was made of 78 Arctic Tern colonies in Shetland and the results compared to the 1980 Bullock and Gomersall survey. In 1980 the estimated number of pairs was 4195 compared to 15925 in 1980. This represents an overall decrease of 19.9% per year.

The breeding biology of Arctic Tern's at ten colonies was studied. The first egg recorded was on 28 May and the laying range was from 28 May to 23 June and hatching range from 20 June to 15 July. The breeding season was eight days behind the season in 1982.

The composition of clutches was:- c/1=181; c/2=165; c/3=4 giving a mean clutch size of 1.49 (n=350). This is significantly lower than for Coquet/Farne Islands 1961 to 1967, Shetland 1980, 1982, Spitsbergen 1971, and South West Finland 1977.

Mortality peaked from 3 to 8 July (70%) and 78% of dead chicks were aged under six days. This is a smaller percentage than recorded on Mousa in 1983 (92%) and 1984 (97%). Therefore a greater number of chicks were dying at an age greater than one week.

Growth curves are plotted for chicks at Fladdabister and for all the other colonies combined. At Fladdabister the

average daily weight increase was approximately constant from Day 1 to 9 but thereafter declined gradually. For the other colonies the average daily weight increase was constant from Day 4 to 14 and then declined gradually with a period of weight loss prior to fledging. The mean daily weight increase of chicks at Fladdabister, Day 1 to 9 was 6.12 $\pm$ 0.21g (n=64) and for Day 10 to 23 was 2.79 $\pm$ 1.27g (n=7). At the other colonies the mean daily weight increase from Day 1 to 9 was 6.76 $\pm$ 0.26g (n=21). Few chicks older than nine were caught because most were dying, before this age. At Fladdabister 35% of chicks were underweight as shown by the wing/weight plot.

Breeding success for 1900 pairs was 0.027 per pair. A total of 52 fledglings were recorded.

Colony desertions occurred all through the breeding season from 24 June to 17 July, and were caused by a series of factors:- egg predation by Arctic Skuas; disturbance/predation by dogs; starvation of chicks.

Observations of size and species of prey carried by adults returning to the colonies were made. Sand eels formed 49% of the observed diet, gadoids/clupeids 33%, "other fish" 15% and "items" 2%. The number of sand eels decreased at a steady rate from 27 June to 15 July. Small sand eels decreased more than larger ones. Provisioning of gadoids/clupeids were approximately constant all through the period but "other fish" increased. The number of commercially fished sand eels landed in Shetland also show a decreasing trend. Catches peaked for the week ending 17

May when eight fishing boats landed 1788 tonnes, and were lowest for the week ending 5 July when four boats landed 66 tonnes.

There was a chronic food shortage in inshore waters around Shetland. The evidence for this is:-

1) Late breeding season;

2) Low mean clutch size;

3) High chick mortality;

4) Low growth of chicks during their period of greatest food demand;

5) The high proportion of chicks which were underweight as shown by the wing/weight plot;

6) Low fledging success;

7) Colony desertion all through the season;

8) Decline in sand eels brought into the colonies by adult terns;

9) Decline in the number of sand eels landed by Shetland fishing boats.

10) Kittiwakes can forage upto 55km compared to 20km for Arctic Terns and they had a breeding success of 0.79 per pair and were therefore not under pressure from food shortage.

A comprehensive survey of Arctic Tern breeding colonies in Shetland is recommended. Further information on chick provisioning rates and diet during a productive season, and the ecology of sand eels and other North Sea fish stocks is required.

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APPENDIX 1

SIZE & COMPOSITION OF DIET, BURRA ISLE, SHETLAND 1986

Date	----Sand Eel----				-Gadoid/Clupeid-				---Fish spp.----			
	sm.	med.	lge.	n	sm.	med.	lge.	n	sm.	med.	lge.	n
21 June	2	0	0	2	0	2	0	2	0	0	0	0
28 June	5	4	1	10	0	0	0	0	0	0	0	0
2 July	0	0	0	0	0	0	0	0	2	0	0	2
4 July	1	0	0	1	1	2	0	3	0	0	0	0
11 July	0	0	0	0	3	5	0	8	7	2	0	9
12 July	0	0	0	0	1	4	1	6	4	1	0	5
16 July	0	0	0	0	0	7	2	9	3	3	0	6
17 July	o	o	o	o	0	7	0	7	0	0	0	0
18 July	0	0	0	0	0	3	0	3	0	0	0	0
19 July	0	0	1	1	2	4	0	6	2	1	0	3
22 July	0	0	0	0	3	10	2	15	1	0	0	1
28 July	0	0	0	0	0	1	0	1	0	0	0	0
Total	8	4	2	14	10	45	5	60	19	7	0	26

SIZE & COMPOSITION OF DIET, MAINLAND VAGALAND, SHETLAND 1986

Date	----Sand Eel----				-Gadoid/Clupeid-				---Fish spp.----			
	sm.	med.	lge.	n	sm.	med.	lge.	n	sm.	med.	lge.	n
30 June	5	1	0	6	4	2	0	6	0	0	0	0
9 July	0	1	0	1	0	3	5	8	0	2	0	2
15 July	0	3	1	4	0	9	5	14	1	2	0	3
18 July	7	1	1	9	3	24	5	32	13	1	0	14
21 July	1	4	0	5	2	17	0	19	6	3	0	9
27 July	0	0	1	1	1	16	1	18	7	0	0	7
Total	13	10	3	26	10	71	16	97	27	8	0	35

SIZE & COMPOSITION OF DIET, S.MAINLAND, SHETLAND 1986

Date	----Sand Eel----				-Gadoid/Clupeid-				---Fish spp.----			
	sm.	med.	lge.	n	sm.	med.	lge.	n	sm.	med.	lge.	n
16 June	3	0	0	3	2	0	0	2	3	0	0	3
26 June	11	1	3	15	1	0	0	1	0	0	0	0
29 June	8	0	0	8	1	0	0	1	0	0	0	0
2 July	15	0	0	15	1	2	0	3	2	0	0	2
17 July	3	5	0	8	0	3	3	6	1	1	0	2
23 July	0	10	1	11	0	14	0	14	1	0	0	1
28 July	0	0	0	0	0	6	0	6	4	1	0	5
Total	40	16	4	60	5	25	3	33	11	2	0	13

APPENDIX 1 (cont.)

SIZE & COMPOSITION OF DIET, PAPA STOUR, SHETLAND 1986

Date	----Sand	Eel----			-Gadoid/Clupeid-				---Fish spp.----			
	sm.	med.	lge.	n	sm.	med.	lge.	n	sm.	med.	lge.	n
4 June	3	5	0	8	1	4	0	5	3	0	0	3

SIZE & COMPOSITION OF DIET, FAIR ISLE, SHETLAND 1986

Date	----Sand	Eel----			-Gadoid/Clupeid-				---Fish spp.----			
	sm.	med.	lge.	n	sm.	med.	lge.	n	sm.	med.	lge.	n
25 July	2	7	0	9	2	7	1	10	4	1	0	4

APPENDIX 2

COMPOSITION OF DIET, BURRA ISLE, SHETLAND 1986

Date	Sand Eel No.	Sand Eel %	Gadoid/Clupeid No.	Gadoid/Clupeid %	Fish spp. No.	Fish spp. %	--Item-- No.	--Item-- %	n
21 June	2	50.0	2	50.0	0	0.0	0	0.0	4
28 June	10	100.0	0	0.0	0	0.0	0	0.0	10
2 July	0	0.0	0	0.0	2	100.0	0	0.0	2
4 July	1	25.0	3	75.0	0	0.0	0	0.0	4
11 July	0	0.0	8	47.0	9	53.0	0	0.0	17
12 July	0	0.0	6	54.5	5	45.5	0	0.0	11
16 July	0	0.0	9	60.0	6	40.0	0	0.0	15
17 July	0	0.0	7	100.0	0	0.0	0	0.0	7
18 July	0	0.0	3	100.0	0	0.0	0	0.0	3
19 July	1	10.0	6	60.0	3	30.0	0	0.0	10
22 July	0	0.0	15	93.8	1	6.2	0	0.0	16
28 July	0	0.0	1	100.0	0	0.0	0	0.0	1
Total	14	14.0	60	60.0	26	26.0	0	0.0	100

COMPOSITION OF DIET, MAINLAND VAGALAND, SHETLAND 1986

Date	Sand Eel No.	Sand Eel %	Gadoid/Clupeid No.	Gadoid/Clupeid %	Fish spp. No.	Fish spp. %	---Item--- No.	---Item--- %	n
30 June	6	50.0	6	50.0	0	0.0	0	0.0	12
9 July	1	9.1	8	72.7	2	18.2	0	0.0	11
15 July	4	20.0	13	65.0	3	15.0	0	0.0	20
18 July	9	16.4	32	58.2	14	25.4	0	0.0	55
21 July	5	15.2	19	57.6	9	27.3	0	0.0	33
27 July	1	3.8	18	69.3	7	26.9	0	0.0	26
Total	26	16.6	96	61.6	35	22.3	0	0.0	157

COMPOSITION OF DIET, SOUTH MAINLAND, SHETLAND 1986

Date	Sand Eel No.	Sand Eel %	Gadoid/Clupeid No.	Gadoid/Clupeid %	Fish spp. No.	Fish spp. %	--Item-- No.	--Item-- %	n
16 June	3	37.5	2	25.0	3	37.5	0	0.0	8
26 June	15	93.8	1	6.2	0	0.0	0	0.0	16
29 June	8	88.9	1	11.1	0	0.0	0	0.0	9
2 July	15	75.0	3	15.0	2	10.0	0	0.0	20
17 July	8	50.0	6	37.5	2	12.5	0	0.0	16
23 July	11	42.3	14	53.8	1	3.8	0	0.0	26
28 July	0	0.0	6	54.5	5	45.5	0	0.0	11
Total	60	56.6	33	31.1	13	12.3	0	0.0	106