BRENT GOOSE (*Branta bernicla* (L.)) WINTER FEEDING PATTERN AND ZOSTERA RESOURCES AT SCOLT HEAD ISLAND, NORFOLK

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Introduction

This paper describes work done in 1955-1958 on the feeding habits of Brent geese wintering in the Scolt Head Island Nature Reserve, Norfolk. The work was planned to find out if the *Zostera* food resources were adequate for the geese or if grazing was seriously reducing the *Zostera*. When it was found that the food habits of the birds were more varied than expected, it was decided that a study of the seasonal feeding pattern of the birds in more detail by regular field observation of their movements and by analysis of their droppings, would be worth while.

Historical Background

Wildfowlers and other bird watchers have frequently reported that *Zostera* is an important food of Brent geese in winter. Interest in the Brent goose was stimulated during the early 1930's when a "wasting disease" wiped out much of the *Zostera* occurring in extensive beds on European coasts and also on the Atlantic coasts of North America. The causes of the "wasting disease" are obscure, but the evidence suggests that a mycetozoan parasite *Labyrinthula* sp. was associated with the "disease" and for some unknown reason became especially active on North Atlantic coasts in 1931-2 (Cottam & Munro, 1954). Butcher (1941) reported that a decline in *Zostera* was noted on British coasts in 1920-22, though the greatest decline was in 1931 and 1932. In this country, *Zostera* was further reduced in amount, especially on south and east coasts, by the very rapid spread of *Spartina townsendii* H. & J. Groves on to the higher lying *Zostera* beds. In Norfolk and Essex the active spread of *Spartina townsendii* on to *Zostera nana* Roth and *Z. hornemanniana* Tutin areas is still going on.

The latest information on the recovery of *Zostera* beds (Cottam & Munro, 1954) shows that there has been a marked improvement in many areas especially in recent years. In Europe the best recovery of *Zostera* is said to be in the English Channel area. At Langstone Harbour, in Hampshire, for example, both *Z. nana* and *Z. hornemanniana* are actively colonising ground in shallow creeks from which they were absent a few years ago (Westrup, *in litt.*).

Cottam (1935) noted that American pale-breasted Brent geese (*Branta bernicla hrota* (Müller)) were actually increasing before the "disease" affected *Zostera*. Numbers had reached more than 250,000 birds before the 1930's, but had dropped to about 22,000 by 1935. Since 1935 there has been a recovery in numbers of American Brents and Cottam & Munro (1954) estimate that numbers in 1954 were again about 250,000. At Terschelling, West Frisian Islands, Holland, Brent geese were formerly at least three times more numerous than at the present time (maximum population 2,000), according to Morzer Bruijns (1955).

There is little information about numbers of Brent visiting the British Isles before or immediately after the onset of the *Zostera* disease. The only conclusion that can safely be drawn from the evidence is that numbers of Brent fluctuate widely from year to year in individual estuaries. There is some evidence that suggests that numbers of Brent visiting the British Isles are partly dependent on the severity of the winter. Chapman (1889) and recently Parish (1953-4) have pointed out that winters in which large numbers of Brent appear on the British coast are usually severe and may coincide with a freeze-up of the Baltic Sea.

Food of Brent

Campbell (1946) examined 12 stomachs from the Blackwater Estuary, Essex, and one from Sussex. *Enteromorpha* and *Zostera* (probably *Z. nana* and *Z. hornemanniana* from leaf measurements given) were the main foods in five of the stomachs from Essex and in the one from Sussex. Grasses, including *Festuca rubra* L. were the main foods in three of the stomachs from Essex. Small quantities of other algae, leaves of *Halimione portulacoides* (L) *Aell*, and seeds of *Armeria maritima* (*Mill.*) *Willd* occurred. One stomach from Essex contained over 40 *Hydrobia ulvae* (*Pennant*) and about 20 other molluscs not identified. Small quantities of Crustacea, *Idotea*

sp. and *Gammarus* sp. were found and thought to have been accidentally ingested with *Enteromorpha.*

Morzer Bruijns (1955) records that Brent geese at Terschelling fed mainly on *Zostera nana* in autumn but also on *Salicornia*, *Puccinellia*, and *Enteromorpha.* In midwinter when the *Zostera* and *Salicornia* died off, birds fed on *Enteromorpha.* In spring the birds fed on *Salicornia* and *Puccinellia* and were also seen on the highest saltings where *Armeria maritima* and *Festuca rubra* occurred. He states that in most cases the flocks of geese remain constant to one area.

Little is known of the food of European dark breasted Brent geese (*Branta bernicla Bernicla* (L.)) breeding grounds, but Turgarinov (1941) reports that they will feed on mosses and lichens on arrival, and later, in spring, on the young shoots of grasses.

Stomach analyses of American pale-breasted Brent collected before 1932 had *Zostera* as the main food. Analyses made after 1932 showed that algae formed the main food (Cottam *et al.*, 1944).

Lynch (see Cottam *et al.*, 1944, p. 48) examined 45 droppings of pale-breasted Brent in New Jersey in 1936 and found 60 per cent. green algae and 40 per cent. rootstocks of *Spartina* sp. in an area where *Zostera* and *Ruppia* were rare or absent.

The available evidence suggests that Brent geese of all races live on a mainly vegetable diet and that *Zostera* when obtainable is an important part of it. Green algae have been important foods at least since the 1930's and a variety of other plants are taken. Animals, including molluscs, worms, and fish eggs, are occasionally taken by individual birds.

Feeding Behaviour of Brent Geese

Witherby *et al.* (1943) recorded that Brent geese feed on *Zostera* beds when these are uncovered by the tide or covered by shallow water. *Zostera* is pulled up bodily, the roots being preferred, though to some extent the leaves are also eaten. The birds are mainly diurnal feeders but Chapman (1889) observed Brent geese feeding by moonlight. Burton (1957) reports that birds at Foulness, Essex, will feed at all states of the tide. He has observed that feeding habits vary according to the thickness of the plant cover. "In areas of thick *Zostera*, the Brent graze haphazardly, walking fast, and tearing up pieces here and there. Where it is thinner, they stop frequently, and spend some time thoroughly clearing an area of mud, taking rhizomes and everything. Looking at the mud afterwards, these areas can be picked out at once as they are 2 to 3 feet in diameter, and bare. In early autumn, they stand out as depressed regions containing short, bright green regenerated *Zostera*, amongst a general cover of older, dark coloured plants. When the *Zostera* is very thin, they walk straight along, not lifting their heads for long periods, clearing every piece in their tracks." He also notes that "Brent in Essex frequently eat bits of *Aster tripolium* L. when high tide forces them up to the edge of the salting."

Brent feeding on *Enteromorpha* appear to take food cleanly off the mud surface without ingesting much mud. Birds feeding on *Zostera* rhizomes ingest a good deal of mud, and Burton (*in litt.*) suggests they may eat gravel deliberately. This would help to grind up food and may even help to scour the gut free of tapeworms (Cottam *et al.*, 1944, p. 47). Plates I, A. & B, show Brent on the feeding grounds.

The Study Area

Scolt Head Island (Fig. 1) lies just below latitude 53° N. on the North Norfolk coast less than 10 miles from the mouth of the Wash. It is about half a mile wide and about four miles long and its long axis is roughly parallel with the coast. The higher parts of the island are covered by vegetated sand dunes which rest on a base of shingle. Lateral shingle ridges again capped with sand dunes project at intervals from the long axis southwards towards the mainland, and between them are salt marches developed on silt (see Steers, 1948, pp. 358-365). The island is separated from salt marshes adjoining the mainland by Norton Creek which dries in places at

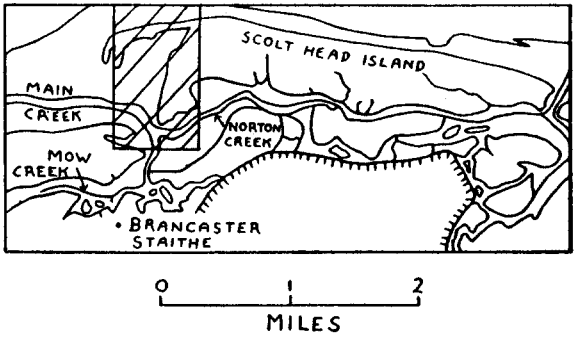


Fig. 1a. Scolt Head Island showing the study area (rectangle shaded diagonally).

low water. A large shallow bay near the western end of the island drains at low water exposing an extensive area of mud flats. This bay is known as the Cockle Bight.

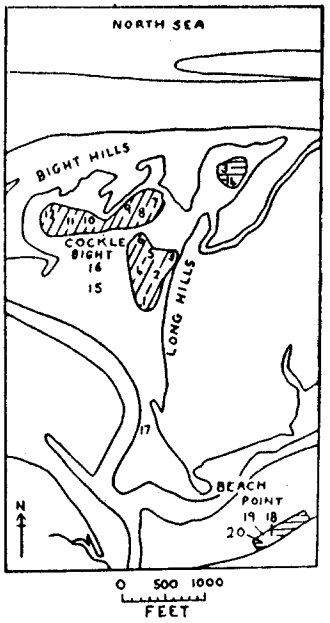


Fig. 1b. The study area showing known distribution of *Zostera* at Scolt Head Island on October, 1955. Diagonal shading shows pure *Zostera nana* areas, horizontal shading shows *Zostera hornemanniana* areas which also contain small amounts of *Zostera nana*. Numbers refer to sampling plots.

Present Food Resources at Scolt

The Cockle Bight is the main site for *Zostera* on Scolt Head Island, and contains about 18 acres (7·3 hectares) of *Z. nana* and about 2 acres (0·8 hectares) of *Z. hornemanniana* (Fig. 1). There are also about 2½ acres (1 hectare) of mixed *Z. nana* and *Z. hornemanniana* on the landward side of Norton Creek near its western mouth. In Mow Creek, less than half an acre (0·2 hectares) of newly developed *Z. nana* was found by R. Chestney in 1956.

About 23 acres (9·3 hectares) of *Zostera* are available to Brent in the Scolt Head Island area and the nearest outside sources are probably at Thornham Harbour five miles to the west and Wells harbour five miles to the east. Mr. R. Chestney, Warden of Scolt Head Island Nature Reserve, reports that Brent from the Reserve occasionally visit Thornham Harbour in hard weather, but for most of the winter they remain in the immediate neighbourhood of the Reserve.

Enteromorpha and other green algae are abundant round the shores of Scolt Head Island and on the adjoining mainland shores. *Puccinellia maritima* (*Huds.*) *Parl.*, *Aster tripolium*, *Halimione portulacoides* and other higher salt marsh plants are also generally abundant. *Zostera* is the least abundant food plant in the area.

Layout of Sample Plots

Plots 20 × 20 yards square were measured out for sampling purposes and these were marked at their corners with polythene tubing pushed on to steel rods.

Seventeen plots were laid out on *Zostera*. Plots 13 and 14 were only 10 × 20 yards and 5 × 20 yards respectively because most of the *Zostera* in this area was on deep liquid mud and only these smaller areas were accessible. Three plots (of full size), Nos. 15, 16 and 17, were also laid out on *Enteromorpha* beds (Fig. 1).

Zostera Cover Sampling by Point Method

The percentage cover of *Zostera* and bare ground was measured by placing a point (4 mm. diam.) 300 times in the plot area and recording whether *Zostera* leaves touched it or not.

The size of the point used over estimates the actual cover substantially (Fig. 2) but the method is rapid to use and quite satisfactory for measuring *changes* in cover which were the primary interest.

Zostera Standing Crop Weight Sampling Method

Some attempt to relate percentage cover results to standing crop weight of fresh green *Zostera* shoots was made outside the plot areas. The method was to lay down a 25 cm. square gridded into 100 smaller squares and estimate the percentage cover with the point placed once in each small square, and in addition, to obtain eye estimates of cover from two independent observers. The sample square was then dug up, the *Zostera* sieved free of mud and taken to the laboratory in polythene bags. The fresh shoots and green leaves were cut off, lightly blotted to remove surplus moisture, weighed fresh, and then weighed again after oven drying at 95°C. Seven of these samples were taken in *Z. nana* and one in *Z. hornemanniana*.

Standing Crop Weight of Zostera Available to Brent at Scolt

It was found that independent observers gave very close eye estimates of cover (± 5 per cent.)

using a gridded 25 cm. square quadrat. The point cover estimates plotted against eye estimates (Fig. 2) show that the point method grossly over-estimates the cover as estimated by eye. When

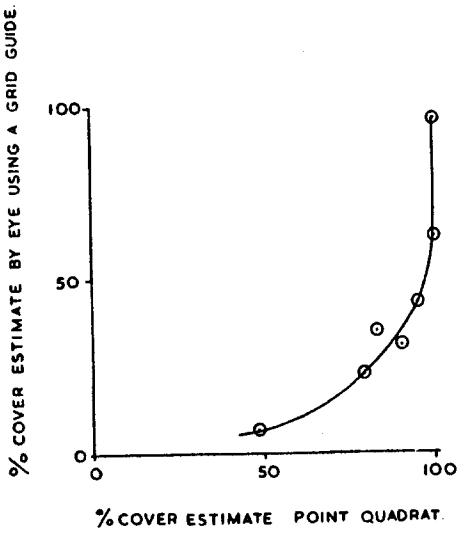


Fig. 2. Approximate relationship between eye and point estimates of *Zostera nana* winter cover—Scolt Head Island, Norfolk.

the eye estimates of cover are plotted against fresh weight of *Zostera nana* (Fig. 3), the graph closely approximates to a straight line passing through the origin. It is concluded in view of this, and the accuracy with which these estimates can be made by different observers, that eye estimates using a small grid would be a better method of assessing the actual *Zostera* cover than the point method. Some estimate of the standing crop of *Zostera* available to Brent geese at Scolt Head Island can be derived from the graphs by taking the average percentage cover of *Zostera* in the sample plots, converting this figure to the actual cover as estimated by eye and reading off the fresh weight. Since there is

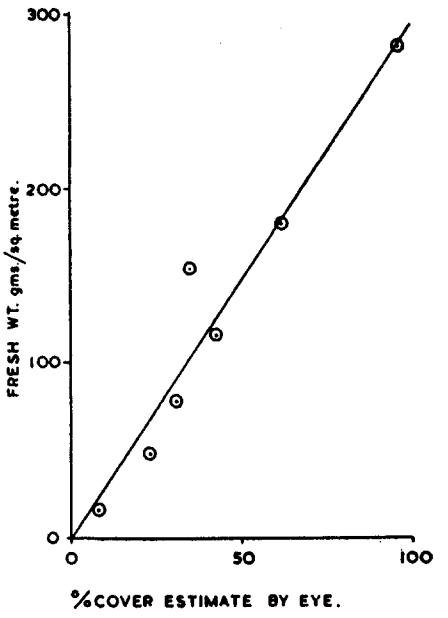


Fig. 3. Regression line showing relationship between eye estimate of cover and fresh weight of *Zostera nana* winter leaves and shoots in gm/sq. metre—Scolt Head Island, Norfolk.

only one sample from *Z. hornemanniana* and the *Z. nana* samples are also inadequate, the result must be considered as very approximate. The figure works out at approximately 12 tons (12·2 tonnes, metric) of fresh green winter leaves and shoots of *Zostera* available at Scolt Head Island in October of each of the two years 1955 and 1956.

Brent Numbers and Movements, and Zostera Changes in the Winter 1955-6

Counts of geese were made by Mr. R. Chestney on 55 days during the winter (see Fig. 4). His observations suggested that the main winter flock of about 200 birds fed in the Cockle Bight

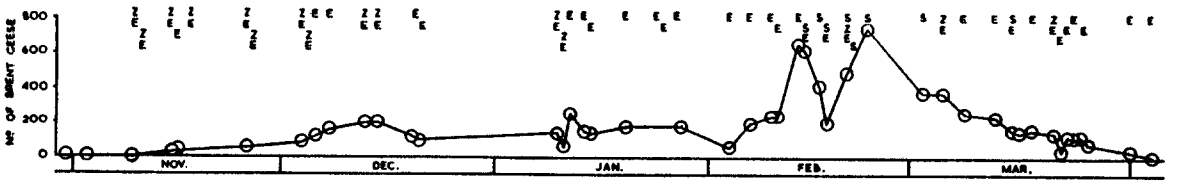


Fig. 4. Brent geese numbers and movements on feeding grounds at Scolt Head Island, Norfolk, in the winter 1955-6.

area on arrival and then worked round by Beach Point to Norton Creek by early January where they stayed for most of the winter. In late February and early March, birds visited the higher marsh.

Birds apparently fed in the main *Zostera* areas in November and December (flocks of 100-200 were seen near the Norton Creek *Zostera* bed on 4th, 7th and 12th December) when the winter leaves of *Zostera* were fresh. Since there is not sufficient *Zostera* in Norton Creek to support the large numbers of birds seen there through the bulk of the winter, it seemed likely that *Enteromorpha* was the main diet from December to February. Finally, the movement to higher marsh in late February and early March suggested that plants of the saltings were taken at the end of the winter. No unusual weather conditions occurred during the winter of 1955-6, except that the month of February was particularly cold.

The *Zostera* and *Enteromorpha* plots were measured in October 1955, before the geese had arrived and again in April 1956, just after the geese had gone. Results (Table I) showed that the October cover values for *Z. nana* plots had been reduced by about 70 per cent. during the winter and that in individual plots as much as 96 per cent. of the original cover had gone. The *Z. hornemanniana* had disappeared entirely and was re-colonising by newly germinating seedlings. *Enteromorpha* had been reduced in amount varying between 20-70 per cent. of the October cover values.

Table I. Point Estimates of *Zostera* and *Enteromorpha* Ground Cover in Sample Plots at Scolt Head Islands, Norfolk, at the Beginning (October) and End (April) of the 1955-6 Brent Goose Season. Losses of *Zostera hornemanniana* were probably mainly due to Wigeon grazing.

Species	Area	Plot No.	17th Oct., 1955 Estimates % ground cover	11th April, 1956 Estimates % ground cover
Z. nana	Cockle Bight South	1	53·4	13·8
		2	87·5	24·4
		3	61·9	31·9
		4	55·6	9·7
		5	65·0	11·9
		6	54·1	24·1
Z. nana	Cockle Bight North	7	81·3	14·7
		8	52·8	9·7
		9	56·3	14·7
		10	76·9	3·1
		11	83·4	9·1
		12	42·5	17·2
Z. hornemanniana	Cockle Bight Pit	13	67·5	7·8 (seedlings)
Z. hornemanniana		14	88·3	
Z. nana			2·5	29·7 (seedlings Z.H. & Z.N.)
Z. hornemanniana	Norton Creek (opposite Beach Point).	18	34·1	
Z. nana			5·3	0·6 (seedlings, Z.H. & Z.N.)
Z. hornemanniana		19	11·3	
Z. nana			15·6	5·0 (seedlings, Z.H. & Z.N.)
Z. hornemanniana		20	26·3	
Z. nana			2·5	5·3 (seedlings, Z.H. & Z.N.)
Enteromorpha	Cockle Bight South	15	84·7	30·3
Enteromorpha		16	78·8	36·9
Enteromorpha	Beach Point	17	89·4	70·0

These results give some idea of the changes occurring during a Brent season. Mr. Chestney observed that Brent rarely visit the main *Z. hornemanniana* bed (Plots 13 and 14). Wigeon have been observed feeding in this area, however, so the losses of *Z. hornemanniana* may be largely due to them. It is likely also that winter losses in *Zostera* are caused by frost and storm wave damage. Nevertheless, the combined action of grazing, frost and wave action had not by any means cleared the *Z. nana* areas completely during the winter.

Brent Numbers and Movements and Zostera Changes in the Winter of 1956-7

Counts were again made by Mr. Chestney on 20 days during the winter (Fig. 5). Birds were seen feeding at all states of the tide and in most cases on the *Enteromorpha* beds. They were not actually seen feeding on *Zostera*, but from the 18th-20th January a big flock of 600-800 birds was seen feeding on *Aster/Puccinellia* saltings when high spring tides had covered up the rest of the feeding grounds.

The pattern of seasonal movements of the birds on the feeding grounds during the winter was substantially the same as in the previous winter.

The winter was exceptionally mild and this was probably the reason the birds left a month earlier than in the previous winter.

Zostera and *Enteromorpha* plots were sampled in October 1956 and there was no significant difference in the aggregate amount of *Z. nana* recorded, from the previous estimates of October 1955. There was an overall loss of 13 per cent. in *Z. hornemanniana* plots, however, which was thought to be partly due to silting up in these *Zostera* areas as a result of the spread of *Spartina townsendii*. There was no significant change in the *Enteromorpha* plots.

Plots were resampled in December, at the beginning and end of a week's visit in an attempt to assess the intensity of grazing occurring at that season.

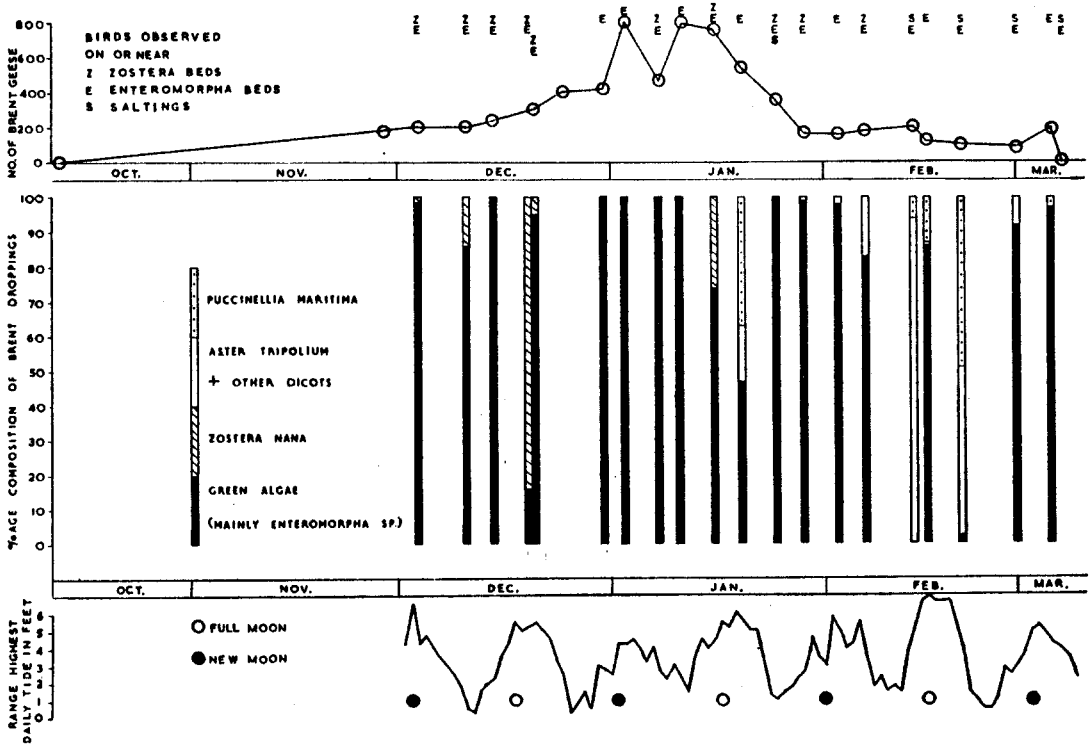


Fig. 5. Brent geese numbers and movements on feeding grounds at Scolt Head Island, Norfolk, in the winter 1956-7, together with the results of dropping analysis on 20 days. The bottom curve shows the range of highest daily tides recorded at Wells, 5 miles to the east of Scolt.

By 14th December, less than a month after the main flock had arrived, a 30 per cent. reduction in *Z. nana* cover and a 75 per cent. reduction in *Z. hornemanniana* cover had occurred. Actual gains had occurred in some *Enteromorpha* plots due to winter growth. On remeasuring the plots at the end of the week's visit in December, Plots 1, 2, and 3 on *Z. nana* had lost a further 18 per cent. of their cover. No significant changes occurred in other plots. There was no severe tidal action or frost during this period and fresh droppings of Brent geese containing *Zostera* were found during the visit, so it seems likely that losses recorded were mainly due to grazing by the geese.

These results again suggested that *Zostera* was eaten mainly during the early part of the winter.

Petrol rationing prevented resampling of plots in the spring, but Mr. Chestney reported on 26th February, 1957, that the *Enteromorpha* had been completely stripped from the plots and from most of the surrounding shores by the geese. By 8th April, regrowth had completely restored the cover. There was still some *Z. nana* winter growth left in the Cockle Bight when the geese left, as in the previous year.

Thus the result of this second winter gave further evidence of a distinctive seasonal feeding pattern of the birds, that *Zostera* was mainly eaten in the early part of the winter and that the *Zostera* resources were not fully used up at the end of the winter.

Brent Numbers and Movements in 1957-8

Mr. Chestney's records of movements on the feeding grounds (Fig. 6) showed again the sequence recorded in the previous two winters, but the geese went on to higher salt marshes in early January, nearly two months earlier than in the previous two seasons and they fed there regularly during most of January and February. Mr. P. Wayre (*in litt.*) noted that the Brent at Blakeney, Norfolk, also took to feeding on *Aster tripolium* and *Puccinellia maritima* on the higher saltings in January when they normally feed on *Zostera* and *Enteromorpha*. This change in behaviour could have been caused by a temporary failure in the *Zostera* and *Enteromorpha* resources due to over-grazing.

A visit in mid-March, 1958, showed that both *Enteromorpha* and *Zostera* resources were much depleted, while food on the higher saltings was generally abundant. Birds were seen feeding on *Enteromorpha*, *Z. nana* and *Aster* during the visit. Very little *Enteromorpha* was left and no *Z. hornemanniana*, but some *Z. nana* was still available in the Cockle Bight.

Analysis of Droppings

As plant fragments could be recognised in the droppings of Brent geese, samples were analysed at least once a week throughout the winters of 1956-7 and 1957-8 in order to follow the feeding, pattern in more detail.

Method

Three or four samples each of 5 to 10 droppings were taken on each sampling date. In the first year 60 samples collected on 20 days were examined. In the second year 109 samples collected on 30 days were examined. At least five sub-samples from each sample were examined.

Each subsample was dispersed in a drop of water by padding with a rubber-tipped glass rod on a microscope slide and examined under a cover-slip at a magnification of 90×.

Plate II A-D show the appearance of typical fragments in the droppings when photographed in their natural state, unstained and in water.

Content of Droppings

Results show (Table II) that the droppings in both years consisted almost entirely of vegetable matter and that green algae (mainly *Enteromorpha* spp.) formed the main constituent in each year. No trace of *Z. hornemanniana* was found in

Table II. Percentage Composition of Total Samples of Brent Droppings for Winters 1956-7 and 1957-8 at Scolt Head Island, Norfolk. (T=Trace only)

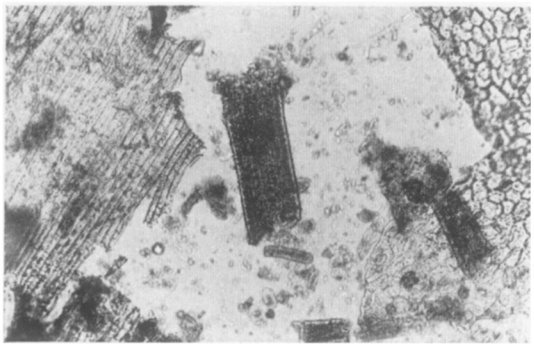
	Vegetable matter	Green algae (thallus)	*Zostera nana* (leaves & rhizomes)	*Aster tripolium* (leaves)	*Halimione portulacoides* (fruits and seeds)	Other dicots. (Mainly *Spergularia marginata*, *Armeria maritima*, and *Plantago maritima*) (leaves & stems)	*Pucinellia maritima* (leaves)	Animal matter
1956-7	100	79	6	10	0	T	5	T
1957-8	100	39	8	15	3	10	25	T

PLATE I

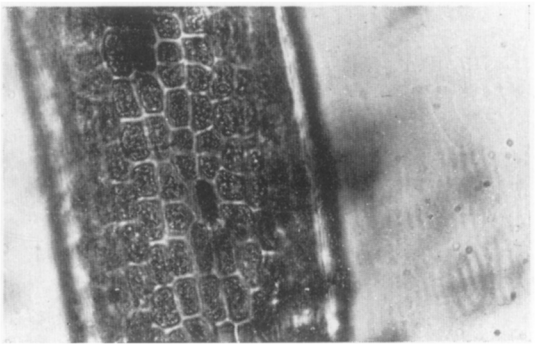
A. Brent geese feeding on mud-flats on the Norfolk coast. *(Photograph by Philip Wayre)*

B. Flock of Brent geese feeding on *Zostera* on the Norfolk coast. Note the thin layer of water on the mud surface which is often characteristic of Brent feeding grounds. On the extreme left is a clump of *Spartina townsendii*, a plant which is invading the *Zostera* feeding grounds at Scolt Head Island and Blakeney, Norfolk. *(Photograph by Philip Wayre)*

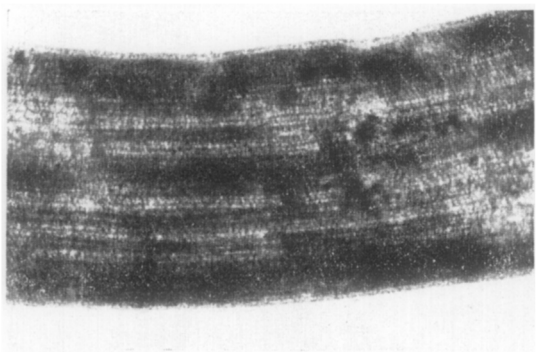
PLATE II



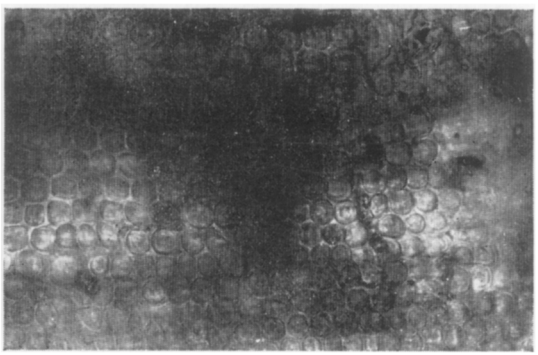
A. Typical sample of plant remains from a Brent goose dropping. On the left is a large fragment of *Puccinellia maritima* leaf tissue. In the centre is a small fragment of *Enteromorpha* sp. On the right is a large fragment *Aster tripolium* epidermal tissue showing stomata. × ·35.



B. Enlarged view of part of the *Enteromorpha* fragment shown in Fig. A. Note good state of preservation of cell contents after passage through gut of Brent goose. × ·180.



C. Typical leaf fragment of *Zostera nana* (showing the full leaf width of *c.* 1 mm.) from a Brent goose dropping. × ·35.



D. Enlarged view of part of *Z. nana* fragment from Brent goose dropping to show the characteristic rounded cells arranged in rows. Compare with Fig. B. × ·180.

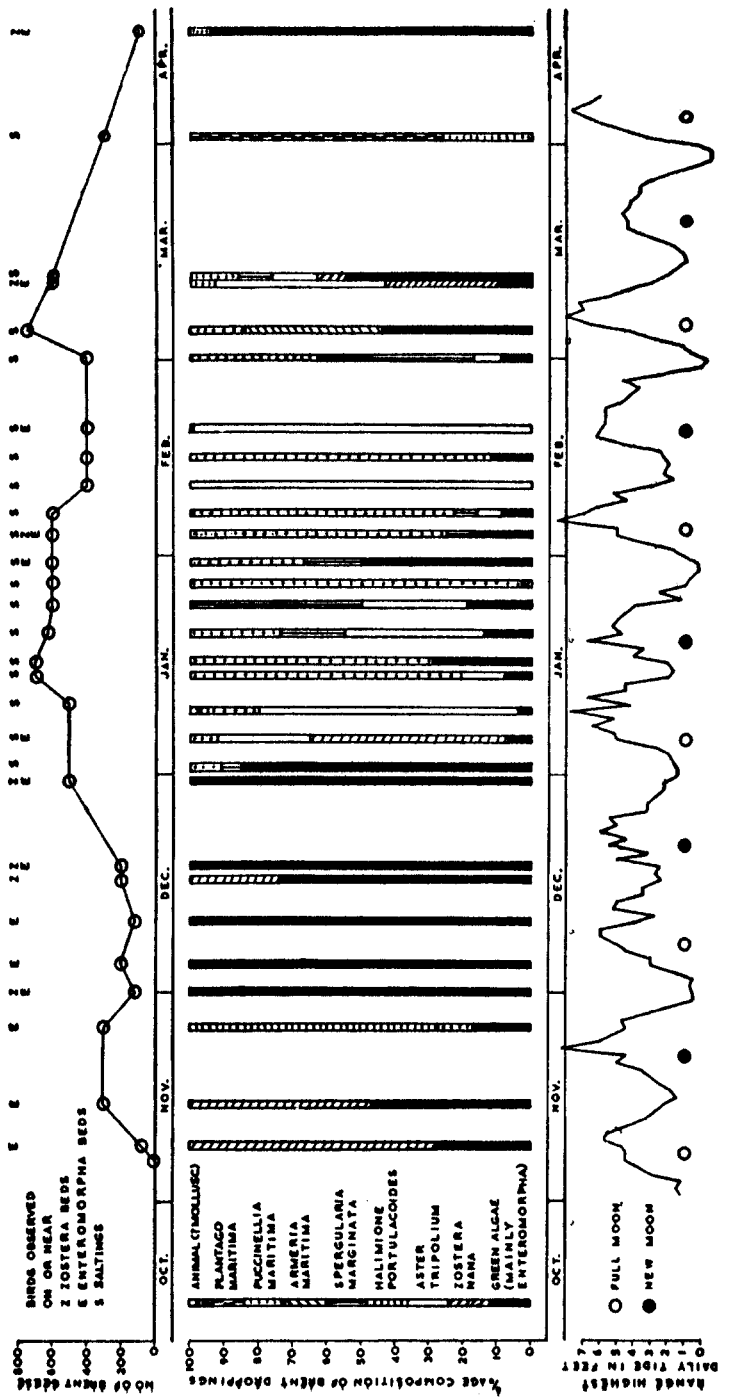


Fig. 6. Brent geese numbers and movements on feeding grounds at Scolt Head Island, Norfolk, in the winter of 1957-8, together with the results of dropping analysis on 28t days. The bottom curve shows the range of highest daily tides recorded at Wells, 5 miles to the east of Scolt.

any sample and *Z. nana* leaf and rhizome fragments formed less than 10 per cent. of the total.

Seasonal Patterns

The results condensed in Table III show that the monthly feeding pattern as indicated by dropping analysis for the two winters, 1956-7, 1957-8, is in accordance with seasonal observations of feeding. *Enteromorpha* and other green algae are main constituents of the diet throughout the winter and especially important in midwinter. *Z. nana* is taken mainly in early autumn, while higher salt-marsh plants, especially *Puccinellia maritima* and *Aster tripolium*, are taken in late winter and early spring.

The histograms in Figs. 5 and 6 give a graphic picture of the seasonal feeding pattern. There is considerable day to day variation, but nevertheless almost every daily sample in both years contains at least some *Enteromorpha* which emphasises its importance in the diet.

Feeding and the Tidal Cycle

High tides combined with an extended potential feeding period by moonlight seem to encourage the geese to feed most frequently on the higher saltings at full moon for these regions are then least disturbed by man.

Note on Dropping Samples from Other Areas

Dropping samples of Brent geese obtained from two sites in Hampshire and two in Essex (Table IV) suggest that *Enteromorpha* is an important food in other areas besides Scolt Head Island.

Brent Geese Feeding Trial

Conclusions drawn from dropping analyses are open to the objection that the proportions of remnants in the droppings may not reflect accurately the proportions of foods actually eaten. In co-operation with the Wildfowl Trust, Slimbridge, a feeding trial with Brent was carried out to obtain some experimental evidence on this point.

The objects of the trial were (1) to find out if Brent in captivity produced droppings similar to those of wild birds when fed on natural foods; (2) to discover how long food takes to pass through the gut of tame Brent geese, and (3) to find out if the proportions of plant remains in droppings reflect reliably the actual proportions of a mixed feed ingested.

Method

European Brent were not available, so four Pacific Brent (*Branta branta nigricans*) were used for the trial. These were penned on a small area (c. 10 × 15 feet) of close mown turf from which all droppings had been cleared.

A food mixture consisting of chopped leaves of fresh *Zostera marina* and *Aster tripolium* was prepared. The proportions of the two foods in the mixture were estimated by two independent observers by eye in 10 subsamples floated out in petri dishes over graph paper. All estimates agreed within ± 8 per cent. and the result indicated a mean composition of 84 per cent. *Zostera* to 16 per cent. *Aster*. The proportions in two of the subsamples were measured by laying out the fragments on graph paper and results agreed with the estimates within ± 7 per cent.

The food mixture was given to the birds in a pan at 8.30 a.m. and the first samples of droppings were collected two hours later and at intervals until 4.30 p.m. The birds were observed feeding on the mixture at 8.30 a.m., 12.30 p.m., and 1.30 p.m. They were very tame and were apparently encouraged to feed by the presence of people. In addition to the foods mentioned, the birds were offered fresh *Enteromorpha* and *Puccinellia maritima* after the mixed feeding trial and these were eaten in small amounts. Subsequently droppings were collected to see if fragments of these other foods could be recognised.

Results

The droppings collected from the Pacific Brent used in the trial were similar in appearance and consistency to those collected from wild Brent geese.

The shortest time taken for the mixed *Zostera*/*Aster* feed to pass through the birds was less than two hours.

The results of dropping analysis (Table V) showed that there was a background of grass feeding throughout the trial and without some bulk food of this kind, it seems doubtful if this kind of experiment could be carried out successfully and without upsetting the digestion of the birds. In every dropping sample containing the mixture, *Zostera* was present in substantially greater quantity than *Aster* and when more than 10 per cent. of the mixed feed showed up in the droppings, some trace at least of the *Aster* (less than one-fifth of the original diet) showed up. The mean proportions of the mixed feed showing up in 18 droppings was 91 per cent. *Zostera* to 9 per cent. *Aster* as compared with the mixture of 84 per cent. *Zostera* to 16 per cent. *Aster*

Table III. Percentage Composition of Brent Droppings indicating the Monthly Feeding Pattern for 1956-7 and 1957-8 at Scolt Head Island, Norfolk. (T = trace)

	Green algae (mainly *Enteromorpha*)		*Puccinellia maritima*		*Zostera nana*		*Aster tripolium*		*Halimione portulacoides*		Other dicots. (Mainly *Spergularia marginata, Armeria maritima, and Plantago maritima*)	
	1956-7	1957-8	1956-7	1957-8	1956-7	1957-8	1956-7	1957-8	1956-7	1957-8	1956-7	1957-8
NOVEMBER	—	47	—	3	—	32	—	0	—	18	—	T
DECEMBER	83	95	0	T	17	5	0	T	0	0	T	T
JANUARY	87	24	6	38	4	6	3	21	0	T	T	11
FEBRUARY	57	6	10	46	0	0	33	36	0	0	T	12

Table IV. Brent Goose Dropping Analysis of Samples from Foulness and Blackwater Estuary, Essex, and Langstone and Chichester Harbours, Hampshire, during Winter, 1957-8. (T = trace)

Site	No. samples	Date	Vegetable matter											Animal matter			
			Enteromorpha sp.	*Cladophora* sp.	*Ulothrix* sp.	*Polysiphonia* sp.	*Zostera nana*	*Zostera hornemanniana*	*Aster tripolium*	Other dicots	*Puccinellia maritima*	*Spartina* sp.	Total vegetable	*Hydroidea*	*Copepoda*	Unidentified animal	Total animal
ESSEX	12	9-2-57	93			7	T			T			100	T		T	T
	24	3-3-57	100						T		T		100		T		T
FOULNESS	16	16-3-57	96	1	T		T		T	T	T	3	100			T	T
	4	9-11-57	T				100				T		100	T			T
ESSEX Blackwater Estuary	6	15-2-58	79				21						100	T			T
HAMPSHIRE Langstone Harbour	10	17-11-57	100										100		T		T
	3	4-1-58	100				T						100		T		T
	39	21-2-58	100										100				
HAMPSHIRE Chichester Harbour	2	1-12-57	T				50	50					100				
	4	15-3-58	100				T						100		T		T

Table V. Dropping Analysis Results after Feeding Tame Pacific Brent Geese with an 84 per cent. *Zostera marina:* 16 per cent. *Aster tripolium* Feed at 8.30 a.m. on 21-11-57.

Time	Sample no.	Grass %	Zostera %	Aster %	Zostera as % of Z + A	Aster as % of Z + A
10.30 a.m.	+ D1	97	3	Trace	—	—
	+ D2	100	—	—	—	—
	D3	60	28	12	70	30
12.15 p.m.	D1	37	62	Trace	100	—
	+ D2	100	—	—	—	—
	D3	67	29	4	88	12
	+ D4	100	—	—	—	—
	D5	53	43	4	91	9
	+ D6	100	Trace	Trace	—	—
	D7	45	54	1	96	4
	+ D8	97	Trace	3	—	—
	D9	15	81	4	95	5
	D10	37	57	6	90	10
1.30 p.m.	+ D1	100	—	Trace	—	—
	D2	22	62	14	82	18
	D3	20	77	3	96	4
	D4	17	74	9	89	11
	D5	30	65	5	93	7
	D6	70	30	Trace	100	—
	D7	5	94	1	99	1
	+ D8	97	3	Trace	—	—
	D9	51	42	7	86	14
	+ D10	93	7	—	—	—
3.30 p.m.	D1	49	47	4	92	8
	D2	19	71	10	88	12
	+ D3	100	—	Trace	—	—
	D4	6	82	12	87	13
4.30 p.m.	+ D1	100	—	—	—	—
	+ D2	100	—	—	—	—
	+ D3	90	10	Trace	—	—
	D4	14	78	8	90	10
				Mean	91% Z.	9% A.

+Results ignored as droppings contain at least 90 per cent. grass.

actually ingested, giving an error of ± 7 per cent. This result supports the assumption that, for the foods given and under the conditions of the trial, food proportions indicated by analyses of droppings gives a good approximation of the food proportions actually ingested.

Enteromorpha, *Zostera marina*, *Puccinellia maritima* and *Aster tripolium*, were eaten by tame Pacific Brent during the trials and these foods were recognisable from fragments in the droppings even when eaten in very small amounts.

Nutritional Analyses

The results in Table VI are derived from analyses carried out by Mr. J. S. Leahy of the Nutritional Research Unit, Huntingdon, to whom our most grateful thanks are due. The results suggest that fresh *Zostera nana* leaves are about three times as rich in protein as fresh *Enteromorpha* thallus, while *Puccinellia maritima* and *Aster tripolium* leaves are intermediate in protein content. Fibre, as estimated by determination of the acid and alkali insoluble material is very low in *Enteromorpha* spp. and there is also relatively little carbohydrate other than algal cellulose. There is unlikely to be much silica in *Entermormorpha*, however, so the ash content will probably consist mainly of mineral nutrients and in this it is relatively rich. There is a higher ash content in *Zostera nana*, but what proportion of this is silica and what proportion mineral nutrient is not known.

Protein determination could not be carried out on the droppings as these would be heavily

Table VI. Nutritional Analyses of Leaf Samples of the Main Brent Goose Foods and of Droppings Derived from Them. Figures show composition as percentage of the fresh weight.

		Zostera nana	*Puccinellia maritima*	*Aster tripolium*	*Enteromorpha* sp
Moisture	(1) Fresh	74·6	76·6	88·6	93
	(2) Droppings	78·3	82·3	80·3	70·7
Fibre	(1) Fresh	1·38	1·17	1·06	0·33
	(2) Droppings	4·37	2·71	5·89	12·46
Ash	(1) Fresh	4·35	1·85	1·12	2·53
	(2) Droppings	7·67	3·58	8·96	22·92
Protein	(1) Fresh	6·43	3·09	2·30	1·98
Carbohydrate other than cellulose + any material not accounted for by analysis	(1) Fresh	13·14	17·29	6·92	2·16

contaminated with other nitrogenous substances which would give a falsely high protein value.

Fibre in the droppings was contaminated with grit and this will increase both the fibre and ash values above their true values. However, since some attempt was made to collect relatively grit free droppings, the results are probably roughly comparable and suggest that *Enteromorpha* droppings, unlike those derived from the other three foods, contain high amounts of indigestible material.

To sum up, the evidence suggests that *Zostera nana* has high nutrient value, *Enteromorpha* relatively low value except perhaps as a source of mineral nutrients, whilst *Puccinellia* and *Aster* are intermediate in protein content between these two species and probably lower than both in mineral nutrient content.

Discussion

The actual time spent on field work at Scolt Head Island was only 19 days during the period of three years covered by the study. The much more frequent field observations made by Mr. Chestney, Warden of the Scolt Head Nature Reserve, are of great value. Records of this type in which not only bird numbers are given, but also what they are doing, *exactly* where they are, the state of the weather and tide, etc., become significant when supported by studies of food availability and droppings analysis. Campbell (1946) has emphasised the importance of adequate food surveys in understanding the significance of stomach analyses. It is also of great importance to know just how far local flocks range in their foraging. Burton (1957) has noticed that certain flocks can be picked out by a constant size and constant proportion of adult to first winter birds, and that some flocks of Brent move about and mix with other flocks much more than others. Observations suggest that the Scolt flock does remain constant to the area, but further observations on these lines are required. Critical observations of the feeding habits of Brent are not easy to make and the careful description given by Burton and quoted above is an excellent example of what is needed.

A point that emerges from this work is that Brent do not take *Zostera nana* whenever it is available so far as the tides are concerned. This might be due to human disturbance in the Cockle Bight area or it might be that the birds have a real preference for *Enteromorpha*. Whatever the explanation, the fact remains that considerable quantities of *Zostera* were left uneaten at Scolt when the birds were feeding in close proximity to it on *Enteromorpha*, and that some winter growth of *Zostera* was still present when the geese left in spring. The observations suggest that choice of food is determined more by the state of growth at different seasons of a variety of food plants rather than by a special preference for any one of them. The three main types of food, *Zostera*, *Enteromorpha*, and higher salt-marsh plants, are favoured in the diet during the season when each is in its most active growth

phase, autumn, midwinter and late winter to early spring respectively.

The results show also that the diet of British Brent geese is considerably more varied (in the Scolt Head area at least) than is generally supposed. In particular, the importance of *Puccinellia maritima* and *Aster tripolium* in the diet has not hitherto been recognised.

The dropping samples from Essex, together with Campbell's results of stomach analyses (1946, see p. 230), suggest that the feeding pattern of Brent in other parts of the south-east coast of England may be similar to that found at Scolt Head. Observations of wildfowlers and bird watchers, together with our results of droppings analyses from Hampshire harbours, suggest that Brent on the south coast have a much more restricted diet, for they are rarely, if ever, seen on the higher saltings. These saltings are much less extensive than in east coast areas as a result of reclamation and the spread of *Spartina*. They are also more subject to human disturbance. These two factors must restrict the Brent to the more remote *Zostera* and *Enteromorpha* zones.

The remarkably fresh state of preservation of plant fragments in Brent droppings is of great interest. Much of the plant tissue is intact and apparently very little damaged. Sturkie (1954) states that birds digest considerably less crude fibre than mammals, so it may be that they rely principally on mechanical crushing in the gizzard rather than on enzymes to break down cell structure, a process which does not seem to be particularly efficient in the Brent goose. Incidentally Ingram (1933) makes the interesting observation that sheep and cattle grazing on the Islands of Coll and Gunna eat the droppings of geese (principally Barnacle geese) in spring when the surrounding turf is short, and apparently derive considerable nourishment from them.

Nutritional analyses of the fresh foods have given some indication of their relative food value. Owing to contamination with grit, analyses of droppings of *Enteromorpha*, *Zostera*, and *Aster*, cannot really be compared with the fresh foods. However, *Puccinellia* droppings from the high marsh were relatively grit free and these show that proportions of crude fibre and ash in the droppings are very little different from those in fresh *Puccinellia*. This supports the view that these birds digest little crude fibre and rely mainly on mechanical crushing of cells in the gizzard.

The results of droppings analyses are open to the criticism that soft bodied animals eaten would not be detectable in the droppings. Also, proportions of plant remnants in the droppings may not reflect accurately the proportions of plants actually eaten.

There seems to be little evidence from stomach analyses carried out by other workers that animals form a significant part of the Brent goose's diet. However, exceptions have been quoted showing that animals are sometimes taken, and further field observations and stomach analyses are needed.

The second criticism, concerning relative digestion efficiency for different plants also requires further study.

Our own results using tame Pacific Brent were encouraging, however, and certainly lent support to the view that intake food proportions and remnant proportions in the droppings are reasonably closely related though of course this may not be so in wild birds. It was particularly encouraging to find that birds of this type with highly developed social behaviour should be amenable to the condtions of the experiment and that their digestion was not apparently upset by it. Storey (1957) has noticed that in his collection of pink-footed, white-fronted and greylag geese that, "there was a considerable difference in the stools of the captive birds from those in the wild state . . . greylag (and two Canada) geese who were free winged and flighted round the countryside produced stools much closer resembling the natural droppings than their pinioned fellows although they frequently took most (if not all) of their feed in the field where the collection was kept." Storey also noticed that there was a difference in composition of droppings during different seasons and particularly during hard weather and immediately preceding hard frosts.

Results of the droppings analyses taken in conjunction with the field observations of the feeding habits of the birds at Scolt, point strongly to similar conclusions about the seasonal feeding pattern of this flock. This fact, together with the experimental evidence, certainly strengthens the view that analysis of droppings on the lines carried out can give a reliable indication of the food actually eaten by Brent geese. If further evidence can be gained supporting this assumption, dropping analysis should prove a valuable tool in further investigation of the feeding habits of these, and other birds. Beyond occasional observations of actual

feeding, our knowledge of Brent food in this country depends on a total sample of 28 birds' stomachs. Only 13 of these stomachs were taken from Brent on the English coast. The dropping samples from Scolt and elsewhere, even though they may not reflect with great accuracy the proportions of different food actually ingested, do seem to indicate the chief food plant taken at any time, and the total of over 250 samples must have come from at least 300-400 birds.

Finally, it is worth pointing out that this approach allows a good deal of information to be obtained about feeding without killing any birds and has the additional advantage that the same flock can be sampled again and again with minimum disturbance to the birds.

Summary

1. Fluctuations in numbers of Brent geese in relation to their food supply is discussed.

2. At Scolt Head Island, Norfolk, *Enteromorpha* species are the main food of Brent geese, and *Zostera nana*, although locally abundant, is not always eaten when the tides make it available.

3. Study of feeding habits supplemented by analysis of food remains in the droppings of the geese suggest that there is a distinct seasonal pattern of feeding correlated with the main growth periods of the different food plants.

4. Evidence is given which suggests that the diet of Brent geese may be much more restricted in Hampshire harbours than it is in Norfolk and Essex.

5. A feeding trial carried out on tame Pacific Brent (*Branta branta nigricans*) at the Wild-fowl Trust, Slimbridge, showed that analysis of the droppings gave a good approximation ($\pm$10 per cent.) of the proportions of food actually ingested.

6. Nutritional analyses of the main foods of Brent geese and of droppings derived from these foods are reported.

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