RECENT RESEARCH ON BRENT GEESE

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FOR many years the status of the Brent Goose (*Branta bernicla* (*L.*)) has caused concern because of a marked decline in numbers in most parts of its range. Strenuous efforts by bird protection organizations in most countries of north-western Europe intended to obtain or increase legal protection for the species have achieved some success and have been accompanied by detailed investigations into the present and past distribution of the bird. The first part of this review consists of an abstract of a lengthy report on the status of Brent in Europe by Dr. Finn Salomonsen, published late in 1958.

Alarming changes in numbers have occurred in the American populations of Brent too. They have provoked vigorous investigations and the second part of this review deals with a major paper on the Pacific coast population by Henry A. Hansen and Urban C. Nelson. The final section is an attempt to synthesise results from the two papers already mentioned and from work by P. J. K. Burton and Russell Marris, in order to assess the prospects in Europe during the next few years and to suggest lines for research.

I. The Present Status of the Brent Goose (Branta bernicla (L.) in Western Europe.

This report, by Dr. Finn Salomonsen of the Zoological Museum, Copenhagen, was published in *Videnskabelige Meddelelser fra Dansk Naturhistorisk Forening*, vol. 120, pp. 43-80, in November 1958 and has been issued as a separate reprint as Publication No. 4 of the International Wildfowl Research Bureau[1]. It summarises investigations made since 1954 by collaborators in many countries working with the International Committee for Bird Preservation through the agency of the I.W.R.B. The evidence for Great Britain was in the form of: a) a historical survey of the literature concerning abundance and distribution from the early 19th century to 1953 by G. L. Atkinson-Willes; b) results of the Wildfowl Counts scheme since 1948; c) results of aerial surveys of south-east England in 1955, 1957, and 1958. Other British evidence was supplied by P. J. K. Burton (detailed counts on the east coast, including age class ratios), Dr. D. S. Ranwell, of the Nature Conservancy (studies of *Zostera* distribution and the effects of grazing by Brent Geese), and Russell Marris.

The abstract which follows here is somewhat selective, reporting most fully those findings of particular interest to British readers, but tries to present only the facts used by Dr. Salomonsen and the inferences and opinions he bases on them. The status of the Brent in Britain was the subject of heated arguments prior to the passage of the 1954 Bird Protection Act, and it would be foolish to reanimate those sterile historical disputes by quibbling about the interpretation of some data of merely subsidiary interest.

The Brent Goose is a circumpolar breeding bird restricted to the Arctic zone in summer and wintering in coastal waters of the temperate regions of Europe, Asia and America. The species is divided into three (or possibly four) sub-species. The Light-bellied[2] Brent (*B. bernicla hrota* (O.F. Müll.)) is a

[1]Obtainable from the headquarters of the Bureau, c/o British Museum (Natural History), Cromwell Road, London S.W.7, price three shillings.

[2]Dr. Salomonsen uses the English forms " Pale-breasted " and " Dark-breasted," but in this paper " Light-bellied " and " Dark-bellied " are substituted, in accordance with Trust practice.

high-arctic form breeding in the Arctic Archipelago of Canada, Ellesmere Island, North Greenland and east to Spitzbergen and Franz Josef Land. It is replaced by the Dark-bellied Brent (*B. b. bernicla* (L.)) in north Russia and west Siberia to the Taimyr peninsula. Further east the Brent becomes darker, reaching an extreme in the Bering Strait population, the Black Brent (or Black Brant in American usage), *B.b.nigricans* Lawrence. *Nigricans* and *hrota* overlap in western Canada, the two forms breeding side by side over an etxensive area, without mixing. Brents wintering in Europe come from three widely-separated breeding populations: 1) light-bellied from Canada and Greenland, 2) light-bellied from Spitzbergen and Franz Josef Land, and 3) the whole dark-bellied population.

Dr. Salomonsen finds that Ireland is the only important European wintering-place of Brent from Canada and Greenland. On passage these geese may stay for some time in West or S.E. Greenland or S. Iceland, some arriving in Ireland in the middle of September but the majority in October. During the winter there is a partial shift from localities in the west to others in the east of Ireland, with a very few birds moving on to the Hebrides, the Firth of Clyde and the coasts of Wales. This population stays in Ireland till the latter part of April, or sometimes May, and visits Iceland and S.E. Greenland on the northward migration, the breeding places not being re-occupied until the first half of June.

Light-bellied Brent from Spitzbergen and Franz Josef Land migrate south in September, to Denmark. Some may rest off the south of Norway but most do not stay long, and very few winter, though in icy winters numbers in Norwegian waters may be increased by an influx from Denmark. Most of this population remains in Denmark, mainly in the north, at least until January-February. In hard weather some may then move to the east coast of Britain, especially Northumberland. Some indication of the mid-winter movements has been obtained from recoveries of geese ringed in Spitzbergen in 1954 (see Goodhart, Webbe and Wright, *Wildfowl Trust Seventh Annual Report,* pp. 17-176 (1955)), as well as from observations. These visitors to Britain usually leave again before the middle of March, returning to Denmark, where the population remains until late May. Formerly Light-bellied Brent were plentiful in eastern Scotland and Salomonsen supposes that these were 'European' rather than from Greenland. At present Brent are few and transitory in Scotland.

Professor S. M. Uspenskij has provided a valuable statement on the present breeding range of the Dark-bellied Brent: "It breeds and moults particularly in the north-eastern part of West Taimyr and in smaller numbers on Kolguiev Island, North Yamal above 70°N. lat., (but is missing from Belij Island), in the north-easternmost part of the Gydan Peninsula, in the southern part of Severnaya Zemlya and on some small islands in the Kara Sea. In Novaya Zemlya only moulting, not breeding birds, occur, according to the most recent investigations. Likewise, on the Kanin and Kola Peninsulas only moulting birds are found. The total population of this subspecies amounts to at least 10,000 birds, according to various censuses carried out in recent years during spring migration on the Kanin Peninsula. This subspecies is replaced by the Black Brent from eastern Taimyr (from about Lake Taimyr) eastwards. All Black Brents migrate to the East and do not visit Europe."

The Dark-bellied Brent leave their breeding grounds in September and migrate along the North Russian coast, cross overland from the White Sea to the Finnish Bay, and move by way of S.W. Sweden to southern Denmark. Though the ranges of pale and dark birds overlap in Denmark there is no considerable mixing. Some dark-bellied birds remain in Denmark but the bulk cross Jutland to the Wadden-See and then move west along the coasts of Germany, Holland and Belgium to S.E. England and France. The visitors to England begin to arrive in quantity in mid-November. Their numbers increase in December and sometimes again in January or even February. Some dark-bellied birds move slowly northward, meeting light-bellied birds. A few have been shot on the north-west coasts of England, implying that flocks sometimes fly overland. The greater part of the British population has gone by mid-April, the dark-bellied birds moving to Holland, Germany and Denmark, where they stay until the end of May.

Dr. Salomonsen draws attention to several important features of the migratory movements of Brent in Europe: 1) the birds are constantly on the move, even in February, when they have reached their final destination, searching for new feeding places; 2) their movements are strongly dependent on the weather, in cold winters their more easterly quarters (Denmark, Germany and Holland) being largely deserted in favour of England and France; 3) the three populations " wintering in European waters occur in distant areas, as if trying to avoid each other. Having identical food requirements they strongly compete for the available resources, and the spatial segregation in the winter grounds is an important factor in avoiding competition."

He emphasises that the midwinter shifts make it difficult to estimate the size of the wintering population and continues " It is necessary, therefore, to limit the counts strictly to the severe winter months (January, February) and, if possible to use average values for a number of consecutive years." With these working assumptions he proceeds to assemble, in the course of seven pages, estimates of the midwinter population which are summed up in Table I (Salomonsen's Table III, for the Dark-bellied form, together with his figures for the two Light-bellied groups).

" In order not to be accused of painting the situation too black, I have everywhere tried to estimate the decrease conservatively and used the maximum figures." " Paying attention to all sources of error we suggest that the European wintering population of Dark-bellied Brent is **not** lower than 15,000 and certainly not higher than 16,500."

Perhaps the most controversial of Dr. Salomonsen's inferences is that at the end of the nineteenth century, the total population of Brent wintering in Europe must have been 350,000 birds, about 216,000 of them Dark-bellied. These figures were arrived at by supposing that the decreases recorded from localities that have been reported on in some detail during the last eighty years are representative of the whole range. His data further suggest that the decline has continued over a long period, so that by the early 1930's the numbers were only about half of what they had been fifty years earlier, and that " since about 1935, the decline has accelerated alarmingly."

Enquiring into the probable causes of the decrease Dr. Salomonsen considers six factors that might be supposed to militate against the Brent:

TABLE I

Present wintering populations of Brent Geese in Europe, **in January/February,** according to data assembled by Salomonsen.

	Dark-bellied (from Siberia)	Pale-bellied (from America and N. Greenland)	Pale-bellied (from Spitzbergen & Franz Josef Land)
Denmark	1700	—	1300
Germany	2200	—	—
Holland	1500	—	—
France	3700	—	—
England	7400	—	2700
Scotland	—	(200)	—
Ireland	—	6000	—
Total	16,500	6000	4000

disturbance of breeding haunts, land reclamation in wintering places, industrialization, the effects of aircraft, over-shooting, and a widespread disappearance of eel-grass (one of the Brent's food plants). The latter is probably not, though the others certainly are, due to man.

Disturbance of the breeding haunts, though it may have had serious local effects in Spitzbergen, is thought not to be a primary cause of the decrease. The Light-bellied birds wintering in Ireland breed in countries almost wholly uninhabited by man, yet this population has decreased with the others; and in other areas disturbance has tended to diminish.

Land reclamation has certainly deprived Brent of some feeding places in Denmark, Germany and Holland, but probably not in France and England (where reclamation was largely accomplished prior to the decrease).

Though industrialization may have caused Brent to leave some areas (e.g. Teesmouth) and bombing ranges and low flying aircraft have apparently made others untenable, Salomonsen notes that there is little positive proof of their ill effects and does not attribute to them a major share of the damage.

It was until recently usual to maintain that the drastic alterations in the distribution and abundance of eel-grass (*Zostera marina*) which occurred in the early 1930's, and from which its recovery is far from complete, were of great importance to Brent. But studies of the feeding habits of the geese made in several countries have shown that they can do without this food and Salomonsen concludes that " the disappearance of the eel-grass did effect the life of the Brent, but has not essentially contributed to its decrease apart from the first years following the disappearance, in which period the number of Brents drastically declined in many places."

On the role of shooting Salomonsen says: " During my work with the Brent problem I could not avoid the impression that shooting in the winter quarters was one of the principle causes of destruction. Many instances could

be cited of species which, being easy victims for hunters, have been completely wiped out, such as the Labrador Duck and the Eskimo Curlew. The Brent might have had the same fate, but has been saved until now, because of its extensive breeding range and its extreme mobility in winter. Shooting pressure became too heavy as early as in the middle of the 19th century, when the decline commenced. All North European nations contributed to the development, but the greatest number of Brents were shot in the British Isles."

Salomonsen makes a number of suggestions concerning protective measures. He notes that attempts to oppose development plans of great economic importance will be fruitless, but that fights against the erection of military establishments may not always be futile, citing the recent success of the I.C.B.P. in securing the abandonment of the R.A.F. bombing range on the Knechtsand in N.W. Germany, the moulting place of most European Shelducks. He continues " Establishment of bird sanctuaries and reserves in suitable places along coasts will render good service for the preservation of the Brent. Most European countries possess a number of such coastal preserves which have strongly contributed to assure the present existence of the Brent in our continent. What really matters, however, is more extensive protection against shooting. This has restored the stock of other large and highly vulnerable wildfowl, like swans and the Shelduck, and in the case of the Brent protective measures form the most urgent demand. It must be required as a minimum that in all countries shooting ceases at 1 January, giving the Brent a chance for survival in the hardest winter and offering it a necessary resting period without disturbance before the final spring migration. It would be only a half measure, however, and would require a very long period before the species was restored. Full protection, therefore, is needed, and should be granted for at least 10 years in all countries in which the Brent spends parts of the year. A more prolonged period than 10 years would, naturally, be better, but for political reasons would be difficult to accomplish. It is also a question of international justice; some nations ought not to reap the fruits which are the results of sacrifices made by other nations."

TABLE II

Close Time for Brent in those European countries frequented by considerable numbers of the species. (Abridged from Salomonsen's Table IV).

Country	Close Time
Belgium	All year round (since 1956)
Denmark	1 January-31 July (for ten years, since 1954)
Iceland	1 November-19 August
Eire	1 March-11 August
Finland	1 March-19 August
France	31 March-14 July
W. Germany	1 April-31 July
Great Britain	All year round (since 1954)
Northern Ireland ..	All year round (since 1954; for 3-year periods)
Holland	All year round (since 1950)
Norway	1 March-31 August, and 24-31 December
Spitzbergen	All year round (since 1955)
Sweden	All year round (since 1957)
U.S.S.R.	Varying, open season in autumn only

Table II adapted from one provided by Salomonsen shows the present extent of legislative protection afforded to the Brent in those countries which harbour considerable numbers in winter, or on migration. It shows that though considerable increases in protection have been achieved in recent years, loopholes remain in four important countries—Denmark, West Germany, France and Eire. " In both Denmark and Germany proposals for full protection have been submitted to the Government recently, but as yet without result."

Dr. Salomonsen has dealt admirably with a mass of data, full of gaps and inconsistencies, to produce a clear and plausible account of the status and movements of Brent in Europe. He is convinced that continued pressure towards increasing protection on the winter quarters is the best way to " check the decline and let the population grow to a reasonable height." This raises two important questions: Would further restrictions on shooting bring about the necessary change? And what is a " reasonable height "? If firm answers, fully supported by incontestable evidence, to these questions were available, much controversy could be avoided. They are not. But a good deal of relevant evidence, not considered by Dr. Salomonsen, does now exist and will be assembled at the end of this review.

II. **Brant of the Bering Sea—Migration and Mortality,** by Henry A. Hansen and Urban C. Nelson, of U.S. Fish and Wildlife Service, Juneau, Alaska

Transactions of the Twenty-second North American Wildlife Conference, pp. 237-256 (1957).

Since the Pacific coast population of the Black Brant has been affected by massive changes in numbers in much the same way as the Brent of Europe, the U.S. Fish and Wildlife Service has devoted considerable effort to nesting studies in Alaska and to inventories of the population in its winter quarters. This research programme has continued since 1949 and the paper by Hansen and Nelson is the first report on its progress to be made generally available, except for a preliminary account of nesting-ground studies by Spencer, Nelson and Elkins in 1951 (America's greatest Goose-Brant nesting area, *Trans. 16th N.A. Wildlife Conference,* pp. 290-295).

Breeding studies. The nesting area studied comprises a strip of about 800 square miles along the coast from Igiak Bay to the south of Nelson Island (between the deltas of the Yukon and Kuskokwim Rivers, from about 62°N, 166°W to 60°N, 163°W). Here Brant nesting densities reach as high as 144 nests per square mile in parts of the zone three to five miles from the coast. A study by S. T. Olson in 1951 showed that nesting commenced in the last week in May and the peak of the hatch occurred from 25 June to 7 July. 97 (79%) of 123 nests studied hatched successfully. The average clutch size, in 116 nests, was 3.5 eggs. In 1951 average brood size decreased from 3.8 (sic.) during 17-24 June to 3.2 young during 2-11 July. In 1954 the average size of 34 Class I (recently hatched) broods was only 2.26 young, that of 159 Class II (half-grown) broods 2.01, and of 31 Class III (newly-fledged) broods 1.71. Individual brood identity is often obscured by the mixing and grouping of broods.

Migration. Between 1949 and 1954 3,440 adult and 5,364 ' local ' (gosling) Brant were ringed in the study area. Recoveries of these birds, numbering 767 (10.2%) up to the time the data were assembled in 1956, have provided

a great deal of information on migratory movements, and also on mortality. On migration the Brant move south to Bristol Bay and the tip of the Alaska Peninsula in the latter part of August and early September. There they stay until about 1 October, when they fly off to the southeast across the open ocean. " The mass arrival and exodus is sometimes great enough to permit radar tracking of the flock." " Where this flight later makes landfall on the coast is not known, but it is probable that it stays well off the coast at least as far south as Puget Sound. Possibly most of the flocks do not stop on land until they arrive in California." (Puget Sound, in north-west Washington, near the Canadian border, is at least 1700 miles from the Alaska Peninsula, and Humboldt Bay, the most northerly of the Californian wintering places, at least 1950 miles). Some Brant follow the coastline of Alaska and British Columbia but they are only a small minority, perhaps the birds which regularly winter off Vancouver Island and in Puget Sound. James Moffitt pointed out nearly twenty years ago that the earliest arrivals move right on through to the southern wintering grounds in Baja California (Mexico), the winter residents of California not arriving until 10-20 November, a month later.

The spring migration is much more leisurely and there are few ring recoveries to chart its course, but there is no mass arrival in Alaska, so that " it is unlikely that a major flight proceeds north across the open ocean, and more probable that the Brant follow closer to the shoreline in smaller flocks."

There is strong evidence from recoveries that geese in adult plumage are shot more often in the north of the winter range than would be expected from the numbers wintering there. This seems to result from pre-breeders performing shorter migrations than members of families. (Dr. Arthur S. Einarsen, Leader of the Oregon Co-operative Wildlife Research Unit, who is at present conducting an intensive study of Black Brant, has collected additional evidence of differential migration, which he hopes to publish soon).

A more puzzling example of differential movements is provided by 28 recoveries from the north coast of Alaska and the MacKenzie Delta (North West Territory of Canada), most in June or July, because " at least nine of the 28 were taken during full maturity while wandering far north of their natal grounds." Such movements are common amongst pre-breeders of various species, but that they should be indulged in by sexually mature geese raises important questions about " non-breeding."

Population size. A part of the Brant investigations of especial interest for comparison with work on the European population is the annual winter inventory, carried out in January. " Of the waterfowl wintering in the Pacific Flyway, many technicians consider that the Black Brant is the easiest species for which complete and reasonably accurate winter inventories can be made by aerial count because of its social behaviour and reaction to low flying aircraft." Since 1951, counts have been made for the entire wintering grounds, excepting the Aleutian Islands (almost certainly of little importance as a wintering place). Complete counts are not available for Baja California, nor for British Columbia before 1951, but British Columbia normally winters relatively few Brant. The annual January inventories have produced the following totals: 168,000 in 1951; 167,000 in 1952; 155,000 in 1953; 132,000 in 1954; 135,000 in 1955; and 110,000 in 1956. (Figures from Table 3 of

Hansen and Nelson, rounded to nearest thousand, and omitting totals for 1949 and 1950 which included estimates, rather than counts, for Baja California). It is important to note that according to the 1957 Status Report for Waterfowl (U.S. Fish and Wildlife Service Special Scientific Report—Wildlife No. 37) the decline of the Black Brant population was abruptly reversed, raising the population to the order of 140,000 in January 1957 (reviewer's calculation from index figures).

Hansen and Nelson also refer to the Black Brant censuses in California organised by James Moffitt in the years 1932 to 1942. These censuses (nearly complete for the state, but probably including only 20 to 40% of the total Pacific coast population) showed wide variations, from a low of 13,800 in 1933 to a peak of 125,150 in 1935, with an eleven-year average of 57,400. The authors remark that " It does not appear likely that the low count in 1933 was due to a major part of the normal California population wintering beyond the boundaries of the state . . . " because in their view the numbers in California and Baja California move synchronously. They suggest " Rather, in light of the recent production study on the Yukon-Kuskokwin Delta, it would seem that the entire annual production for one or more years had been wiped out." It is interesting to note, however, that the 11-year high in Moffitt's California censuses followed by only two years the drastic low of 1933, indicating the potential revival of the species on one or two good production years."

The Fish and Wildlife Service has also made winter inventories of the Atlantic coast population of the Pale-bellied Brent. Hansen and Nelson illustrate the results obtained from 1950 to 1956: in January 1950 about 78,000; in 1951, 110,000; in 1952, 104,000; in 1953, 150,000; in 1954 235,000; in 1955, 180,000 and in 1956 168,000. Thus during most of the time that the Black Brent was decreasing rapidly the Atlantic coast Brent was increasing even more rapidly.

Mortality. The analysis of mortality and kill by man presented by Hansen and Nelson is cautious and provisional, since they are well aware of the many difficulties in interpreting recovery data. For this reason only a brief report of their principal findings, without a discussion of such topics as regional distribution of kill, need be given here. Using the Bellrose and Chase method for calculating total mortality they arrive at a first-year mortality rate of Brant marked as goslings of 45.4% with an average mortality in later years of about 32%. From two different approaches it appears that mortality due to shooting, including allowances for crippling losses, is about 27%, or more than four-fifths of the total losses. Because of the method of calculation used, the calculated total mortality is almost certainly too high, but the general conclusions drawn from the pattern of recoveries are worth quoting. " It is apparent from the rate of band (i.e. ring) returns that brant hunting in 1954 was relatively poor throughout the flyway. It is equally evident that hunting during 1955 was proportionately better with a holdover of banded, unharvested Brant from the previous year . . . The important implication . . . is that adult Brant (yearlings and older) may not be subject to as great a natural mortality as most of the other waterfowl species. A more likely possibility is that mortality from hunting is so great in the Black Brant that there is little or no margin left for natural mortality, and those Brant which survived the 1954 hunting season were not subjected to as severe

environmental pressures during the ensuing year as birds in an under-harvested population. Thus, they survived in proportionately greater numbers."

Management Implications and Needs. " Is the steady decline in the Black Brant population since 1949, as deduced from the winter inventory, a result of over-shooting, a gradual deterioration of habitat, or merely normal population dynamics which have occurred coincidental to the period of study?" Hansen and Nelson firmly reject the latter. " The last of the three possibilities seems to be quite remote from the evidence at hand. Observed population changes in both American (i.e. Light-bellied) and Black Brant in the past have been more abrupt and of greater annual magnitude. There is no recorded historical basis for such consistent, though moderate, attrition to a flyway population of brant." The reviewer accepts these statements, but does not see in them any reason for excluding the possibility that the recently observed changes could be due to " normal population dynamics." The earlier records, notably Moffitt's Californian census, dealt with segments of the population, instead of the whole, and given the existence of wide variations in annual breeding success and the occurrence of differential migration, such as have been demonstrated, it seems very probable that numbers in part of the winter range should show changes " more abrupt and of greater annual magnitude " than are apparent in the total population.

Hansen and Nelson can find no evidence of a gradual deterioration of habitat. There were signs of an eel-grass shortage in three Californian wintering places in 1950-51 and 1951-52 but no report that it adversely affected the Brant population. They are thus driven to seek an explanation in over-shooting, but their evidence is incomplete and unconvincing. Indeed, they concede as much: " Nevertheless, logic is sometimes subservient to expediency when data are insufficient, and in the case of Black Brant, comparisons with other studies are necessary."

So the problem remains unsolved. But this paper remains important, first, because it presents much new information and, second, because its authors are able to point to weaknesses in existing research and to suggest how these may be overcome, by additional ringing, by the collection of age-ratio data, and by better measurements of losses due to shooting.

III. The prospects for the Dark-bellied Brent

Salomonsen puts the numbers of this population in January at " not lower than 15,000 and certainly not higher than 16,500." This is a misleading way of summarising the data available to him, since it suggests a census of high precision, whereas the national totals he uses are " average values for a number of consecutive years " of estimates differing considerably in reliability, so that counting errors alone must produce greater variability than the quoted figures allow. An even more important reason for modifying Salomonsen's conclusion is the likelihood of important differences between one year and another in the numbers of Brent alive in January.

The midwinter population is determined by the size of the breeding population in the preceding summer, the number of young geese reared, and the losses inflicted on both adults and young between August and January. None of these quantities is known, but there are strong reasons for supposing that they all vary considerably from year to year. Bruton (see pp. 91-92 of

this Report) has shown that the proportion of first-winter geese in the Essex flocks in midwinter was 40%, 26%, 7% and 53% in successive winters from 1954-55 to 1957-58. If these proportions are in any way representative of the population as a whole (and there is increasing evidence from counts abroad that this is so) then the total numbers must have altered considerably from winter to winter, unless losses of adults have exactly offset the changes in production. Burton has not been able to detect significant differences in the first-winter/adult ratio during the course of any winter (November-March), implying that shooting losses amongst the geese after their arrival in Essex are slight—as is to be hoped, since the species is legally protected there—but their losses in Denmark in autumn are considerable. Kill figures for years after 1954, when spring shooting ceased to be legal in Denmark, have not yet been published, but earlier totals for the fiscal years 1941-1951 showed that the claimed kill in Denmark in those years varied between 2,500 (in 1951) and 7,000 (in 1943). Recent evidence from recoveries of Spitzbergen-ringed Brent shows a striking concentration of reported losses in the months September-December, 25 of a total of 27 having been in those four months and in Denmark. While reported losses are not wholly representative of all losses, since geese dying from natural causes are unlikely to be reported and only some of the rings from shot geese were notified, it does seem likely that the bulk of casualties suffered by European Brent Geese after they have fledged occur nowadays in the autumn and early winter.

The observed changes in the annual survival of young geese up to their arrival in Britain seem to be due mainly to differences in the numbers of successful parents, since from counts of broods the average number reared by a successful pair shows little variation. This implies either that the numbers of sexually mature geese change considerably, or that varying proportions of mature geese fail to breed or to raise young, or that all these possibilities occur together. The Black Brant research has shown it to be probable that, in some years at least, a substantial fraction of the mature geese do not raise young, as seems also to be true of Arctic-breeding grey geese.

Large differences in the numbers of young geese reared in different years must subsequently result in changes in the size of the breeding population as successive year-classes become sexually mature. The age at which maturity is reached is of great importance in determining the reproductive potential of a population. Unfortunately it is very difficult to determine in the field, since the ideal procedure requires the identification or collection of birds of known age while they are actually nesting. It seems likely, from the behaviour of the Brent in captivity at Slimbridge, and by analogy with other Arctic geese, that most Dark-bellied Brent will be mature at 34 months. It is quite certain that they are immature in the year after hatching, and unlikely that many are mature at 22 months.

If the population at the start of the breeding season includes two year-classes which are immature, two conclusions must follow: first, the breeding population is much smaller than the total surviving population and, second, the proportion of immature pre-breeders depends on the numbers of young geese reared in the two previous summers. The reviewer has calculated that, if the Dark-bellied Brent numbered 16,000 in late May in each of the years 1956 to 1958, the proportion of mature geese would have been about 44%

in 1956 and 1958 and 69% in 1957[1]. Using more realistic models, with a total population varying between 11,600 in 1957 and 22,600 in 1958 as extremes, the potential breeding population was found to be in the range of 4,200-5,300 breeding pairs. If it must be assumed that in some years one-third or more of this potential breeding population will fail to rear young, the reproductive capacity of the Dark-bellied Brent appears to be very much smaller than might be expected. Yet the example of the Light-bellied Brent of the American Atlantic coast has shown that in favourable circumstances the species is capable of increasing at a very rapid rate (by 125% in two years).

It seems to be characteristic of natural populations of birds that they fluctuate within comparatively narrow limits, due to compensatory interactions between the forces affecting reproduction and mortality. For the continued existence of a population it is essential that net fertility should not fall below mortality for any long time. The implication of Salomonsen's historical survey is that during the last eighty years mortality has exceeded recruitment, and his argument appears to be that the most practical aim for conservationists is to try to reduce adult mortality, and mortality of young geese between fledging and sexual maturity, by reducing "shooting pressure," so that net fertility may come to exceed mortality and the population increase in consequence.

This course of action appears sensible. Yet, since it has encountered, and will continue to encounter, strong opposition from some shooting interests, and since it could prove wholly ineffective, it is highly desirable that it should be accompanied by research, to find out not only what changes in numbers and age-structure occur during the next ten years or so but also whether alteration in losses due to shooting have any marked effect on the total annual losses or on productivity. It is by no means certain that the kill by man and losses from other causes are related in any simple way.

Studies of the breeding population must be left to Russian ornithologists, since the Taimyr National Okrug is apparently closed to foreigners ('The Times,' 10 November 1958). From the correspondence Dr. Salomonsen has had, it is clear that the Russians are interested in the welfare of the Brent, and ornithologists in western Europe must attempt to sustain that interest by carrying out intensive investigations during the autumn, winter and spring.

In such inquiries Denmark must play the key role. Censuses in autumn and spring, when the Dark-bellied Brent is for considerable periods largely concentrated in Danish waters, could provide direct measures of population size and, if they can be made precise enough, of losses during the winter. Midwinter surveys, such as have been made in England, are less useful and seemingly more difficult to make complete, since they require simultaneous searches in at least five countries. Censuses of the English population without comparative material from elsewhere may prove more dangerous than helpful since, like the Black Brant censuses in California in the 1930s, they cannot be assumed to reflect changes in the total population, because of differences from year to year in the dates and rate of immigration and emigration. However they should be carried on since it may be possible to combine them

[1]These and subsequent calculations are not worth giving in full, since in the absence of adequate data they must be merely illustrative, but they include allowances for varying mortality based on analogies with Black Brant and Light-bellied Brent survival, as well as using Burton's age-ratio data.

with age-ratio information and occasional data from overseas into a passable substitute for autumn and spring censuses should the latter prove impossible to achieve. Age-ratios and brood-size checks in Britain must certainly be made each year.

The collection of kill statistics in Denmark is apparently being continued. Estimation of the kill in other countries, which may not be negligible even where full protection is ostensibly afforded, presents great difficulties, but should be explored. Wildfowlers' organisations are probably more likely to succeed in this task than people suspected of ' protectionist ' leanings.

In Britain there is need for further investigation of the distribution and numbers of the Pale-bellied as well as the Dark-bellied Brent, especially in areas where both forms occur. The recent work of Dr. D. S. Ranwell and his assistants has clarified the question of what Brent eat, where and when, so that it may be possible to assess with comparatively little further effort whether food in Britain is important as a limiting resource.

Any ringing of any Brent, whether in this country or elsewhere within the range of the European-wintering groups, must be helpful at this stage.

For the welfare of Brent populations it is essential to consider the various groups as complete units and to act " conservatively " at least until it is clear that the populations have reached levels as high as can be maintained in the face of persistent natural hazards*. It is possible that the existing populations are already near the upper limit set by to-day's environment, but it seems worthwhile to assume that this is not so. There have been some signs of increase in the numbers of Brent in England since 1954. These have already led to agitation for the removal of protection in some of the localities where increase has been most marked (notably in the north of Norfolk). If shooting were to be allowed wherever local flocks show signs of flourishing, the chances of a substantial improvement in numbers of the whole population would be sadly reduced, It is important to do everything possible to set parochial and insular claims in their proper, continental, context.

*From age-ratio counts (Burton *in litt*) it is now apparent that 1958 was a very bad breeding year. 1956 was nearly as bad and probably 1953 too, so that it is necessary to assume that only one summer in two will add substantially to the future breeding stock.