ARCTIC INSTITUTE OF NORTH AMERICA

TECHNICAL PAPER NO. 4

# THE RELATIONSHIP OF THE PEARY AND BARREN GROUND CARIBOU

*By*

T. H. MANNING

PUBLISHED JUNE 1960

# THE ARCTIC INSTITUTE OF NORTH AMERICA

The Arctic Institute of North America was formed to further the scientific study and exploration of the Arctic. The Institute provides information on the Arctic through its three Offices, awards research grants, and publishes scientific papers and other contributions in its journal *Arctic* and other publications. Those interested in this work are invited to become Members. Members receive all numbers of the journal. The Library and Map Collection at the Montreal Office are principally for their use, and they are welcome there and at the other Institute offices. Membership dues are $5.00 annually. All remittances should be sent to the Montreal Office.

**Offices of the Institute**

3485 University Street, Montreal 2, Que., Canada
1530 P Street, N.W., Washington 5, D.C., U.S.A.
2 East 63rd Street, New York 21, N.Y., U.S.A.

ARCTIC INSTITUTE OF NORTH AMERICA

TECHNICAL PAPER NO. 4

# THE RELATIONSHIP OF THE PEARY AND BARREN GROUND CARIBOU

*By*

T. H. MANNING

PUBLISHED JUNE 1960

# CONTENTS

Figures

# THE RELATIONSHIP OF THE PEARY AND BARREN GROUND CARIBOU

### T. H. Manning

### Abstract

This is primarily a taxonomic study of four caribou (*Rangifer*) populations, the Queen Elizabeth Islands, Banks Island, Dolphin and Union, and mainland. Skulls, skins, hooves, and antler velvet were used in the comparisons. Statistics are given for 19 skull measurements, and the results of covariance analysis of 14 paired measurements. Two methods of covariance analysis were used. One ignores sex differences, the other segregates and corrects for them. The results proved similar; differences in detail are discussed. Clines, probably stepped between the populations considered, are demonstrated for pelage colour, size, and adjusted skull measurements. The forms *arcticus* and *pearyi* are considered conspecific; the Banks Island population is referred to the latter, the Dolphin and Union 'herd', more tentatively to the former. Historical records of the Dolphin and Union herd and its extinction as a migratory unit are summarized.

## Introduction

While studying the collections made on Banks Island in 1952 and 1953 (Manning and Macpherson, 1958) it became apparent that the caribou taken by Dr. R. M. Anderson in 1915 and 1916 at Bernard Harbour averaged smaller than comparable specimens from other parts of the Canadian mainland and had other attributes which linked them with *pearyi.* The labels on two of the Bernard Harbour specimens stated that they were migrants from Victoria Island, and it is logical to assume that all belonged to the group which has now vanished but which used to summer on Victoria Island and cross Dolphin and Union Strait and Coronation Gulf to the mainland after freeze-up. This group I shall call the Dolphin and Union herd. As the taxonomic status of *arcticus* and *pearyi* was unsettled, and as the Banks Island population and the Dolphin and Union herd appeared to bridge the gap between these forms, it seemed advisable to expand the original study of the Banks Island specimens into a separate paper in which more emphasis could be placed on the extinct Dolphin and Union herd.

The four main groups considered in detail are the Queen Elizabeth Islands population, the Bank Island population, the Dolphin and Union herd, and the mainland population. The Queen Elizabeth Islands population is split into five sub-groups: the Ellesmere, Axel Heiberg, Isachsen, Prince Patrick, and Melville populations.

Within the resident mainland population are included all specimens of *Rangifer arcticus* taken east of Liverpool Bay other than those believed to belong to the Dolphin and Union herd. They were grouped together because of the small numbers available when the work was started and because they were also the subject of a study by Dr. A. W. F. Banfield on the relationship of the barren ground and woodland forms[1]. It would not be surprising, however, if a good series from two or three well-separated areas showed statistical differences in some measurements. There may also be differences between those animals which migrate to the bush country and those which winter scattered across the northern barrens.

The skulls of only one adult and one subadult have been seen from Victoria Island, and none from the islands lying between there and Baffin Island[2]. A casual examination of the good series of Baffin Island specimens in the National Museum indicated that this population does not intergrade with *pearyi* and therefore did not need to be considered in the present paper.

The relationship of *tarandus*, *caribou*, and *arcticus* is outside the scope of this paper, and the specific name *arcticus* for the North American barren ground form is used without prejudice.

## *Acknowledgments*

The study comprises part of the work done under grants from the Arctic Institute of North America and from the Northern Research Coordination Centre of the Department of Northern Affairs and National Resources. I am indebted to Dr. L. S. Russell, Director of the Natural History Branch of the National Museum of Canada, and to Dr. A. W. Cameron, Curator of Mammals[3], for facilities at the Museum, and to Dr. H. E. Antony and Mr. T. Donald Carter for their kindness during a two-day visit to the American Museum of Natural History in 1956. Mr. E. H. McEwen, of the Canadian Wildlife Service, contributed an excellent series of skulls obtained from Banks Island in 1953 and 1954, and Dr. A. W. F. Banfield[4], their Chief Mammalogist, has generously allowed me to use specimens obtained especially for his own study. I assume full responsibility for the statistical work, but wish to acknowledge my debt to Miss P. M. Clarke, of the Department of Agriculture, for her valuable advice, and to my wife for her assistance in checking the calculations.

The National Museum's collection of caribou from the Queen Elizabeth Islands was obtained by Sergeants A. H. Joy, R. W. Hamilton, and H. Kearney of the R.C.M. Police, by Messrs. S. D. MacDonald and G. Blanchard of the Museum staff, and by Mr. A. H. Macpherson. A good series of skins and skulls was collected on Banks Island by Mr. H. G. Wilkins (later Sir Hubert Wilkins) of the Canadian Arctic Expedition, and the whole series from the Dolphin and Union herd was obtained on the same expedition by, or under the direction of, Dr. R. M. Anderson, without whose work the herd would have vanished without the preservation of a single specimen. The other mainland specimens were collected by Dr. R. M. Anderson, Col. H. Snyder, Dr. C. H. D. Clarke, Mr. G. H. Blanchet, and Sergeant J. E. F. Wight, R.C.M. Police. Mr. F. Johansen, of the Canadian Arctic Expedition, took the Victoria Island specimens.

---

[1] Now expanded to a revision of the genus.

[2] Since this was written A. H. Macpherson and I made a small collection on Prince of Wales Island. These caribou have not been studied in detail but are definitely part of the *pearyi* complex.

[3] Now Curator, Redpath Museum, McGill University.

[4] Now Chief Zoologist, National Museum of Canada.

## Previous knowledge of the Dolphin and Union herd and other Victoria Island migrants

Rae, who explored the south coast of Victoria Island in the spring of 1851, was the first to record the caribou migration across Dolphin and Union Strait into southwestern Victoria Island. He (1852, p. 79) says, "All the land near the coast, from Cape Lady Franklin to Cape Baring, is so extremely barren, that, although many deer cross from the main, they do not remain near the shore, but make their way directly inland, too far for persons travelling as we were, and abundantly supplied with food, to follow them." A year and a half later members of Collinson's party who spent the winter of 1852–3 at Cambridge Bay saw evidence of an autumn migration from eastern Victoria Island across Dease Strait to Kent Peninsula (Collinson, 1889, p. 244). In early October during a journey around the peninsula immediately east of Cambridge Bay C. T. Jago saw an estimated 1,500 caribou which had collected in large herds preparatory to crossing to the mainland as soon as the ice formed over Dease Strait (p. 290). In the first week of November Collinson saw tracks of several hundred caribou near the Finlayson Islands, which are just west of Cambridge Bay (p. 290). During the next fifty years the Coronation Gulf region was seldom visited by travellers, and nothing more is heard of the Victoria Island caribou migration until the Stefansson-Anderson expedition of 1908–12.

### *Dates and places of migration to and from Victoria Island*

According to Jenness (1922, p. 15), the first herds reached the mainland coast as early as the end of April, and the northward migration continued well into June, when the ice of Dolphin and Union Strait usually became too unstable for further crossing. However, Stefansson (1913a, p. 106) considered that the migration across Dolphin and Union Strait began about April 1 and was practically over by May 20. Anderson (1913b, p. 503) says it took place in April and May. Probably there was some variation from year to year. Johansen (1920, pp. 136–7) thought that caribou might occasionally cross Coronation Gulf as early as mid-March, and Stefansson (1913a, p. 95) also mentions them crossing Dolphin and Union Strait in March. Perhaps occasional small bands moved to and fro throughout the winter. During the spring migration the caribou moved northward in numerous small groups which Stefansson (1913b, p. 204) says generally consisted of five to 12 caribou and (p. 277) never more than 40. O'Neill (1920, p. 37) says that the number in a herd was probably anywhere from five to 50, and Hoare (1920, p. 76) thought that the biggest band he had seen perhaps numbered 60.

Jenness (1922, p. 15) says that the caribou mustered again on the south shore of Victoria Island in October, and crossed the straits between the end of that month and early December. However, on page 125 he indicates that the migration from the north side of Dolphin and Union Strait is usually over by November. In 1915 it certainly appears to have been over before November 7 (Jenness, 1928, pp. 187–91). Hoare (1927, p. 36) says that the crossing usually took place in November, and Anderson (1913a, p. 6) and Stefansson (1914, p. 41) that it occurred as soon as Dolphin and Union Strait and Coronation Gulf were frozen. In 1910 this happened about November 8 to 10

(Anderson, 1913b, pp. 502-3). In 1911 the first band of migrating caribou from Victoria Island reached the Coppermine River on November 8 (Stefansson, 1913a, p. 106).

Although in normal years the greatest concentration of caribou crossing to and from western Victoria Island was probably at Dolphin and Union Strait, it is evident that they also crossed Coronation Gulf in considerable numbers (J. F. Bernard *in* Anderson, 1922, p. 73; Johansen, 1920, p. 136), and in the autumn when the ice was late making in Dolphin and Union Strait the main migration was probably over Coronation Gulf (O'Neill, 1920, p. 37; Chipman, 1920, p. 101; Jenness, 1928, pp. 12–13). In fact, before either the eastern or the western migration had been seen, Simpson (1843, pp. 277–8) had noted the large number of caribou trails leading to the coast west of Bathurst Inlet, and from this and the fact that his party had seen only males along the mainland coast in July, he inferred that the females crossed the ice to bring forth their young on the islands. There is, therefore, no geographical barrier or separating line between the caribou which crossed in the Dolphin and Union Strait region and those which crossed Dease Strait.

Caribou seldom crossed to Victoria Island west of Cape Bexley, and the number of migrants increased along the strait eastward from there (Stefansson, 1913b, p. 203). In the east few caribou crossed Queen Maud Gulf, as the ice was too rough (J. F. Bernard *in* Anderson, 1922, p. 74).

### *Numbers involved in the Victoria Island migration*

The total number of caribou involved in the migration to Victoria Island has been variously estimated. After reviewing the literature, Clarke (1940, p. 98) concluded that it was never very large. This is a relative term, and, in relation to the total mainland population, is no doubt correct. However, it was primarily this group of caribou which supplied the very considerable Eskimo population living on southern Victoria Island, including those about Prince Albert Sound and possibly Minto Inlet, the southern coast of Coronation Gulf, Kent Peninsula, and possibly to some extent (O'Neill, 1920, p. 37; Anderson, 1922, p. 73), Bathurst Inlet. Jenness (1920, pp. 166–7) estimated the number of caribou crossing to Victoria Island at 20,000, apparently exclusive of those which crossed from Kent Peninsula. He considered that about 2,000 remained in the vicinity of Wollaston Peninsula during the summer. Stefansson (1920, pp. 135–6) also mentioned 20,000, apparently for the western migration, and thought an outside estimate of the total migration would be 100,000. Anderson (1920, p. 544) put the total migration to Victoria Island at 100,000 or 200,000.

After reaching Victoria Island, the caribou moved north fairly rapidly, and evidently passed Prince Albert Sound in considerable numbers (Stefansson, 1913a, p. 94 and 1914, p. 54). The Eskimos there told Stefansson (1913a, p. 99) that the caribou continued on to the north coast, and it seems probable that they did in fact spread out over the whole island, as appears to have been the opinion of Jenness (1922, p. 15). A few may have crossed to Banks Island as Storkerson (1920, p. 277) seems to have supposed, but it seems unlikely that this was a regular migration as the southern portion of the strait is wide and the return migration would be delayed by open water, so that the rut would very likely occur on Banks Island. Casual wanderers might in this way become absorbed into the Banks Island population or, returning late, remain on Victoria Island.

Dunbar and Greenaway (1956, p. 194) give the area of Victoria Island as about 85,500 square miles. One hundred thousand migrant caribou equally distributed over the whole island would therefore amount to an average of 1.2 caribou per square mile. To this figure must be added the caribou which wintered on Victoria Island. They were evidently not numerous (Stefansson, 1921, pp. 401, 402; Anderson, 1922, p. 74; Johansen, 1920, pp. 136–7; Hoare, 1920, p. 76), perhaps less than 0.1 per square mile, or roughly half the estimated number per square mile for Banks Island (Manning and Macpherson, 1958). Thus, the total summering population, excluding fawns, may be estimated at about 1.3 per square mile. When this figure is compared with Banfield's (1954, p. 20) estimate of 2.2 per square mile for the mainland summer range, it does not appear unreasonable, particularly as Anderson (1913a, p. 6) mentioned that Victoria Island pastured great numbers of caribou in summer.

In July, Simpson (1843, p. 277) saw only males along the mainland coast of Coronation Gulf, and inferred that the females had gone north to the islands. Stefansson (1913b, pp. 204, 277) saw more females than males amongst the migrating herds, and Hoare (1920, p. 80) saw no males during the first three or four nights of the 1919 spring migration, and from this and presumably other observations was convinced (1927, p. 36) that it was chiefly the females which went to Victoria Island. However, some adult males certainly went to Victoria Island (Stefansson, 1913b, p. 277) and J. F. Bernard (*in litt.*) says that he never saw any of the Victoria Island migrant type of caribou on the mainland in summer. But the most serious objection to Hoare's theory appears to be that, judging by the mainland caribou (Banfield, 1951, p. 26), the return crossing must usually have occurred about two weeks after the height of the rut. More direct evidence that the rut occurred on Victoria Island is given by Jenness (1928, p. 179), who considered that it was at its height before the southward crossing commenced. Possibly most of the adult males crossed to Victoria Island later and by a route different from that taken by the females and younger animals.

### *Destruction of the migrant herds*

Before the introduction of firearms there appears to have been little hunting of caribou in the Coronation Gulf region in the spring (Stefansson, 1913b, p. 264 and 1914, p. 54; Jenness, 1920, p. 165 and 1928, p. 102), but this had changed before 1920, and J. F. Bernard (Anderson, 1922, pp. 74–5; Jenness, 1922, pp. 248–9) describes the slaughter then taking place and prophesied that if it continued there would be no caribou left within ten years. The main caribou migration over Dolphin and Union Strait ended in 1919, but continued across Coronation Gulf and Dease Strait for two or three more years (J. F. Bernard *in* Jenness, 1922, p. 244; Hoare, 1927, p. 36; Rasmussen, 1927, p. 246). In the autumn of 1923 few caribou crossed south from western Victoria Island, and none went north in the following spring (Hoare, 1925, pp. 1–2). In the autumn of 1924 Hoare (1925, p. 3) travelled on the ice from Coppermine to Bernard Harbour and back at the time when the caribou should have been crossing from Victoria Island in large numbers, but he saw only one caribou and the tracks of 13 others. The natives camped along the coast had seen only seven caribou, and Patsy Klengenberg had killed only five on Victoria Island opposite Bernard Harbour. In the following spring, while travelling across Coronation Gulf from Bernard Harbour to Tree River between May 13 and 20, Hoare (1925, p. 11) saw tracks of only 13 caribou, whereas he says, ". . . In the years 1915 and 1918, one could hardly go a few steps on the ice in Coronation Gulf, at this season, without crossing caribou tracks."

There can be no doubt that the whole caribou migration to and from Victoria Island was halted by the slaughter (Rasmussen, 1927, p. 246; Godsell, 1937, pp. 288–9 and 1943, pp. 273–4) which resulted on the introduction of firearms to the Eskimos of that region. Whether virtually all of the migrant caribou were killed off, as Clarke (1940, p. 98) thought, or whether some remained on the mainland to be absorbed into the other herds, or on Victoria Island to join the resident population, is not certainly known. However, it does not appear that many remained on Victoria Island, as H. Bjorn reported to Hoare (1925, p. 7) that there were none on southeast Victoria Island in the summer or autumn of 1924, and shortage of caribou forced most of the Victoria Island Eskimos to move over to the mainland at about that time (Hoare, 1925, pp. 10–11 and 1927, pp. 33, 36).

### *Physical appearance*

Anderson and Stefansson appear to have been the first to record physical differences between the caribou migrating into western Victoria Island and the resident mainland caribou. Stefansson (1913b, pp. 276–7) considered that the Dolphin and Union caribou, including those seen and killed on both sides of the strait, were smaller and paler than those in the large herds seen on the Dease River in October 1910. Their muzzles and legs also were paler, and they had a "fuzzy-faced head reminding one of the donkey rather than of the horse" (Stefansson, 1913a, p. 106). Their eyes appeared "deep set through the length of the hair on the face, and with an appearance of thickness of the face below the eyes, caused no doubt largely by the growth of hair." (Stefansson, 1913b, pp. 241–2). Anderson, though not necessarily referring exclusively to the western Victoria Island migrants, confirms this when he (1913b, p. 505) says, ". . . The Caribou seen east of the Coppermine River and on the south side of Coronation Gulf seemed to average much lighter in color than the Caribou found on Great Bear Lake or on the Arctic coast west of Cape Parry. With very few exceptions the Coppermine Caribou were very light, with legs nearly white. The heads of these Caribou appeared to be much shorter than those of the Great Bear Lake Caribou, with a noticeable fullness or convexity between forehead and nose, reminding one in some degree of the profile of a rabbit. The difference is not very noticeable on the skulls, the fullness of the face being largely due to the fuzziness of the whorl of hair on front of face." Later, Anderson (1922, p. 75), after having spent two more years in the Dolphin and Union Strait area, says, "Captain Bernard thinks that there are two different kinds of caribou in the region about the mouth of the Coppermine. The smaller, whiter animals are the ones that come across from Victoria Island in the fall and go back in the spring. Some [apparently the darker animals, see p. 9] of them may remain on the mainland all summer, however. He has seen larger, darker, animals up the Kogaryusk river in the spring. He thinks that these may be the variety which winters farther inland

and comes back toward the coast in the spring. The smaller variety probably does not go very far inland south of Coronation gulf and south of Dolphin and Union Strait in winter.

"The above coincided with my own view that the caribou wintering around east end of Great Bear lake (Caribou point, Dease river, etc.) are larger and darker, with shorter [Evidently 'longer' is meant. See Anderson 1913b, p. 505, quoted above] heads than the Coppermine river winter caribou. The Bear lake caribou go a ways north in summer, to Dismal lake and beyond, also the 'caribou ground' of the Indians outside of the timber north of Great Bear lake. That is, the winter ground of the Victoria island caribou overlaps the summer range of the Great Bear lake caribou. Presumably some of the caribou which summer around Great Bear lake go south in winter to Great Slave lake, etc., to the type locality of *arcticus* (Fort Enterprise region). . . ."

The characters mentioned above as differentiating the western Victoria Island migrant caribou from other mainland caribou are also characters by which the Peary Caribou may be separated, and it is surprising that Anderson does not appear to have called attention to the resemblance. Perhaps he implied it when he (1934, 1938, maps) placed all Victoria Island within the range of *R. a. pearyi,* which, he says, probably intergrades with *R. a. arcticus* (Anderson, 1937, p. 103). Later (1946), he recognized *pearyi* as a full species, and included the "southern fringe of islands north of the mainland Arctic coast", which presumably includes Banks Island and Victoria Island, within the range of *R. a. arcticus.* Storkerson (1920, p. 277), who was familiar with the caribou of Alaska, Banks and Victoria islands, and the western Queen Elizabeth Islands, but not with those of the Canadian mainland, considered that all the island caribou were very similar and probably the same as those which migrated from the mainland to Victoria Island. It is not clear, however, if he had actually seen any of the latter.

The above descriptions refer only to the caribou migrating to western Victoria Island. However, in a recent letter (4 October 1959) J. F. Bernard says that he well remembers when he and Dr. R. M. Anderson remarked that the Victoria Island migrant caribou looked different from the resident mainland caribou, which were darker in colour and, it seemed, slimmer and swifter on their legs, a difference he had noticed as far east as Taylor Island at the east end of Victoria Island.

Ten or fifteen years ago the summering population of caribou increased on Kent Peninsula, and a few crossed to Victoria Island (Banfield, 1949, p. 481). According to Superintendent H. A. Larsen these, which were soon killed by the Eskimos, appeared to be the usual mainland caribou, and quite different from the small, pale caribou which he has seen in the northern part of Victoria Island. However, there is no reason to suppose that these recent migrants were descendants of those which used to cross Dease Strait two or three decades earlier.

## Comparison of skins

It is well known that the pelage colour of caribou varies greatly with age, season, and individual, and, after casual examination of a considerable number of caribou skins used for clothing and bedding in the north, I had concluded that skins were unlikely to be of much taxonomic value. This proved to be

**Table 1.** Summer skins.

| *Queen Elizabeth Islands* | | | *Banks Island* | | |
|---|---|---|---|---|---|
| **Complete new summer pelage** | | | | | |
| 21600 | ♂ | Prince Patrick Id. 10 Aug. 1954 | 21161 | ♂ | Banks Id. 6 Aug. 1952 |
| 21727 | ♂ | Prince Patrick Id. 10 Aug. 1954 | | | |
| **Partial new summer pelage** | | | | | |
| 20340 | ♂ | Prince Patrick Id. 30 July 1949 | 21170 | ♂ | Banks Id. 29 July 1953 |
| 21709 | ♂ | Central Ellesmere Id. 13 July 1955 | 21168 | ♂ | Banks Id. 29 July 1953 |
| 21712 | ♂ | Central Ellesmere Id. 13 July 1955 | | | |
| 14949 | ♂ | Southern Ellesmere Id. 12 June 1936 | | | |
| 21708 | ♀ | Northern Ellesmere Id. 26 July 1951 | | | |
| **Moult commencing** | | | | | |
| 21711 | ♂ | Isachsen, Ellef Ringnes Id. 17 July 1954 | | | |
| 21710 | ♂ | Isachsen, Ellef Ringnes Id. 17 July 1954 | | | |

Banks Island skin NMC 21161 has hair 30 mm. to 35 mm. long on the back. When shot, the other two Banks Island skins had remnants of winter hair which was easily rubbed off before skinning and left new hair 15 mm. to 20 mm. long on the back.

incorrect, at least for the groups considered here. However, most of the work had to be done in artificial light, and only a few skins could be laid out at a time. In these circumstances comparison of colours, either directly between skins or with a standard colour chart, was not considered worth while, and, indeed, the variability mentioned above might in any event render this valueless. Instead, a comparison was made of the extent of the dark hair and on the degree of its darkness.

### *Comparison of Queen Elizabeth Islands and Banks Island caribou skins*

The most satisfactory skins for taxonomic comparisons are those in fresh and complete summer pelage, that is to say, skins of animals killed between about mid-August and the beginning of September. Table 1 shows the summer skins available. There is more dark hair on the lower part (i.e., below wrist and ankle joints) of the legs of the three summer Banks Island specimens than there is on any of the seven comparable skins from the Queen Elizabeth Islands except NMC 14949 from southern Ellesmere Island. Also, in the Banks Island specimens, dark hair is continuous all the way up the leg, and joins the dark dorsal patch, whereas in three, NMC 21712, 21727, 21600, out of the four Queen Elizabeth Islands skins sufficiently advanced in summer pelage to show this character satisfactorily, white or almost white hair separates the dark of the back from the dark of the leg. The exception is again NMC 14949. Judging by the old hair, the two moulting specimens, NMC 21711 and 21710, also have a gap between the dark hair of the legs and that of the back. The three Banks Island specimens are darker on the neck and shoulders than any of the six comparable skins from the Queen Elizabeth Islands. The difference is particularly noticeable in the three skins (one Banks Island, two Prince Patrick Island) in full summer pelage. Two of the Banks Island specimens (NMC 21161, 21168) are darker on the lower part of the face, that is to say, between the eyes and the nose, than any of the six comparable Queen Elizabeth Islands specimens. The third Banks Island skin, NMC 21170, cannot be distinguished by this character, but it has a mottled forehead, a feature also well developed in NMC 21161 but in none of the Queen Elizabeth Islands specimens. It seems probable that in full summer pelage 11 out of the 12 skins listed in Table 1 could be assigned correctly to the district of origin. The exception is the southern Ellesmere Island skin, NMC 14949, which does not have sufficient new hair on the neck, shoulders, or face to be considered in the last two comparisons.

The National Museum of Canada has seven caribou skins from Banks Island taken in October and November and showing well-developed winter pelage. If the hair on the upper parts of the legs of these skins is parted, the dark hair joining the dark of the lower legs with the dark patch on the back can be clearly seen. In 15 out of the 22 autumn, winter, or spring skins from the Queen Elizabeth Islands there is a definite gap in the dark under-hair of the upper part of both front and hind legs. In two others, NMC 21725 (Isachsen) and 12512 (southern Ellesmere Island), there is a gap in the dark under-hair on the front legs, but continuous, although pale, dark under-hair on the hind legs. Another skin, NMC 8798 (Axel Heiberg Island) has continuous dark under-hair on both hind and fore legs, but this hair is distinctly paler than in any of the Banks Island series. The skins of two large males, NMC 14058, 12511, from southern Ellesmere Island cannot be distinguished from those of female and smaller male Banks Island specimens by the above character, but are separable from the only two large Banks Island males available, NMC 2764, 2765, and it is suspected that large adult males may have more dark on the upper part of the legs than the smaller animals. Only two, NMC 21724 and 12513, of the 22 winter skins from the Queen Elizabeth Islands are therefore really inseparable from the seven winter Banks Island skins. The first, rather surprisingly, is from Isachsen, the other, from southern Ellesmere Island. All the 11 north Ellesmere skins in winter pelage lack dark hair joining the dark of the lower legs and of the dorsum, and it is possible that there is a cline of increasing whiteness from south to north on this 500-mile-long island.

### *Comparison of Banks Island and the Dolphin and Union caribou skins*

There are 11 caribou skins in the National Museum of Canada labelled Bernard Harbour. Ten, all in winter pelage, are believed to belong to the Dolphin and Union herd. Two large males, a small male, and three females were taken in mid-November, a medium-sized, unsexed specimen on February 29, two small females on April 3, and an adult female on April 15. The eleventh skin, NMC 2762, is labelled female, 18 April 1916. It is, however, a male, and equally obviously in summer or early autumn pelage and therefore taken at a time when most, if not all, of this herd were on Victoria Island. It is also distinctly darker than I should expect the Dolphin and Union caribou to be even in summer. Leaving out of consideration the two small and rather white spring females, NMC 2559 and 2560, from Bernard Harbour, with which none of the Banks Island specimens are comparable, the backs of the remaining eight skins from Bernard Harbour, considered to belong to the Dolphin and Union herd, are darker than the backs of any of the seven winter Banks Island skins except NMC 2766, which is darker than NMC 2747 from Bernard Harbour, although on the latter the dark area of the dorsum is wider. In all the Banks Island skins there is a white area on the *surface* of the hair separating the dark dorsal patch from the dark on the lower part of the front and back legs. In four Bernard Harbour skins the dark of the legs and the dark of the back is continuous on the surface of the hair. In two others, NMC 2763 and 'no number', the connecting hair is less distinct, although the dark of the legs and back is not separated by pure white as on the Banks Island skins, and the dark dorsal patch is wider on rump and shoulder. In NMC 2760 and 2758 the dark of the front legs is separated from the dark of the back. In NMC 2760 it is continuous, and in 2758, nearly continuous on the back legs. Both have a pronounced dark patch on the shoulder and along the flank.

From the above comparisons it is apparent that two main criteria may be used for separating winter skins of Banks Island caribou from those of the Dolphin and Union herd. One is the generally paler shade of the dorsal patch; the other, the size of the patch and the extent to which it is continuous on the smoothed surface of the hair with the dark of the legs. If both criteria were used, it is probable that of the 17 skins in winter pelage from Banks Island and Dolphin and Union Strait only the two young spring females from Bernard Harbour and the dark Banks Island skin could not be correctly identified. It is evident that this Banks Island skin is dark at least partly because of wear. Apparently it is either a late spring skin which has been mislabelled, or it has suffered post mortem wear, perhaps while being used as a sleeping skin. Banks Island skins comparable in age and date to the two young spring Bernard Harbour females have not been seen. Possibly such skins would show distinguishing features.

### *Comparison of Dolphin and Union and other Barren Ground Caribou skins*

When these comparisons were being made there were no topotypical winter skins of the Barren Ground Caribou in the National Museum; in fact, the only two winter or autumn skins from the mainland, apart from the Bernard Harbour collection, were NMC 2752 and 2751, taken at Port Epworth, Coronation Gulf, on or about 5 October 1915, and thus too early to be Victoria Island migrants. NMC 2751 is distinctly darker, more brown, than the Bernard Harbour skins, the difference being greater than would be expected from the difference of season. NMC 2752, however, closely matches those from Bernard Harbour, and is farther advanced into winter pelage than 2751. I would have been tempted to suggest that it had been confused with NMC 2762, which, as mentioned above, is definitely wrongly labelled, were it not for the narrowness of its hooves.

The following ten autumn and winter mainland skins were examined in the American Museum of Natural History. Unfortunately the labels of some of these specimens have also been confused (cf. Harper, 1955, p. 117).

| *No.* | *Place* | *Date* | *Sex* |
|---|---|---|---|
| 19504 | Hudson Bay | — | — |
| 22936 | Wager Bay | — | (♂ Allen, 1908) |
| 34431 | Langton Bay | Sept. 22 | ♂ |
| 34432 | Darnley Bay | Oct. 29 | ♂ |
| 34434 | Horton River | Oct. 30 | ♀ |
| 34437 | Dease River | Feb. 24 | ♀ |
| 34433 | Coronation Gulf | April 21 | ♀ |
| 34430 | Horton River | Oct. 28 | ♀ |
| 34426 | Langton Bay | March 6 | ♀ |
| 34443 | Great Bear Lake | Feb. 5 | ♀ |

The first seven are dark-haired skins, all easily separable from specimens of the Dolphin and Union herd. Some (perhaps including AMNH 34433 and 34437, which may be wrongly dated) were taken earlier in the autumn than the Dolphin and Union specimens, but the differences are distinctly greater than those which could be ascribed to season only. The last three skins look very much like those of caribou from the Dolphin and Union herd. There is no reason why the Langton Bay and Great Bear Lake specimens should not belong to that herd, individuals of which might easily have visited these places in mid-winter, but October 28 is surely too early for one of them to be at the Horton River. I therefore suggest that its label has been confused, possibly with the Dease River specimen, AMNH 34437. Skull measurements of the Langton Bay and Great Bear Lake specimens are not available; those of the supposed Horton River caribou are inconclusive; and if there has been confusion, the skin and skull may not have come from the same animal. Measurements of this skull have not been included with those of either the mainland group or the Dolphin and Union herd. Fig. 1 shows that hoof measurements support the supposition that all three skins are from the Dolphin and Union herd. If, as some observers evidently thought (p. 9), some males from the Dolphin and Union herd summered on the mainland, skins NMC 2752 and AMNH 34430 could both be explained as specimens of the Dolphin and Union herd without resorting to the supposition that labels have been confused. They could also be explained if it is supposed that there was sufficient gene exchange with the neighbouring mainland herds to induce marked variability. However, there is irrefutable evidence that there have been errors in both the Canadian National Museum and the American Museum of Natural History specimens from this area, whereas the evidence that any appreciable number of Dolphin and Union caribou remained on the mainland is contradictory, and there is no evidence that caribou in winter contact with the Dolphin and Union herd were more variable or differed in any obvious manner from caribou elsewhere.

The evidence, although admittedly the material is most unsatisfactory, indicates that the pelage of the Dolphin and Union caribou was closer to that of the Banks Island caribou than to that of the other mainland caribou. The three summer skins in the National Museum from the mainland barren grounds, NMC 14055, an adult male from Chesterfield Inlet, NMC 14903, a yearling female from Clinton-Colden Lake, and NMC 22510, recently obtained from Adelaide Peninsula, are much darker, particularly on the legs, than comparable Banks Island skins, but are naturally of little use for comparison with the winter skins of the Dolphin and Union herd.

Two caribou skins in the American Museum of Natural History are labelled Point William, Victoria Island. If they are really from Point William, they would almost certainly be from caribou belonging to the Dolphin and Union herd, as Point William is just northwest of Dolphin and Union Strait and the pelage indicates that both are summer skins. However, AMNH 34428, which still has some old hair, is labelled February 24, while the skull with this number is dated July 28. The place of origin on the label attached to the other skin, AMNH 34427, has been changed from Langton Bay by the collector, but evidently some time after collection. This suggests that the origin of these two skins is doubtful, and, as they were judged to be much nearer to comparable skins of mainland caribou than to skins of Banks Island caribou, although they were not actually seen beside any of the latter, it seems quite likely that once again there has been a confusion of labels. The hoof measurements (Fig. 1) of AMNH 34427 are nearer the mean for the Dolphin and Union herd than to that for the mainland herd, but are still well within the range of the latter. The hooves of AMNH 34428 were not measured.

Since the above comparisons were made I have examined two wet skins, intended for part of a museum group, taken about the beginning of December near Stony Rapids, and two new study skins from southeast of Great Bear Lake (NMC 22010, December 18, Lever Lake, and NMC 22012, January 15, Grant Lake). All four are adults or near adults. They are far darker than any skins judged to belong to the Dolphin and Union herd, and they therefore support the conclusions previously reached with regard to the differences between the skins of caribou from the Dolphin and Union herd and those from the mainland.

### Comparison of antler velvet

The National Museum has two sets of about half-grown antlers in clean velvet from Ellesmere Island. One set is from an old adult male, NMC 21712, collected on 13 July 1955 at Slidre Fiord, central Ellesmere Island, the other, from a young adult, NMC 12512, taken in June 1934 at Fram Fiord in the extreme south of the island. There is no appreciable difference between the two sets in colour of the velvet. In general, it is best matched by Pale Olive-Buff[1], but two or three inches from the base it is Vinaceous-Buff with patches of Wood Brown. Another set of antlers in velvet, from an old male, NMC 21709, taken on 30 July 1955 in central Ellesmere Island, are nearly full-grown. They lack the buff and vinaceous tints of those described above, and are between Smoke Gray and Pale Smoke Gray all over. Nearly full-grown tines from two medium-aged males, NMC 21600 and 21727, taken on Prince Patrick Island on 10 August 1956, are similarly coloured. The last three sets have been exposed to light and dirt, but the colour difference between them and the two clean sets is probably due to their more advanced growth. Unfortunately no antlers in velvet are available from Banks Island or from the Dolphin and Union herd. The velvet on the nearly full-grown antlers, NMC 2743 and 2744, of two mainland caribou from Coronation Gulf taken on 24 and 27 August 1915, is much browner and darker than that on the Ellesmere Island specimens. In some places there are greyish 'hairs', which give the whole a general colour between Hair Brown and Saccardo's Umber, but in other places where the greyish 'hairs' are absent, the velvet is between Sepia and Bister. The colour of the velvet on two Baffin Island specimens is very similar, but that on a probable Mountain Caribou, *R. a. fortidens,* taken 24 August 1917 at Jasper Park, Alberta, is quite different, being uniform Bister to Warm Sepia. Evidently the colour of the velvet may be an important taxonomic character. However, velvet on tips, but not the base, of growing antlers collected on Adelaide Peninsula in mid-August 1957 is almost as pale as that on the antlers of Peary Caribou, so that it will apparently be necessary to compare antlers, or at least velvets, which are in the same stage of development. It would be particularly interesting to obtain velvet from Banks Island and Victoria Island caribou. Whole antlers with growing velvet are difficult to handle, both in

---

[1] Capitalized colours are from Ridgway, 1912.

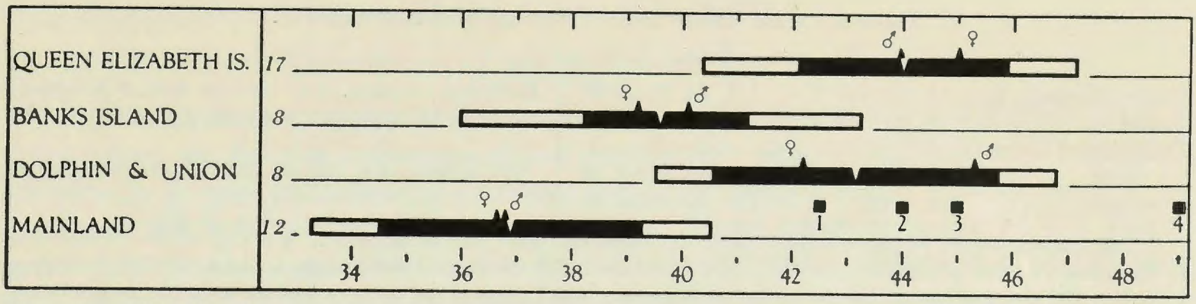

**Fig. 1.** Width of hooves 20 mm. from tip, adjusted to a mean hoof length of 76.62 mm. along four parallel regression lines with coefficients of 0.200. (See Table 2).

The white V's represent the means of the combined male, female, and unsexed specimens; the black Λ's show the means for males and females independently adjusted by the same regression coefficient and to the same standard mean as used for the sexes combined. The distance from the tip of the white V to the outer edge of the line terminating the white rectangle equals one standard error of estimate. The distance from the white V to the extremity of the black rectangle equals two standard errors of the mean of the combined sexes.

The four black squares give the adjusted hoof breadth for the four females: 1. AMNH 34427, Point William, Victoria Island; 2. AMNH 34443, Great Bear Lake; 3. AMNH 34426, Langton Bay; 4. AMNH 34430, Horton River. These specimens are discussed in the text on pages 15 and 16.

the field and in the museum, but sections from the base and tip can easily be collected and stored, or, if weight is a problem, a ring of velvet can be skinned off and pinned out flat to dry.

## Comparison of hooves

The hooves of caribou from the Queen Elizabeth Islands are obviously shorter and blunter than those of caribou from the mainland barrens. Indeed, some of the former have hooves which are almost square tipped. The difference is not, however, readily measurable, and, as the hooves are usually attached to large skins, it is impracticable to lay them out in a series unless a large room is available. Various methods of measuring were tried, including matching the outer curve of the hoof with a series of concentric circles, to obtain the radius. This failed because of variation in the position of the sharpest angle, particularly in the very blunt hooves. The measurement finally decided on was the width of the hoof 20 mm. from the tip and parallel to the growth lines. It is not a measurement which can be taken with great accuracy because in some animals the hoof broadens rapidly where the measurement is taken. The length of the hoof parallel to the long axis of the foot was also measured. Both measurements were taken on the hooves of the fourth toe of both front feet, and the means of the result recorded.

As comparatively few specimens with hooves were available, all were used, irrespective of age and sex, and the measurements analyzed by covariance and regression of breadth on length. If the breadth measurement had been taken at a distance from the tip of the hoof proportional to the hoof length rather than at a fixed distance of 20 mm., the coefficients of regression and correlation would no doubt have been greater, but it would have made the measurements more awkward to take and probably would have produced a result only a little more satisfactory. The coefficients of regression, that is to say, the slope of the regression lines, do not differ significantly, but there is a significant difference (Table 2) in their position, or, what is equivalent, in

**Table 2.** Hoof breadth 20 mm. from tip $Y$ on hoof length $X$.

| | *No.* | $\hat{y}$ *when* $\bar{x}=76.62$ | |
|---|---|---|---|
| Queen Elizabeth Is. | 14 ♂♂, 2 ♀♀, 1 ? | $43.98 \pm 0.95$ | Difference of slope. $F=1.90$, *d.f.* 3:37, $P > .05$ |
| Banks Id. | 4 ♂♂, 4 ♀♀, | $39.63 \pm 1.30$ | Difference of position. $F=7.00$, *d.f.* 3:40, $P < .005$ |
| Dolphin and Union herd | 3 ♂♂, 4 ♀♀, 1 ? | $43.17 \pm 1.31$ | Parallel lines. $b=.200 \pm 0.061$, $S_{y \cdot x}=3.67$, $r=.46$ |
| Mainland | 4 ♂♂, 7 ♀♀, 1 ? | $36.91 \pm 1.19$ | |

The standard error of the adjusted mean was obtained from the formula $S_{y \cdot x}\sqrt{1/k + x^2/Sx^2}$ where $S_{y \cdot x}$ is the standard error of estimate for the four parallel lines, $Sx^2$ the sum of the squares associated with these lines, $k$ the number of specimens in the individual series, and $x^2$ the square of the deviation of the individual series mean from the standard mean (76.62 mm.) of the independent variate.

**Specimens used**

*Queen Elizabeth Islands.* Ellesmere Island: 12512, 14058, 14949, 21708, 21709, 21712; Axel Heiberg Island: 8797, 8798, 8799; Isachsen: 21710, 21724, 21725, 21726; Prince Patrick Island: 20340, 20343, 21600, 21727.

*Banks Island.* 2764, 2765, 2766, 2767, 2768, 2769, 2770, 21161.

*Dolphin and Union herd.* Bernard Harbour: 2559, 2747, 2748, 2749, 2750, 2760, 2763, no number.

*Mainland.* Wager Bay: AMNH 22936; Chesterfield: 14055; Clinton-Colden Lake: 14903; Artillery Lake: AMNH 29032; Coronation Gulf: 2751, 2752, AMNH 34433; Bernard Harbour: 2762; Dease River: AMNH 34437; Darnley Bay: AMNH 34432; Langton Bay: AMNH 34431; Horton River: AMNH 34434.

Certain of the skins with their attached hooves classed as 'mainland' could, from their origin, have been from the Dolphin and Union herd. Such doubtful skins were separated on pelage colour as indicated under the section on comparison of skins. The only specimen retained in the mainland group which, from its pelage colour, seemed more closely related to the Dolphin and Union herd was NMC 2752, which was taken at Port Epworth, Coronation Gulf, about October 5 and therefore, if correctly labelled, too early for a Victoria Island migrant (see p. 7). Its hooves are typical of the mainland caribou.

the adjusted means of hoof breadth. The regressions are therefore best represented by parallel lines. A remarkable feature, shown in Fig. 1, is that the adjusted mean width of the hooves of the Dolphin and Union series is similar to that of the Queen Elizabeth Islands series but markedly different from that of the other mainland specimens. The adjusted mean width of the Banks Island series falls between the mainland and the Dolphin and Union series rather than between the latter and the Queen Elizabeth Islands series. An independent test of the Banks Island and Dolphin and Union series showed that the positional difference in the regression lines is not quite statistically significant, that is to say, $F = 4.23$ with *d.f.* 1:13, whereas $P = .05$ when $F = 4.67$. The difference between the Dolphin and Union series and the other mainland specimens is obviously significant (Fig. 1), and, as has been pointed out above, the measurement used does not do full justice to the differences apparent to the eye. The bluntness of the hooves of caribou from the Queen Elizabeth Islands and from Victoria Island may be caused in part by the more rocky and stony terrain of these places when compared with the mainland and Banks Island. Also, the shape of the hooves might be expected to vary with the seasons, the shell growing out (cf. Seton, 1927, p. 70) and therefore becoming less blunt in the winter; but presumably if there is a winter growth it would have started, at least in the Arctic, by November, when most of the Dolphin and Union caribou were killed. Their hooves should therefore have been less, rather than more, blunt than the mainland and Banks Island caribou, the majority of which were killed about a month earlier. Specimens from the Queen Elizabeth Islands fall into two seasonal groups. One group of eight, taken between late March and early May and centering about mid-April, have a mean adjusted hoof width of 46.7 mm.; the other group, also of eight specimens, taken between early June and early August and centering about mid-July, have an adjusted mean of 41.8 mm. This also is the reverse of what would be expected if bluntness resulted from summer wear.

## Comparison of skulls

### *Description of measurements and methods*

All measurements used in this paper are in millimetres. Skull measurements were taken on the side indicated in the description unless that side was damaged. Originally it was intended to measure only the Banks Island specimens and to compare the results with Allen's (1908) published measurements of the Ellesmere Island and mainland barren ground specimens. When the study was enlarged, a few additional measurements were taken, and all the Queen Elizabeth Islands and barren ground specimens available in the National Museum of Canada were measured. A few measurements, then believed to be the most important, but unfortunately not including any breadth measurements, were also taken on as many skulls in the American Museum of Natural History as a short visit permitted. As Allen (1908) gives no means, and as these and the other statistics had already been calculated from his raw data, they and their corresponding Dice squares have been included for comparison and support of the measurements taken by me. They have not been combined with my measurements because Allen gives no detailed description of his methods of taking the measurements, and there may well be some discrepancies. Particularly suspect are length of mandible and the lengths of both tooth rows (see description of skull measurements). There are also significant differences between the means derived from his measurements and those from mine for skull breadth above M2 of the mainland males (Table 15, Fig. 5A) as well as for mastoid breadth of the mainland males (Table 18, Fig. 5D). As there is reasonable agreement between the means for the mainland females and for both series of the Queen Elizabeth Islands, there is no obvious explanation for differences in the mainland males, but, in view of other errors found amongst Allen's measurements, it is suspected that there may have been errors here which were too small to show in scatter diagrams. Six major errors in Allen's figures were apparent in scatter diagrams, and before calculating the statistics from his figures corrections were obtained for five of these; the sixth, palatal length of AMNH 27987, was not available when the calculations were made, and the measurement was therefore omitted. The corrections which have been used here are[1]: condylobasal length (AMNH 27930 = 327 mm., AMNH 27920 = 257 mm., AMNH 19505 = 309 mm.); skull breadth above M2 (AMNH 22936 = 116 mm.); zygomatic breadth (AMNH 19505 = 118 mm.). "Breadth above m1" on p. 493 of Allen (1908) is assumed to be the equivalent of "breadth of skull above m2" on p. 492 and in Allen's earlier publications on caribou.

In some measurements a number of the same specimens were used by both Allen and myself. These measurements may be distinguished by the increased number of Queen Elizabeth Islands and mainland specimens in my series. In the following list the measurements starred are the same, or nearly the same, as those taken by Allen (1908). Some of them involve bones, notably the nasals, the extremities of which exhibit irregular and apparently local growth and are unsatisfactory terminal points for measurement. In future studies it would be advisable to substitute measurements which would give a more exact picture of the skull shape. The surprising differences in the relative lengths of the

---

[1] I am indebted to Mr. T. Donald Carter and Dr. A. W. F. Banfield for taking these measurements.

inner and outer anterior extremities of the nasals are of interest. The two measurements of skull depth were designed so that they could be taken with ordinary vernier bar calipers. They are reasonably satisfactory, although the correct terminal points on the condyles and lambdoidal crest are sometimes difficult to determine. By using curved calipers or, perhaps still better, bar calipers with extra long jaws, more efficient measurements of depth could be taken.

### *Description of skull measurements*

* *Condylobasal length.* From the posterior extremity of the right condyle to the tip of the premaxilla.

* *Palatal length.* From the anterior extremity of the posterior border of the left palatine to the tip of the premaxilla on the same side.

* *Mandible length.* From the angle to the anterior extremity of the bone. Allen (1908, pp. 492–3) describes his measurement as "incisive border to angle". A check of 20 of his jaw measurements suggests that in most cases he used the total length as here, but sometimes measured only to the dorsal border of the alveolus of the canine. Left side.

* *Distance between tip of premaxilla and tip of nasals.* Measured on the left side from the premaxilla to the longer projection, whether central or lateral, of the nasal on the same side.

* *Nasal length.* The distance measured between parallels (i.e., not diagonal distance) from the anterior tip of that nasal bone which projects farthest forward to the posterior tip of the nasal bone which projects farthest backward.

* *Diastema length.* From the alveolus of p2 to the upper border of the alveolus of the canine. Left side.

* *Distance between tip of premaxilla and alveolus of P2* (P1 of Allen (1908)). Left side.

*Incisive foramen length.* Measured from the anterior border to the extremity of the curve at the posterior border or, when this curve was absent, to what was judged to be the equivalent position, usually the point at which the foramen proper ended and the inner border of the maxilla angled posteriorly more sharply. Right side.

* *Mandibular tooth row length.* The maximum length of the tooth row. This frequently, but not always, coincided with alveolar length. Left side.

* *Maxillary tooth row length.* Maximum length of the tooth row. This is usually from near the worn surface of M3 to the cingulum of P2. Allen describes his measurement as "crown surface". This may mean the worn surface, which is slightly less, probably 1 mm. to 3 mm., than my measurement. Left side.

*Maxillary breadth at canines.* The jaws of the calipers were held approximately parallel to the canines.

* *Palatal breadth at M1.* The distance between the alveoli of M1's measured at the central point between the anterior and the posterior root.

* *Skull breadth above M2.* Measured by placing the bar of the calipers vertically on the centre of the M2's so that the tips of the jaws (4.1 mm. long) reached to the widest part of the maxillae above.

* *Zygomatic breadth.* Measured between the centres of the junctions between the malars and the zygomatic processes of the squamosals. An objection to this measurement is that in some skulls the two bones had parted, one apparently moving outward and the other inward. An attempt was made to take the measurement as it would have been before the bones parted, but errors of 2 mm. may be expected on some skulls.

* *Orbital breadth.* This was the greatest breadth obtainable. It is normally posterior to the orbit, but in one case it was below and somewhat anterior. The irregularity of the bones around the orbit makes this measurement rather unsatisfactory.

* *Mastoid breadth.* The breadth across the mastoid processes.

*Depth of skull at M2.* Distance between the centre of the outer border of the alveolus of M2 and the junction of the nasals and frontals on the saggital plane. Right side.

*Condylo-lambdoidal depth.* From the point at which the upper, lower, and internal faces of the condyles meet, vertically to the well-marked line formed where the dorsal and posterior surfaces of the skull join at the lambdoidal crest. In skulls where this line was rounded rather than sharp, the measurement was taken to its centre. Right side.

*Central minus lateral anterior projections of nasals.* Measurements were taken parallel to the long axis of the skull on both left and right nasals. The mean of these measurements was recorded to the nearest half millimetre. When the central points were longer, the value was given a plus sign; when the outer points were longer, a minus sign. It is difficult to take this measurement with precision, but, owing to the great variation in the relative length of the anterior nasal processes, refinements are unnecessary.

### *Age of caribou used*

The last part of the maxillary tooth row to show wear is the posterior cusp of M3. According to Banfield (1954, p. 8), wear on this cusp begins when the caribou is about 26 months old. When this criterion is adopted there is usually no difficulty in identifying animals in their third summer. In order to exclude from the calculations animals killed during the summer, when it is reasonable to expect growth to be most rapid, the lower age limit was set at 28 rather than 26 months. A higher age limit was not used because too many specimens would have had to be excluded and because once all the teeth show any considerable wear aging is more difficult. It must, however, be recognized that growth has not entirely ceased at 28 months. Banfield (1954, p. 1) gives the age at which caribou reach almost full size as three years, and, from his Table 18 on p. 72, it can be seen that males in their third year (eight specimens) are 5.6 per cent short of the adults (nine specimens) in total length, and the females in their third year (three specimens), are 3.1 per cent short of the adults (nine specimens).

### *Analysis of absolute measurements*

Before grouping the Ellesmere Island and Axel Heiberg Island specimens with those from Prince Patrick and Melville islands, *F* ratio tests of their differences were made for all 19 measurements of the males. Only in palatal breadth at M1 was there a significant difference at the 5 per cent level. For the five males in the Ellesmere Island–Axel Heiberg Island group the mean of this measurement was 60.42 mm., and for the Prince Patrick Island–Melville Island males, 54.38 mm. As 19 measurements were tested, this single significant difference could well be due to chance, but with more adequate series other differences may become apparent. A test for difference in condylobasal length was also made using the three male series, Ellesmere Island–Axel Heiberg Island, Prince Patrick Island–Melville Island, and Isachsen. The result was $F = 6.7$, *d.f.* 2:12, *P* just greater than 0.01. In view of this, the three Isachsen specimens were separated from the Queen Elizabeth Islands series, not because a genetic difference was suspected, but because it was felt that the limited food on northern Ellef Ringnes Island had probably resulted in stunting.

Condylobasal length may be assumed to give a better idea of the skull size as a whole than other linear measurements, and it is probably the measurement most closely related to body size. Table 3 and Fig. 2A, therefore, suggest that the Banks Island caribou average only slightly larger than the Queen Elizabeth Islands caribou, that there is a somewhat larger difference between Banks Island and Dolphin and Union caribou, and that the main step up in size is between the Dolphin and Union and the mainland caribou. It may be questioned whether differences in mean size of the four main populations result from genetic or from ecological differences, presumably chiefly differences in range, acting on the individual. Certainly it has been shown by Huxley (1932, p. 207) that changes in environment caused major and reversible differences in size of Red Deer, *Cervus elaphus*, introduced into New Zealand, and it is tentatively

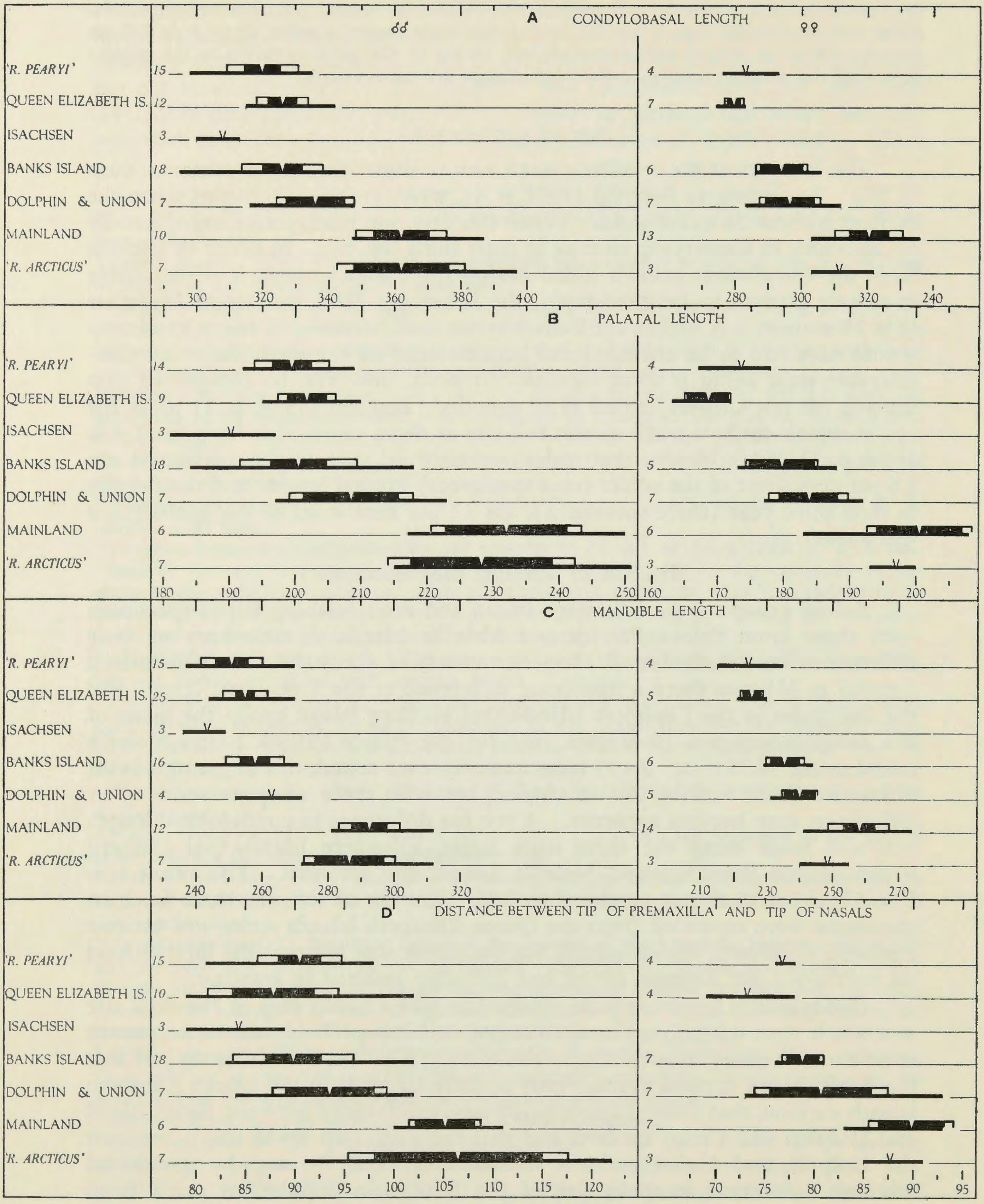

**Fig. 2.** Condylobasal length, palatal length, mandible length, and distance between tip of premaxilla and tip of nasals. The heavy base line represents the observed range. The mean is shown by a white V. The distance from the tip of the V to the outer edge of the line terminating the white rectangle is one standard deviation. The distance from the white V to the extremity of the black rectangle is two standard errors of the mean. See Tables 3 to 6 for statistics.

**Table 3.** Condylobasal length.

| | Males | | | | | Females | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Origin of specimens* | *No.* | *Range* | *Mean* | *SD ± SE* | *CV ± SE* | *No.* | *Range* | *Mean* | *SD ± SE* | *CV ± SE* |
| '*R. pearyi*' (from Allen, 1908) | 15 | 298[1]–335 | 320.00 ±2.78 | 10.78 ±1.97 | 3.37 ±0.62 | 4 | 276–293 | 283.00 | | |
| Queen Elizabeth Is. (ex. Isachsen) | 12 | 315–342 | 325.77 ±2.30 | 7.96 ±1.63 | 2.44 ±0.50 | 7 | 274–283 | 279.26 ±1.08 | 2.86 ±0.76 | 1.03 ±0.27 |
| Isachsen, Ellef Ringnes Id. | 3 | 300–313 | 307.87 | | | | | | | |
| Banks Id. | 18 | 295–345 | 325.89 ±2.95 | 12.52 ±2.09 | 3.84 ±0.64 | 6 | 286–306 | 294.15 ±3.35 | 8.21 ±2.37 | 2.79 ±0.81 |
| Dolphin and Union herd | 7 | 316–348 | 336.03 ±4.61 | 12.21 ±3.26 | 3.63 ±0.97 | 7 | 283–312 | 296.71 ±3.66 | 9.69 ±2.59 | 3.27 ±0.87 |
| Mainland (ex. D. and U. herd) | 10 | 347–387 | 362.18 ±4.45 | 14.07 ±3.15 | 3.88 ±0.87 | 13 | 303–336 | 320.29 ±2.92 | 10.52 ±2.06 | 3.28 ±0.64 |
| '*R. arcticus*' (from Allen, 1908) | 7 | 345–397 | 362.14 ±7.37 | 19.50 ±5.21 | 5.38 ±1.44 | 3 | 303–322 | 311.33 | | |

In this and the following tables the standard deviation has been calculated from the formula $\sqrt{\frac{Sx^2}{n-1}}$

**Table 4.** Palatal length.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| '*R. pearyi*' (from Allen, 1908) | 14 | 192–209 | 199.50 ±1.56 | 5.85 ±1.07 | 2.93 ±0.54 | 4 | 167–178 | 173.50 | | |
| Queen Elizabeth Is. (ex. Isachsen) | 9 | 195–210 | 201.72 ±1.49 | 4.46 ±1.05 | 1.48 ±0.35 | 5 | 163–172 | 168.46 ±1.59 | 3.56 ±1.13 | 2.11 ±0.67 |
| Isachsen, Ellef Ringnes Id. | 3 | 181–197 | 190.20 | | | | | | | |
| Banks Id. | 18 | 184–218 | 200.60 ±2.10 | 8.89 ±1.48 | 4.43 ±0.74 | 5 | 173–188 | 179.80 ±2.49 | 5.56 ±1.76 | 3.09 ±0.98 |
| Dolphin and Union herd | 7 | 197–223 | 208.39 ±3.58 | 9.46 ±2.53 | 4.54 ±1.21 | 7 | 177–192 | 183.86 ±2.30 | 6.08 ±1.63 | 3.31 ±0.88 |
| Mainland (ex. D. and U. herd) | 6 | 217–250 | 232.00 ±4.71 | 11.52 ±3.33 | 4.97 ±1.43 | 6 | 186–208 | 200.60 ±3.24 | 7.95 ±2.29 | 3.96 ±1.14 |
| '*R. arcticus*' (from Allen, 1908) | 7 | 215–251 | 228.29 ±5.43 | 14.37 ±3.84 | 6.30 ±1.68 | 3 | 193–200 | 197.00 | | |

**Table 5.** Mandible length.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| '*R. pearyi*' (from Allen, 1908) | 15 | 237–270 | 250.87 ±2.42 | 9.36 ±1.71 | 3.73 ±0.68 | 4 | 215–235 | 224.25 | | |
| Queen Elizabeth Is. (ex. Isachsen) | 25 | 244–270 | 254.96 ±1.42 | 7.12 ±1.01 | 2.79 ±0.40 | 5 | 221–230 | 225.36 ±1.59 | 3.55 ±1.12 | 1.58 ±0.50 |
| Isachsen, Ellef Ringnes Id. | 3 | 236–249 | 243.53 | | | | | | | |
| Banks Id. | 16 | 240–271 | 258.02 ±2.29 | 9.17 ±1.62 | 3.56 ±0.63 | 6 | 229–244 | 235.57 ±2.37 | 5.81 ±1.68 | 2.46 ±0.71 |
| Dolphin and Union herd | 4 | 252–274 | 263.20 | | | 5 | 231–245 | 239.80 ±2.50 | 5.59 ±1.77 | 2.33 ±0.74 |
| Mainland (ex. D. and U. herd) | 12 | 281–312 | 292.51 ±2.68 | 9.29 ±1.90 | 3.18 ±0.65 | 14 | 241–274 | 257.75 ±2.51 | 9.39 ±1.78 | 3.64 ±0.69 |
| '*R. arcticus*' (from Allen, 1908) | 7 | 272–312 | 286.29 ±5.37 | 14.20 ±3.79 | 4.96 ±1.33 | 3 | 240–255 | 248.33 | | |

**Table 6.** Distance between tip of premaxilla and tip of nasals.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| '*R. pearyi*' (from Allen, 1908) | 15 | 81–98 | 90.47 ±1.12 | 4.32 ±0.79 | 4.78 ±0.87 | 4 | 76–78 | 76.75 | | |
| Queen Elizabeth Is. (ex. Isachsen) | 10 | 79–102 | 87.80 ±2.11 | 6.69 ±1.50 | 7.62 ±1.70 | 4 | 69–78 | 73.18 | | |
| Isachsen, Ellef Ringnes Id. | 3 | 79–89 | 84.30 | | | | | | | |
| Banks Id. | 18 | 83–102 | 89.78 ±1.44 | 6.12 ±1.02 | 6.82 ±1.14 | 7 | 76–81 | 78.79 ±0.83 | 2.20 ±0.59 | 2.79 ±0.74 |
| Dolphin and Union herd | 7 | 84–102 | 93.44 ±2.22 | 5.86 ±1.57 | 6.28 ±1.68 | 7 | 73–93 | 80.67 ±2.58 | 6.82 ±1.82 | 8.45 ±2.25 |
| Mainland (ex. D. and U. herd) | 6 | 100–111 | 105.18 ±1.50 | 3.67 ±1.06 | 3.49 ±1.01 | 7 | 83–93 | 89.83 ±1.66 | 4.40 ±1.18 | 4.90 ±1.31 |
| '*R. arcticus*' (from Allen, 1908) | 7 | 91–122 | 106.57 ±4.22 | 11.18 ±2.99 | 10.49 ±2.80 | 3 | 85–91 | 87.67 | | |

---

[1] See p. 19.

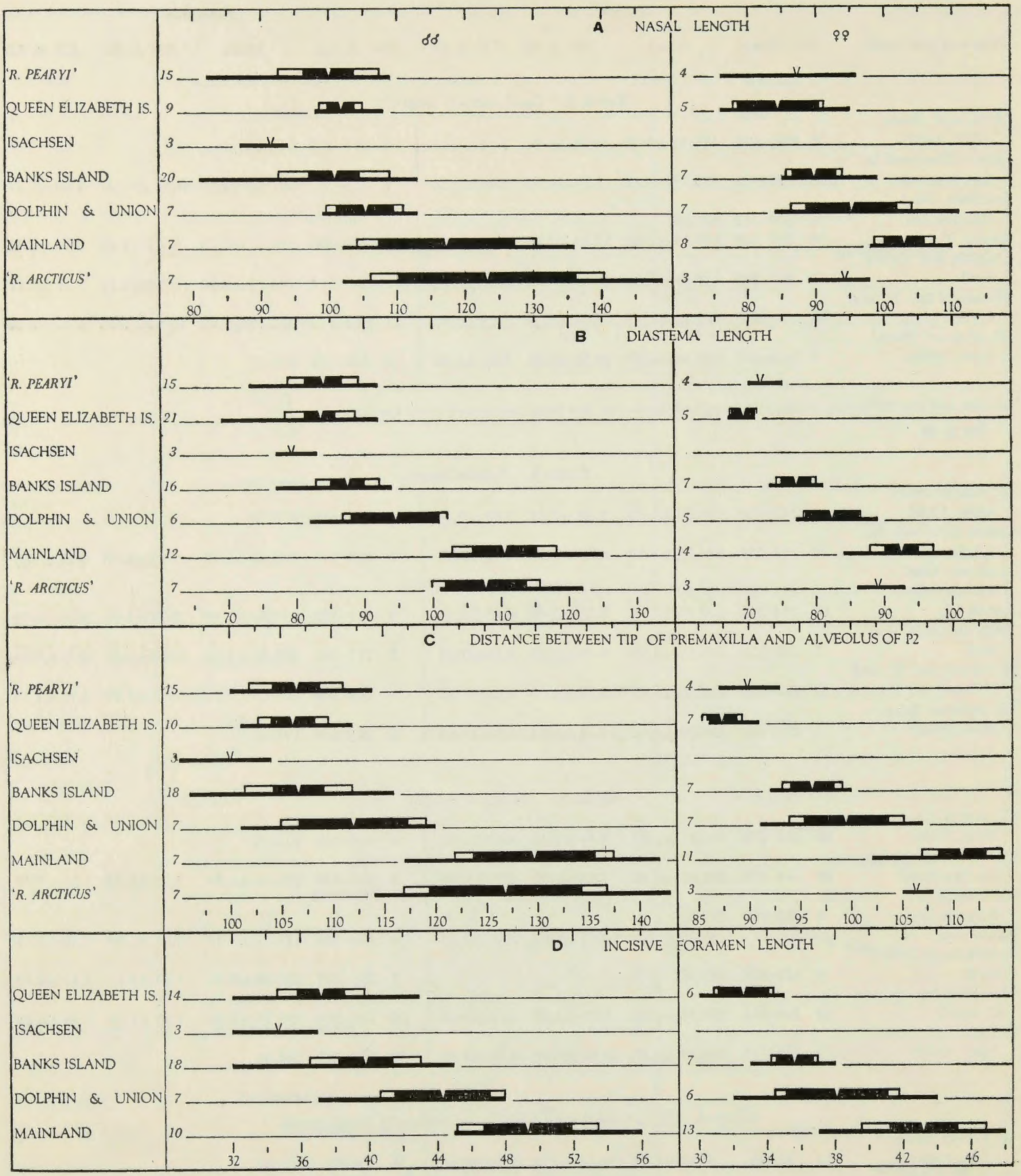

**Fig. 3.** Nasal length, diastema length, distance between tip of premaxilla and alveolus of P2, and incisive foramen length. See Fig. 2 for explanation and Tables 7 to 10 for statistics.

| | **Males** | | | | | **Females** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Origin of specimens* | *No.* | *Range* | *Mean* | *SD*±*SE* | *CV*±*SE* | *No.* | *Range* | *Mean* | *SD*±*SE* | *CV*±*SE* |
| **Table 7.** Nasal length. | | | | | | | | | | |
| '*R. pearyi*' (from Allen, 1908) | 15 | 82–109 | 100.07±1.91 | 7.40±1.35 | 7.40±1.35 | 4 | 76–96 | 87.25 | | |
| Queen Elizabeth Is. (ex. Isachsen) | 9 | 98–108 | 101.67±1.06 | 3.19±0.75 | 3.14±0.74 | 5 | 76–95 | 84.48±2.98 | 6.67±2.11 | 7.90±2.50 |
| Isachsen, Ellef Ringnes Id. | 3 | 87–94 | 91.47 | | | | | | | |
| Banks Id. | 20 | 81–113 | 100.66±1.83 | 8.16±1.29 | 8.11±1.28 | 7 | 85–99 | 89.70±1.60 | 4.23±1.13 | 4.72±1.26 |
| Dolphin and Union herd | 7 | 99–113 | 105.14±2.16 | 5.72±1.53 | 5.44±1.45 | 7 | 84–111 | 95.14±3.43 | 9.07±2.42 | 9.53±2.55 |
| Mainland (ex. D. and U. herd) | 7 | 102–136 | 117.36±5.05 | 13.35±3.57 | 11.38±3.03 | 8 | 98–110 | 102.98±1.55 | 4.40±1.10 | 4.27±1.07 |
| '*R. arcticus*' (from Allen, 1908) | 7 | 102–149 | 123.29±6.55 | 17.32±4.63 | 14.05±3.75 | 3 | 89–98 | 94.33 | | |
| **Table 8.** Diastema length. | | | | | | | | | | |
| '*R. pearyi*' (from Allen, 1908) | 15 | 73–92 | 83.93±1.37 | 5.30±0.97 | 6.31±1.15 | 4 | 70–75 | 71.75 | | |
| Queen Elizabeth Is. (ex. Isachsen) | 21 | 69–92 | 83.44±1.15 | 5.28±0.82 | 6.33±0.98 | 5 | 67–71 | 69.22±0.84 | 1.87±0.59 | 2.70±0.86 |
| Isachsen, Ellef Ringnes Id. | 3 | 77–83 | 79.33 | | | | | | | |
| Banks Id. | 16 | 77–94 | 87.61±1.22 | 4.86±0.86 | 5.55±0.98 | 7 | 73–81 | 76.97±1.16 | 3.07±0.82 | 3.98±1.06 |
| Dolphin and Union herd | 6 | 82–101 | 94.75±3.14 | 7.70±2.22 | 8.12±2.35 | 5 | 77–89 | 82.18±1.95 | 4.37±1.38 | 5.32±1.68 |
| Mainland (ex. D. and U. herd) | 12 | 101–125 | 110.40±2.37 | 7.87±1.68 | 7.13±1.52 | 14 | 84–100 | 92.59±1.30 | 4.86±0.92 | 5.25±0.99 |
| '*R. arcticus*' (from Allen, 1908) | 7 | 101–122 | 107.86±3.06 | 8.09±2.16 | 7.50±2.00 | 3 | 86–93 | 89.00 | | |
| **Table 9.** Distance between tip of premaxilla and alveolus of P2. | | | | | | | | | | |
| '*R. pearyi*' (from Allen, 1908) | 15 | 100–114 | 106.47±1.20 | 4.64±0.85 | 4.36±0.80 | 4 | 87–93 | 89.75 | | |
| Queen Elizabeth Is. (ex. Isachsen) | 10 | 101–112 | 106.18±1.09 | 3.45±0.77 | 3.25±0.73 | 7 | 86–91 | 87.36±0.75 | 1.97±0.53 | 2.26±0.60 |
| Isachsen, Ellef Ringnes Id. | 3 | 95–104 | 100.00 | | | | | | | |
| Banks Id. | 18 | 96–116 | 106.65±1.26 | 5.34±0.89 | 5.00±0.83 | 7 | 92–100 | 96.23±1.11 | 2.94±0.79 | 3.06±0.82 |
| Dolphin and Union herd | 7 | 101–120 | 112.07±2.69 | 7.11±1.90 | 6.34±1.70 | 7 | 91–107 | 99.50±2.11 | 5.59±1.49 | 5.61±1.50 |
| Mainland (ex. D. and U. herd) | 7 | 117–142 | 129.67±2.99 | 7.91±2.11 | 6.10±1.63 | 11 | 102–115 | 110.77±1.20 | 3.99±0.85 | 3.60±0.77 |
| '*R. arcticus*' (from Allen, 1908) | 7 | 114–143 | 126.86±3.78 | 9.99±2.67 | 7.88±2.10 | 3 | 105–108 | 106.33 | | |
| **Table 10.** Incisive foramen length. | | | | | | | | | | |
| Queen Elizabeth Is. (ex. Isachsen) | 14 | 32–43 | 37.17±0.70 | 2.60±0.49 | 7.00±1.32 | 6 | 30–35 | 32.58±0.74 | 1.82±0.53 | 5.59±1.62 |
| Isachsen, Ellef Ringnes Id. | 3 | 32–37 | 34.70 | | | | | | | |
| Banks Id. | 18 | 32–45 | 39.80±0.78 | 3.32±0.55 | 8.34±1.39 | 7 | 33–38 | 35.61±0.54 | 1.43±0.38 | 4.00±1.07 |
| Dolphin and Union herd | 7 | 37–48 | 44.27±1.39 | 3.68±0.98 | 8.31±2.22 | 6 | 32–44 | 38.10±1.49 | 3.65±1.05 | 9.59±2.77 |
| Mainland (ex. D. and U. herd) | 10 | 45–56 | 49.32±1.32 | 4.18±0.93 | 8.47±1.89 | 13 | 37–48 | 43.15±1.01 | 3.65±0.72 | 8.46±1.66 |

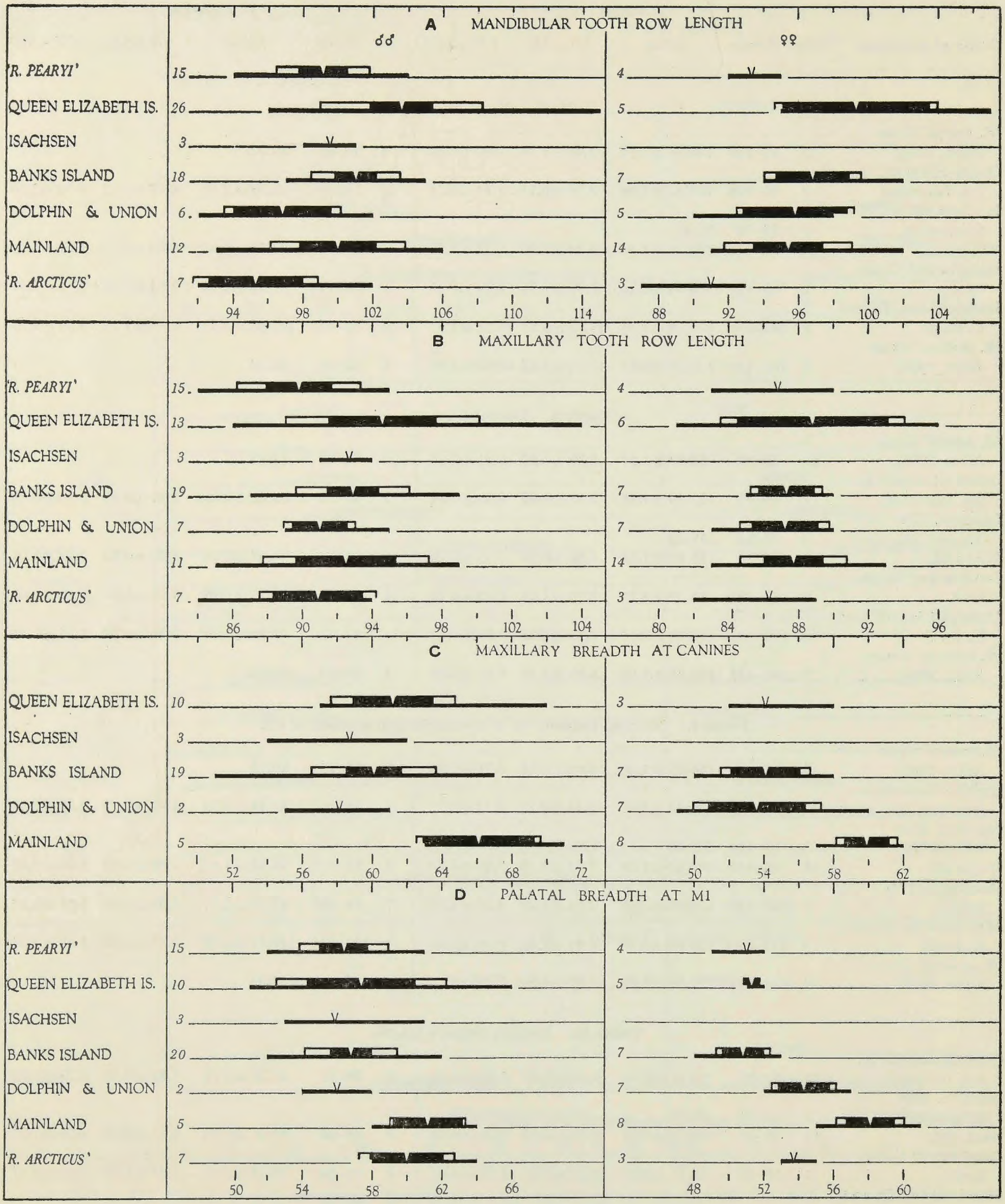

**Fig. 4.** Mandibular tooth row length, maxillary tooth row length, maxillary breadth at canines, and palatal breadth at M1. See Fig. 2 for explanation and Tables 11 to 14 for statistics.

**Table 11.** Mandibular tooth row length.

| *Origin of specimens* | Males | | | | | Females | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *No.* | *Range* | *Mean* | *SD±SE* | *CV±SE* | *No.* | *Range* | *Mean* | *SD±SE* | *CV±SE* |
| '*R. pearyi*' (from Allen, 1908) | 15 | 94–104 | 99.07±0.70 | 2.71±0.50 | 2.74±0.50 | 4 | 92–95 | 93.25 | | |
| Queen Elizabeth Is. (ex. Isachsen) | 26 | 96–115 | 103.59±0.92 | 4.67±0.65 | 4.51±0.63 | 5 | 95–107 | 99.28±2.10 | 4.69±1.48 | 4.73±1.50 |
| Isachsen, Ellef Ringnes Id. | 3 | 98–101 | 99.50 | | | | | | | |
| Banks Id. | 18 | 97–105 | 101.57±0.61 | 2.60±0.43 | 2.56±0.43 | 7 | 94–102 | 96.76±1.06 | 2.81±0.75 | 2.91±0.77 |
| Dolphin and Union herd | 6 | 92–102 | 96.82±1.38 | 3.38±0.98 | 3.50±1.01 | 5 | 90–98 | 95.84±1.51 | 3.38±1.07 | 3.53±1.12 |
| Mainland (ex. D. and U. herd) | 12 | 93–106 | 99.97±1.12 | 3.88±0.79 | 3.88±0.79 | 14 | 91–102 | 95.39±0.99 | 3.69±0.70 | 3.87±0.73 |
| '*R. arcticus*' (from Allen, 1908) | 7 | 92–102 | 95.29±1.34 | 3.55±0.95 | 3.72±0.99 | 3 | 87–93 | 91.00 | | |

**Table 12.** Maxillary tooth row length.

| *Origin of specimens* | Males | | | | | Females | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *No.* | *Range* | *Mean* | *SD±SE* | *CV±SE* | *No.* | *Range* | *Mean* | *SD±SE* | *CV±SE* |
| '*R. pearyi*' (from Allen, 1908) | 15 | 84–95 | 89.80±0.93 | 3.59±0.66 | 4.00±0.73 | 4 | 83–90 | 86.75 | | |
| Queen Elizabeth Is. (ex. Isachsen) | 13 | 86–106 | 94.62±1.54 | 5.56±1.09 | 5.88±1.15 | 6 | 81–96 | 88.82±2.17 | 5.30±1.53 | 5.97±1.72 |
| Isachsen, Ellef Ringnes Id. | 3 | 91–94 | 92.67 | | | | | | | |
| Banks Id. | 19 | 87–99 | 92.86±0.75 | 3.25±0.53 | 3.50±0.57 | 7 | 85–90 | 87.34±0.80 | 2.11±0.56 | 2.41±0.64 |
| Dolphin and Union herd | 7 | 89–95 | 91.01±0.78 | 2.06±0.55 | 2.27±0.61 | 7 | 83–90 | 87.16±0.97 | 2.57±0.69 | 2.95±0.79 |
| Mainland (ex. D. and U. herd) | 11 | 85–99 | 92.49±1.45 | 4.82±1.03 | 5.21±1.11 | 14 | 83–93 | 87.66±0.83 | 3.10±0.59 | 3.54±0.67 |
| '*R. arcticus*' (from Allen, 1908) | 7 | 84–94 | 90.86±1.28 | 3.39±1.00 | 3.73±0.91 | 3 | 82–89 | 86.33 | | |

**Table 13.** Maxillary breadth at canines.

| *Origin of specimens* | Males | | | | | Females | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *No.* | *Range* | *Mean* | *SD±SE* | *CV±SE* | *No.* | *Range* | *Mean* | *SD±SE* | *CV±SE* |
| Queen Elizabeth Is. (ex. Isachsen) | 10 | 57–70 | 61.23±1.13 | 3.57±0.80 | 5.83±1.30 | 3 | 52–58 | 54.10 | | |
| Isachsen, Ellef Ringnes Id. | 3 | 54–62 | 58.73 | | | | | | | |
| Banks Id. | 19 | 51–67 | 60.12±0.81 | 3.55±0.58 | 5.90±0.96 | 7 | 50–58 | 54.10±0.99 | 2,63±0.70 | 4.86±1.30 |
| Dolphin and Union herd | 2 | 55–61 | 58.05 | | | 7 | 49–60 | 53.57±1.40 | 3.70±0.99 | 6.91±1.85 |
| Mainland (ex. D. and U. herd) | 5 | 63–71 | 66.06±1.59 | 3.56±1.13 | 5.39±1.70 | 8 | 57–62 | 59.90±0.63 | 1.79±0.45 | 2.99±0.75 |

**Table 14.** Palatal breadth at M1.

| *Origin of specimens* | Males | | | | | Females | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *No.* | *Range* | *Mean* | *SD±SE* | *CV±SE* | *No.* | *Range* | *Mean* | *SD±SE* | *CV±SE* |
| '*R. pearyi*' (from Allen, 1908) | 15 | 52–61 | 56.40±0.68 | 2.64±0.48 | 4.68±0.85 | 4 | 49–52 | 51.00 | | |
| Queen Elizabeth Is. (ex. Isachsen) | 10 | 51–66 | 57.40±1.56 | 4.92±1.10 | 8.57±1.92 | 5 | 51–52 | 51.30±0.24 | 0.54±0.17 | 1.05±0.33 |
| Isachsen, Ellef Ringnes Id. | 3 | 53–61 | 55.87 | | | | | | | |
| Banks Id. | 20 | 52–62 | 56.77±0.61 | 2.73±0.43 | 4.82±0.76 | 7 | 48–53 | 50.77±0.61 | 1.62±0.43 | 3.20±0.85 |
| Dolphin and Union herd | 2 | 54–58 | 56.00 | | | 7 | 52–57 | 54.26±0.73 | 1.92±0.51 | 3.54±0.94 |
| Mainland (ex. D. and U. herd) | 5 | 58–64 | 61.20±1.00 | 2.23±0.71 | 3.64±1.15 | 8 | 55–61 | 58.06±0.69 | 1.96±0.49 | 3.38±0.84 |
| '*R. arcticus*' (from Allen, 1908) | 7 | 58–64 | 60.00±1.05 | 2.77±0.74 | 4.61±1.23 | 3 | 53–55 | 53.67 | | |

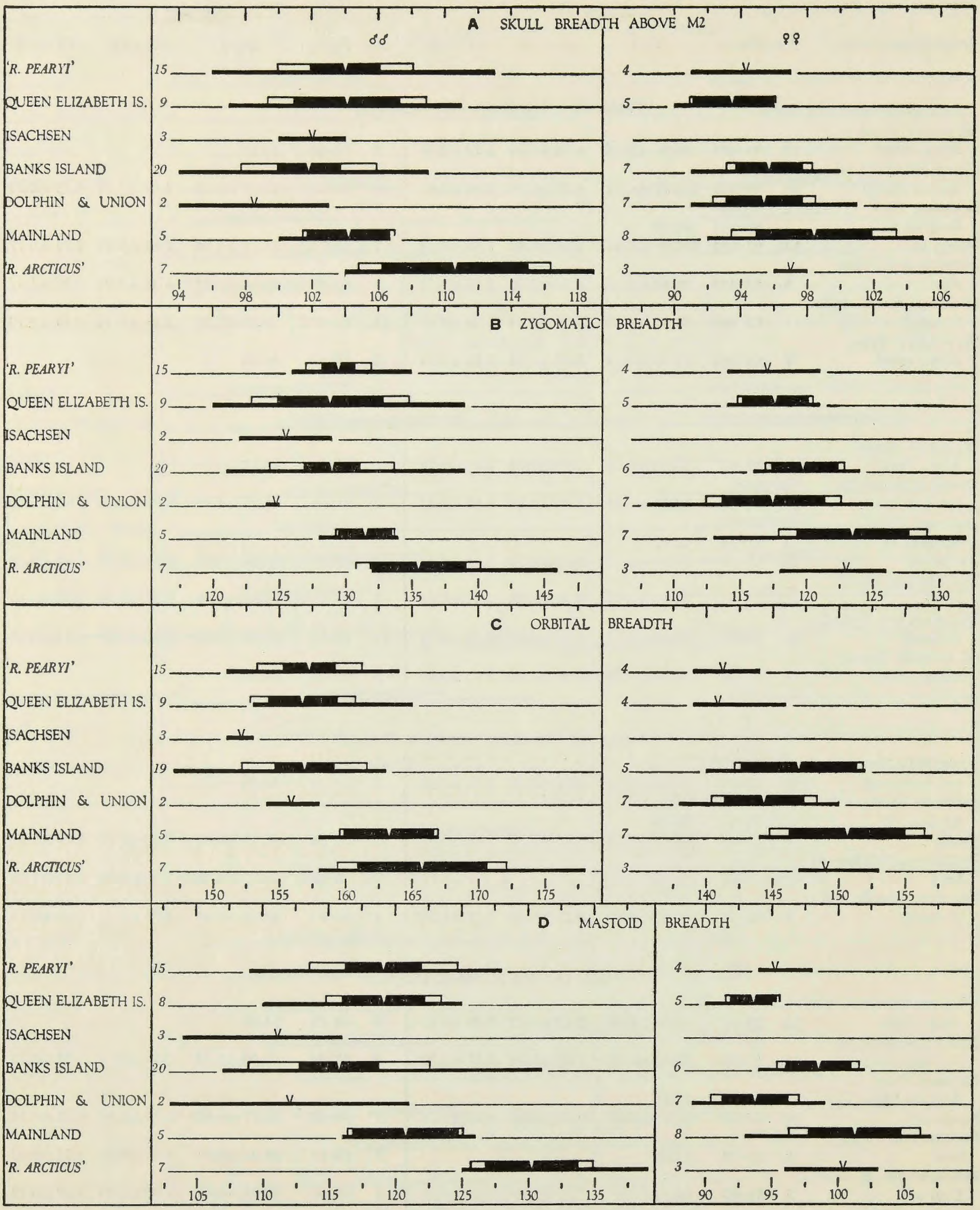

**Fig. 5.** Skull breadth above M2, zygomatic breadth, orbital breadth, and mastoid breadth. See Fig. 2 for explanation and Tables 15 to 18 for statistics.

| | **Males** | | | | | **Females** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Origin of specimens* | *No.* | *Range* | *Mean* | *SD±SE* | *CV±SE* | *No.* | *Range* | *Mean* | *SD±SE* | *CV±SE* |
| **Table 15.** Skull breadth above M2. | | | | | | | | | | |
| '*R. pearyi*' (from Allen, 1908) | 15 | 96–113 | 104.00±1.06 | 4.09±0.75 | 3.93±0.72 | 4 | 91–97 | 94.25 | | |
| Queen Elizabeth Is. (ex. Isachsen) | 9 | 97–111 | 104.16±1.59 | 4.76±1.12 | 4.57±1.08 | 5 | 90–96 | 93.52±1.18 | 2.64±0.84 | 2.83±0.89 |
| Isachsen, Ellef Ringnes Id. | 3 | 100–104 | 102.00 | | | | | | | |
| Banks Id. | 20 | 94–109 | 101.81±0.93 | 4.14±0.65 | 4.07±0.64 | 7 | 91–100 | 95.69±0.99 | 2.63±0.70 | 2.75±0.73 |
| Dolphin and Union herd | 2 | 94–103 | 98.45 | | | 7 | 91–101 | 95.40±1.17 | 3.09±0.83 | 3.24±0.87 |
| Mainland (ex. D. and U. herd) | 5 | 100–107 | 104.22±1.25 | 2.79±0.88 | 2.68±0.85 | 8 | 92–105 | 98.44±1.75 | 4.96±1.24 | 5.04±1.26 |
| '*R. arcticus*' (from Allen, 1908) | 7 | 104–119 | 110.57±2.18 | 5.77±1.54 | 5.22±1.39 | 3 | 96–98 | 97.00 | | |
| **Table 16.** Zygomatic breadth. | | | | | | | | | | |
| '*R. pearyi*' (from Allen, 1908) | 15 | 126–135 | 129.47±0.64 | 2.47±0.45 | 1.91±0.35 | 4 | 114–121 | 117.00 | | |
| Queen Elizabeth Is. (ex. Isachsen) | 9 | 120–139 | 128.89±2.01 | 6.02±1.42 | 4.67±1.10 | 5 | 114–121 | 117.66±1.28 | 2.87±0.91 | 2.44±0.77 |
| Isachsen, Ellef Ringnes Id. | 2 | 122–129 | 125.45 | | | | | | | |
| Banks Id. | 20 | 121–139 | 129.04±1.05 | 4.71±0.74 | 3.65±0.58 | 6 | 116–124 | 119.83±1.22 | 3.00±0.86 | 2.50±0.72 |
| Dolphin and Union herd | 2 | 124–125 | 124.70 | | | 7 | 108–125 | 117.51±1.94 | 5.12±1.37 | 4.36±1.16 |
| Mainland (ex. D. and U. herd) | 5 | 128–134 | 131.48±0.98 | 2.20±0.70 | 1.67±0.53 | 7 | 113–132 | 123.53±2.13 | 5.65±1.51 | 4.57±1.22 |
| '*R. arcticus*' (from Allen, 1908) | 7 | 132–146 | 135.57±1.80 | 4.76±1.80 | 1.27±0.94 | 3 | 118–126 | 123.00 | | |
| **Table 17.** Orbital breadth. | | | | | | | | | | |
| '*R. pearyi*' (from Allen, 1908) | 15 | 151–164 | 157.20±1.03 | 3.99±0.73 | 2.54±0.46 | 4 | 139–144 | 141.25 | | |
| Queen Elizabeth Is. (ex. Isachsen) | 9 | 153–165 | 156.71±1.31 | 3.94±0.93 | 2.52±0.59 | 4 | 139–146 | 140.85 | | |
| Isachsen, Ellef Ringnes Id. | 3 | 151–153 | 152.13 | | | | | | | |
| Banks Id. | 19 | 147–163 | 156.93±1.10 | 4.79±0.78 | 3.05±0.50 | 5 | 140–152 | 147.06±2.16 | 4.83±1.53 | 3.29±1.04 |
| Dolphin and Union herd | 2 | 154–158 | 155.90 | | | 7 | 138–150 | 144.39±1.50 | 3.97±1.06 | 2.75±0.74 |
| Mainland (ex. D. and U. herd) | 5 | 158–167 | 163.30±1.70 | 3.80±1.20 | 2.33±0.74 | 7 | 144–157 | 150.63±2.20 | 5.82±1.56 | 3.86±1.03 |
| '*R. arcticus*' (from Allen, 1908) | 7 | 158–178 | 165.71±2.41 | 6.37±1.70 | 3.84±1.03 | 3 | 147–153 | 149.00 | | |
| **Table 18.** Mastoid breadth. | | | | | | | | | | |
| '*R. pearyi*' (from Allen, 1908) | 15 | 109–128 | 119.07±1.45 | 5.61±1.02 | 4.71±0.86 | 4 | 94–98 | 95.25 | | |
| Queen Elizabeth Is. (ex. Isachsen) | 8 | 110–125 | 119.08±1.56 | 4.41±1.10 | 3.70±0.93 | 5 | 90–95 | 93.66±0.88 | 1.98±0.63 | 2.11±0.67 |
| Isachsen, Ellef Ringnes Id. | 3 | 104–116 | 111.07 | | | | | | | |
| Banks Id. | 20 | 107–131 | 115.70±1.53 | 6.85±1.08 | 5.92±0.94 | 6 | 94–102 | 98.47±1.25 | 3.07±0.89 | 3.11±0.90 |
| Dolphin and Union herd | 2 | 103–121 | 112.05 | | | 7 | 89–99 | 93.74±1.26 | 3.34±0.89 | 3.56±0.95 |
| Mainland (ex. D. and U. herd) | 5 | 116–126 | 120.76±1.97 | 4.41±1.40 | 3.66±1.16 | 8 | 93–107 | 101.30±1.78 | 5.03±1.26 | 4.97±1.24 |
| '*R. arcticus*' (from Allen, 1908) | 7 | 125–139 | 130.29±1.77 | 4.68±1.25 | 3.59±0.96 | 3 | 96–103 | 100.33 | | |

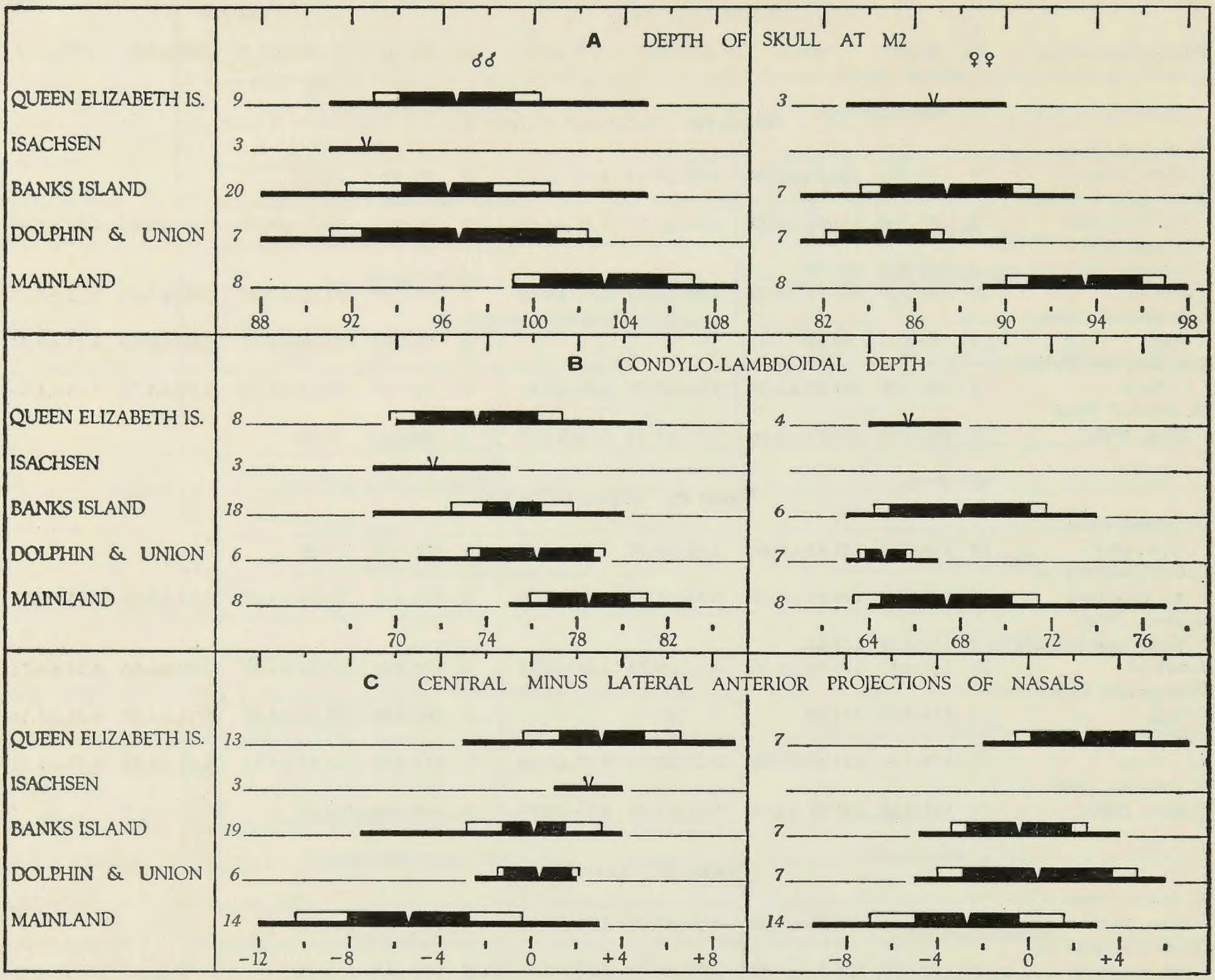

**Fig. 6.** Depth of skull at M2, condylo-lambdoidal depth, and central minus lateral anterior projections of nasals. See Fig. 2 for explanation and Tables 19 to 21 for statistics.

accepted that the poorer range of the arctic islands may at least be a contributing factor to the small size of the caribou living there. However, it remains to be explained why the apparently much better grazing of Banks Island produces caribou only slightly larger than those of Prince Patrick Island, or why the caribou of Baffin Island are larger than those of Banks Island, although grazing appears similar. Also, if range conditions materially affect size, there should recently have been an increase in size of caribou in areas such as Ungava, where human agencies have reduced the population with a consequent apparent improvement in range.

All the length measurements used (Tables 3–10, Figs. 2, 3), except those of the tooth rows, have the same general inter-population pattern as condylobasal length, but the differences between populations are greater in measurements of the anterior part of the skull. The four main populations show less difference in skull breadth measurements (Tables 13–18, Figs. 4, 5) than in those of length, but again the main differences are between the Dolphin and Union herd and the mainland population, no doubt because of the larger general

**Table 19.** Depth of skull at M2.

| | Males | | | | | Females | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Origin of specimens* | *No.* | *Range* | *Mean* | *SD±SE* | *CV±SE* | *No.* | *Range* | *Mean* | *SD±SE* | *CV±SE* |
| Queen Elizabeth Is. (ex. Isachsen) | 9 | 91–105 | 96.63±1.24 | 3.71±0.87 | 3.84±0.90 | 3 | 83–90 | 86.83 | | |
| Isachsen, Ellef Ringnes Id. | 3 | 91–94 | 92.57 | | | | | | | |
| Banks Id. | 20 | 88–105 | 96.15±1.01 | 4.53±0.72 | 4.71±0.74 | 7 | 81–93 | 87.36±1.45 | 3.84±1.03 | 4.39±1.17 |
| Dolphin and Union herd | 7 | 88–103 | 96.70±2.14 | 5.65±1.51 | 5.84±1.56 | 7 | 81–90 | 84.69±0.99 | 2.63±0.70 | 3.11±0.83 |
| Mainland (ex. D. and U. herd) | 8 | 99–109 | 103.14±1.42 | 4.02±1.01 | 3.90±0.97 | 8 | 89–98 | 93.46±1.24 | 3.52±0.88 | 3.77±0.94 |

**Table 20.** Condylo-lambdoidal depth.

| | Males | | | | | Females | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Origin of specimens* | *No.* | *Range* | *Mean* | *SD±SE* | *CV±SE* | *No.* | *Range* | *Mean* | *SD±SE* | *CV±SE* |
| Queen Elizabeth Is. (ex. Isachsen) | 8 | 70–81 | 73.48±1.33 | 3.76±0.94 | 5.11±1.28 | 4 | 64–68 | 65.68 | | |
| Isachsen, Ellef Ringnes Id. | 3 | 69–75 | 71.63 | | | | | | | |
| Banks Id. | 18 | 69–80 | 75.07±0.63 | 2.67±0.45 | 3.56±0.59 | 6 | 63–74 | 67.98±1.54 | 3.78±1.09 | 5.56±1.61 |
| Dolphin and Union herd | 6 | 71–79 | 76.23±1.24 | 3.03±0.88 | 3.98±1.15 | 7 | 63–67 | 64.67±0.44 | 1.15±0.31 | 1.78±0.48 |
| Mainland (ex. D. and U. herd) | 8 | 75–83 | 78.51±0.91 | 2.58±0.64 | 3.29±0.82 | 8 | 64–77 | 67.44±1.45 | 4.10±1.03 | 6.08±1.52 |

**Table 21.** Central minus lateral anterior projections of nasals.

| | Males | | | | Females | | | |
|---|---|---|---|---|---|---|---|---|
| *Origin of specimens* | *No.* | *Range* | *Mean* | *SD±SE* | *No.* | *Range* | *Mean* | *SD±SE* |
| Queen Elizabeth Is. (ex. Isachsen) | 13 | − 3 to +9 | +3.08±0.97 | 3.51±0.69 | 7 | −2 to +7 | +2.36±1.13 | 2.98±0.80 |
| Isachsen, Ellef Ringnes Id. | 3 | + 1 +4 | +2.50 | | | | | |
| Banks Id. | 19 | − 7.5 +4 | +0.08±0.69 | 3.01±0.49 | 7 | −4 +4 | −0.36±1.15 | 3.04±0.81 |
| Dolphin and Union herd | 6 | − 2.5 +2 | +0.25±0.73 | 1.78±0.51 | 7 | −5 +6 | +0.36±1.66 | 4.38±1.17 |
| Mainland (ex. D. and U. herd) | 14 | −12 +3 | −5.43±1.34 | 5.00±0.94 | 14 | −9.5 +3 | −2.68±1.15 | 4.30±0.81 |

size difference between these populations. The breadth measurements of the three northern populations are very similar, but there is a slight tendency to broader skulls in the Queen Elizabeth Islands series. The similarities and differences in depth of skull at M2 (Table 19, Fig. 6A) amongst the four main populations follow much the same pattern as those of breadth measurements. It is less regular in condylo-lambdoidal depth (Table 20, Fig. 6B). In both males and females the mandibular and maxillary tooth rows (Tables 11, 12, Figs. 4A, B) of the mainland caribou average shorter than those of the Queen Elizabeth Islands caribou. In view of the much greater length of the skulls of mainland caribou this difference is remarkable. Presumably the longer tooth rows of the northern form are either unmodified characters derived from an ancestor of greater total size than the present mainland Barren Ground Caribou, or at least one with relatively larger teeth; or, they are the result of selection for more severe arctic conditions, such as poorer or tougher food. In this connection it is interesting to recall that the arctic islands Muskoxen also average longer tooth rows than the mainland form (Allen, 1913, p. 179).

If a count is made in Tables 3 to 20, it will be found that where the same measurement has been taken on five or more males and five or more females of the same population, the coefficient of variation is greater in males than in females in 41 cases, and greater in females than in males in only 19 cases. It may therefore be supposed that males are more variable than females. This, perhaps, is partly because the former reach maturity later (Banfield, 1954, p. 31, and p. 21 above).

### *Covariance analysis*

This sub-section deals principally with methods and with results not directly related to taxonomy. The results which bear directly on the interrelationship of the four populations are given in Tables 23–5 and Figs. 7 and 8, which are virtually self-explanatory. They are briefly considered in the discussion.

*Reasons for omitting young animals.* In caribou the molar and premolar tooth row is not completed until the animal is about two years old. As the posterior molars develop those anterior to them change position relative to other points on the skull, such as the anterior edge of the orbit. Measurements of young animals based on any part of the mandibular or the maxillary tooth rows cannot therefore be combined satisfactorily with those of adults. It was originally intended to group young and adults for covariance treatment of other measurements. However, the scatter diagrams indicated difficulties which could not be adequately examined with the material available. Thus in some pairs of measurements, for instance mastoid breadth on condylobasal length, the regression lines for younger animals, although apparently parallel to those of the adults, appeared to be displaced positionally, in this case toward greater relative breadth. If this be not due to an error of sampling, there must be two changes in coefficients of regression during growth, or rather, one change during growth and one at or near maturity. It also appeared that differences between the positions of the regression lines of the four populations were much less in the young caribou than they were in adults. If this is indeed the case, it follows that during the growth period taken as a whole there would have to be differences in slope between the regression lines of the four populations. However, if the regression coefficients change during growth, the regression lines of the four populations may be parallel when short periods of growth are considered. Inter-population differences over the whole period would, in that case, be caused by variations in the time at which growth switched from one regression coefficient to another.

*Methods.* As condylobasal length was considered the best available measurement of total size as well as of total skull length, it was in most instances the obvious choice for the independent variate. Mandible length was used as the independent variate for analysis of diastema length and of mandibular tooth row length because more jaws were measured than skulls. The 11 measurements used as dependent variates were considered representative of the measurements originally taken, and it can be seen from the Dice squares for the unadjusted measurements (Figs. 2–6) that all except one of the measurements not used have an inter-population pattern similar to one or more of those which were used. The exception is distance between length of central and lateral nasal projections. Theoretically, it might be expected that where the difference was large it would be more likely to be affected by the total skull length than when it was small, so that covariance analysis could not be expected to yield useful results.

As distance between tip of premaxilla and alveolus of P2 is clearly a part of condylobasal length, and diastema length a part of mandible length, condylobasal length minus distance between tip of premaxilla and alveolus of P2 and mandible length minus diastema length are also used as independent variates. The sums of squares and products for these two independent variates were obtained from the formulae $Sx'^2 = Sx^2 + Sy^2 - 2{*}Sxy$ and $Sx'y = \frac{1}{2}(Sx^2 - Sy^2 - Sx'^2)$ when $x' = x - y$. When, as in this case, a calculating machine is available so that sufficient places of decimals can be carried, these formulae are exact and can be used to save unnecessary measuring and calculating.

In all, 14 pairs of measurements (Table 22) were used for covariance analysis. As only full-grown and nearly full-grown caribou were included, the ranges of the measurements were comparatively small. This made it unlikely that any advantage would accrue from converting the measurements to logarithms, and the linear regression formula was therefore used.

In the analysis of the absolute measurements specimens from Isachsen were kept separate because of their obvious small size. For regression and covariance treatments they were combined with the remainder of the Queen Elizabeth Islands series. The four main populations considered were therefore those of the Queen Elizabeth Islands, Banks Island, the Dolphin and Union herd, and the mainland barrens.

When the scatter diagrams were first examined no obvious difference in slope or position of the male and female regression lines was seen. The sexes were therefore pooled. Analysis showed that there was no significant difference in any measurement between the slope of the regression lines for the four populations, but that there were highly significant differences in the positions of these lines (Table 23, Fig. 7). When, however, the regression lines for the combined males and females were plotted on the scatter diagrams, it was realized that the original assumption that there were no significant positional differences between the regression lines of males and females had, in some measurements, been incorrect. The sexes were therefore analyzed separately.

In the females there were no significant differences in the regression coefficients; in the males there was one significant difference. This was for diastema length on mandible length, C in tables, which reached significance at the 1 per cent level. The number of specimens and individual regressions with their standard errors for males and females are given below.

| | ♂♂ | | ♀♀ | |
|---|---|---|---|---|
| | *n* | *b* | *n* | *b* |
| Queen Elizabeth Is. | 23 | 0.48 ± .09 | 5 | 0.49 ± .08 |
| Banks Id. | 16 | 0.39 ± .10 | 6 | 0.47 ± .14 |
| Dolphin and Union | 4 | 0.78 ± .31 | 5 | 0.67 ± .18 |
| Mainland | 13 | 0.83 ± .07 | 14 | 0.44 ± .07 |

It will be seen that the regression coefficients for the females do not support the differences found in the males. In order to be sure that the apparently more rapid relative increase in diastema length of the larger animals was not

---

*Owing to a copying error this 2 was omitted in Manning, 1956a, p. 42.

**Table 22.** Numbers and sexes of specimens used in covariance analysis of skull measurements and the standard means of the independent variates to which the dependent variates have been adjusted in Tables 23 and 24.

| | | | *Numbers and sexes of specimens used* | | | | | | | | | | | *Standard mean* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Dependent variate* | *Independent variate* | *Queen Elizabeth Is.* | | | *Banks Id.* | | | *Dolphin and Union* | | *Mainland* | | | |
| | | | ♂ | ♀ | ? | ♂ | ♀ | ? | ♂ | ♀ | ♂ | ♀ | ? | |
| A | Distance between tip of premaxilla and alveolus of P2 | Condylobasal length | 12 | 7 | 1 | 18 | 6 | 2 | 7 | 7 | 7 | 11 | 2 | 315.0 |
| B | Distance between tip of premaxilla and alveolus of P2 | Condylobasal length *minus* distance between tip of premaxilla and alveolus of P2 | 12 | 7 | 1 | 18 | 6 | 2 | 7 | 7 | 7 | 11 | 2 | 210.0 |
| C | Diastema length | Mandible length | 23 | 5 | 1 | 16 | 6 | 2 | 4 | 5 | 13 | 14 | 2 | 260.0 |
| D | Diastema length | Mandible length *minus* diastema length | 23 | 5 | 1 | 16 | 6 | 2 | 4 | 5 | 13 | 14 | 2 | 175.0 |
| E | Incisive foramen length | Condylobasal length | 15 | 6 | | 18 | 6 | 2 | 7 | 6 | 10 | 13 | 2 | 315.0 |
| F | Mandibular tooth row length | Mandible length | 28 | 5 | 1 | 16 | 6 | 2 | 4 | 5 | 13 | 14 | 2 | 260.0 |
| G | Maxillary tooth row length | Condylobasal length | 13 | 6 | 1 | 18 | 6 | 2 | 7 | 7 | 8 | 13 | 2 | 315.0 |
| H | Skull breadth above M2 | Condylobasal length | 12 | 5 | 1 | 18 | 6 | 2 | 2 | 7 | 4 | 7 | 1 | 315.0 |
| I | Zygomatic breadth | Condylobasal length | 11 | 5 | 1 | 18 | 6 | 2 | 2 | 7 | 4 | 6 | | 315.0 |
| J | Orbital breadth | Condylobasal length | 12 | 4 | 1 | 17 | 5 | 2 | 2 | 7 | 4 | 6 | | 315.0 |
| K | Mastoid breadth | Condylobasal length | 11 | 5 | 1 | 18 | 6 | 2 | 2 | 7 | 4 | 7 | 1 | 315.0 |
| L | Depth of skull at M2 | Condylobasal length | 12 | 3 | 1 | 18 | 6 | 2 | 7 | 7 | 5 | 7 | 1 | 315.0 |
| M | Condylo-lambdoidal depth | Condylobasal length | 11 | 4 | 1 | 18 | 6 | 2 | 6 | 7 | 5 | 7 | 1 | 315.0 |
| N | Mastoid breadth | Distance between tip of premaxilla and alveolus of P2 | 11 | 5 | 1 | 18 | 6 | 2 | 2 | 7 | 4 | 7 | 1 | 105.0 |

**Table 23.** Statistics derived from covariance analysis of skull measurements of males and females and unsexed specimens. Sex differences ignored.

|  | *n* | $S_{y\cdot x}$ | *b* ±SE | *r* | *Adjusted means* |  |  |  | *F* |
|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  | *Queen Elizabeth Is.* | *Banks Id.* | *Dolphin and Union* | *Mainland* |  |
| A | 80 | 2.39 | .396±.013 | 0.96 | 104.2±0.56 | 105.1±0.49 | 107.3±0.67 | 110.2±0.56 | 19.86**** |
| B | 80 | 3.89 | .602±.034 | 0.90 | 102.4±0.89 | 104.1±0.78 | 107.7±1.07 | 113.1±0.89 | 26.73**** |
| C | 91 | 3.13 | .501±.022 | 0.93 | 84.9±0.63 | 87.6±0.70 | 90.3±1.14 | 92.6±0.63 | 22.26**** |
| D | 91 | 5.81 | .718±.076 | 0.72 | 80.9±1.10 | 86.1±1.21 | 90.5±1.98 | 97.8±1.10 | 40.47**** |
| E | 85 | 2.63 | .147±.014 | 0.77 | 37.4±0.59 | 39.3±0.53 | 42.0±0.76 | 43.1±0.55 | 16.72**** |
| F | 96 | 3.84 | .131±.027 | 0.46 | 103.9±0.70 | 100.9±0.83 | 97.3±1.35 | 95.7±0.75 | 18.70**** |
| G | 83 | 3.62 | .112±.019 | 0.56 | 94.9±0.84 | 91.9±0.74 | 89.6±1.00 | 87.7±0.78 | 12.31**** |
| H | 65 | 3.44 | .190±.023 | 0.73 | 102.2±0.84 | 100.3±0.70 | 98.4±1.19 | 97.3±1.03 | 5.17*** |
| I | 62 | 3.92 | .250±.027 | 0.78 | 127.0±0.99 | 126.7±0.80 | 122.1±1.36 | 121.5±1.29 | 6.95**** |
| J | 60 | 3.61 | .320±.026 | 0.86 | 154.1±0.91 | 154.0±0.77 | 151.1±1.25 | 149.5±1.19 | 4.74** |
| K | 64 | 3.87 | .534±.026 | 0.94 | 114.9±0.97 | 110.4±0.79 | 104.1±1.34 | 99.8±1.16 | 37.25**** |
| L | 69 | 2.62 | .275±.016 | 0.91 | 95.9±0.67 | 94.7±0.53 | 91.7±0.72 | 93.0±0.75 | 7.21**** |
| M | 68 | 3.10 | .204±.019 | 0.80 | 73.4±0.80 | 73.8±0.63 | 70.9±0.89 | 68.3±0.89 | 9.38**** |
| N | 64 | 4.69 | 1.319±.082 | 0.90 | 116.9±1.21 | 111.9±0.98 | 102.1±1.66 | 95.3±1.44 | 44.49**** |

The total number of specimens used is given under *n*. The standard errors of estimate, the regression coefficients, and the correlation coefficients are means for the four populations. The independent and dependent variates corresponding to the letters at the left of the table are given in Table 22. That table also gives the standard means of the independent variates to which the means of the dependent variates have been adjusted, and the number of males, females, and unsexed specimens for each population. The *F* ratios, with 3: $n-5$ degrees of freedom, show the significance of differences amongst the adjusted means. One, two, three, and four stars indicate differences respectively at the 5, 1, 0.5, and 0.1 per cent levels of significance. An average value for mean minus standard mean has been obtained as described by Finney (1946) and used in calculating the standard errors of the adjusted means.

**Table 24.** Statistics derived from covariance analysis of skull measurements of males and females. Sex differences eliminated.

|  | *n* | $S_{y\cdot xz}$ | *Regression coefficients* ±SE |  | *Adjusted means* |  |  |  | *F* |
|---|---|---|---|---|---|---|---|---|---|
|  |  |  | $b_{y\cdot x}$ | $b_{y\cdot z}$ | *Queen Elizabeth Is.* | *Banks Id.* | *Dolphin and Union* | *Mainland* |  |
| A | 75 | 2.39 | .438±.026 | −2.17±1.11 | 101.8±0.71 | 102.1±0.63 | 104.1±0.83 | 105.9±0.73 | 3.82* |
| B | 75 | 3.97 | .549±.072 | +1.75±2.00 | 100.7±1.10 | 102.2±0.98 | 106.3±1.29 | 112.7±1.13 | 14.17**** |
| C | 86 | 3.18 | .544±.040 | −1.77±1.38 | 86.3±0.80 | 88.7±0.90 | 91.0±1.41 | 92.2±0.82 | 5.46*** |
| D | 86 | 5.46 | .341±.120 | +8.63±2.19 | 84.4±1.18 | 89.8±1.33 | 95.3±2.08 | 105.7±1.20 | 41.55**** |
| E | 81 | 2.54 | .187±.026 | −2.02±1.18 | 36.0±0.66 | 37.7±0.70 | 39.8±0.67 | 40.3±0.89 | 5.65*** |
| F | 91 | 3.85 | .073±.049 | +2.40±1.66 | 103.8±0.90 | 101.3±1.10 | 98.4±1.72 | 98.0±1.00 | 4.64** |
| G | 78 | 3.67 | .070±.039 | +2.23±1.77 | 94.5±1.08 | 92.0±0.96 | 90.1±1.26 | 89.2±1.03 | 3.54* |
| H | 61 | 3.51 | .167±.044 | +1.17±1.89 | 102.0±1.06 | 100.4±0.89 | 98.8±1.45 | 97.8±1.32 | 1.72 |
| I | 59 | 4.05 | .230±.052 | +0.99±2.22 | 126.7±1.26 | 126.6±1.03 | 122.3±1.68 | 122.2±1.60 | 2.61 |
| J | 57 | 3.59 | .255±.046 | +3.35±1.97 | 153.9±1.12 | 154.1±0.96 | 152.3±1.50 | 152.2±1.42 | 2.90 |
| K | 60 | 3.55 | .437±.046 | +4.43±1.95 | 114.6±1.12 | 111.4±0.91 | 105.9±1.49 | 103.0±1.35 | 11.56**** |
| L | 65 | 2.55 | .300±.030 | −1.14±1.32 | 94.3±0.81 | 93.0±0.64 | 89.7±0.83 | 90.1±0.90 | 6.73**** |
| M | 64 | 2.79 | .128±.034 | +4.13±1.46 | 72.9±0.89 | 74.0±0.71 | 72.3±0.96 | 71.5±1.00 | 1.44 |
| N | 60 | 3.68 | .913±.103 | +8.41±1.69 | 117.5±1.18 | 114.6±0.97 | 107.8±1.58 | 104.4±1.43 | 12.22**** |

The total number of specimens used is given under *n*. The standard errors of estimate and the regression coefficients are means for the four populations. The independent and dependent variates corresponding to the letters at the left of the table are given in Table 22. That table also gives the standard means of the independent variates to which the means of the dependent variates have been adjusted, and the number of males, females, and unsexed specimens for each population.

Since $z = 1$ for males and $= 0$ for females, the regression coefficient $b_{y\cdot z}$ is in effect the regression of $Y$ on the proportion of males to the total number of specimens in the sample. The adjusted mean $\bar{y}$ is obtained by subtracting $b_{y\cdot x}\,(\bar{x}-x_0) + b_{y\cdot z}(\bar{z}-1)$ from $\hat{y}$. If the sample consists entirely of males the second term cancels out. The regression coefficient $b_{y\cdot z}$ is equivalent to the adjusted means of males minus that of females after the population effects have been eliminated. The *F* ratios with 3: $n-5$ degrees of freedom are suitable for testing the significance of differences amongst the adjusted means. One, two, three, and four stars indicate differences of significance respectively at the 5, 1, 0.5, and 0.1 per cent levels. The method described by Finney (1946) but modified for the double regression was used in calculating the standard errors of the adjusted means.

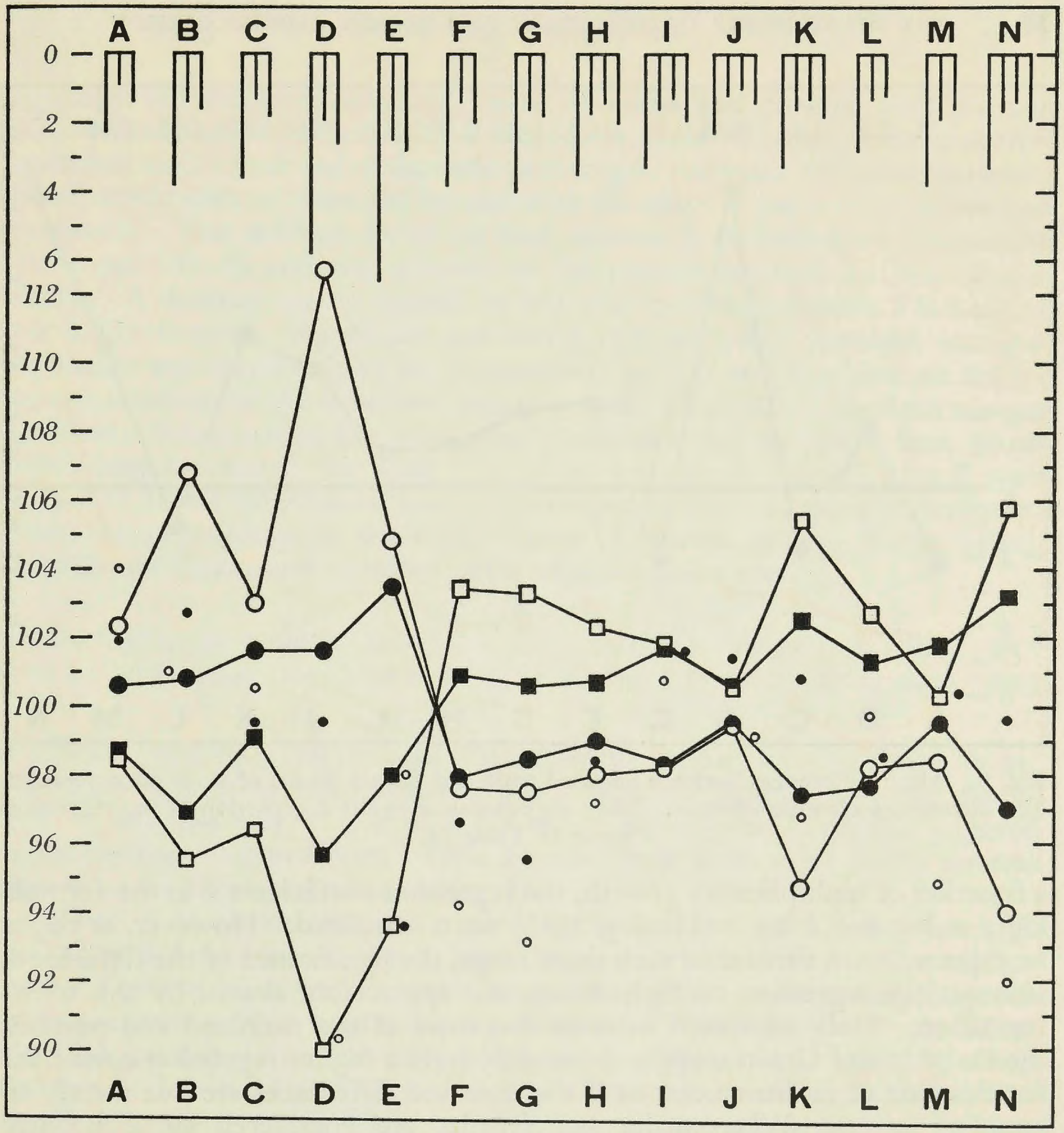

**Fig. 8.** Adjusted means of skull measurements, sex differences eliminated by adjustment of female to male values. The description given for Fig. 7 applies equally to this figure except that 1) the adjusted means are taken from Table 24, and 2) the black dots represent the adjusted measurements of NMC 2755 when assumed to be a female, and the small open circles, the adjusted means when it is assumed to be a male.

**Table 25.** Summary of adjusted means of skull measurements and their differences in standard measure.

| | *Queen Elizabeth Is.* | | *Banks Id.* | | *Dolphin and Union* | | *Mainland* |
|---|---|---|---|---|---|---|---|
| **Sex difference ignored** | | | | | | | |
| Sum F–N *minus* A–E | 147.9 | | 139.9 | | 125.4 | | 115.7 |
| Difference | | 8.0 | | 14.5 | | 9.7 | |
| Percentage of total difference | | 24.8 | | 45.0 | | 30.1 | |
| **Sex difference eliminated** | | | | | | | |
| Sum F–N *minus* A–E | 158.5 | | 152.0 | | 139.0 | | 131.6 |
| Difference | | 6.5 | | 13.0 | | 7.4 | |
| Percentage of total difference | | 24.2 | | 48.3 | | 27.5 | |

In order to eliminate difference of scale the adjusted means have been reduced to standard means by dividing by the standard error of estimate. As the northern populations have the smallest adjusted means for the paired measurements A to E and the largest for those from F to N (see Figs. 7, 8), the sum of the former is subtracted from the sum of the latter to give the maximum differences between populations.

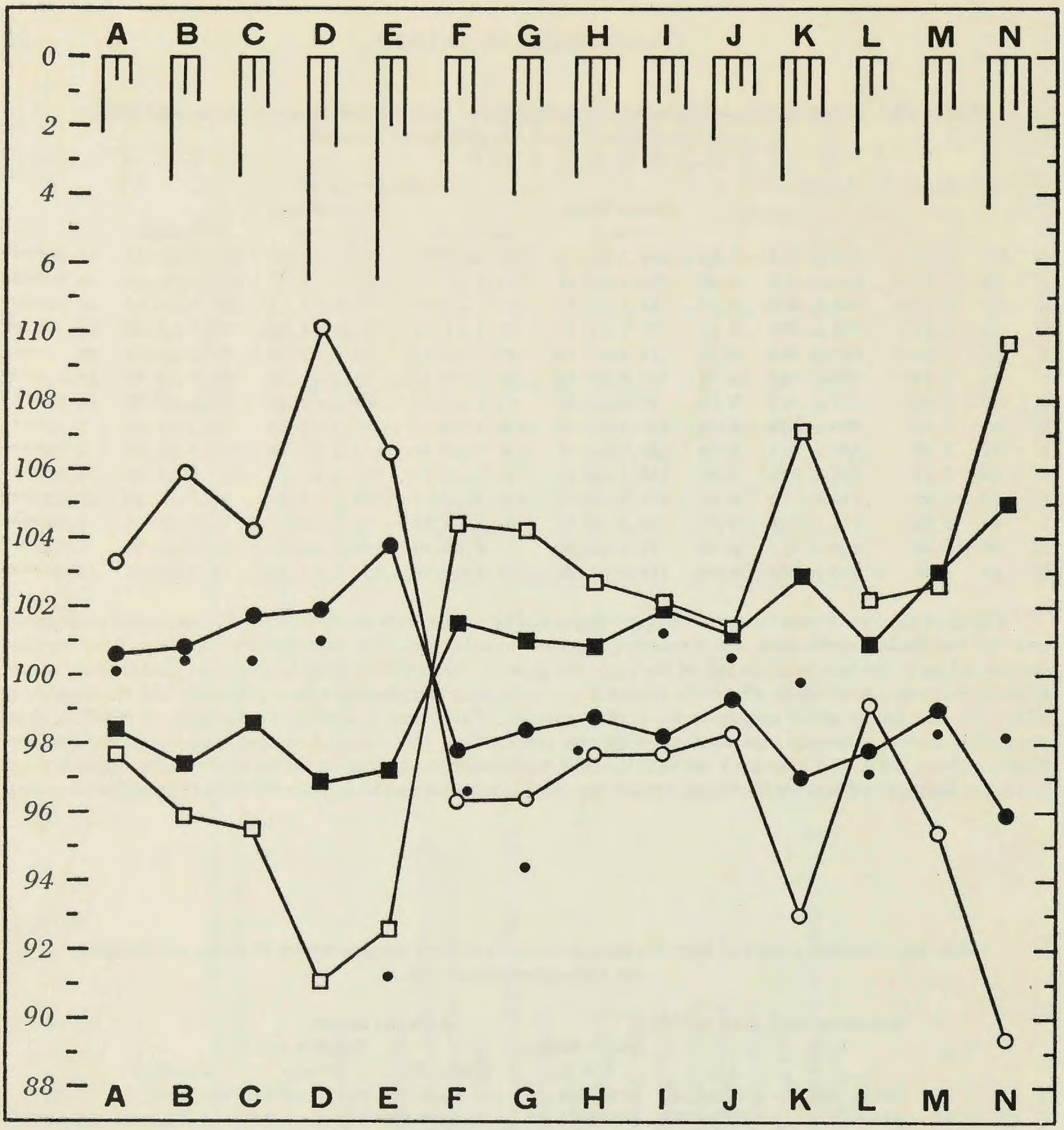

**Fig. 7.** Adjusted means of skull measurements, sex differences ignored. The adjusted means given in Table 23 of measurements A to N listed in Table 22 are indicated as follows: □ Queen Elizabeth Islands; ▪ Banks Island; ● Dolphin and Union herd; ○ mainland. To equalize the scales and make it possible to plot the means on a single graph, the individual means for each population were converted to a percentage of their unweighted mean. The lines joining the circles and squares merely lead the eye from mean to mean of a single series and thereby make the presentation clearer. The small black dots represent the adjusted measurements of NMC 2755, taken in southern Victoria Island on 19 March 1916 (see p. 44). The vertical lines at the top of the figure represent the standard errors of estimate and the standard errors of difference between means. All are reduced to the same scale as the means for the corresponding measurements. The first line for each set of means is the standard error of estimate; the other lines are standard errors of difference. The second line for measurements A to G is suitable for comparisons of the Queen Elizabeth Islands or Banks Island and mainland samples; the third is for comparison of the Dolphin and Union sample with any one of the other three. For measurements H to K and N, the second line is the mean of the standard errors of difference for all four samples and the most suitable for comparison of either the Queen Elizabeth Islands or Banks Island with either mainland or Dolphin and Union. The third line is suitable for comparisons of the Queen Elizabeth Islands with Banks Island; the fourth, for comparisons of Dolphin and Union and mainland. For measurements L and M, the second line should be used for comparisons of Queen Elizabeth Islands, Dolphin and Union, and mainland; the third, for Banks Island with any one of these. The comparative lengths of the different sets of lines for standard errors of difference taken in conjunction with the different numbers of specimens in the series will give an estimate of the accuracy of those standard errors that are average values. The individual standard errors for each mean are given in Table 23.

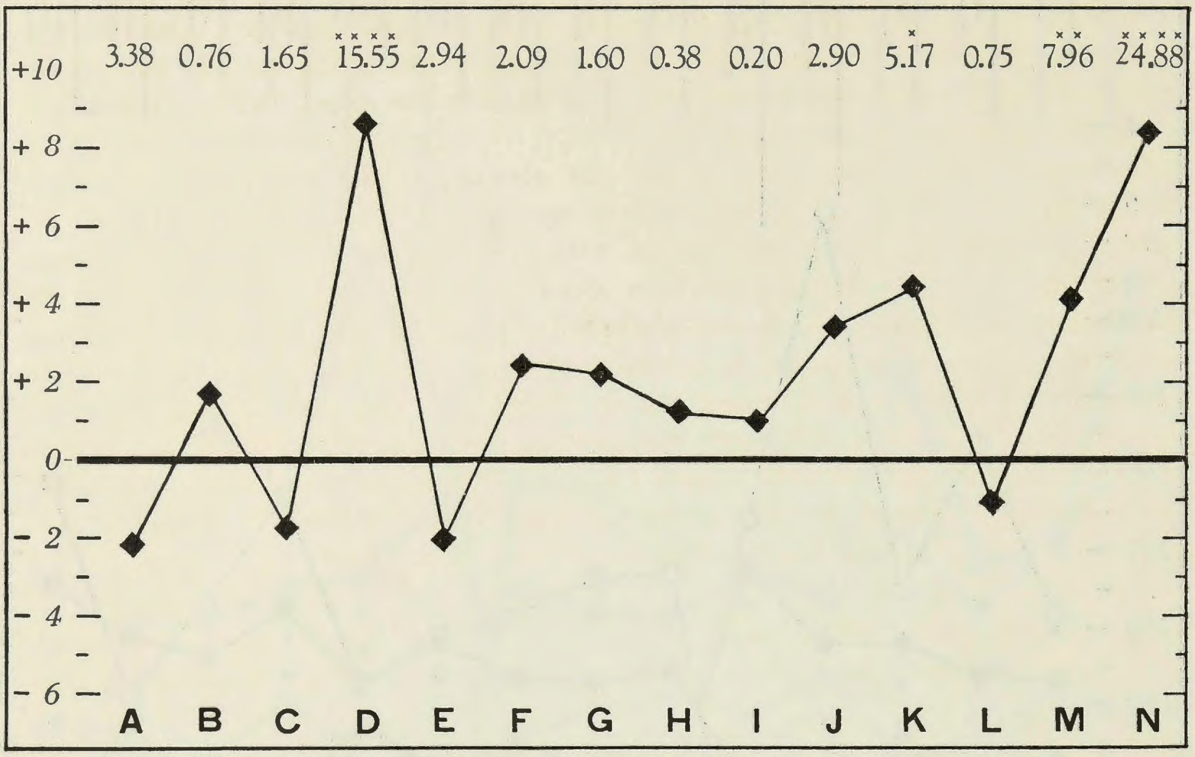

**Fig. 9.** Mean differences between adjusted male and female means of skull measurements. The differences are male—female. They are equivalent to the $b_{y.z}$ portion of the regression given in Table 24.

a function of multiplicative growth, the regression coefficients *k* in the formula $\log y = \log b + k \log x$ (Huxley, 1932) were calculated. However, as might be expected with variates of such short range, the significance of the differences amongst the regression coefficients was not appreciably altered by this transformation. Only additional material can show if the mainland and possibly the Dolphin and Union caribou do actually have a higher regression coefficient for this pair of measurements or if the observed differences are due merely to sampling errors. When males and females are considered simultaneously (eight parallel lines), the significance of the difference between their regression coefficients is reduced to between the 1 per cent and the 5 per cent levels, and for the remaining calculations it has been ignored.

When the mean regression coefficient (four parallel lines) for females was tested against the mean regression coefficient (four parallel lines) for males, there were significant differences at the 5 per cent level for mastoid breadth on condylobasal length (K in tables) and on distance between tip of premaxilla and alveolus of P2 (N in tables). The mean regression coefficients for K are: ♂♂, 0.49 ± .06, ♀♀, 0.28 ± .07; and for N, ♂♂, 1.11 ± .14, ♀♀, 0.55 ± .15. As mastoid breadth is involved in each case, and as 11 dependent variates were tested, the difference may again be a result of sampling error. Except for the paired measurements, C, discussed in the preceding paragraph, there was no significant variation amongst the eight lines for males and females of the four populations when not grouped by sexes. With some reservations about the measurement pairs K and N, the mean regression coefficients for these eight parallel lines could therefore be used to obtain the separate means for males and females.

Except for the two pairs of measurements, A and B, discussed below, the separate means of males and females are not given as a third analysis was made to obtain the combined adjusted means of males and females with the sex effect eliminated; or rather, with a correction made to adjust females to the equivalent male values and at the same time to give the mean difference between the adjusted means of males and females with the effect of population differences eliminated. This method, based on least squares, is described by Quenouille (1950, pp. 262–5) and was adapted to the present problem by Miss P. M. Clarke. A dummy variate is used, in this case $z$, with the value 1 for males and 0 for females. Significant interaction ($.05 > P > .01$) between sex and population was found only in the measurement pairs A and B, which are different combinations of the same two measurements (Table 22). As there was no significant difference in the regression coefficients for the eight lines (four populations, two sexes), the mean regressions, 0.427 for A and 0.541 for B, may be used to obtain the adjusted means for the populations and sexes respectively. With the populations in the order Queen Elizabeth Islands, Banks Island, Dolphin and Union, and mainland, these adjusted means are:

A ♂♂ 102.4, 102.0, 103.1, 107.4 ♀♀ 102.6, 104.8, 107.3, 107.5
B ♂♂ 101.8, 101.6, 104.5, 114.8 ♀♀ 97.2, 102.4, 106.4, 109.8

It appears from these figures that the interaction results from variation in sex difference of samples from adjacent populations. It seems reasonable, therefore, to suppose that it is caused by errors of sampling, and the adjusted means for the combined sexes (Table 24) are likely to be more nearly correct than those of either sex taken separately.

There is an obvious similarity between Fig. 7, based on calculations which ignore sex differences, and Fig. 8, based on those which eliminate these differences. Conclusions drawn from either graph regarding relationship between the populations will be approximately the same. There are, however, differences for individual measurements which require explanation; also some of the statistics in Tables 23 and 24, based on the above calculation methods, show considerable differences. Since in caribou there is a relatively large average size difference between the sexes, separation of that part of regression referable to sex necessarily reduces the length of the remaining $b_{y.x}$ portion of the regression line and hence increases its standard error. Therefore the reduction in significance of the regressions naturally affects the significance of the differences between the adjusted means, as shown by the $F$ ratios in the last column of each table. In one pair of measurements, D, the ratio is slightly increased. Here the difference between the sexes is large (Fig. 9), and as the smaller sex, i.e., the females, are displaced on the $Y$ axis in the same direction as the population which contains the smallest animals, i.e., the Queen Elizabeth Islands series, elimination of the sex difference tends to separate the adjusted means of the four populations. This is observed when Figs. 7 and 8 are compared. The other pairs of measurements where the smaller sex and smaller population are displaced in the same direction are B and L. When the sex effect is eliminated, their adjusted means are also farther apart, although the difference is not sufficient to counteract the loss of significance caused by the shorter regression line. In the eleven other pairs of measurements the smaller sex is displaced in the opposite direction to the population which contains the smallest individuals, and the range of the adjusted means is reduced when the effect of sex is eliminated, the most notable case being N, which has the second largest sex difference. Most of the differences shown by Figs. 7 and 8 in the relative positions of the population sample means for any one measurement result from differences between the proportion of males and females in the populations. Some small differences, however, are no doubt sampling differences due to the addition of a few unsexed specimens.

Museum material is of varied origin, and in some species an astonishing proportion is unsexed; in other species mis-sexing may be suspected. Most of the caribou examined for this study were sexed, probably correctly, although undoubtedly some skulls have been sexed or re-sexed by size and antlers long after death without this fact having been recorded on the labels. It is therefore worth while to consider some of the advantages or disadvantages of ignoring sex in covariance analysis.

The obvious advantages are that unsexed specimens, which are often from areas not otherwise well represented in the collection, may be included and errors due to mis-sexed specimens avoided; the calculations are shorter than those needed to segregate the differences of sex and population; and the regression lines are longer and steadier, so that the significance of the adjusted means is usually greater (compare Tables 23, 24). However, it should be remembered that one portion of the greater length of the regression line is due to the various factors affecting size while the other is caused only by the different average size of the sexes. In taxonomic work this distinction does not appear to be important as long as the slope and position of the two parts of the regression lines do not differ significantly.

There appear to be three main disadvantages to ignoring sex differences: 1) The range of the population means may be extended or contracted by the interaction of size, as opposed to shape, differences and of sex differences. This is likely to have a serious effect on conclusions only if regression is being relied upon to remove all size effect, as would be the case if the series from one population were believed to average distinctly younger and therefore smaller than the others. 2) There is usually a slight increase in scatter about the adjusted means (compare standard errors of estimate in Tables 23 and 24). 3) Unequal numbers of males and females in the samples from the different populations will cause differences in the adjusted means. The differences, however, are small compared with differences which would be caused by mis-sexing when the sex differences are eliminated.

The method here used to segregate sex and population differences avoids the disadvantages mentioned in the preceding paragraph and also gives the mean differences between the sexes when population differences are eliminated. On balance, this method is evidently preferable, at least for species such as caribou which have marked secondary sex characters which may be expected to affect the conformation of the skull. However, it is clear that even for these, very reasonable results may be obtained when sex is ignored, although the statistical significance of the adjusted means must be treated with caution. Of course, if really adequate samples of both sexes for all or most populations are available, each sex can be treated independently, and this may be necessary if significant interaction is present, as it would be if there were a large geographical variation in sex difference. When the samples are small, as in the present study, separate treatment is likely to lead to inconclusive or even conflicting results which are difficult to assess.

*Sex differences.* The mean difference between the adjusted means of males and females is given in Table 24 under $b_{y.z}$. It is also shown graphically in Fig. 9. Only four of the differences are significant. However, it seems probable that the skulls of males are generally slightly broader relative to their length than are those of females, the largest difference being at the proximal end. The condylo-lambdoidal depth is also greater in males, and this heightening and broadening of the posterior portion of the skull is probably associated with the greater relative size of antlers in males.

*Tooth row regressions.* The correlations between mandibular tooth row length and jaw length and between maxillary tooth row length and condylobasal length are distinctly lower than the other correlations in Table 23, and whereas the $b_{y.x}$ portions of the regression (Table 24) are significant at the 0.01 per cent level for all other pairs of measurements, those for the two which contain tooth row measurements are not significant even at the 0.5 per cent level. Lack of correlation between skull size and tooth size appears to be common in a number of animals both at the individual and at the racial level. It may therefore be assumed to be at least partly innate. However, as rooted teeth usually cease growth before the skull has attained full size, variation in nutrition may play a part. In some ungulates there is the additional complication that the maxillary and mandibular tooth rows shorten with wear. In really old caribou this shortening is very obvious. In the Muskox shortening commences soon after M3 is fully developed (Manning and Macpherson, unpublished). The tooth rows of fully grown adults will therefore average shorter than those of animals which have a fully developed M3 but have not yet attained full body growth or full skull length.

## Discussion

### *Summary of the differences between the four populations*

Before the relationship and origin of the four main populations with which this paper is concerned are discussed, it seems advisable to summarize the differences which have been observed. The criteria considered are: relative darkness of pelage, colour of antler velvet, shape of hooves, skull dimensions (19 measurements), and skull shape (14 paired measurements).

Differences of pelage due to season, sex, and age are bound to make comparisons subjective, particularly when the available specimens are very limited, and, as in the present instance, could not all be spread out together. The following figures must therefore be treated cautiously. Thirty-eight out of 41 skins (93 per cent) from the Queen Elizabeth Islands and Banks Island were judged separable when allowance was made for variation due to season and sex. No summer skins of the Dolphin and Union herd were available, but 14 out of 17 (82 per cent) Banks Island and Dolphin and Union winter skins were separable. When the original comparisons were made few mainland barren ground skins in winter pelage were available, and some of the Dolphin and Union and mainland skins appeared to have been confused. However, if the colour of the pelage of Dolphin and Union caribou was as consistent as those skins definitely referable to that population indicate, it seems probable that the greatest step in the southward cline of darkening pelage observed is between the Dolphin and Union and the mainland caribou.

At similar developmental stages there appears to be no overlap between the pale antler velvet of the Queen Elizabeth Islands caribou and the darker velvet of the mainland caribou. Presumably the gap would be bridged by velvet from Banks Island and from the Dolphin and Union herd, but none has been available for comparison.

The hooves of the Queen Elizabeth Islands caribou are obviously shorter and blunter than those of mainland caribou. An attempt was made to measure the difference by adjusting the breadth 20 mm. from the tip of the fourth toe to a standard hoof length. An interesting feature of the result (Fig. 1) is that the hooves of the Dolphin and Union series averaged broader than those of the Banks Island series and were only slightly narrower than those of the Queen Elizabeth Islands series.

The variations in absolute skull measurements can be seen in Figs. 2–6. The skull measurement best suited for estimating total size is probably condylobasal length. This increases slowly from the Queen Elizabeth Islands caribou through the Banks Island population to the Dolphin and Union herd, then abruptly between them and the mainland caribou. The joint non-overlap (Mayr *et al.*, 1953, p. 146) is 84 per cent for males and 88 per cent for females. The length of the central minus lateral anterior projections of the nasals is mainly independent of skull size and appears to be a measurement of taxonomic importance. Table 21 and Fig. 6C show that the greatest difference occurs between the Dolphin and Union and the mainland series (joint non-overlap, 80 per cent for males, 63 per cent for females).

Most of the other measurements are highly correlated with skull size (condylobasal length), and the significance of their variation can therefore best be estimated by covariance. This is true of even the less well-correlated mandibular and maxillary tooth row lengths (Tables 11, 12, Figs. 4A, B), although it is worth noting that in spite of the larger size of the mainland caribou their tooth rows average shorter.

Variation in skull shape was investigated by two methods of covariance analysis, described in the preceding section. In one method differences of sex are ignored and in the other, eliminated. These methods yielded results which differed in detail, although the differences were not sufficient to affect the general taxonomic conclusions. The statistics are given in Tables 22–4, and the adjusted means are plotted in Figs. 7 and 8. From these figures it is evident that relative to condylobasal length there is a southerly cline of increasing length of the rostral region and decreasing skull breadth and height. There is also a decrease in tooth row length relative to condylobasal and jaw lengths. Figures 7 and 8 and Table 25 indicate that the most consistent step in the cline, and for the adjusted means of most measurements the largest, is between the Banks Island and the Dolphin and Union caribou, thus differing from the other criteria considered. The pair of measurements which, on the basis of Table 24 and Fig. 8, would separate most specimens in these populations is N, mastoid breadth on distance between tip of premaxilla and alveolus of P2. The joint non-overlap is 82 per cent. For separating the Dolphin and Union and the mainland specimens the best pair of measurements is D, diastema length on mandible length minus diastema length (joint non-overlap, 83 per cent); and for separating the Queen Elizabeth Islands and the Banks Island specimens, K, mastoid breadth on condylobasal length (joint non-overlap, 67 per cent).

Slightly different and less reliable figures would be obtained from Table 23 and Fig. 7, as explained in the preceding section. Although no single pair of measurements will separate many Banks Island and Queen Elizabeth Islands specimens, Figs. 7 and 8 and Table 25 indicate that the difference in skull shape is as great between these populations as between the Dolphin and Union and the mainland. However, as the correlation between the adjusted means is not known the variance of their sums cannot be calculated.

### *Isolation and intergradation of the four main populations and the Victoria Island population*

From the above summary as well as from the graphs it is clear that, with the possible exception of hoof width, all the characters studied form clines extending from the Queen Elizabeth Islands caribou through the Banks Island population to the Dolphin and Union herd, and finally to the mainland caribou. It is therefore necessary to consider whether the four groups studied are homogeneous, semi-isolated populations or if more material and finer grouping would show the clines to be smooth and the population divisions arbitrary.

*Queen Elizabeth Islands.* The major islands of the Queen Elizabeth group are separated by channels less than twenty miles wide; most of these channels freeze early and thaw late. They cannot therefore be considered serious barriers to free movement of caribou, and it would be natural to expect a fairly homogeneous population. The available specimens indicate this to be true. Skins from southern Ellesmere Island may average a little darker than those from the north of the island, and, judged by condylobasal length, three adult males from Isachsen were significantly smaller than other Queen Elizabeth Islands specimens, but this was probably because of poor feeding on the barren northern part of Ellef Ringnes Island and is not a genetic difference. The small series of winter skins from Prince Patrick Island and Melville Island showed no constant difference from the average Ellesmere, Axel Heiberg, or Isachsen skins, although some were taken over 700 miles apart. Likewise, analysis of variance of the 19 skull measurements showed no differences that could not be attributed to sampling error. Nevertheless, longer series would surely show significant differences, possibly with the southern Ellesmere Island population standing out from the remainder.

*Banks Island.* M'Clure Strait, which lies between Banks Island and Melville and Prince Patrick islands, is a much greater obstacle to caribou movement than the channels separating the individual islands of the Queen Elizabeth group. It is close to sixty miles wide at its narrowest point, probably freezes rather late (Stefansson, 1921, p. 477), and the ice is likely to be rough. Farther east, north of Victoria Island, Viscount Melville Sound is still wider. No doubt caribou could cross and have crossed M'Clure Strait—they appear even to have made the still longer and more difficult crossing from Banks Island to the mainland (Manning and Macpherson, 1958, pp. 66–7), but it is unlikely that they would do so with any regularity. Certainly there appears to be no record of caribou or their tracks having been seen on the ice of M'Clure Strait at any distance from land, although about 25 sledge crossings have been recorded. Banks Island is less than 250 miles from north to south and averages only about 100 miles wide. Caribou which crossed Prince of Wales Strait from the east would therefore spread quickly over the island. If it be granted that there is no regular migration from the north across M'Clure Strait, panmixia may be expected, particularly as there are seasonal movements on the island (Manning and Macpherson, 1958).

*Victoria Island.* Stefansson (1914, p. 39) considered that no great number of caribou crossed Prince of Wales Strait. There appear to be only three published records of caribou crossing, or apparently crossing, Prince of Wales Strait (see Manning and Macpherson, 1958, p. 65), but as the strait is only eight to twelve miles wide for a good part of its length, it is unlikely to be, or to have been, a serious barrier to their movements between early November and early June when it is frozen. As the population of Banks Island must have been denser than the resident Victoria Island population (see p. 9), it seems likely that most of the movement would be easterly, although it is possible that in spring some resident Victoria Island caribou would move west as the Dolphin and Union herd increased the population pressure on Victoria Island. A few Dolphin and Union caribou may also have crossed (see p. 8). The net result would be gene flow in both directions but probably at a slightly higher rate to the east. If this were so it would have helped to balance the gene exchange between the Victoria Island resident population and the Dolphin and Union herd and thus retain the intermediate character of the resident Victoria Island population. However, a letter from an Eskimo at Holman Island post on the central west coast of Victoria Island indicates that the Eskimos there were able to distinguish the Banks Island caribou which crossed to Victoria Island in 1952 from the local resident caribou. If this is correct, the present Victoria Island caribou presumably resemble the extinct Dolphin and Union herd more closely than they do the Banks Island caribou, but it is possible that after migration across Dolphin and Union Strait ceased sufficient caribou from that herd remained on Victoria Island to alter the gene complex of the resident caribou, and until more definite evidence is obtained to the contrary it is reasonable to suppose that the resident Victoria Island caribou, at least towards the north, were intermediate between the Banks Island and the Dolphin and Union caribou.

Unfortunately there are no recent specimens from Victoria Island, and I have seen only one older adult specimen that may have been referable to the resident caribou of the island. This skull, NMC 2755, is labelled male, 19 March 1916, Richardson Island Sound, which is near the centre of the south coast. With a condylobasal length of 296 mm., it is unusually small for an adult male, and the antlers resemble those of a female. Its measurements, adjusted and reduced to scale, are plotted on Fig. 7. From this figure and from the sum of its measurements, 128.9, reduced to standard measurement as in Table 25, it appears to be intermediate between the Banks Island and the Dolphin and Union series. On Fig. 8, its measurements have been plotted after having been adjusted on the assumption that it was a male (open circles) as indicated on the label, and also on the assumption that it was a female (closed circles) as suggested by its size and antlers. A comparison of Figs. 7 and 8 then leaves little doubt that either it has been incorrectly sexed or that its shape is so aberrant as to resemble that of a female. Possibly the fact that its antlers were of female form would mean reduced neck musculature and hence a female-shaped skull.

To test the relationship of this specimen to the Banks Island and Dolphin and Union caribou, the summation of the differences in standard measure appeared unsatisfactory, as equal weight would be given to all measurements, whether there was a large or a small difference between these series. The measurements for the adjusted standard measure means of the Banks Island and Dolphin and Union series and the single Victoria Island specimen were therefore weighted by multiplying them by the difference between the means (standard measure) of the Banks Island and Dolphin and Union series, then summing measurements A to E and F to N and taking the difference, as in Table 25. If the result for the migrants is taken as 0 and that for Banks Island as 100, the Victoria Island specimen will be 29.4 when sex is ignored and 39.3 when it is considered a female. The significance of the figures cannot be tested, and it would be unwise to do more than note that they are in tolerably close agreement, and consistent with the hypothesis that the specimen belonged to a resident Victoria Island population intermediate between the migrant and Banks Island caribou. The comparable figure when the specimen was adjusted as a male is -16.1, or closer to the mainland than to the Banks Island population.

*Dolphin and Union herd.* In spring the Dolphin and Union herd used to cross Dolphin and Union Strait and western Coronation Gulf in small bands and spread out over western Victoria Island, some individuals probably reaching the north coast. Possibly some males remained on the mainland although the evidence for this is not satisfactory. In autumn the herd collected on the south coast of Victoria Island and crossed to the mainland as soon as the ice was sufficiently solid. By this time the rut was probably nearly over. Caribou also reached eastern Victoria Island from Kent Peninsula, and some evidently crossed most parts of the intervening Coronation Gulf. A reasonable estimate of the total Victoria Island migration appears to be 100,000.

Morphological evidence, both from contemporary observers and from collections, indicates that the Dolphin and Union herd was separated rather sharply from neighbouring mainland caribou in pelage colour, and the available skulls indicate that the migrants were distinctly smaller, although difference in skull shape was comparatively slight. Migrants into eastern Victoria Island were probably similar to those which crossed Dolphin and Union Strait. It may be supposed that these genetic differences were maintained by the rut taking place on Victoria Island, or, if it did occur or was continued on the mainland, by the fact that it was at its height later than that of the rut of the mainland caribou (see p. 9). The Dolphin and Union herd would usually pick up a few mainland caribou which would pass with them to Victoria Island, but it may be supposed that the genetic effect of this was counterbalanced by some interbreeding with resident Victoria Island caribou or even wanderers from Banks Island. The migration across Dolphin and Union Strait virtually ceased in 1919, and that into eastern Victoria Island two or three years later. Any caribou that remained were presumably absorbed by the resident Victoria Island or mainland herds.

### *Origin of the Peary Caribou and its intergrades*

The most likely cause of a cline, particularly a north–south cline of size and colour, is a gradual change in environmental conditions acting through natural selection on the available gene pool of the species. If this were the manner in which the differences between the populations described here originated, it could be supposed that a relatively uniform population, concentrated by glacial conditions, spread northward as the retreating ice permitted. However, the resemblance of the Boothia Peninsula, Melville Peninsula, and Baffin Island caribou to the mainland rather than to the Dolphin and Union or Banks Island caribou throws doubt on this hypothesis, particularly when it is remembered that the wintering ground of the Dolphin and Union caribou was close to the tree-line and that parts of southern Victoria Island and Banks Island are within 200 miles of it, whereas even Melville Peninsula is 500 miles distant. Also, according to L. A. Learmonth (oral), large, dark, migrating mainland caribou meet small, pale, resident caribou on Somerset Island without intergrading. Another difficulty is the marked difference in colour between the Dolphin and Union and the resident mainland caribou, a difference which cannot easily be explained by selection under present conditions. Indeed, the dark mainland caribou are so difficult to distinguish from rocks in winter, and the pale Peary Caribou so easy to see in early summer after the snow has gone, that one may wonder if their pale coats may not, from this viewpoint at least, be a disadvantage under present conditions. Lacking any positive geological evidence to the contrary, it may therefore be supposed that the Peary Caribou evolved in a high arctic glacial refugium.

The ice appears to have retreated from Banks Island comparatively early (Manning, 1956b, p. 61), certainly before Victoria Island and the mainland to the south were ice-free. This would allow any caribou able to cross from Prince Patrick Island or Melville Island to become established on Banks Island while it was still inaccessible to mainland caribou. Judging from the historic distribution of *pearyi-arcticus* intergrades, it seems likely that Victoria Island was also colonized by *pearyi* before any *arcticus* reached it. This could have resulted from an eastward retreat of the ice on Victoria Island before the adjacent mainland coast was clear, or from the impassibility, because of the submergence of the land and lack of firm ice, of the water barrier south of Victoria Island.

It may be supposed, therefore, that for a while those parts of the Queen Elizabeth Islands, Banks Island, and Victoria Island which were ice-free were inhabited by a single, nearly uniform, caribou population resembling that which now occupies the Queen Elizabeth Islands. Once caribou were able to cross the geographical barrier between Victoria Island and the mainland, so that *pearyi* and *arcticus* could meet, gene interchange began, and the Banks Island and Victoria Island populations were gradually modified. In the absence of any selective advantage, caribou crossing back from Banks Island to the Queen Elizabeth Islands were probably too few to affect the high arctic population; indeed, they may well had difficulty in surviving the severe conditions in competition with the local herds. The mainland population may likewise have remained unaffected, because of natural selection against *pearyi* characters, because of the swamping effect of its great numerical superiority, or more probably because the rut took place on Victoria Island, so that for a mainland caribou to mate with a Victoria Island caribou or even a Dolphin and Union intergrade it would have in effect to become part of the migrating herd.

The habits and movements of caribou are such that a migration between Victoria Island and the mainland could have grown gradually from a few vagrant herds crossing from either or both sides, or it could have been initiated or augmented by a sudden emigration such as that attempted from Banks Island in the winter of 1951–2 (Manning and Macpherson, 1958). In any case, it is easy to see that migrants would be favoured by the superior mainland winter grazing and by comparative freedom from wolves on Victoria Island during the summer, including the fawning season, and this would increase the growth of the herd.

The direction of the early migration makes an interesting speculation but has no bearing on the taxonomic relationship of the Dolphin and Union herd as it existed in historic time. This must be judged from its genetic composition as evidenced by our knowledge of the phenotype which, owing to integradation clearly differed from both typical *arcticus* and typical *pearyi.* At first sight, the sharp difference between the Dolphin and Union caribou and the resident mainland caribou with which they were in close contact seems to suggest that the migration originated from Victoria Island and that time has been insufficient for the equilibrium of a smooth cline to be achieved. However, if, as the evidence indicates, the rut occurred on Victoria Island, the original pure stock migrants could only become contaminated while on Victoria Island, and for this to occur mainland caribou would have to cross to Victoria Island. This may be the key to the direction of the original migration as well as to the means by which the Dolphin and Union herd began and was maintained as a semi-isolated, interbreeding population which did not contaminate the neighbouring mainland resident caribou.

The above discussion has emphasized the effect of gene flow on the origin of the Banks Island and the Dolphin and Union caribou as distinctive populations. Natural selection has also no doubt played a part, but how big a part is by no means clear, and it may be doubted if, insofar as the characters considered here are concerned, the Banks Island caribou, for instance, is better adapted to its environment than the mainland or Queen Elizabeth Islands caribou would be on Banks Island. Gene flow, through Victoria Island, between the mainland and Banks Island caribou ceased about thirty-five years ago, and is not likely to recommence under present conditions. Modifications of the island populations may therefore occur. Alternatively, if by properly enforced and suitable regulations a new migration from the mainland to Victoria Island is established, as I have no doubt it could be, the first migrants would be true mainland caribou and a further change in the resident Victoria Island caribou might be expected to result.

### *Formal taxonomic position*

It has been shown that the Banks Island and Victoria Island populations and the migrant Dolphin and Union herd form parts of a cline joining typical *arcticus* and *pearyi.* These forms must therefore be considered as races of *Rangifer arcticus.* The Banks Island population is referred to *R. a. pearyi*, the Dolphin and Union herd more tentatively to *R. a. arcticus.* The evidence is too meagre to attempt to place the resident Victoria Island population.

## Future research and specimens needed

A number of taxonomic problems, the solution of which would lead to a better understanding of the evolution and origin of the various caribou populations, have been mentioned in this paper. These and some others within the geographical area covered are now gathered together in the hope that others may consider them, or at least help to collect the material necessary.

Collections from some places will help specific problems more than those from others, but there is no place from which additional material could not be put to good use. The largest single collection from the Canadian Arctic is probably the Peary collection from northern Ellesmere Island, but a new series from that area would be most welcome to see if any changes have occurred during the last fifty years.

The most important problem of the *arcticus-pearyi* complex centres around Prince of Wales Island, Somerset Island, and Boothia Peninsula because caribou migrate between these places and because on Somerset Island the mainland caribou are said to meet the *pearyi* type caribou without intergrading. There appear to be no specimens from Boothia Peninsula or Somerset Island, and only a small collection, definitely of the Peary type, from Prince of Wales Island.

The Victoria Island wintering population is represented by only one adult and one subadult skull from the south coast. A good series of the present caribou population would be most informative. No more skins of the Victoria Island migrant caribou can be obtained, but it is possible that skulls and long bones can still be found, and if reasonably well preserved they would be very valuable. A few skulls might also be obtained from archaeological excavations, and they would be particularly interesting if the age could be determined from associated artifacts.

There is some indication that caribou from southern Ellesmere Island average darker and possibly larger than those from the north, but until more southern Ellesmere Island material is available this cannot be proved. If this is correct, the caribou of Devon Island should be still darker and larger, but no material from there is available. The question would then arise whether the difference was caused by intergradation with the caribou of northern Baffin Island or with those of Prince of Wales Island or Somerset Island, possibly through Cornwallis Island. More specimens are required from the western Queen Elizabeth Islands before it can be said with any certainty that they do not differ from those farther east and have not been affected by intergradation with Banks Island caribou.

A further collection from the Isachsen area is needed to determine if the small size of those previously collected is a constant character and if there are any other differences.

Although there are now more specimens of the mainland caribou available than when the calculations for this paper were being done, there are still very few skins, and insufficient skulls from the eastern areas for satisfactory comparison with western material. A winter collection of the caribou which remain scattered throughout the northeastern barrens is needed to test if they differ morphologically from the migrants which visit these areas in summer.

This paper has dealt with skins, hooves, skulls, and antler velvet. When possible all these parts should be collected. In addition, long bones may prove very useful. The National Museum of Canada has a number of these from the Dolphin and Union herd, but comparative material is very scarce.

Skull measurements of young caribou have not been used, mainly because the number was insufficient for separate treatment. A good series of varying ages might prove very interesting and throw light on the manner in which differences in the adults of the different populations develop.

## Specimens examined

Specimens preceded by AMNH are in the American Museum of Natural History; the remainder are in the National Museum of Canada. An asterisk indicates that the skull was examined.

### *Skins*

*R. a. pearyi.* **Queen Elizabeth Islands population.** Ellesmere Island (north): 21708*, AMNH 27920*, AMNH 27922, AMNH 27924, AMNH 27926, AMNH 27940, AMNH 29980, AMNH 29982, AMNH 30000*, AMNH 30044, AMNH 30045, AMNH 30046. Ellesmere Island (central): 21709*, 21712*. Ellesmere Island (south): 12511*, 12512*, 12513, 14058*, 14949*. Axel Heiberg Island: 8797, 8798*, 8799. Isachsen: 21710, 21711, 21724*, 21725*, 21726*. Prince Patrick Island: 20340*, 20343*, 21600*, 21727*.

*R. a. pearyi > R. a. arcticus.* **Banks Island population:** 2764*, 2765*, 2766*, 2767*, 2768, 2769, 2770*, 21161*, 21168*, 21170.

*R. a. arcticus > R. a. pearyi.* **Dolphin and Union herd.** Bernard Harbour: 2559, 2560, 2747*, 2748*, 2749*, 2750*, 2758* (Liston Island), 2760*, 2763*, no number. Langton Bay: AMNH 34426. Horton River: AMNH 34430*. Great Bear Lake: AMNH 34443.

*R. a. arcticus.* **Mainland population.** [West ?][5] Hudson Bay: AMNH 19504. Wager Bay: AMNH 22936. Chesterfield Inlet: 14055*. Clinton-Colden Lake: 14903. Artillery Lake: AMNH 29032*. Southeast of Great Bear Lake: 22010, 22012. Coronation Gulf: 2751*, 2752, AMNH 34433. Bernard Harbour: 2762[7]. Point William, Victoria Island (assumed to be mislabelled; see text): AMNH 34427, AMNH 34428*[8]. Dease River: AMNH 34437. Darnley Bay: AMNH 34432. Langton Bay: AMNH 34431. Horton River: AMNH 34434*.

### *Skulls*

*R. a. pearyi.* **Queen Elizabeth Islands population.** Ellesmere Island (north) ♂ ♂ : AMNH 27901[1], AMNH 27902[1], AMNH 27913[1], AMNH 27920[1], AMNH 27921[1], AMNH 27925[1], AMNH 27927[2], AMNH 27930[2], AMNH 27937[2], AMNH 27939[1], AMNH 27948[1], AMNH 27958[1], AMNH 27987[1], AMNH 27988[2], AMNH 27989[1], AMNH 30035[2]; ♀ ♀ : 21708, AMNH 27909, AMNH 27909[3], AMNH 30000[2], AMNH 30007[2]. Ellesmere Island (central) ♂ ♂ : 21709, 21712. Ellesmere Island (south) ♂ ♂ : 12511, 14058, 14949; sex ?: 12512. Axel Heiberg Island ♀ : 8798. Isachsen ♂ ♂ : 21724, 21725, 21726. Melville Island ♂ : 21599. Prince Patrick Island ♂ ♂ : 20340, 20343, 21600, 21727; ♀ : 20341.

---

[1] Measurements limited to 3, 6, 9 (see list of measurements).

[2] Measurements limited to 1, 3, 6, 7, 8, 9, 10, 19 (see list of measurements).

[3] Two females in collection with the same numbers.

[4] Not used in calculations.

[5] Collected by Captain Comer and therefore assumed to be from the west side of Hudson Bay.

[6] Sex doubtful notwithstanding evidence of *new* label.

[7] A dark summer skin dated April 18 and therefore probably wrongly labelled. See text.

[8] But skull with this number possibly from different specimen. See text.

*R. a. pearyi* > *R. a. arcticus.* **Banks Island population** ♂ ♂: 2764, 2765, 2766, 21161, 21166, 21167, 21168, 21169, 21171, 21173, 21670, 21671, 21672, 21747, 21748, 21750, 21751, 21755, 21758, 21759; ♀ ♀: 2767, 2770, 21164, 21716, 21749, 21752, 21757; sex ?: 21163, 21172.

*R. a. arcticus* ? *R. a. pearyi.* **Victoria Island population.** Richardson Island Sound ?: 2755.

*R. a. arcticus* > *R. a. pearyi.* **Dolphin and Union herd.** Liston Island ♀: 2758. Bernard Harbour ♂ ♂: 2746, 2757, 2760, 2761, 2763, 2750, 21715; ♀ ♀: 2573, 2574, 2747, 2748, 2749, 2754. Horton River ♀: AMNH 34430[4].

*R. a. arcticus.* **Mainland population** ♂ ♂. [West?][5]* Hudson Bay: AMNH 14999[2], AMNH 19500[2], AMNH 19501[2]. [West Hudson Bay?][5]: AMNH 22936[2], AMNH 22985[2], AMNH 22986[2]. Chesterfield Inlet: 14055. Near Eskimo Point: 22061, 22065. Artillery Lake: AMNH 29031[2]. Southeast of Great Slave Lake: 22068, 22069. Bathurst Inlet: 2744, 2745. Coronation Gulf: 2743. Horton River: AMNH 34502. Aylmer Lake: 5227. ♀ ♀. [West Hudson Bay?][5]: 19503[2], 19505[2]. Wager Bay: AMNH 22937[2]. Near Eskimo Point: 22062, 22064. Near Churchill: A. H. Macpherson 20. Aylmer Lake: AMNH 29034[2]. Artillery Lake: AMNH 29032[2]. Clinton-Colden Lake: 14087. Great Slave Lake area: near Fort Resolution, 10335; north-northeast of Great Slave Lake, 22066; southeast of Great Slave Lake, 22067. Coronation Gulf: 2751. Horton River: AMNH 34434[2]. Sex ?. Wager Bay: AMNH 22938[2]. Near Eskimo Point: 22063[6].

---

* For footnotes see p. 49.

## АВТОРЕФЕРАТ

Эта работа представляет в основном таксономическое исследование четырех популяций карибу *Rangifer* с островов Королевы Елизаветы, острова Банкса, пролива Дольфин и Юнион, и с континента. Для сравнения были использованы черепа, шкуры, копыта и бархат рогов. Приводятся данные статистической обработки 19 измерений черепа, а также результаты ко-вариационного анализа 14 парных измерений. Были применены два метода ко-вариационного анализа. Первый не учитывает половых различий, второй разделяет полы и вносит соответствующие поправки. Результаты оказались сходными; обсуждаются различия наблюденные в деталях. Клайны, возникшие, повидимому, между данными популяциями, демонстрируются для цвета шерсти, размеров и согласованных измерений черепа. Формы *arcticus* и *pearyi* считаются принадлежащими к одному виду. Популяция с острова Банкса относится к последней, “стадо” с Дольфин и Юнион относится, возможно, к первой. Суммируются исторические данные о стаде с пролива Дольфин и Юнион и его исчезновении как мигрирующей единицы.

## References

Allen, J. A. 1908. "The Peary Caribou (*Rangifer pearyi* Allen)". *Bull. Amer. Mus. Nat. Hist.* Vol. 24, pp. 487–504.

1913. "Ontogenetic and other variations in Muskoxen, with a systematic review of the Muskox group, recent and extinct". *Mem. Amer. Mus. Nat. Hist.* New Ser. Vol. 1, Pt. 4, pp. 103–226, pls. 11–18.

Anderson, Rudolph M. 1913a. "Arctic game notes". *Amer. Mus. J.* Vol. 13, pp. 4–21.

1913b. "Report on the natural history collections of the expedition" pp. 436–527 *in* Stefansson, 1913b.

1920. [Evidence given by]. 'Proc. Roy. Comm. to investigate the possibilities of the Reindeer and Musk-ox industry in northern Canada'. Vol. 3, pp. 514–46. *In* Lib. Dept. Northern Affairs, Ottawa. (Mimeo.)

1922. "Memorandum on Barren Ground Caribou and Musk-ox" pp. 72–6 *in* 'Rept. Roy. Comm. to investigate the possibilities of the Reindeer and Musk-ox industries in the arctic and sub-arctic regions of Canada'. Ottawa: Dept. Interior, 99 pp.

1934. "The distribution, abundance, and economic importance of the game and fur-bearing mammals of western North America". *Proc. Fifth Pacific Sci. Congr.* pp. 4,055–75.

1937. "Mammals and birds of the western arctic district, Northwest Territories, Canada" pp. 97–122 *in* 'Canada's western northland'. Ottawa: Dept. Mines and Resources, 162 pp.

1938. "The present status and distribution of the big game mammals of Canada". *Trans. Third North Amer. Wildl. Conf.* pp. 390–406.

1946. 'Catalogue of Canadian recent mammals'. *Nat. Mus. Can. Bull.* No. 102, Biol. Ser. No. 31, v + 238 pp. (Issued 1947).

Banfield, A. W. F. 1949. "The present status of North American caribou". *Trans. Fourteenth North. Amer. Wildl. Conf.* pp. 477–91.

1951. 'The Barren-ground Caribou'. Ottawa: Dept. Res. and Devel. v + 52 pp. (Mimeo.)

1954. 'Preliminary investigation of the Barren Ground Caribou. Pt. II. Life history, ecology, and utilization'. *Wildl. Manag. Bull.* Ser. 1, No. 10B, 112 pp. Ottawa: Dept. Northern Affairs. (Mimeo.)

Chipman, K. G. 1920. [Evidence given by]. 'Proc. Roy. Comm. to investigate the possibilities of the Reindeer and Musk-ox industry in northern Canada'. Vol. 1, pp. 95–108. *In* Lib. Dept. Northern Affairs, Ottawa. (Mimeo.)

Clarke, C. H. D. 1940. 'A biological investigation of the Thelon Game Sanctuary'. *Nat. Mus. Can. Bull.* No. 96, Biol. Ser. No. 25, 135 pp.

Collinson, Richard. 1889. 'Journal of H.M.S. Enterprise, on the expedition in search of Sir John Franklin's ships by Behring Strait. 1850-55'. London: xii + 531 pp.

Dunbar, Moira and Keith R. Greenaway. 1956. 'Arctic Canada from the air'. Ottawa: Defence Research Board, 541 pp.

Finney, D. J. 1946. "Standard errors of yields adjusted for regression on an independent measurement". *Biometrics Bull.* Vol. 2, pp. 53–5.

Godsell, Philip H. 1937. "The 'blond' Eskimos and the 'created want'". *Nat. Hist.* Vol. 39, pp. 285–9.

1943. 'Arctic trader'. New York: viii + 329 pp.

Harper, Francis. 1955. 'The Barren Ground Caribou of Keewatin'. *U. Kan. Mus. Nat. Hist. Misc. Publ.* No. 6, 163 pp.

Hoare, W. H. B. 1920. [Evidence given by]. 'Proc. Roy. Comm. to investigate the possibilities of the Reindeer and Musk-ox industry in northern Canada'. Vol. 1, pp. 76–86. *In* Lib. Dept. Northern Affairs, Ottawa. (Mimeo.)

1925. "Report of investigations [affecting Eskimo and wild life District of Mackenzie] 1924–25". Ottawa: N.W.T. and Yukon Branch, Dept. Interior, 15 pp. (Mimeo.)

1927. "Report of investigations [affecting Eskimo and wild life District of Mackenzie] 1925–1926 together with general recommendations". Ottawa: N.W.T. and Yukon Branch, Dept. Interior, 44 pp. (Mimeo.)

Huxley, Julian S. 1932. 'Problems of relative growth'. London: xix + 276 pp.

Jenness, D. 1920. [Evidence given by]. 'Proc. Roy. Comm. to investigate the possibilities of the Reindeer and Musk-ox industry in northern Canada'. Vol. 1, pp. 155–67. *In* Lib. Dept. Northern Affairs, Ottawa. (Mimeo.)

1922. 'The life of the Copper Eskimos'. *Rept. Can. Arctic Exped. 1913-18.* Vol. 12 [Pt. A], 277 pp.

1928. 'The people of the twilight'. New York: xii + 247 pp.

Johansen, Frits. 1920. [Evidence given by]. 'Proc. Roy. Comm. to investigate the possibilities of the Reindeer and Musk-ox industry in northern Canada'. Vol. 1, pp. 121–44. *In* Lib. Dept. Northern Affairs, Ottawa. (Mimeo.)

Manning, T. H. 1956a. 'The Northern Red-backed Mouse, *Clethrionomys rutilus* (Pallas), in Canada'. *Nat. Mus. Can. Bull.* No. 144, Biol. Ser. No. 49, 67 pp.

1956b. "Narrative of a second Defence Research Board expedition to Banks Island, with notes on the country and its history". *Arctic,* Vol. 9, pp. 1–77.

Manning, T. H. and A. H. Macpherson. 1958. 'The mammals of Banks Island'. *Arctic Inst. North. Amer. Tech. Pap.* No. 2, 74 pp.

Mayr, Ernst, E. Gorton Linsley, and Robert L. Usinger. 1953. 'Methods and principles of systematic zoology'. New York: ix + 328 pp.

O'Neill, J. J. 1920. [Evidence given by]. 'Proc. Roy. Comm. to investigate the possibilities of the Reindeer and Musk-ox industry in northern Canada'. Vol. 1, pp. 36–48. *In* Lib. Dept. Northern Affairs, Ottawa. (Mimeo.)

Quenouille, M. H. 1950. "Computational devices in the application of least squares". *J. Roy. Statistical Soc.* Vol. 12, pp. 256–72.

Rae, John. 1852. "Journey from Great Bear Lake to Wollaston Land". *J. Roy. Geogr. Soc.* Vol. 22, pp. 73–82.

Rasmussen, Knud. 1927. 'Across arctic America'. New York: xx + 388 pp.

Ridgway, Robert. 1912. 'Color standards and color nomenclature'. Washington: 44 pp. + 53 pls.

Seton, Ernest Thompson. 1927. 'Lives of game animals'. Vol. 3. "Hoofed animals". New York: xix + 780 pp.

Simpson, Thomas. 1843. 'Narrative of the discoveries on the north coast of America; . . . during the years 1836–39'. London: xix + 419 pp.

Stefansson, Vilhjalmur. 1913a. "Victoria Island and the surrounding seas". *Bull. Amer. Geogr. Soc.* Vol. 45, pp. 93–106.

1913b. 'My life with the Eskimo'. New York: ix + 538 pp.

1914. 'The Stefánsson-Anderson arctic expedition of the American Museum: preliminary ethnological report'. *Anthrop. Pap. Amer. Mus. Nat. Hist.* Vol. 14, Pt. 1, 395 pp.

1920. [Evidence given by]. 'Proc. Roy. Comm. to investigate the possibilities of the Reindeer and Musk-ox industry in northern Canada'. Vol. 1, pp. 76–280. *In* Lib. Dept. Northern Affairs, Ottawa. (Mimeo.)

1921. 'The friendly Arctic'. New York: xxxi + 784 pp.

Storkerson, Storker T. 1920. [Evidence given by]. 'Proc. Roy. Comm. to investigate the possibilities of the Reindeer and Musk-ox industry in northern Canada'. Vol. 1, pp. 255–80. *In* Lib. Dept. Northern Affairs, Ottawa. (Mimeo.)

*TEC* OF

Copies al Office
of the Insti

Number 1. AS OF THE
ARCTI Johnson.
1956.

Number 2. nd A. H.
Macpl *to Mem-*
*bers o*

Number 3. ES IN THE
SUBAR gures, and
8 plat *ers $2.00.*

Number 4 CARIBOU.
By T. *to Mem-*
*bers o*

## PUBLICATIONS COMMITTEE

## CONTRIBUTIONS TO THE *TECHNICAL PAPERS*

Scientific papers on all aspects of arctic work which are either too technical or too long for publication in the Institute's journal *Arctic*, may be submitted for publication in the *Technical Papers*. Manuscripts should be complete with maps, diagrams, and good glossy enlargements of photographs. Proofs will be sent to authors for correction.

An allowance of free reprints will be made.

All manuscripts should be addressed to the Editor, The Arctic Institute, 3485 University Street, Montreal 2, Que., Canada.

PRINTED IN CANADA